

GUNNER'S MATE M 3 & 2

NAVAL TRAINING COMMAND

NAVY TRAINING COURSE NAVTRA 10199-B

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INSIDE FRONT COVER

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PREFACE

This Rate Training Manual was written to serve as an aid for enlisted men of the U. S. Navy and Naval Reserve who are preparing for advancement to the rates of Gunner's Mates M (Missiles) 3 & 2. It is one of a series of Rate Training Manuals designed to give enlisted men background information necessary for the proper performance of the duties of their rates.

The predominant factor in the selection of content for this publication has been the Manual of Qualifications for Advancement, NavPers 10868C. When supplemented by practical experience in the maintenance and repair of launching system equipment, this manual will help the GMM meet the Qualifications for Advancement.

This manual was prepared for the Naval Training Support Command by the Naval Personnel Program Support Activity, Training Publications Division, Washington, D.C. Acknowledgement is made to the Naval Ordnance Systems Command, Washington, D.C.: Naval Examining Center, Great Lakes, Illinois: and to the Gunner's Mates School, Great Lakes, Illinois, whose technical review, comments, ideas, and suggestions
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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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Phillip Hays PhD LT USNR-R

April 2009

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CHAPTER 1

THE GUNNER'S MATE (MISSILES) RATING

This training manual has been prepared to help men of the Navy and of the Naval Reserve meet the occupational qualifications for advancement to Gunner's Mate Missiles 3 & 2. The Gunner's Mate qualifications used as a guide in the preparation of this training manual are those contained in the Manual of Qualifications for Advancement in Rating, NavPers 18068-C. Therefore, the qualifications pertaining to your rating are not reproduced in this training manual. We suggest that you study the latest changes and revisions listed in NavPers 18068-C to get an idea of the scope of the skills and knowledge you must have to advance in rating.

This training manual has been organized in such a way as to give you a systematic understanding of your job. Chapter 2 discusses the fundamental fire control problem presented by a projectile or a guided missile. Chapter 3 introduces you to missiles and rockets and their principles of flight. Chapter 4 covers missile guidance and control techniques. Chapter 5 presents the functional requirements of guided missile launching systems. Chapter 6 combines fire control, guns and missiles, and launching systems into a weapons system. In chapter 7 you will study servomechanisms. Chapter 8 describes the use of hydraulics and pneumatics in missile systems. Chapter 9 describes many of the electrical devices used in launching systems and some of their applications therein. Since you are required to handle explosives and know how to maintain magazines, chapter 10 covers them. A new qualification for the GMM rating - small arms, landing party equipment and demolition - is covered in chapter 11. Chapter 12 includes information about general maintenance, such as maintenance aids and procedures. Chapter 13 reviews common test equipment and some troubleshooting hints. Chapter 14 discusses special test equipment used in keeping launchers in top working order. This chapter also covers several methods of replenishing missile firing ships. Chapter 15, the last chapter in this manual, tells about the paper work you do and the many sources of information needed to keep your equipment in good operating condition. Many of the publications you must use are classified. Basic Military Requirements. NavPers 10054-C, gave you basic rules for safeguarding classified publications and material that you use in your work.

The remainder of this chapter gives information on the enlisted rating structure, the Gunner's Mate rating, requirements and procedures for advancement in rating, and references that will help you in working for advancement and in performing your duties as a G M. This chapter also includes information on how to use Navy Rate Training Manuals. Therefore, it is strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of this training manual.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

THE GUNNER'S MATE RATING

Prior to the introduction of missiles and rockets into the Navy, the Gunner's Mate rating was covered under the abbreviation of GM. This denoted the general rating to which all

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Gunner's Mates belonged. The GM was the jack-of-all-trades in the ordnance field.

When guided missiles were added to the Navy's arsenal of weapons, the general rating of Gunner's Mate was given the responsibility of maintaining these systems. This action effectively bridged the gap for a period of time. Eventually, however, a decision was made to separate the general rating into three service ratings. One of these is to maintain gun and rocket launching systems and Basic Point Defense Missile System. This rating is designated GMG. Another service rating, GMM, was assigned to maintain missile launching systems, Still another service rating GMT, was established to maintain nuclear weapons, and recently, the ASROC launching group.

The GMT rating is separated from the other two service ratings up through the pay grade of E-9. The remaining two service ratings, GMG and GMM, remain separated up to and including E-7. At the E-8 and E-9 levels they are combined into the general rating of Gunner's Mate (GMCS and GMCM).

This means that the E-7 Gunner's Mate M, in order to advance, must be prepared to maintain conventional gun systems and rocket launching systems. In other words, an E-7 GMM taking an examination for E-8 will be examined on the qualifications expected of the GMG in addition to his own.

The GMM rating can be further subdivided into classes. Each class is assigned a Navy Enlisted Classification (NEC) number. The purpose of these codes is to assist in identifying personnel in a rating when a broad definition (such as GMM) is not enough. Code numbers are assigned to personnel with specialized skills and training. Examples of such codes are GM- 0986, assigned to gunner's mates who have graduated from the guided missile launching system Mk 10 maintenance course, and GM-0988 the number given to the GMM who has graduated from the Tartar Mk 13 GMLS and missile maintenance course. A complete list of the codes is found in the Manual of Navy Enlisted Classifications, NavPers 15105 (latest revision).

As a GMM you are responsible for maintaining guided missile launching systems. Also, you must prepare guided missiles for testing, and replace faulty missile components when tests indicate that this should be done. To be effective in these duties, you must have a broad background in many occupational fields.

A GMM must be a mechanic in order to maintain, adjust, and repair machinery such as loaders, rammers, hoists, blast doors, and magazine doors. You must learn the principles of machines and how to use handtools, gages, measuring instruments, and test equipment.

Another field you must have a thorough knowledge of is electricity. This knowledge is applied in working with electric motors and generators, switchboards, and control panels for the equipment in the launching system.

You must be knowledgeable in the field of electronics. You will make tests and repairs on vacuum tubes, transistors, magnetic amplifiers, and power supplies.

You must be a hydraulic and pneumatic specialist because many units based on hydraulic and pneumatic principles are used in the launching systems you will be assigned to.

GMM BILLETS

GMM is a seagoing rating. This is not to say that GMMs never get duty on the beach. They do. But most of the billets are on combatant ships. These ships range from the small destroyer escort types to the large attack carriers.

Your billet, as you know, is the place or job to which you are assigned. The billets aboard ship to which you may be assigned are in guided missile launching systems. Primarily your billet calls for a man who will assist a senior GMM in the maintenance of a portion of a system. For example, you may work under a GMM2 whose responsibility is to keep the A-side of a launching system in top working order.

We will not give a list of detailed duties that you will perform in a particular billet. But in general we can say that you will be simply an assistant who will work under the direction of a more senior petty officer. If you are a striker, he will supervise your work closely. If you are third class, supervision will be a little less close and you will be allowed to show more initiative in performing your job. Besides the occupational or professional duties, you will have certain military duties, as do all ratings in the Navy. These military duties include the manning of battle stations, watch standing, and other assignments related to the requirements for naval operations, management, and security. This manual is concerned with your occupational and technical duties - NOT your military duties.

YOUR PART IN NAVAL LEADERSHIP

The Navy and Marine Corps have a continuing program of moral leadership and character education to ensure that naval leadership is maintained at a consistently high level. The Navy

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stresses moral responsibility and personal example. In 1963 the Secretary of the Navy reissued General Order 21. The objective of this general order is to revitalize and reemphasize naval leadership in all of its aspects. The three major aspects of naval leadership are:

1. Technical competence
2. Personal example
3. Moral responsibility

As a petty officer you will have an important practical part to play in your shipboard leadership program. You may take charge of a group of strikers. This will put you in a position of leadership. You will have two responsibilities- to accomplish a mission and to take care of your men. The general principles and techniques of leadership are fully discussed in Military Requirements for PO 3 & 2, NavPers 10056-C. However, let's do a little thinking about how you can help to carry out General Order 21 on a day-to-day basis.

Assume for a moment that your mission aboard ship is to maintain a launcher, and you have strikers to assist you. Now a big part of your job is to learn everything you can about the launcher and to pass on your knowledge to your men. Technical competence is a major aspect of good leadership. But being a skilled technician is not enough. You must inspire your strikers to do their work as efficiently as possible.

A national characteristic of the American fighting man is that he wants to know why he is called upon to perform certain tasks. You must explain to your strikers the importance of their work and how it affects the overall fighting efficiency of your ship. Make the smallest mechanical task take on the nobility of a cause. During exercises or drills make them feel they are winning a war, not just turning knobs on equipment. Keep in mind they are the men who will fight by your side in combat. When led with courage, spirit, and intelligence, they will fight as willingly and as efficiently as any fighter in the world. But it is up to you to provide inspiration so that it will seep down to them.

To inspire your strikers and others, you must have a strong moral character. Some of the character traits you can develop by conscientious study and practice are loyalty, integrity, and quiet self-confidence.

Loyalty is one of the most essential factors of leadership. Experienced officers and petty officers say that they would rather have a loyal man who is not an excellent worker than a disloyal man who does excellent work. Loyalty to the country, to the Navy, to your ship, to your division, to your chief, to your senior petty officer, and to the men who work with and for you-these are the prime requisites of leadership. The surest way to get the respect and loyalty of your men is to be loyal yourself.

Everytime you feel the urge to criticize the handling of your ship's affairs, stop short. You are a part, and an important part, of your ship. How can you expect your strikers to be loyal if you are not?

Deal with your men squarely and honestly. If you do, you will win and hold their respect. Be dependable. This mark of integrity involves keeping promises promptly. A reputation of being a "square shooter" is worth every effort on your part. Help to build this reputation early by not tolerating "gun-decking" or other methods of falsifying reports.

Good leaders have a quiet self-confidence (not an arrogant or cocky manner) based on thorough knowledge of the job and a belief in their own ability. Confidence begets confidence. If you have confidence in yourself, you can inspire confidence in your men.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

But the advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating, and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.

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2. Complete the required military and rating manuals.

3. Demonstrate your ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NavPers 1414/1.

4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.

5. Demonstrate your KNOWLEDGE by passing written examinations on the occupational and military qualification standards for advancement.

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the most recent qualifications.

Advancement in rating is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to" 'sew on the crow" or "add a stripe." The number of men in each rate and rating is controlled on a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

Merit rating system
Personnel testing system
Longevity, or seniority, system

The Navy's system provides credit performance, knowledge, and seniority, and, while it cannot guarantee that anyone person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

Factor	Maximum Credit
Examination score	80
Performance factor (Performance evaluation)	50
Length of service (years x 1)	20
Service in pay grade (years x 2)	20
Medals and awards	15
	185

All of the above information (except the examination score) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores, for those passing, are added to the other factors to arrive at the final multiple; A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required for advancement in your rating. To prepare for advancement, you will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, (3) a NavPers publication called Bibliography For Advancement Study NavPers 10052, and (4) applicable rate training manuals. The following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

Quals Manual

The Manual of Qualifications for Advancement, NavPers 18068-C, gives the minimum occupational and military qualification standards for advancement to each pay grade within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals" The qualification standards are of two general types: (1) military qualification

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REQUIREMENTS*	E1 to E2	E2 to E3	#† E3 to E4	#E4 to E5	† E5 to E6	† E6 to E7	† E7 to E8	† E8 to E9
SERVICE	4 mos. service—or comple-tion of	6 mos. as E-2.	6 mos. as E-3	12 mos. as E-4	24 mos. as E-5.	36 mos. as E-6. 8 years total enlisted service.	36 mos as E-7. 8 of 11 years total service must be enlisted.	24 mos. as E-8. 10 of 13 years total service must be enlisted.
SCHOOL	Recruit Training.		Class A for PR3, DT3, PT3, AME 3, HM 3, PN 3, FTB 3, MT 3,			Class B for AGC MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST			Specified ratings must complete applicable performance tests be-fore taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.	Counts toward performance factor credit in ad-vancement multiple.						
EXAMINATIONS**	Locally prepared tests.	See below.	Navy-wide examinations required for all PO advancements.				Navy-wide, selection board.	
RATE TRAINING MANUAL (INCLUD-ING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school comple-tion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition).					Correspondence courses and recommended reading. See NavPers 10052 (current edition).	
AUTHORIZATION	Commanding Officer	Naval Examining Center						

* All advancements require commanding officer's recommendation.

† 1 year obligated service required for E-5 and E-6; 2 years for E-7, E-8 and E-9.

Military leadership exam required for E-4 and E-5. †† Waived for qualified EOD personnel.

** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.

Figure 1-1. — Active duty advancement requirements.

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REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 8 yrs service	36 mos. with total 11 yrs service	24 mos. with total 13 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavPers 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIRE MENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO Advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		Naval Examining Center					

* Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for training duty.

Figure 1-2. — Inactive duty advancement requirements.

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standards and (2) occupational qualification standards.

MILITARY STANDARDS are requirements that apply to all ratings rather than to anyone particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL STANDARDS are requirements that are directly related to the work of each rating.

Both the military requirements and the occupational qualification standards are divided into subject matter groups; then, within each subject matter group, they are divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

In most subject matter areas, you will find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find only one or the other. It is important to remember that there are some knowledge aspects to all practical factors, and some practical aspects to most knowledge factors. Therefore, even if the QUALS MANUAL indicates that there are no knowledge factors for a given subject matter area, you may still expect to find examination questions dealing with the knowledge aspects of the practical factors listed in that subject matter area.

You are required to pass a Navywide military/leadership examination for E-4 or E-5, as appropriate, before you take the occupational examinations. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates are required to pass the applicable military/leadership examination only once. Each of these examinations consists of 100 questions based on information contained in Military Requirements for Petty Officers 3 & 2, Navpers 10056 and other publications listed in Bibliography For Advancement Study, Navpers 10052.

The Navywide occupational examinations for pay grades E-4 and E-5 will contain 150 questions related to. occupational areas of your rating.

If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The Quals Manual is kept current by means of changes. The occupational qualifications for your rating which are covered in this training manual were current at the time the manual was printed. By the time you are studying this manual, however, the quals for your rating may have been changed. Never trust any set of quals until you have checked it against an UP-TO-DATE copy in the Quals Manual.

Record of Practical Factors

Before you can take the service-wide examinations for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military qualifications and the occupational qualifications. The RECORD OF PRACTICAL FACTORS mentioned earlier. is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors. both military and occupational. As you demonstrate your ability to perform each practical factor appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for. Advancement and revised forms of Navpers 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical F actors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

Until completed. the NavPers 1414/1 is usually held by your division officer; after completion it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all practical factors the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form actually is inserted in your service record before you are transferred. If the form is not in your service record you may be required to start all over again and requalify in the practical factors which have already been checked off.

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Navpers 10052

Bibliography For Advancement Study, Navpers 10052 (revised), is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NavPers 10052 is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter following the Navpers number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NavPers 10052, a supplementary list of study material may be issued in the form of a BuPers Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a Bupers Notice has been issued to supplement Navpers 1005 for your rating.

The required and recommended references are listed by pay grade in Navpers 10052. If you are working for advancement to third class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using Navpers 10052 you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY - that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Navy school.

Do not overlook the section of NavPers 10052 which lists the required and recommended references relating to the military qualification standards for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NavPers 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in Navpers 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

There are two general types of rate training manuals. RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NavPers number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavPers 10061. (Navpers 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NavPers 10052, the Naval Examining Center uses it as a source of questions in preparing the fleet- wide examinations for advancement. In case of discrepancy between any publications listed in NavPers 10052 for a given rate, the Examining Center will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military qualifications and the occupational qualifications for your rating before you study the training manual, and refer to the Quals frequently as you study. Remember, you are studying the manual primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of

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day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit- it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying anyone unit-chapter, section, or subsection-write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying-a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can It give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use enlisted correspondence courses whenever you can. The correspondence courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an enlisted correspondence course based on the rate training manual. You will probably find it helpful to take other correspondence courses as well as those based on mandatory manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

Besides training manuals, Navpers 10052 lists official publications on which you may be examined. You should not only study the sections required, but should become as familiar as possible with all publications you use. One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the occupational qualifications of your rating.

PUBLICATIONS YOU SHOULD KNOW

Some of the publications described here are subject to change or revision from time to time-some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that 'you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work

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to advance in rating; it is likely to be a waste of time, and may even be seriously misleading.

NAVORDSYSCOM Publications

As you might expect, the publication most often referred to in this manual as a source of amplifying information is the Ordnance Pamphlet (OP). OPs are the basic type of technical publications issued by the Naval Ordnance Systems Command (NAVORDSYSCOM). The equipment OP (which is the one you will most generally use) provides detailed instructions on operational theory, physical description of components, installation, maintenance, repair, and safety precautions for each item of ordnance equipment.

The manufacturer's technical manuals furnished with some items of equipment are valuable sources of information on operation, maintenance, and repair.

The OPs needed for your equipment will be aboard. If you feel a need for additional information, you can consult OP 0, the index of all OPs, for the titles and numbers of other publications, and then request them.

INSTRUCTIONS issued by the NAVORDSYSCOM are another source of information referred to in this manual. The purpose of these instructions is to pass out the details concerning the Command's policy in matters of operation and maintenance. The numbering system for the instructions is explained in chapter 15. The ones pertaining to the work of your division are filed in the office and additional copies of some may be kept in the work spaces.

BUPERS Publications

Some of the BUPERS publications that you will need to study or refer to as you prepare for advancement have already been discussed earlier in this chapter. The basic courses, published by BUPERS, will be referred to frequently in the manual. These include:

Basic Electricity, NavPers 10086-B
Basic Electronics, NavPers 10087-C
Fluid Power, NavPers 16193-B
Military Requirements for Petty Officer 3 & 2, Navpers 10056-C
Blueprint Reading and Sketching, Navpers 10077-C
Basic Machines, NavPers 10624-A
Basic Handtools, Navpers 10085-A

Large changes have been made in some of the revisions so be sure you have the latest revision of each book.

Since you will be working closely with Fire Controlmen and Gunner's Mates (Guns), you may find it useful to consult the rate training manuals prepared for those ratings.

Naval Ship Systems Command (NAVSHIPSYSCOM)

Missile launching systems and missile magazines must be installed and maintained to comply with ship's rules. These are given in NAVSHIPS Technical Manual, consisting of chapters, many of which are in pamphlet form. Use the table of contents to locate a particular chapter, and then use the index at the end of the chapter to find the topic you want.

The electricity used in your division is supplied by the ship, and ship's rules and regulations must be observed. These too, are given in the Technical Manual, along with some detailed instructions on care and repair of components.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777 (formerly NAVWEPS 10-1-777-) published in 1969. Copies may be ordered in accordance with the Navy Stock List of publications and Forms, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

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CHAPTER 2

HITTING A MOVING TARGET FROM A MOVING SHIP

As mentioned in chapter 1 of this training manual, the duties of the Gunner's Mate (Missiles) include the operation and maintenance of guided missile launching systems and associated handling equipment. Your duties as a GMM also include the handling and stowage of guided missiles and guided missile components, replacement and/or maintenance of components, assembly and inspection of missiles, and preparation of missiles for testing.

It would be fairly easy at this point to go right into the subject of guided missile launching systems and let it go at that. However, the launching system is only one part-though a very important part- of the overall shipboard weapons system.

As a GMM, you must know a great deal more about the launching system than merely the operation and maintenance of the mechanisms associated with it. To understand what the mechanisms do, you must know how they fit into the overall weapons system. Thus you must come to understand the basic fire control problem that must be solved to position a missile launcher, and to direct the missile to the target. You must also have a fairly good understanding of the guided missile which you are to launch- especially its propulsion system and warhead.

As a GMM you will be part of a weapons delivery team made up of Radarmen, Fire Control Technicians, and Gunner's Mate Technicians, to name some of the ratings directly involved. In studying this manual, you will come to know something of their jobs as, indeed, they will learn something about yours in their rate training manuals.

You learned some of the basics of fire control in Seaman, Navpers 10120-E, in the chapter on gunnery. With these ideas in mind, let us now take a brief look at some of the basic aspects of the shipboard fire control problems.

DEFINITIONS

A MISSILE may be defined as ANY object capable of being hurled, thrown, projected, or propelled, so as to strike a distant object.

An UNGUIDED MISSILE is a missile which is AIMED - but which CANNOT CONTROL its own trajectory, or flight path. A thrown rock is an example of an unguided missile.

A GUIDED MISSILE is a missile whose trajectory IS CONTROLLED during all or part of its flight, by mechanisms within the missile, or by responding to the missile guidance system.

A ROCKET is a missile which carries a propulsion system that is not dependent on the oxygen in the atmosphere.

Thus, the term MISSILE is a general one. The term ROCKET is specifically limited to missiles propelled by air-independent systems. The distinction between the two terms will become clearer to you later in this course. The important thing to remember now is that a rocket is limited in its meaning.

What is fire control? FIRE CONTROL can be defined as the practical application of exterior and interior ballistics, and the methods and devices used to control missiles, gun projectiles, torpedoes, and other weapons. Another way to put it, in terms of weapons, would be to say that fire control is the process of determining the exact relationship between a weapon and its target, and then using that information to get the weapon to strike or inflict damage on that target.

BASIC FIRE CONTROL PRINCIPLES

We will now cover briefly some basic fire control principles to give you an appreciation of the problems inherent in placing a missile or projectile on the proper trajectory. The principles will be covered in a simple and direct fashion, with no attempt to examine the mathematical aspects of the fire control problem.

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(The details of the problem, for the most part, are the responsibility of Fire Control Technicians.)

To illustrate the basic principles of fire control, we will use a simple gunfire control situation. This method of presenting the problem is valid because missile concepts are similar to tried and proven gunnery principles. For example, the first experimental shipboard missile weapon system used modified gunfire control radars and computers to solve the missile fire control problem. Even the launching system used gun power drives to position the launcher. So you can see that there is a close relationship between gunnery and missilery ideas and equipment. As we progress through this chapter, we will point out the similarities and differences between the missile and gunfire control problems.

We will cover gunfire control principles as well as missile fire control concepts. As a GMM you should be familiar with the fire control problem. To advance in rating, a background knowledge of gunfire control is required. So, an early start in the study of gun and missile fire control will better prepare you to meet the professional (technical) qualifications for advancement in rating.

At the beginning of this chapter we distinguished between a guided missile and an unguided missile. Under our previous definitions, it may be said that a football, a bullet from a hunter's rifle, and a 5" projectile, as well as a thrown rock, are unguided missiles.

The problem of delivering a projectile from a gun to a target has been studied for years. Accurate computing devices have been developed to consider many factors before sending a projectile on its way to the target. These factors include target range and bearing, target course and speed, wind direction and speed, movements of the firing platform, and gun ballistics. When these and certain other factors have been determined, the gun may be fired. From that instant on, there is no control over the projectile's trajectory. It is "on its own." Whether or not it hits the target depends on the accuracy of the calculations prior to firing. If the calculations were inaccurate, and the projectile misses, corrections are introduced to bring the next one on the target. This process is repeated, if necessary, until the target is destroyed.

All of the calculations which go into the firing of a missile - whether it be guided or unguided - fall under the general heading of fire control. The term FIRE CONTROL SYSTEM denotes all of the equipollents necessary to achieve this objective.

ELEMENTS OF FIRE CONTROL SYSTEMS

It was stated earlier that a football falls under the category of a missile. Strangely enough, the "launching" of a football requires a fire control system which is in many ways similar to that required for guided missiles or unguided projectiles.

To place a missile - whether it be a football, gun projectile, or a missile - on a trajectory toward a target, there are three essential elements in the fire control system. These are:

1. A means of detecting the target and observing its movements. (Detection and tracking.)
2. A computing system which will accept various inputs and solve the fire control problem.
3. Communications channels which link the detecting equipment and the computing system.

Considering a football as a missile, the passer's eyes serve as the detection system. The passer's brain accepts detection information relayed from the eyes and computes the direction, elevation, and force which must be applied to the ball to place it on a trajectory to the receiver. In computing the proper direction, elevation, and force, the brain takes into consideration such factors as the thrower's motion, the instantaneous direction of the receiver, the direction and speed of the receiver's motion, and the direction and speed of the wind. If all of these are analyzed correctly, the missile launching system (in this case the passer's body) will release the ball with the proper force and in the proper direction to cause a "hit."

In this "human fire control" system, there are two obvious communication links. One of these connects the detection system (the eyes) to the computing system (the brain). The other connects the brain to the launcher - the body, or, more specifically, the arm.

We mentioned earlier that a bullet from a hunter's rifle also falls under the category of a missile. As in the football example, the eye serves as the detecting system, the brain as the computing system, and the body of the hunter and the rifle as the launching system.

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Again, if the motions of the target are correctly detected and analyzed, the rifle should ultimately be correctly positioned in train and elevation to bring about a hit.

You will notice that there is one basic difference in the foregoing examples. In the case of the football player, the passer computed direction, elevation, AND force. In the case of the hunter, he computed only direction and elevation. The distinction lies in the fact that the force exerted on the football can be varied at the will of the passer. He may throw the ball 5 yards, or he may throw it 25 yards (or more). In the case of the hunter's rifle, the bullet will leave the rifle at essentially the same velocity (and with the same force) regardless of the distance or direction of the target. From experience, the hunter instinctively allows for this constant initial velocity as he leads his target in bearing and elevation.

By leading his target (a flying bird or running animal) in bearing we mean that the hunter must aim, not at where his target is now, but where he expects it will be when the bullet arrives. He also must aim slightly above the target because gravity pulls the bullet downward.

You will notice that the two key factors in placing a missile initially on its trajectory are bearing and elevation. If we have a rifle, 5" gun, or guided missile launcher initially aimed on the right bearing, and pointed in the proper direction above the horizontal (elevation), the missile will leave its launcher on the desired trajectory.

Earlier we said that the trajectory of a guided missile could be controlled after the missile left its launcher, whereas the trajectory of unguided missiles could not. This is an extremely important consideration, since a change in the target's motion (course and speed) while a projectile is in flight will cause a miss. The guided missile has been designed so that it can alter its trajectory while in flight. Even though the target's speed and direction may change after a guided missile has been launched, the missile guidance system will cause the missile to turn toward the target and yield a hit. The ways in which this is accomplished are described later in this course.

INFLUENCES ON TRAJECTORY BY OUTSIDE FORCES

Once a missile (guided or unguided) is launched, certain outside forces work on it during its entire flight. We will now look at the effects of some of these forces to give you an idea of some of the factors associated with the fire control problem.

Gravity

The primary natural force acting on a gun projectile or guided missile is gravity. The effects of gravity are felt throughout the entire universe. Everybody in the universe has a gravitational field which works on every other body in the universe. This has been stated mathematically in terms of mass and distance as follows:

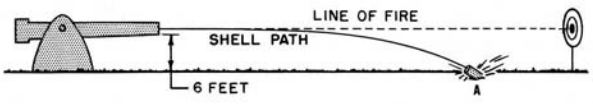
Every body in the universe exhibits an attracting force on every other body which is proportional to the product of the mass of the bodies concerned, and inversely proportional to the square of the distance between them.

You have probably heard that the gravitational effects of the moon are considerably less than those on the earth. This is due to the fact that the moon has much less mass than the earth. The effects on the moon's gravity are readily apparent on earth as evidenced by the changing tides. The moon's closeness to the earth permits these effects to be detected. The planet Mars (in our solar system but much farther away than the moon) has a much stronger; gravitational field than the moon, but exhibits no apparent effects on the earth.

Let's come back to earth, and neglect the effects of gravitational fields other than our own. You have heard the old expression that everything that goes up must come down (long since proven dead wrong). For practical purposes, we can consider the expression to be true when the flight of a projectile or guided missile is considered. The earth's gravitational field is pulling on these objects throughout their entire flight.

In 1600, the Italian astronomer Galileo made an interesting observation about the pull of gravity. Legend has it that he dropped several objects of different weight from the Leaning Tower of Pisa, and noted that all of them struck the ground at about the same time. You may readily challenge this statement by persisting that a steel ball will fall faster than a feather. This occurrence is due to the air density rather than the difference in weight of the two objects. If a steel ball and a feather were dropped simultaneously from the same height in a vacuum, they I would strike the ground at precisely the same instant. Many experiments have shown that the pull of gravity causes a falling body to accelerate

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12.1

Figure 2-1.—How gravity affects the trajectory of a projectile.

at the rate of about 32 feet per second (32 ft/sec^2). Acceleration is often expressed in terms of g's, one g being equal to an acceleration of 32 ft/sec^2.

Several simple formulas have been developed which will help you to understand the relationships of acceleration, distance, velocity, and time with respect to a freely falling body. For example, the distance a body will fall in a given amount of time may be computed by the formula:

$$d = 1/2\ gt^2$$

where d = distance in feet, t = time in seconds, and g = 32 ft/sec^2. By using this formula. we can show that a freely falling object will fall 16 feet the first second, i.e.:

$$d - (1/2)\ (32\ ft/sec^2)\ (1\ sec)^2 = 16\ ft$$

During the first two seconds, the body will fall (1/2) (32 ft/sec^2) (2 sec^2)2 = (32) (4) ÷ 2 = 64 ft.

To determine the velocity at any instant of fall, you can use the formula:

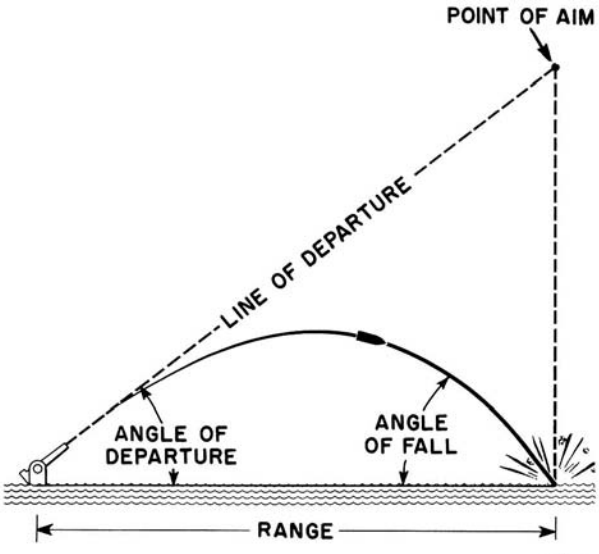
$$v = v_1 + gt$$

where v_1 is the initial velocity, g is 32 ft/sec^2, and t is the time in seconds. For example, at the instant of release, v_1 will equal zero. Therefore, the body would fall at the rate of 32 ft/sec at the end of the first second, since v = 0 + (32 ft/sec^2) (1 sec). At the end of 5 seconds, the same body would be falling at the rate of 160 ft/sec, i.e.:

$$v = 0 + (32\ ft/sec^2)\ (5\ sec) = 160\ ft/sec$$

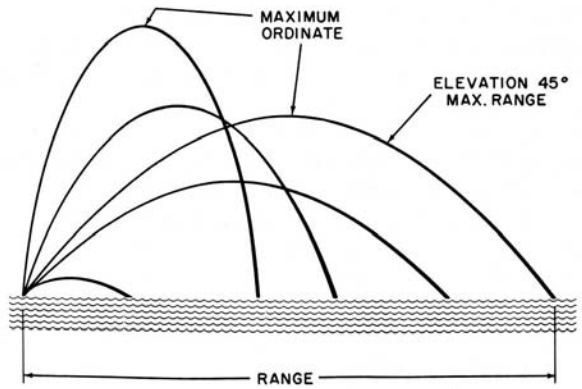
Now let's look at figure 2-1 to see how gravity affects the trajectory of a projectile. In this figure, the gun is pointed directly at the target. The line along the axis of the bore, which is extended from the end of the barrel, is called the LINE OF DEPARTURE or the LINE OF FIRE (LOF).

At the instant the projectile leaves the muzzle and is free from the constraining effects of the barrel, the pull of gravity begins to affect it. The projectile immediately starts to drop, and falls substantially short of the target. It



12.2

Figure 2-2.—Increased elevation produces increased range.



12.4

Figure 2-3.—Parabolic trajectories.

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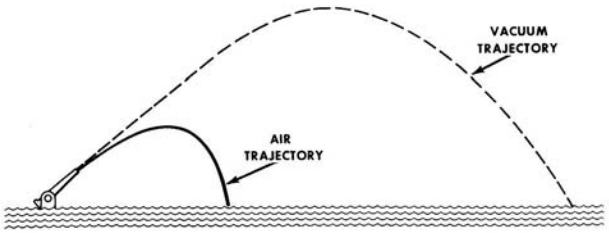
is obvious from the figure that the gun must be elevated to hit the target. Suppose the gun is elevated by the amount shown in figure 2-2. Note that the projectile again drops with respect to the line of departure, even though it is going up with respect to the horizontal. The angle between the horizontal and the line of departure is called the ANGLE OF DEPARTURE. The distance from the gun to the target is called the RANGE.

The two primary forces, neglecting air resistance, which work on a projectile in flight-gravity and the force imparted by the propellant charge - cause an unguided projectile to follow anyone of an infinite number of parabolic trajectories such as those shown in figure 2-3. From this figure, you can see that a gun elevation of 45° produces maximum range for a projectile. At gun elevations greater than 45°, the maximum ordinate (highest point on the trajectory) will be higher, but the range will be less. At elevations less than 45°, both the maximum ordinate and the range will be less.

The gun elevation necessary to compensate for the shape of the trajectory is called SUPER-ELEVATION. Thus, superelevation is the angle through which the gun in figure 2-1 would have to be elevated to hit the target. Superelevation is calculated for various types of projectiles by tests and observations at the Naval Weapons Laboratory, Dahlgren, Va., and is a factor in the elevation computations of the fire control problem.

Looking again at figure 2-1, an interesting point to be observed is that the fired projectile would strike the ground at point A in exactly the same amount of time that it would strike the ground if it were merely dropped from the end of the gun barrel. In both cases, the projectile would be a maximum of 6 feet from the ground. The constant acceleration of gravity would yield the same time of flight in either case. To increase projectile time of flight, the gun must be elevated above the horizontal and, neglecting air resistance, the angle of departure will equal the angle of fall (fig. 2-2). The initial (muzzle) velocity of the projectile will be equal to the striking velocity, and the time that it takes the projectile to proceed to its maximum ordinate will equal the time that it will take it to fall from its maximum ordinate to the height of the muzzle.

The force of gravity will affect a missile's trajectory just as it affects the trajectory of a gun projectile. To correct the gravity error, you just elevate the launcher the proper amount.



12.4

Figure 2-4.— Effects of air density on ideal trajectory.

Effects of Air Density

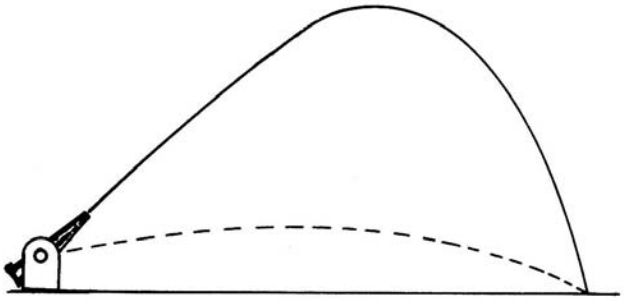
Up to this point, the effects of air density on a projectile's flight path have been ignored. However, in actual practice, we must account for the density of the air, which causes significant changes in the ideal trajectories just discussed. Figure 2-4 shows how the air density might affect an ideal trajectory of a projectile fired in a vacuum. The effect of air is to set up a resistance against any body passing through it. The resistance causes both a loss in speed and a loss in range.

A peculiar thing about air resistance is that it increases rapidly as the speed of the body increases. Roughly, when the speed doubles, the retardation of the projectile becomes more than four times as great. Thus, if a projectile traveling at 1000 ft/sec were retarded 100 ft/sec every second, a projectile traveling 2000 ft/sec might be slowed as much as 400 ft/sec every second. Just as an object passing through water creates waves that retard its movement, an object passing through air creates air waves. The effects of shape, size, speed, and angle of attack of an object upon air movements will be discussed in the next chapter with regard to effect on missile flight.

With a little thought you can see what air resistance does to the shape of the ideal trajectory. The longer the projectile travels through the air, the slower it goes. Shortening of the trajectory will be more noticeable at the far end. The high point of the trajectory will not be at the middle as it would be in a vacuum, but will be nearer the point of impact than it is to the gun.

The way to compensate for air resistance is to increase range by additional elevation. In figure 2-5, the dotted line shows the trajectory of a projectile in a vacuum. Notice how much

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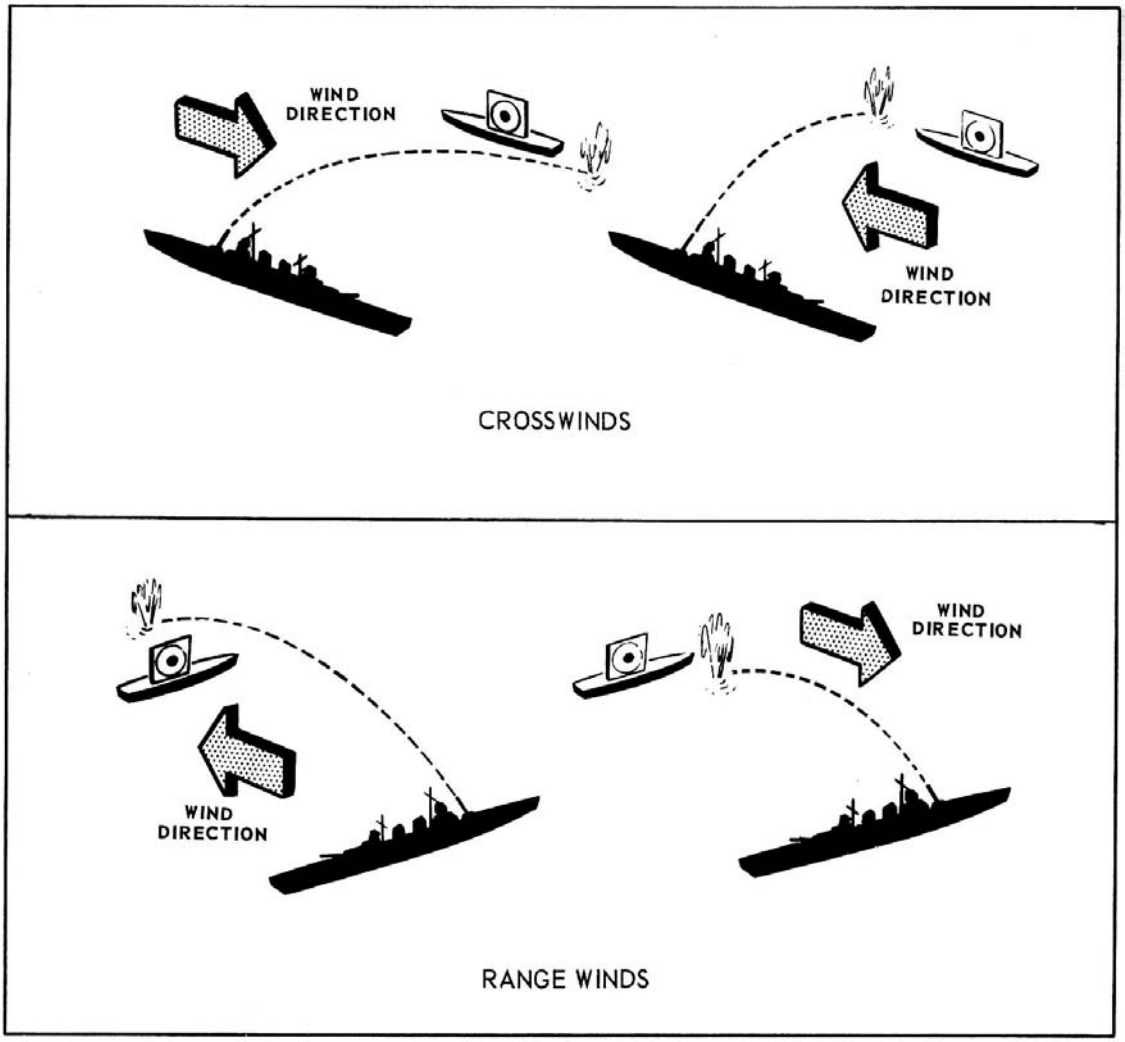
12.5

Figure 2-5.—The way to compensate for air resistance.

additional elevation the gun must have to fire the projectile the same range through air (solid line trajectory).

It would be a very simple matter to compensate for air density in the gunfire control problem if the density were constant in all localities. Actually, air density depends in great measure on temperature and barometric pressure. Needless to say, these two factors are continuously varying. Moreover, air density decreases with altitude along the trajectory, as does temperature.

The shape of the projectile also makes a difference. Obviously, the bigger around the projectile is, the more air will push against it. A pointed nose makes it easier for the projectile to push its way through the air, and thus reduces resistance. Boat-tailing, or tapering, the after end of the projectile reduces the drag



12.8

Figure 2-6.—Wind effects on projectile.

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resulting from air turbulence behind the projectile, and this also reduces resistance.

Guided missiles, like any physical body, are affected by air density. To make their passage through air easier, guided missiles are streamlined. They also contain instruments that measure air density. At high altitudes, where the air is thin, the control surfaces of a missile must deflect more to turn a missile a given amount. The air density measuring device provides a signal to the missile's control system, telling It to increase or decrease the amount of rudder required for a particular maneuver.

Wind

Another natural force which works on a guided missile or projectile is wind. You will remember that the football player takes the wind into account before throwing a forward pass. If you have ever played football on a windy day, you will remember that a well-aimed forward pass may have curved to the right or left, or fallen short of or beyond the point where you wanted it to land.

Wind has exactly the same effect on a projectile in flight. The effect of wind can be seen in figure 2-6. If the wind blows from the left, the projectile will turn to the right, and vice versa. If the projectile is headed into the wind, its range will be decreased. If it travels with the wind, the range will be increased. You can see that effects of wind must be considered in the solution of the fire control problem.

A wind that is blowing at right angles to the projectile's line of fire is a "crosswind." If it is blowing along the LOF, either with' or against the projectile, it is called a "range wind."

If the wind is blowing along the LOF against the projectile, the projectile will fall short of the target. To compensate for this, we must elevate the gun to increase the range of the projectile. If the wind is b1owing with the projectile, the projectile will land beyond the target. To compensate for this, we must depress (lower) the gun or launcher to decrease the range.

If the wind is blowing from the right (at 90° to the LOF), the projectile will land to the left of the target. To compensate for this, we must train the gun or launcher to the right. If the wind is blowing from the left at 90° to the LOF, the projectile will land to the right of the target. To compensate for this we must train the gun or launcher to the left. The corrections for both types of wind are shown in figure 2-7.

The examples given here are special cases. Obviously, wind does not always blow directly at right angles to the line of fire or directly along it. If the wind were cooperative enough to perform in this manner, it would be a relatively simple matter to compute the wind corrections. In most cases, the wind will be at some other angle to the LOF. To correct for wind, it is necessary to resolve the true wind into components in line with and perpendicular to the LOF. When this is done, each component can be treated individually and the proper gun setting or launcher adjustments made.

Immediately after firing, a projectile is traveling at such a high speed that the wind does not affect its flight very much. As the projectile slows down during its flight, the wind effects become more noticeable. Hence, the longer a projectile remains in flight, the more its trajectory will be altered by the wind, so that the wind deflection increases with range. While the effects of wind on missile trajectory are modified by the powered flight, they must be included in the calculations. Wind effects can be especially noticeable on long-range missiles, such as intercontinental ballistic missiles. The computations are further complicated by the decreasing mass of the rocket or missile as the fuel burns up.

Two other factors which affect the trajectory are wind speed and projectile size. Obviously, the greater the wind velocity, the greater the effect on the projectile. At the same initial velocity, a heavy projectile would be affected less by wind than would a light one.

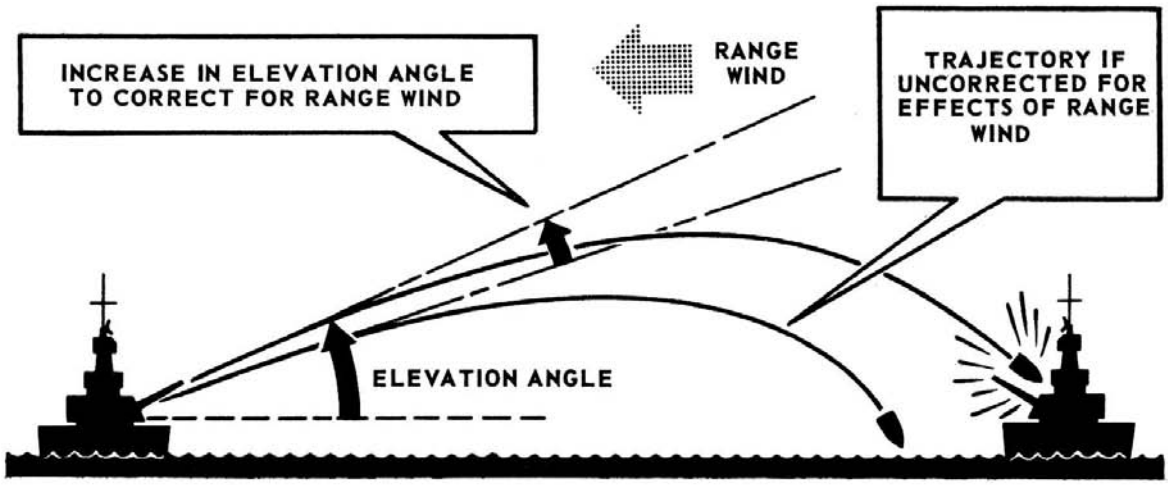
Corrections for the effects of wind are only approximate, because wind speed and direction are usually different at various levels. For instance, the wind might be blowing from the north on the surface of the ocean, and from the south at an altitude of 6000 feet. In such a case, a projectile's trajectory would be affected differently as it is acted on by the winds at various altitudes.

Wind conditions at different altitudes are sometimes determined by observations from airplanes or by observing the movements of small balloons. If it is found that a projectile's trajectory will take it through winds which move in different directions, a "weighted ballistic wind" may be used to compute gunsetting or launcher corrections.

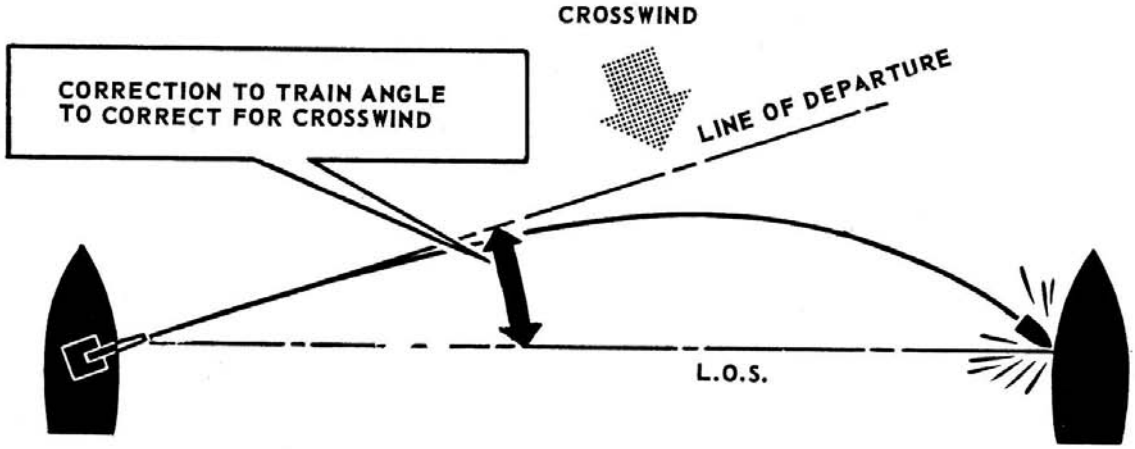
If the projectile's trajectory is low, and passes through winds of one direction only, surface wind is used to compute corrections.

In the upper air, winds blow up and down as well as horizontally. These vertical winds can lift the projectile or hold it down, and thus lengthen or shorten the range. Because these winds are extremely difficult to measure, and

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CORRECTING FOR THE EFFECTS OF RANGE WIND



CORRECTING FOR THE EFFECTS OF CROSSWIND

12.9

Figure 2-7.—Correcting for wind.

actually have little practical effect, they are not considered in fire control computations.

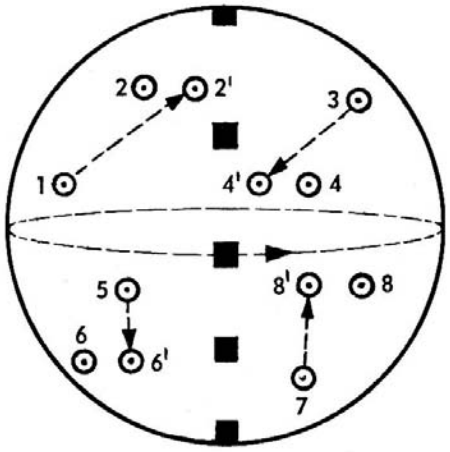
The guided missiles that concern you are boosted into the air. This boost portion of flight is very short, about 5 seconds. During this time the missile is essentially an unguided projectile. Wind, gravity, and air density affect it just as they would a gun projectile. After the boost period is over, the missile enters its guided phase of flight. Even then, these external forces are still at work. But they are corrected for by control surface (wing or tail) movements. To correct for wind and gravity effects during the boost phase, corrections are included in launcher elevation and train orders. Air density is taken care of by booster thrust design.

Corio1is Effect

The Corio1is effect (named after the French scientist Corio1is) also has an effect on the trajectory of a missile or projectile. Although not compensated for in all fire control problems, the Corio1is effect is worth discussing since it becomes important especially with respect to long range gunfire and missiles.

The effect is based on the fact that the different points on the earth's surface have different velocities around the axis of the earth. In figure 2-8 the object at the Equator has a velocity of about 1000 miles per hour around the

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Figure 2-8.—Coriolis effects.

earth's axis. The two objects between the Equator and the poles will have a considerably smaller velocity. The objects at the poles will have zero velocity.

If we fire a projectile from point 1 toward point 2 and do not correct for the Coriolis effect, it will be deflected to the right of the target, as shown by the dotted lines. In this case, the velocity of the launching point is greater than that of the target. The launching point component of velocity will cause the projectile's deflection to the right, and cause it to strike at point 2'.

Now assume that we fire from point 3 to point 4, again failing to correct for the Coriolis effect. The projectile will again be deflected to the right of the target, landing at point 4'. In this case, the launch point has a smaller velocity than the target point.

From the foregoing, we can say that if the Coriolis effect is not corrected for, a projectile will be deflected to the right of the target in the Northern Hemisphere due to the difference in velocity of points at different latitudes.

In the Southern Hemisphere, the effect is reversed; that is, a projectile is deflected to its left. This can be seen when firing from point 5 toward point 6 in the illustration. The higher velocity at point 5 (relative to point 6) will cause the projectile to be deflected to its left, landing at point 6'. If we fire in a northerly direction in the Southern Hemisphere, the projectile will still be deflected to its left as shown by points 7, 8, and 8'.

Therefore, we can say that if the Coriolis effect is not corrected for. a projectile will always be deflected to the left of the target in the Southern Hemisphere.

The curvature of the earth. too, is of little significance in short-range firing, but must be included in the computations for long-range shots.

Stabilization

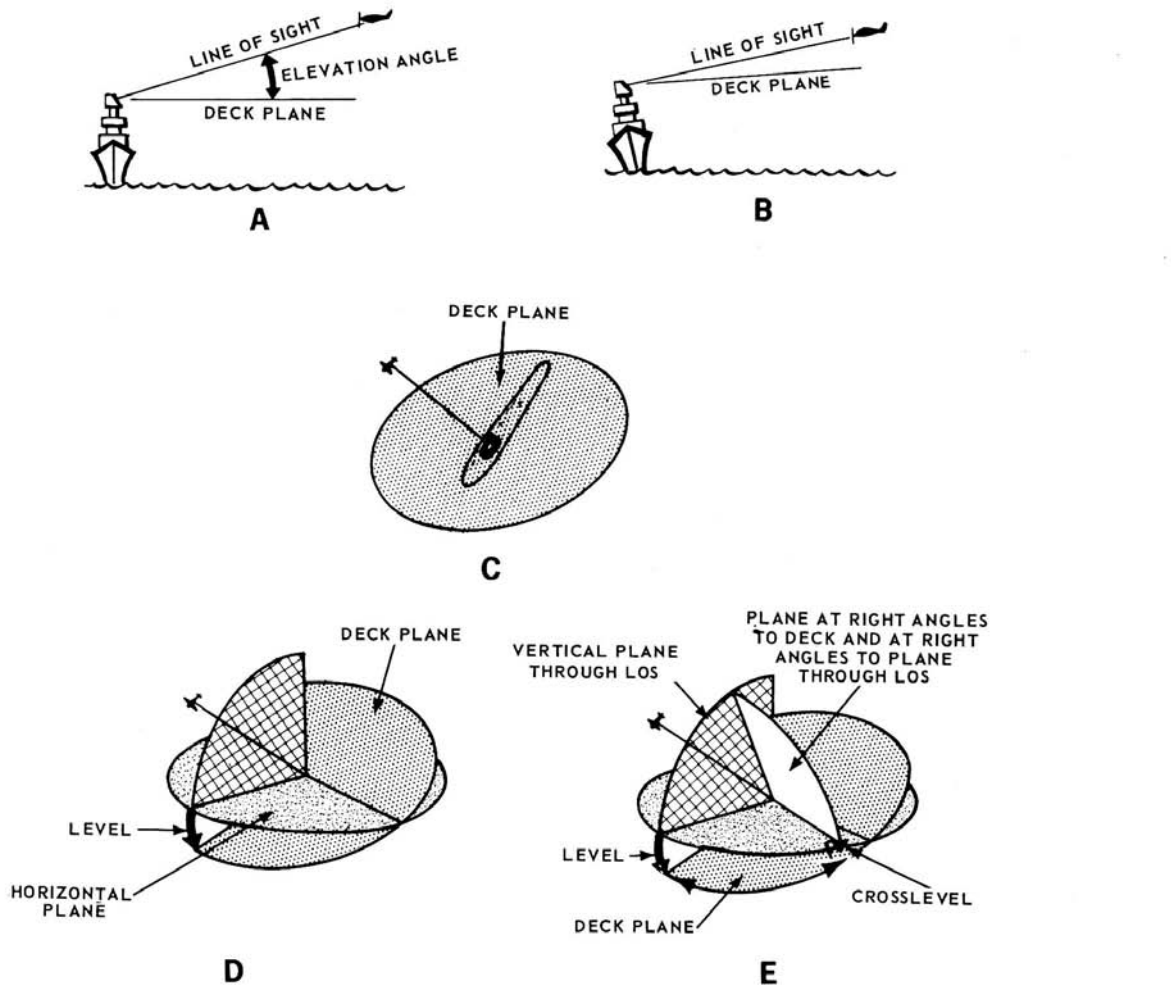
Another very important factor which must be taken into consideration is solving the shipboard fire control problem is stabilization. In figure 2-9A, we show a ship whose deck plane is horizontal. In this case, the target elevation and bearing noted by the detecting equipment is referenced correctly to the horizontal plane. Now look at figure 2-9B. In this illustration you can see that the pitch and roll of the deck causes the values of target elevation to vary, since they are measured from the tilting deck plane. Since a ship is continuously rolling and pitching, the amounts by which the deck plane varies from the horizontal plane must be continuously measured and compensated for in the solution to the fire control problem. (Although not shown. bearing will also vary because of the roll and pitch.)

Stabilization information consists of two quantities -level and crosslevel. Level is the angle between the deck plane and the horizontal plane, measured in a vertical plane through the line of sight. CROSSLEVEL is the angle between the deck plane and the horizontal plane measured in a plane at right angles to the vertical plane through the line of sight at right angles to the deck. Figure 2-9C, D. and E show the relationships of level and crosslevel to the planes involved. Level and crosslevel angles are continuously measured by the ship's STABLE ELEMENT, and are a significant factor in the correct solution to the fire control problem.

Trunnion Tilt

Guns and missile launchers are mounted between trunnions, which tilt as the deck rolls and pitches. Trunnion tilt corrections are corrections necessary to keep the guns or launchers pointing along the line of fire despite the tilting of the trunnions. In figure 2-10, you can see that a tilting deck would cause a miss if the tilt were not compensated for. Thus, trunnion tilt must also be measured continuously and corrected for in the gun or launcher train and elevation orders.

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Figure 2-9.— The effect of ship roll and pitch on the fire control problem: A. Ship's deck horizontal; B. Roll and pitch tilt the deck angle; C. Plane of reference; D. Angle of level; E. Angle of cross-level.

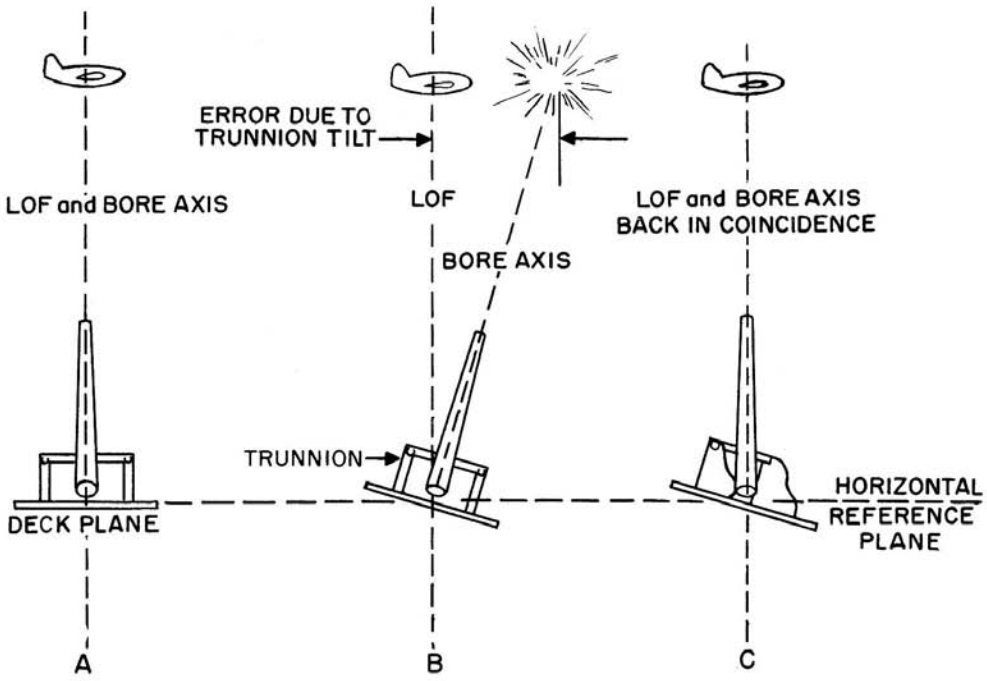
Parallax

Another factor to be considered in the fire control problem is parallax. In figure 2-11, the detecting equipment is trained on a target on the port beam. You can see that only one of the guns would hit the target if all were trained on the port beam.

The problem of parallax stems from the fact that the guns and launchers are displaced from the tracking (fire control director) equipment. Thus, the line of sight between the tracking equipment and the target does not coincide with the line of sight between the guns and launchers and the target.

The director must correct its orders for LOF so lines of sight from the guns and launchers in different parts of the ship will all converge on the target. The farther the gun or launcher is from the director, the greater the horizontal parallax correction will be. Figure 2-11B shows how the guns are brought to bear on the target when the parallax has been compensated for. Figure 2-11C shows that an elevation correction is also necessary since the gun and tracking equipment are

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Figure 2-10.—Trunnion tilt and fire control: A. Deck level—a hit without corrections; B. Trunnion tilt not compensated for—projectile misses; C. Correction made for trunnion tilt—projectile hits.

at different heights. Actually, the parallax corrections are relatively small angles (greatly exaggerated in the figures) which change the gun orders only slightly. Moreover, parallax may be corrected for with little difficulty, since the guns and launchers are at fixed distances from the tracking equipment on any given ship.

It is important to mention that parallax effects become more significant at short ranges such as those shown in the figures than they would be at long ranges. At extremely long ranges, the effects become negligible.

EFFECTS OF INTERIOR FORCES

Interior ballistics is the study of what happens while the projectile travels through the bore of the gun from the instant of firing. Since missiles are fired from launchers and do not pass through a bore, you can readily see that some of the factors will not affect the trajectories of missiles. Both gun barrel and launcher give the initial direction to the projectile or missile.

Initial Velocity

The "send-off", of a projectile or missile makes a big difference in how far and how fast it goes. In the old days when each gun was hand loaded by tamping in a measured quantity of gunpowder, wadding, and shot, the result was not predictable. With the manufacture of ammunition rounds in factories according to precise standards, it became possible to prepare range tables for all sizes and types of ammunition. Until the more recent replacement by automatic computations, range tables were consulted in all gunnery computations. While Navy officers still had to learn how to figure where their shots would land, the range tables were a convenient source of prefigured data for every type of ammunition in the Navy.

The initial velocity for missiles is furnished by the booster. Its size, weight, and type of propellant determine the initial velocity of the missile.

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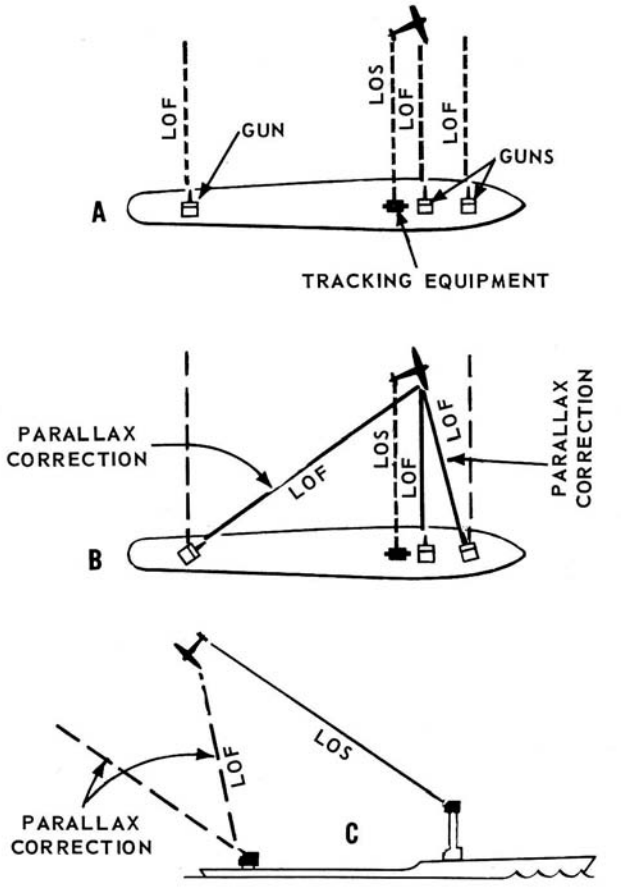


Figure 2-11.—Parallax correction: A. Cause of parallax problem; B. Correction of horizontal parallax; C. Correction of vertical parallax.

Condition of Propellant

With composition, size, shape, quantity, configuration, and containment of the propellant all determined with exactitude before you receive the projectiles or missiles, what influence does the work of Gunner's Mates have in initial velocity? The condition of the propellant at the time of use can have great influence. One of these conditions is the temperature. Another condition is humidity. Temperature and humidity of the missile storage spaces must be carefully regulated. A higher temperature results in greater energy release, and therefore the booster propellant "burns up" faster.

Drift

Another factor that affects the trajectory of a projectile is drift. Drift is not a simple effect; it's the product of the interaction of three other factors - namely, the clockwise spin of the projectile, the force of gravity, and air resistance. As the spinning projectile moves through the air, it tends to point slightly above the trajectory, and the air pressure on its underside develops a thrust that tends to tumble the projectile end over end. But like any other rapidly spinning mass, the projectile reacts to a thrust tending to displace its axis of spin by precessing gyroscopically. (You'll learn more about gyroscopic action as you learn more about fire control, so we won't go into detail about it at this point.) In this case, the precessing movement is a slow turn to the right. The result is that the projectile's course is deflected to the right-relatively slowly at first, but more and more as the trajectory lengthens.

The direction of drift depends entirely on the direction of rotation of the projectile. Every rifled weapon in the Navy (with one exception - the .45 caliber pistol) causes projectile spin to the right (that is, clockwise as viewed from the projectile base), and drift to the right.

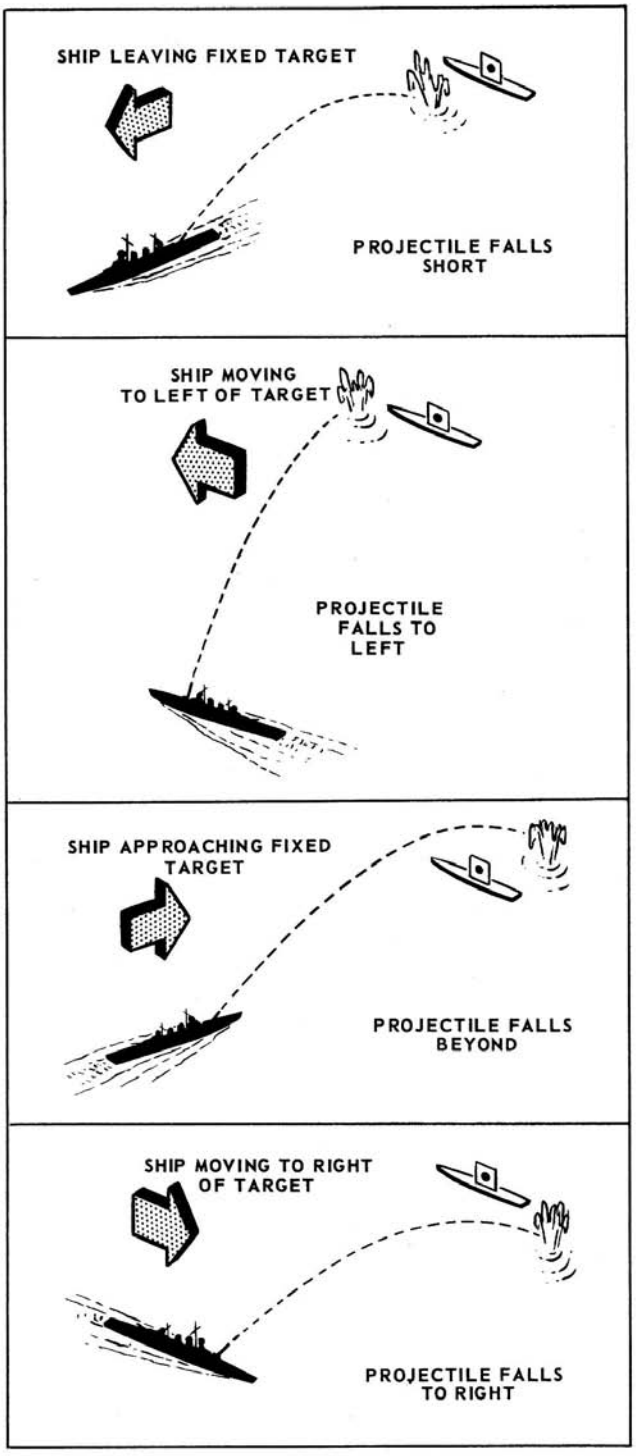
Drift increases with range, but it is completely independent of wind. Since missiles are not fired from rifled barrels, this type of deflection does not occur.

WHY WE NEED FIRE CONTROL INSTRUMENTS

Picture yourself on the deck of a modern warship, charged with the responsibility of directing the ship's gunfire. The target is visible on the horizon and it is up to you to tell the gunner how he must elevate and train his guns in order to score a hit on the enemy. You are familiar with the corrections that must be applied and you know how they are calculated. So, first you determine range and bearing' 'by eye"; then you must correct for drift, wind, air resistance, earth's curvature, and rotation of the earth. You must determine the target's course and speed, predict its future position, allow for own ship's motion, predict future range and deflection, and correct for level and crosslevel. You work rapidly and after a half-hour or so, you come up with the answer. By that time the target has disappeared or has blown you out of the water.

The solution of the modern fire control problem cannot be reached rapidly nor accurately enough without the help of various fire control

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Figure 2-12. — Errors in gunfire caused by movement of own ship when target is fixed.

equipments and related equipment. A hit or miss method is intolerable; modern fire control instruments are essential to get the most out of our expensive, modern weapons. Gunner's Mates need to know the basic principles of fire control.

HITTING A MOVING TARGET FROM A MOVING SHIP

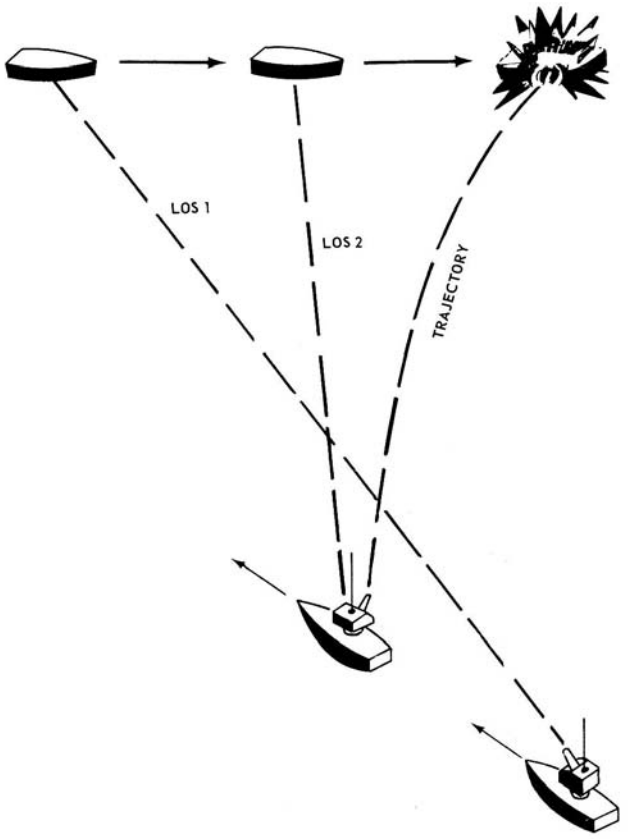
From what has been discussed to this point, you know that we must offset a gun or launcher from the line of sight (LOS) between the tracking equipment and the target to compensate for such factors as superelevation, air density (gunfire only), wind, stabilization, and parallax. Important as these factors are in the ultimate correct solution to the fire control problem, they must be accurately related to the movements of own ship and target if we are to come anywhere close to getting a hit.

Thus far, we have been discussing various factors affecting the fire control problem as though the target were standing still. In the vast majority of cases, the target is moving- either on the surface of the sea, or in the air over it. The movement of the target with respect to the firing ship is by far the most important factor in the computation of the fire control solution and the correct positioning of the guns and launchers.

In any fire control problem involving a moving target, the target must be led - just as the duck hunter leads the duck or the passer in a football game leads his receiver running down the field. For a surface ship target, the problem is relatively simple. The first thing to be considered is the motion of own ship. Figure 2-12 shows how the motions of the firing ship will cause errors in the projectile trajectory if not compensated for. In the first part of the figure, the firing ship is headed away from the stationary target at, say, 5 knots. With own ship's course and speed not compensated for, the projectile falls short. If the firing ship's speed were greater in the same direction, the projectile would fall short by an even greater amount. The next three parts of the figure show that different courses of the firing ship with relation to the target will produce similar errors. By taking own ship's course and speed into consideration in the solution of the problem, these effects are compensated for and the errors are nullified.

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Now, let us see what happens when the target starts moving. Figure 2-13 shows a situation in which the firing ship and target ship are both moving. You can see that if we fired at the instantaneous position of the target - that is, along the line of sight - the target would have moved to a new location while the projectile was in flight. We therefore must predict a future position of the target which will permit the gun to be offset from the line of sight by the amount necessary to cause a hit. To do this we must first know the target's course and speed, as well as our own.



83.4

Figure 2-13.—Movement of target and own ship affect line of sight.

APPLICATION OF FIRE CONTROL PRINCIPLES

Fire control systems vary on different ships and for different gun and weapon systems. In all modern systems, computations of the effects of the various forces, internal and external, that affect the trajectory of projectiles and missiles, are made automatically.

SOLVING THE SURFACE PROBLEM

Earlier we said that a detection system, a computing system, and communications links were the elements of a fire control system. Figure 2-14 shows how these elements are linked together with a gun and a launcher.

For the detection system we use a radar set. The radar uses the transmission and reception of electromagnetic radio frequency energy to provide us with information as to the target's precise location with respect to our own ship at any given time. This information is automatically transmitted to the computer in the form of target ranges and bearings. The computer automatically compares the range and bearing information with elapsed time and continuously generates target course and speed.

The computer also accepts course and speed information automatically from own ship's gyro and pitometer log, certain inputs (such as initial velocity), air density, wind speed and direction, level and cross1eve1 signal information from the ship's stable elements, trunnion tilt, and parallax corrections, in some cases Corio1is effect, and other inputs which have a lesser bearing on the problem. In addition, it automatically compensates for supere1evation (defined earlier in this chapter). (The use of a pitometer 1og in measuring own ship's speed is described and illustrated in Basic Machines, NavPers 10624-A, page 61.)

The computer continuously analyzes all of this information (some of which may be set in by hand, depending on the system involved), and comes up with a continuous solution to the problem. This solution consists primarily of two continuously generated quantities:

1. The angle by which the line of fire must be offset from the line of sight in bearing. This angle is called sight deflection.
2. The angle which the line of fire must be offset from the line of sight in elevation. This angle is called sight angle.

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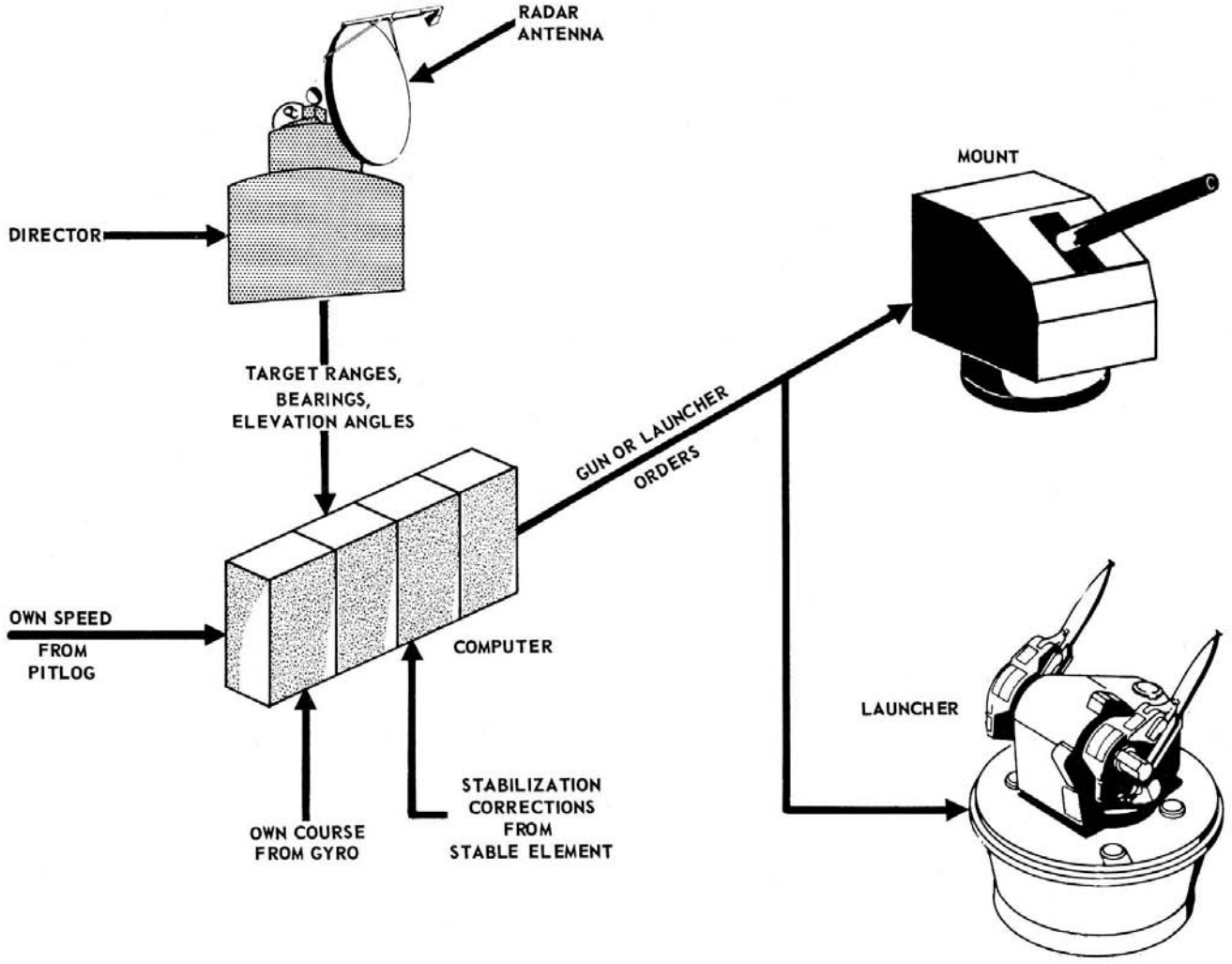


Figure 2-14. — Elements of simplified fire control system.

These quantities (fig. 2-15) are generated continuously and automatically. After they are corrected for roll and pitch, they arrive as gun train and elevation orders at the mount power drives, thus causing the gun barrel to continuously lead the target by the amount necessary to yield a proper trajectory.

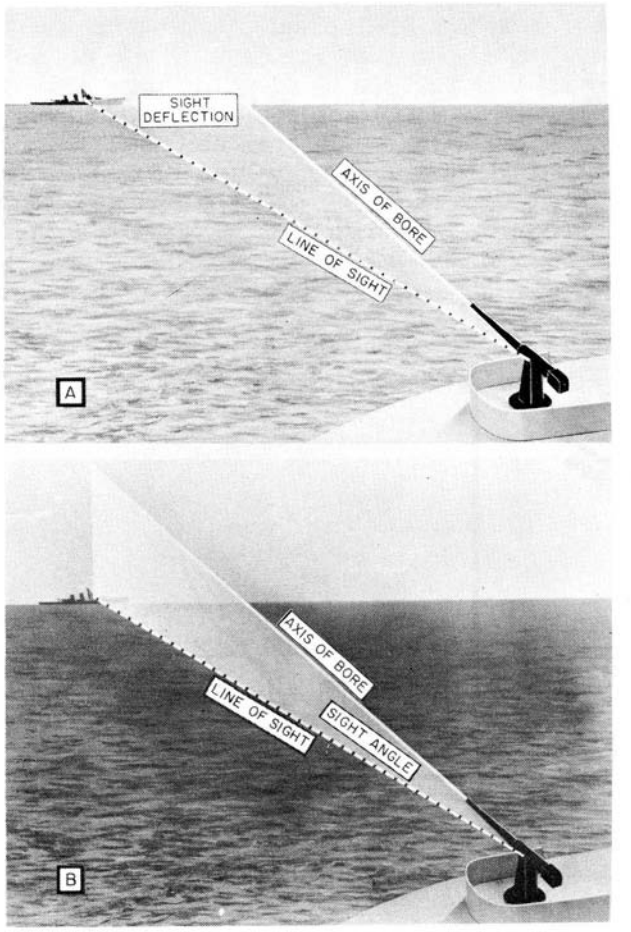
SOLVING THE ANTIAIRCRAFT PROBLEM

The gun antiaircraft problem is somewhat more complicated than the surface problem because target altitude is involved, and also because of the greater speed of air targets.

Figure 2-16 shows an aircraft approaching a ship. Again, the line of sight represents the instantaneous direction and range from the detecting equipment to the target. As with the surface problem, firing along the line of sight would be to no avail, since the target would have passed to a new position during the time of flight of the projectile. In computing the air target's course and speed, the target elevation angles are continuously measured by the ship's detecting equipment in addition to the bearings and ranges. As in the case of the surface target, own ship motions and target motions (in this case bearings, ranges, and elevation angles) are used to position the gun or launcher to lead the target by the correct amount.

It is worthwhile mentioning here that any changes in target course and speed (surface or air problem) are quickly recognized by the detection equipment, and the new information fed to the computer, which immediately corrects the solution and the gun orders. The original predicted target position is continuously

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Figure 2-15.—Offset of gun from line of sight: A. Sight deflection; B. Sight angle.

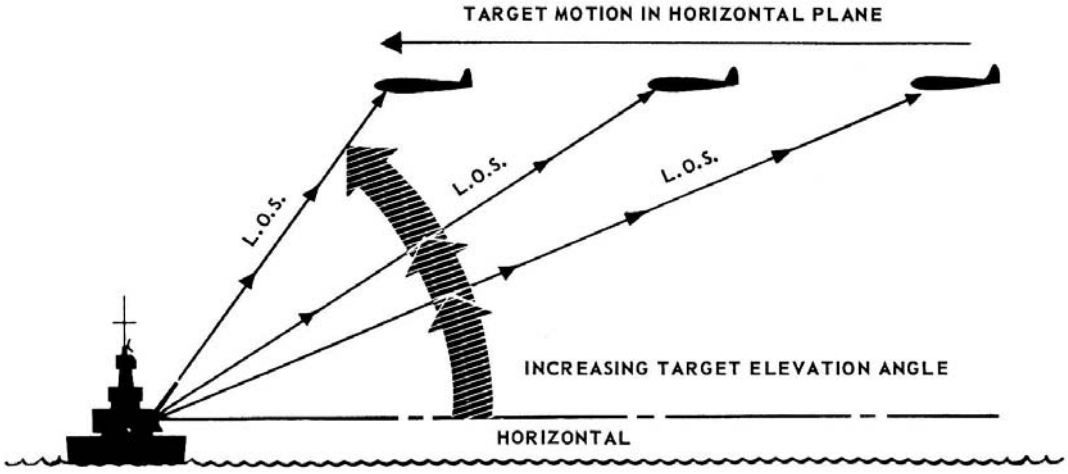
and automatically revised as information is received by the computers and the corrections are sent to the gun or launcher.

The line of sight to the moving air target in figure 2-16 assumes that the ship's deck remains horizontal, which is rarely the case. Corrections for roll and pitch of the ship are included in the computation for the correct line of fire to be used in order to hit the target where it will be at the time calculated.

Figure 2-17B shows that sight angle for the air target includes allowance for target elevation angles. Compare it with figure 2-17 A. The line of sight establishes the relationship between the target and the gun. Sight angle and sight deflection are measured from the line of sight to the line of fire. However, for an air target (fig. 2-17B) , the line of sight is not in the horizontal plane but in the slant plane. The angles are measured from the slant plane.

THE BEAM-RIDER MISSILE AA FIRE CONTROL PROBLEM

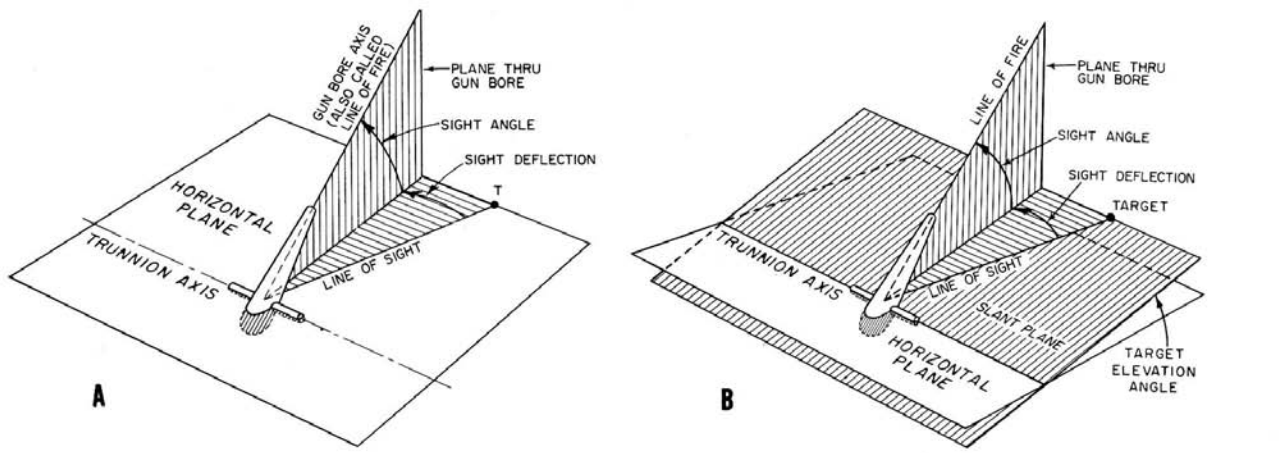
So far in this chapter, we have emphasized the gunfire control problem. Now let's change our thinking a little and look at the fire control problem presented to one type of beam-rider missile. We won't have to shift our mental gears very much because, as you will see, there is very little difference between the two problems. In the gun problem we pointed a gun at an airplane with enough lead angle to compensate for target motion during projectile flight and to correct for the effects of wind, drift, gravity, and initial velocity. Basically, the only difference



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Figure 2-16.—Changing elevation angles for air target.

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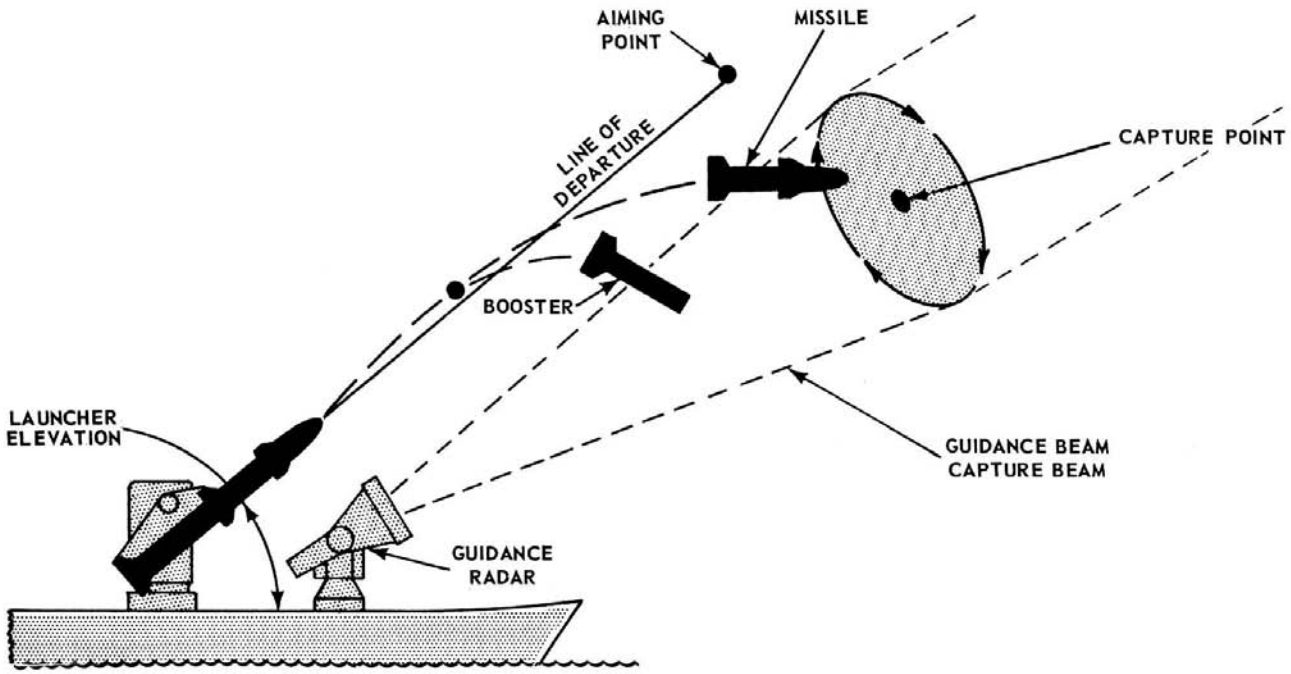
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Figure 2-17.—Sight angle and sight deflection: A. In the surface problem; B. In the air problem.

between the gun and beam-rider missile problems is the target. Instead of pointing the launcher in the general direction of a physical target, we point it at a big radar beam. This beam is called the guidance beam. The missile is launched along a curved line (trajectory) which intercepts a point within the guidance beam called the capture point. Figure 2-18 illustrates the beam- rider fire control problem.

After the search radar has located the attacking aircraft, the tracking and guidance radar follows the aircraft with its beam. The missile follows or "rides" the beam to the target. The booster case drops off after booster burnout, and the missile continues onward.

Before the missile can follow the guidance beam, it must come within the area of the beam. that is, it must be captured by the beam in order



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Figure 2-18.—Simplified beam-rider missile fire control problem—capture phase.

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to be controlled by it. The missile must be aimed into the beam, not at the enemy aircraft in the distance, which may maneuver out of the way. In figure 2-18 you see that the "aiming point" is outside the beam, but that is because corrections for the effects on missile trajectory (air density, gravity, wind, etc.) will deflect the trajectory so the missile enters the radar beam and comes under its control.

You can visualize the guidance beam as a big circle several hundred yards wide with a small dot near the center. The dot symbolizes the capture point. In real life, of course, it is invisible. And so is the radar beam. If guided missile launchers had sights like guns have, you could look through them during missile launch and see only the sky. From an abstract and mathematical point of view, however, you would be looking at a point in space. Figure 2-18 shows this abstract point in more concrete form and it is labeled, simply, capture point. The fire control missile computer continuously figures out where the guidance beam and the capture point are. The computer determines the launcher train and elevation orders based on beam position and ballistic factors. These order are electrical signals which position the launcher. The missile is fired and if the lead angle is accurate, the missile hits the capture point and is captured by the beam. Once the beam has control of the missile, the missile is guided to a point high in the atmosphere. The missile rides the guidance beam until it intercepts the target (fig. 2-19).

While figure 2-19 shows the missile, flying straight to the target, in actual practice this is far from the case. The target is moving rapidly; the radar beam follows it, and the missile follows the beam. The target may change its course, and this may mean sharp changes in the course of the radar beam and the missile that rides it. A missile is subject to the same forces as a gun projectile while in flight. Corrections to the trajectory are calculated before the missile is fired, so it will have a correct start on its flight.

Lead angle is made up of two corrections- lead due to target motion, and lead due to ballistics. Assume that lead because of target motion is correct. If the missile is launched on a line pointed directly at the capture point, the missile will miss the capture point. Why? Because ballistic corrections have not been added to launcher train and elevation orders. These ballistic factors are (1) parallax, (2) gravity, and (3) wind deflection.

Parallax

Figure 2-20 shows what happens if the missile's trajectory is not corrected for parallax. The missile trajectory and guidance beam are offset, and the trajectory does not intercept the capture point. If we launched a missile under these conditions, the result would be a missile "by the deep-six." Like the gunfire control equipment, missile fire control equipment is spread out over the ship. The launcher and the guidance radar are physically offset along the centerline of the ship and also are at different heights above the deck of the ship. Therefore, if the launcher and radar are positioned at the same bearing and elevation angles, the line of fire of the launcher will be parallel to the guidance beam. As you know, the amount these parallel lines are offset from each other is called parallax. To compensate for parallax, the launcher bearing and elevation angles are offset toward the guidance beam. Then the launcher line of fire intersects the guidance beam, and the missile trajectory will intersect the capture point. Time to beam capture is very short, about 5 seconds after launch; booster burnout occurs about 1 sec second before this.

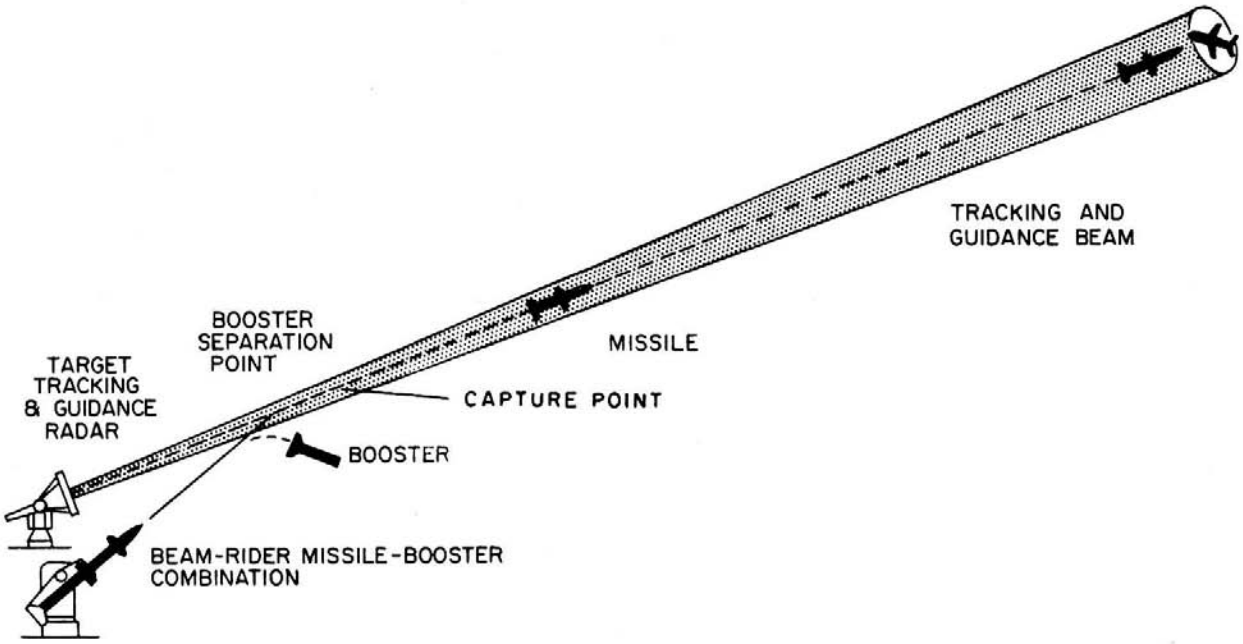
Gravity

In figure 2-21 you can see the effect of gravity on the missile's trajectory. For clarity, we have neglected the parallax and wind effects. Between launch and capture, gravity acts on the missile. At the instant when the missile should be captured by the guidance beam, it is actually some distance below the capture point. To compensate for the gravity effect, the launcher must be elevated so that the launcher line of fire intersects a point above the capture point. This is the same technique used in gunfire control to compensate for the effect of gravity. The name is the same too - superelevation correction.

Wind

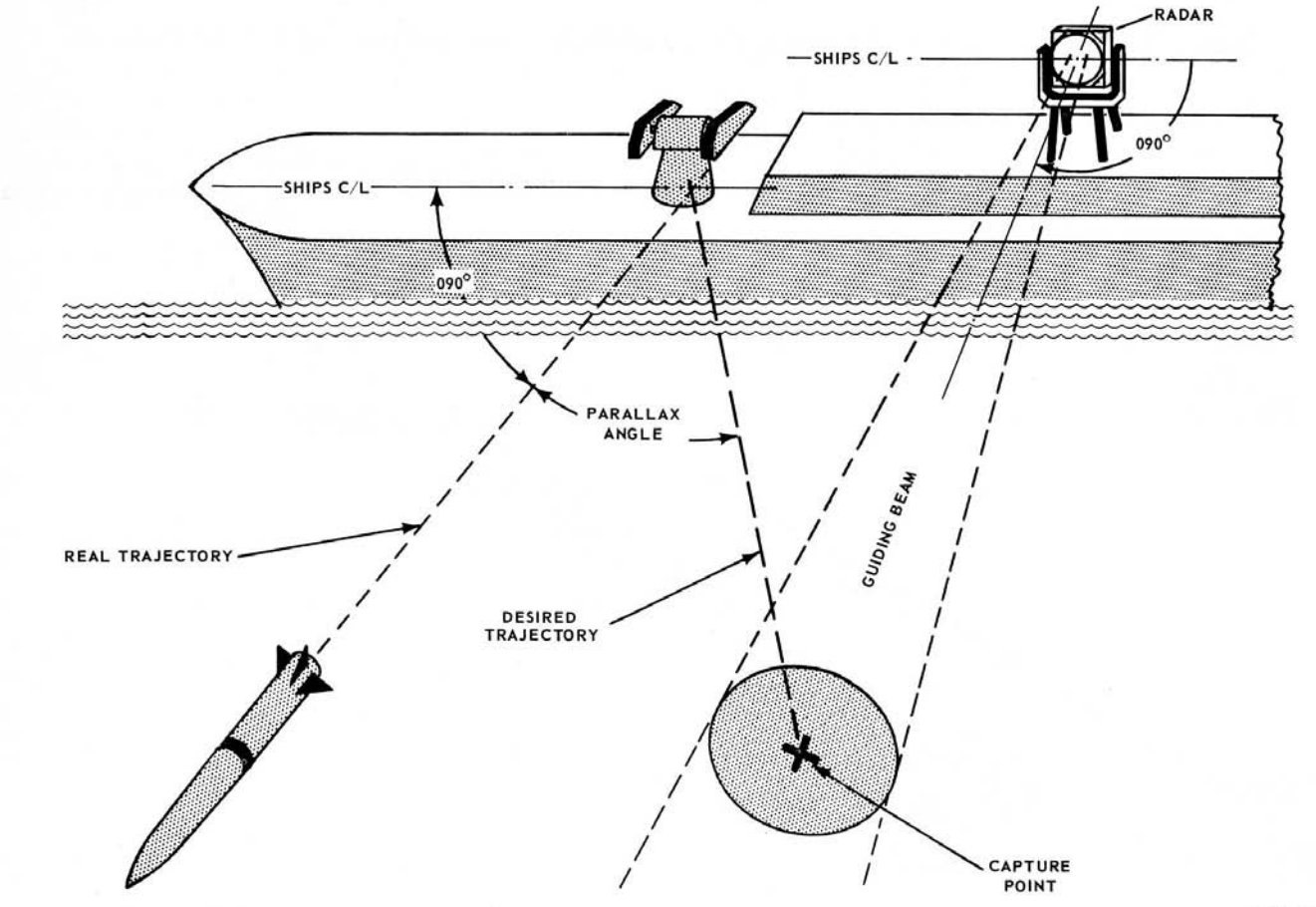
Figure 2-22 illustrates the effects of wind on the missile trajectory. Once again, other effects are ignored. The wind tends to blow the missile off course during the period between launch and capture. Since the missile is not guided during this portion of its flight, wind corrections must be made before launch. The fire control computer calculates these corrections and sends them to the launcher. Therefore. the launcher is offset from the guidance radar line of sight

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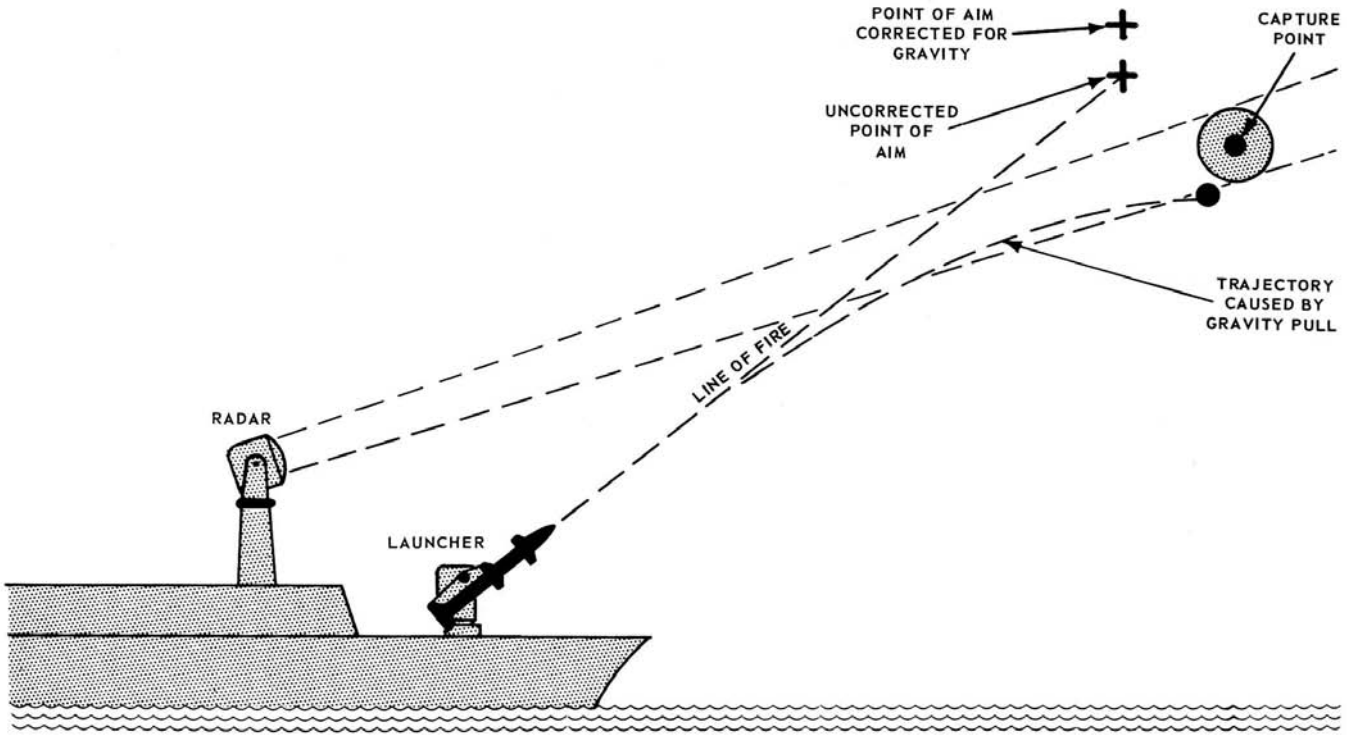
Figure 2-19.— Beam-rider missile follows the radar beam to the target.



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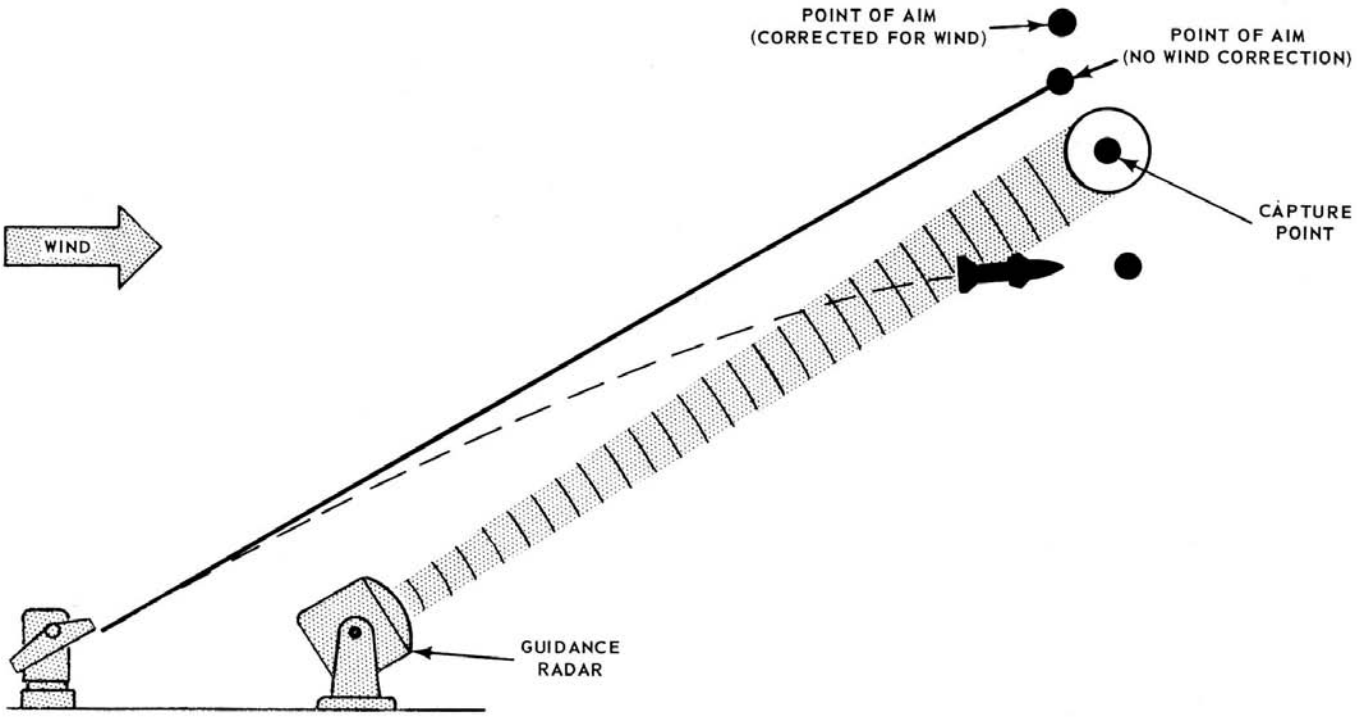
Figure 2-20.— Effect of parallax on a guided missile's trajectory (flight path) during boost.

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Figure 2-21.—The effect of gravity on a missile's flight path during the boost phase.



83.9

Figure 2-22.—Effect of wind on a guided missile's flight path.

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by an amount proportional to the speed of the wind, and in a direction opposite to that of the wind. Now the wind will blow the missile into the guidance beam at the capture point.

The correction for wind includes not only true wind (atmospheric) speed and direction, but also apparent wind, caused by the ship's movement.

SUMMARY

This chapter has briefly covered some of the more important aspects of the surface and air fire control problems. You have seen that the correct solution of a fire control problem depends on many factors. First of all, the target must be detected and tracked. Detection and tracking require an equipment such as radar, which will continuously and automatically provide target bearings and ranges. In the air problem, it must also provide continuous information regarding the elevation angles of the target. This information must be automatically transmitted to a fire control computer, which will compare it with own ship's motion as measured by gyrocompass and pitometer log. In addition, the computer also takes into consideration such factors as level and crosslevel information from the stable element, superelevation, trunnion tilt, wind speed and direction, parallax, in some cases Coriolis effect, air density, and powder temperature (in missile FC computers). The resulting gun and missile orders are continuously generated by the computer and are electrically transmitted to the gun (or launcher) train and elevation power drives, thus causing the line of fire to lead the line of sight by the proper amounts in bearing and elevation. There are many more details of computation in the solution of the fire control problem for guns and missiles, but these are not covered in this text.

Later chapters of this training course will show you in greater detail how a modern weapons system operates. The next chapter will discuss the flight principles and propulsion units of guided missiles.

You may be asked yourself, "Why should I learn more about fire control?" One answer to that question might be: You'll be able to see how important your job is.

The quals for your job require you to know the basic principles of missile flight control, ballistics, and fire control variables. The same forces of nature (wind, air density, gravity, etc.) that affect projectile flight also affect missile flight. The man made thrust force has some variations from guns to missiles, but the principles are the same. As you advance, you must learn how various components function in fire control. The same types of components were used for gun fire control before missiles were invented.

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CHAPTER 3

PRINCIPLES OF MISSILE FLIGHT AND JET PROPULSION

INTRODUCTION

In this chapter and the next we will take up the subject of guided missiles in general. As a GMM, the information in these two chapters will help you to understand the missiles used in the launching systems. Also, the information here represents a substantial portion of the knowledge required by your advancement qualifications.

Specifically, this chapter deals with basic flight principles, the principle of jet propulsion, and the various types of missile propulsion systems. Chapter 4 covers missile components such as SERVOMECHANISMS and GYROS, and the various types of missile guidance systems. You are urged to study these two chapters carefully since the remainder of this course will concentrate primarily on launching systems. Whatever knowledge you can gain in chapters 3 and 4 will be of considerable help to you in understanding the material which follows.

MISSILE AERODYNAMICS

Guided missiles launched from surface ships have their flight paths within the earth's atmosphere, so it is important that you understand some basic aerodynamic principles.

Aerodynamics may be defined as the science that deals with the motion of air and other gases, and with the forces acting on bodies moving through these gases.

THE ATMOSPHERE

The atmosphere is a gaseous envelope surrounding the earth to a height of roughly 250 miles. Although there is some difference of opinion as to where the atmosphere ends and space begins, the limit defined above is quite generally accepted. So far as tangible evidence goes, the 750-mile upper limit of the aurora borealis is the "top" of the atmosphere. The behavior of the electrical discharges indicates that elements of air are present, although extremely rare.

As mentioned in chapter 2, one of the most important characteristics of the atmosphere is that air density changes with altitude. As altitude increases, air density decreases significantly. At sea level, the density of air is about .076 pound per cubic foot. At 20,000 feet, air density is only about .0405 pound per cubic foot. Because of the decrease in air density with altitude, a missile flying at 35,000 feet encounters less air resistance-that is, has less drag-than a missile flying close to sea level.

Air pressure also varies with altitude. The pressure acting on each square inch of the earth's surface at sea level is actually the weight of a column of air one inch square, extending from sea level to the outer limits of the atmosphere. On a mountain top, this column of air would be shorter, and so the weight (pressure) acting on ' each square inch would be less. Therefore, air pressure decreases as altitude increases.

Another characteristic of the atmosphere which changes with altitude is temperature (see fig. 3-1). But, unlike density and pressure, temperature does not vary directly with altitude. From sea level to about 35,000 feet, the temperature drops steadily at a rate of approximately 3 1/2°F per thousand feet. It then remains fairly constant at -67°F up to about 105,000 feet. It then increases at a steady rate until another constant- temperature zone is reached. This zone lasts for several miles. Then the temperature starts decreasing. The procedure repeats itself - that is, a second temperature minimum is reached, and after a short constant-temperature zone, it starts rising again. These temperature minimums mark the boundaries between the four regions in the atmosphere: the troposphere, the stratosphere, the mesosphere, and the thermosphere, shown in figure 3-2. In this figure the regions beyond are simply labeled "outer space," but they may be divided into further layers, according to the findings of space probes and explorations of recent times.

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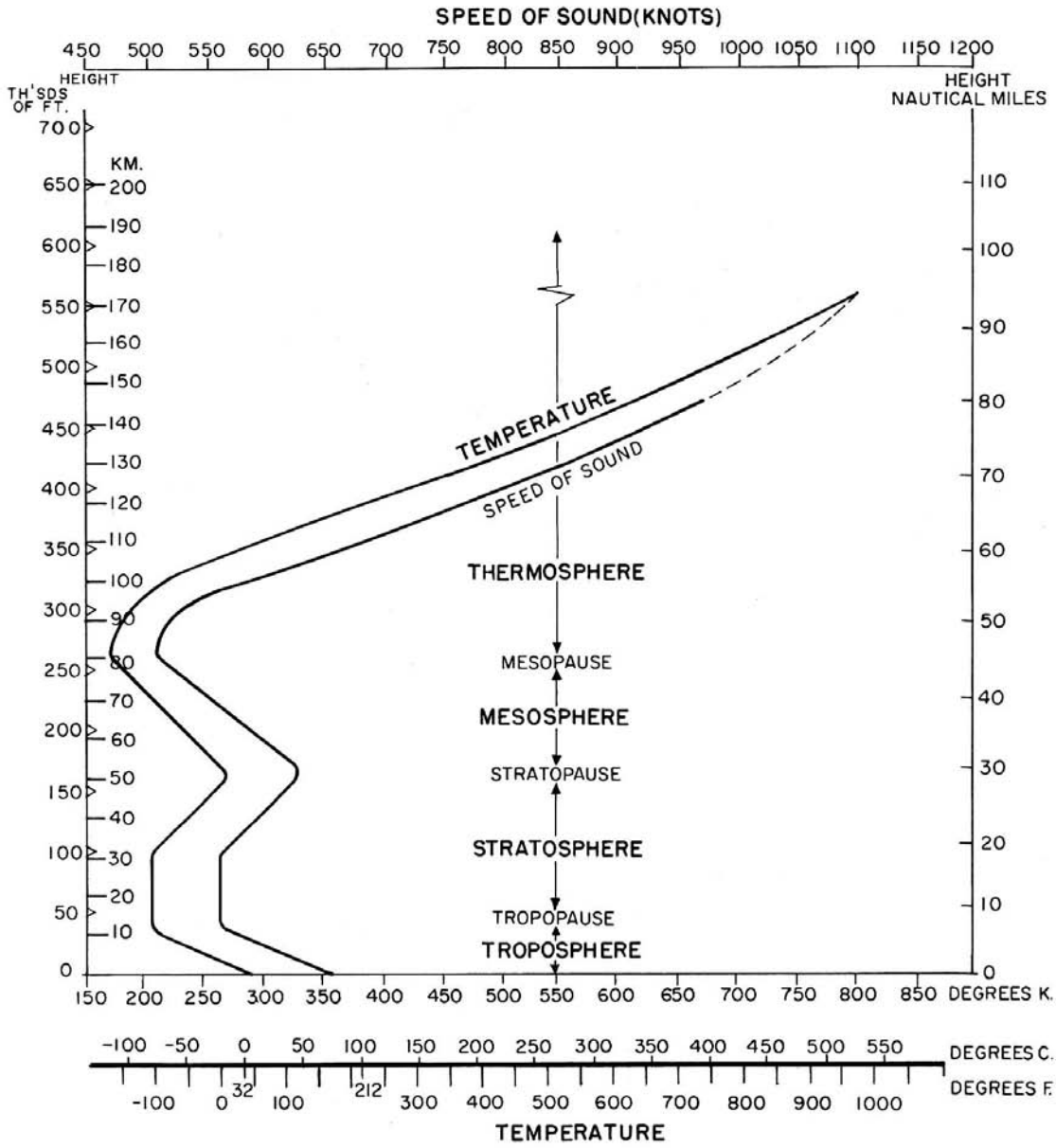


Figure 3-1.—The vertical structure of the atmosphere.

Troposphere

The troposphere is the lowest layer of the atmosphere and extends from the surface of the earth to a height of 10 miles. This is not a firm figure, as the height of the troposphere varies over different parts of the earth. Near the poles it may be only 4 miles. It is made up mostly of nitrogen and oxygen, and accounts for three- fourths of the weight of the atmosphere. Within this layer temperature decreases with altitude, and it is here that clouds, snow, rain, and the seasonal changes occur.

Because the troposphere is dense, aerodynamic surfaces can be used efficiently to control missiles. However, this high density causes a large amount of drag. You will remember from chapter 2 that the dense lower atmosphere slows down a projectile. It will have the same effect on a missile. The German V-2, rocket which was used to bomb England during World War II, was slowed down from 3300 to 1800 mph as it passed through the troposphere. The friction of the air also causes extremely high skin temperatures on missiles or reentry craft, high enough to melt common metals.

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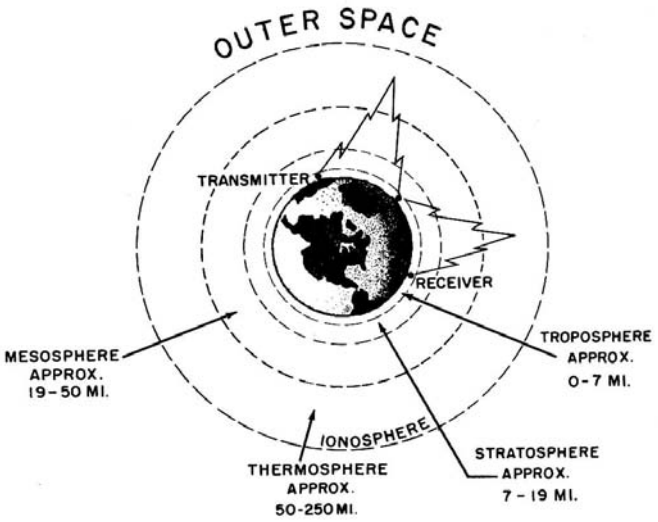


Figure 3-2. — Atmospheric regions around the earth. 33.21

Stratosphere

The stratosphere is the layer of air above the troposphere. Its upper limits are around 20 miles above sea level. In this region temperature no longer decreases with altitude, but stays nearly constant and actually begins to increase in the upper levels. Higher temperatures in the upper levels are caused by ozone which is heated by ultraviolet radiation from the sun. (Ozone is a gas which is produced when electricity is discharged through oxygen.) The composition of the stratosphere is similar to that of the troposphere; however, there is practically no moisture in the stratosphere. There are almost no clouds and no storms, and an almost complete absence of dust. At the earth's surface the air contains about 21 percent oxygen, but this decreases to a small value in the stratosphere, while the percent of hydrogen rises from 0.01 percent to 95 percent. The air is said to be "thin" and will not support human life nor air breathing engines. Propeller-driven vehicles cannot penetrate this region because of the low air density, and aerodynamic surfaces have greatly reduced effect in controlling missiles. But increases in missile speeds are possible because thrust is used more for acceleration and less to overcome drag.

Mesosphere

Above the stratosphere is the mesosphere, extending from about 19 miles to 50 miles. Within this region the minim\lm temperature is reached at about 47 1/2 nautical miles (fig. 3-1), decreasing from about 7°C at its lower edge to -100°C at its upper limit. Ozone is generated in this region and it is the seat of transformation of most primary into secondary radiation. Intense meteor trains reach down into the mesosphere and their brilliant combustion gave rise to the belief that this was a region of comparatively high temperature.

Intermediate Layers

In figure 3-1 you find the words "tropopause," "stratopause," and "mesopause." These are applied to rather narrow regions between the layers described above. In each case, they are the regions of transition from one type of atmosphere to the next one, and are likely to have turbulence because of the inversion or reversal characteristics.

Thermosphere

The thermosphere starts at about 47 1/2 nautical miles (fig. 3-1) and extends to the ionosphere. Sometimes the two areas are considered as the ionosphere as they have a continuing upward trend in temperature. The increase in temperature IS due to the presence of ozone, which is formed by the action of ultraviolet rays from the sun on the oxygen in the atmosphere. Tremendous fluctuations of wind speed (70 knots or more) occur on a daily basis. These fluctuations are referred to as atmospheric tides.

Ionosphere

Above the thermosphere, ranging up to about 250 miles above sea level, is the ionosphere. This is a region rich in ozone, and consists of a series of electrified layers. The ionosphere is extremely important because it refracts (bends) radio waves (fig. 3-2). This property enables a radio transmitter to send waves to the opposite side of the world by a series of refractions and reflections taking place in the ionosphere and at the surface of the earth. The characteristics of the ionosphere vary with daylight and darkness, and also with the four seasons. The term "ionosphere" is used particularly in referring to the electrical characteristics of the region, while "exosphere" is the name used when referring to the meteorological aspects.

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Higher Atmospheres

The reaches of space beyond the ionosphere have not been fully explored and much of the information about them is conjecture. Much information about the upper air has been transmitted to earth from orbiting satellites and spacecraft which have carried instruments to measure radiation, temperature, and other information that could be measured.

Weather information, and reports of meteorites and micrometeorites are recorded. There is still a great deal more to learn about space. If you read different writers on the subject, you will find variations in statements about the size of atmospheric zones and even differences in names for the regions. As conjecture is replaced by real information, these differences will be resolved.

Several belts of high intensity charged particles, called Van Allen Belts, surround the earth in space. They were discovered by the early U. S. satellites, Explorer I and Explorer II, in 1958. The zones fluctuate and it is believed solar flares or other phenomena of the sun cause the changes. It is almost certain that the outer zone owes its existence to ionized solar gas ejected from the sun.

BASIC FLIGHT PRINCIPLES

The principles of low speed aerodynamics which underlie the operation of most aircraft also apply to missiles, at least in the first few seconds of flight. Before we discuss high speed missile flight, let us consider the motions and forces that are common to both guided missiles and conventional airplanes flying at low speeds.

BASIC MOTIONS

Like any moving body, the guided missile executes two basic kinds of motions: rotation and translation. In pure rotation all parts of a body pivot about the center of gravity, describing concentric circles around it. In movements of translation, or linear motions, the center of gravity of a body moves along a line, and all the separate parts follow lines parallel to the path of the center of gravity. Any possible motion of the body is composed of one or the other of these motions, or is a combination of the two.

Since missiles are free to move in three dimensions, we describe their motions by using a reference system containing three reference lines, or axes. The missile axes (fig. 3-3A) are mutually perpendicular lines which intersect at the center of gravity of the missile.

A missile can make three kinds of rotary movements: pitch, roll, and yaw. Pitch, or turning up or down is rotation about the lateral or Y axis of the missile (fig. 3-3B).

The missile rolls, or twists, about the longitudinal axis, which is the reference line running through the nose and tail and designated the X axis in figure 3-3C. It yaws, or turns to the right or left, about the Z or vertical axis (fig. 3-3D). Rotary motions about all three of these axes are controlled by devices within the missile. Hereafter, these axes will be referred to as the pitch axis, the roll axis, and the yaw axis.

The second type of movement is called translation. Translation includes any linear movement of the missile. For example, a sudden gust of wind or an air pocket could throw a missile a considerable distance off its trajectory without causing any significant angular movement. If you have ever flown in an airplane, this should be fairly easy to understand. If the plane hits an air pocket, it may drop sever al hundred feet, but still maintain a straight and level altitude. Any linear movement, regardless of direction, can be resolved into three components: lateral movement, vertical movement and movement in the direction of thrust. So, besides the three angular degrees of movement, we have three linear degrees of movement. A missile in flight can therefore be said to have six degrees of movement, or freedom.

In an airplane. the pilot checks his instruments or visually observes angular and linear movement. On the basis of his observations, he repositions the control surfaces as necessary to keep the plane where he wants it.

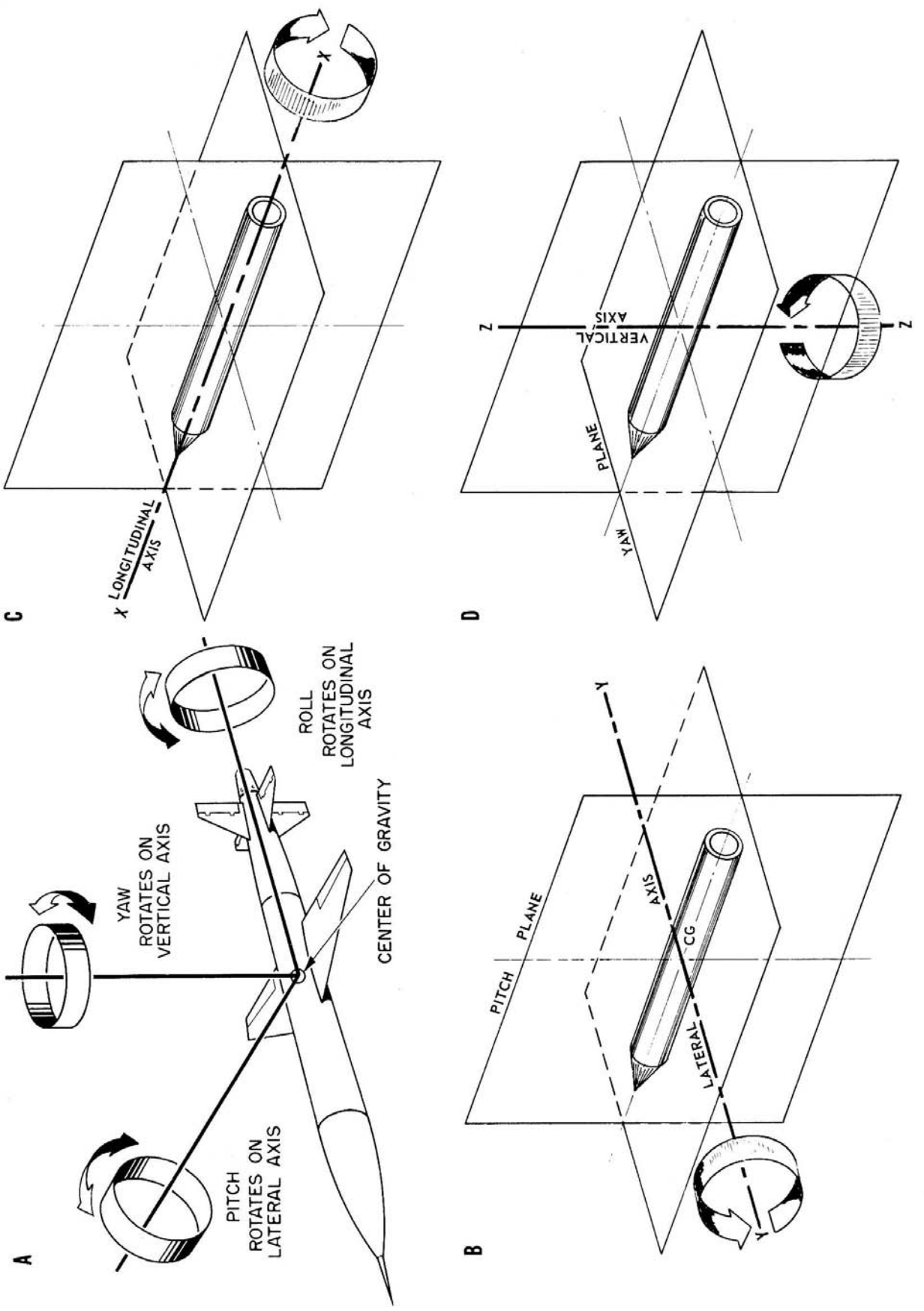
Since we don't have a pilot in a guided missile to note these movements, we install devices that will detect them, as will be discussed in chapter 4.

AERODYNAMIC FORCES

The principal forces acting on a missile in level flight are thrust, drag, weight, and lift. Like any forces, each of these is a vector quantity. You will remember from your study of Mathematics, Navpers 10069-C, that a vector has magnitude (length) and direction. These forces are illustrated in figure 3-4.

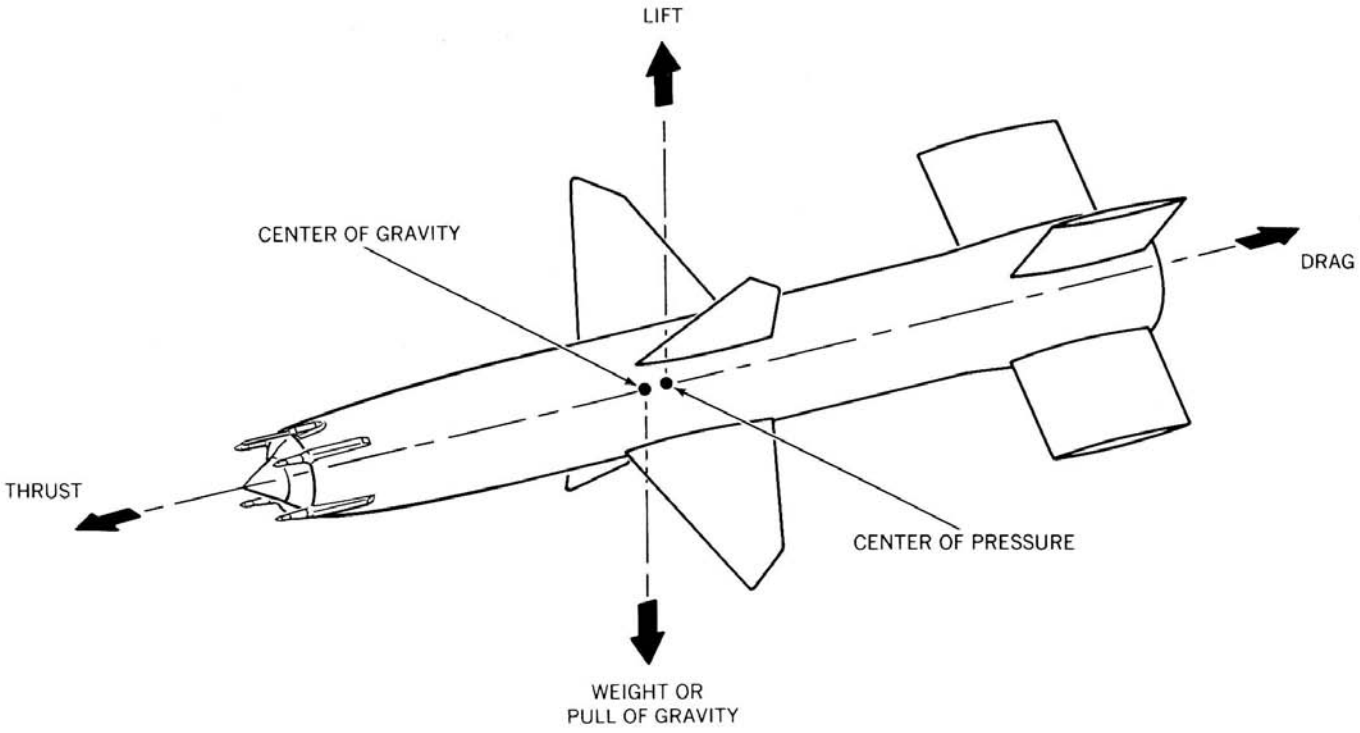
Thrust (force) is directed along the longitudinal axis of the missile and is the force

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33.22(83A)
Figure 3-3. — Rotational movements about missile axes: A. Pitch, roll, and yaw axes are mutually perpendicular; B. Pitch axis and plane; C. Roll axis and plane; D. Yaw axis and plane.

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33.23

Figure 3-4. — Principal forces acting on a moving missile.

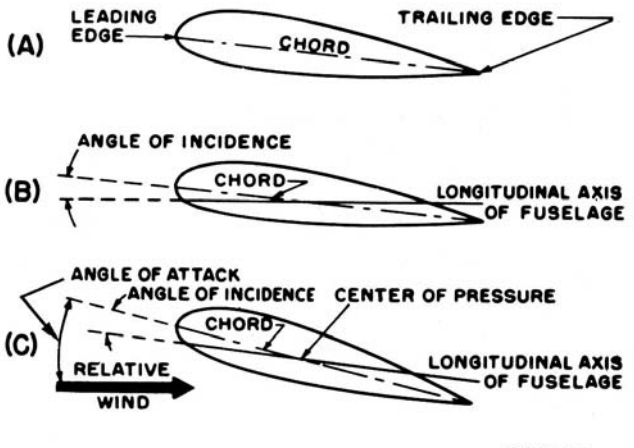
which propels it forward at speeds sufficient to sustain flight. Drag is the resistance air offers to the passage of the missile through air, and is directed rearward. The weight of the missile is the pull of gravity on the missile, and is directed downward toward the center of the earth. Opposed to the force of gravity is lift, an upward force which supports the missile. Lift is directed perpendicular to the direction of drag.

Lift is produced by means of pressure differences. The primary factor contributing to lift is that the air pressure on the upper surface of an airfoil (wing) must be less than the pressure on the underside. The amount of lifting force provided is dependent to a large extent on the shape of the wing. Additional factors which determine the amount of lift are the wing area, the angle at which the wing surface is inclined to the airstream (angle of attack), and the density and speed of the air passing around it. The airfoil that gives the greatest lift with the least drag in subsonic (less than the speed of sound) flight has a shape similar to the one illustrated in figure 3-5.

Some of the standard terms applied to airfoils are included in the sketch. The foremost edge of the wing is called the leading edge, and that at the rear the trailing edge (fig. 3-5A). A straight line between the leading and the trailing edges is called the chord. The distance from one wingtip to the other (not shown) is known as the SPAN. The angle of incidence (fig. 3-5B) is the angle between the wing chord and the longitudinal axis of the fuselage. In figure 3-5C, the large arrow indicates the relative wind, the direction of the airflow with reference to the moving airfoil. The angle of attack is the angle between the chord and the direction of the relative wind.

In actual flight, a change in the angle of attack will change the airspeed. But if for test purposes we maintain a constant velocity of the airstream while changing the angle of attack, the results on the nonsymmetrical wing will be as shown in figure 3-6. The sketches show a wing section at various angles of attack, and the effect these different angles have on the resultant force and the position of the center of pressure. The burble point referred to in

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33.24A

Figure 3-5.—Nomenclature for parts of a subsonic airfoil.

figure 3-6C and D is the point at which airflow over the upper surface becomes rough, causing an uneven distribution of pressure. Note that the center of pressure changes with the angle of attack.

The relative wind strikes the tilted surface, and as the air flows around the wing, different amounts of lifting force are exerted on various points on the airfoil. The sum (resultant) of all these forces is equivalent to a single force acting at a single point and in a particular direction. This point. is called the center of pressure. From it, lift can be considered to be directed perpendicular to the direction of the relative wind.

The dynamic or impact force of the wind against the lower surface of the airfoil also contributes to lift, but no more than one-third of the total lift effect is provided by this impact force.

ACCELERATION

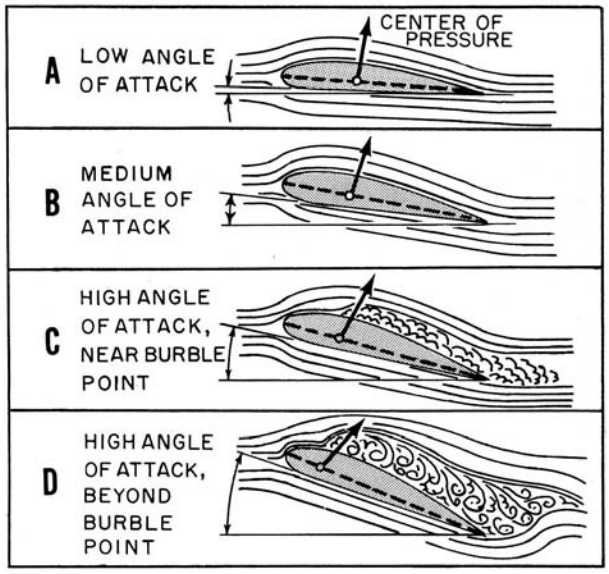
Acceleration is rate of change, either in speed or in direction of motion or both. A missile accelerates in a positive or negative sense as it increases or decreases speed along its line of flight. It also accelerates in a positive or negative sense as it changes direction in turns, dives, pullouts, and as a result of gusts of wind. During accelerations a missile is subjected to large forces which tend to keep it flying along its original line of flight. This is in accordance with Newton's first law of motion which states:

A particle remains at rest or in a state of uniform motion in a straight line unless acted upon by an external force.

Like gravity, acceleration is measured in terms of g's. The acceleration of a body in free fall is said to be one "g." Missiles making rapid turns or responding to large changes in thrust will experience accelerations many times that of gravity, the ratio being expressed as a number of "g's." The number of "g's" which a missile can withstand is one of the factors which determines its maximum turning rate and the type of launcher suitable for the weapon. The delicate instruments contained in a missile may be damaged if subjected to accelerations in excess of design values.

MACH NUMBERS AND SPEED REGIONS

Missile speeds are expressed in terms of Mach numbers rather than in miles per hour or knots. The Mach number is the ratio of missile speed to the local speed of sound. For example, if a missile is flying at a speed equal to one half the local speed of sound, it is said to be flying at Mach 0.5. If it moves at twice the local speed of sound, its speed is then Mach 2.



33.24B

Figure 3-6.—Effect of angle of attack on air flow and center pressure.

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Local Speed Of Sound

The speed expressed by the Mach number is not a fixed quantity, because the speed of sound in air varies directly with the square root of air temperature. For example, it decreases from 760 miles per hour (mph) at sea level (for an average day when the air is 59~) to 661 mph at the top of the troposphere. The speed of sound remains constant (with the temperature) between 35,000 feet and 105,000 feet, then rises to 838 mph, reverses, and falls to 693 mph at the top of the stratosphere. Thus, you can see that the speed of sound will vary with locality.

The range of aircraft and missile speed is divided into four regions which are defined with respect to the local speed of sound. These regions are as follows.

SUBSONIC FLIGHT, in which the airflow over all missile surfaces is less than the speed of sound. The subsonic division starts at Mach 0 and extends to about Mach 0.75. (The upper limit varies with different aircraft, depending on the design of the airfoils.)

TRANSONIC FLIGHT, in which the airflow over the surfaces is mixed, being less than sonic speed in some areas and greater than sonic speed in others. The limits of this region are not sharply defined, but are approximately Mach 0.75 to Mach 1.2.

SUPERSONIC FLIGHT, in which the airflow over all surfaces is at speeds greater than sound velocity. This region extends from about Mach 1.2 upward.

HYPERSONIC FLIGHT, in which the time of passage of the missile is of the order of relaxation time. (Relaxation time is the time required for molecules of air to adjust themselves after the passage of the body.) Mach numbers on the order of 10 may be considered as hypersonic. Velocities that are not hypersonic at sea level may become so at high altitudes, since relaxation times will be longer where densities are relatively low.

Subsonic Flight

At subsonic speeds, sustained flight is dependent on forces produced by the motion of the aerodynamic surfaces through the air. If the surfaces of airfoils are well designed, the stream of air flows smoothly over, under, and around them. And the air stream conforms to the shape of the airfoil. If, in addition, the airfoils are set to the proper angle, and if motion is fast enough, the airflow will support the weight of the aircraft or missile.

Since most modern missiles are supersonic, with only a few seconds of flight in the subsonic region of speed, the forces that affect missile flight at supersonic speeds are of more importance to you.

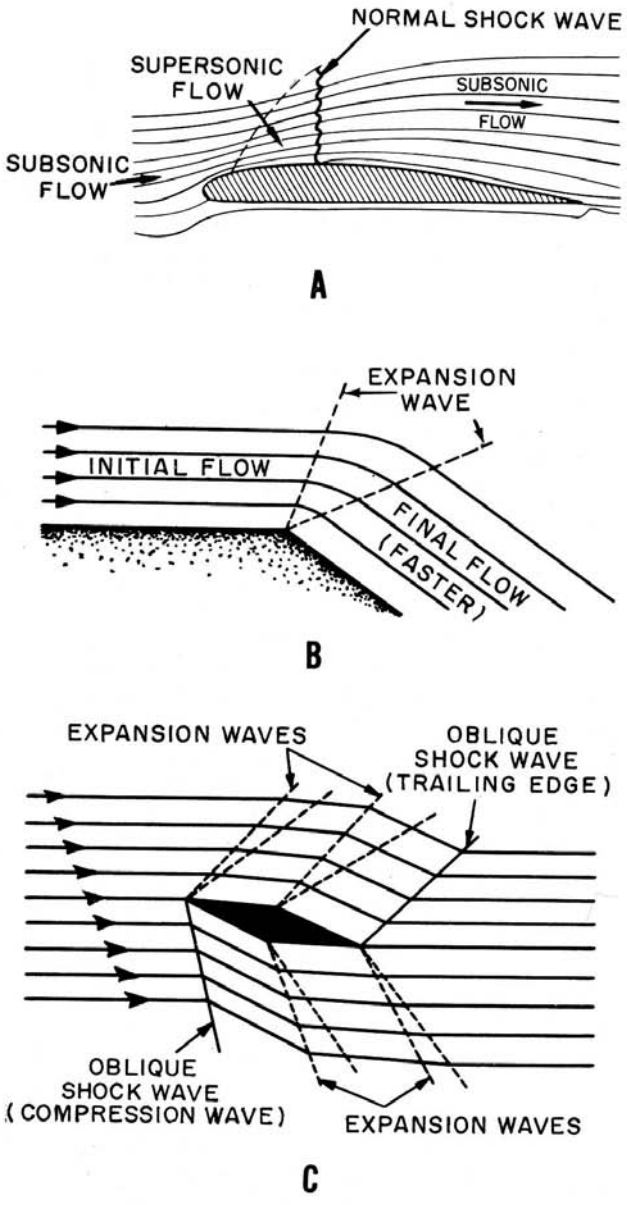
Missile Speed and Air Flow

A missile thrusting its way through the atmosphere may be compared to a boat pushing its way through the water. You can see the effect on water, so picture the air waves the same way. A boat moving slowly through the water gently pushes the water out of the way, but if it speeds up, the water is churned up into rushing waves that require increased thrust to push through. An object pushing through the air produces small pressure disturbances in the air, and each pressure wave expands equally in all directions, moving at the speed of sound. As long as the object is moving more slowly than the air waves, there is no buildup of pressure waves, but as the speed increases, the air waves begin to pile up in front of the object. When the speed of the object reaches the speed of sound the pressure waves can no longer outrun it, and the piled up airstream just ahead of the object collides with the unmoved air farther ahead, which a moment before was completely undisturbed. This causes a shock wave at the boundary between the air stream and the undisturbed air. The air stream is reduced in speed very rapidly and at the same time the pressure, density, and temperature increase. A normal shock wave is usually very strong, and the air passes through without changing direction (fig. 3-7A), but always changes from supersonic to subsonic velocity. In an oblique shock wave (fig. 3-7C), the airstream changes direction upon passing through the transition marked by the wavefront. These waves are produced in supersonic airstreams at the point of entry of wedge- shaped or other sharply pointed bodies. The change in speed, density, pressures, and temperature are generally less severe than with normal perpendicular shock waves.

STABILITY AND LIFT IN MODERN MISSILES

So far we have discussed the principles of producing lift by the use of cambered (curved) wings. Cambered wings are still used on conventional aircraft, but are not used on most

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33.27-.30

Figure 3-7. — Movement of air over airfoils:

A. Formation of normal shockwave;

B. Expansion waves;

C. Airflow about a supersonic wing.

present day guided missiles. Most operational missiles use streamlined fins to provide stability and some lift.

In some missiles lift is achieved entirely by the thrust of the main propulsion system. The Navy's Polaris missile, for example, has no fins.

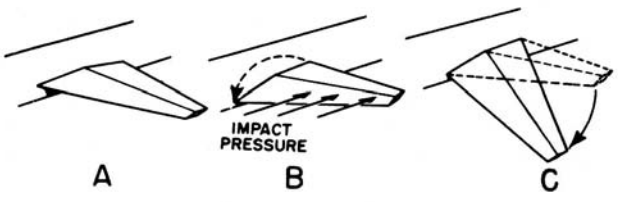
The flight of an arrow is an example of the stability provided by fixed fins. The feathered fins on an arrow present streamlined airflow surfaces which ensure accurate flight. Since supersonic missile fins are not cambered, a slightly different lift principle is involved than with the conventional wing. At subsonic speeds a positive angle of attack will result in impact pressure on the lower fin surface which will produce lift just as with the conventional wing. At supersonic speeds, the formation of expansion waves and oblique shock waves also contributes to lift. Figure 3-7B shows the upper surface of a supersonic fin. Due to the fin shape, the air is speeded up through a series of expansion waves. This results in a low pressure area above the fin. Figure 3-7C shows the fin cross section. Beneath the fin, the force of the airstream (dynamic pressure) and the formation of oblique shock waves result in a high pressure area. The differences in pressure above and below the fin produce lift.

Control Surfaces, External

Movable fins, called control surfaces, provide a means for controlling missile flight attitude. A control surface provides control by presenting an obstacle to airflow. This causes a force (due to impact pressure) to be exerted on the surface. The magnitude of the force depends on the angle between the control surface and the direction and speed of airflow. In figure 3-8, we are looking at one effect of control surface movement.

Fixed (stabilization) fins and movable control surfaces may be located in several ways on the missile. In figure 3-9A and B, we see two possible combinations. In the first, control is achieved by movement of control surfaces located at the missile's center of gravity. In the second, ~ control is achieved by movement of tail surfaces. ; Other combinations are possible, and are used in some operational missiles. The important thing for you to remember is that control is attained due to impact pressure exerted on the control surfaces, and that fixed fins contribute primarily to stability. If you have ever watched an airplane being landed and noticed how the pilot tilted

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Figure 3-8. — Control surface deflection: A Control surface in neutral position; B. Control surface tilted; C. Impact pressure of air causes missile roll.

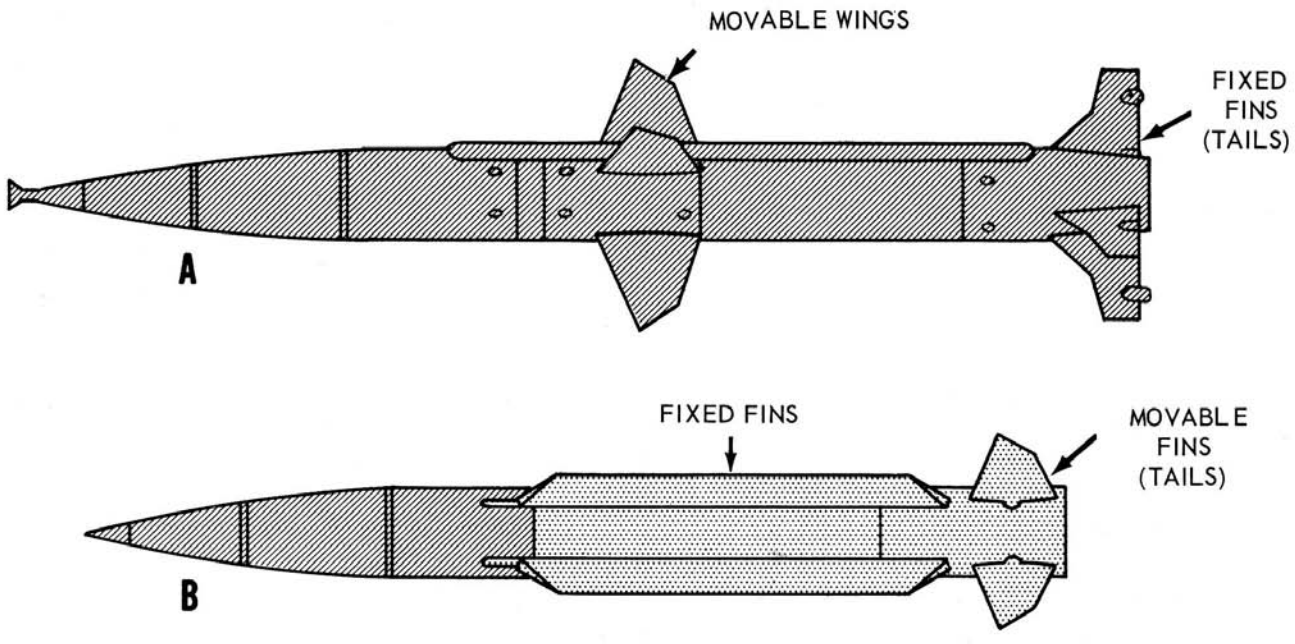
certain portions of the wings, folded other parts, and extended other portions, you have some conception of how movement of missile wings, fins, tails, or other control surfaces can be used to change the course of the missile.

FIN DESIGNS. - Supersonic fins are symmetrical in thickness cross section and have a small thickness ratio - the ratio of the maximum thickness to the chord length. The double wedge, shown in figure 3-10, has the least drag for a given thickness ratio, but in certain applications is inferior because it lacks strength. As you saw in figure 3-7C, the air flows over and under a double wedge airfoil without developing a severe shock wave.

The modified double wedge has a relatively low drag (although its drag is usually higher than a double wedge of the same thickness ratio) and is stronger than the double wedge. The biconvex, shown in figure 3-10, has about one-third more drag than a double wedge of the same thickness ratio. It is the strongest of the three but is difficult to manufacture.

The planform of the fins - the outline when viewed from above - is usually either of the delta-modified delta (raked tip) or rectangular types shown in figure 3-11A. These shapes considerably reduce unwanted shock wave effects.

Figure 3-11B shows some of the movable parts of control surfaces that help to offset unstabilizing forces and to keep the missile on course. The ailerons on the wings help in roll control. When one aileron is raised, the other is lowered; the wing with the raised aileron moves down and the other moves up. Elevators attached to the horizontal tail fins are raised or lowered together and help in pitch control. The rudders on the vertical tail fins may be used for tail



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Figure 3-9. — Arrangement of exterior control surfaces on missiles: A. Movable surfaces at center of gravity; B. Movable tail surfaces.

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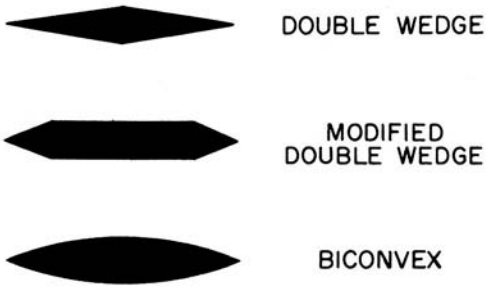


Figure 3-10.—Cross sections of supersonic airfoils. 33.33

control. If one rudder is moved to the right, the tail moves to the left and the missile yaws to the right. In most missiles in present use, the movements of the various parts are caused by the hydraulic system in the missile, which receives instructions electrically as to what moves are necessary to keep the missile on its course.

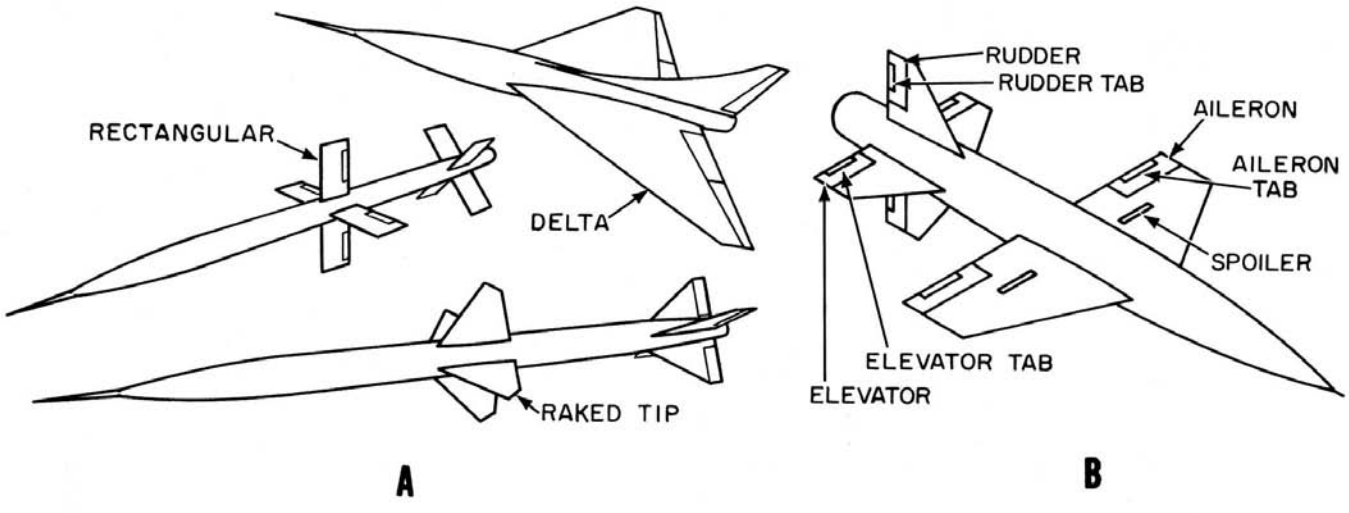
The Bullpup missile uses a form of tab (fig. 3-11B) as a method of control. Some of the newer missiles combine two devices, such as an elevator and an aileron, into an elevon, which allows control of both pitch and yaw by a single control mechanism.

ARRANGEMENT OF FINS. - Fins are mounted on the airframe in several arrangements, some of which are shown in figure 3-12. The CRUCIFORM is the most popular tail arrangement. It is used in surface-to-air missiles. Both the INLINE and INTER-DIGITAL cruciform arrangements are widely used, especially for supersonic missiles.

Control Surfaces, Internal

We mentioned earlier that some missiles do not have external control surfaces such as wings, fins, and tails. They may have small control surfaces that must be supplemented by other means of control. Two types have been used as auxiliary controls-exhaust vanes and jet control.

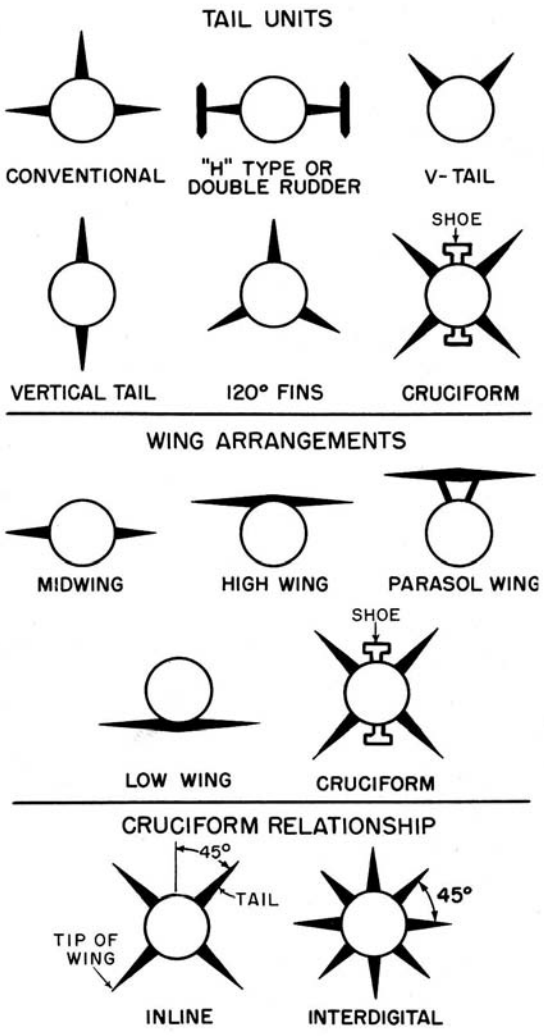
Exhaust vanes are control surfaces mounted directly in the exhaust path of a jet or rocket engine (fig. 3-13B). When the exhaust vanes are moved they deflect the exhaust, resulting in a change in the direction of thrust so as to keep the missile pointed in the desired direction. Even when the missile has just begun to move after launching, the exhaust velocity is very high. One disadvantage is that the tremendous heat of the exhaust makes the life of the vanes very short. The German V-2 missile used exhaust vanes of carbon; these lasted, on the average, about 60 seconds before they were burned up completely. Various forms of vanes are used and may be called jet vanes, jetevators, or jetevons. Some are fixed and some are movable.



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Figure 3-11.—External control devices on missiles: A. Plan forms of airfoils; B. Movable parts of fixed airfoils.

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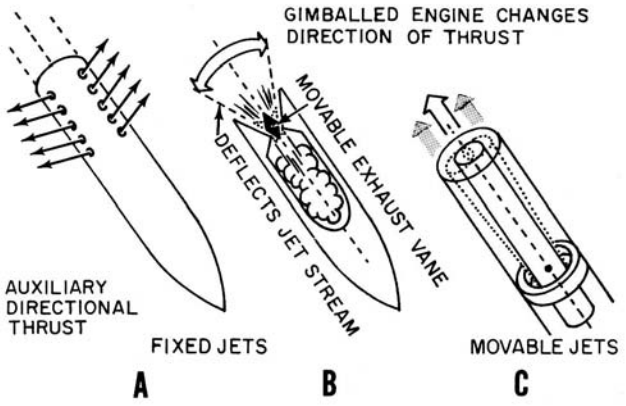
Figure 3-12. — Arrangements of airfoils on missiles.

Movable jets are another method of controlling the flight attitude of a missile. One method is to mount the engine itself in gimbals (fig. 3-13C), and turn the whole engine to deflect the exhaust stream. This system requires that the engine be fed with flexible fuel lines, and the control system that turns the engine must be very powerful. Also, it cannot control roll of the missile. To get control of all axes, two gimbal- mounted jets may be positioned in the missile. Both jets must be free to move in any direction, and must be able to respond to signals from any of the three control channels (pitch, roll, and yaw). Another system uses four movable jets mounted in the aft end of the missile. Two jets control yaw, two control pitch, and all four together control roll. Sometimes a fifth jet is fixed in the middle, in the space between the movable jets.

Fixed steering jets (fig. 3-13A) are placed around (inside) the missile so as to give directional control by exerting a force in one direction or another. Heat shields are necessary to protect the main body of the missile against the heat of exhaust from the jets. The use of these auxiliary jets makes it possible to eliminate all outside control surfaces. Missiles and spacecraft that reach into the higher, rare atmospheres, where external control surfaces are of little use, must depend on internal control means.

MISSILE AIRFRAMES

The airframe of a guided missile serves the same purpose as the airframe of the conventional aircraft: it carries the necessary components and controls to ensure proper flight. But, since the guided missile is essentially a one-shot weapon, the body structure can be simpler in structure than that of a conventional aircraft. Missile bodies are designed so that inner components are readily available for testing, removal, and repair. The major components are mounted to form independent units. Adequate room is provided to permit slack in electrical cables and harnesses so that inner sections can be removed easily during maintenance.



33.177:.181

Figure 3-13. — Jet control of flight attitude: A. Fixed jets; B. Exhaust vanes; C. Gimballed engine.

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The configuration of a guided missile is the principal factor controlling the drag and lift forces that act on it as it passes through the atmosphere. Supersonic missiles must be designed for minimum drag. Both lift and drag are directly proportional to the square of missile speed. The shape of the nose, the body, and external control surfaces (if used) must be scientifically designed to obtain a maximum of lift and a minimum of drag.

Another effect that must be considered in missile design is that of heat. Heat results not only from friction as the missile passes through the atmosphere, but also from the temperature rise caused by the ram effects as the air is compressed by the speeding missile. A significant part of the development effort for long-range ballistic missiles has been devoted to development of nose cones capable of withstanding extreme temperatures.

Most missile bodies are slender cylindrical structures similar to those shown in figure 3-9. Several types of nose sections are used. If the missile is intended for supersonic speeds, the forward section may have a pointed arch profile in which the sides taper in lines called ogive curves (fig. 3-14A). Missiles which fly at lesser speeds may have blunt noses as shown in figure 3-14B. Rounded noses which house radar equipment may look like the one in figure 3-14C. Figure 3-14D shows an air-breathing missile nose which includes the duct for the ramjet propulsion system. The nose design of our ICBM has been modified several times, each one made to meet the need of the missile design with the least drag effect.

Most modern missiles are made up of several sections. Each section is a cylindrical shell machined from metal tubing rather than a builtup structure with internal bracing. Each shell contains one of the essential units or components of the missile, such as the propulsion system, the electronic control equipment, the warhead, or the fuze assembly.

Sectionalized construction has the advantage of strength with simplicity, and also provides ease in replacement and repair of the components since the shells are removable as separate units. The sections are joined by various types of connections designed for simplicity of operation. Access ports are sometimes provided in shells, through which adjustments can be made prior to launching.

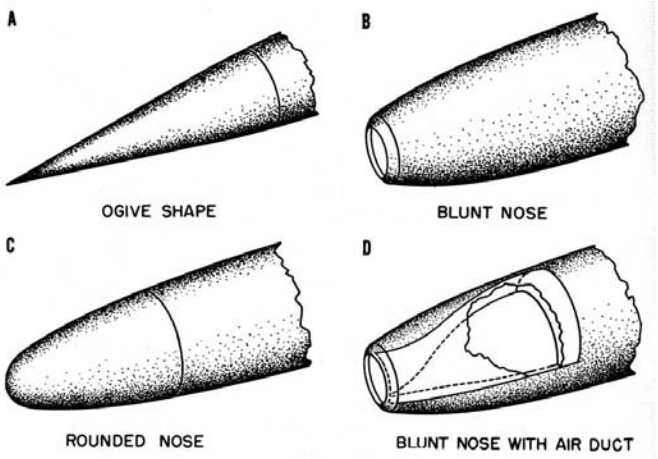


Figure 3-14. — Missile noses.

MISSILE PROPULSION SYSTEMS

Guided missiles must travel at high speeds to be effective. To reach high speeds, missiles use jet propulsion. This chapter will introduce the theory of jet propulsion and several types of propulsion systems. Before you can understand how jet propulsion works, you need to know the basic laws of physics that apply to gases and liquids; then you can see how they are applied in jet propulsion of missiles.

GASES UNDER PRESSURE

Before taking up propulsion systems, let us look at the way gases are affected by variations in pressure and temperature. As a Gunner's Mate (Missile) you will use pressurized gases in many ways. Gases at high temperatures and pressures are used in the main propulsion systems of missiles. These gases may be in the form of high pressure air (or other inert gases) stored in flasks, or in the form of fuel combustion products.

From the safety standpoint it is especially important that you understand the theory of pressurized gases. Gases under pressure can be extremely dangerous if not handled in accordance with the applicable safety precautions. Many of these precautions will be presented later in this manual.

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Theory

If you put a pint of milk into a quart bottle, the milk does not expand and fill the entire bottle. However, if you fill an inflatable life jacket with a CO_2 cartridge, the gas expands to occupy a much greater volume than it did formerly. You can easily measure the volume of a liquid, but the volume that a gas will occupy depends on the pressure to which it is subjected. Also, gases expand when heated, and contract when cooled. Since the volumes of gases depend on pressure and temperature, we must establish a standard of temperature and pres sure for measuring volume.

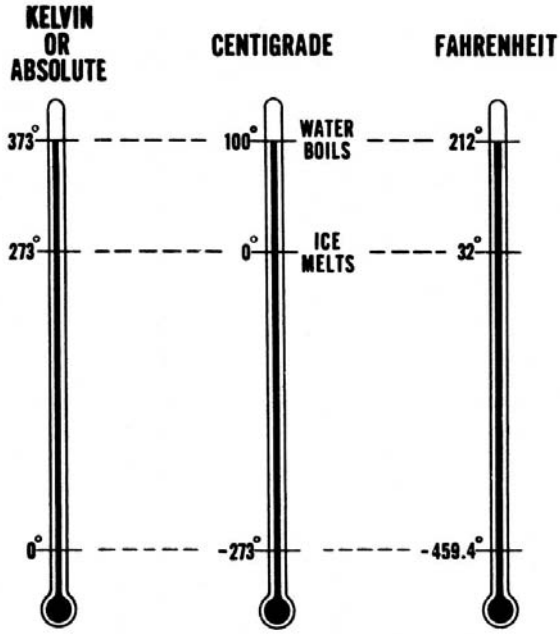
ABSOLUTE PRESSURE. - Although we live at the bottom of an ocean of air, we do not feel the pressure which the atmosphere exerts on us because it is equal in all directions. Atmospheric pressure at sea level will support a column of mercury 30 inches high. This pressure is equal to 14.7 psi (pounds per square inch).

In all problems involving the laws of gases, pressure should be figured in pounds per square inch absolute, which is the gauge pressure plus 14.7 psi at sea level.

Absolute Temperature

The temperature of a gas can be measured with respect to an absolute zero value. This value, which is usually expressed in terms of the centigrade scale, represents one of the fundamental constants of physics. (The relationship between the Centigrade and Fahrenheit scales can be seen in figure 3-15.) It was established experimentally during a series of tests made in the study of the kinetic theory of gases.

According to this view, a gas, like other forms of matter, is composed of molecules made up of combinations of atoms. Normally, the molecules of any substance are in constant motion. In the gaseous state, the motions are assumed to be entirely random. That is, the molecules move freely in any direction and are in constant collision, both among themselves and with the walls of the container (fig. 3-16A). The moving particles possess energy of motion, or kinetic energy, the total of which is equivalent to the quantity of heat contained in the gas. When heat is added, the total kinetic energy is increased. When the gas is cooled, the thermal agitation is diminished and the molecular velocities are lowered.



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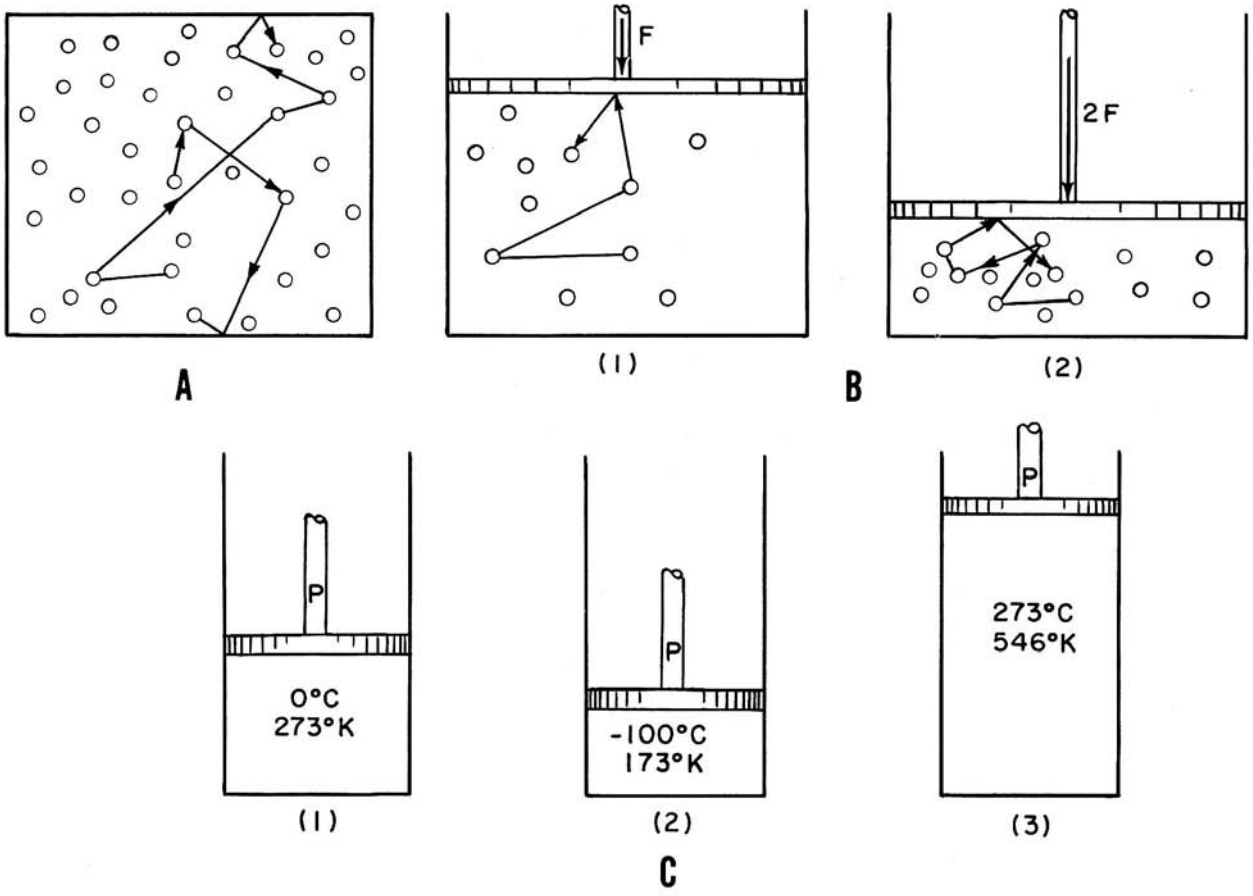
Figure 3-15. — Temperature scales.

The molecules do not all have the same velocity, but display a wide range of individual velocities. The temperature of the gas, according to the kinetic theory, is determined by the average energy of the molecular motions. PRESSURE is accounted for by considering it as resulting from the bombardment of the walls of the container by the rapidly flying molecules. The particles are considered to have perfect elasticity, so that they rebound from the walls with the same velocities with which they strike them.

In accordance with the kinetic theory, if the heat energy of a given gas sample could be reduced progressively, a temperature would be reached at which the motions of the molecules would cease entirely. If known with accuracy, this temperature could then be taken as the absolute zero value. It was the purpose of the experiments mentioned above to establish the existence and value of this temperature, which was predicted by the kinetic theory.

Since any change in the temperature of a gas causes a corresponding change in the pressure, it was necessary to consider temperature, pressure, and volume together. Hydrogen gas was enclosed in a cylinder containing a movable piston, so that the volume could be adjusted to maintain the initial pressure. The experiment was started with the gas at a temperature of 0° centigrade.

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Figure 3-16. — Laws of gases: A. Collision of gas molecules; B. Boyle's Law, where gas volume is halved and pressure doubled; C. Charles' law, showing changing volume at different temperatures, with pressure constant.

It was found that when the gas was cooled enough to drop the temperature by 1°C, the volume had to be decreased by moving the piston in order to keep the sample at the same pressure. The new gas volume was then equal to 272/273 the volume at 0°C. As the temperature was lowered further, the volume (for constant pressure) decreased by an amount equal to 1/273 the initial volume for each decrease of one centigrade degree.

If, however, the volume was kept constant by keeping the piston unchanged in position, it was found that the pressure varied at the same rate. That is, it decreased by an amount equal to 1/273 the pressure at 0° C for each drop of 1 ° in the temperature.

The same rates of change of volume and pressure were found to be present in all gases; and they were uniform over a wide range of temperature. All these facts led to the conclusion that if any gas were cooled to -273°C (actually -273.16°), with the pressure kept constant, the volume would shrink to zero. However, all known gases change to the liquid state before this temperature is reached. Also, if the volume were maintained at the initial value, the pressure would approach zero as the temperature approached this same value. It was then assumed that -273°C represents the theoretical absolute zero point at which all molecular motion ceases, and no more heat remains in the substance.

The existence of absolute zero cannot be determined directly by observing the volume

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of gas cooled to -273°C, since all gases are converted to the liquid state before this temperature is reached. In many experiments, however, this condition has been approached closely, the actual temperature reached being within a small fraction of a degree of the theoretical zero value.

THE KELVIN SCALE. - When temperatures are measured with respect to -273°C they are said to be expressed in the absolute, or Kelvin, scale. Specific absolute temperatures are designated by the letter K. Thus, 0° C is equivalent to 273° K, 20° C equals 293° K, and 100° C equals 373° K. The relationship between the three temperature scales is shown in figure 3-15. The Kelvin scale is used in scientific work. In formulas, Kelvin temperatures in general are represented by T and Centigrade or Fahrenheit temperatures by t.

Gas Laws

The natural laws that affect the behavior of gases were determined by experiments by scientists long ago. The first of these is Boyle's law (Robert Boyle, 1627-1691), which is stated as follows:

> "The volume of any dry gas, the temperature remaining constant, varies inversely with the pressure on it; that is, the greater the pressure, the smaller the volume becomes."

Figure 3-16B illustrates this law, showing the volume halved when the pressure is doubled, where F represents force applied. In the second part of the picture, there are twice as many gas molecules per unit of volume (density is double), and twice as many collisions per second.

This law may be stated as an algebraic formula:

$$V_1 P_1 = V_2 P_2$$

where V_1 and P_1 refer to the original volume and pressure, and V_2 and P_2 refer to the new volume and pressure. This equation is true only if the temperature has remained the same. Although this law was formulated for a perfect or ideal gas, it holds closely for ordinary gases except under high compression, when a modified equation is applied.

A second gas law has to do with the effects of changes in temperature:

All gases expand and contract to the same extent under the same change of temperature, provided there is no change in pressure. In general, when the pressure is kept constant, the volume of a gas is proportional to its absolute temperature (Kelvin). This is known as Charles' law. See figure 3-16 C. It is also known as the Gay-Lussac law.

In equation form this becomes:

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

where V is the volume and T is the absolute temperature (Kelvin).

Finally, since the volume of a gas increases as the temperature rises, it is reasonable to expect that if a confined sample of gas were heated, its pressure would increase. Experiments have shown that the pressure of any gas kept at a constant volume increases for each degree centigrade rise very nearly 1/273 of its pressure at 0° C. Because of this finding it is convenient to state this relationship in terms of absolute temperatures. For all gases at constant volume, the pressure is proportional to the absolute temperature.

The first two formulas (Charles' law and Boyle's law) may be combined to give the general gas law, by which the effect may be computed of the variation of any or all of the three quantities - pressure, volume, and temperature - at the same time.

It is not likely that you will have to perform computations with any of these formulas, but the effects of the gas laws influence your daily work. Although air is a mixture of gases, it obeys the same laws. You have just studied how changes in air density and pressure affect missile flight. The combustion gases formed by the burning propellant inside the missile respond to the same laws. Gases that you use in various ways in your work aboard ship, such as compressed air, oxygen, and carbon dioxide, conform to the gas laws. A number of the safety regulations are necessary because of the way these gases behave. You can see there are plenty of reasons why you should know how gases react to different situations.

PRINCIPLE OF JET PROPULSION.

The principle of jet propulsion is based on Sir Isaac Newton's third law of motion which

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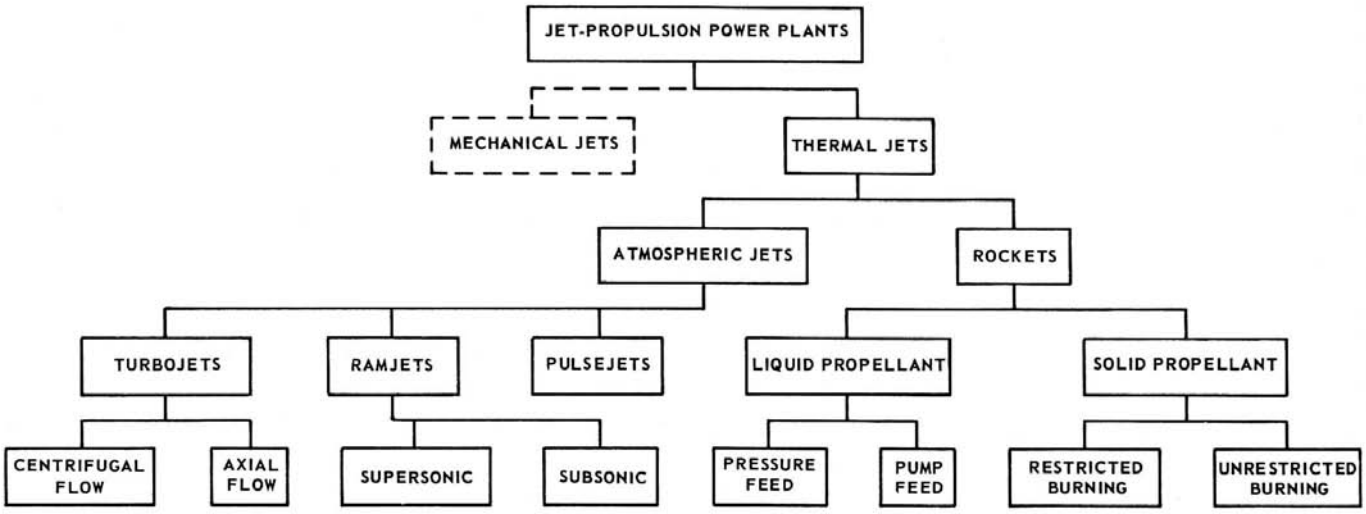


Figure 3-17.—Classification of jet powerplants.

states that "For every action there is an equal and opposite reaction." As an example of the reaction principle, remember your firefighting training in boot camp. You will probably recall your first experience with a large diameter high pressure firehose. With the hose pressurized and the nozzle closed, a single man can handle the charged firehose; but as soon as the nozzle is opened, two or three men are required. The reason for this is that as soon as water is permitted to escape from the nozzle, reaction to this water flow causes the nozzle to buck or kick in the opposite direction. The amount of reaction or "thrust" is equal to the force of the escaping water. This force can be determined by measuring the mass and velocity of the water which escapes.

The two most common methods by which we produce thrust are by mechanical means (pumps or fans), and by thermal means (chemical reaction). The firehose is an example of a mechanical jet. Another example of the mechanical jet may be found in nature. The squid draws water into its body and then by muscle contraction forces this water rearward through a small opening at an increased velocity, thus propelling itself forward.

In guided missiles we are concerned with thermal jets - those that operate by reaction to the exhaust of combustion gases. It is a common misconception that a jet engine is dependent on the atmosphere to obtain its thrust, or force, in the direction of motion. (Air- breathing jets require air for oxygen to support combustion of the propellant.) Actually, thrust is the reaction to the ejection of exhaust gases. If you take a firehose and direct the water stream against a wall, the reaction force experienced is the same as if the wall were not there. To continue the analogy, missile thrust is the same regardless of whether the missile is in the atmosphere or in the vacuum of space. Jet engines are frequently called reaction motors, since the exhaust gases produce the action while the opposite motion of the missile or aircraft represents the reaction.

Figure 3-17 charts the types of jet propulsion systems. The systems falling under the heading of rockets are those which carry within themselves all the materials necessary for their operation. In most rockets these materials include an oxidizer. An oxidizer is a substance which contains the oxygen necessary to support combustion of the fuel. (You will remember that a rocket was defined earlier as a missile with an independent propulsion system.) Rockets are sometimes referred to as air-independent units, since they do not rely on the oxygen in the atmosphere.

The atmospheric jets, on the other hand, depend on air to support combustion. Both the rocket and the atmospheric jet receive their thrust as a reaction to the exhaust of combustion gases.

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It should be remembered that the rocket is the only jet engine capable of operating outside the earth's atmosphere.

Present day surface-to-air missiles have either ramjet or solid propellant propulsion systems. In this section we will discuss only these two types.

COMPONENTS OF JET PROPULSION SYSTEMS

To achieve high thrust, it is necessary to produce large quantities of exhaust gases at high temperatures and pressures. To produce these exhaust gases, jet propulsion systems consist of a combustion chamber, an exhaust nozzle, and a fuel supply.

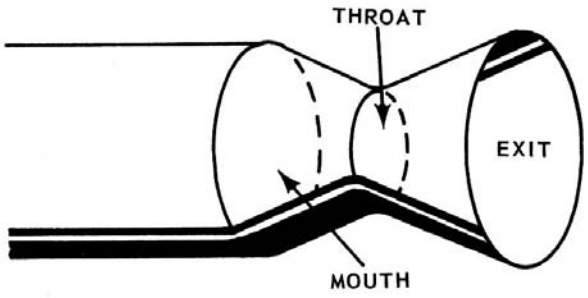
Combustion Chamber

The combustion chamber is that part of the system in which the chemical action (combustion) takes place. Combustion is necessary to provide thrust. Useful thrust cannot be attained in an atmospheric jet unless the combustion products are exhausted at a velocity greater than that of the intake gases (air). The chamber is usually called a cylinder, although it may have the shape of a sphere. It must have the proper length and diameter to produce a chamber volume suitable for complete and stable combustion.

In all thermal jets, the heat energy released by the combustion process is converted to kinetic energy through expansion of the gases of combustion as they pass through the exhaust nozzle.

Exhaust Nozzle

An exhaust nozzle is a nonuniform chamber through which the gases generated in the combustion chamber flow to the outside. Its most important areas are the mouth, throat, and exit. These areas are identified in figure 3-18. The function of the nozzle is to increase the velocity of the gases. The principle involved was announced many years ago by a Swiss physicist, Daniel Bernoulli. Bernoulli's principle applies to any fluid (gas or liquid). It may be stated as follows: "Provided the weight rate of flow of a fluid is constant, the speed of the fluid will increase where there is convergence in the line. It will decrease where there is a divergence in the line." Figure 3-19 illustrates this principle. The velocity of the fluid will increase at point 1. At the point of divergence, point 2, the speed of the fluid will decrease.



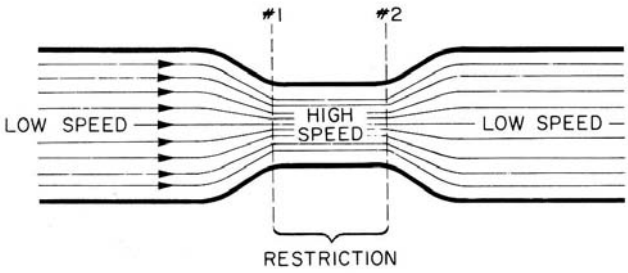
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Figure 3-18. — Location of nozzle areas.

The increase in speed between points 1 and 2 is caused by a conversion of potential energy (fluid pressure) to kinetic energy. Thus, the pressure drop of the fluid through the restriction is proportional to the velocity gained. When the fluid reaches point 2, the kinetic energy is again converted to potential energy. At point 2, the fluid velocity decreases, and the pressure of the fluid increases.

This relationship also holds true for subsonic flow of gases. In the convergent nozzle in figure 3-20A, the speed will increase up to the speed of sound, depending on the degree of convergence. In the divergent nozzle in figure 3-20B, gases at subsonic speeds will slow down, depending on the degree of divergence.

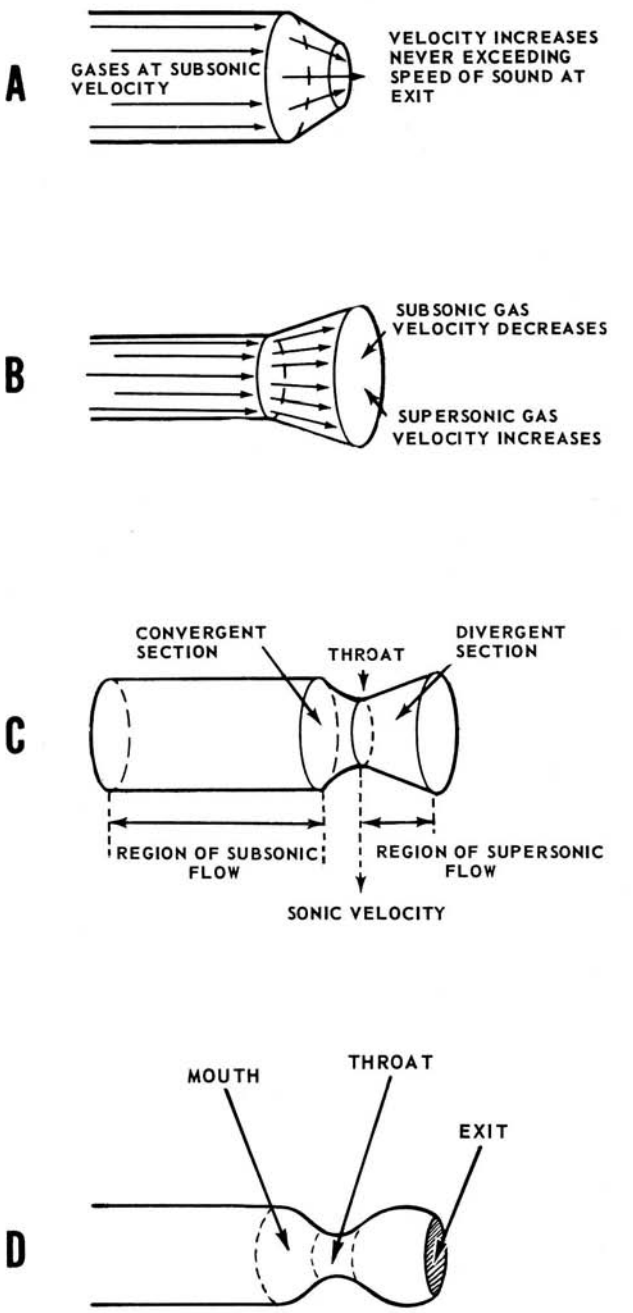
Gases at supersonic (faster than sound) speed behave differently. As these gases pass through the divergent nozzle, their velocity is INCREASED because of their high state of compression. The drop in pressure at the point of divergence causes an instantaneous release of kinetic energy. This imparts additional speed to the gases. To obtain supersonic exhaust velocity, the DeLaval nozzle in figure 3-20C is commonly used. This nozzle



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Figure 3-19. — Fluid flow through a restriction.

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Figure 3-20.—Gas flow through nozzles: A. Subsonic flow through a convergent nozzle; B. Flow through a divergent nozzle; C. Convergent-divergent nozzle (DeLaval); D. Prandtl nozzle.

first converges to bring the subsonic flow up to the speed of sound. Then the nozzle diverges, allowing the gases to expand and produce supersonic flow.

The Prandtl nozzle (fig. 3-20D) is more efficient than the straight-coned DeLaval nozzle but is more difficult to engineer and produce. It increases the rate of flow at a higher rate than the normal convergent-divergent type. The shape of the nozzle determines the characteristic of the gas flow, which must be smooth.

Other nozzles of increasing importance are the adjustable area type, in which the nozzle area is varied to suit varying combustion environmental conditions. The best size for the nozzle throat is different for different propellants. The nozzle must be designed for a specific set of propellant and combustion characteristics to obtain higher velocity and increased thrust.

Fuel Supply

The fuel supply consists of solids, liquids, gases, or various combinations of these. However, fuels in the gaseous state are rarely us~ in missiles. Liquids or solids have a higher density than most gases, even when the latter are highly compressed; thus a larger quantity of solid or liquid fuel can be carried in a given space. Many factors must be considered when selecting the fuel or fuels to be used in a certain missile. Among these factors are cost, availability, safety, ease of handling and storage, storage life, and amount of "push" it will furnish to the missile.

ROCKET FUELS. - Several means have been worked out for rating, or comparing, various rocket fuels (propellants). Comparison is made by determining total impulse. Total impulse is the product of the thrust in pounds times burning time in seconds. Or,

I_T (Total Impulse in lb-sec) =
T (Thrust in lbs) x t (Duration in secs).

Solid propellants are rated, or compared, on the basis of specific impulse. Specific impulse is the amount of impulse produced by one pound of the propellant. Stated in formula:

I_{sp} (Specific Impulse in lb-sec/lb) =
$\frac{I_T \text{ (Total Impulse in lb-sec)}}{W \text{ (Weight of Solid Fuel in lbs)}}$

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A common method of comparing liquid propellants is on the basis of specific thrust. Specific thrust is equivalent to specific impulse [or solid propellants but derived in a slightly different way. Specific thrust is defined as the thrust in pounds divided by the rate of fuel now in pounds per second. Or,

$$T_{sp} \text{ (Specific Thrust in lbs/lb/sec)} = \frac{T \text{ (Thrust in lbs)}}{W \text{ (Weight Rate of Flow in lb. per sec)}}$$

Specific thrust is expressed in seconds.

You sometimes may see the term "specific impulse" used for liquid as well as solid propellants. However, the term "specific thrust" more correctly brings out the correct meaning for liquids. As for solid propellants, it would be impractical to attempt to measure the weight rate of flow; therefore, specific impulse is used for comparison of solid fuels.

Specific propellant consumption is another term of importance in liquid propellant systems. [t is the reciprocal of specific thrust. It is defined as the propellant flow in pounds per second necessary to produce one pound of thrust. Or,

$$\text{Specific Propellant Consumption} = \frac{\text{Weight Rate of Flow (lbs/sec)}}{\text{Thrust (lbs)}}$$

Other terms you should know are mixture ratio and exhaust velocity.

Mixture ratio designates the relative quantities of oxidizer and fuel used in the propellant combination. It is numerically equal to the weight of oxidizer flow divided by weight of fuel flow. (Many liquid propellants are stored in separate containers, one holding the oxidizer, the other containing the fuel, until the moment of use.)

Exhaust velocity is determined theoretically on the basis of the energy content of the propellant combination. The actual velocity of the exhaust gases is of course less than this theoretical value since no jet engine can completely convert the energy content of the propellant into exhaust velocity. Thus, effective exhaust velocity is sometimes used and is determined on the basis of thrust and propellant flow:

$$\text{Effective Exhaust Velocity} = \frac{\text{Thrust (lbs)}}{\text{Mass Rate of Flow (lbs/sec)}}$$

Solid Propellants

The ingredients of a solid propellant are mixed so as to produce a solid of specified chemical and physical characteristics. Some examples of materials used in making solid propellants are asphalt-oils, nitroglycerin, asphalt-potassium perchlorates, black powder with ammonium nitrate, and other recently developed combinations. The finished product takes the shape of a grain, or stick. A charge may be made up of one or more grains. Do not think of a grain of propellant as the size of a grain of sand or a grain of wheat. It may be that small, but it may be several feet long, see figures 3-30 and 3-31. Combustion of solid propellants will be discussed later in this chapter.

An ideal solid propellant would:

1. Have a high specific impulse.
2. Be easy to manufacture from available raw materials.
3. Be safe and easy to handle.
4. Be easily stored.
5. Be resistant to shock and temperature.
6. Ignite and burn evenly.
7. Be non-water-absorbent.
8. Be smokeless and flashless.
9. Have indefinite service life.

It is doubtful if a single propellant having all of these qualities will ever be developed. Some of these characteristics are obtained at the expense of others, depending on the performance desired.

Liquid Propellants

The liquid propellants are classified as monopropellants or as bipropellants.

Monopropellants are those which contain within themselves both the fuel and oxidizer, and are capable of combustion as they exist. Bipropellants are those in which the fuel and oxidizer are kept physically separated until they are injected into the combustion chamber. An example of a monopropellant would be the mixture of hydrogen peroxide and ethyl alcohol; an example of bipropellant would be liquid oxygen and kerosene.

While solid propellants are stored within the combustion chamber, liquid propellants are stored in tanks and injected into the combustion chamber. In general, liquid propellants provide a longer burning time than solid propellants.

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They have a further advantage in that combustion can be easily stopped and started at will by controlling the propellant flow.

When oxygen or an oxygen-rich chemical is used as an oxidizer, the best liquid fuels appear to be those rich in both carbon and hydrogen.

In addition to the fuel and oxidizer, a liquid propellant may also contain a catalyst to increase the speed of the reaction. A catalyst is a substance used to promote a chemical reaction between two or more other substances.

Inert additives, which do not take part in the chemical reaction, are sometimes combined with liquid fuels. An example is water, which is often added when alcohol is used as a fuel. Although the water does not take part in the chemical reaction, the water does provide additional particles which contribute to a higher thrust by increasing the rate of mass flow through the system.

An ideal liquid propellant would:

1. Be easy to manufacture from available raw materials.
2. Yield a high heat of combustion.
3. Have a low freezing point.
4. Have a high specific gravity.
5. Have low toxicity and corrosive effects.
6. Have stability in storage.

As with the solid propellants, it is unlikely that all of these characteristics can be combined in a single fuel. One that has a high specific thrust may be very toxic and therefore dangerous and difficult to handle. Another may be very unstable and difficult to store. Liquid oxygen is an example - it must be kept in high pressure tanks until just before launching. In spite of the best care, there is a large loss by evaporation while transferring the oxygen to the missile. No "best" propellant has been discovered.

ATMOSPHERIC JETS

As mentioned previously, the atmospheric jet relies on the surrounding atmosphere for oxygen to support combustion. Ramjets fall under the category of atmospheric jets. The first successful application of atmospheric jets to missile propulsion was the pulsejet engine used in the German V-I missile, the "buzz bomb" of World War II. It was so called because of the intermittent or pulsating combustion process. An early U. S. Navy missile used a pulsejet engine, but it is now considered obsolete.

Another form of atmospheric jet is the turbojet. It is not used in any Navy missiles at present but is used in some aircraft. Three Air Force missiles are turbojets - Matador, Mace, and Hound Dog. Future inventions may make the turbojet principle applicable to high speed missiles as well as to aircraft.

Ramjet Engine

The ramjet shown in figure 3-21 is an atmospheric jet which is essentially a pipe open at both ends. From this the term "flying stove pipe" originated. The principal parts of this engine are the diffuser, the combustion chamber and associated fuel-feed system, and the exhaust nozzle. The combustion process in the ramjet is continuous rather than intermittent as in the, pulsejet. The ramjet has no bank of valve, to restrict the flow of gases to one direction For this reason, the ramjet must be boosted to a speed very near its operating speed before. it takes over on its own. To attain this speed a rocket or other type of booster is used, an. it is generally larger and heavier than the ramjet itself. The Talos missile for example has a ramjet sustainer.

This engine is ideally suited to long range high-speed missiles, since the thrust increase: with speed, and the rate of fuel consumption per unit of thrust decreases with speed. In other words, the faster a ramjet flies, the greater it efficiency. The ram action of the air increases with the speed of the missile.

OPERATING CYCLE. - The cycle of subsonic ramjet operation is as follows (fig. 3-22A)

1. The ramjet is boosted by a separate propulsion unit to the required velocity. Ail enters the diffuser inlet and, due to the increasing cross section, decreases in velocity as it approaches the after end of the diffuser (an application of Bernoulli's principle).
2. This decrease in velocity is accompanied by an increase in pressure, with the result that a relatively high pressure barrier exists at the after end of the diffuser.
3. Fuel, usually kerosene, is sprayed into the combustion chamber through injection nozzles.
4. This fuel, thoroughly mixed with the incoming air, is ignited by a spark plug.
5. The combustion gases tend to expand in all directions.

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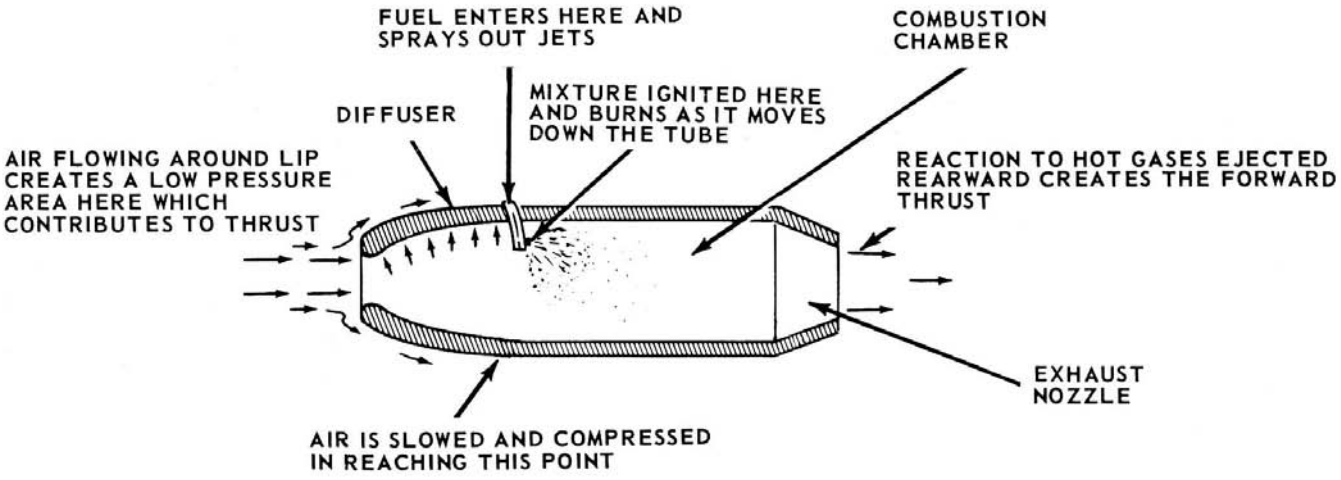


Figure 3-21. — Ramjet engine.

6. Expansion in the forward direction is restricted by the pressure barrier existing at the after end of the diffuser; consequently, the gases must expand down the tailpipe and leave the exhaust nozzle with a greater velocity than that of the air at the intake.

Once ignition takes place, there is no further need for an electric spark because combustion is continuous as long as the air-fuel mixture is maintained with proper limits. The flame holder (figs. 3-22A, B, C), prevents the flame from being blown too far to the rear of the engine. Without it, the flame could be blown out by the high speed air stream.

The diffuser design is very important since a higher pressure barrier results in greater thrust.

The operation of a supersonic ramjet (figs. 3-22B and C) is the same as that of a subsonic ramjet, with the following exceptions. First, the supersonic jet must be boosted to a supersonic speed. Second, a higher pressure barrier exists in the supersonic engine, resulting in greater thrust. Talos missiles have supersonic ramjet propulsion systems.

Note the differences in the shape of the diffuser section and the throat in figure 3-22. They must be designed for a predetermined missile speed, according to Bernoulli's principle. Note, too, that the fuel injection systems can be varied. The effect of the shape of the exit nozzle on the speed of the exhaust gases is also illustrated. Compare the nozzles in figure 3-22 with those in figure 3-20.

ROCKETS

Present day operational rockets may be divided into two classes - solid propellant and liquid propellant.

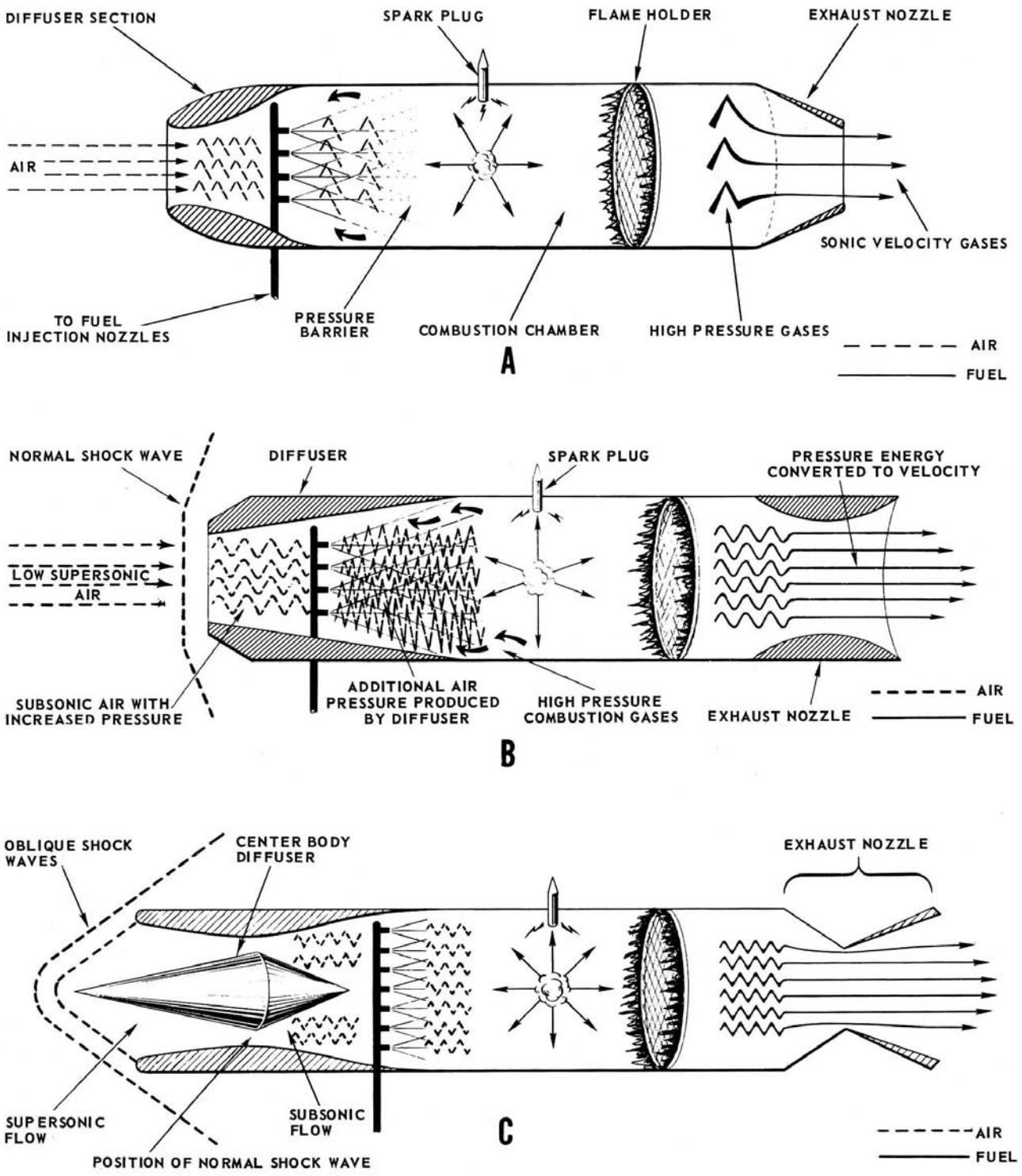
The more important characteristics of all rocket engines are:

1. The thrust of a rocket is nearly constant, and is independent of speed.
2. Rockets will operate in a vacuum.
3. Rockets have relatively few moving parts.
4. Rockets have a very high rate of propellant consumption.
5. Burning time of the propellant in a rocket is short.
6. Rockets need no booster. They have full thrust at take off; therefore, when rockets do employ boosters it is for the purpose of reaching a high velocity in minimum time.

Solid Propellant Engines

The combustion chamber of a solid propellant rocket contains the charge of solid propellant. Solid propellant charges are of two basic types: restricted burning and unrestricted burning (fig. 3-23). The restricted burning charge is designed so that burning is permitted on only one surface at a time. A common example of restricted burning is a lighted cigarette. The restricted burning charge provides relatively low thrust and long burning time. Uses of this type of charge include JATO (jet-assisted take off) units, barrage rockets, and sustaining rockets for guided missiles.

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Figure 3-22.—Structure of ramjets and combustion processes in them: A. Subsonic ramjet; B. Low supersonic ramjet. C. High supersonic ramjet.

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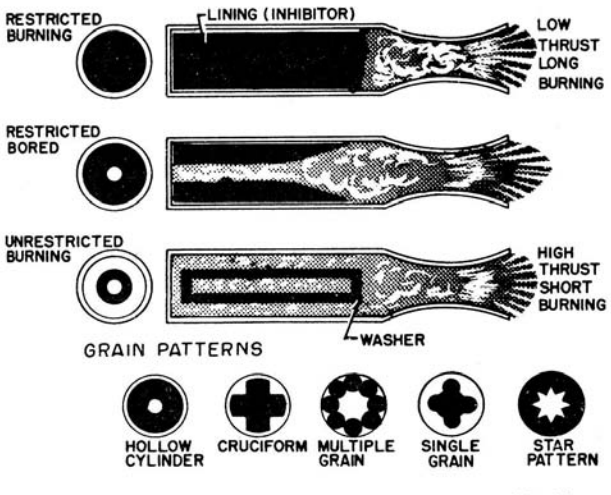


Figure 3-23.—Solid propellant grains used in rockets.

A modification of the restricted burning charge is the bored restricted charge. The main difference is that the longitudinal hole in the charge provides somewhat more burning surface and thus a higher thrust and shorter burning time.

In the unrestricted burning charge, burning takes place on several surfaces at one time. This results in a very high thrust during a short burning time. This type of charge is commonly used in booster rockets.

It should be clearly understood that in both the restricted and unrestricted burning charges, the burning rate is controlled - there is no explosion. Controlling the burning rate of a solid propellant has always presented a problem to rocket designers. You will recall that one of the properties of an ideal solid propellant would be that it ignite and burn evenly. The burning rate may be controlled in several ways. One is by means of inhibitors. An inhibitor is any substance which interferes with or retards combustion. The lining and washer shown in figure 3-23 are examples of inhibitors. Another way that burning is controlled is by use of various grain shapes. Examples are the shapes shown in the lower part of figure 3-23. Resonant burning or "chugging" may be offset by the use of resonance rods. There metal or plastic rods are sometimes included in the combustion chamber to break up regular fluctuations in the burning rate and their accompanying pressure variations. The purpose of the various designs is to maintain a constant burning area while the surface of the grain is being consumed.

To start the combustion process, some form of electrically detonated squib is ordinarily used to ignite a smokeless or black powder charge. Upon igniting, the black powder charge provides sufficient heat and pressure to raise the exposed surface of the propellant grain to a point where combustion will take place.

Until fairly recently, a serious disadvantage of the solid propellant had to do with the problem of dissipating the extreme heat of combustion. One way this has been overcome to a considerable extent is by use of the internal burning grain. Since the burning process actually takes place within the grain, the outer portion of the grain provides a shield between the intense heat and the combustion chamber wall until the grain is almost completely consumed.

Solid propellant rockets are particularly adaptable to shipboard use. They are easily stored and ready for immediate use. So great have been the improvements in solid propellants in the past few years that they are now used in such missiles as the Navy's Polaris, Tartar, Standard, and Terrier, and the Air Force's Minuteman.

Liquid Propellant Rockets

You know from your reading of the newspapers that liquid fuel is used in space vehicles and satellites and that this fuel is put into the tanks of the space vehicles immediately before launching. A missile cannot wait to be fueled when it is needed for defense or offense-it must be ready. That is one of the reasons why solid propellants have replaced liquid propellants in most of our missiles.

COMPONENTS OF LIQUID-FUEL ROCKETS. - The major components of a liquid-rocket system are the propellant, propellant-feed system, combustion chamber, igniter, and exhaust nozzle. The feed systems may be of the pressure-feed type or the pump-feed system, in which air or some other gas (preferably inert) is stored under pressure in the accumulator of the missile and is used to force the proper amounts of propellant and oxidizer into the combustion chamber when the rocket is fired. Generated-pressure feed systems contain substances, carried in the missile that generate high-pressure gas as needed. An example is hydrogen peroxide, which, when passed through a catalyst, decomposes to form a high pressure vapor. This vapor is then injected

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into the storage tanks to force the propellant into the combustion chamber.

Many other devices, such as valves, regulators, deli very tubes, and injectors, are necessary for the operation of either system.

Pump-feed systems are used in those missile rocket motors which are designed to burn large volumes of propellants and in power plants requiring a high rate of flow. A pump-feed system consists of a fuel pump and an oxidizer pump. Each pump is driven by a turbine wheel. Power for, the wheel may be developed by chemical gas or by the rocket's exhaust gases. The auxiliary devices and controls required by a pump-feed system are far more complicated than for a stored-pressure system and a complicated checkout is required.

PREPACKAGED LIQUID-FUEL ENGINES. - The Bullpup missile can use a prepackaged liquid-fuel engine. The first trials were made with the prepackaged version used in place of the regular solid propellant in Bullpup A, and can still be so used. It is the standard fuel package for the Bullpup B. The propellant and the oxidizer are in separate containers until the missile is fired, when the two liquids are mixed in controlled quantities and combustion occurs upon contact. The containers are designed so accidental mixing cannot occur.

The success of the prepackaged method in the Bullpup missile gives the advantages of a liquid propellant without its disadvantages. Research is continuing in the development of high power fuels that meet the requirements for storability, safety, and cost.

HYBRID PROPULSION

A hybrid engine combines the use of liquid and solid propellants. The liquid is the oxidizer and the solid is the propellant. Neither will support combustion by itself in the hybrid engine. Ignition is usually hypergolic, that is, spontaneous ignition takes place upon contact of the oxidizer with the propellant. The combustion chamber is within the solid grain, as in a solid-fuel rocket; the liquid portion is in a tank with pumping equipment as in a liquid-fuel rocket. This type is sometimes called a forward hybrid to distinguish it from a reverse hybrid, in which the oxidizer is solid and the fuel is liquid. Combustion takes place on the inside surface of the solid fuel, after the liquid fuel is injected, and the combustion products are exhausted through the nozzle to produce the thrust as in other rockets (fig. 3-24). Nozzle systems and control methods are the same as in other reaction engines. It is possible to start, stop, and restart the system as in a liquid fuel system by shutting down or I' reopening the liquid oxidizer flow system.

Missiles such as the Talos, which has a solid-fuel booster and a liquid-fuel sustainer, are not hybrid systems; the liquid and the solid propellants do not interact.

The hybrid system has several advantages on either solid or liquid systems by combining the advantages of both. At present we do not have an operational hybrid propulsion missile, but research and development are continuing.

FEATURES OF SURFACE-TO-AIR MISSILES

Now that you have a little background in missile flight and propulsion principles, we will relate what you have studied to specific Navy surface-to-air missiles (RIMs: see chapter 4). At this writing there are four types of operational missiles: Talos, Terrier, Tartar and Standard. As a GMM you will maintain launching system equipment that stows, handles, and launches Talos, Terrier, Tartar and Standard missiles. Therefore, we will cover briefly some of the characteristics and features of these missiles.

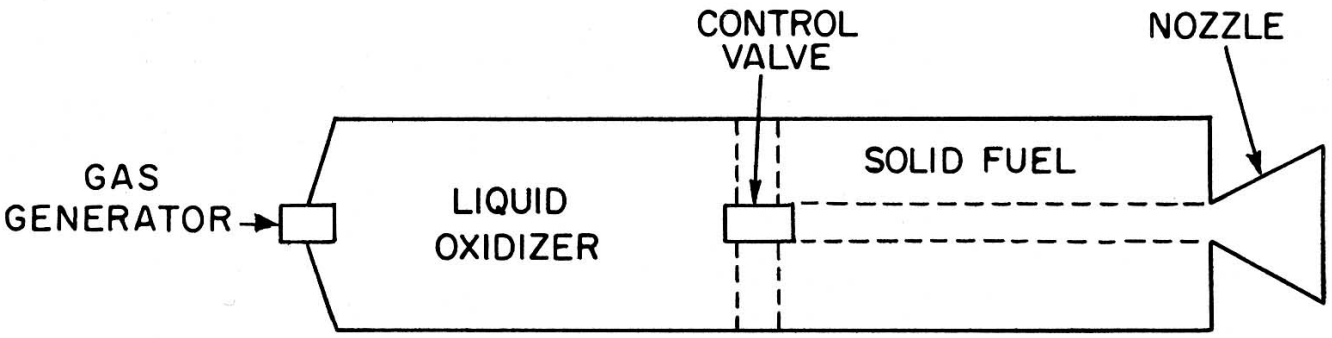
Coupled with your launching system maintenance duties, you will help handle and maintain missiles. The more you know about the missile you are working with, the better you can do your job.

TALOS MISSILE ROUND

Figure 3-25 shows you what a Talos missile looks like. It is the largest of the RIMs. Notice that it is made up of two sections or stages. The first stage is the booster; the second stage is the missile proper. These two sections, when they are connected, form what is called a complete round, weapon, or missile booster combination. You will see the terms used interchangeably.

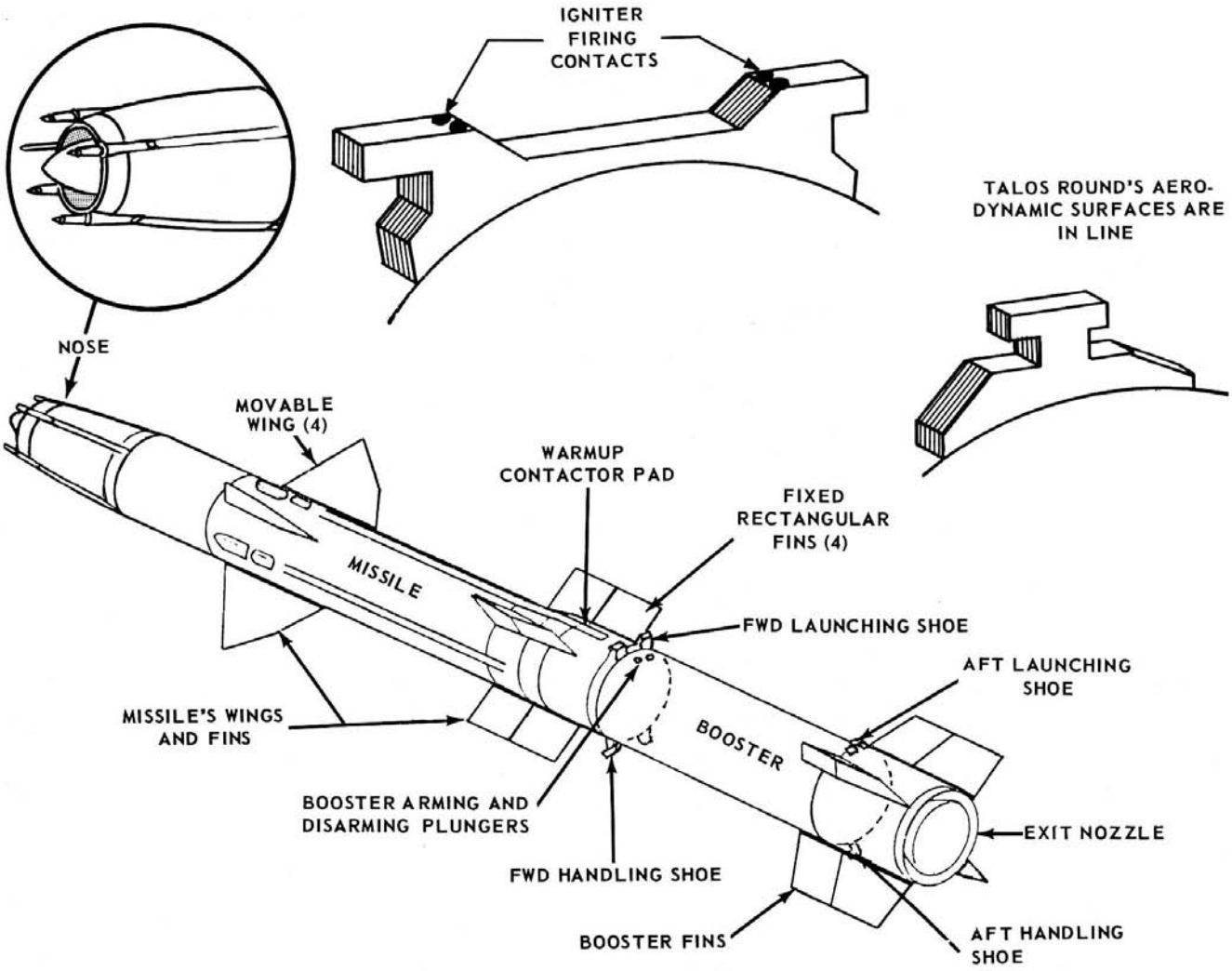
First, consider the missile section. It only takes a quick glance at figure 3-25 to see that Talos is a ramjet propelled missile. The clue to recognizing it as a ramjet is the diffuser opening in its nose (fig. 3-14). Four raked-tip biconvex (figs. 3-10, 3-11) wings steer the missile. The wings are located near the missile's center of gravity. Four fixed rectangular fins are attached near the end of the missile. Like the wings, they are biconvex. Both wings

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144.26

Figure 3-24. — Sketch of a hybrid propulsion engine.



83.10

Figure 3-25. — Talos missile round configuration.

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and fins are arranged in a cruciform pattern about the missile body (fig. 3-12). The wings and fins are in line with each other. Now. look at the booster. You learned earlier that the purpose of a booster is to propel the missile to flight speed. Talos has a ramjet sustainer, and it operates most efficiently in the supersonic range.

The Talos booster is a solid propellant rocket unit. Basically, it consists of the propellant, combustion chamber (called the case), igniter assembly (includes arming and disarming mechanisms), and exit nozzle.

The booster case is a long, round, metal tube. It serves two purposes. First, it acts as a storage place for the propellant, and second, it serves as a chamber in which solid propellant burning takes place. The propellant consists of nitrocellulose explosive and a metal compound. These materials are mixed together to make an even burning grain. The grain is star shaped. When propellant grains are shaped in this fashion, many constant burning surfaces are provided. The booster produces a large amount of thrust for a short time - in the order of 4 or 5 seconds. To reduce chugging, resonance rods are placed along the length of the grain. The rods absorb vibrations set up in the combustion chamber.

The front end of the booster is enclosed by a metal cap. The cap supports the igniter assembly. The igniter consists of a small charge of pyrotechnic material and several electrical squibs. When current flows through the squibs the pyrotechnic material starts burning. The material generates enough heat and flame to ignite the main rocket propellant.

Another unit attached to the head cap is the booster arming-disarming device. Its purpose is to mechanically open and close that portion of the booster firing circuit that is in the booster igniter. The rest of the firing circuit is in the launching system. (We'll cover firing circuits in detail in chapter 9 of this manual.) Boosters are in the disarm (safe) condition while they are in stowage. They are not armed until they are ready to be launched. Then they are armed by a mechanical device (called an arming tool) on the launcher.

A clamping arrangement on the head cap connects the missile and its booster. When the booster burns out, the clamp is released and the booster falls away from the missile. Then the missile continues on its way under its own sustainer power.

An exit nozzle is at the after end of the booster case. It compresses the propellant gases as they escape through the opening in the nozzle. The nozzle is a convergent-divergent (fig. 3-20) type. The nozzle also provides a foundation for the four fixed fins.

The only continuous physical contact the Talos round has with its launcher is through the top set of shoes. These hooklike metal lugs are solidly attached to the booster case. And they fit into slots cut into the launcher's guide rails. Igniter firing contacts are located on the forward top shoe. The bottom set of shoes are used to handle the weapon. By handling we mean the operations and steps involved in stowing the weapon and loading it on the launcher.

TERRIER GUIDED MISSILE ROUND

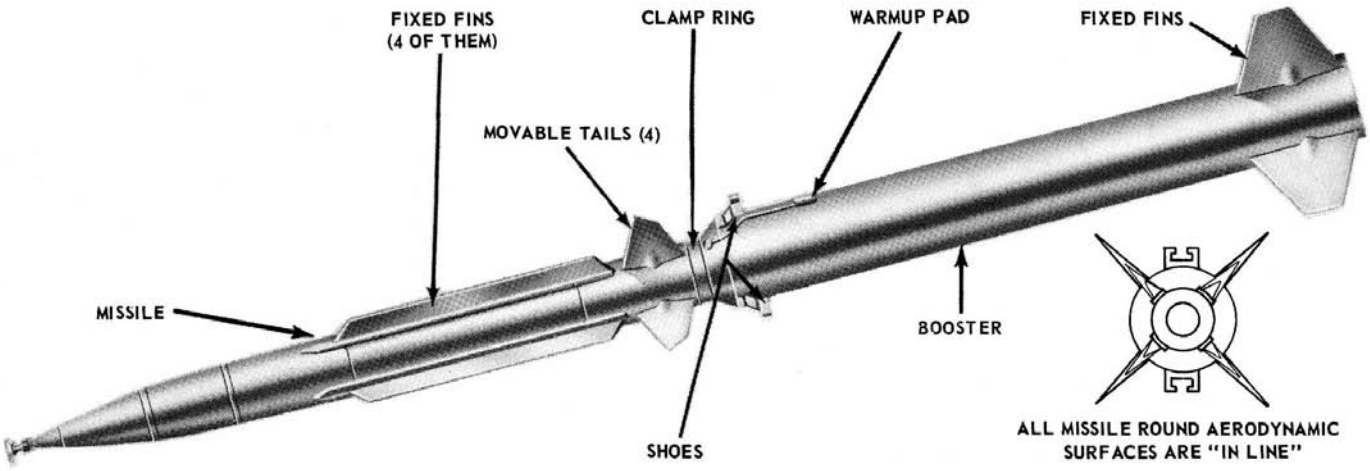
Terrier is the name applied to a large family of missiles. The most obvious common feature of Terrier missiles is that each type has a separate booster. Some Terriers have movable tails; others have movable wings near the missile center of gravity to do the steering job. The tail controlled missiles have fixed fins that resemble the dorsal fins of a sail fish or marlin. The earliest Terriers put aboard ship were the wing-controlled BW-O and BW-l. They are now obsolete as weapons but may be used as target drones.

The beam-riding, tail-controlled missile, designated the BT-3 (B for beam-riding the T for tail-controlled) was next to be tested and improved. The improvements included the BT-3A and the BT-3B, each of which had a choice of warheads. These, too, are no longer being produced, but there are some around.

In the next chapter we will briefly cover the rest of the Terrier family and point out the similarities and differences between members. Now then, look closely at figure 3-26. It shows the general outline of the BT-3 and its booster. Variations in the mods of the BT-3 will not be discussed here.

Let's start at the nose of the BT-3 and work aft. The nose has an ogival shape, which is a characteristic of most supersonic missiles. Four fixed dorsal fins are attached to the missile in cruciform arrangement. They stabilize the missile and provide some lift. Four control surfaces, called tails, steer the missile and keep it from rolling. Another feature of the tails is that they can be folded. This cuts down on the space needed for stowage, and makes handling

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83.11

Figure 3-26.—BT-3 Terrier round.

easier. Before a missile is put on its launcher, the tails are manually unfolded.

Notice the clamp ring between the end of the missile and the head of the booster. The clamp holds them together. For the present, we'll leave the missile, and return to it in chapter 4.

Now consider figure 3-27. It shows a cutaway drawing of the BT-3 booster. The drawing is simplified but shows all the booster's essential parts. The booster is basically a round steel shell, closed at the forward end and open at the after end. Four fixed fins (not shown in fig. 3-27) are attached to the after end of the booster. The fins simply help stabilize the complete round during the boosted part of the missile's flight. Notice the shoes at both ends of the booster. The top set is used to hang the missile from the launcher. The bottom set is used for handling the missile. The booster and missile are held together by a mechanical clamping device attached to the forward end of the booster. An electrical connection is also made between missile and booster. The booster igniter is in the forward end of the booster, and is wired to contacts on the upper forward shoe. Booster ignition current is applied from the launcher to the pair of shoe contacts and then to the igniter squibs.

On the top forward part of the booster you can see an electrical receptacle (pad). It receives a hydraulically operated contactor which extends from the launcher and jabs into the pad. It can also be retracted. (More about this in chapter 6.)

The separation action of booster from missile is extremely crucial. It must take place very quickly and smoothly so as not to disturb the flight of the missile. Many other factors must be calculated by the designers to/ achieve successful separation of missile and booster in flight.

The HT-3 Terrier Missile

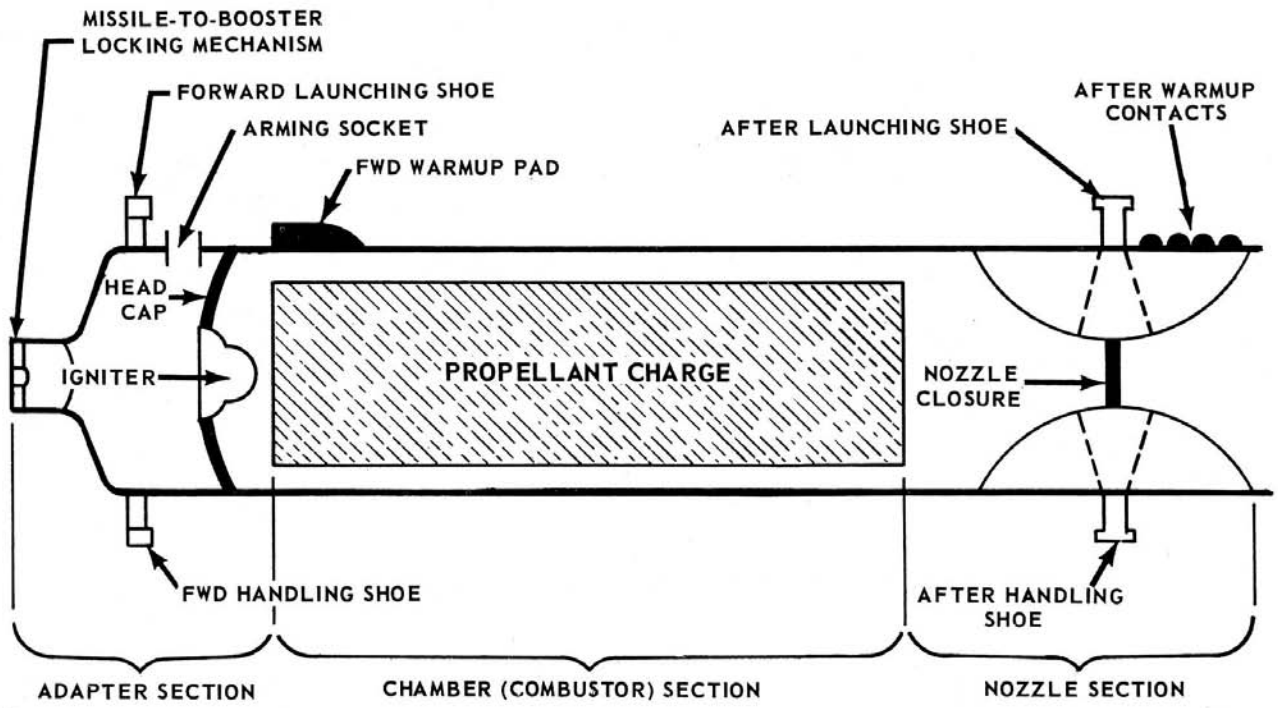
In outward appearance, the HT-3 missile is much like the BT-3. Figure 3-28 shows the exterior of the HT-3 and the BT-3 for comparison, and indicates the location of the main components of each. The booster is not shown; all mods of the BT-3 and the HT-3 can use the same booster.

Much of the actual hardware is the same in the BT-3 and the HT-3. The booster (mentioned above), the sustainer, and the aft section are identical.

The big difference is in the method of guidance used. All mods of the BT-3 missile are beam-riders, while the HT-3s are homing missiles. Semi active homing is the type usually used, but some mods have the capability of switching to passive type of homing. Guidance methods are discussed in the next chapter.

With a homing missile, its target seeker is in the nose, or forward end of the missile. A radome encloses the instruments to provide a streamline shape to the missile; it is transparent to radar waves, which the missile must receive and interpret in order to locate the target.

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Figure 3-27.—Cut away of BT-3 Terrier booster.

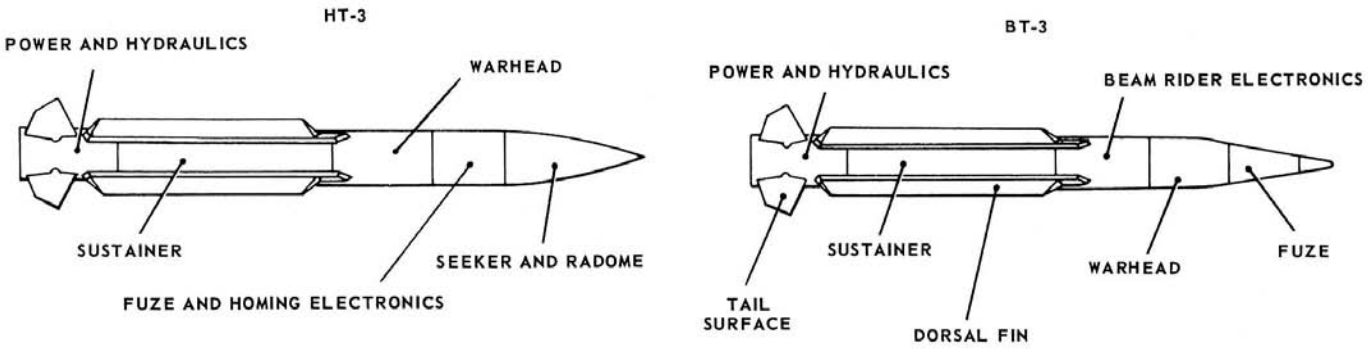
Additional differences and similarities are pointed out in chapter 4.

TARTAR MISSILE ROUND

Tartar does not have a separate booster. The missile comes all in one piece as you can see in figure 3-29. Instead of a separate booster, it has what is called a dual thrust rocket motor (DTRM). The DTRM has two propellant grains: one to boost the missile to flight speed, and one to keep it flying at this speed.

The Tartar missile looks just like the HT-3 Terrier, though it is considerably longer, so we won't dwell on Tartar's physical appearance. Briefly, it is round, with an ogival nose. Four fixed dorsal fins are in line with four independently movable tails. Unlike the other two missiles you must read about, Tartar is designed to fly in either of two flight positions.

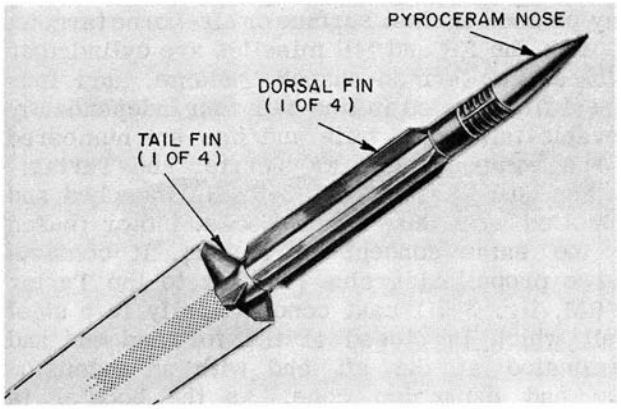
Figure 3-30 shows a cutaway view of the DTRM. You will notice that it has all the parts that Terrier and Talos boosters have. There



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Figure 3-28.—Terrier HT-3 and BT-3 exterior configuration.

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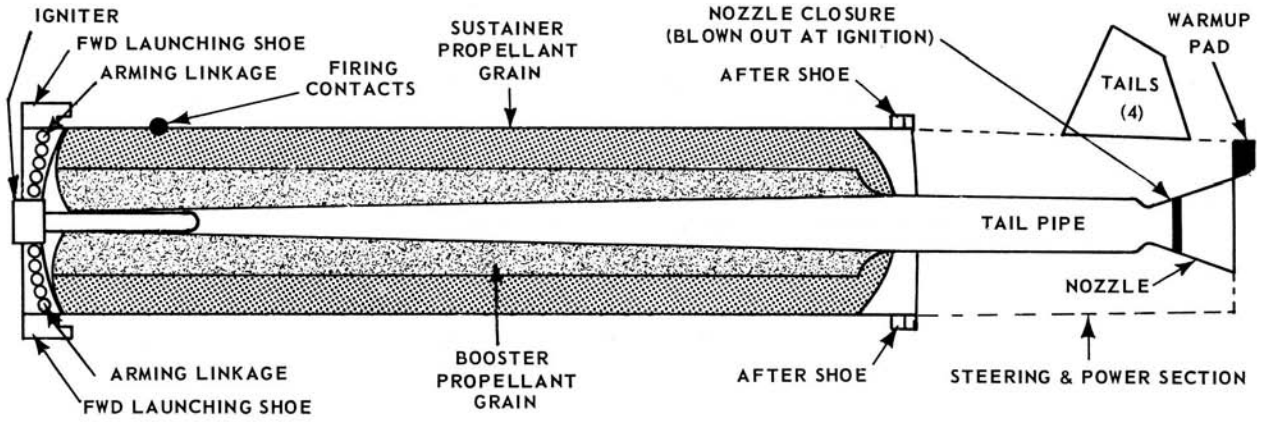
Figure 3-29.—Tartar missile.

is a booster igniter, and an igniter arming-disarming device. An arming tool on the Tartar launcher mechanically arms or disarms the igniter circuit. Firing contacts on the missile skin scrape contacts on the launcher to complete the missile-to-launcher part of the firing circuit. The warmup pad is not located in the same place as on Terrier and Talos, but on the after face of the steering and power section. This section fits around the tail pipe and is indicated by the broken lines in figure 3-30. The warmup pad has the same function, of course, as the pads on Talos and Terrier - to provide an external warmup power connection.

The Tartar propulsion unit is unique because it has two separate grains in its propulsion system. Figure 3-31 shows a cross- sectional view of the DTRM as seen from the end of the missile. The steering and control section have been removed. You can see that the two grains are cast in a concentric grain design-the sustainer grain encloses the inner booster grain. There are no resonance rods because the grains burn so smoothly that chugging does not happen. The inner, or booster part of the DTRM is a fast-burning type of propellant and burns first and then the slower burning propellant in the sustainer portion takes over to furnish the thrust during the main part of the missile's flight.

Several advantages of dual-thrust rocket motors over separate boosters are:

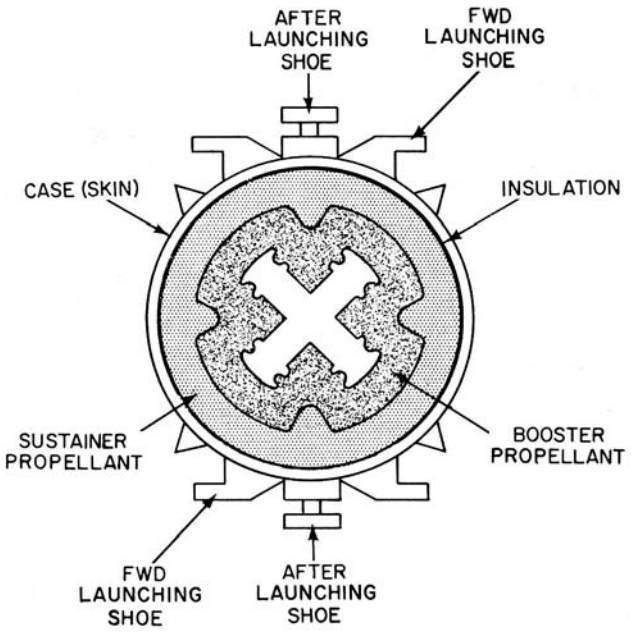
1. There is no empty booster case to get rid of. Sometimes booster cases fail to separate from the missile, clamping devices fail to operate, or, during handling the booster and missile are tightly jammed together. Another problem caused by empty boosters is related to safety. Care must be taken to keep a booster from falling on another ship. The booster splash point (the area in the sea where the empty case will hit at the end of its fall) must be predicted. This requires extra computing equipment on board ship.
2. Heavy power-driven equipment is needed to hold and to move the missile and separate booster during the mating operation. These equipments are not required for single-stage missiles.



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Figure 3-30.—Cutaway of Tartar DTRM.

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Figure 3-31.—Cross section of Tartar DTRM, showing booster propellant and sustainer propellant grain conformation.

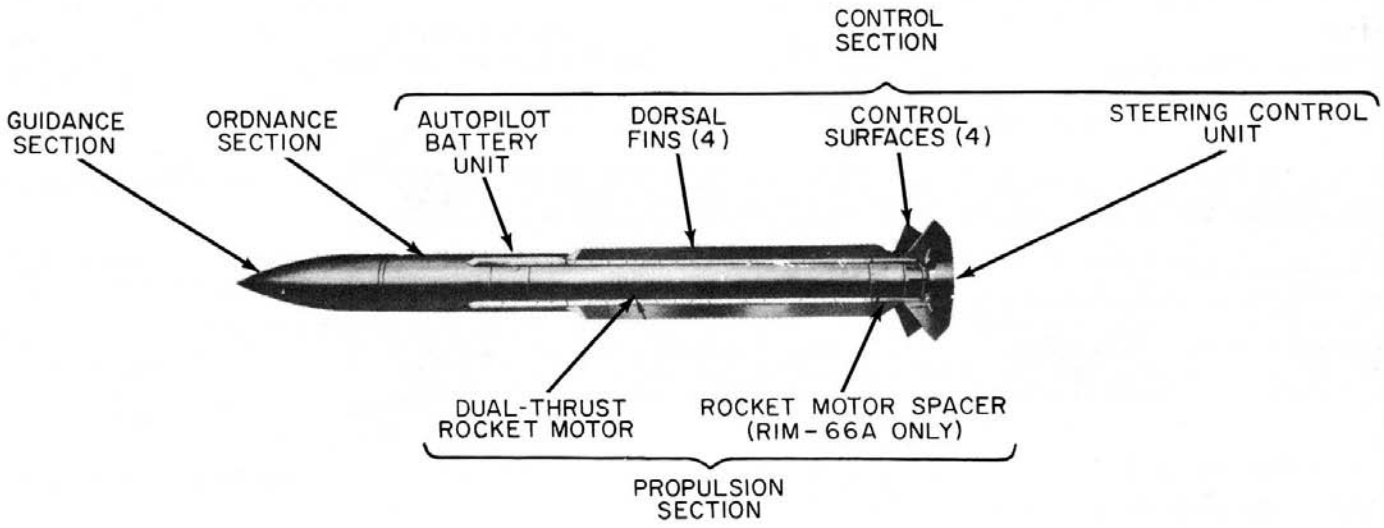
STANDARD MISSILE ROUND

Figures 3-32 and 3-33 show the configuration of the Standard missiles. There are two versions of the Standard missiles: RIM-66A is a Medium Range (MR) missile and RIM-67A is an Extended Range (ER) missile. Both configurations are surface-launched, supersonic guided missiles that may be used against surface or air-borne targets.

Both the ER and MR missiles are cylindrical with a VonKarman-shaped radome, and four dorsal fins located in line with four independently movable tails. The tails and fins are numbered in the same manner as Terrier and Tartar.

The MR version, fig. 3-32. is launched and propelled by a dual thrust rocket motor (based on the same concept as Tartar). It consists of two propellant grains (similar to the Tartar DTRM, fig. 3-31) cast concentrically in a steel shell which is closed at the forward end and terminated at the aft end with an extension tube and expansion cone. As the booster is consumed, the sustainer (outer) grain is ignited and provides the thrust necessary to maintain velocity acquired during the boost phase.

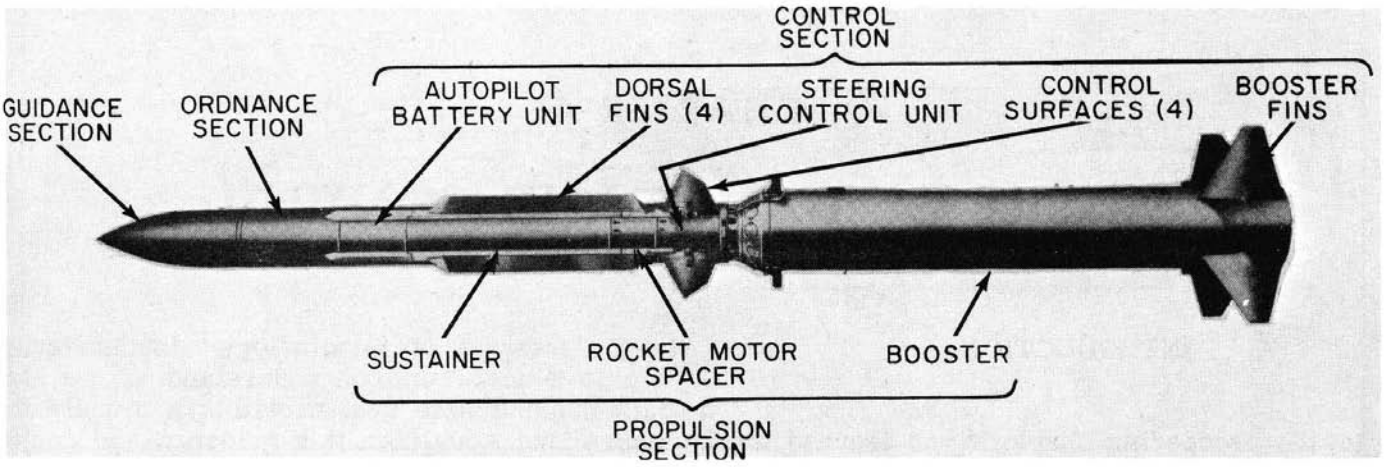
The ER version, fig. 3-33, is launched and propelled in two stages by a solid fuel rocket motor (booster and sustainer). The booster is a cylindrical rocket motor consisting of a dual- propellant grain housed in a steel shell which is terminated at the aft end in a nozzle and closed at the forward end by an adapter assembly. When ignited, the booster grain provides the initial thrust necessary to accelerate the ER missile to supersonic velocities. The sustainer is a cylindrical rocket motor consisting of a propellant grain housed within a steel shell which is closed at the forward end and terminated at the aft end with a nozzle assembly. An in-flight arming-firing device if armed by acceleration during the boost phase



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Figure 3-32.—Standard missile RIM-66A (MR), major sections and components.

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141.234(141B)B

Figure 3-33.—Standard missile RIM-67A (ER), major sections and components.

and thereafter, upon receipt of firing voltage, ignites the igniter train. The sustainer provides the necessary thrust to maintain the velocity acquired during the boost phase.

The guidance system of the ER and MR missiles operates as either a semiactive or passive homing guidance system. Roll stabilization and steering are accomplished by the movement of four aerodynamic control surfaces (tails). Guidance systems are discussed more in detail in chapter 4.

Missile operating power is provided by the primary battery which consists of two electric ally separate cell packs (electronic battery and electromechanical battery) and an activator assembly. The electronic cell block supplies power to signal and low power level circuits. The electromechanical cell block supplies power to major power consumption circuits. Both cell packs are of the silver zinc type and are inactive until filled (at launch) with the electrolyte contained in the activator assembly. Battery power eliminates the need for hydraulics and for power conversion during flight.

CONCLUSION

The material in this chapter will be extremely valuable to you in your duties as a Gunner's Mate Missile. An understanding of aerodynamics, the jet propulsion theory, the gas laws, and the various basic missile propulsion systems will help you to realize why missile launching systems and missile magazine spaces are designed as they are. Much of the information covered will also relate directly to the operational aspects of missile launching systems.

The next chapter of this manual will take up missile guidance - that is, it will discuss the basic components of guided missiles which enable them to alter their trajectories and collide with moving targets. We'll also have more to say about Talos, Tartar, Terrier, and Standard missiles.

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CHAPTER 4

MISSILE GUIDANCE AND CONTROL

INTRODUCTION

In the preceding chapters you learned that the essential parts a guided missile needs to perform properly are:

1. Airframe and control surfaces.
2. Propulsion system.
3. Warhead system.
4. Guidance and control system.

In addition, in chapter 2 you studied the basic fire control problem, and learned how some of the forces of nature affect the trajectory of a guided missile as it flies to its intended target. In chapter 3 you learned how wings and fins steer a missile and keep it pointed along its flight path. The use of interior control devices by missiles without exterior control surfaces (or limited ones) was described briefly. The different types of guidance systems used in missiles are inertial, command, beam-rider, and homing guidance.

In this chapter we will show you the basic functional components of a guidance system. Some of them are within the missile, and some are on the launching ship. Then we will discuss briefly some of the parts in the missile's guidance and control equipment and how they work. Finally, we will cover the way specific missiles (the ones you will work with) are divided into sections or compartments.

GUIDANCE AND CONTROL

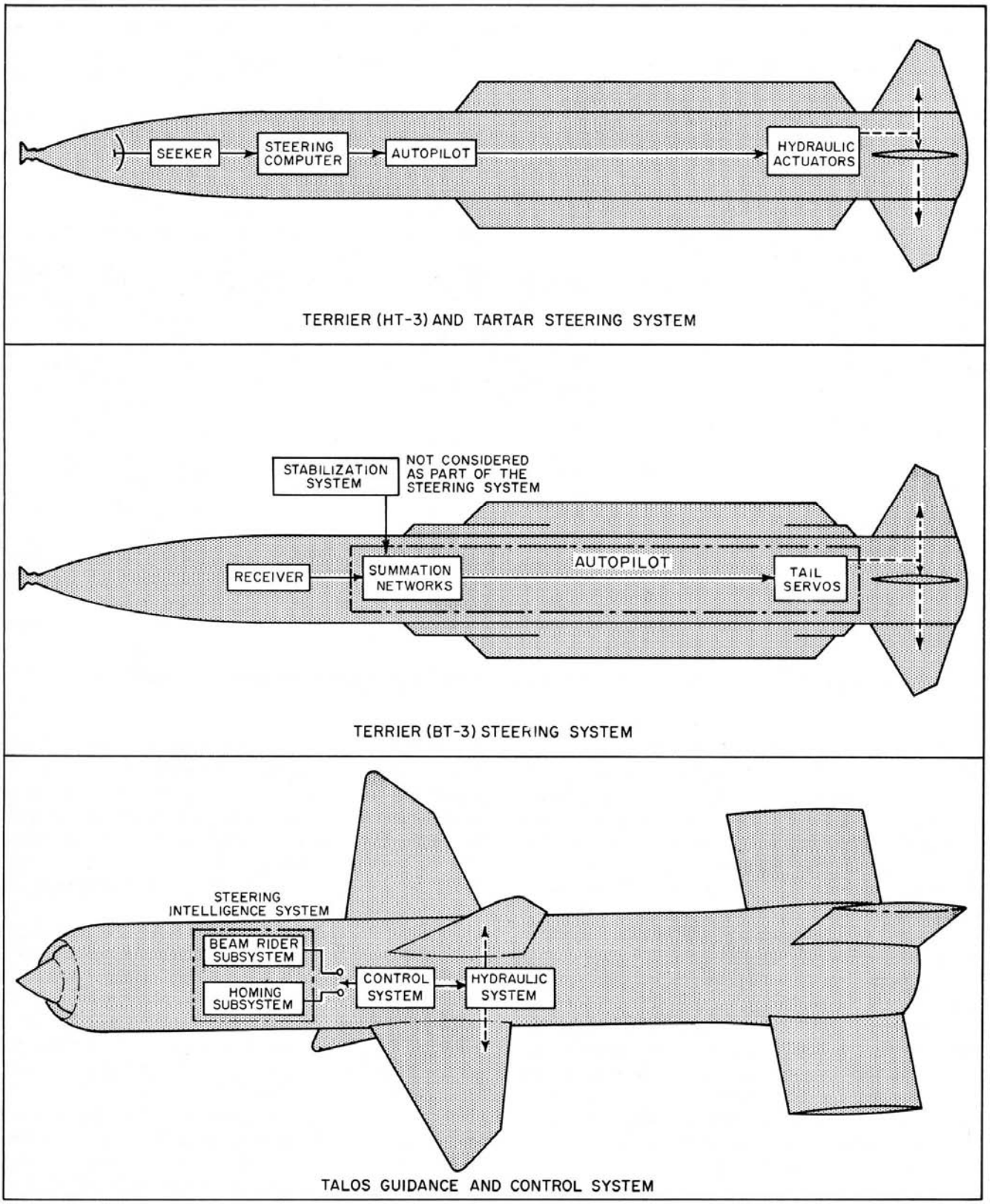
Before we go on to discuss any particular type of guidance system, it is necessary to consider first the overall operation of an entire missile guidance and control system; to divide it into convenient groups of units; and to indicate the general function of each major group so that the operation of the particular units may be understood in relation to the operation of the guidance and control system as a whole. Also, in the interest of terminology standardization and to assist common understanding, we shall call the complete system within a missile that steers and stabilizes it a guidance and control system. Depending on your experience with missiles, you may take exception to this designation. And if you do, there is good reason for it. The reason is shown in figure 4-1. For example, if you have worked on the Tartar or Terrier missiles you will consider the system that guides and controls a missile to be its steering system. On the other hand, a Talos GMM would call it a guidance and control system. We will stick with the latter designation - not because we favor Talos but because most manuals, and many Navy publications, use this term.

SUBSYSTEMS AND COMPONENTS

In figure 4-2 we show that the complete system for steering and stabilizing a surface- to-air missile may be considered as consisting of two major divisions or systems: (1) the guidance system and (2) the control system, which functions similarly to an automatic pilot in an aircraft. For convenience, we will include the control surfaces (wings and fins) and interior control devices as part of the control system.

In many ways a guidance and control system is simply a flying servomechanism. At first thought this idea may not be clear to you. So to make it clearer, let's review the definition of a servomechanism and see if the definition fits a missile guidance and control system. You learned in Basic Electricity. NavPers 10086-B, that, and we quote the text - "A servomechanism is an electromechanical device that positions an object in accordance with a variable signal. The signal source may be capable of supplying only a small amount of power. A servomechanism operates to reduce the difference (error) between two quantities."

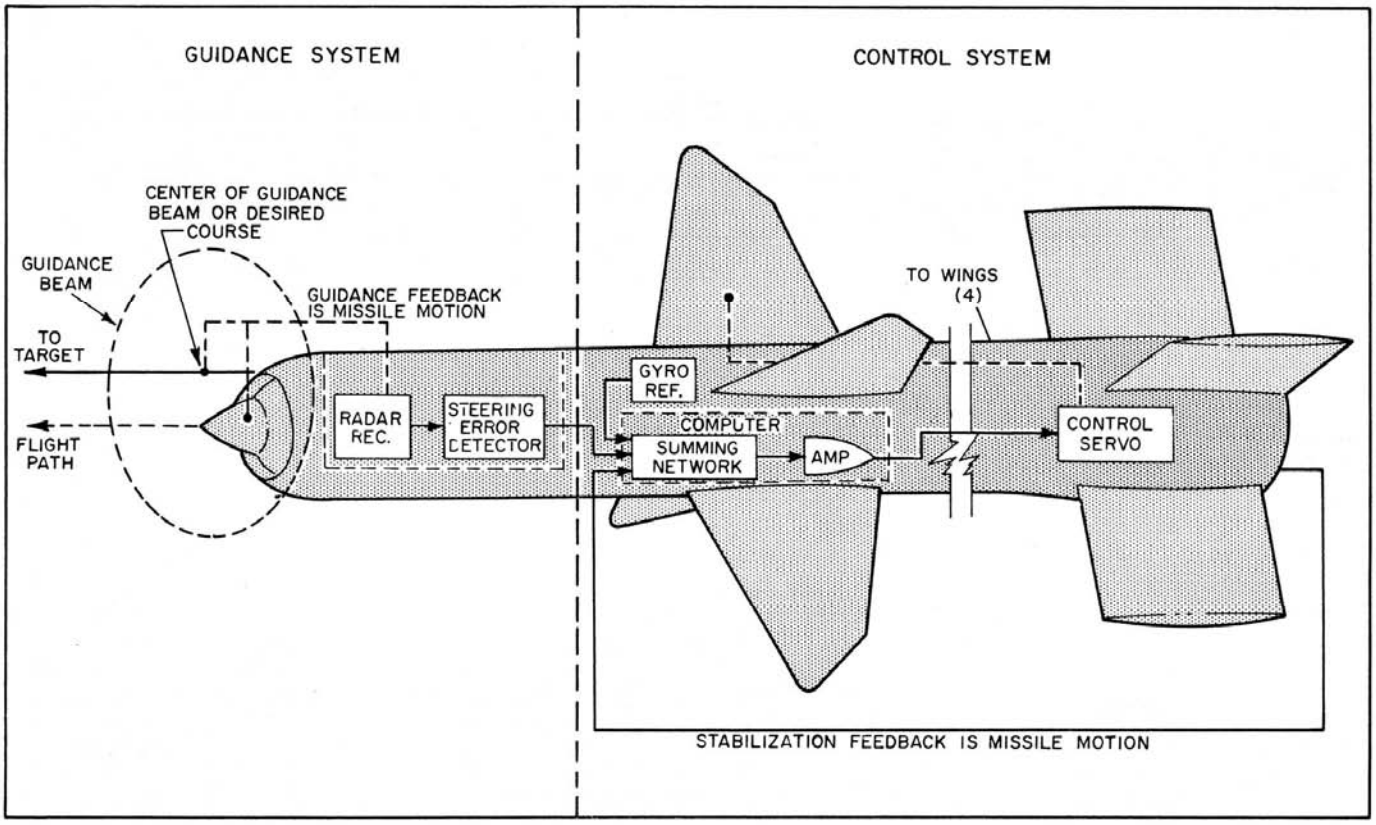
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83.16

Figure 4-1.—Names for guidance and control systems and system components.

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83.17

Figure 4-2. — Essential parts of a basic missile guidance and control system.

A guidance and control system meets the requirements of a servomechanism as it is implied in the above definition. The guidance portion of the system develops the variable input signal. The input signal represents the desired course to the target. The missile control system operates to bring the missile onto the desired course. Therefore, you can say that the output of the guidance and control system is the actual missile flight path. If there is a difference between the desired flight path (input) and the one the missile is actually on (output), then the control system operates to change the position of the missile in space to reduce the error. When the missile has been steered to the desired course, the guidance system will detect no error and the control system will not move the control surfaces in response to a guidance error, because there isn't any.

The units of the guidance system may be carried in the missile (as in active and passive homing), or they may be distributed between the missile and the launching ship (as in beam-rider and semi active homing missiles). The principal functions of the guidance system are to detect the presence of the target and track it; to determine the desired course to the target; and to produce electrical steering signals which indicate the position of the missile with respect to the required course.

The units that respond to the guidance signals and actuate the control surfaces make up the major division referred to in figure 4-2 as the CONTROL SYSTEM. For convenience we will include gyros in this system. The units in the control system may be considered as consisting of two groups: the COMPUTER, and the CONTROL-SURFACE SERVOSYSTEM.

Specific computer units vary widely in design because of basic differences in the type of guidance used. But in most cases this section contains damping instruments (accelerometers and rate gyros), summing networks (electrical circuits that add and subtract voltages), and servoamplifiers as principal components. In general,

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these units originate information about missile motion and flight attitude, add this data to incoming guidance signals, and produce output voltages suitable for operating the control-surface servo.

A typical control-surface servosection is made up of hydraulic units. This section serves as a power stage of the control system; it releases large amounts of energy under accurate control. The principal parts of this section are electrically operated servovalves and the wing or tail hydraulic actuator units which make the adjustments to guide and stabilize the missile. In the newest missiles, hydraulic actuators are replaced by electric systems. This saves considerable weight and space in the missile.

TYPES OF FEEDBACK LOOPS

As indicated by the feedback loops shown in figure 4-2, the basic operation of the guidance and control system is based on the closed-loop or servo principle. The control units make corrective adjustments of the missile control surfaces when a guidance error is present, in other words, when the missile is not on the correct course to the target. The control units will also adjust the control surfaces to stabilize the missile in roll, pitch, and yaw. You must keep in mind that guidance and stabilization are two separate processes, even though they occur simultaneously. To make this idea clearer, think of yourself throwing a dart with its tails removed. It is possible for you to hit the bulls-eye of a target because your arm and brain guide the dart onto the proper trajectory to score a hit. But without its tail surfaces to stabilize it, it is very possible that the dart will land on the target in some position (attitude) other than point first. Well, missiles are like darts or arrows in this respect, and must be stabilized about the three (roll, pitch, and yaw) axes we talked about in chapter 3, so that the missile will fly nose first and will not oscillate about its direction of flight. So in summary we can say that, if there is an error in missile heading due to guidance or stabilization, the corrective actions taken by the control system are such that any error present in the system is reduced to zero. This is true servo action, as you have learned in previous Navy courses on basic electricity and electronics.

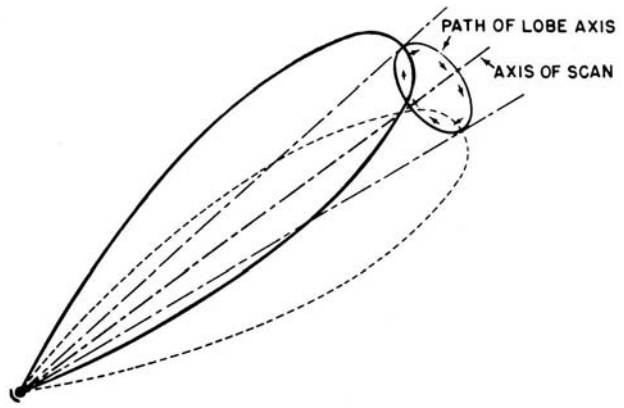
Now that you have a general picture of the overall operation of a missile guidance and control system, let's turn our attention to the feedback loops in our flying servo.

Guidance Feedback Loop

Consider first the guidance feedback loop, which is indicated by the broken line between the desired course line and missile flight path (fig. 4-2). The loop is not a physical circuit, but rather a method of operation that is built into the system. By means of this operation, the position of the airframe, as well as the guidance signals, determines the amplitudes and polarities of the guidance signals that actuate the control units.

For example, in the beam-rider system, steering (guidance) error voltages are produced in the radar receiver in the guidance section by comparing the position of the missile with the center of the guidance beam (fig. 2-17) or to be more exact, with the nutation axis (fig. 4-3) of the beam. If the missile is not flying along the nutation axis, then the guidance system produces error voltages and sends them to the control section. The control section makes corrective adjustments of the control surfaces in response to the error signals. As the missile approaches the nutation axis of the radar beam (which defines the course to the target), the error voltages get smaller, and become zero when the missile flies along the nutation axis.

Before proceeding further, let's stop to define "nutation axis," mentioned above. Nutation is difficult to describe in words but easy to demonstrate. Hold a pencil in both hands; while holding the eraser end as still as possible, swing the point through a circle. This motion



33.113

Figure 4-3. — Nutating lobe of radar beam, conical scanning

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of the pencil is nutation. The pencil point corresponds to the open or transmitting end of the radar waveguide antenna. The radar beam moves in a similar manner when scanning, moving in a conical pattern without changing the vertical or horizontal orientation. Figure 4-3 illustrates a conical scanning pattern and the axis of scan. When a conically scanned radar beam is used for missile guidance, the desired path of the missile is not along the axis of the beam but along the axis of scan.

In the operation of most homing missiles, error signals are produced by measuring the position of the target with respect to the line of sight of a gyro stabilized radar antenna called the seeker head. It is located in the nose of the missile and points at the target. A line drawn through the fore-and-aft axis of the antenna to the target describes the desired course for the missile. Any deviations of the missile that throw the antenna off course result in guidance signals which are sent to the control system. The control system reacts by correcting the missile heading, and the error signals progressively decrease and approach zero as the missile comes on course. Thus, in either beam riding or homing systems, feedback action is a fundamental process of guidance, and consists of altering the position of the airframe. Thus the missile acts like a position servo as it responds to guidance signals. 14W

Stabilization Feedback Loop

The stabilization feedback loop shown in figure 4-2 indicates in a general way the basic method used in most missile control systems for stabilizing the missile. The stabilization loop is completed by the inputs and outputs of DAMPING devices, which in most systems are rate gyros and accelerometers. The input to each of these instruments is some motion of the missile. The rate gyros measure angular velocity about a missile axis and the accelerometers measure the linear acceleration along an axis. Thus the control system receives stabilization signals that are proportional to the particular component of motion to which a damping instrument is sensitive.

The damping voltages are applied to the input of the summing circuits in the computer Another input to the summing network is the guidance signals. The two sets of signals art added in the summing network and product control signals which ultimately keep the missile on course and in the proper flight attitude. The general effects of damping are:

1. To oppose any tendency of the missile to move from the desired course or heading once it is established.
2. To prevent or minimize overshooting and oscillation when the missile is maneuvering in response to guidance command signals.

The stabilization loop in a missile does the same thing for it as the stabilization loop in the launcher power drive does for a launcher. In both applications the stabilizing loop prevents overshooting and hunting about the desired position.

In chapter 7 of this book we will cover the fundamental principles of servo operation in detail. What you learn there about controlling the position and movements of launching system equipment can be applied directly to automatic control of missiles. We suggest that after you read chapter 7, you return to this chapter and reread it. Then you will see for yourself that there are many parallels between the two applied fields of servomechanism theory. For example, launcher power drive servos use tachometer generators to measure the angular velocity of a launcher. The output of the generator is a voltage proportional to the angular velocity (rate) of the launcher. This voltage is sent to a servoamplifier to aid in stabilizing the launcher. Missiles use a similar technique. But in a missile, a rate gyro is used instead of a tachometer generator. The gyro measures the missile's angular velocity about a particular axis (yaw, pitch, or roll). The output of the gyro is a voltage that is proportional to missile angular velocity (rate) about an axis. This rate voltage is sent to a servoamplifier to help stabilize the missile motion about the selected axis. You will a find other parallels after you study chapters 7 and 8, and read a missile OP.

COMPONENTS AND INSTRUMENTS

In the last few pages several components of guidance and control systems have been mentioned without explanation of what the) are, or how they operate. The following pages will contain these explanations.

Earlier, we talked about the overall operation of the guidance and control system of a missile. For convenience and standardization, we divided the system into two parts: the guidance system and the control system. We indicated the general function of each major system so that its operation

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could be understood in relation to the operation of the overall system as a whole. With this background, we are ready to take up some of the particular instruments and electronic components in guidance and control systems.

Gyroscopes

One of the most important instruments in a missile control system is the gyroscope, or gyro for short. Any spinning object - a top, a wheel, a planet, or a spinning projectile - is fundamentally a gyro. But strictly speaking, a gyro may be defined as a mechanical device containing a spinning mass mounted in such a manner as to have either one or two degrees (directions) or freedom.

A gyro that has two degrees of freedom is sometimes called a universally mounted gyro or a free gyro. In a free gyro the rotor is mounted in gimbals so that it can assume any position. Notice in figure 4-4A which shows a drawing of a free gyro, that the rotor can turn about axes Y or Z, or you can say the rotor has two degrees of freedom. Figure 4-4B shows a rate gyro, also called a single degree of freedom gyro. Its rotor can move about only one axis. Incidentally, when you are counting degrees of freedom of a gyro rotor you never count the freedom of a rotor to move about its axis.

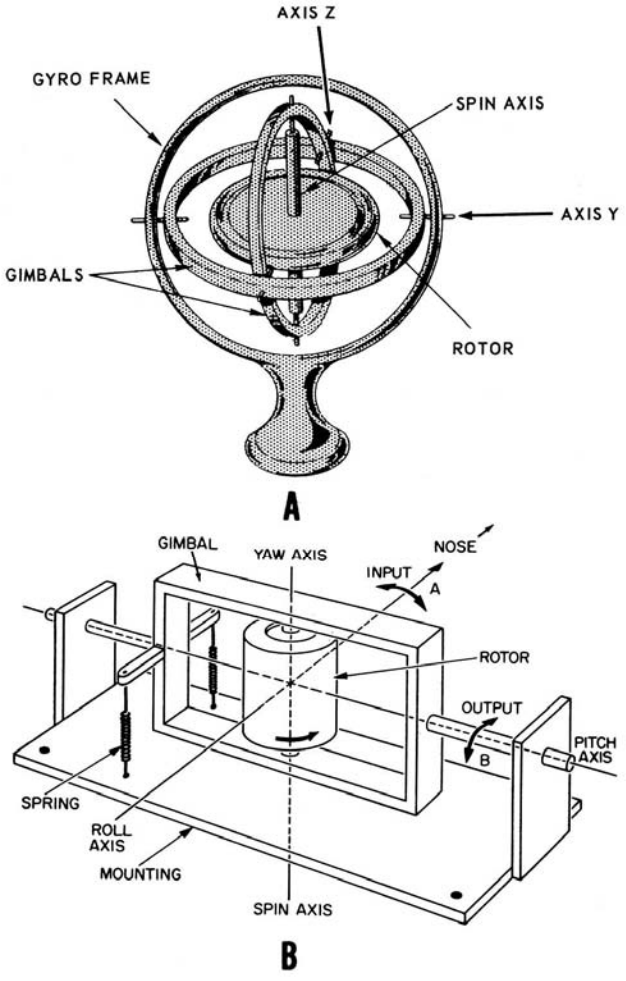
The two characteristics of gyros that are most useful in missile control systems are:

1. The gyro rotor tends to remain fixed in space, if no force is applied to it. For example, if you started the rotor of a free gyro spinning, and pointed the gyro rotor spin axis at a star, the spin axis would remain pointed in that direction unless some force moved it off.

2. The spin axis has a tendency to turn at a right angle to the direction of an applied force.

The idea of maintaining a fixed plane in space is easy to show. When any object is spinning rapidly, it tends to keep its axis pointed in the same direction. A toy top is a good example. As long as it is spinning fast, it stays balanced on its point. It resists the tendency of gravity to change the direction of its spin axis.

The resistance of the gyro against any force which tends to displace the rotor from its plane of rotation is called rigidity in space.



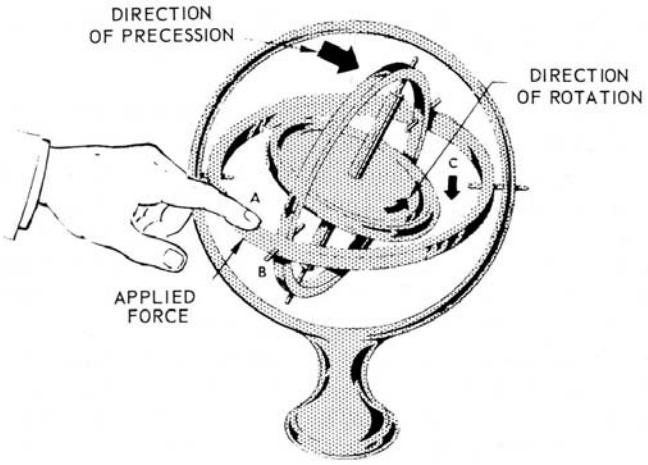
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Figure 4-4. — Gyroscopes: A. Free gyro has two degrees of freedom; B. A rate gyro has one degree of freedom.

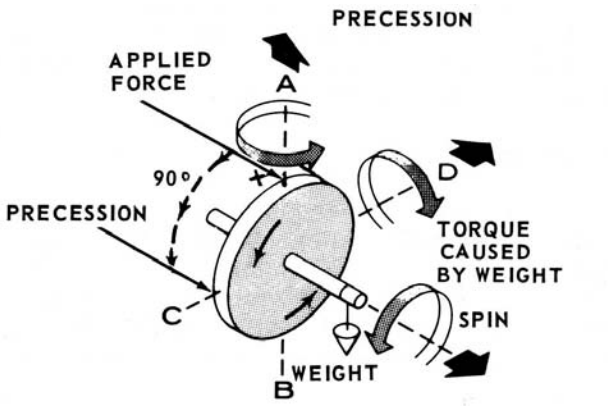
Precession

As previously mentioned, the second property of the gyro is that its spin axis has a tendency to turn at a right angle to the direction of a force applied to it. Take a look at figure 4-5. When a downward force is applied at point A, the force is transferred through pivot B. This force causes downward movement at C. This movement at a right angle to the direction of the applied force is called precession. The force associated with this movement (also at right angles to the direction of the applied force) is called the force of precession. Other spinning objects, such as a spinning projectile, show the same tendency to deviate from the direction of the force applied.

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33.64
Figure 4-5. — Precessing a gyro.



33.65
Figure 4-6. — Direction of gyroscopic precession.

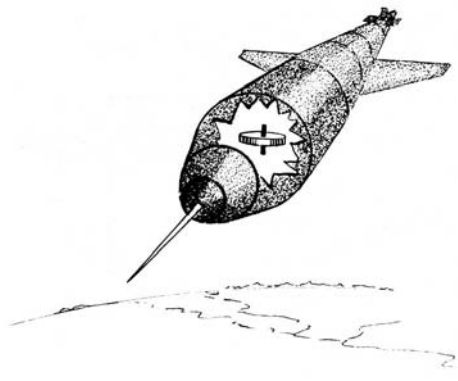
The earth precesses as it spins on its axis. A spinning bicycle wheel acts as a gyroscope and so do airplane propellers. You can probably think of other examples.

DIRECTION OF GYROSCOPIC PRECESSION. - Let us now see how we can determine the direction of precession caused by the application of a force tending to turn the rotor out of its plane of rotation. In figure 4-6, a weight is attached to the spin axis. This is in effect the same as applying a force at point X. The resulting torque tends to turn the rotor around axis CD. But due to the property of precession, the applied force will be transferred 90° in the direction of rotor spin, causing the rotor to precess around axis AB.

Free Gyros In Guided Missiles

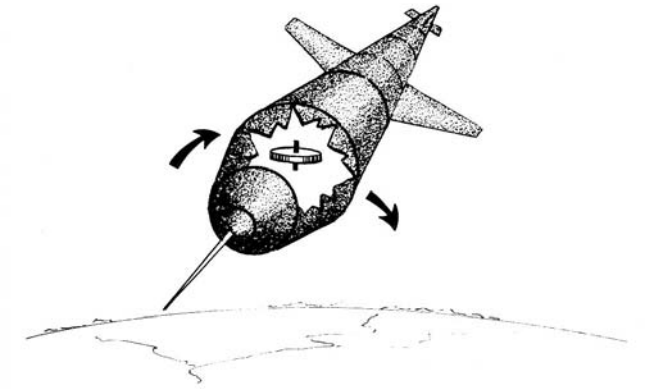
To illustrate how free gyros are used in detecting missile attitude, let us first refer to figure 4-7. Suppose that the design attitude of the missile is horizontal as shown in the figure The gyro within the missile has its spin axis in the vertical plane, and is mounted in gimbals in such a manner that a deviation in the horizontal attitude of the missile would not physically affect the gyro. In other words, the missile body can roll around the gyro and the gyro will still maintain its same position in space. Figure 4-8 shows this occurrence. Note that the missile has rolled approximately 30°, but the gyro has remained stable in space. If we could measure the angle between the rotor and a point on the missile body we would know exactly how far the missile deviated from the horizontal attitude Having determined this, the control surface could then be positioned to return the missile to the horizontal.

Actually, a minimum of two free gyros s required to keep track of pitch, roll, and yaw. The vertical gyro just described can also be used to detect missile pitch as shown in figure 4-9. To detect yaw, a second gyro is used with its spin axis in the horizontal plane and its rotor in the vertical plane. Yaw will then be detected as shown in figure 4-10.



33.67
Figure 4-7. — Missile horizontal — gyro remains fixed in space.

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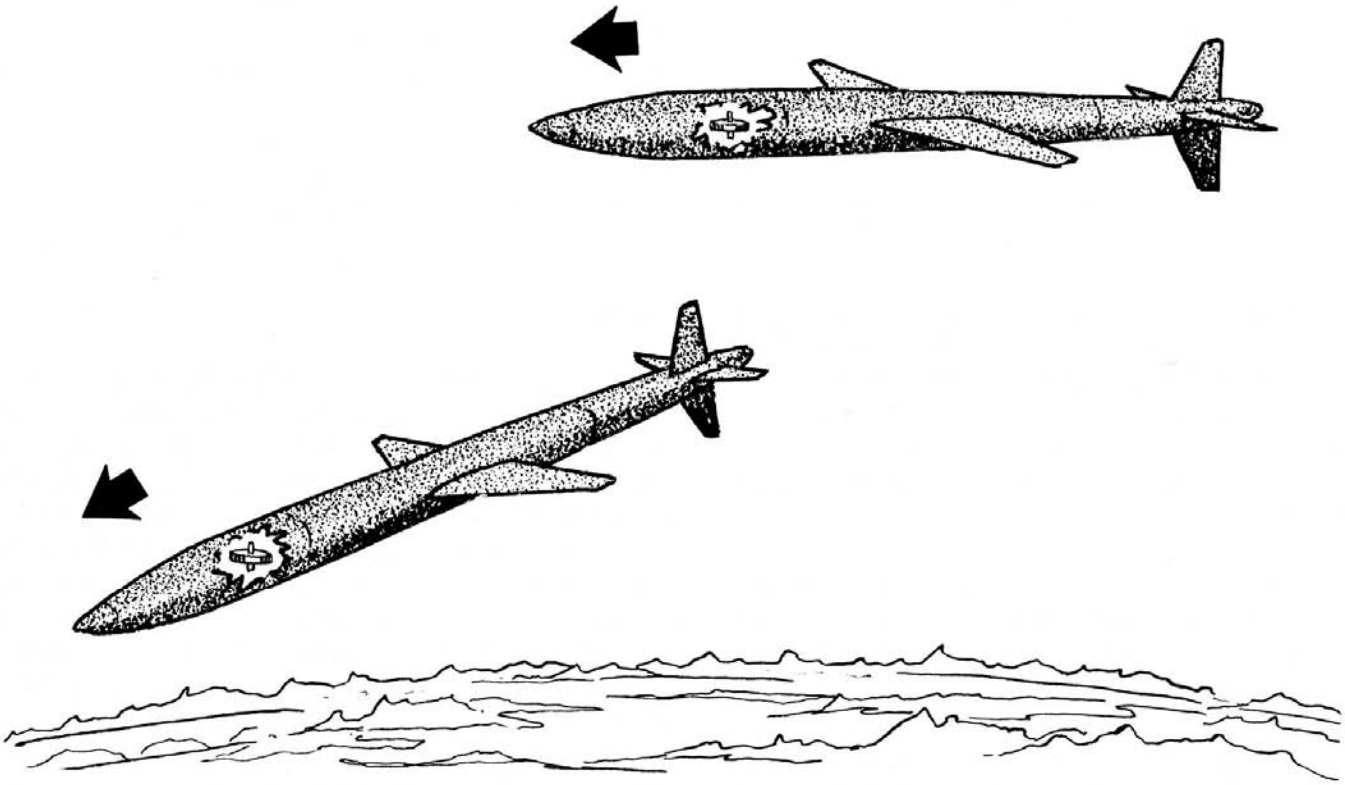
33.68

Figure 4-8. — Missile rolls — gyro stays fixed in space.

Rate Gyros

The free gyros just described provide a means of measuring the amount of roll, pitch, and yaw. The free gyros therefore can be used to develop signals, which are proportional to the amount of roll, pitch, and yaw. Due to the momentum of a missile in responding to free gyro signals, large overcorrections would result unless there were some means of determining how fast the angular movement is occurring. For example, suppose that a correction signal is generated which is proportional to an error of 10° to the left of the proper heading. The control surfaces are automatically positioned to bring the missile to the right. The missile responds by coming right. But because of its momentum it will pass the correct heading and introduce an error to the right. To provide correction signals that take momentum of the missile into account, rate gyros are used. These gyros continuously determine angular accelerations about the missile axes. By combining free gyro signals with rate signals from the rate gyros, the tendency to overcorrect is minimized and a better degree of stability is obtained. The rate gyro actually provides a refinement or damping effect to the correcting process. Without rate gyros, a missile would over-correct constantly.

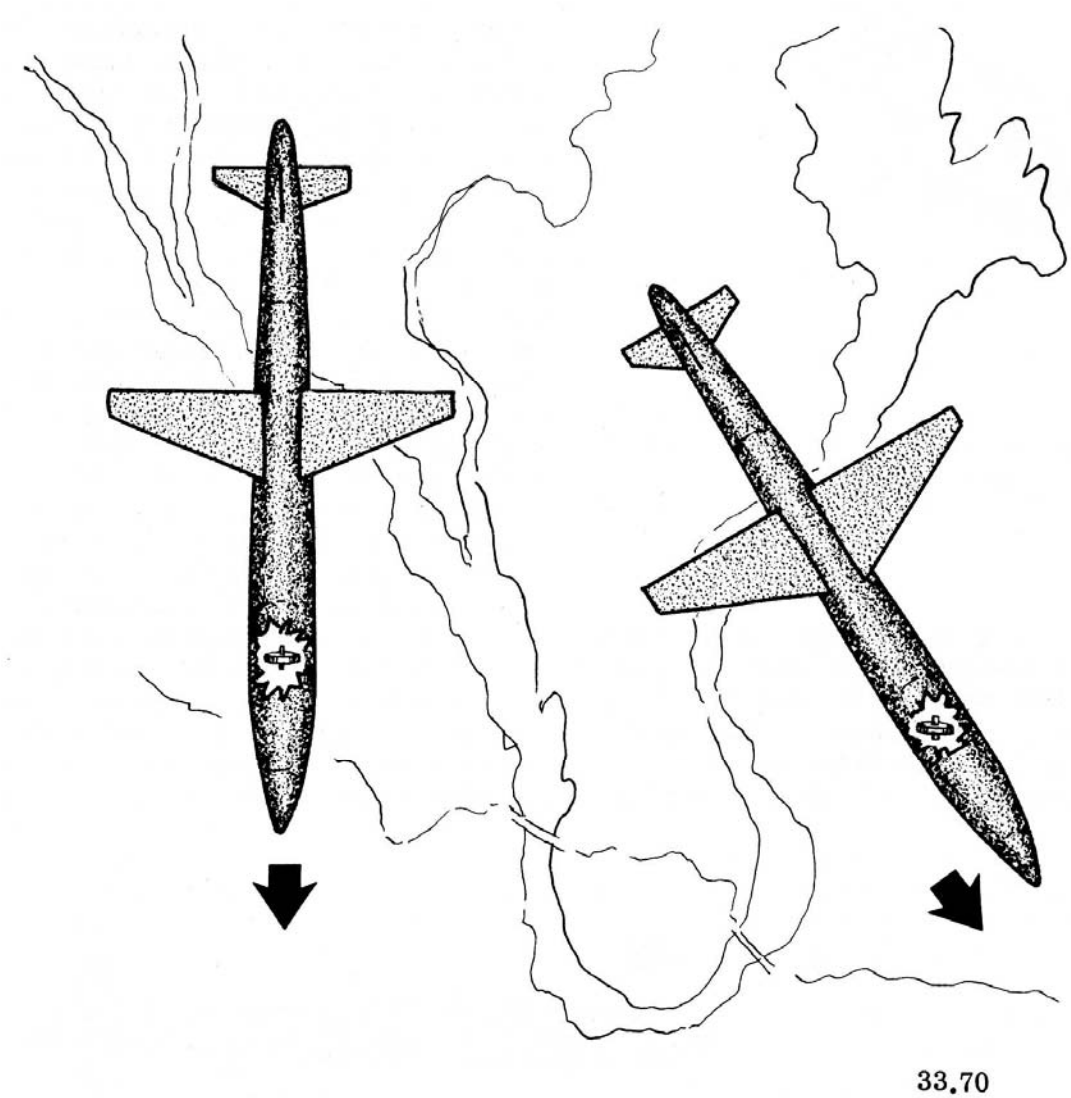
The basic difference between the free gyro and the rate gyro is in the way they are mounted. Figure 4-4 shows a simplified view of a roll rate gyro. Notice that the rotor is mounted in single gimbals rather than the two sets of gimbals which supported the free gyro. This



33.69

Figure 4-9. — Missile pitches — gyro stays fixed in space.

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33.70

Figure 4-10.—Missile yaws—gyro remains fixed in space.

arrangement restricts the freedom of the gyro rotor. When the missile rolls, the gyro mounting turns about the roll axis (arrow A) carrying the gyro rotor with it. This causes a force of precession at a right angle to the roll axis, which causes the rotor to turn about the pitch axis (arrow B).

Restraining springs may be attached to the gimbals as shown. The force on the springs would then be proportional to angular acceleration about the roll axis.

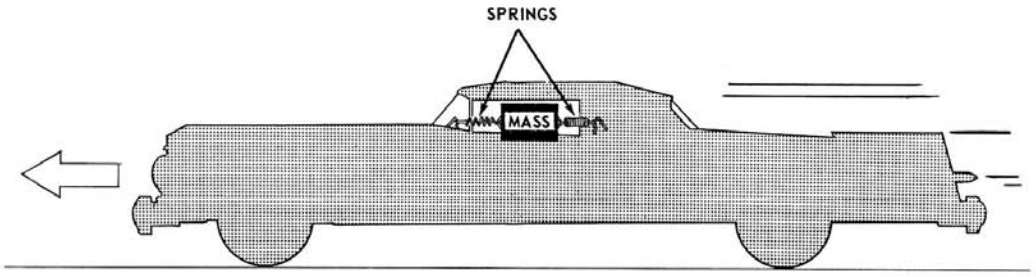
Three rate gyros are normally installed in a missile to measure the accelerations about the three mutually perpendicular missile axes (fig. 3-3A).

Accelerometers

An accelerometer is an inertia device. A simple illustration of the principles involved in accelerometer operation is the action of the human body in an automobile. You know that if an automobile is subjected to acceleration in a forward direction you are forced back in the seat. If the auto comes to a sudden stop, you are thrown forward. When the auto goes into a turn you tend to be forced away from the direction of the turn-that is, if the auto turns left, you are forced to the right, and vice versa.

In figure 4-11 we replace the human in an auto with a mass suspended in an elastic mounting system. Any accelerations of the auto will cause movements of the mass relative to the car.

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33.130

Figure 4-11. — Spring-suspended mass reacts to acceleration of car, proportional to the force and opposite in direction.

The amount of displacement will be proportional to the force causing the acceleration. The direction in which the mass moves in relation to the auto will be opposite to the direction of the acceleration.

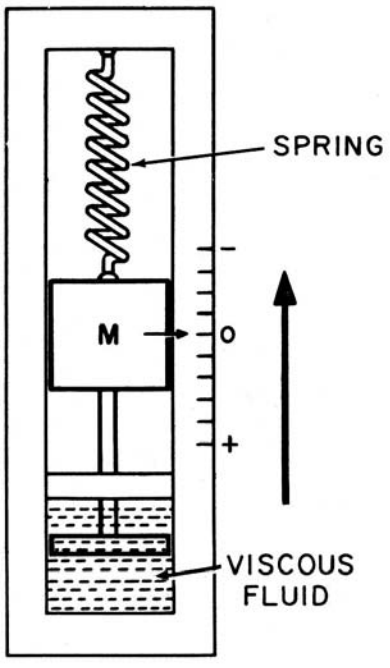
The movement of the mass is in accordance with Newton's second law of motion which states that when a body is acted on by a force, its resulting acceleration is proportional to the force and inversely proportional to the mass of the body. In mathematical terms this may be expressed as a = F/M, or by transposition F = Ma, where F equals force, M equals mass, and a equals acceleration.

When the auto in figure 4-11 is standing still, the mass will be at its rest point. When the car starts off in the forward direction the mass will lag in proportion to the acceleration force. It will also tend to oscillate about its rest point due to the spring tension. If permitted to oscillate, the movement of the mass would not represent the true accelerations of the auto. To eliminate the unwanted oscillations, a damper is included in the accelerometer unit. The damping effect should be just great enough to prevent any oscillations from occurring but still permit a significant displacement of the mass. When this condition exists, the movement of the mass will be exactly proportional to the accelerations of the auto.

Figure 4-12 shows a mass suspended by one spring in a liquid-damping system. If the case experiences an acceleration in the direction indicated by the arrow, the spring will offer a restraining force proportional to the downward displacement of the mass. The viscous fluid tends to oppose the movement of the mass, and therefore damps its action and prevents its oscillation. By including an electrical pickoff in the system, we can measure the displacement of the mass which is proportional to force and acceleration.

SENSORS AND PICKOFFS

Most guided missiles contain a variety of sensors. A sensor is a device which can detect energy. There are many sensors found in nature. The ear is a sensor which detects sound energy. The eye detects the presence of light energy.



33.131

Figure 4-12. — Liquid-damping system.

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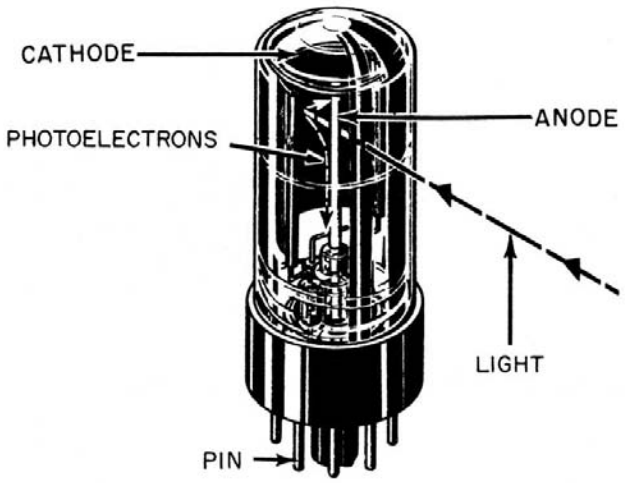
In addition to the sensors found in nature, man has been able to devise a large number of energy detectors which have industrial and military applications.

Types of Sensors in Missiles

A simple example of a man-made sensor is the photoelectric cell in a light meter. The photoelectric cell can detect the presence of light in much the same manner as the eye. Various types of photoelectric cells are used for different purposes. Figure 4-13 shows a vacuum-type photoelectric cell. When no light enters the tube, no electrons are released and none move from cathode to anode. When light enters the cell, electrons are released and can move to the anode and cause current to flow in the circuit. The small current from the photocell can be amplified so it can operate a relay and open or close a switch. This is popularly called an electric eye and has countless uses in industry. An electrical pickoff attached to the photocell can detect the direction of the light source. Many different types of light cells are made for different purposes, but all are dependent on light and therefore are ineffective when the light is obscured or absent.

Another simple example of a sensor is the aneroid barometer which detects atmospheric pressure. Devices which can sense radiated heat energy (all objects on earth radiate some heat energy in the form of electromagnetic waves) are infrared (heat) sensors. Radio receivers, although not commonly thought of as sensors, actually perform the same basic function as a sensor that is, they detect energy. Radar sensors have been developed since World War II.

Energy detection in itself is of no practical value. For a control system - whether it be associated with the human body or a guided missile - to respond to detected energy, there must be some type of mechanism associated with the sensor which will convert its intelligence into usable form. In the case of the vibrating eardrum, a nerve must be connected between it and the brain if the brain is to respond to noise. In response to the mechanical vibrations of the eardrum, the nerve produces signals which are transmitted to the brain. Without the nerve, the eardrum could vibrate continuously, yet no indication of sound would reach the brain. The same is true of the photoelectric cell (or the eye) which generates an electric current proportional to the intensity of light. Unless the electric current produces a meaningful effect, the cell has no useful application.



33.89

Figure 4-13. — Photoelectric cell.

In most light meters the current is accepted by an electrical circuit and then converted to mechanical motion of an indicating needle. In the aneroid barometer, mechanical motion may be transmitted through a mechanical linkage to an indicator, or an electrical device may be associated with the bellows to cause indicator movement.

The devices which receive energy from sensors and transmit this energy-either in the same form or another form - to a point where it is put into practical use are generally referred to as pickoffs. In the case of the ear, the nerve was the pickoff. An electrical circuit acted as the pickoff in the light meter. An electrical circuit or mechanical linkage served as the pickoff in the barometer.

Pickoffs Used In Missiles

Most of the pickoffs used in guided missiles are electrical devices. In addition to transmitting energy from sensors, they are also used to measure outputs of physical references such as gyros. In this second respect, the pickoffs themselves act as sensors. (The gyro rotor in itself cannot determine missile attitude information. For this reason the gyro has been classed as a physical reference rather than a sensor.) Pickoffs must be used in conjunction with free and rate gyros to determine missile attitude and motion information.

Electrical pickoffs are extremely sensitive and reflect little torque back to the sensor or reference unit. It is primarily these qualities

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which make them useful in guided missiles. The most common types of electrical pickoffs are:

1. Potentiometer pickoffs
2. Synchro pickoffs

Potentiometers and synchros are covered in chapter 7 of this course. Also, the fundamental types of synchro units and their basic principles of operation are discussed in Basic Electricity, NavPers 10086-B so we won't cover these units here.

MISSILE GUIDANCE PHASES

Missile guidance is generally divided into three phases - boost, midcourse, and terminal. Figure 4-14 illustrates these three phases of guidance for Tartar, Terrier, and Talos (the three T's) missiles.

As you learned in the preceding chapter, Navy surface-to-air missiles are boosted to flight speed. This boosted period lasts from the time a missile leaves the launcher until the booster burns up its fuel. In the case of missiles with separate boosters, the booster drops away from the missile at burnout.

Boost is a very important phase of a missile's flight. The missile must get off to a good start or it will not hit its target. Before launch the missile is aimed in a specific direction on orders from afire control computer. Movement of the launcher in response to the computer orders establishes a line of flight (called a trajectory or a flight path) along which the missile must fly during the boosted portion of its flight. The flight path extends from the launcher to a point in space. And at the end of its boost period the missile should be at this point.

There are several reasons why this is important. First, if the missile is a homing missile, it must "look" in a predetermined direction for the target. The fire control computer calculates this predicted target position, based on where the missile should be at the end of boost phase. Before launch, this information is fed into the missile.

Finally, when a beam-riding missile reaches the end of its boosted period, it must be in a position where it can be captured by a radar guidance beam. Therefore, it is absolutely necessary that all missiles fly along the prescribed launching trajectory as accurately as possible. If they don't, then a homing missile will not see its target, nor will a beam rider be captured by its guidance beam (fig. 2-17). To assure that missiles will fly along the launching trajectory, special guidance systems are added to them, as in the Tartar and Talos. Or, like Terrier, each missile is made with such built-in stability that it can fly as straight as an arrow. But regardless of which technique is used, the boost phase guidance system keeps the missile heading exactly as it was at launch.

The MIDCOURSE phase begins where the boost phase ends, and ends where the terminal or last phase begins. It is during the midcourse phase that most of the major corrections to the missile's flight path are made.

The TERMINAL phase occurs as the missile approaches the target. This phase requires very high accuracy from the guidance system since the missile may have to make sharp turns and undergo high accelerations, especially against fast-moving and maneuvering targets.

In some missiles a single guidance system may be used for all three guidance phases. Other missiles may have a different guidance system for each phase, and this is usually the case with Navy surface-to-air missile systems.

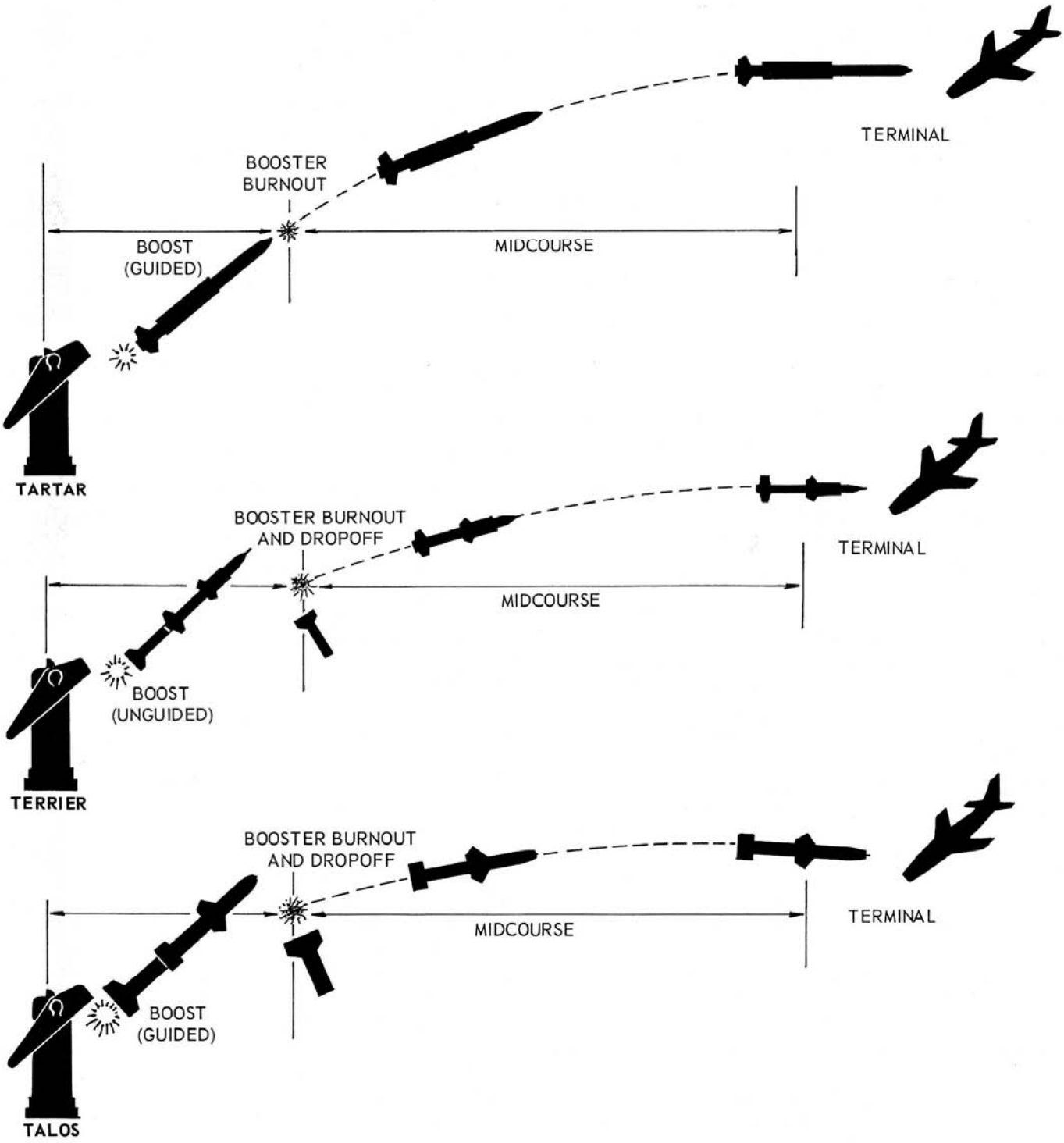
TYPES OF GUIDANCE SYSTEMS

So far, we have looked at missile guidance and control from the missile's viewpoint. Now let's consider the overall guidance and control picture in terms of shipboard and missile guidance systems. Guidance systems for missiles launched from ships can be divided into four groups: (1) self-contained, (2) command, (3) beam-rider, and (4) homing. No one system is best suited for all phases of guidance. It is logical then to combine a system that is excellent for midcourse guidance with one that is excellent for terminal guidance. Combined systems are known as composite guidance systems or combination systems. A particular combination of command guidance and semiactive homing guidance is called hybrid guidance. When a missile changes from one type of guidance to another while in flight, it must also contain some type of switching device to make the change. This device is called a control matrix, a highly sophisticated equipment found in modern missiles.

Self-Contained Guidance Systems

The self-contained group consists of the guidance systems in which all the guidance and control equipment is inside the missile. Some of the systems of this type are: PRESET, TERRESTRIAL, INERTIAL, and CELESTIAL-NAVIGATION. These systems are most commonly

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Figure 4-14.—Guidance phases of flight for the 3 T's.

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applicable to surface-to-surface missiles, and countermeasures are ineffective against them. Such systems neither transmit nor receive signals that can be jammed.

PRESET GUIDANCE. - The term "preset" completely describes this guidance method. All the control equipment is inside the missile, and all the information relative to the target location and the trajectory the missile must follow are calculated and set into the missile before it is launched. One disadvantage is that the trajectory cannot be changed once the missile is launched. For this reason it is used against stationary targets and large land masses; it cannot be used against a moving target. It is a relatively simple type of guidance system. The German V-2 is an early example of a guided missile with preset guidance. A completely preset system probably will not be used in missiles of the future, but some features of the preset system will be combined with other systems.

INERTIAL GUIDANCE. - The inertial guidance method is used for the same purpose as the preset method and is actually a refinement of the preset method. The inertially guided missile also receives programmed information prior to launch, Although there is no electromagnetic contact between the launching site and the missile after launch, the missile is able to make corrections to its flight path with amazing precision. The method of controlling the flight path is based on the use of accelerometers which are mounted on a gyro-stabilized platform. An accelerometer is an inertia device. (Inertial guidance gets its name from this property of matter.) A simple illustration of the principle involved in accelerometer operation is the human body in an automobile. If the automobile is subjected to sudden acceleration, the body is forced back into the seat, and it does the same thing for the missile. All in-flight accelerations are continuously measured by this arrangement; and the missile generates corresponding correction signals to maintain the proper trajectory. The use of inertial guidance takes much of the guess work out of long-range missile delivery. The unpredictable outside forces working on the missile are continuously sensed by the accelerometers. The generated solution enables the missile to continuously correct its flight path. The inertial guidance method has proved far more reliable than other long-range guidance method developed to date.

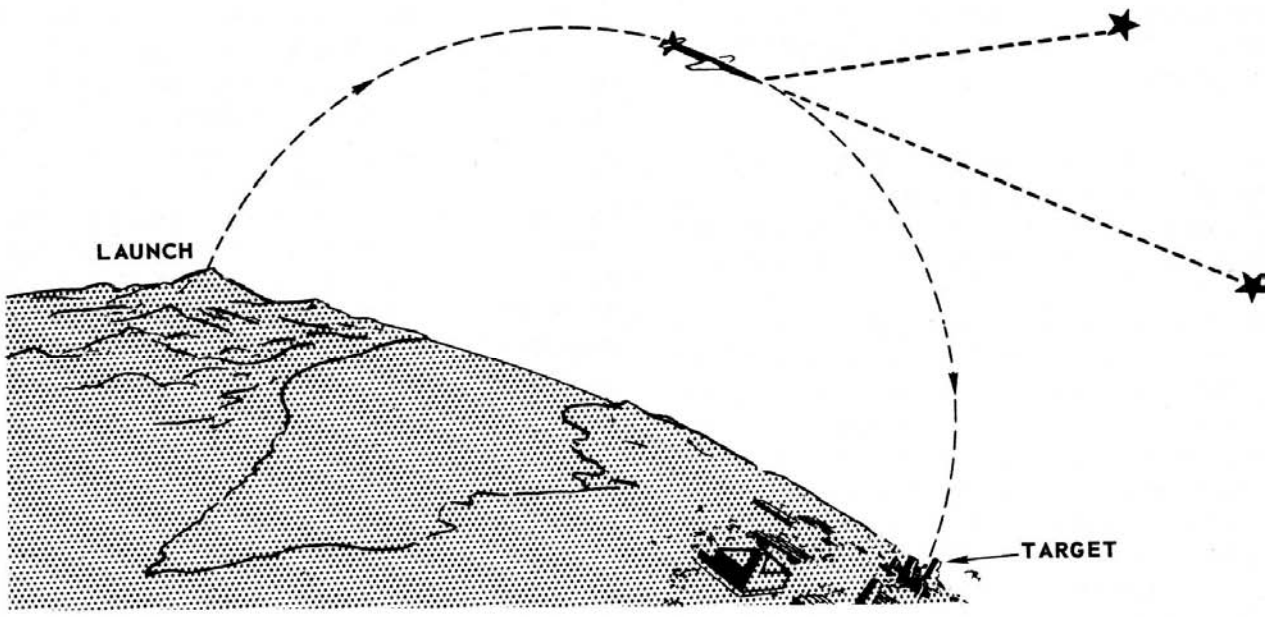
CELESTIAL-INERTIAL SYSTEM. - Navigation by the stars has been used for many centuries. The navigator measures the angular elevation of two or more known stars or planets, using a sextant. From these measurements, the ship's position can be plotted. The adaptation for missiles uses an inertial system that is supervised by an series of fixes on celestial bodies (fig. 4-15). Since a missile does not carry a human navigator, checking of the position must be done by a mechanical substitute. One of the systems is known as Stellar Supervised Inertial Autonavigator; another is called Automatic Celestial Navigation.

TERRESTRIAL GUIDANCE METHOD.- Several picture and mapmatching guidance systems have been suggested and tried. Terrestrial reference navigation relies on comparisons of photos or maps carried in the missile with an image of the terrain over which the missile is flying at that time. The basic idea can be shown by using the common photograph as an example. If a photographic negative is placed over its coinciding, positive, the entire area will be black. If the positive were a transparency, the entire area would be opaque and no light would get through. If either the negative or positive is moved slightly with respect to the other, light will show through where the prints are not matched. This is the theory on which a radar-mapmatching system works. Instead of a transparency for the positive image, the projected image of the terrain from a lens or a radarscope is used. Such a system is usable only against large land targets. Since landscape features can change over a period of time (buildings can be demolished or whole new complexes of buildings can be erected and roads changed), the "negative" to be used for comparison by the missile radar must be a recent one.

Development of Surface-to-Air Guidance Systems

Once an inertially guided missile is launched, it loses contact with any manmade devices located on the earth. The principal link, however, between an inertially guided missile and earth is the force of gravity. But Navy surface- to-air missiles, while in flight, normally have some manmade link between them and their launching platform (ship). The link is always in the form of electromagnetic energy from a shipboard radar. Depending on the type of guidance system used, the link is either a direct one

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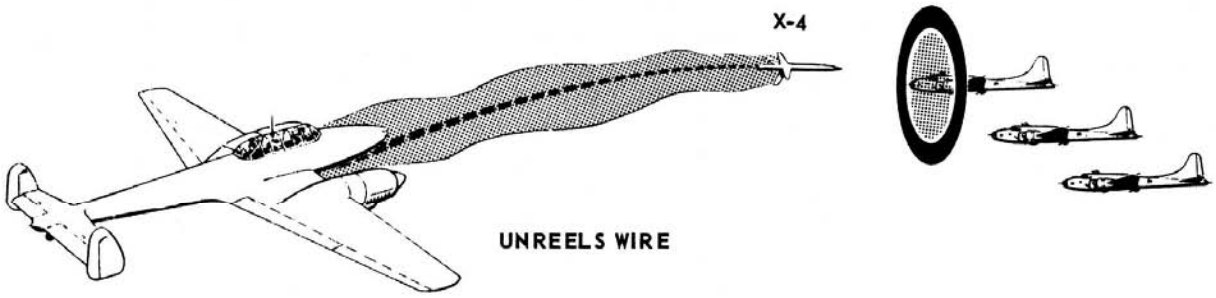
33.94
Figure 4-15.—Celestial guidance.

between the radar and missile, or it takes a roundabout path from its source to the missile. But regardless of the guidance method used, the missile and ship, under normal operating conditions, are linked by radar waves. However, under unusual circumstances such as a jamming target, the radar string between ship and missile is broken, and the missile is then linked by electromagnetic energy with the target.

When you consider the size of the earth, the distance covered by a Navy surface-to-air missile is very short. Range of the Tartar missile is in excess of 10 miles, and Talos a range in excess of 65 miles. Therefore, the targets that these missiles are used against must be kept under constant observation. Also, SAM (RIM) targets are usually moving. So, some means must be used to bring the missiles on target rapidly. Radar meets these two basic requirements perfectly. It can "see" in the dark and in bad weather, and it sends out beams of electromagnetic energy which can provide a control link between a missile and its launching platform (ship). Then, if guidance information is sent over this link, the missile can be directed onto the proper course to the target. When this guidance technique is used the missile is, in a sense, a puppet on the end of a string - an electromagnetic string. The radar tells the missile where to go and remotely controls its flight. The missile acts on this guidance information through control equipment inside the missile. The control equipment actuates the missile's wings or tails to bring the missile heading to the course prescribed by the radar. In this view of a guidance system, again notice that some of the overall guidance equipment is in the missile and some is on the ship.

The history of missile guidance systems is short. All of the significant developments are recent, principally because the state of electronics before the nineteen forties was relatively primitive. One of the first guided missiles was the German X-4. It was an air-to-air missile designed for launching from fighter aircraft as shown in figure 4-16. It was propelled by a liquid-fuel rocket, and roll-stabilized by four fins placed symmetrically. The X-4 was guided by electrical control signals sent from the launching aircraft, through a. pair of fine wires that unrolled from two coils mounted on the tips of the missile fins. The pilot observed the target, and measured its position relative to the missile. He compared their relative positions and computed the guidance commands necessary to bring the missile onto the right flight path. Then he sent these steering commands over the two wires to the missile control system which moved the control surfaces. This was a crude guidance system, but the point is that it contained all of the essential functional parts of present

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Figure 4-16.—Wire guidance.

day guidance systems - (l) units to detect the presence of targets, (2) to track them, (3) compute guidance commands, (4) direct, and (5) control missile motions. Also note especially that the link with the launching platform (plane in this case) was a pair of wires. The wire link is analogous to the radar link of today's SAM (RIM) guidance systems.

One obvious disadvantage of a wire guidance link is that it shortens the range of a missile. So the next step in the development of guidance systems was to replace the wire link with one that could be stretched.

However, wire guidance is not obsolete. The Navy has a wire-guided torpedo (Astor), and several of the newest anti-tank missiles use wire guidance. Among these are Entac, SS-10, SS-11, TOW, and MAW. Since anti-tank missiles are necessarily short-range, wire guidance is well-suited to them.

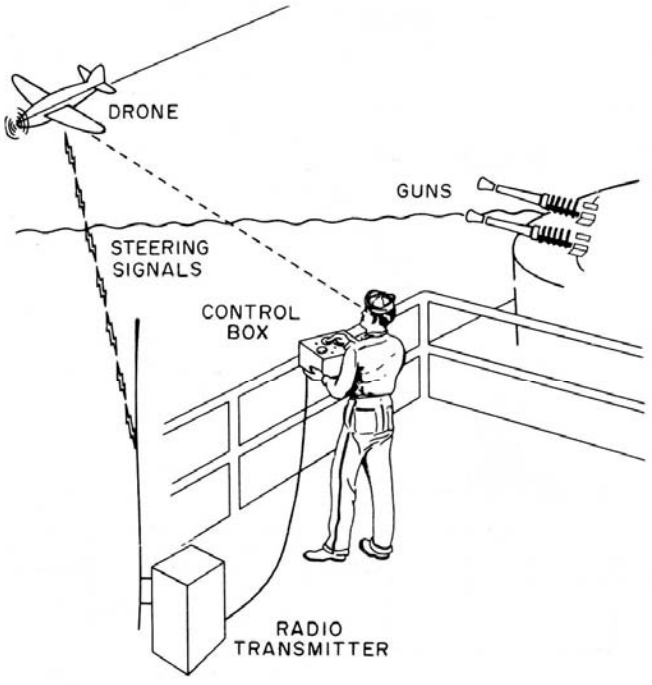
Command Guidance

The wire-link guidance system is obviously a command system, with the missile receiving commands from the ship's radar via the wires unreeled as it flies. Other command systems are by radio and radar without wire connections. A possible reason for the name of this guidance system category is that the shipboard portion of the overall guidance system sends directly to the missile specific commands such as turn right, go up, turn left, reverse throttle, and detonate warhead.

Remote Control by Radio

A guidance system based on remote control of the missile by radio was a natural step in the development of missile guidance systems. Using this technique, the control link could be stretched many miles, and any physical contact between launching platform and the missile eliminated.

A simple radio remote control system is shown in figure 4-17. In this system the operator visually observes the drone (tracking) and mentally decides the changes necessary in course, speed, and altitude (computing). Guidance commands such as up - down, right - left, and slow down - speed up are then sent to the drone by



12.31
Figure 4-17.—Drone radio control system.

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radio (directing) where a receiver in the missile picks them up. The guidance commands are then sent to the missile's flight control system to execute the desired maneuver (steering). This method was used in World War II to direct obsolete, wornout airplanes (nicknamed "Weary Willies"), loaded with explosives, to enemy targets, such as factories and bridges; then explode them. In this radio guidance system the guidance commands originate from a source outside the missile. Later on we will show how more sophisticated missiles develop their own guidance signals. But first, let's talk about a further step in the development of missile guidance systems.

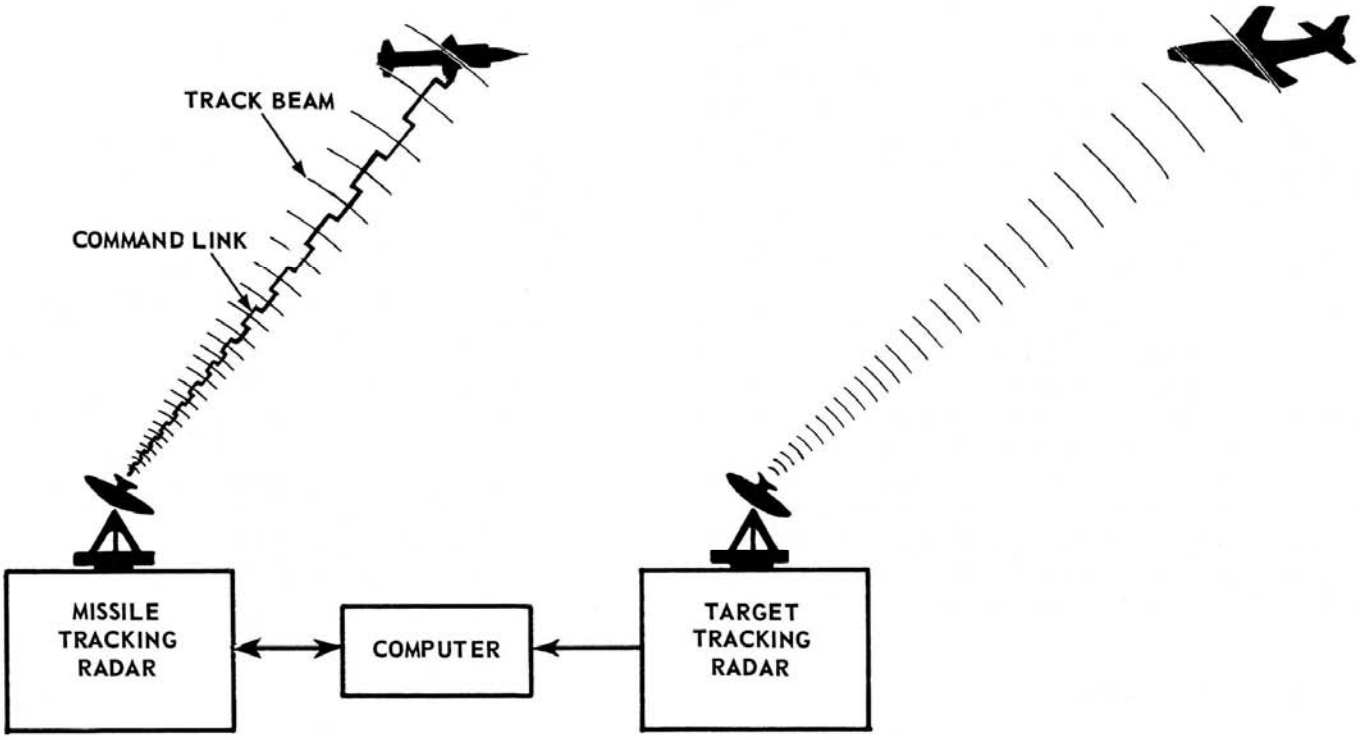
Missile Remote Control by Radar

The basic missile guidance system shown in figure 4-18 contains two radars and a computer. These three units replace the human operator we needed in the radio remote control system we talked about a moment ago. One radar tracks the target, the other tracks the missile. Both radars are located at the launching platform. And so is the computer which takes the two sets of tracking data and issues commands so that the missile will either collide with the target or pass within lethal range of it. The command signals are sent to the missile by the missile tracking radar beam. Notice that here, as in the radio remote control system, guidance signals are developed in a source outside the missile. The two systems we have just talked about come under the broad category of command guidance.

But in the systems that we will study next, only information is sent over the radar beams- not guidance signals. It is the missile's guidance system that acts on the information and develops guidance signals to direct the missile to the desired flight path.

BEAM-RIDER METHODS

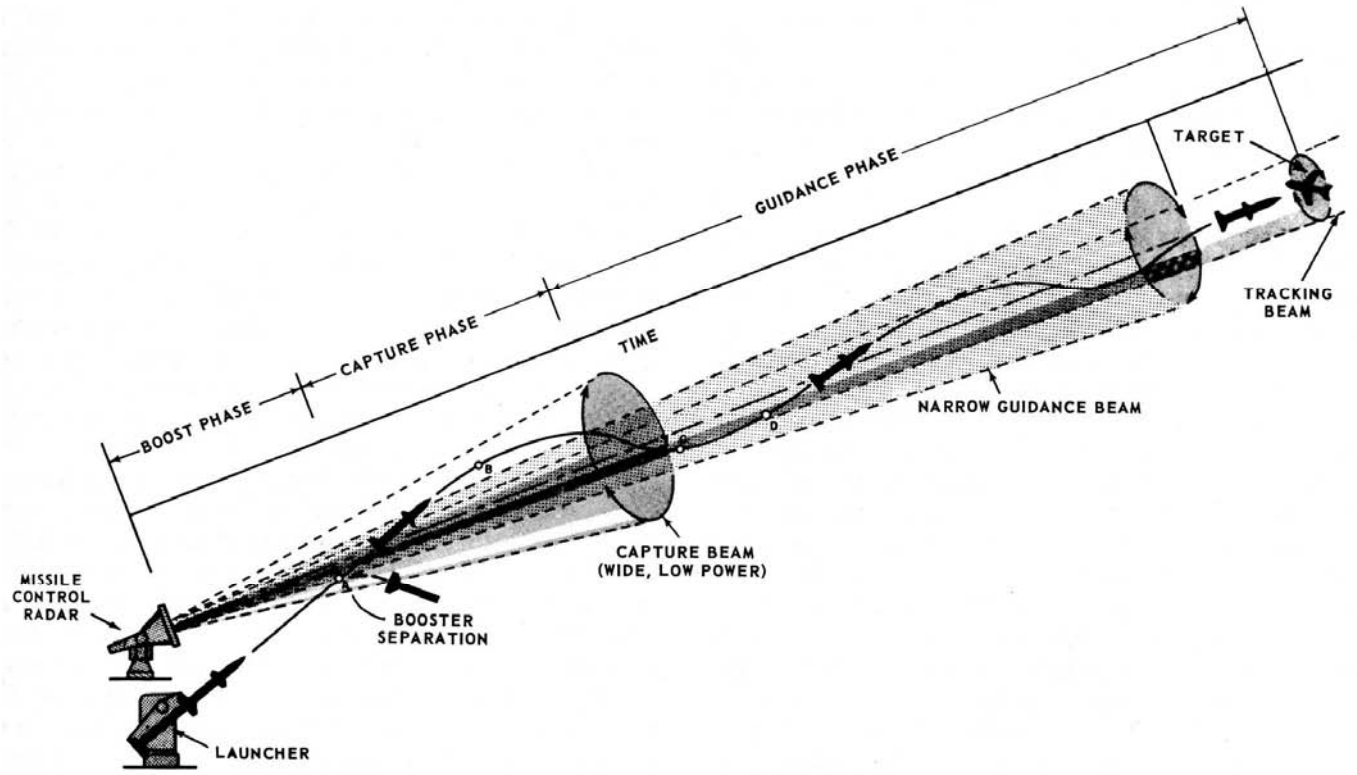
In the beam-rider guidance system, shown in figure 4-19 a device in the missile keeps it centered in the beam. (The basic principles of radar and the general characteristics of a radar beam are discussed in Basic Electronics, NavPers 10087-B.)



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Figure 4-18.—Radar command system.

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Figure 4-19.—Beam-rider guidance system.

The basic beam-rider system resembles the method for controlling rockets first proposed in 1925. At that time, it was suggested that a rocket could be made to follow a searchlight beam using a simple control system containing four light sensitive, selenium cells. The cells were to be attached to the tail assembly of the rocket in a cross-shaped arrangement. After launching, the rays of the guiding searchlight would fall equally on the four cells as long as the rocket stayed in the center of the beam.

If the rocket strayed from the desired track, the four cells would then pick up different amounts of light. Since the electrical resistance of a cell is proportional to the amount of light that falls on its sensitive surface, the unequal responses of the four units could be converted into corresponding electrical signals. The signals were to be amplified, and then sent to a control system which would turn the rudders to bring the rocket back to the center of the beam.

Missile engineers never developed this system in the form proposed. But it is nevertheless interesting and noteworthy since the modern beam-rider missile works on the same general principle. Of course, there are many refinements in the present systems. For example, instead of a light beam, the beam of a fire control radar is used for guidance.

In place of selenium cells, the missile has a radar antenna-receiver system which senses the missile direction and distance from the center of the guidance beam. The missile control system then corrects the missile's flight to place the missile in the center of the guidance beam.

So far in this book, we have assumed that there is one beam, the guidance beam. There are actually two- a capture beam and a guidance beam. (See fig. 4-19.) The capture beam is a wide-angle low power beam used during the early part of missile flight to capture the missile. The guidance beam is a very narrow, high power beam used for guidance over the major part of the missile's flight. A wide capture beam is needed because missiles with external boosters have dispersion.

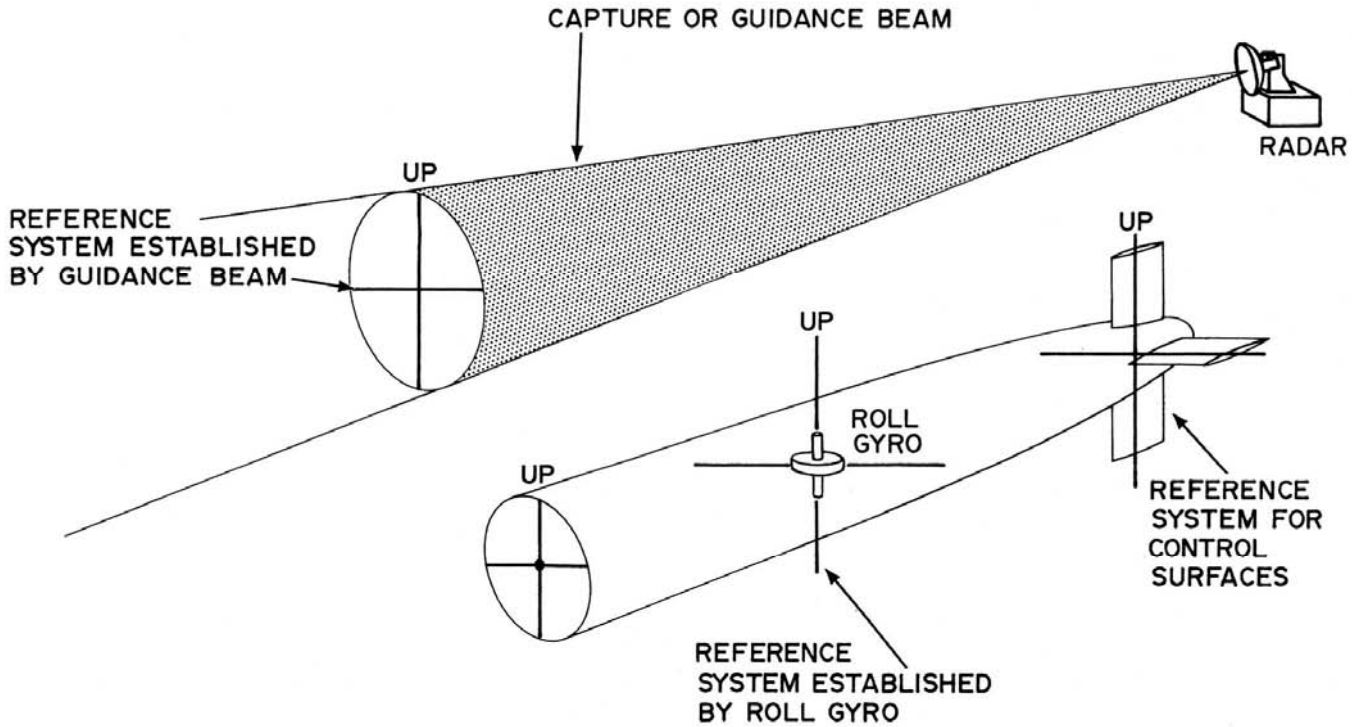
When the booster is ignited, the missile- booster combination is launched in such a direction that it will intersect the capture beam,

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as we explained in chapter 2. The booster burns out after about 4 seconds of flight, and aerodynamic drag causes it to separate from the missile.

When the booster separates, the missile should be in the capture beam. The capture and guidance beam contain the same kind of guidance information, and both nutate about the radar line of sight to the target. The guidance beams are kept on the target by the tracking radar and its associated director controls. Depending on the missile, the missile is roll stabilized somewhere between the time it is launched and after it enters the capture beam. The missile must be roll stabilized so that it can properly determine which way it must deflect the control surface in response to the guidance information in the beams. Proper operation of the missile guidance and control system depends on correct missile roll attitude relative to the guidance beams. In figure 4-20 you can see that the guidance beams contain a reference system. It is enough to say here that the beam reference is established by frequency-modulating the pulse repetition rate of the shipboard radar. What is important to you as a GMM is the roll gyro in the missile. Radar guidance information may be properly received and processed regardless of roll attitude, but when the missile makes corrections to its flight path, the control surfaces must be properly positioned in respect to the radar beam reference to turn the missile in the proper direction.

After the missile is captured (by the capture beam), it rides the capture beam for a few seconds. During this time it gets closer to the scan axis of the radar beam. Then, capture-guidance change-over takes place. This means that the radar receiver in the missile switches from the capture beam to the guidance beam, and starts receiving guidance information from it. As we said a moment ago, at capture-guidance change-over the missile should be close to the axes of the two radar beams, and the change to the guidance beam should be fairly smooth. Since the missile follows the guidance radar axis, which in turn follows the target, the missile approaches the target on an arc until intercept is attained as illustrated in figure 4-21. The missile may have to make a sharp turn to follow the radar beam to the target. This is a disadvantage of the beam-rider method, for the angle of turn may be too great for the missile to make safely.



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Figure 4-20.—Radar reference system and missile roll reference system.

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Homing Systems

The types of homing systems are active, passive, and semiactive. They may also be named according to the type of signal followed, such as infrared homing, acoustic homing, or optical homing. Still another method of naming may be according to the flight path or trajectory followed, as pursuit homing, lead homing, or zero-bearing.

Active Homing

In active homing (fig. 4-22) the missile contains both a radar transmitter and receiver. The transmitter sends out radar signals. They strike the target and are reflected. The returned echoes are picked up by the missile's antenna and passed into the receiver. Here the information locating the target with respect to the missile is extracted. The output of the receiver is guidance information; it is sent to the computer, where steering corrections are computed. The output of the computer is sent to the control section, which in turn corrects the missile flight path to cause collision of the missile and target.

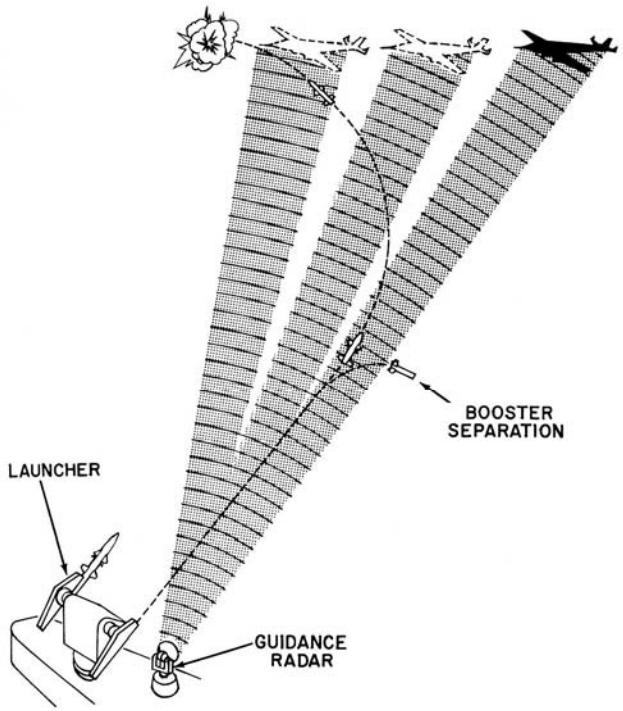


Figure 4-21.—Beam-rider track.

Passive Homing

Passive homing guidance equipment in a missile consists basically of an antenna and a receiver. The receiver-antenna combination detects the presence of a target and tracks it by sensing some type of radiation that the target emits. A passive homing system, like an active system, is completely independent of the launching ship. Unlike the active method, however, the operation of the passive homing system cannot be detected by the enemy since there is no electromagnetic radiation from the missile. A passive homing system is illustrated in figure 4-23.

Some surface-to-air missiles use passive homing when their normal guidance system is jammed. Then the target is the source of electromagnetic energy used by the passive homing system to develop guidance signals. The energy source within the target may be an electronic jammer. The jammer is used to mix up the guidance information in the radar beams that are transmitted from the launching ship's equipment.

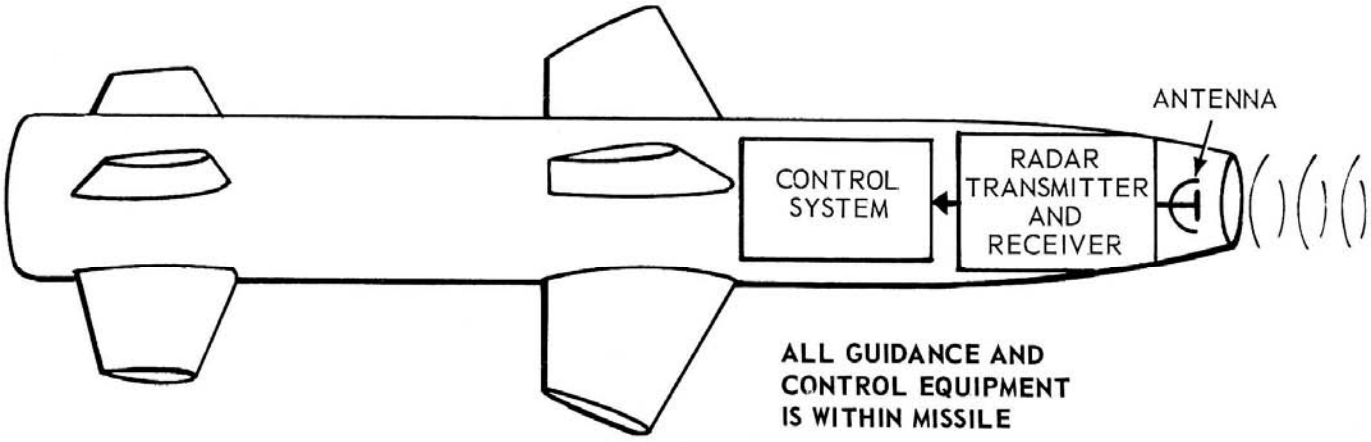
Other sources of energy located at the target are light, heat from the propulsion system, and sound, to name a few. No ship-launched surface-to-air missiles (RIMs) in current use depend on passive homing guidance all the way.

Several air-launched missiles use the homing method of guidance. The Navy's Shrike uses passive radar homing, Sidewinder used infrared homing, and Sparrow III uses semiactive continuous wave (CW) radar homing.

SEMIACTIVE LEAD HOMING GUIDANCE

A missile using semiactive homing guidance receives radar energy along an indirect path. Radar waves are sent out from a fire control radar to a target. The transmitted waves strike the target and bounce off it. Some of the reflected waves of radar energy travel toward the semiactive homing missile sent out from your ship to intercept the target. Figure 4-24 shows the paths of the homing signals. A radar receiving antenna, called the seeker, or seeker head, in the nose of the weapon picks up the reflected energy. Then the rest of the missile guidance system causes the missile to home on the target.

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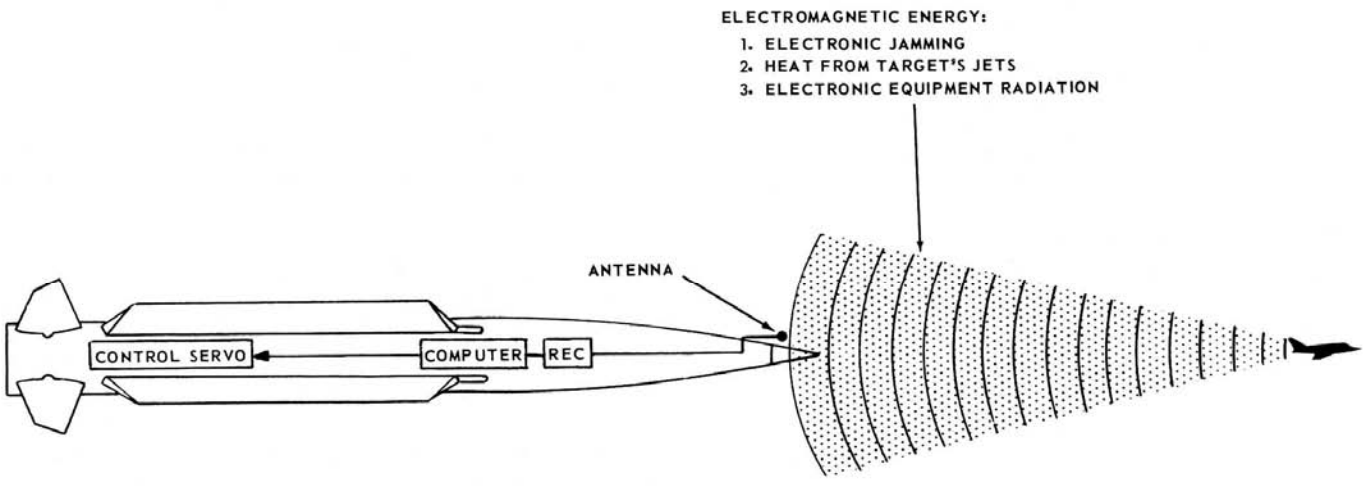


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Figure 4-22. — Active homing guidance system.

Semiactive homing is more accurate than beam-rider guidance because the closer a semiactive guidance system gets to a target the more accurate the system becomes. On the other side of the guidance coin, the beam rider becomes less accurate as it approaches the target because the guidance beam spreads out from its source. The farther the target is from the ship, the wider the beam is in the target area. Thus the beam rider missile must maneuver more to stay in the center of the beam. But the semiactive homing missile receives stronger radar echoes as it approaches the target, and gets tighter control over its movements. We're not implying that the beam rider is not effective, because it is. We just want to point out that the beam rider technique has decreased accuracy at extended range.

The radar receiver in a semi active homing missile acts similarly to the beam-rider receiver, but with one exception. Instead of receiving target position information from a beam the semi active missile receives echoes from a target. You will recall that the fire control radar determines the direction to the target for the beam rider. The semi active homer itself must determine its course to the target. Briefly, this is the way it does it. The missile's homing antenna system



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Figure 4-23. — Passive homing guidance system.

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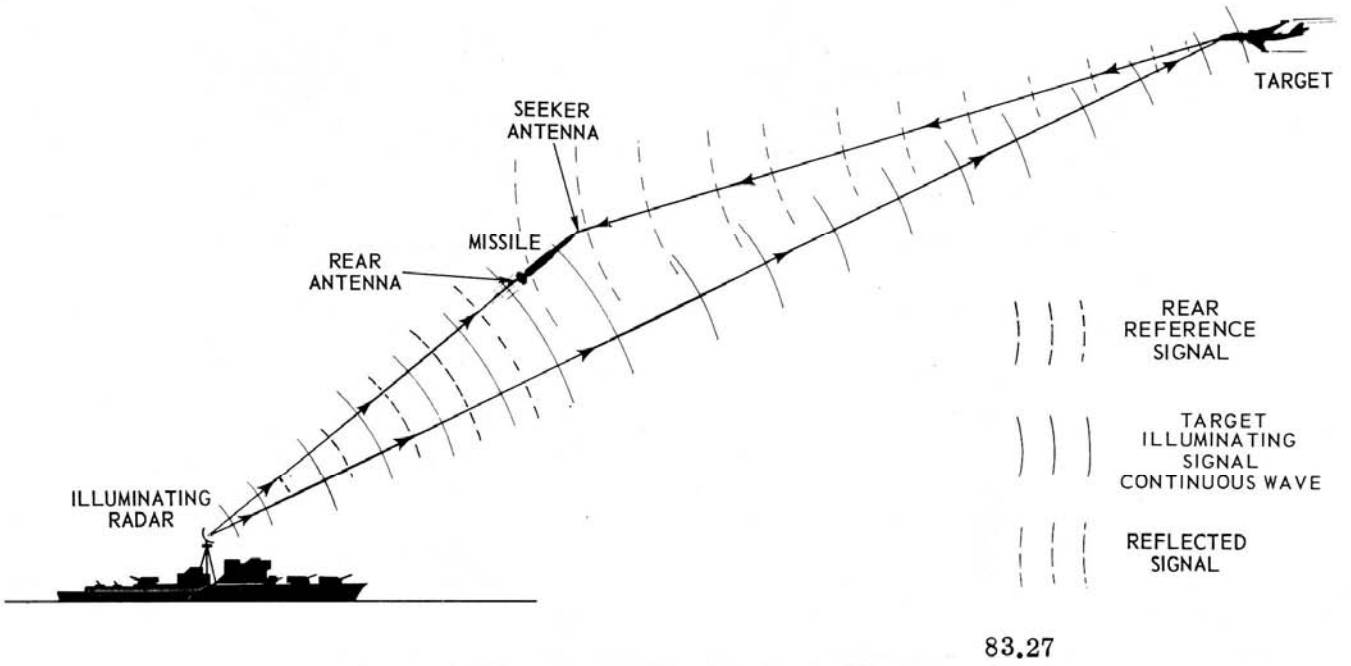


Figure 4-24.—Semiactive homing guidance system.

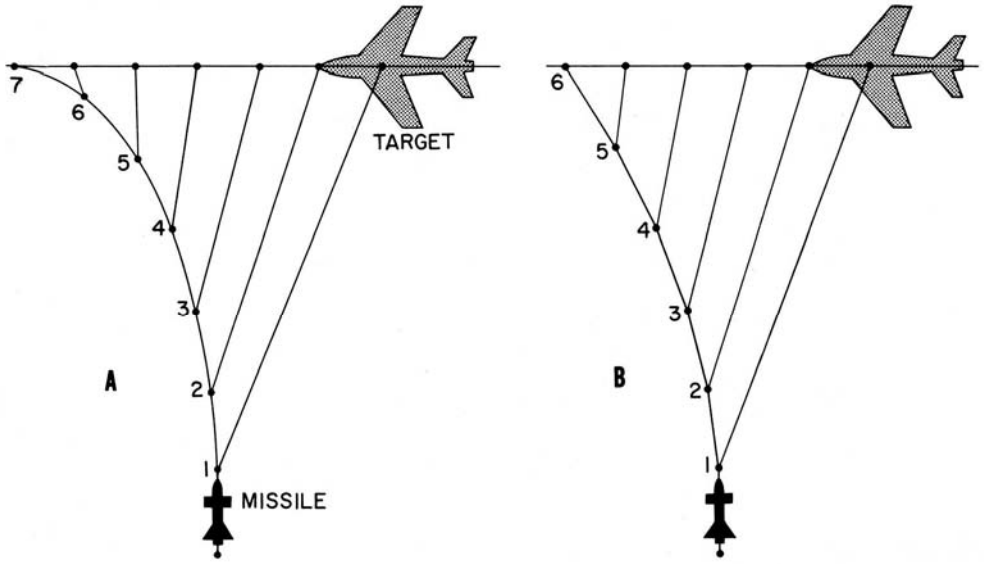
locates the target, and automatically tracks it. The tracking process established the line of sight between the missile and target. A computer in the guidance system uses this tracking information to produce steering signals.

You might think that the missile flies along the line of sight, but this is not the case. The missile is made to fly a collision course. If you have ever stood a wheel watch on board ship, you know what a collision course is. It's the one that causes a lot of excitement when steering unintentionally. But to illustrate a point, let's say you are the helmsman and the officer of the deck gives you a course to intercept a ship. Say the ship bears 045° relative. If the intercept course is correct, this bearing will not change as your ship steams along its track. As you shall soon see, the semi active homing missile uses a similar navigational technique to intercept a target. The guidance system uses a refined collision course, and it is the refinement to the course that interests you. The missile receives this refinement before it is launched. And how does it get it? Like the other preflight information we have talked about, the missile receives navigational information through the warmup contactor on the launcher.

Now back to semi active homing navigation. Figure 4-25 shows a situation similar to the one on board ship that we talked about a moment ago. But in this case the missile contains the helmsman in the form of the guidance system. Now the target is a supersonic bomber instead of a ship. To intercept high-speed targets like aircraft and missiles, a semi active homing missile must follow a lead (collision) course. The intercept point is at the intersection of the missile and target flight paths. The best collision or lead course happens when the missile heading keeps a constant angle with the line of sight to the target. This course requires missile accelerations to be only as great as target accelerations. Specifically, if the target flies a straight-line, constant-velocity course, the missile can also follow a straight-line collision course if its velocity does not change. But in practice, this ideal situation does not exist. Missile velocity seldom stays constant. Irregular sustainer propellant burning changes thrust, and therefore affects speed. Outside disturbances such as wind gusts change the speed and path of the missile. So the missile will often have to adjust its direction to maintain a constant bearing with the target.

If the missile path is changed at the same rate as the changes in target bearing (see part A of figure 4-25), the missile will have to turn at an increasing rate (positions 1 to 6), and will end up chasing the target (positions 6 to 7). This flight path follows a pursuit curve and the

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Figure 4-25. — Proportional navigation.

missile cannot maintain a constant bearing with the target. The missile is just keeping up with changes in target bearing and may not be able to catch up with the target. At the same time, it is burning up a lot of needed fuel.

So, to achieve the desired straight-line course during the final and critical portion of the attack, the missile must turn at a rate greater than the rate at which the line of sight is turning. By overcorrecting the missile path in this way, a new collision heading is reached; and the bearing angle will remain almost constant, especially near intercept. This type of control is depicted in part B of figure 4-25. The ratio of rate of turn of the missile to the rate of turn of the line of sight (rate of change of target bearing) is called the navigation ratio, and is usually between three to one and four to one.

This technique of overcorrection results in a course called proportional navigation or, as you will sometimes see it written in OPs, N factor. Regardless of name, the shipboard missile fire control computer calculates the ratio and transmits it to the missile launching system for transfer to the missile's guidance and control system before launch.

DOPPLER PRINCIPLE

This principle, which bears the name of its discoverer, Christian Doppler (1803-53), pertains to the shift or change in frequency of a series of waves that occurs when there is relative motion along the line of transmission of energy between the source and the receiver of these waves. Some examples of waves that can be frequency shifted are sound, light, infrared, radio, and radar. A simple illustration of the Doppler effect in terms of sound waves is familiar to everyone who has observed the change in pitch of a train whistle as it approaches or recedes rapidly. When approaching, the sound-producing whistle comes a little nearer between each two successive sound waves it emits, and the waves strike the ear in more rapid succession, so that the frequency becomes greater and the pitch rises. If the train is moving away from the observer, the interval between successive sound waves is slightly increased, the frequency received by the ear is slightly decreased, and as a result, the pitch is lowered. The difference between the frequency of the sound waves when the train is standing still and when it is in motion is called the Doppler shift. This frequency difference could be used to measure the speed of the train with respect to the observer. The acoustical Doppler effect varies with the relative motion of the listener and the source, and the medium through which the sound passes. In the familiar example given, the sound waves were passing through normal atmosphere. By applying the principle to light waves, scientists are able to estimate the velocity of luminous bodies, such as stars.

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The laws applying to light and other electromagnetic waves, applied to radar, gave us the Doppler radar system to measure the relative velocity of the system and the target. A radar set radiates waves of r-f energy. When these waves strike an object, some of the r-f energy is reflected back as an echo. When the echo returns to the radar set, the radar detects or "sees" the target. A continuous-wave (CW) radar set beams uninterrupted energy of a constant frequency toward the target. The target, in reflecting the waves, is in effect a second transmitter. The difference in frequency between the reflected waves and the original is the Doppler shift, and mixing the reference and the echo voltages gives the Doppler signal. The presence of this signal indicates a moving target. To eliminate the possibility of homing on objects other than the target, a band-pass filter is inserted in the control circuit to eliminate interfering signals. A band-pass filter will pass only a narrow band of frequencies.

The Doppler principle is illustrated in figure 4-26. Note that the received wave from a distant moving object is shifted both to the right and upward with respect to the original transmission. Consequently, the beat frequency (the signal resulting from mixing the two signals in the receiver) will be alternately very small and very large on succeeding half cycles. Thus the frequency-modulated radar determines the distance to a reflecting surface by measuring the frequency shift between the transmitted and the reflected waves.

Pulse Doppler Radar

Theoretically, continuous-wave systems are the most efficient in use. The chief difficulty is leakage of spurious signals from the transmitter to the receiver. Pulsing enables the receiver to be rendered insensitive during transmission, thereby avoiding leakage signals. The pulse- Doppler method uses high frequency c-w in the form of short bursts or pulses. The pulse repetition rate (PRR) is much higher than that of a conventional pulse radar, and the pulse length is longer. The pulse radar radiates energy at a selected time interval; this permits very accurate measurement of range.

CLASSIFICATION OF NAVY MISSILES

Although missiles are often known by their popular names (for instance, TERRIER, TARTAR, TALOS, or STANDARD), every missile is also assigned a military designation. This designation indicated the launch environment (where launched and from what type of launching device), mission, delivery vehicle type, design number, and series symbol of the missile.

The following letters are used to indicate the launch environment:

A - air launched.

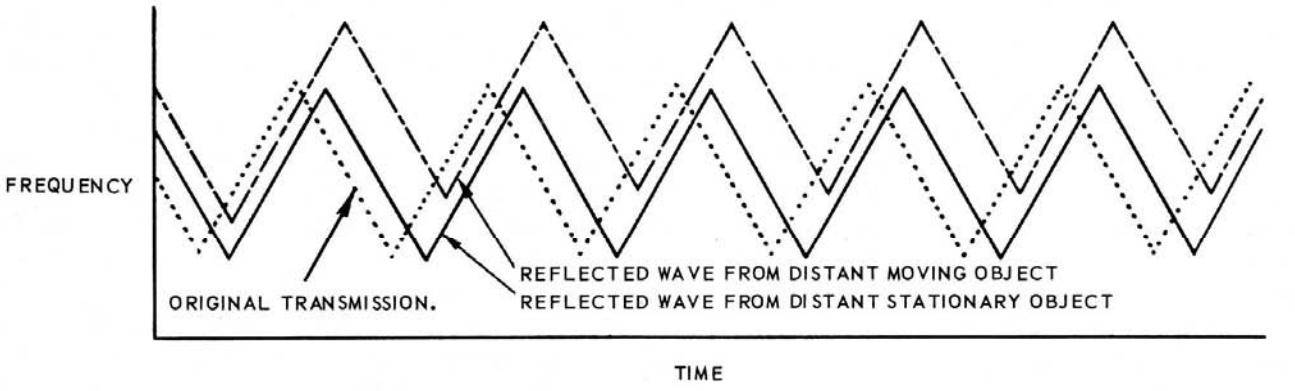
B - capable of being launched from more than one environment.

C - horizontally stored in a protective enclosure (coffin type structure) and launched from above ground level.

H - vertically stored below ground (silo stored) and launched from above ground.

L - vertically stored and launched from below ground level (silo launched).

M - launched from a ground vehicle or movable platform (mobile).



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Figure 4-26.—Doppler effect on frequency modulation (sawtooth wave) of radar.

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P - partially protected or nonprotected in storage (soft pad) and launched from above ground level.

R - launched from a surface vessel, such as a ship, barge, or other surface craft. (TERRIER, TARTAR, TALOS, and STANDARD have "R" designation.)

U - launched from a submarine or other underwater device.

The following letters are used to indicate the mission:

D - decoy (confuse, deceive, or divert enemy defenses).

E - special electronics (communications, countermeasures, etc.).

G - surface attack (enemy land and sea targets).

I - intercept-aerial (TERRIER, TARTAR, TALOS and STANDARD fall into this category.)

Q - drone.

T - training.

U - underwater attack.

W - weather.

The following letters are used to indicate the vehicle type:

M - guided missile (the 3 Ts and Standard).

N - probe.

R - rocket.

The design number is a number assigned to each type of missile with the number "1" assigned to the first missile developed. For example, all five modifications of the TERRIER missile (BW-0, BW-l, BT-3, BT-3A and HT-3) have the design number "2." TARTAR missile modifications (Basic and Improved TARTAR) have the design number" 24."

To distinguish between modifications of a missile type, series symbol letters beginning with "A" are assigned. Therefore, the TERRIER BW-0 has been assigned the symbol letter "A" and the TERRIER BW1 has been assigned the symbol letter "B." The series symbol letter follows the design number. Incidentally, to avoid confusion between letters and numbers, the letters "I" and "O" will not be used for series symbol letters.

If necessary, a prefix letter is included before the military designation. A list of applicable prefix letters follow:

J - special test, temporary.

N - special test, permanent.

X - experimental.

Y -prototype.

Z - planning.

The following list of Navy shipboard missile and rocket designations is included for reference:

TERRIER (BW-0) - RIM-2A
TERRIER (BW-1) - RIM-2B
TERRIER (BT-3) - RIM-2C
TERRIER (BT-3A) - RIM-2D
TERRIER (HT-3) - RIM-2E
TALOS (6b) - RIM8A
TALOS (6b1) - RIM-8C
TALOS (6bW) - RIM-8B
TALOS (6bW1) - RIM-8D
TALOS (6c1) - RIM-8E
TALOS (6b1/CW) - RIM-8F
TARTAR (Basic) - RIM-24A
TARTAR (Improved) - RIM-24B
STANDARD (MR) - RIM-66A
STANDARD (ER) - RIM-67A
POLARIS (A-1) - UGM-27 A
POLARIS (A-2) - UGM-27B
POLARIS (A-3) - UGM-27C
SUBROC - UUM-44A
WEAPON ALPHA - RUR-4A
ASROC-RUR-5A J

All Navy missiles are assigned mark (Mk) and modification (Mod) numbers. These numbers and the name of the missile constitute the official nomenclature approved by Ordnance Systems Command. Missiles having two stage propulsion systems (separate boosters), for instance, the TERRIER, TALOS, and STANDARD (ER), have one Mk and Mod number for the complete round. However, the individual missile and booster sections have their own mark and modification numbers. A chart of all Navy missile designations, including the former designations is published periodically by Ordnance Systems Command and for all the Services by the Department of Defense.

SURFACE-TO-AIR MISSILES

Long known as SAMs, the ship-launched missiles you will handle are now designated RIMs. Shore-launched surface-to-air missiles are still called SAMs.

So far in this text, we have emphasized the principles which underlie the operation of guided missiles in general. Very little mention has been made of specific Navy missiles. This has been done intentionally with several reasons in mind,

First, many of the principles Which have been discussed are common to all missiles To discuss each principle with relation to each operational missile is beyond the scope of this course.

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Second, a given principle might be related to one model of a missile family and unrelated to another model of the same family. Thus, confusion would arise.

Finally, your duties aboard ship in regard to missiles require that you have only a general knowledge of how missiles work.

TERRIER MISSILE CHARACTERISTICS

Terrier missiles (fig. 4-27), come in three different varieties - beam-rider, wing-controlled (BW); beam-rider, tail-controlled (BT); and semiactive-homing, tail-controlled (HT). The beam-rider, wing-controlled missiles have the popular designation of BW-0 and BW-1. These missiles are being phased out of operation so we won't cover them here.

The beam-rider, tail-controlled (BT) missiles are of two major types, BT-3 and BT-3A. The BT-3A is similar to the BT-3. The principal difference between the two is that the BT-3A can carry a conventional or a nuclear warhead. When a nuclear warhead is installed in the BT-3A, the missile is designated BT-3A (N). A fragmentation warhead can also be used. In this case the missile is called a BT-3A (F). The range of the BT-3B is much greater than that of the BT-3A.

In outward appearance and size, the HT-type Terrier missiles are similar to the BTs, though somewhat longer. Figure 4-27D shows the general appearance and the location of the four major units. You can see a difference in the appearance of the nose section, but the chief difference is in the method of guidance, which will be explained later.

BT Terrier Missiles

Figure 4-28 shows the general outline of the components of the BT-3 and BT-3A (F) Terrier missile. Note that this is the Terrier missile, not the Terrier round - the booster rocket is not included here. We covered the external features of the Terrier in the previous chapter. Now we will discuss the various sections in the BT type missiles. BTs are composed of six sections:

1. Mounted on the front of the missile is the nose section. This section contains an air pressure measuring instrument called a nose probe. It has an electrical output which is proportional to missile speed and to air density. This signal changes the gain of the tail steering control amplifiers. This variable gain is needed because the higher a missile flies, or the lower its speed, the more tail deflection is needed to produce a given movement of the missile body.

A dust cover is placed over the pressure probe to prevent dirt and other foreign material from entering the nose probe. The dust cover is torn away or split apart at launch.

2. Just aft of the nose section is the fuze section. It contains the target detection device (TDD) and the warhead safety and arming device (S&A). The TDD senses the presence of a target and sends a signal through the S&A device to detonate the fragmentation warhead. The primary purpose of the S&A device is to delay arming the warhead until the missile is clear of your ship. (There is more about the TDD and the S&A device in chapter 10.)

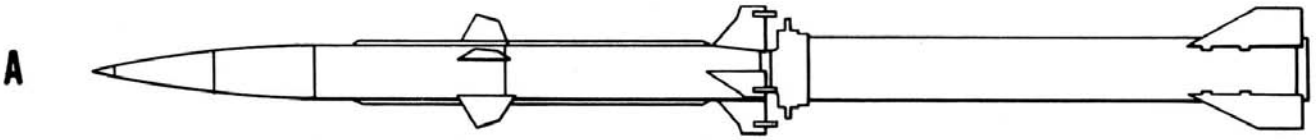
3. Aft of the fuze section is the warhead. This is the' 'reason for being" of the entire missile, as well as the weapon system itself. The main idea behind the millions of dollars worth of equipment on your ship is to put the warhead section where it will do the most damage to the target.

When the missile approaches close to or collides with the target, this is the "moment of truth." The kill is made with small metal fragments ejected from the exploding warhead (fragmentation type).

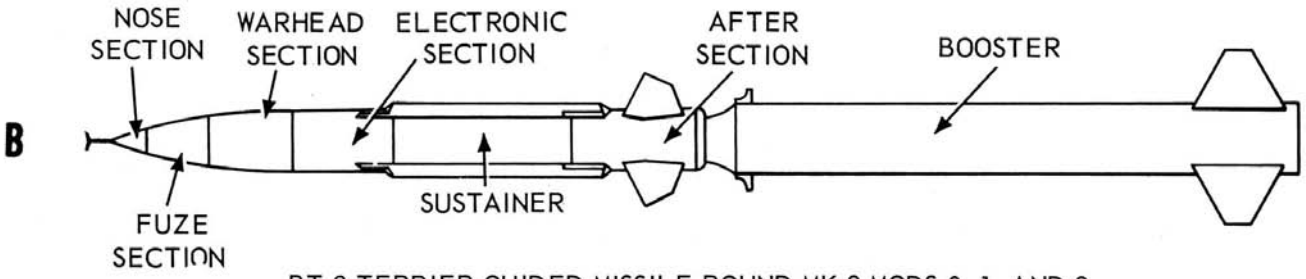
4. Next to the warhead section is the electronic section. This section contains the guidance equipment and electrical power supplies. The major unit in the electronic section is the radar receiver. It picks up radar information from the guidance beam and converts it into steering signals. You might say that the receiver compares the missile's position with that of the guidance beam's center. For illustration, if the missile is to the right and up from beam center, the receiver circuitry generated tail control signals to bring the missile down and to the left. When the missile is flying in the exact center of the beam, no steering signals are produced. But this seldom happens. Wind gusts blow the missile off course, and gravity is always at work tending to push it down. The missile fights both forces by constantly correcting its flight path. In practice, the missile's flight is often a spiral around the axis of the guidance beam.

The electronic section contains vacuum tubes. As you know, vacuum tubes control the flow of electrons that are emitted from heated cathodes. For stable operation of vacuum tube circuits the flow of electrons from the cathode surface must be even, steady cathode emission

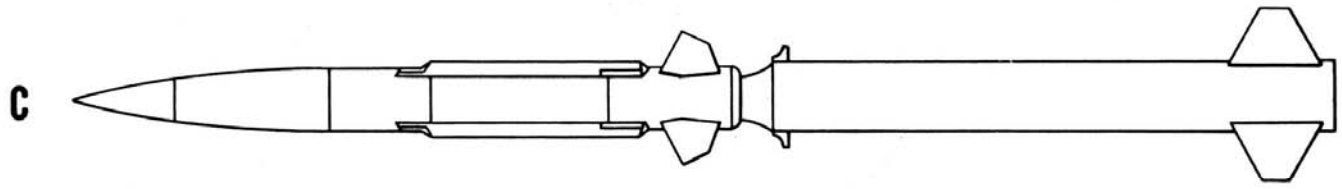
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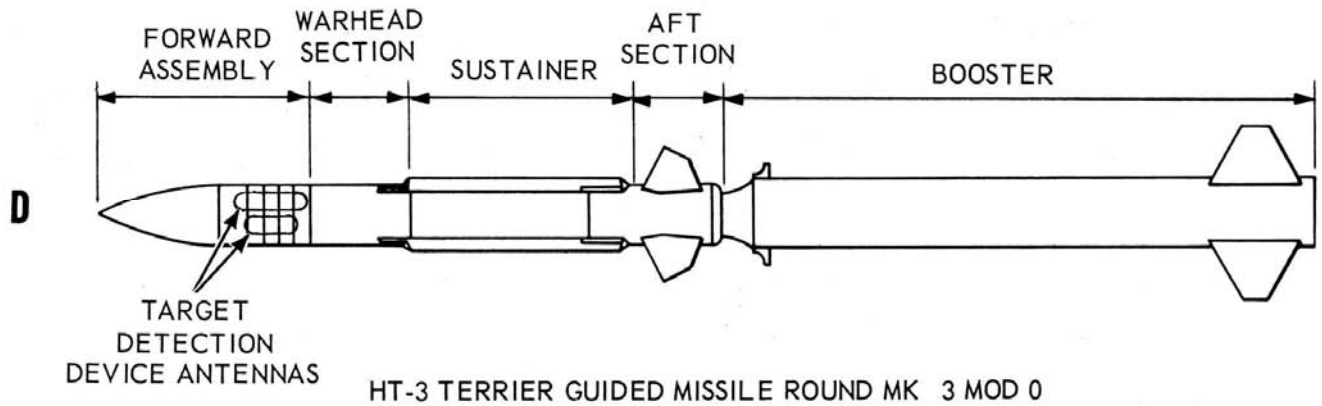
BW-1 TERRIER GUIDED MISSILE ROUND MK 6 MOD 0



BT-3 TERRIER GUIDED MISSILE ROUND MK 2 MODS 0, 1, AND 2
BT-3A(F) TERRIER GUIDED MISSILE ROUND MK 2 MOD 3



BT-3A (N) TERRIER GUIDED MISSILE ROUND MK 2 MOD 4



HT-3 TERRIER GUIDED MISSILE ROUND MK 3 MOD 0
HT-3A TERRIER GUIDED MISSILE ROUND MK 3 MODS 1, 2

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Figure 4-27. — Terrier missile family.

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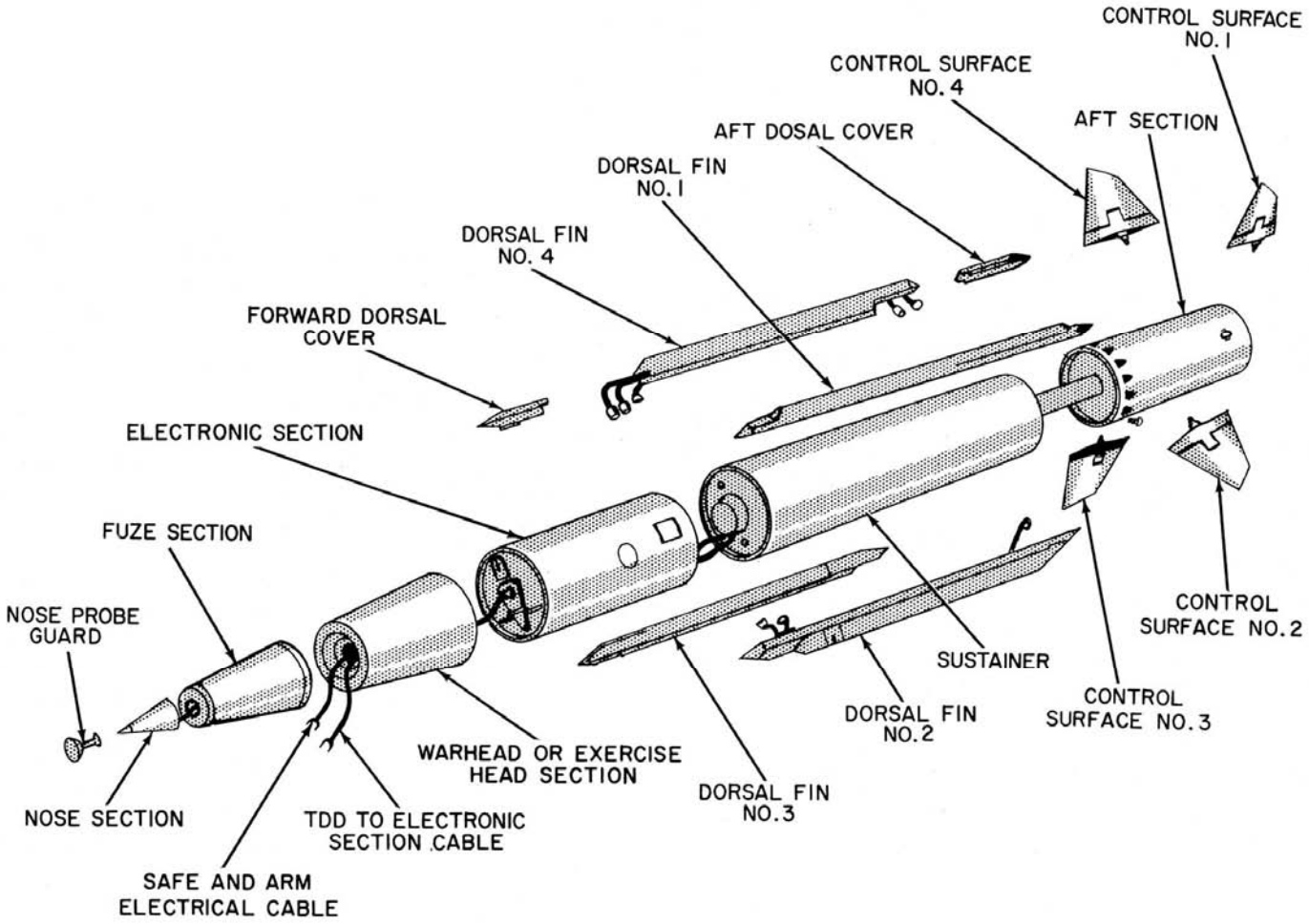


Figure 4-28.—Beam-rider tail-controlled (BT) Terrier missile; components.

occurs when the filament reaches a certain temperature. This process takes time- about 20 seconds. So before a missile is launched, electrical power from a source outside the missile is applied to it.

The electronic section contains other units that require "warming up" before the missile is launched. These are the gyros. It takes time for a gyro to reach its proper operating point. Temperature is not a critical factor in gyro operation, however, but the speed of its rotor is. Therefore, the missile's gyro must be warmed up before flight. The same external source that warmed up the filaments is used to apply current to the gyro wheels and bring them up to operating speed.

There are four gyros in the electronic section- three rate gyros and one position (directional) gyro. Earlier we said that the missile had to know which way is up before it could respond to guidance commands. The position gyro, called the roll free gyro, provides this reference direction. Incidentally, the term roll free gyro does not mean the gyro is free to roll. It means that a free gyro is used to provide a vertical reference line about which missile roll motion may be measured. A characteristic of a free gyro is that its spin axis will remain in the direction in which it is originally pointed. In this case, the rotor (spin) axis of the roll free gyro is placed in the vertical before missile launch. Theoretically, the missile could spin about its center of gravity and when these

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gyrations were finished the spin axis would still be pointing straight up and down. The other gyros, the rate gyros, are not free.

Two of the three rate gyros, called steering rate gyros, sense and measure the angular velocity of the missile as it turns about its center of gravity in answer to steering commands. The output of the steering rate gyros is a voltage that is proportional to the angular velocity (rate) of the missile body about the yaw and pitch axes. The purpose of these rate signals is to prevent the missile from overshooting and oscillating across the beam axis as it responds to steering commands. This damping technique is similar to the damping method used in some launcher power drive servos. There, tachometer generators sense and measure launcher velocity and send a voltage proportional to velocity to the servoamplifier to reduce over-shooting and oscillation about the desired position. Tach generators can't be used in missiles because there is nothing to gear them to except air. But rate gyros can sense the motion of a body in this kind of environment.

The third rate gyro, called the roll rate gyro, senses the missile's speed and direction as it rolls. The roll rate gyro provides a damping signal to the roll amplifier in the steering system to reduce overshoots and oscillation of the missile about its correct roll attitude.

5. The sustainer is the missile's longest section. It houses a solid propellant which, as it burns, exhausts hot gases through the after section to the atmosphere. The reaction to the hot gas flow is the force that propels the missile. The sustainer of the BT-3B missile is a longer burning type, with a corresponding increase in operation time, which accounts for its greatly increased range.

6. The aft section could have been called the muscle section because it provides the sources of electrical and hydraulic power. This section is the last section of the missile proper. The aft section contains two power supplies- a hydraulic auxiliary power supply and an electrical auxiliary power supply. (The term auxiliary is used to differentiate between these two units and the sustainer, which is considered to be the primary source of missile power.) The hydraulic auxiliary power supply furnishes hydraulic fluid under pressure to the four hydraulic systems that control the movement of the tail surfaces. The electrical auxiliary power supply furnishes all the electricity to operate relays, gyros, electronic circuits, and other electrical units within the missile.

HT TERRIER MISSILES

The HT-Type Terrier missile, figure 4-29, looks like the BT-3, but the HT-3 is longer. Also, the length of the BT-3 varies with the type of its warhead. Besides the HT-3, the basic version of the homing type Terrier, there is the HT-3S.

Much of the actual hardware of the HT-3 missile is common to the BT-3 missile. Both types use the same Mk and Mod booster and the same sustainer. Also, the after sections of the HT-3 and the BT-3 are identical.

The HT-3 has a semi active homing guidance system. The missile receives signals transmitted from an illuminating radar aboard ship and illumination signals reflected from the target. The missile uses this information to follow a collision course to the target.

The HT missile has four major units: (1) forward assembly, (2) warhead section, (3) sustainer and (4) aft section.

The forward assembly has two main parts - the guidance section and the target detecting device insert and antennas. The radome covers the antennas and is transparent to radar waves. The ram pressure probe in the tip and the blow- away shield are similar to those in the BT-3 missile. The guidance section is composed of five round and flat sections called wheels.

The HT-3 Terrier missile is electronically similar to the Improved Tartar missile. Because these missiles are so similar we will skip a discussion of the HT-3 and turn our attention to the improved version of the Tartar missile. Thus, we call kill two birds with one stone.

TARTAR MISSILES

Tartar (fig. 4-30), is a single-stage, rocket-propelled, supersonic, tail-controlled missile. There are two versions of Tartar - Basic Tartar and Improved Tartar. Basic Tartar is being phased out of operation. At present it is not in production, and is being used only as a training missile. Therefore we will cover it in this text. The improved version however, is one of our major defenses against close-in air targets, and it is the one we will talk about here.

The Improved Tartar, called IT hereafter, contains a semi active homing and a passive guidance system. Normally, the missile uses

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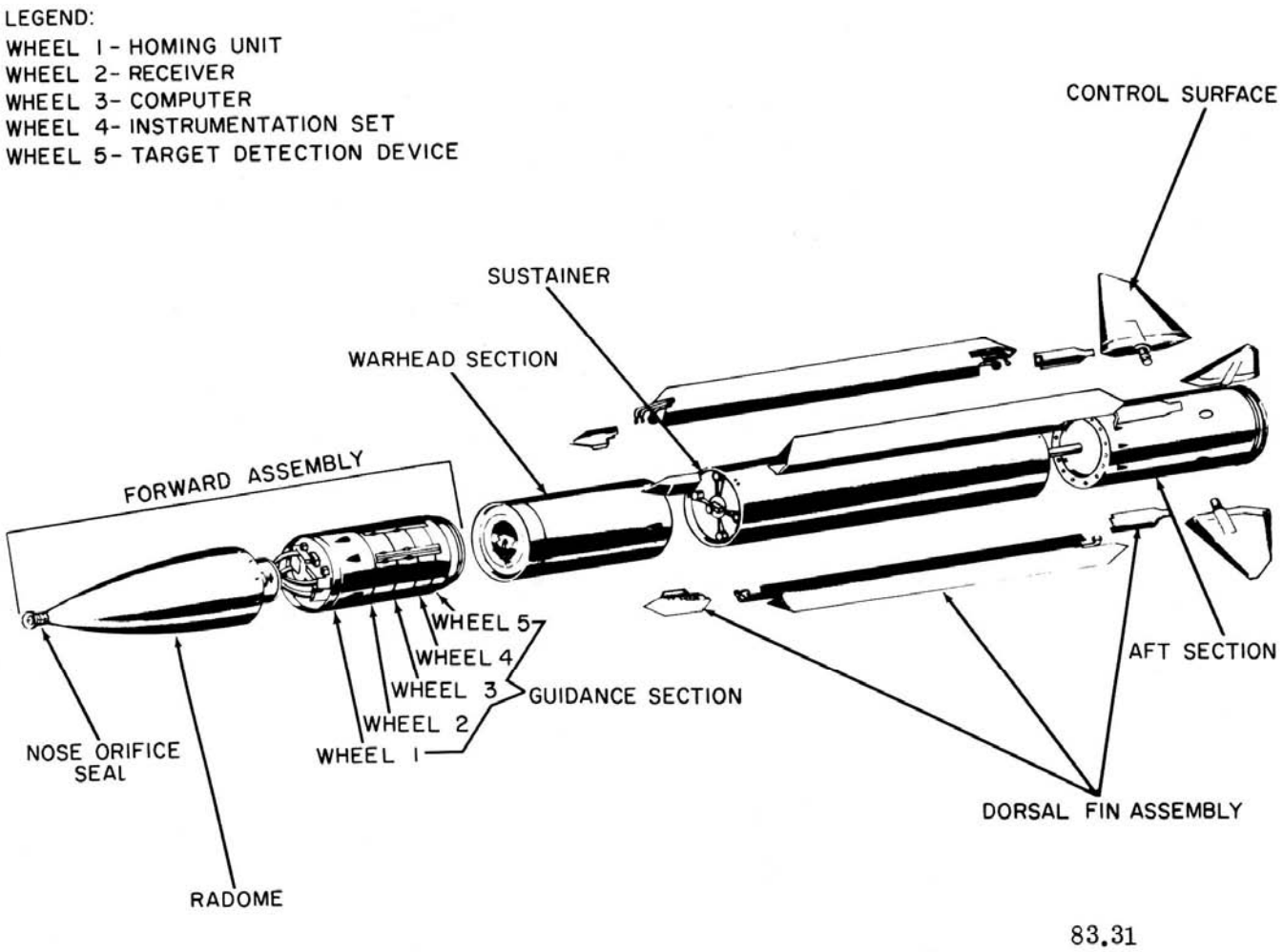


Figure 4-29. — Homing tail-controlled (HT) Terrier missile; components.

semi active guidance to intercept the target. But if the IT is flying toward a target that is jamming, the missile switches from semi active homing to passive homing. Then it homes in on the target.

The IT missile consists of four principal assemblies. An exploded view of the missile is shown in figure 4-30, which indicates the four major assemblies: (1) forward assembly, (2) warhead section, (3) dual-thrust rocket motor, and (4) steering-power section. Note that this is a complete round; the Tartar does not have a separate booster rocket.

Forward Assembly

This assembly consists of the guidance section and the Target Detection Device (TDD) with its antenna system. The purpose of the homing section is to track the target and develop guidance signals. The TDD senses the presence of the target when it is within destructive range of the warhead.

The guidance section is made up of five ring-shape units called wheels, or wheel packages. They are numbered 1 through 5 from front to rear. These five wheels are:

1. Homing Unit (Wheel 1). The first wheel contains the seeker head antenna, reference antennas, and passive homing circuitry.
2. Homing Receiver (Wheel 2). This package contains most of the seeker head guidance circuits and the self-destruct circuits.
3. Guidance Computer (Wheel 3). The computer uses output signals from the homing system to produce missile steering orders that keep

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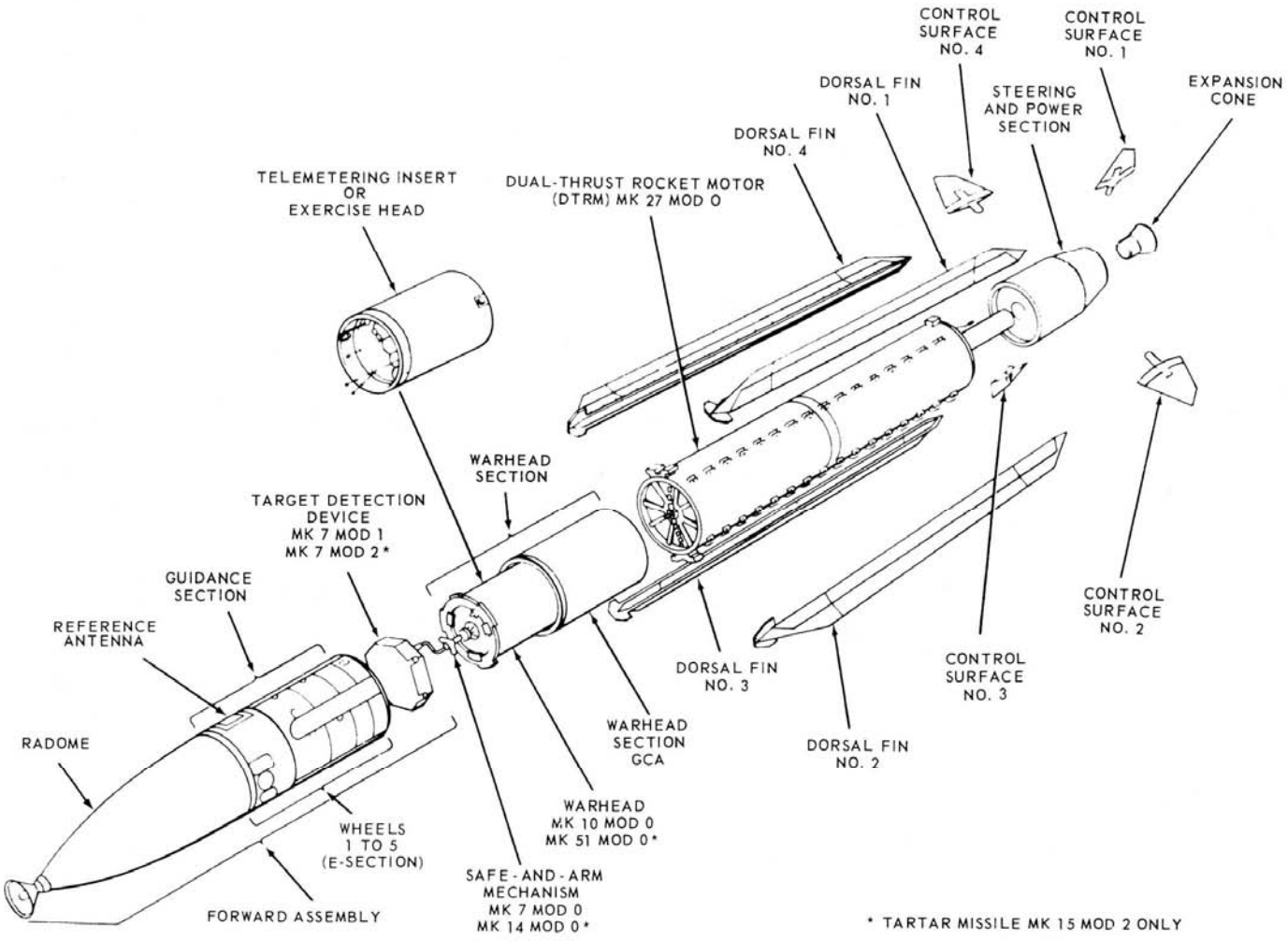


Figure 4-30.—Improved Tartar round; exploded view.

the missile on a collision course with the target. Outputs of the roll free and roll rate gyros are also used by the guidance computer to generate roll stabilization commands to the control surfaces.

4. Instrument Set (Wheel 4). The instrument set contains the circuitry that connects the roll stabilization gyros mentioned above to the guidance computer. This section also contains the circuitry that times various functions in the missile.

5. Target Detection Device (Wheel 5). The target detection device is located here. It detects the presence of the target when it is within lethal range of the warhead. At intercept the target detection device sends a pulse of energy to the warhead. This pulse sets off the warhead charge.

Warhead Section

The warhead section contains a high-explosive charge and a continuous rod warhead. A Safe and Arm (S&A) mechanism, along with a fuze booster, is installed in the center of the warhead. The S&A device will detonate the warhead charge if:

1. The target detecting device senses the target.
2. The missile fails to receive the illuminating radar signal at the reference antenna.
3. The missile electrical power fails.

The S&A device permits safe handling of the missile aboard ship and makes sure that the warhead will not detonate until the missile is a

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safe distance from the ship after launch. The explosive units in the missile are discussed in more detail in chapter 10.

As seen in the figure, the warhead section GCA is simply a metal sleeve that forms the missile skin along the warhead section. The letters GCA stand for Guidance, Control, and Airframes, and indicate components, in addition to the explosive, that are part of the warhead section.

Figure 4-30 also shows an exercise head or telemetering insert. This is inserted in place of the warhead when the missile is used for practice. You are not going to use live missiles, each costing many thousands of dollars, when you have practice sessions with missile firing.

Dual-Thrust Rocket Motor (DTRM)

This section was covered in chapter 3. At the present time, the Tartar and Standard (MR) are the only Navy missiles that use this type propulsion system, which combines the sustainer and the booster.

Steering and Power Section

In Terrier missiles BT-3 and HT-3, the components of this section are contained in the part called aft section (figs. 4-28, 4-29).

Two auxiliary power supply (APS) gas generators are in the steering and power section. One generator supplies hydraulic power, whereas the other unit supplies electrical power to operate the electronic section. The tail control system which moves the missile tails is also a part of the steering-power section.

Fuel carried in the steering-power section is ignited in a combustion chamber. This produces hot gases which drive the electrical and hydraulic generators. After the gases are used, residue from the gases is vented out the sides of the steering-power section. Incidentally, this bit of information is helpful in distinguishing between a misfire and a dud. But we'll talk about this in chapter 9 where we will cover missile firing.

The APS gas generators, described very briefly above, form a complex system. New missiles will use a much simpler all-electric power source.

STANDARD MISSILES

The Standard missiles RIM-66A and RIM- 67A are surface launched, rocket propelled, homing type, supersonic guided missiles that may be used against surface or air-borne targets. RIM-66A is a medium range missile (MR) that resembles the Tartar missile. RIM-67 A is an extended range missile (ER) that resembles the Terrier missile.

The following paragraphs give a brief description of the sections and components of the missiles. Unless otherwise indicated, the discussion applies to both the ER and MR configurations. This is in part due to the interchangeability of many sections and components of the two configurations.

Figure 4-31 shows the major sections and components of the MR missile and figure 4-32 shows the major sections and components of an ER missile.

The ER and MR missiles consist of the following major sections: (1) Guidance section, (2) Ordnance section, (3) Control section, (4) Propulsion section.

Guidance Section

The guidance section of the ER and MR missiles operate as either a semi active or passive homing system. Roll stabilization and steering are accomplished by the movement of four aerodynamic control surfaces (tails).

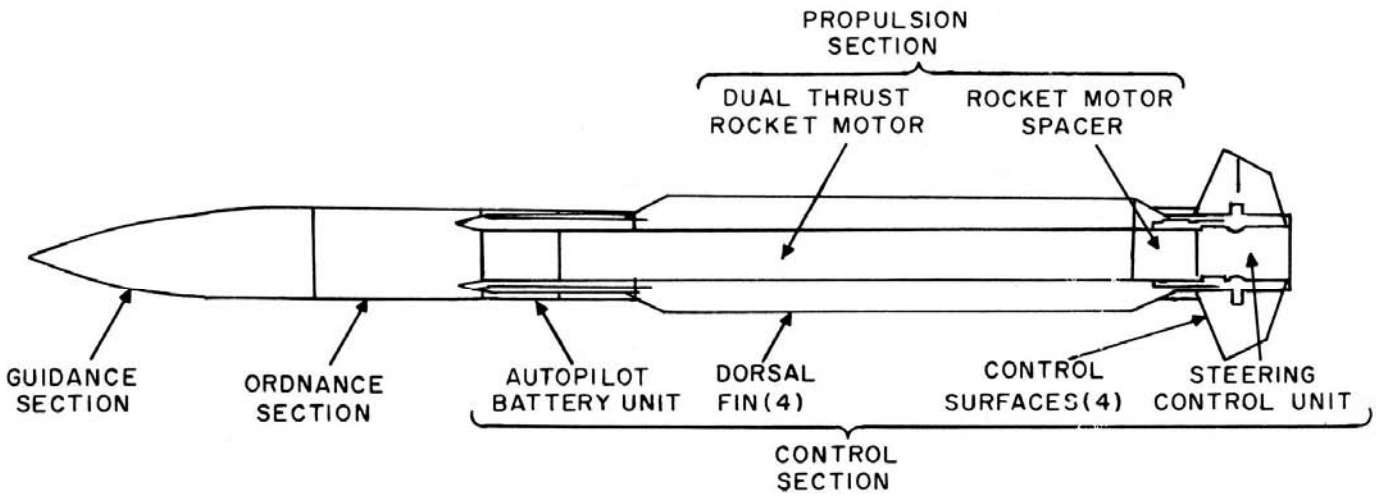
Guidance by semiactive homing requires a surface based continuous-wave (CW) radar signal to illuminate the target, and a missile receiver to continuously receive and track the energy reflected from the target. Angular changes in the missile or target heading are sensed by the missile guidance system and transferred into appropriate control surface movements to steer the missile along a target intercept course.

The guidance section is identical for ER and MR missiles and consists of a radome assembly, two reference antennas, and a guidance assembly. The radome structure assembly consists of an aluminum guidance section shell and an rf transparent radome. The radome serves as a protective covering for the guidance unit while allowing reception of the target signal, and is made of a pyroceramic material terminated at the forward end with a small metal tip. The reference antennas are flush-mounted in cutouts on the top and bottom of the radome structure and receive the rf energy directly from the surface based radar.

Ordnance Section

The ordnance section for the ER and MR missiles in interchangeable and consists of a fuze shroud assembly, warhead, safety and arming

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Figure 4-31.—Standard missile RIM-66A, major sections and components.

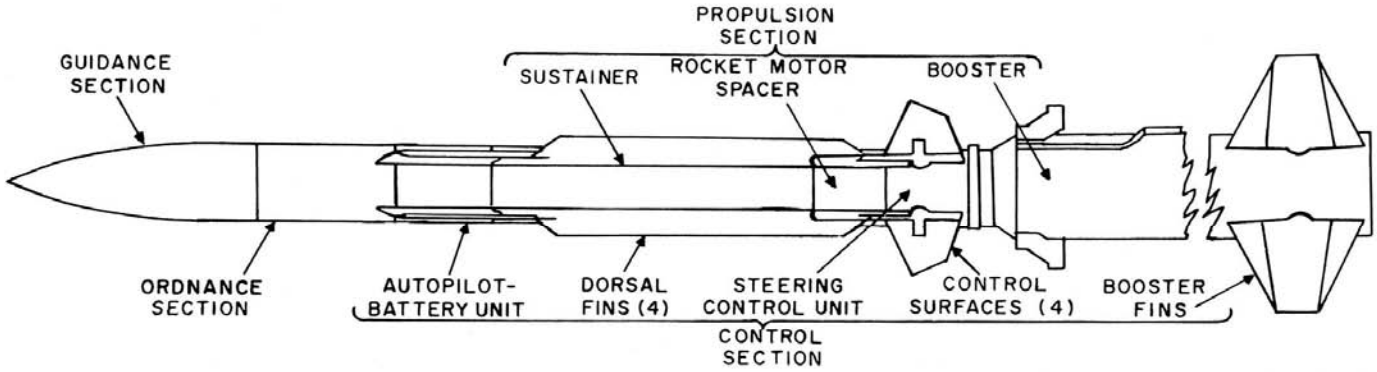
(S&A) device, and a fuze booster. The fuze shroud assembly houses the components of the ordnance section. The fuze shroud includes a proximity fuze, contact fuze, and an antenna assembly, which are all installed in the aft end of the antenna shroud.

The proximity fuze with its associated four antennas, detects the target through its own radar transmitting and receiving system. The fuze trigger circuit is enabled for an airborne target and disabled for a surface target by a target select signal prior to launch. The contact fuze is a shock sensing device consisting of a piezoelectric crystal accelerometer and a switching circuit. When the crystal accelerometer output exceeds a predetermined level (caused by impact with the target), it drives a switching circuit which supplies a signal to the proximity fuze firing circuit.

The fuze booster is an explosive device that continues the fuze train initiated by the S&A device to detonate the warhead.

Control Section

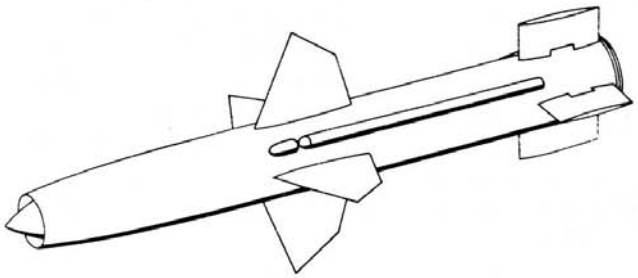
The control section consists of the autopilot-battery unit, steering control unit, dorsal fins, dorsal telemeter assembly, and control surfaces.



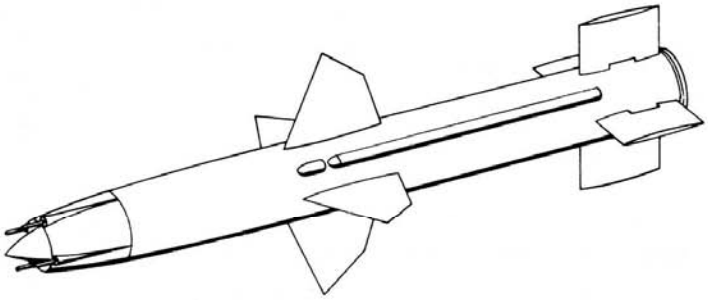
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Figure 4-32.—Standard missile RIM-67A, major sections and components.

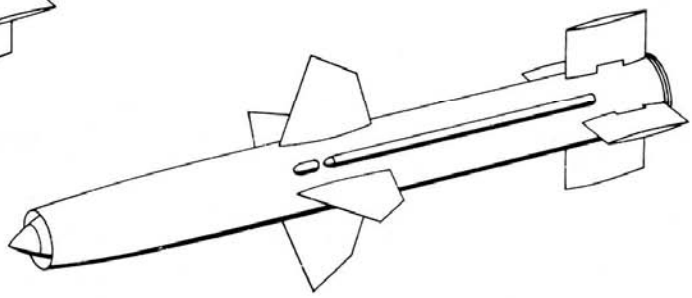
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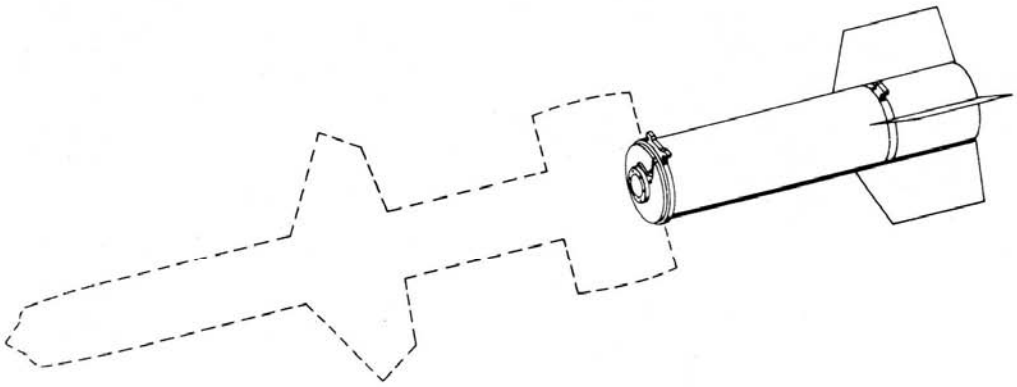
TALOS MISSILE MK 11 MOD 5,
6c1,
"S" OR "W"



TALOS MISSILE MK 11 MOD 3,
6b1 (CW),
"S"



TALOS MISSILE MK 11 MOD 4,
6bW1



MISSILE BOOSTER MK 11 MODS 1 AND 2

83.33

Figure 4-33. — Talos missile types, and booster.

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With the exception of the control surfaces, none of these assemblies are interchangeable between the ER and MR missiles.

Power Supply

The missile power supply is composed of a primary battery and a power distribution assembly. The remotely activated, dry charged primary battery supplies all missile power during flight. The power distribution assembly distributes the primary battery power to the various missile components and contains circuits for limiting the delaying power to certain missile components.

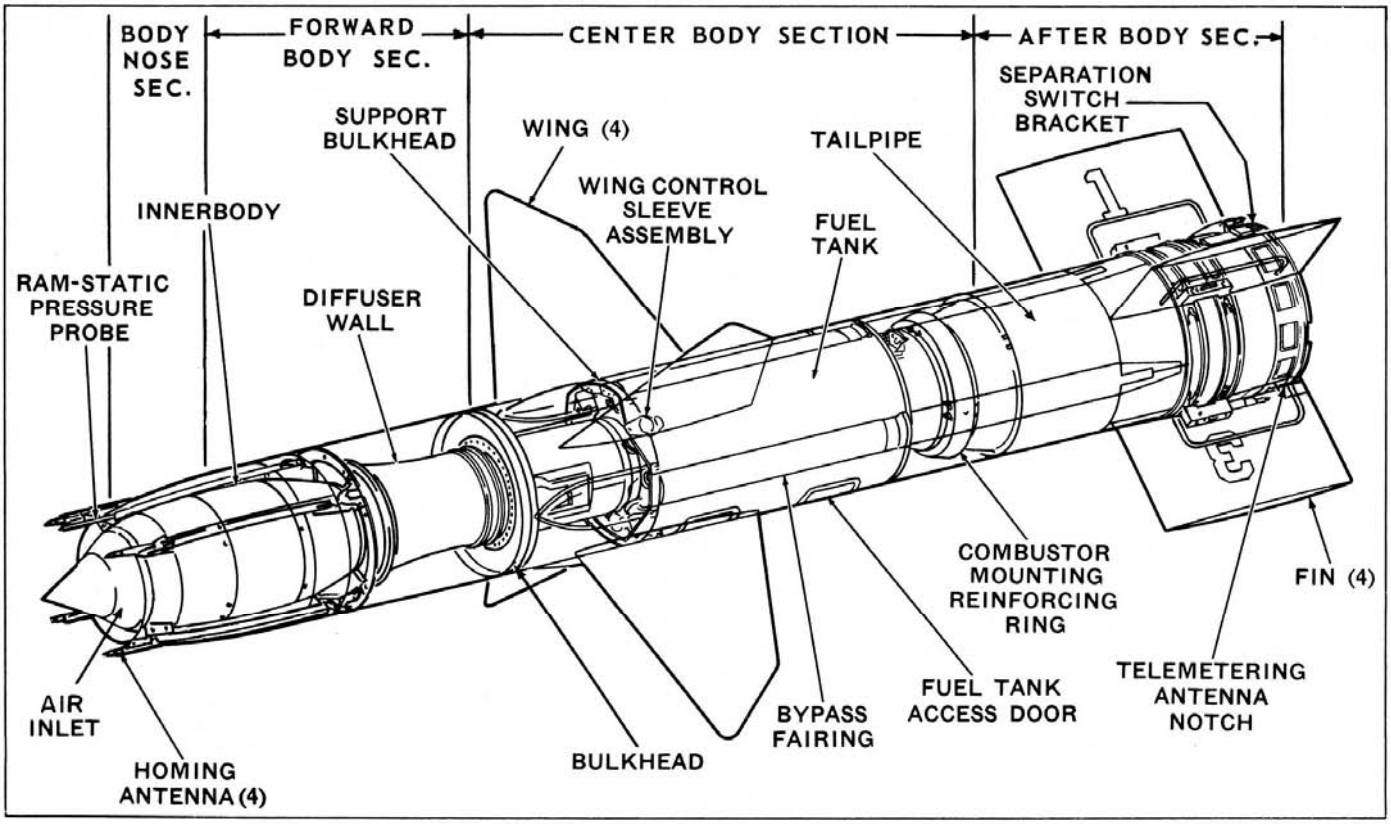
Propulsion System

Propulsion for the MR missile is supplied by a solid fuel, dual-thrust rocket motor (DTRM) which provides short duration high thrust for the initial or boost flight period, and long duration low thrust for the remainder of the propelled flight.

. The ER missile is propelled by a solid fuel booster which provides short duration high thrust for the initial or boost flight period. When booster thrust decays, aerodynamic drag forces separate the booster from the missile. Separation of the booster results in ignition of the sustainer rocket. When ignited, the solid-fuel sustainer rocket supplies long duration low thrust for the remainder of the propelled flight.

TALOS

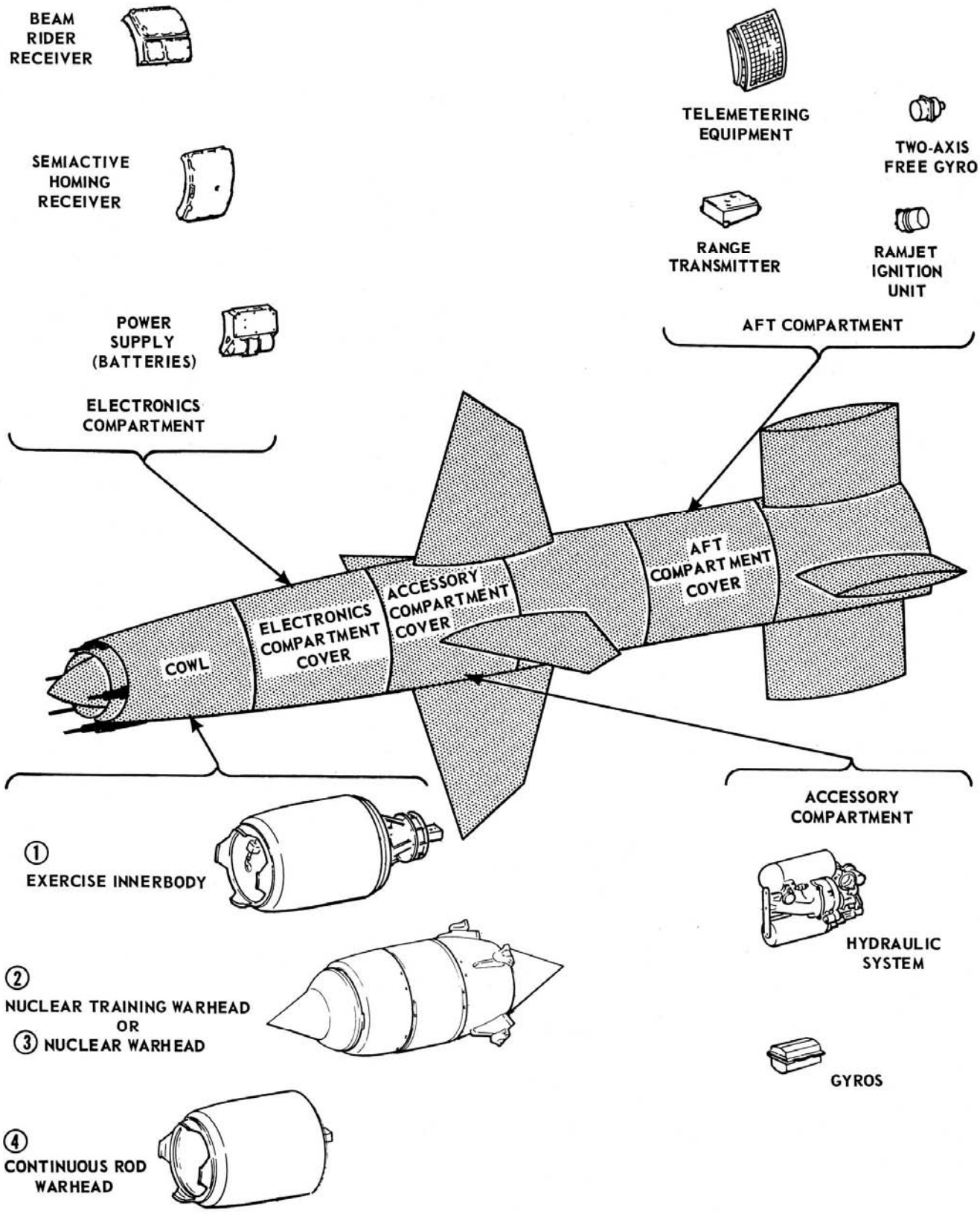
Talos is larger than either Terrier, Tartar or Standard. It differs from Terrier, Tartar and Standard missiles not only in size but in its type of propulsion. Talos is a ramjet, whereas Tartar, Terrier and Standard are rocket propelled. Talos is supersonic and so are the other members of the Bumblebee family. Like Terrier and Standard (ER), Talos is a two-stage missile, consisting of a solid propellant rocket booster and the missile proper. Talos missiles are either beam-riders with terminal homing guidance, or beam-riders during their entire flight.



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Figure 4-34. — Major sections and some components of Talos missile.

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Figure 4-35. — Talos compartment and compartment covers.

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The Talos missile itself is officially designed as guided missile Mk 11. There are three modifications: 3, 4, and 5, as shown in figure 4-33. The mod designation is further elaborated with descriptive symbols such as:

1. 6b1 (CW) for the mod 3 (RIM 8F).
2. 6bW1 for the mod 4 (RIM 8D).
3. 6c1 for the mod 5 (RIM 8E).

For practical purposes, the Talos missile is categorized according to the type of warhead it is intended to carry. The capital letter S indicates a high explosive warhead, and capital letter W indicates a missile intended to carry a nuclear warhead. Therefore, Talos Guided Missile Mk 11 Mod 3, 6b1 (CW) is an S type missile because it is designed to carry only a standard high explosive warhead. But Talos Missile Mk 11 Mod 5 can be called either an S type or W type because it can carry either a standard or nuclear warhead. The Mk 11 Mod 4 (6bW1 or RIM 8D) is only a "W" missile.

At first reading the methods of classifying Talos missiles may seem confusing but in a few years it will be easy. There will be only the 6c1 to worry about. It is planned to phase out the other two missiles. And this is one of the reasons we will cover only the 6c1 in this course. Another reason we will limit the coverage to this particular missile is that it contains all the features of the 6b1 and 6bW1. In other words, the 6c1 is a unified version of the 6b1 and 6bW1.

The Talos 6c1 is a two-stage, surface-to-air, solid-rocket launched, ramjet propelled, guided missile. After it is boosted to supersonic speed, it is guided during its midcourse flight phase by a beam-rider guidance system. Near the end of the missile's flight it switches from beam-rider to semi active homing guidance. During this terminal phase, the target is illuminated by a shipboard tracking and illuminating radar. The missile then homes in on the reflected radar energy from the target. When the missile is in the vicinity of the target, the kill is made with either a nuclear warhead or a standard continuous-rod high explosive warhead. (The continuous-rod warhead is described and illustrated in chapter 11.) The 6c1 is capable of carrying one or the other. For peacetime exercises the missile can be fitted with the continuous-rod warhead, exercise warhead, or a nuclear training warhead. Aboard ship you will handle the warheads we mentioned above.

The body structure of the 6c1 (fig. 4-34), is divided into three major sections:

1. Forward body section
2. Center body section.
3. Aft body section

They are not taken apart on board ship. But you will have to remove and replace modules or packages in these sections. As in the case of Terrier, the trend is toward packaging components so if a part malfunctions, the complete component can be pulled out as a unit and a new one put in without disassembling the module. To make it easy to get at the modules, compartment covers are provided. Figure 4-35 shows the location of the covers. Now let's start forward on the missile and work aft.

First, the cowl is a one-piece removable cover. Incidentally, the cowl is very easily damaged and must be very carefully handled. A scratch or dent will destroy the missile in flight. The inner body is under the cowl. There are three interchangeable innerbody assemblies. One innerbody assembly can be used for either the tactical nuclear warhead or for the nuclear warhead training warhead. Another innerbody is used for the exercise head. Still another innerbody is for the continuous rod warhead. The outer contours of all three innerbodies are the same. Together with the cowl, the inner body, besides acting as a container for warheads, forms the compressor section for the ramjet propulsion system.

Now we come to the electronic compartment cover. It is a one-piece removable wraparound cover which forms the outer skin of the forward section. Hinged doors on the cover provide access to test receptacles and switches.

Most of the missile's electronic guidance and control equipment is located under the electronic compartment cover. The beam rider and semi active homing receivers are there The power supply for the electronic equipment is also located there.

Next is the accessory compartment cover. It is a two-piece cover which provides access to the hydraulic system, wing control components, missile batteries, and the ramjet fuel system. The gyro packages and accelerometers are also there.

Finally, we come to the two-piece aft compartment cover. The principal units under it are the telemetering equipment, the range transmitter (Beacon), and the ramjet ignition unit.

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CHAPTER 5

GUIDED MISSILE LAUNCHING SYSTEMS

INTRODUCTION

The guided missile launching system (GMLS) on a ship is that part of a ship's installation designed to stow and launch the missiles. Its purpose is to deliver a missile, ready for firing, from the missile magazine to the launcher guide arm. It must also return a missile from the launcher to the magazine for stowage. The launching system includes the feeder system, the launcher, and the launching system control. The feeder system stores the missiles and delivers them to the launcher. A typical feeder system consists of the missile magazine, loader, assembler, and strikedown and checkout equipment. Figure 5-1 shows these components for the Mk 12 GMLS (Talos). Not all launching systems have all these major components. The Tartar system, for example, does not have an assembler. For launchers with two arms, there are also duplicate components of the other parts of the system, one for the A-side and the other to supply the B-side, either simultaneously or independently.

Although the ship's fire control system is essential for successful missile action, it is not considered part of the launching system.

In your work around missiles and launchers you have undoubtedly heard the term "launching groups." The term "group" means the same thing as system - a group of inter-related equipments. The launching system for the ASROC, which is the responsibility of the Gunner's Mate (T), is called "launching group."

GENERAL DESCRIPTION

The discussion here, because it is limited to but one chapter in a course that must take up many topics other than this, will unavoidably omit a good many details.

The overall configuration of a missile launching system is determined by the type of missile used and the class of ship on which it is installed. The missile type is the most important factor to be considered.

The types of launching systems, however, are designed for specific ships, or rather, classes of ships. Many changes have evolved since the USS Gyatt was converted from a conventional DD to the first guided missile ship.

The arrangement of the major components of a launching system that handles the same type missile will vary with the Mk and Mod of the launching system, and the ship on which it is installed. This is especially the case with the location of the stowage area or magazine.

The Talos system, being large, is placed only on CGs, CLGs, and CGNs. The much smaller Tartar system is placed on smaller ships, such as DDGs, although CGs may have Tartar as well as Talos systems aboard.

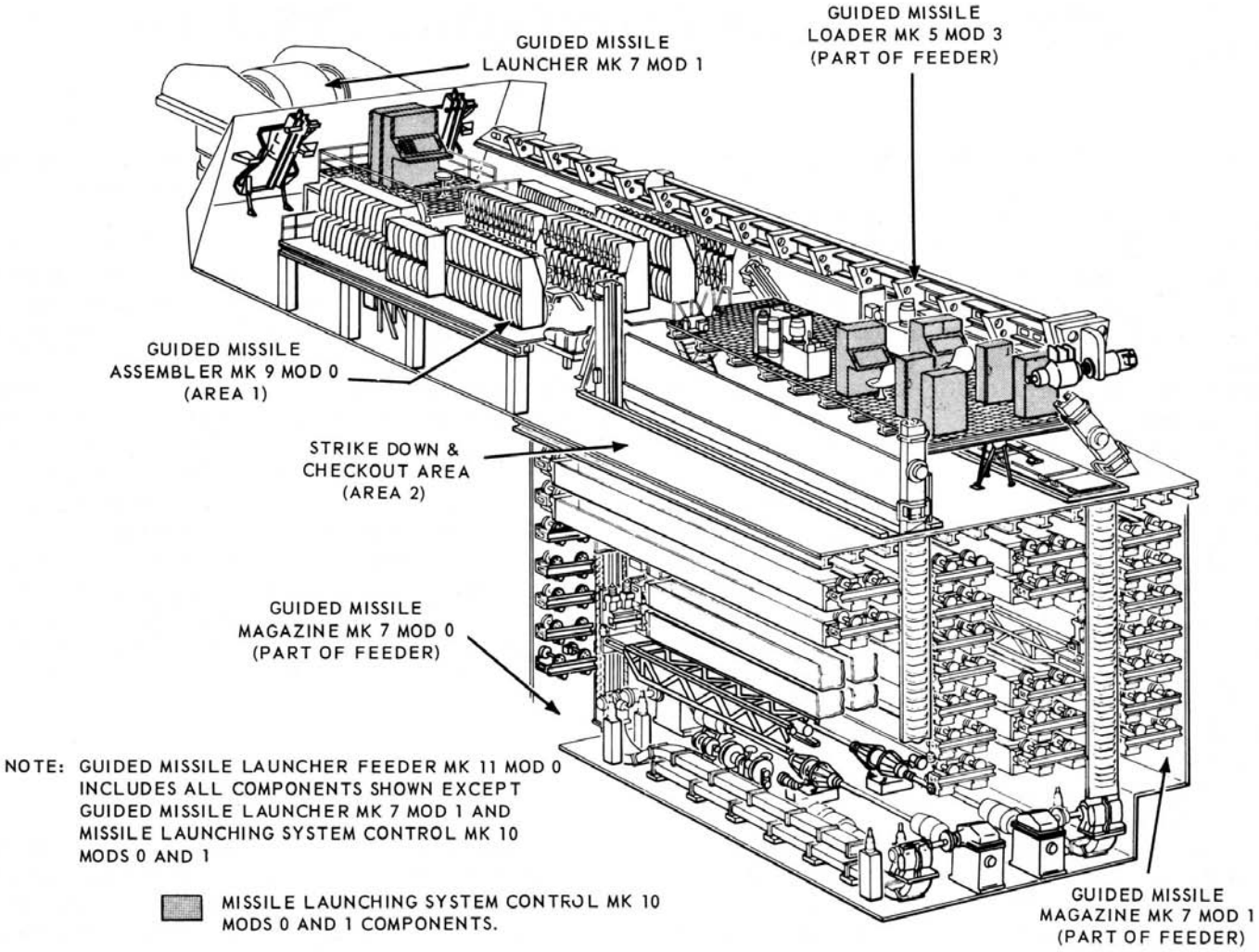
LAUNCHERS

The main purpose of a launcher is to provide a launching platform or pad for missiles. But launchers have secondary purposes too: they must support missiles, aim them, prepare them for firing and, finally, launch them in the direction of the target. All missile launchers you will work with do these fundamental jobs.

The modern missile launcher is characterized by:

1. Its ability to position itself in train and elevation.
2. A structure that can support missiles singly or in pairs.
3. Devices that provide a method of inserting information into the missile before it is fired.
4. Devices that fire the missile.
5. Systems that provide for the safety of the ship, missile, and personnel.

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Figure 5-1. — Guided Missile Launching System Mk 12. (Talos)

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Every missile launcher has these general characteristics. In this section we will take up the more significant and common features of launchers.

Types of Launchers

Missile launchers may be classified in many ways:

1. By the common name of the missile it launches. Thus, you can call a launcher a Talos, Tartar, or Terrier launcher.

2. By the number of rails or guide arms. This method of classification is illustrated in figure 5-2. Notice that Terrier and Talos launchers are dual-arm ones, while Tartar launchers come in two varieties - single- or dual-arm types.

3. By the elevation position of the guide or missile-supporting structure when loading missiles. All Tartar launchers are vertical-load types. Early Terrier launchers are also vertical- load launchers. But the more modern Terrier launchers load missiles with the guide arms horizontal to the deck plane, or nearly so (at an angle on forward installations). Talos launchers receive missiles with the guide arms horizontal to the deck.

4. By the distance the missile travels on the launcher during firing. If the first motion of the missile during the launching process releases it from the launcher, the launcher is called a zero-length type. But, if the missile travels any distance along its supporting rail, the launcher is designated a rail-type launcher. Terrier and Talos launchers are sometimes loosely called zero-length launchers, but their missiles during launch do travel several inches before they detach themselves from the launcher.

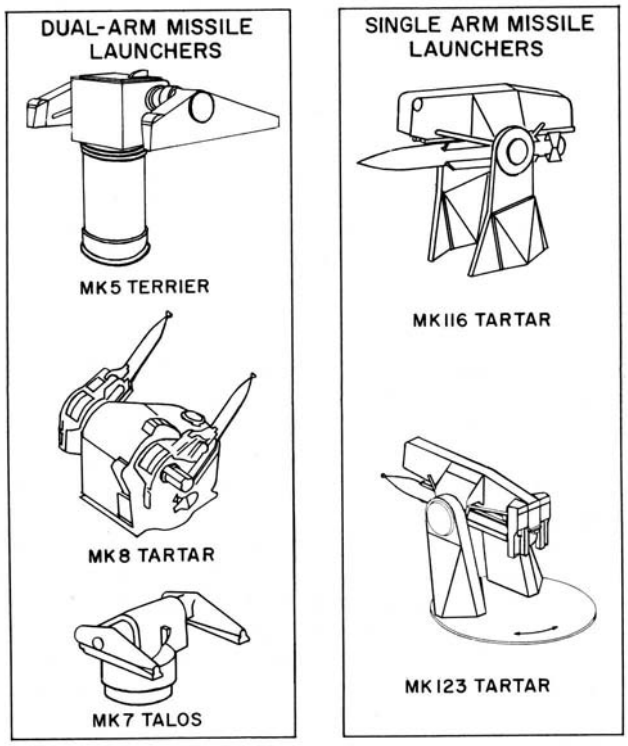


Figure 5-2.—Launchers classified according to the number of arms. 83.37

Various proposals have been made to use guns for launching missiles, but at present this method has not been used on ships, although successful test firings have been made. The Tartar Mk 22 launching system was designed to use the training circle of a 5"/54 caliber gun.

FEEDER SYSTEMS

Some of the most noticeable differences are in the components of the feeder system.

Magazines

The three Terrier systems use magazines of entirely different designs. The Mk 4 system, which is installed on the USS Boston and USS Canberra, has the missiles stored in a vertical position and the launcher is located directly over the magazine, so the missiles are loaded vertically. The Mk 10 system, now used on most Terrier ships, stows the missiles in a horizontal position; but there are differences in the details of loading and unloading. The Mk 10 system has the missiles stowed in a ready service ring that rotates to the position directed when a missile is to be transferred. The Mk 9 system also had the missile stowed in a horizontal position, but in cells, and the hoist (a transfer car on rails) has to go to the missile to bring it up, instead of the missile being brought up to the hoist for moving to the loader, as in the Mk 10 system. The missile is extracted from the cell, and placed on the transfer car, which moves it to the loader.

The Mk 7 Talos system stows the missiles in a ready service compartment which contains trays that index to bring the selected missile to the hoist for loading. In addition, there is a replenishing magazine for additional missiles.

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The Mk 12 Talos system (fig. 5-1) stows its missiles in trays, positioned like the cells in the Mk 9 Terrier system, but movable.

The missiles in all of the Tartar systems are stored in a vertical position in ready service rings directly below the launcher. Since Tartar missiles are complete, no assembly area is needed. The missile fins, which are on the missile in a folded position, unfold automatically after the missile is on the launcher.

Loader

In figure 5-1, locate the loader, sometimes called the rammer. It picks up the missile after it has been brought up from the magazine, moves it to the assembly area, where the wings and fins are attached, and then moves it to the launcher. Of course there are many more steps in this sequence, which we will not detail here. In systems where the launcher is directly above the magazine, there is no need for this lengthy transfer, and the loading sequence is shortened.

Assembler

The assembly area is in the missile house, near the launcher. The wings and fins that are to be attached to the missiles are stored in racks in this area. Men are stationed here (the number varies with the type of missile and its Mk and Mod) and they attach a wing or fin to the missile as it rests on the loader. It must be done very quickly to maintain the timing sequence of the launcher, and the men must have had precision- timed training before they are assigned to the task.

Strikedown and Checkout Equipment

By strikedown we mean the loading of the ship's magazines with missiles, boosters, and other missile components. Checkout means the preflight checks on missiles by the use of special test equipment. The tests are conducted by men of other ratings; your part of the job is to position and prepare the missiles for testing. Mating and unmating of missiles is performed in the checkout area; this, too, is part of your job. The layout and the location of the checkout area varies with the missile and the ship. See chapter 14 for illustrations and detailed discussion.

LAUNCHING SYSTEM CONTROL

The third major component of the launching system is the control equipment. The control panels for components are located as close to the component as possible. The large control panel offers pushbutton control of most if not all parts of the system. The large control panel offers automatic control, but local control is necessary for testing, checking, repairing, or replacing individual units of components. The local control panels are necessary for those procedures. A "typical location" diagram is shown later in this chapter.

TERRIER LAUNCHING SYSTEMS

As we have mentioned before, Terrier systems have been under development for a number of years and many changes have resulted. The Mk 10 launching system is the one found on the largest number of Terrier missile ships, but there are variations in the mods of this, ranging from Mod 0 to Mod 8. The Terrier Launching System Mk 9 is installed on three CLGs: USS Providence, USS Topeka, and USS Springfield.

We will describe the Mk 10 launching system, pointing out the important differences in mods and showing where the Mk 4 and the Mk 9 systems are different.

LOCATION AND ARRANGEMENT ABOARD SHIP

The location of the components of the Terrier launching system varies with the type of ship and the Mk and Mod of the system.

Mark 10 and Mods

On a DLG-26 class destroyer, the launcher of the Mk 10 Mod 7 system is mounted at the ship centerline of the 01 level and the feeder system (magazines, loaders, strike-down equipment) is located below and aft of the launcher. As shown in figure 5-3, the Mk 10 Mod 7 Terrier system has three magazines (ready service rings), two of them at the upper level and one at a lower level. The one at the lower level is for auxiliary stowage purposes, and only Terrier missiles are stowed in it. The other two magazines can hold Terrier or a mixture of Terrier and Asroc (fig. 5-3). Each ready service ring has trays to hold twenty weapons. Because the Asroc is considerably shorter than the Terrier, it must be stored with an adapter attached to it. When an

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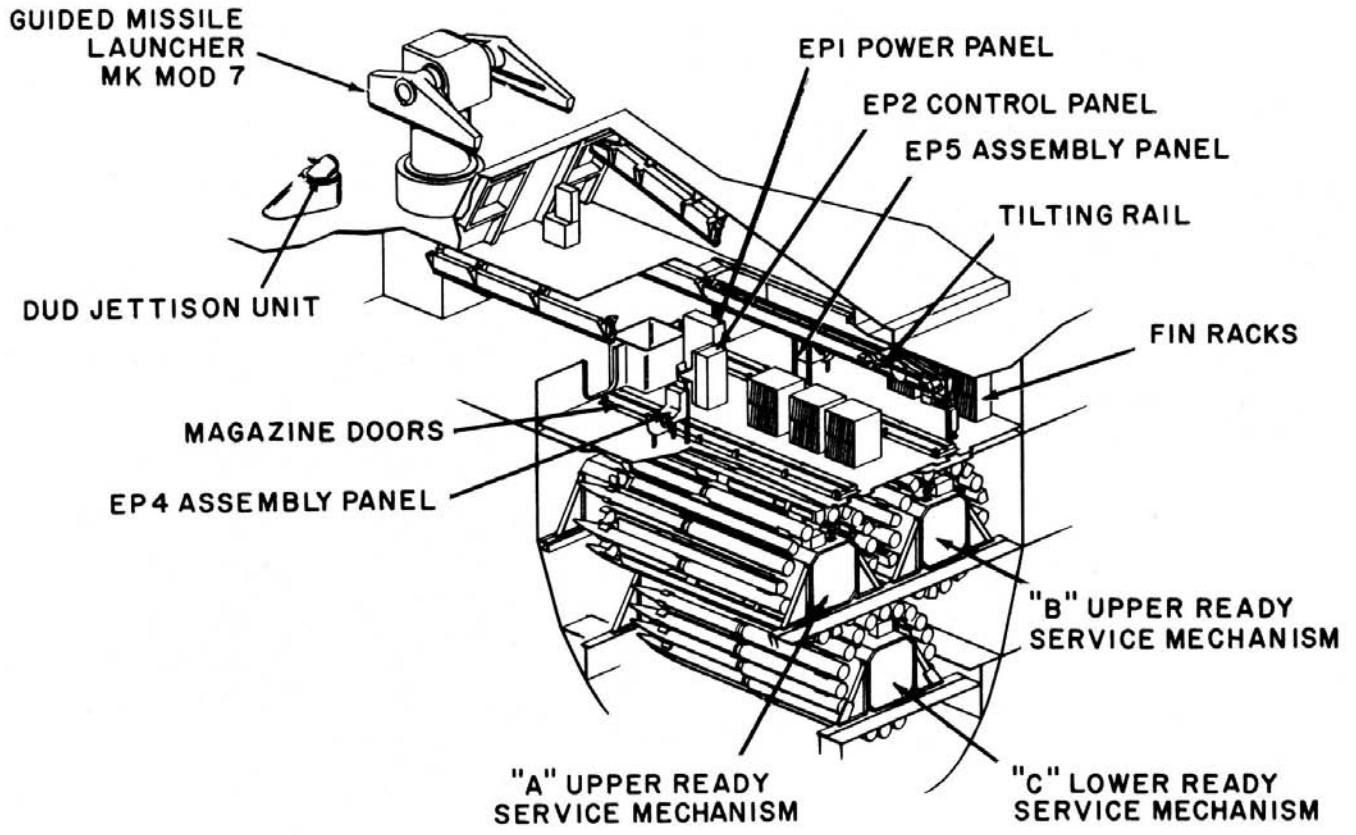


Figure 5-3.—Guided Missile Launching System Mk 10 Mod 7 With Complement of Asroc.

Asroc is fired, the adapter rail is left behind and must be returned to the ready service ring.

GMLS Mk 10 Mods 0, 5, and 6, has two ready service rings instead of three, and it does not accept Asroc missiles. Figure 5-4 shows a Mk 10 Mod 0 system. The launcher is near the aft end of the ship. Part of the launching system is in the aft deckhouse (missile house); the magazine area, containing the ready service rings, is below decks.

The aft deckhouse is divided into two compartments. The part nearest the launcher is the strikedown and checkout area, and the other compartment is the assembly area, with the missile magazine area directly beneath it. The missiles are transferred from the magazine area to the assembly area through the magazine doors (fig. 5-4) by the hoist. After assembly is completed, the missile is moved out of the assembly area on a loader r ail that extends from the magazine door, through the assembly area and the strikedown and checkout area, to the blast door. When the blast door is open, a rail extension connects the loader rail to the guide arm on the launcher, so the missile can move onto the launcher. The blast doors remain closed except during the moment of actual transfer of a missile to the launcher (or when unloading the launcher and moving the missile from the launcher to the magazine).

Mk 9 System

Instead of ready service rings that rotate to bring the selected missile to the hoist, the Mk 9 system stores its missiles in individual cells, and (instead of the hoist) a transfer car moves to the cell that contains the selected missile. This arrangement is shown in figure 5-5. The cells are numbered and identified on the control panel so that any missile may be selected for transfer from the cell to the launcher by pushing the correct button on the launcher control panel. A transfer car, which is part of the loader, runs athwartships on tracks to the selected cell, where an extractor beam extracts the round. As you can see in figure 5-5, there are two sets of magazines, one next to the assembly area and another for additional stowage.

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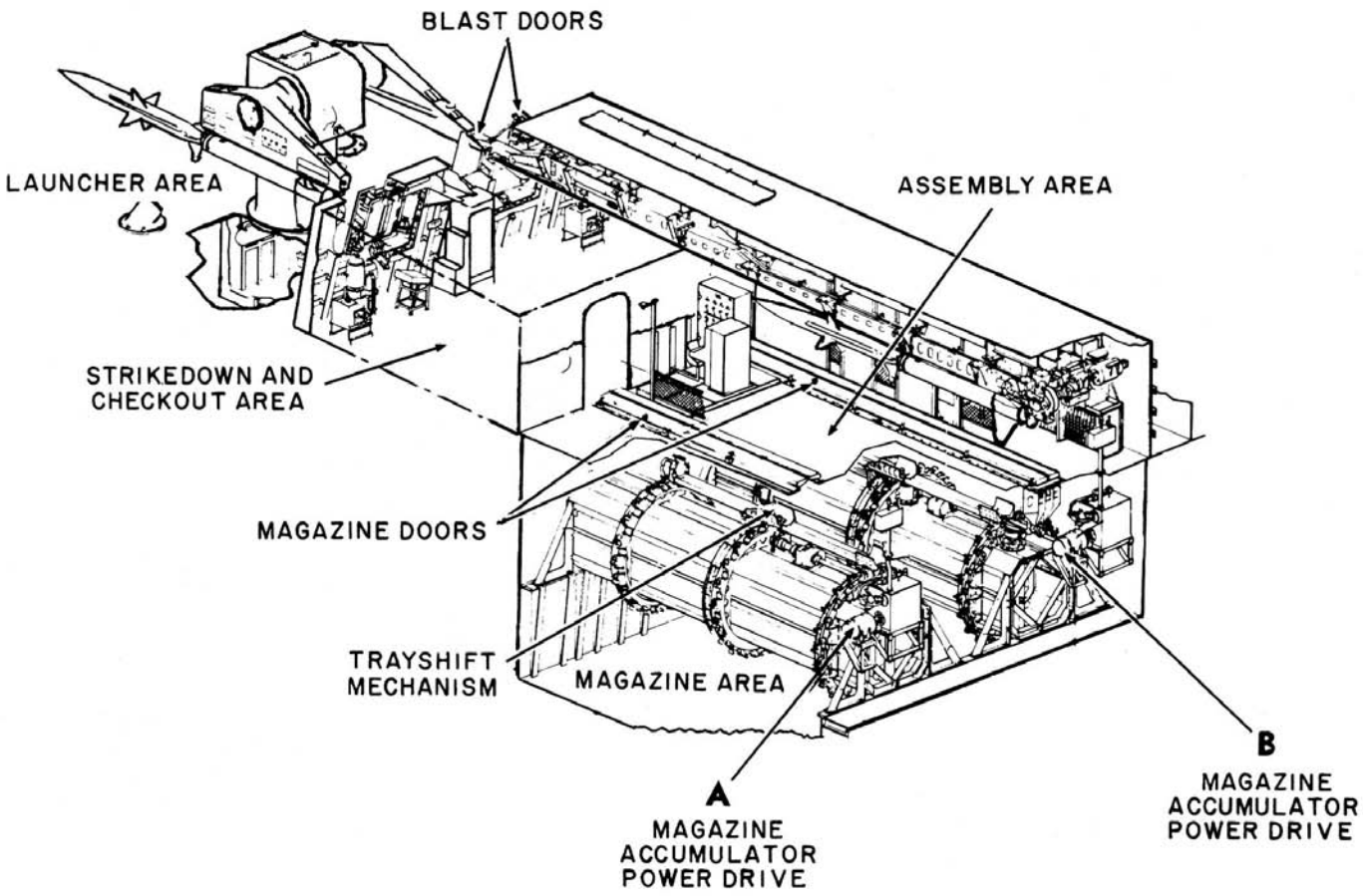


Figure 5-4.—GMLS Mk 10 Mod 0, General Arrangement.

The system is divided longitudinally into two independent halves, as is the Mk 10 system. The "A" side equipment is the starboard side and the "B" side is the port equipment. The two halves operate simultaneously or separately, each to supply the launcher arm on its side.

Instead of a loader to move the missile round from the hoist to the assembly area, the Mk 9 system has a rammer system. The missile round rides on the rammer rail, which is driven by a continuous sprocket-driven chain that engages the booster shoe on the round. The first stage rammer carries the round to the assembly area and the second stage rammer takes the round from the assembly area, after the wings and fins have been assembled to it, to the launcher. The two stages have separate and independent hydraulic drives located in the overhead above the loader rails. Warmup power is applied to the missile while it is on the second stage rammer.

Mk 4 Launching System

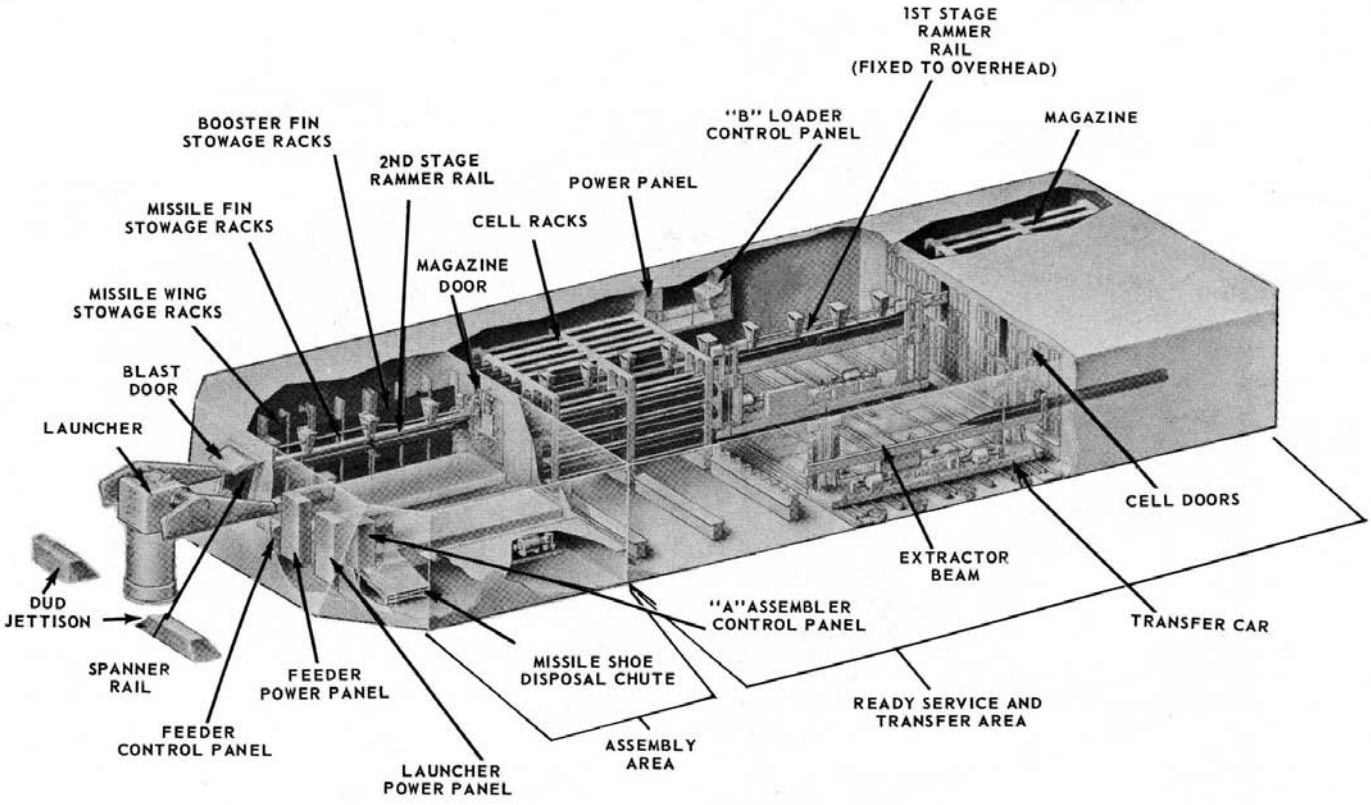
The Mk 4 launching system is installed on two CAGs, USS Boston and USS Canberra. At this writing both ships have been placed in an inactive status in the reserve fleet so the system will not be discussed. Figure 5-6 is presented, however, to show the method of missile stowage in the magazine.

Control Equipments

Control panels for various parts of the launching system equipment are shown in figure 5-1, 5-3, 5-4, and 5-5. Most of them are in the assembly area of the system, but the power panels usually are placed as close as possible to the equipment they supply.

Power panel EP1 and Control Panel EP2 (fig. 5-4) of the launching system are manned by the launcher captain. If it is necessary to

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Figure 5-5. — Guided Missile Launching System Mk 9.

use EP3 and Dud Jettison panels, a crew member is assigned. The EP1 panel is the basic power distribution system for all electrical power to the launching system. It contains switches, circuit breakers, fuses, relays, and contractors for the power and control circuits. The EP2 panel is the operations control panel for the system. It contains the switches and relays to select the type of operation wanted, lights to indicate the phase or sequence of operation, the position synchros for the launcher, and the amplifier for the train and elevation movements of the launcher.

The EP3 panel is primarily a test panel, and is not manned during normal launching activities. Various test equipments can be plugged into it, and it can also be used for local control of the launching system.

The number and the functions of control panels vary with the launching system. Some systems have many more control panels than the three mentioned above.

So far we have talked only about the control panels in the launcher-feeder area. Orders for the operation of these controls must come from a higher authority. The Weapons Control System controls all the weapons on the ship, including missiles, guns, torpedoes, rockets, and depth charges. It consists of the Weapon Direction System and one or more Fire Control Systems. Figure 5-7 shows a specimen weapon control station with typical equipments. The launcher and feeder system are controlled by the operator of the Weapon Assignment Console (WAC). The WAC operator selects the missile rail to be loaded and the method of loading (single or continuous), applies warmup power to the missiles, selects the number of missiles to be fired per salvo, and assigns the launcher to a fire control system; or he can cancel the launcher assignment. These orders are not the whim of the operator, but are based on the information supplied to him by the WAC and the other equipment in the station. The men below deck can't see the target; they depend on the radars above deck to locate and track the target, the

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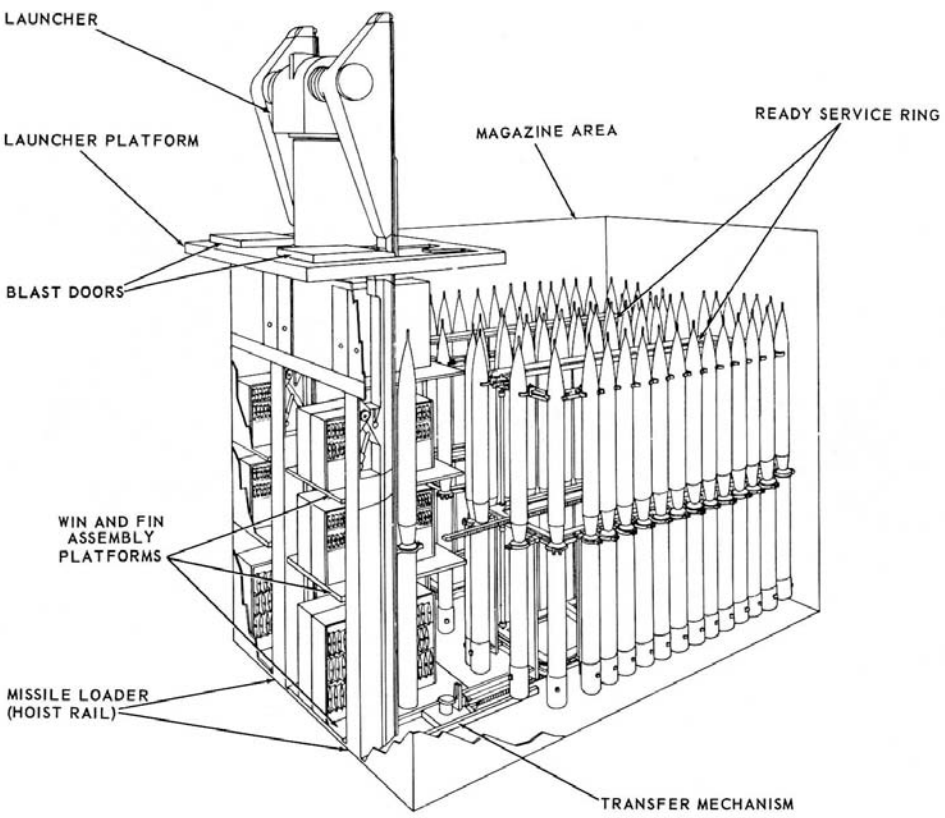


Figure 5-6.—Missile Launching System Mk 4.

computer to figure the angle of train and elevation necessary for the launcher so the missile will intercept the target, and signals from various equipments in CIC to transmit decisions and orders.

THE FEEDER SYSTEM

The feeder systems of the different Terrier launching systems may be seen in the illustrations of the launching systems; figures 5-3, 5-4, 5-5, and 5-6. The general arrangement of the magazines, the assembler, and the launcher may be seen in the illustrations. The placement of control panels may be seen in figures 5-3 and 5-4.

Location

When missile systems were first installed on ships, ships already in service with conventional firepower were converted for missile use. The deckhouse was made to house much of the feeder system. The magazines were placed below deck as much as possible for protection of the explosives.

New ships, designed and built to carry missile systems, provide space below deck for every thing in the system except the launcher. Figure 5-8 shows the location of launchers and feeder systems on three types of ships. Figure 5-8A shows the arrangement on the first ships converted to missile use-the USS Boston (CAG-1) and the USS Canberra (CAG-2). Each ship is equipped with twin launchers, which replace the aft 8- inch gun turrets. The two automatic vertical missile launching systems, one for each twin launcher, provide the means for stowing, handling, and loading 144 Terrier rounds. Originally designed for BW missiles, the equipments have been modified to take BW1 Terriers.

Figure 5-8B shows the arrangement on the converted light cruisers, the USS Providence (CLG-6), USS Springfield (CLG- 7), and USS Topeka (CLG-8). On these ships, much of the launching equipment is in the deckhouse, mounted aft,

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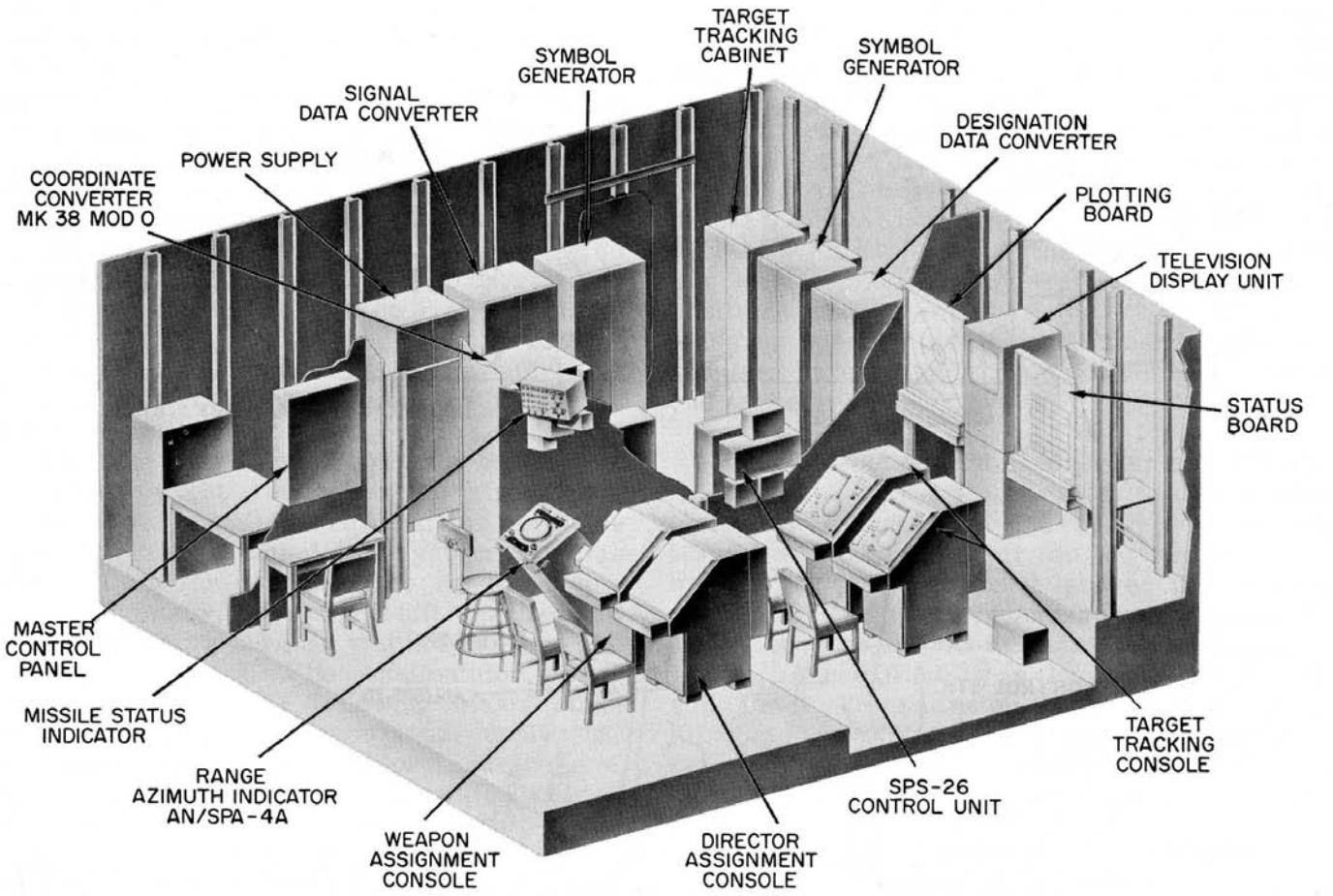


Figure 5-7.—Weapon Control Station (WCS).

with one twin launcher on the main deck. All of them have the missiles stowed in horizontal position.

Most of the ships carrying Terrier missiles are guided missile destroyers. The first of these, a converted DD, was the USS Gyatt (DDG-1), from which many lessons were learned in designing missile ships. Everything except the launcher is below deck. The dud jettison unit is mounted to the deck, but its control panel is below deck, as is the power supply. Figure 5-8C shows the location of missile system major components on a destroyer class ship. All of them use the Mk 10 launching system, varying in the mods used.

The Navy also has some missile frigates and these, too, carry the Mk 10 launching system installation. Carriers, too, have the Mk 10 Terrier system as part of their missile armament.

Components of Missile Magazine

Of the four major components of the feeder system, we've already given most attention to the missile magazine, its type (ready service ring or cell; vertical or horizontal stowage), and its location with regard to the launcher on different ships. Let's turn our attention now to other components.

POWER SUPPLIES. - You realize that considerable power is necessary to turn the ready service ring loaded with large, heavy missiles. We've mentioned a power panel that supplies electric power. In figure 5-3, locate the EP1 panel in the assembly area. In figure 5-4, locate the A magazine accumulator power drive and the B magazine accumulator power drive. Where there is an accumulator, there is hydraulic power. Figure 5-5 points out the power panels

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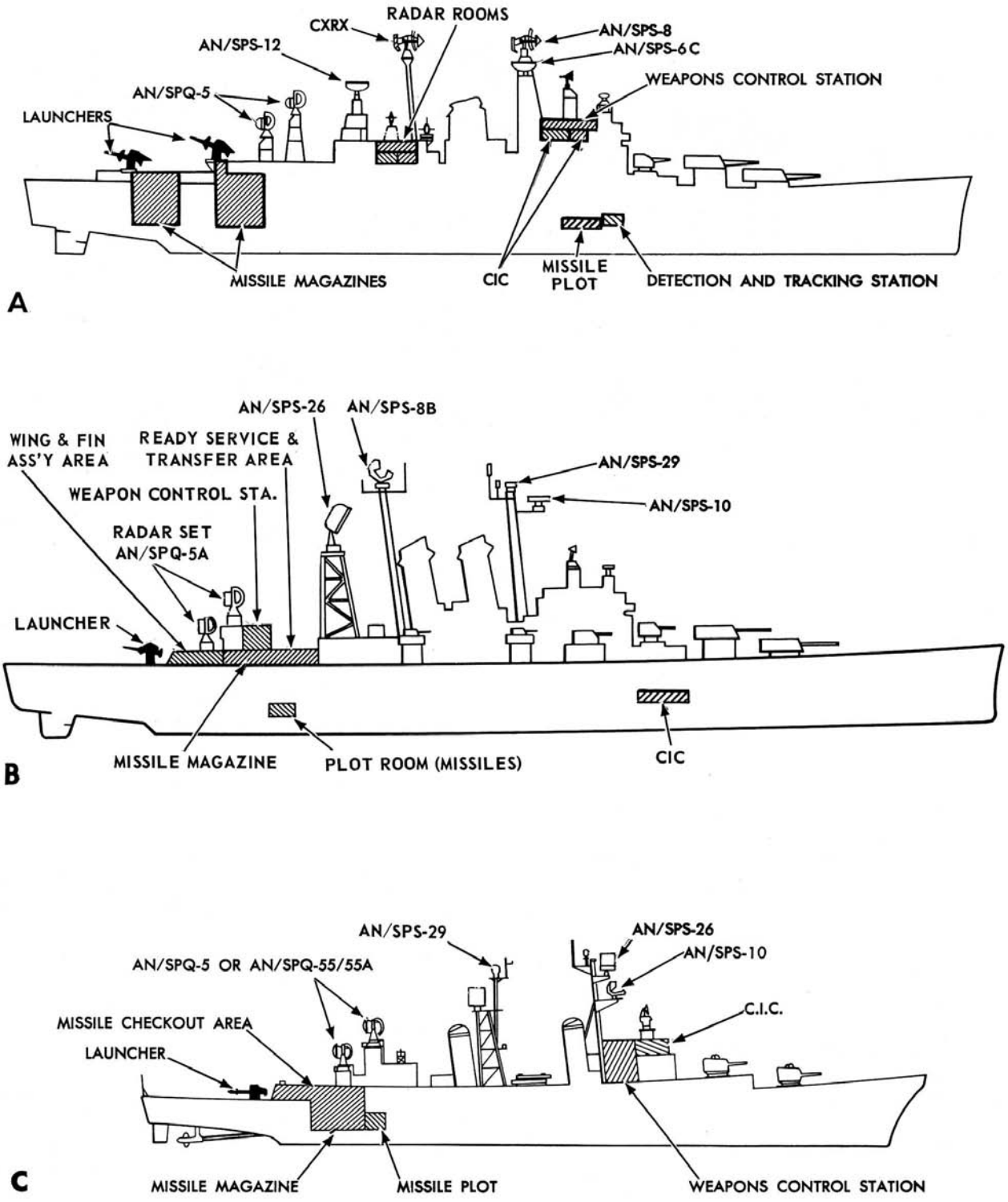


Figure 5-8.—Terrier Missile System Installations: A. On CAG (Terrier); B. On CLG (Terrier); C. On Destroyer Class Ship. 141.4-.6

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for the feeder, the launcher, and another panel in the transfer area. These panels provide electric power supplied from the ship's electric power supply.

Hydraulic power is used to rotate the ready service rings: (1) to move the tray shift mechanisms that move the missiles from the trays in the ready service ring to the hoist; (2) to open the magazine doors to permit missiles to pass from the magazine (or return to it); and (3) to operate the hoist mechanism that carries the missile from the ready service ring tray to the loader-rail.

The magazine accumulator power supply system is located on the bulkhead near the ready service ring booster (aft) bearing assembly (fig. 5-4). The four accumulators for the system are located on the ready service ring truss. Separate power supplies are used for each side (A and B). The accumulator system supplies hydraulic fluid for operating the ready service ring drive motor, the tray shift mechanism, the magazine hoist, the load status recorder, and the magazine doors. The accumulator power system consists of the following major components: electric motor, piston pump, supply tank, header tank, control valve block, and accumulators. A conventional B-end hydraulic motor is used. (See Fluid Power, NavPers 16193-B for review of hydraulic motors and valve blocks.) Directional valves control the hydraulic fluid flow so the ready service ring can be turned clockwise or counterclockwise as desired. A power-off brake makes it possible to move the ready service ring manually, which may be necessary during repair.

In the Mk 9 system, hydraulic fluid and power are supplied to the first and second stage rammers, the blast and magazine door mechanisms, and to the rail operating fixtures such as latches and positioning pistons. The launcher power panel Mk 180 contains the circuit breakers, contractors, and overload relays for the launcher power drives. The Feeder Power Panel Mk 183 contains the circuit breakers, contactors, and overload relays for the feeder system motors. They are activated by the launcher captain at the beginning of operations and are then left unmanned. They are located in the after area of the deckhouse.

TRAY-SHIFT MECHANISM. - The ready service ring rotates to bring the selected missile to the loading position at the top, but there must be some means of transferring the missile from the tray that holds it in the ready service ring. This device is the tray-shift mechanism. The tray-shift mechanisms are hydraulic-mechanical devices (fig. 5-9) that shift the weapon and tray as a unit, disengaging the weapon shoes from the ready service ring and engaging them on the hoist. Two tray-shift mechanisms are mounted on each ready service ring, one at each transfer station. Each Terrier has forward and aft shoes by which the booster is secured in the ready service ring. Each tray in the ring has three saddles with two clamp arms that fasten around the missile. When the tray-shift mechanism positions a tray for the hoist, the clamps release by opening the arms. The center and rear saddles have cutouts to receive the forward and aft hoists, respectively.

HOISTS. - The hoist mechanism can transfer a booster or a booster-missile combination (complete round) from the ready service ring trays to the loader rail (or the reverse when unloading). As mentioned above, the forward shoe hoist engages the center saddle and the aft hoist engages the aft saddle on the tray. Power is supplied by a hydraulic drive unit and lower transmission and an upper transmission and drive shaft. As the weapon is raised to the loader, a guide on the aft hoist head contacts the overhead trunk and assures alignment.

MISSILE TRANSFER IN MK 9 SYSTEM. - In the Mk 9 system, with its missiles stored in banks of fixed individual cells, another method must be used to get the missile out of its cell and move it to the assembler. A transfer car which runs athwartship on tracks carries the missile from its cell to the loader (rammer). An extractor beam on the car can be lowered or raised and it can extract a missile round from a cell or return one to it. After extracting the missile round, it deposits it on the overhead loader rail, or it can transfer it to the checkout area for checkout tests. The last named is a semiautomatic operation.

INTER-RING TRANSFER. - If the missile needed is not in the A or B side ready service ring, it is possible to obtain it from the reserve supply. In the Mk 10 Mod 7 system (fig. 5-10), this is in the single lower ready service mechanism. Other Mk 10 mods have two lower ready service rings and the Mk 9 has a rear bank of cells from missiles.

We've mentioned station 1 in discussing the tray-shift mechanism (fig. 5-9). In the upper ready service rings (fig. 5-10), there is a

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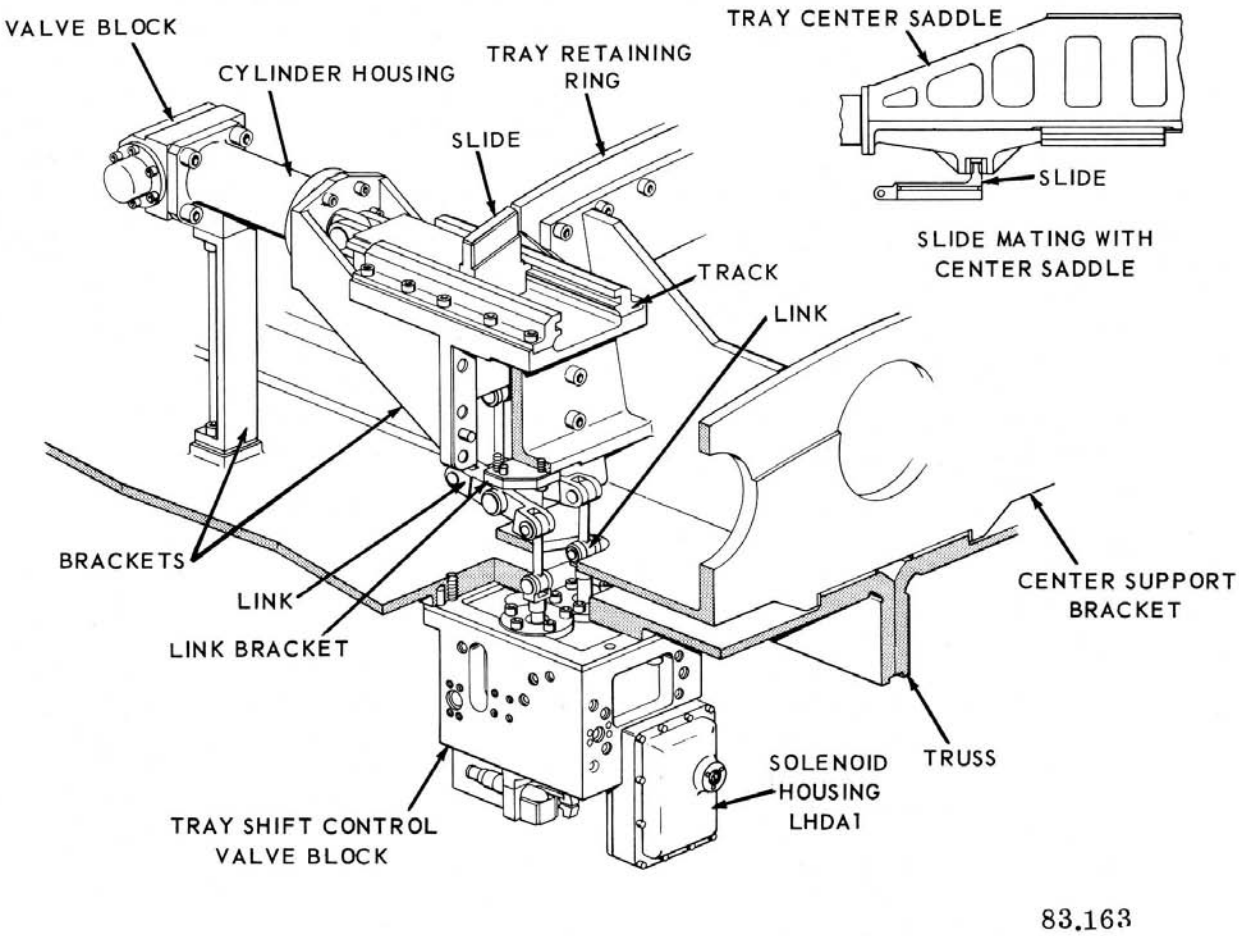


Figure 5-9.—Tray Shift Mechanism At Station 1 on ready service ring.

station 1 on both the A and the B sides, and missiles may be transferred to the loader from those positions. For inter-ring transfer, hoists are positioned to transfer between station 3 on the lower ready service ring and station 13 of the B side upper ready service ring. The other transfer point is between station 19 on the lower ready service ring and station 9 of the A side upper ready service ring.

The Mk 9 system uses the transfer car for this operation.

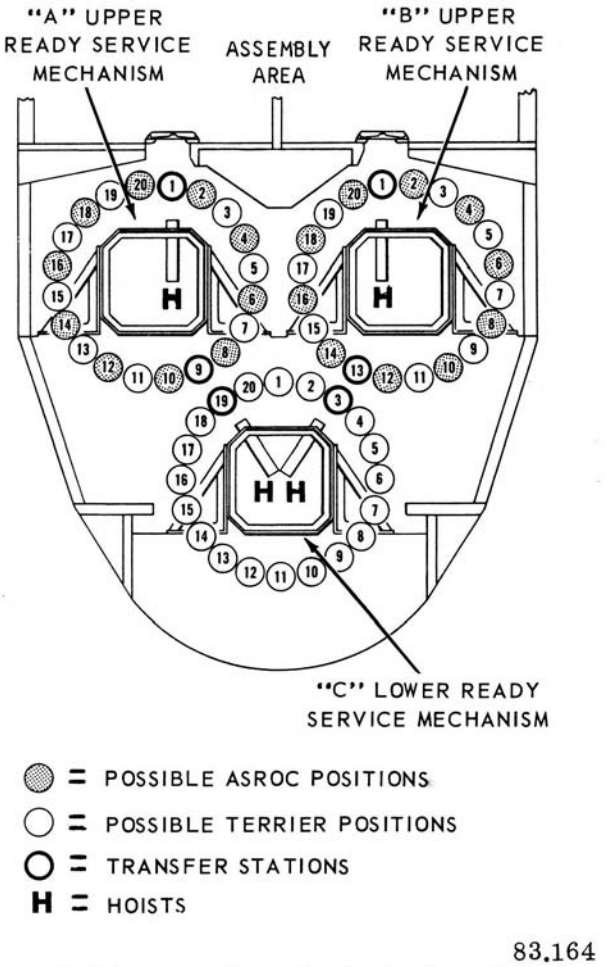
The Loader Components

The loader consists of duplicate components for the A-side and B-side assemblies. It supports and moves the weapons between the assembly area and the launcher or between the assembly area and the strikedown area. Each loader assembly receives a weapon from the magazine hoist, moves it into position at the assembler, and then moves it onto the launcher. It is also capable of returning individual weapons or adapters (from Asroc) for restowage, or to the strikedown area, where they are tested.

Major components of each loader assembly are the loader trunk assembly and two types of power drives. The loader trunk is made up of several sections; a tilting rail (Mod 8 does not have this), a spanning rail, a blast door, and numerous operational components (fig. 5-11). The tilting rail may be latched in the horizontal position or at an incline. In figure 5-11 it is shown in the horizontal position as it receives the missile from the hoist. It is latched in this position to transfer missiles to the strikedown and checkout area via loader trunk sections I, II, and III. To move the missile to the launcher, the tilting rail is tilted up to meet loader trunk sections VI, VII, and VIII.

The Terrier shoes and the Asroc adapter shoes slide on rail segments bolted to the underside of the trunk sections. A sprocket-driven loader chain travels in the chain track in the

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Figure 5-10.—Location of missile transfer stations on Mk 10 Mod 7 ready service rings (cross section of ship's hull).

loader rail. Power is furnished by the CAB- type power drive located in the overhead adjacent to the tilting rail.

LOADER PAWL CONTACTOR. - Missile warmup has been mentioned several times. The pawl contactor (fig. 5-12), a five-prong electrical connector, mates with the warmup contactor pad for Terrier boosters or with the identification contactor pad on the Asroc adapter rail. When the aft shoe of the weapon engages the loader pawl, the contactor is forced onto the booster or adapter rail pad. The five-pronged contactor completes the circuitry to the missile. The loader pawl contactor remains mated until the contactor on the launcher takes over, so the warmup is continuous. Vacuum tubes in the missile must be warmed up to operating temperature, and gyros must reach a stable spinning speed.

SPANNING RAIL. - The spanning rail (fig. 5-11) bridges the gap between the loader rail attached to trunk section No. VIII and the launcher guide arm. It is operated hydraulically. When the blast doors open to permit the assembled weapon to pass onto the launcher, the spanning rail extends to meet the loader rail and provides a continuous path for the missile. After the missile has passed through the blast doors and is on the launcher, the spanning rail retracts and the blast doors close.

All Mk 10 Terrier systems have a spanning rail of this type for each launcher. In the Mk 9 system, the spanning rail is a component of the second stage rammer and bridges the gap between the launcher guide rails and the fixed second stage rammer rail. As the blast doors open, the spanner rail rotates into position and latches to the launcher rails. Although the relative position is different in the Mk 4 system, the operation of the spanner rail is similar to that of other models.

BLAST DOORS. - The blast doors are blast-proof and watertight hinged doors that prevent the entrance of missile blast (when closed) into the feeder compartment. A pair of doors is mounted on the exposed bulkhead between each launcher guide arm (fig. 5-11) and the A- and B-side loaders. The two doors are mechanically coupled to the spanning rail, causing the doors to open when the spanning rail is extended and to close when the spanning rail is retracted. Interlocks prevent opening the doors when there is a missile on the launcher and a condition is set. The position of the blast doors is different in the Mk 4 system, but the purpose is the same and the operation is similar to that of other launching systems.

The second power drive mentioned at the beginning of the section on the loader is the one that operates an accumulator-type power drive. It is located in the strikedown and checkout area. It supplies hydraulic power to operate the spanning rail, the blast doors, the tilting rail, the floating tracks, and the other loader components, such as latches and positioning pistons. The floating track mechanisms are located on the tilting rail to engage the missile shoes, fore and aft. The floating nature of these rail segments assures positive alignment between the loader and the hoist.

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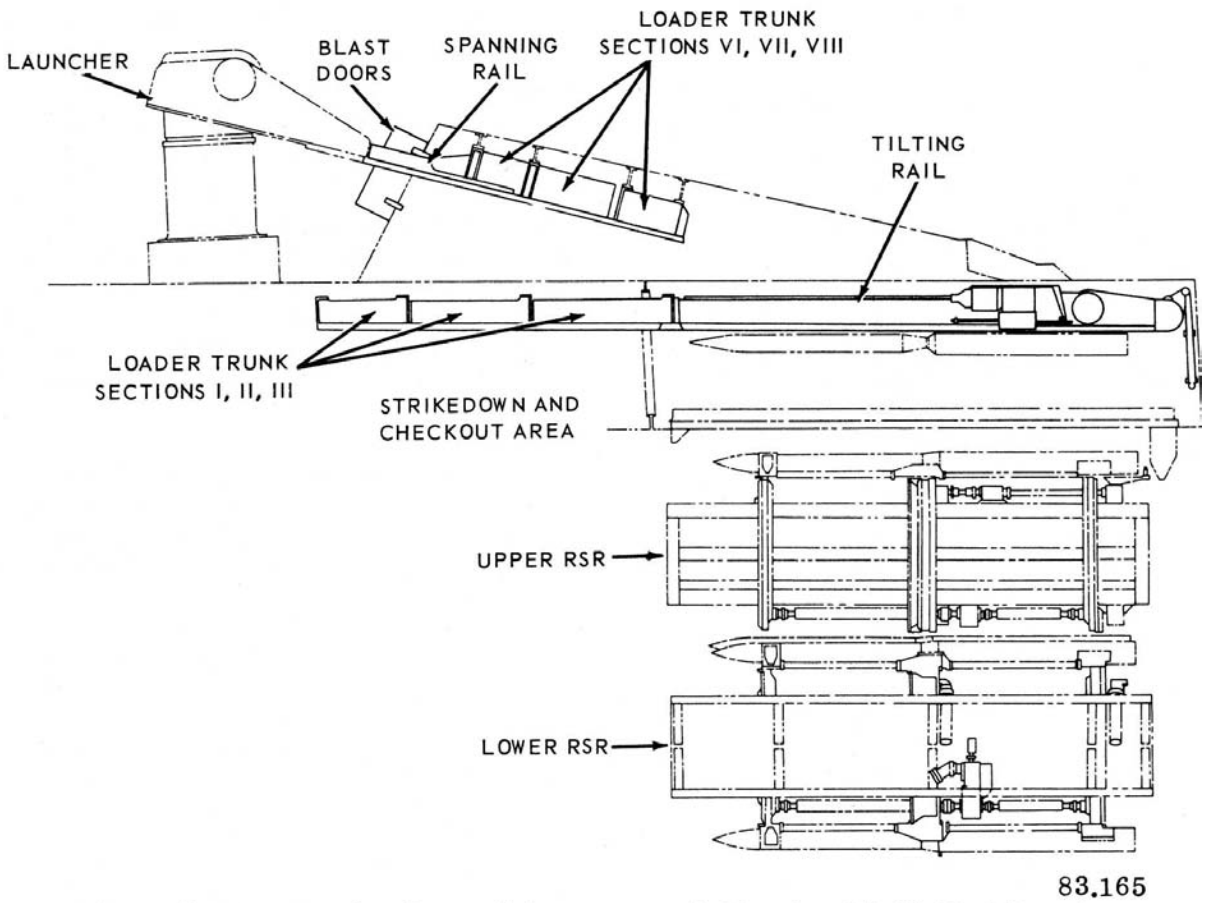


Figure 5-11.—Loader General Arrangement, Terrier Mk 10 Mod 7 system.

The Assembler and Assembly Area

The assembler consists of stowage racks for the wings and fins that are to be assembled to the missile in the assembly- area. The older missiles, the BW type, had to have wings and fins attached, and fourteen assemblymen were required to man the assembly area. Only six men are needed for the BT3 missiles. Figure 5-13 shows the arrangement of the assembly area in the Mk 10 Mod 7 system, which also requires sixteen men, though only six per side (A and B) do the assembly work. It is located directly above the magazine area. Terrier booster fins and Asroc motor fins are stowed in the fin racks, arranged on each side of the loader for easy access. Each man has a safety foot switch which he presses after he has completed his portion of the assembly job and has stepped behind his safety screen. All six assemblymen must have their safety switches depressed before the missile can be moved. If both sides of the launcher are being loaded, simultaneously, there are twelve men, each with a safety switch to depress when he has "finished his work and assumed a safe position. Some foot switches have recently been deleted and twelve men are no longer required in systems with this change.

If the weapon is to be armed, this is done in the assembly area.

If a missile is being returned to the magazine, the removable fins are removed and stowed; the folding fins are folded; and the missile is disarmed in the assembly area before it is allowed to move on to the magazine area.

Strikedown and Checkout Equipment

In the strikedown and checkout area, testing and handling facilities are provided for missile checkout, maintenance, servicing, warhead substitution, and booster or rocket inspection. A checkout car that operates on rails is used when performing tests, checks, and adjustments. The area contains: (1) a guided missile test set (AN/DSM-23), (2) a hydraulic fluid pumping

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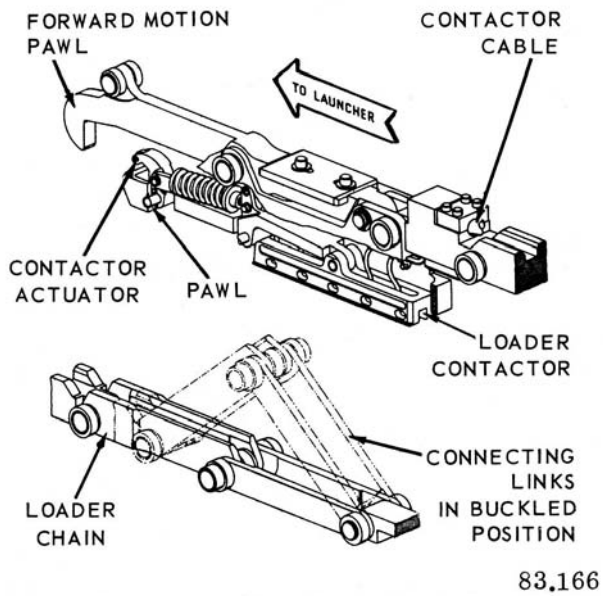


Figure 5-12.—Loader Chain Pawl Assembly, showing contactor parts.

unit (HD-259/DSM) for filling and flushing the hydraulic system in the missile and for operating the hydraulic system while testing the missile; (3) a compressed air supply; (4) radar test sets; (5) Dynamic Tester Mk 32 and Error Recorder Mk 9, for testing the computing and recording the results; (6) an operations event recorder which is a pen-tape recorder to mark on tape as the missile checkout is conducted; and (7) a photographic recorder which automatically photographs dials of the testers as the missile tests are conducted.

The testing of the missiles is done by other ratings, but you must transfer the missiles to the checkout area, and prepare them for the tests, then return them to the ready service ring. The operator at the control panel follows the step Control procedure to bring the missile to the checkout area. The steps are listed in the proper sequence in the OP for your equipment.

The checkout cars are also used for inter- ring transfer of missiles. Strikedown procedure is used, and the steps listed in sequence in

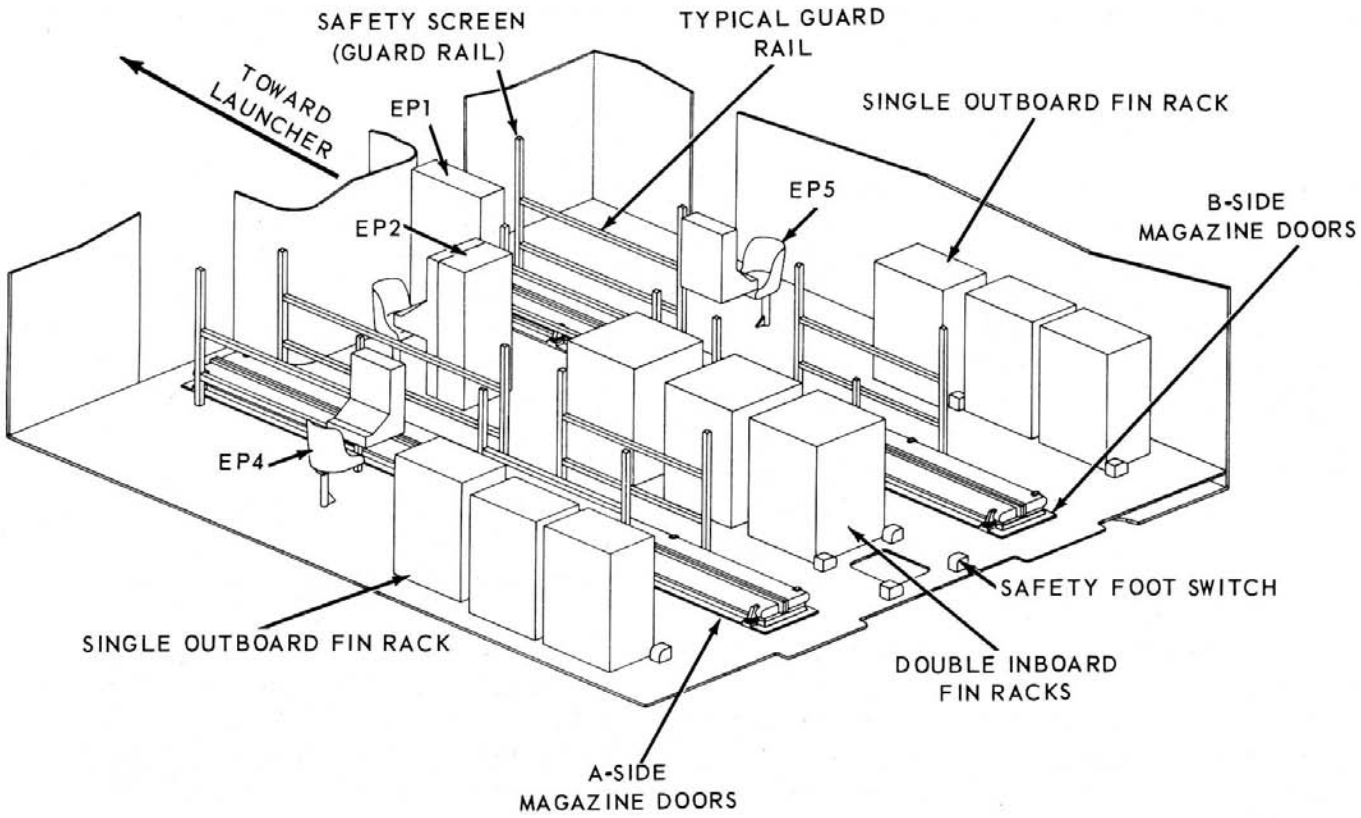


Figure 5-13.—Assembler, perspective view.

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your OP must be followed. The Asroc is transferred without its adapter, but the tray to which it is transferred must have an adapter in it. Asrocs cannot be loaded in adjacent trays but must always have a Terrier or an empty tray between them. An Asroc with its adapter rail is shown in figure 5-14. When an Asroc is prepared for launching, the adapter is removed from the launcher guide arm after the missile is fired, and is returned to the tray in the magazine. As it is returned through the assembly area, the assemblymen must re-snub the snubbers and check the electrical cable.

THE LAUNCHER

All Mk 4, Mk 9, and Mk 10 launching systems use the Mk 5 launcher, but there are different mods. This means that there are differences but not great differences.

The launcher is a dual-rail mount that receives, aims, and fires single rounds or two- round salvos in accordance with signal orders received from the weapons system. After launching a weapon (or weapons), the launcher automatically returns to its load position, ready to receive the next ordered weapon or to return a weapon to the feeder for stowage. If an Asroc -was fired, the launcher must first return the adapter rail before it is ready to receive another missile. It is only the Mk 10 Mods 7 and 8 that can handle Asroc as well as Terrier missiles. The launcher is Mk 5 Mods 8 and 9. All mods have two guide arms but there are differences in the degrees of train and elevation possible. This is due in part to the location on the ship, for the launcher must never be pointed where a missile could strike any part of the ship.

Components

The main components of the launcher are the stand, carriage, power drive assembly, guide and guide arms, and the train and elevation system. (See figure 5-15.) Each of these is composed of many mechanisms and parts.

STAND. - The stand is a heavy circular steel weldment flange-mounted to the deck of the ship in a fixed position. The stand supports the carriage and the guides.

CARRIAGE. - The carriage is the rotating portion of the launcher. It is mounted within the stand. The electrical, mechanical, and hydraulic equipments for operating the launcher are mounted in it. The two principal parts of the carriage structure are the base ring and the trunnion support. The base ring is bearing mounted in the stand. The bearings permit horizontal movement in train. The trunnion support, a box-like weldment, is secured to the top of the base ring, and is exposed above the stand. Within it is the trunnion tube which supports the guides.

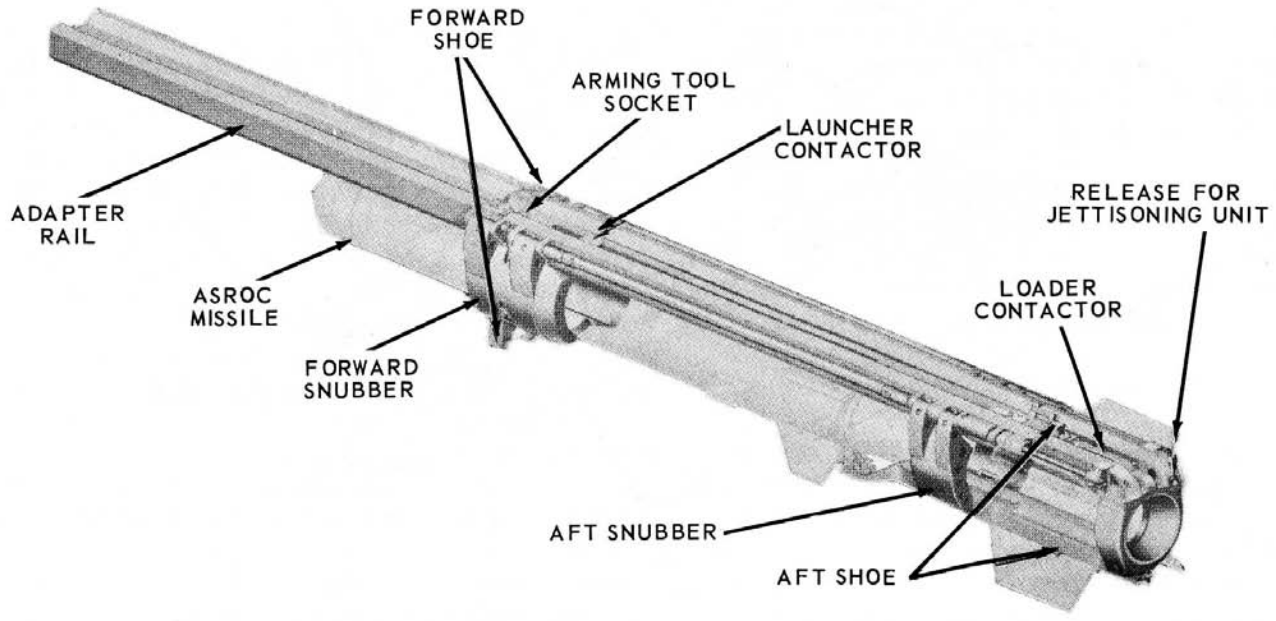


Figure 5-14. — Asroc adapter for use in Mk 10 Mod 7 launching system.

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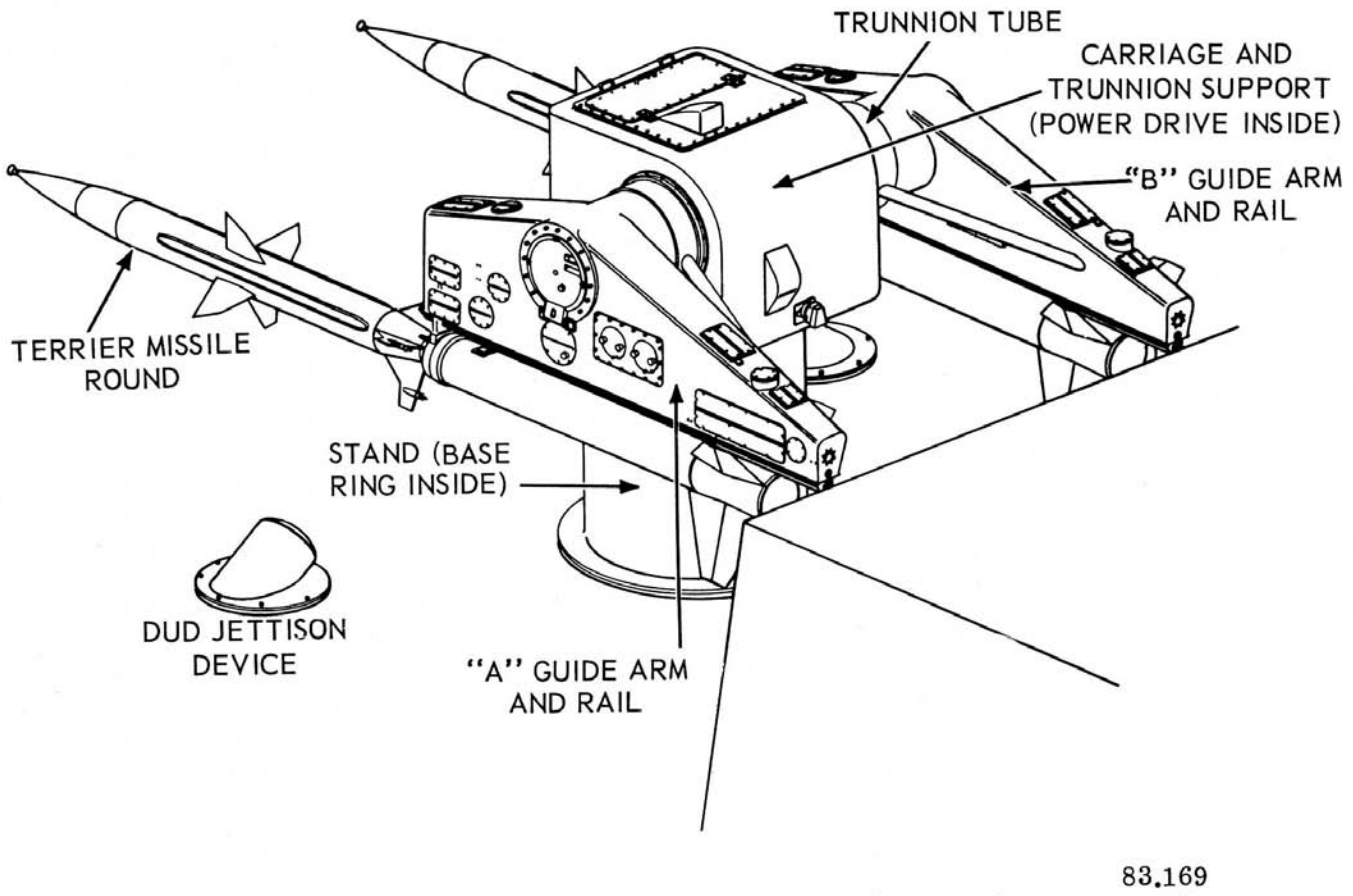


Figure 5-15. — Guided missile launcher Mk 5 Mod 3, general arrangement.

POWER DRIVE ASSEMBLY. - The power drives for operation of the launcher are mounted inside the carriage. Control orders are fed to the power units from the ship's fire control system.

Power Drive Assembly Mk 46 Mod 1 consists of two separate electric-hydraulic systems. One system operates the train system and the other operates the elevation system. The train and elevation systems position the weapons for firing by rotating the carriage (in train) and the guides (in elevation) as directed by orders from a computer in the Weapons Control Station (remote control).

Each system operates independently, but they synchronize their movements to place the weapon in the desired position for firing. They may be operated locally from an electrical panel at the launcher, but this is only for exercise and test, not for firing.

A third power drive, much smaller than the others with a small electric motor and an accumulator, is mounted in the right-hand corner of the trunnion support and supplies power to the guide arm components that position and retain the weapon on the guide arm, provide external warmup power to the weapon, and arm the booster. An electrical device ignites the booster.

A hand pump is mounted in the left side of the carriage to provide a means of operating the guide arms and the components of the train and elevation latch in case of power failure or during maintenance operations.

GUIDE AND GUIDE ARMS. - The launcher guide consists of two arms, a trunnion tube, a gear segment called the elevating arc, and a buffer actuating arm. The A- and B-guide arms are fastened to opposite ends of the trunnion tube, which is horizontally mounted through the carriage trunnion support.

The elevating arc is fastened to the trunnion tube and is inside the trunnion support. Elevation

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bearing assemblies located at each end of the trunnion tube allow the elevation movement of the guide arms.

The launcher guide arms are movable in two planes: in the training movement and in the elevating movement. They rotate with the carriage in train, and about the trunnions in elevation. The power is supplied by the train and elevation power drives.

TRAIN AND ELEVATION SYSTEMS. - The train and elevation power drives mentioned above are the main parts of the train and elevation systems. The elevation arc is one comparatively small part of the elevation system. Other parts of this system are the pinion gear (to mesh with the elevation arc), reduction gear assembly, elevation brake, latch, positioning valve, latch- control valve block, elevation and depression buffers, buffer accumulator, firing cutout mechanism, and ventilation power unit. The train system has similar components plus the training circle. The training circle is a heavy gear mounted in the stand. Figure 5-20 shows the training circle for a Talos; for the Terrier, the chief difference is in dimensions.

Each system receives and responds independently to order signals. The principal function of the receiver-regulator and servoamplifier in each unit is to convert electrical order signals into hydraulically powered mechanical movements. These movements control the velocity, acceleration, deceleration, and position of the launcher carriage and the guide arms.

Dud Jettison Unit

A dud jettison unit is associated with each Mk 5 launcher. Its purpose is to rid the ship of a dud missile by tossing it overboard from the launcher without firing the booster. Dud missiles usually are not jettisoned unless there is danger to the ship and personnel.

Dud Jettison Unit Mk 108 Mod 0 consists of two ejectors, mounted to the deck, and a control panel located below the deck near the launcher support, One ejector is located on the starboard side of the launcher and the other on the port side. Figure 5-15 shows the deck appearance of the unit when not in use. Figure 5-16 shows its mounting in cross section and its relation to the launcher when aligned for use.

When it has been determined that a missile must be jettisoned, the launcher is slewed into position to align the defective missile with the dud jettison unit. Launcher control is transferred to the jettison control panel. The ejector is a pneumatic cylinder with a disc designed to engage the after end of the booster nozzle. When the panel operator positions the handle to jettison on the control panel, the missile is pushed from the launcher by a quick thrust of the ejector.

LAUNCHER CONTROL

The launcher is controlled by the following five methods: remote control, local control, dud jettison control, load-order control, and test control. These are also called modes of operation.

Normal operation of the launcher is by remote control from the Weapons Control Station (fig. 5-7), by electrical signal through the control panels there. Remote control is normally used for target tracking and is also the only method used for weapon firing.

A local control station is provided in the launching system for exercise and routine maintenance. This is also called step control because each move in the system is activated by pushing a button on the control panel. Figures 5-3 and 5-13 show the location of a number of the control panels in the launching system. After the EP1 power panel is activated, it is not manned. The launcher captain then stations himself at the EP2 operations panel. During automatic operation, he monitors the panel, quickly reporting anything that seems wrong. In step operation, he pushes the buttons in the required sequence to perform the loading or unloading operation as needed.

The EP3 panel is primarily the test panel and is not manned during normal launching activities. It can also be used for local control.

EP4 and EP5 panels (A-side and B-side) control assembly, strikedown, checkout, and inter-ring transfer.

Before the dud-jettison panel can be used, it must receive an electrical signal from a preset synchro in the EP 2 panel, which synchronizes the launcher with the dud jettison units.

Load-order control automatically returns the launcher to the "Load" position after the weapons have been fired from both rails. It is provided by means of an electrical signal from a preset synchro in the EP2 panel.

The EP3 panel contains the switches and jack connections necessary to perform tests on the launcher train and elevation systems.

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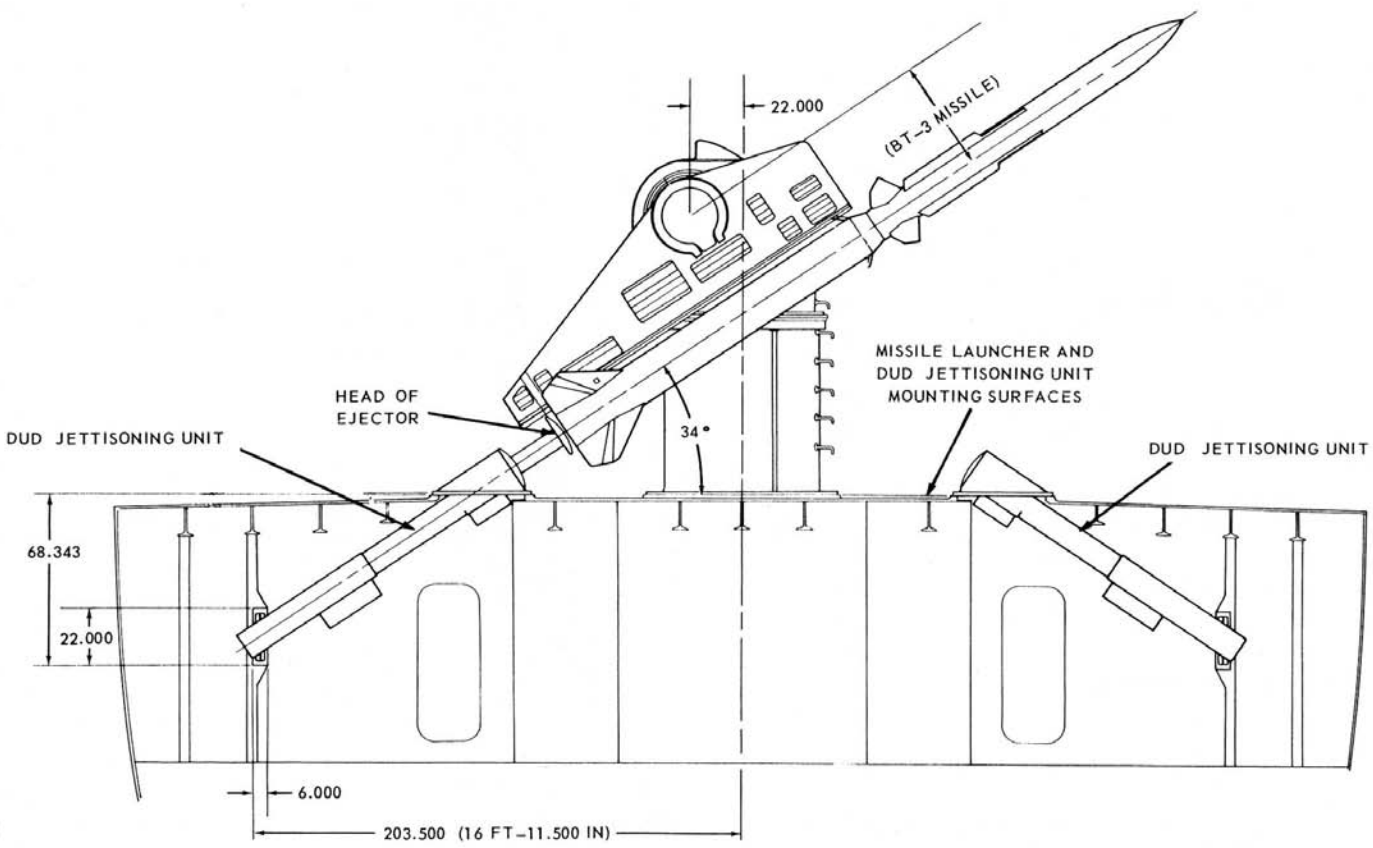


Figure 5-16.—Dud jettisoning unit Mk 108 mounted for DLG Terrier launching system Mk 10.

Dummy directors, signal generators, oscillographs, and other test equipment may be plugged into the EP3 panel. The test order signals originate in the dummy director. Chapters 13 and 14 describe testing.

Manual control is possible when all other types of operation fail, or for installation, maintenance, and checking purposes. Hydraulic handpumps, handcranks, and air motors are used, and operation of the launching system components is quite slow.

We've talked a good deal about control panels in this chapter. Your quals require you to be familiar with the work at all stations in the launching system which includes control panel stations. Figure 5-17 shows the face of the assembler control panel which is manned by the assembler captain. Each button or lamp is labeled; in automatic control the assembler captain does not operate the panel but watches the lights to see that they light up in proper sequence, so he can notify the launcher captain if anything is not right. When all the assemblymen have completed assembly or disassembly and have depressed their switches, the Wing and Fin Assemblers Clear light goes on indicating that all is clear for the weapon to be moved on to the launcher (or returned to the ready service ring). The ring of 20 lights represents the 20 spaces in the ready service ring. The lights are color coded to indicate the type of missile assigned to each station in the ready service ring. On the Mk 10 Mods 7 and 8 Launching System there is a second ring of light to represent the lower service ring, but those lights do not go on unless there is inter-ring transfer of weapons. In local control or step operation, the assembly captain

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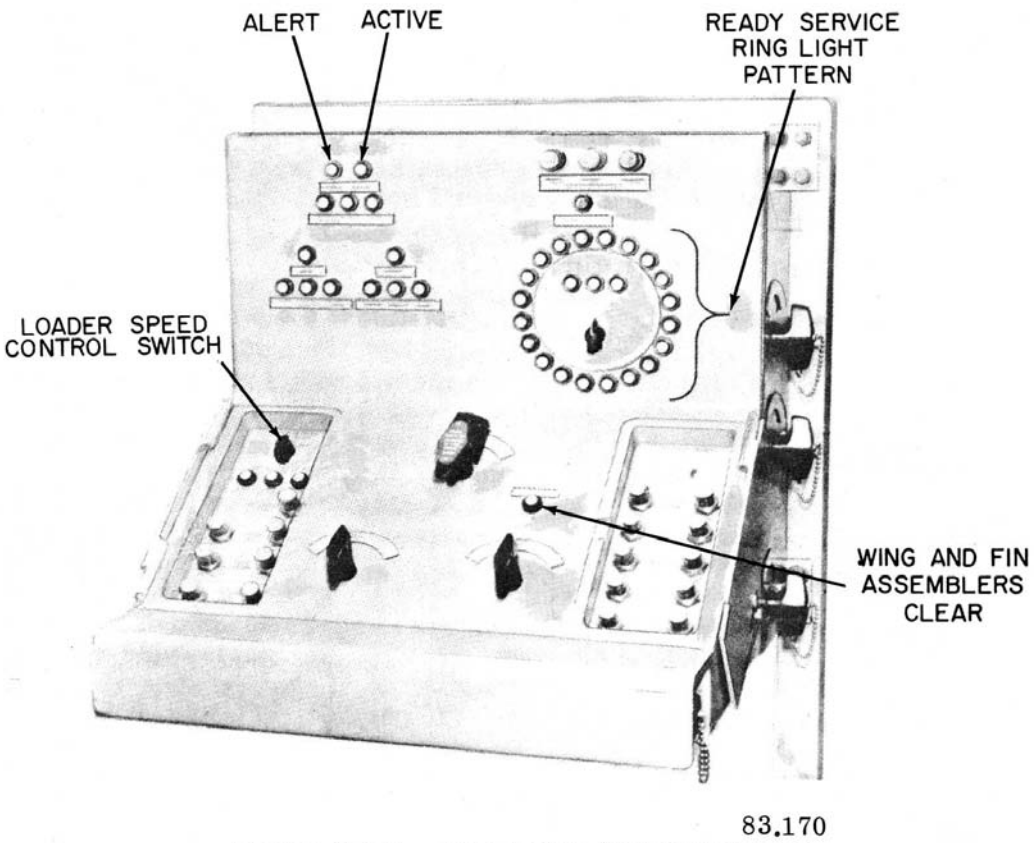


Figure 5-17.— EP4 (EP5) Assembly Panel.

must have before him the step-by-step instructions for operation of the assembler panel. These are in the OP for the equipment and should also be posted beside the panel.

The assembly panel shown in figure 5-17 is a combination strikedown, checkout, and assembly captain's control panel. EP4 is the A-side panel, and EP5 is the B-side panel, identical except for switch and light designations.

LAUNCHING SYSTEM OPERATION

As modes of operation, automatic control and step control have been mentioned several times. With the Mk 10 Mods 7 and 8 launching systems, we also have to consider the Asroc mode of operation and the Terrier mode.

Load Orders

Which mode of operation is to be used and which weapon is to be loaded must be decided before any launching system operation is undertaken. Load orders of the following types may be transmitted from the weapons control station:

1. Missile order-type of round(s) to be loaded.
2. Load select - simultaneous operation of A and B sides, or separate operation of either A or B side.
3. Loading order - hold, single, or continuous loading of the type of missile ordered.
4. Unloading order - unload launcher or unload assembly area.

If the load order (item 3) is for "single", the launching system proceeds to load one missile and then stop until further orders are received. If the order is for "continuous", the system automatically continues to bring up missiles of the type ordered for the launcher, each time the empty loader pawl returns to the load position in the assembly area. If both A and B sides are to be loaded, both sides proceed to load their launcher.

Sequence of Operation in Automatic Mode

At the sounding of General Quarters, the launching system captain activates the EP1 power

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panel, takes his station at the EP2 panel, sets it up for" step" operation, starts all motors, and then turns his ready switch to "Standby." This indicates to the EP4 and EP5 assembly captains and to the weapons control station that the launching system is activated and is at standby.

When the alert signal is given by the weapons control station, the" Alert" signal light flashes on the EP2, EP4, and EP5 panels, and an audible alert signal sounds.

The launching system and assembly captains signal the weapons control station when their crews are ready. The weapons control station signals what type of weapons are to be loaded, and the missile order signal lights on the EP2 panel.

ASROC MODE OF OPERATION. - If the signal is for an Asroc weapon (Mods 7 and 8 can handle Asroc), the launcher captain checks to be sure everything is clear and that there are no missiles outside the magazine. Then he presses the ASROC MODE button on his panel, which automatically switches the launching system. When the ASROC MOD E light becomes steady, the switching is completed and the launcher captain can press the LOAD button. Only one side can be used for Asroc loading and loading cannot be continuous. After a missile leaves the launcher, the adapter must be returned to the magazine. While the adapter is in the assembly area on its way back to the magazine, the fin assemblymen must close the snubbers and make sure that the umbilical cable is clear. The hoist then returns the adapter to its tray in the ready service ring of the magazine.

If another Asroc missile is wanted, another order is signaled from the weapons control station.

TERRIER MODE OF OPERATION. - On Mods 7 and 8, the launcher captain must switch to the Terrier mode after he has received the signal from the weapons control station that a Terrier missile is to be loaded. All other Mods handle only the Terrier, so this switching step is not necessary. Assuming that the system is activated and on Automatic, pushing the LOAD button starts the loading operation. The ready service ring rotates to bring the designated missile to the hoist station. Then the tray holding the round shifts to engage the booster shoes on the hoist. Simultaneously, the magazine door opens. The hoist raises the round to the loader rail. At this point the warmup contactor on the missile booster engages the electrical connector on the loader chain pawl and warmup power flows to the booster. The loader chain moves the round off the hoist and onto the loader rail, or tilting rail, which moves it to the assembly area. As soon as the hoist is free of the round, it lowers, the tray shifts back to its place in the ready service ring, and the magazine doors close. The ready service ring rotates to place another round at the no. 1 hoist station.

In the assembly area the crewmen attach the booster fins, erect the missile wings, then take safe positions and operate the safety foot switches. As soon as the assembler captain sees (on his control panel) that all the switches are closed, he positions his assembly ready switch to ASSEMBLED and the tilting rail can move on with the assembled round. As soon as the tilting rail elevates, the blast doors open, the spanning rail extends and the loader moves the Terrier onto the launcher rail. The loader chain pawl and its warmup connector disengage and retract from the round before the blast doors close.

The round is rammed onto the launcher where it is positioned and retained by the launcher positioning mechanism. Warmup power is applied through the launcher-booster electrical contactor. The arming tool extends. The train and elevation latches retract. As soon as the order is received from the weapons control station, the launcher synchronizes to the director signal, moving in train and elevation until the missile is pointed where ordered.

With a firing rate of approximately two rounds per minute, you can see that all the actions must take place very rapidly and in measured time sequences. If the wing and fin assemblymen, for example, were too slow in doing their work, it would disrupt the loading sequence. The next missile would have to be held at the no 1 station in the ready service ring until the way was cleared.

TALOS LAUNCHING SYSTEM

The Guided Missile Launching System Mk 12 is designed to stow and to launch all types of Talos missiles. The Mk 12 is made up of three major groups of equipment. Figure 5-1A shows a cutaway view of the Mk 12. You can

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see in a general way the three equipment groups and their physical location in relation to each other. The names of these groups are:

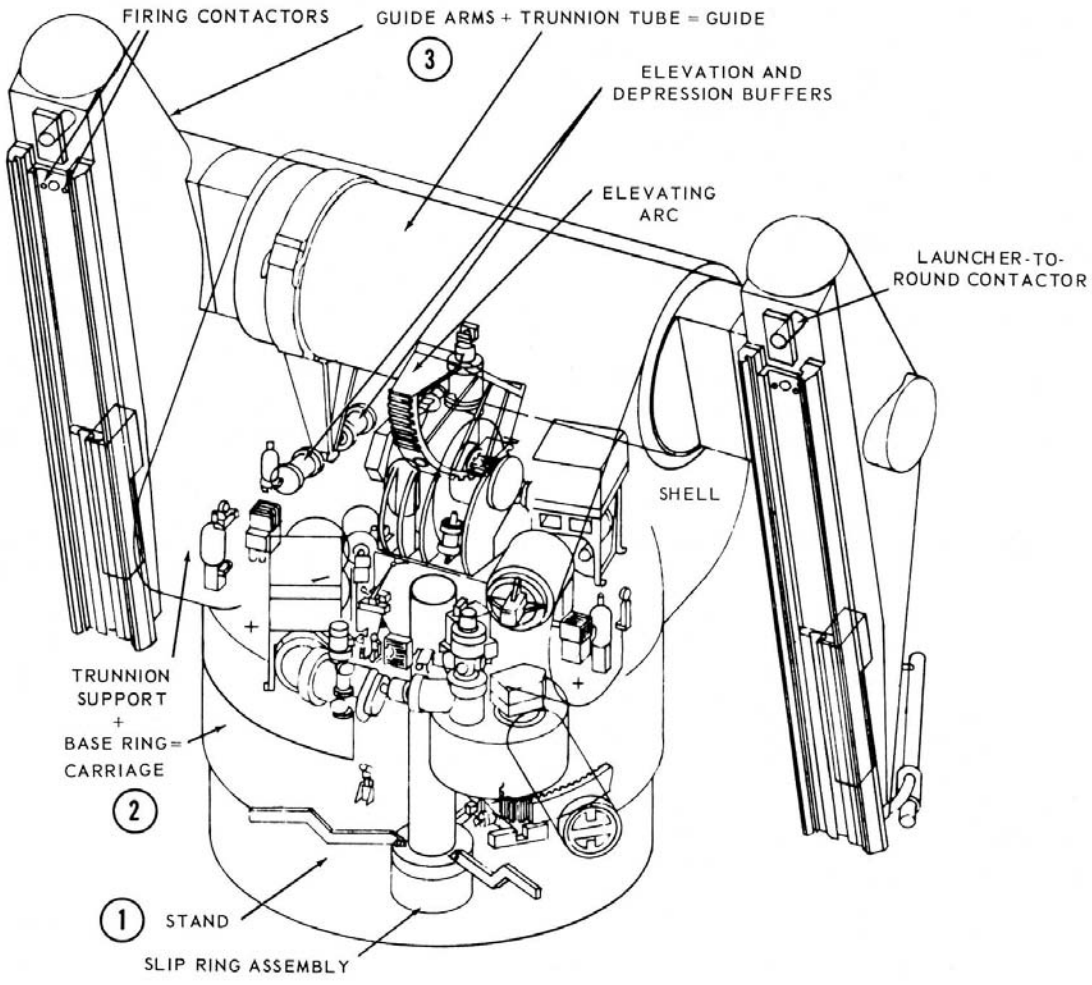
1. Guided Missile Launcher Mk 7. It serves as a launching platform for the Talos weapon. The launcher has two launcher guide arms which can be trained and elevated to point the missile at a capture beam.
2. Guided Missile Feeder Mk 11. This group of equipments provides for weapon stowage, for missile warmup, and for loading the weapons on the launcher.
3. Missile Launching System Control Mk 10. This group of units includes consoles and electrical devices and circuits to control and to monitor system operations. Now we shall take up each of these major equipment groups and explain what they do. We will use the Mk 12 GMLS to illustrate how they do it.

MISSILE LAUNCHER Mk 7

The Mk 7 launcher (fig. 5-18) is designed for installation aboard Talos missile ships. It is an automatically loaded, remotely controlled, dual-arm launcher which provides a launching platform for all types of Talos missiles. 1 We can consider the structure of the Mk 7 launcher as being made up of three major components:

1. A launcher stand which is a stationary structure.
2. A carriage which rotates (trains).
3. A launcher guide which also rotates (elevates).

The stand is a round metal structure which is fixed to the deck and forms a permanent foundation for the launcher. The carriage, which is bearing mounted on top of the stand, is capable



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Figure 5-18.—Main parts of the Talos launcher (Mk 7).

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of unlimited train. Electric, hydraulic, and mechanical gearing devices used to rotate the carriage are mounted directly within it. The carriage itself is composed of a base ring section and a trunnion support section.

The major components of the launcher guide are the trunnion tube and the guide arms. These components form an H-shaped assembly. The trunnion tube is a shaft that is common to both arms and extends through the trunnion's support. The trunnion support is bearing mounted to the carriage. Rotation of the trunnion tube elevates and depresses the guide arms as the elevating arc moves up or down. Electric, hydraulic, and mechanical devices necessary for rotating the trunnion tube are housed within the launcher carriage.

Again consider the carriage. It houses the power drives for operation of the launcher. Control orders are fed to the power drives from a selected fire control computer. When the launcher is loaded and assigned to a fire control system, it is controlled by orders from a remotely located missile fire control computer. When the launcher is released or when both rails are empty, launcher control is transferred from remote control to fixed load order signals from load control transmitters in the launching system. Under control of these fixed signals, the launcher returns to and latches in the load position.

The train and elevation systems are electric-hydraulic power drives. The train system (fig. 5-19) rotates the launcher carriage; the elevation system (fig 5-19) rotates the launcher guide. These systems operate independently but simultaneously for synchronized operation of the launcher.

Components of the launcher guide prepare the missiles for flight, and arm and ignite the booster. The guide power drive operates the guide components. It is an accumulator type of hydraulic unit that operates the arming devices, the warmup contactors, the aft motion latches, and the emergency igniter injectors. The booster, as you learned in chapter 3, is ignited electrically.

The launcher guide components function independently of the train and elevation systems but are interlocked with them to ensure proper loading and safety during firing.

The launcher functions as part of the guided missile launching system and also as a part of the fire control system. When empty, the launcher aligns with its feeder system and is loaded. When loaded, the launcher is isolated from its feeder and is under the control of the missile fire control computer (remote operation).

As the launcher follows a remote signal, its missiles receive external warmup power to prepare them for flight. When firing is ordered (upon closing the firing key) and all conditions (safety and missile functions) are satisfied, the booster is armed, the warmup contactor and the arming tool are retracted, and the weapon is fired by electrically igniting the booster.

In salvo firing, two weapons are fired from the launcher with a short time interval between firings. Only the S-type Talos weapons can be fired in salvos. Nuclear tipped (W) missiles are fired singly.

A weapon, as loaded onto the launcher, consists of a mated missile and booster with wings and fins installed (and missile arming devices if necessary): it is in a ready-for-firing condition.

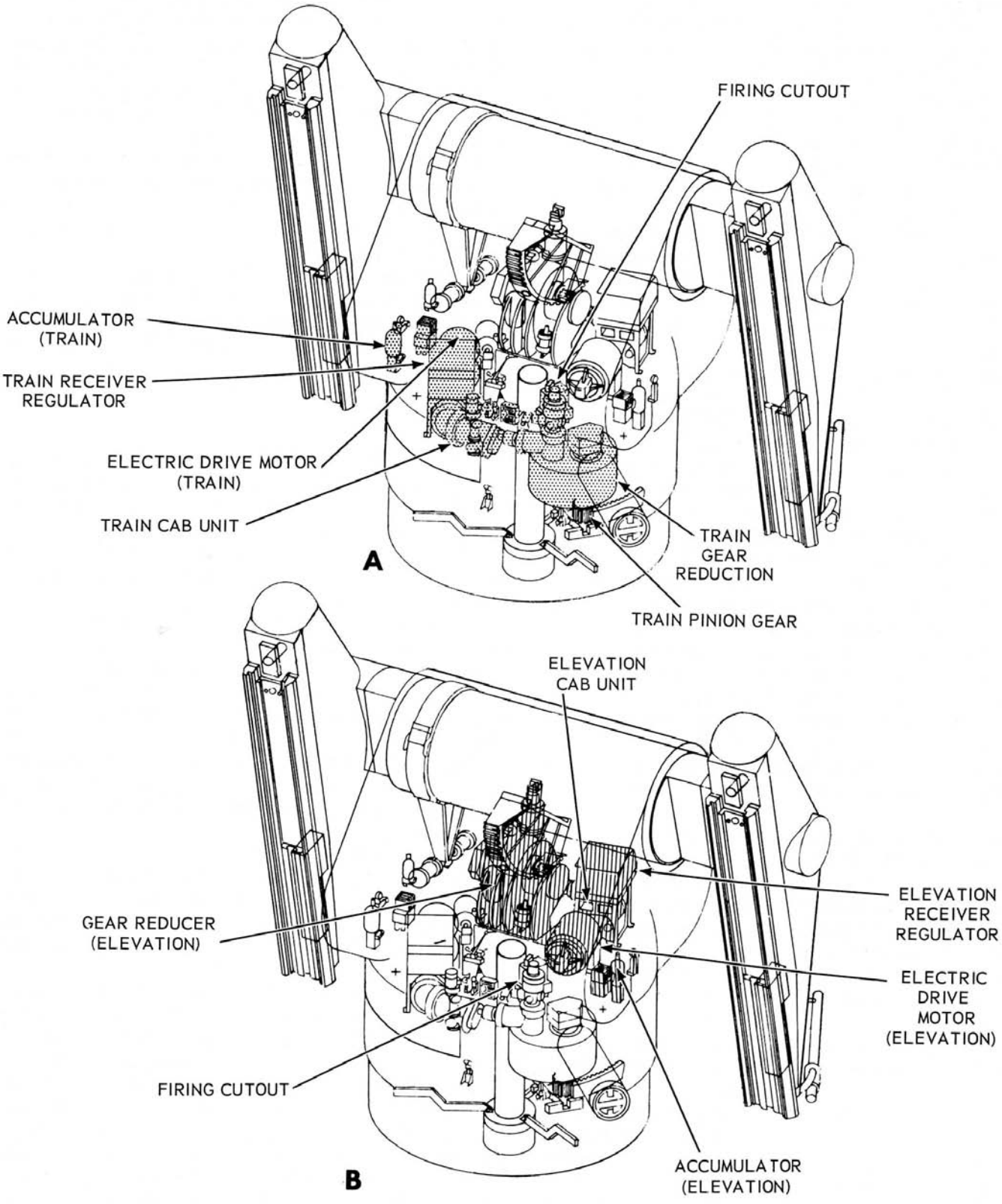
Stand

The stand (fig. 5-20) supports the carriage and guide. (The carriage and guide, when considered as a complete unit, are called the rotating structure.) The stand is a fixed round steel structure attached to the ship's deck. The carriage, together with the guide, is free to rotate on the stand.

A large ring-shaped internal gear is mounted inside the stand. This gear has many names. Some of these are: training circle, training rack, and train circle gear. A pinion gear engages the teeth of the training circle, so that when the pinion gear turns, it trains the carriage and thus the guide. Bearing assemblies are mounted in the stand to support the rotating structure and to reduce friction between the stand and carriage.

Figure 5-20 shows the major subassemblies of the launcher stand. A drilled flange on the inside bottom of the stand is used to bolt it to the ship's deck. (You won't see the drilled holes in the illustration because the photograph was taken before any holes were drilled.) Now locate the upper thrust bearing assembly, sometimes called the main thrust bearing. The carriage assembly sits on top of this assembly. You can see that the entire weight of the carriage and guide rests on the upper thrust bearing assembly. At this point you may be wondering what keeps the launcher from leaving the stand if vertical movement of the ship pushes up on the bottom of the carriage, tending to push it off of the stand. Figure 5-21 gives us a better view of the train bearing assembly and the method used to oppose a

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Figure 5-19.—A. Launcher train system. B. Launcher elevation system.

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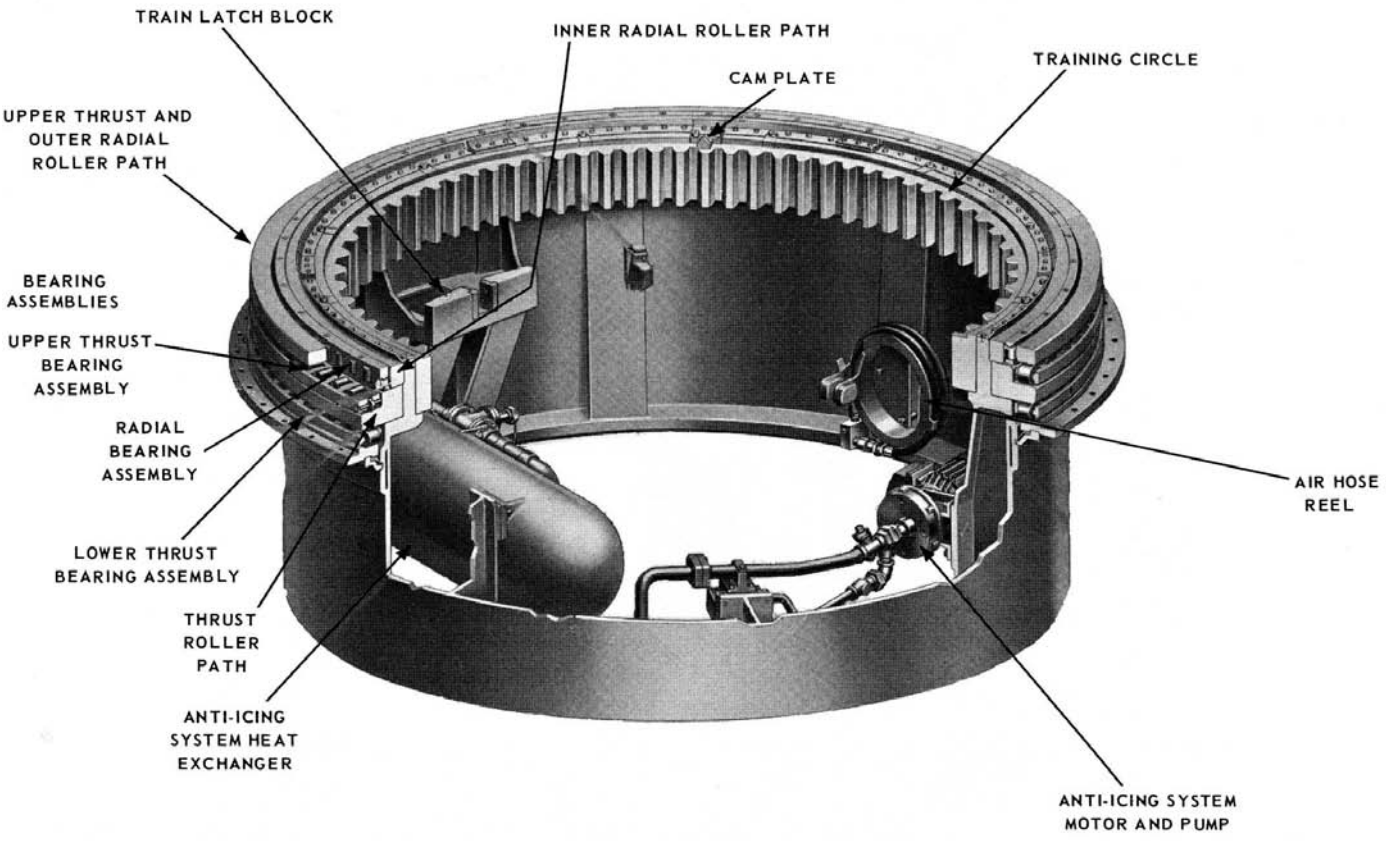


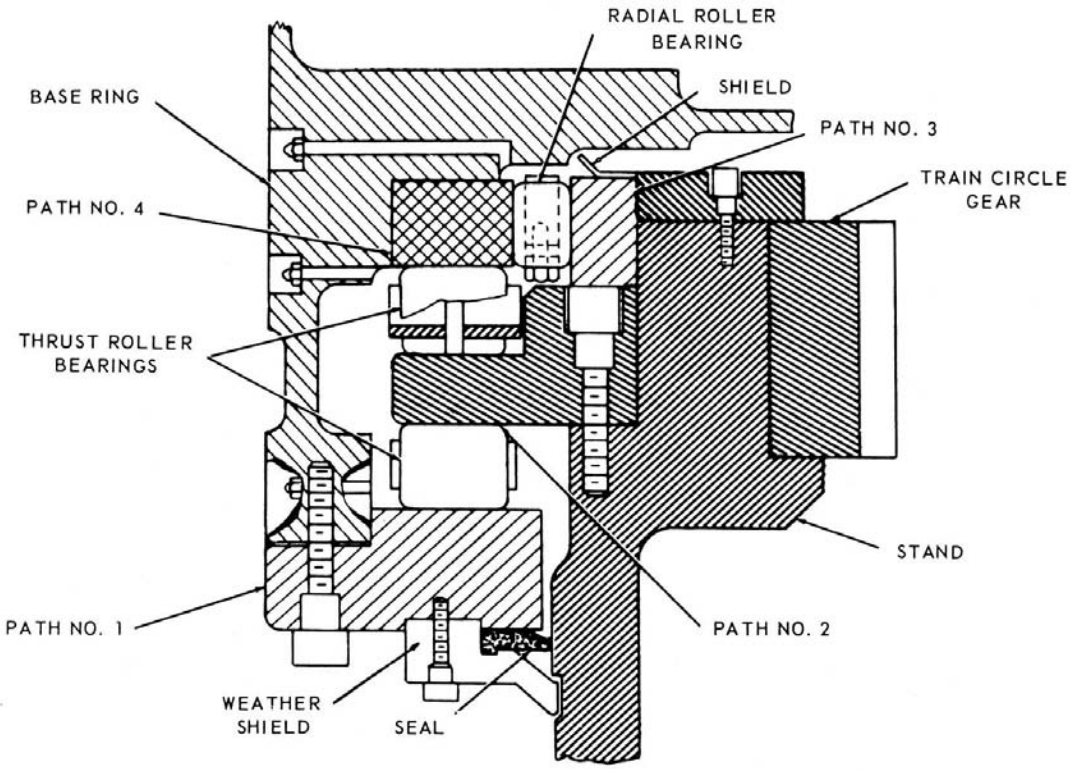
Figure 5-20. — The launcher stand and its main parts.

vertical upward thrust (force) on the base of the carriage. Essentially, the way this is prevented is to connect the carriage to the stand through a lower thrust bearing assembly. This arrangement also reduces frictional forces as the carriage is trained. The upper and lower bearing assemblies pretty well restrain the rotating structure in the vertical direction. But what about in a lateral or horizontal direction? The radial bearing assembly takes care of this problem. This assembly prevents lateral movement between the carriage and stand, and also decreases frictional forces between the carriage and stand.

Now look at figure 5-21 again. The big gear with teeth on its inside face is the training circle. This gear is classed as an involute gear, an internal ring gear, or an internal spur gear. A small pinion gear meshes with the training circle. The pinion gear is part of the carriage, and is driven by the train power drive. As the power drive motor rotates in response to an electrical order from the computer to move the launcher, the pinion gear rotates and walks around the ring gear, carrying the rotating structure (carriage and guide) With it. Look back at figure 5-19 and you can see how the pinion gear meshes with the training circle.

The weather shield and seal (Fig. 5-21) prevent water or spray from getting into the bearing assemblies. The shield is metal, and the seal is synthetic rubber. Both are attached to the carriage. The shield supports the seal and keeps it pressed against a smooth surface on the stand. The shield and seal form continuous rings which rotate as the carriage turns. Notice that the shield fits into a groove cut in the outside of the stand. Most of the water or spray will be kept out of the bearing assemblies by the shield; the seal is designed to stop the rest. But don't count on this; seals wear out or tear, and must be replaced periodically. All launcher stands, regardless of Mark or Mod, have the same component assemblies we have covered here. It is true

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Figure 5-21.—Sectional view of train bearing assembly (launcher stand).

that these assemblies are different in construction in various stands, but their function remains the same. Gun mounts are placed on the same type of stand; in fact, some missile installations have made use of the already emplaced stand formerly used for a gun. The anti-icing units shown in figure 5-20 have pipes that extend to the blast doors up on the deck at the launcher, through various internal passages in the launcher, and to emergency igniter units. All launchers that are exposed on the deck have anti-icing systems so they will be ice-free and operable in the most severe weather.

Carriage Assembly

The carriage (see fig. 5-22) is the part of the launcher that trains. As we said before, the missiles must be aimed before they are fired. This means the launcher guide must be trained and elevated to point the missiles in the right direction. Since the carriage is trainable, it meets the first aiming requirement. Later you will see how the missiles are pointed in elevation by the guide.

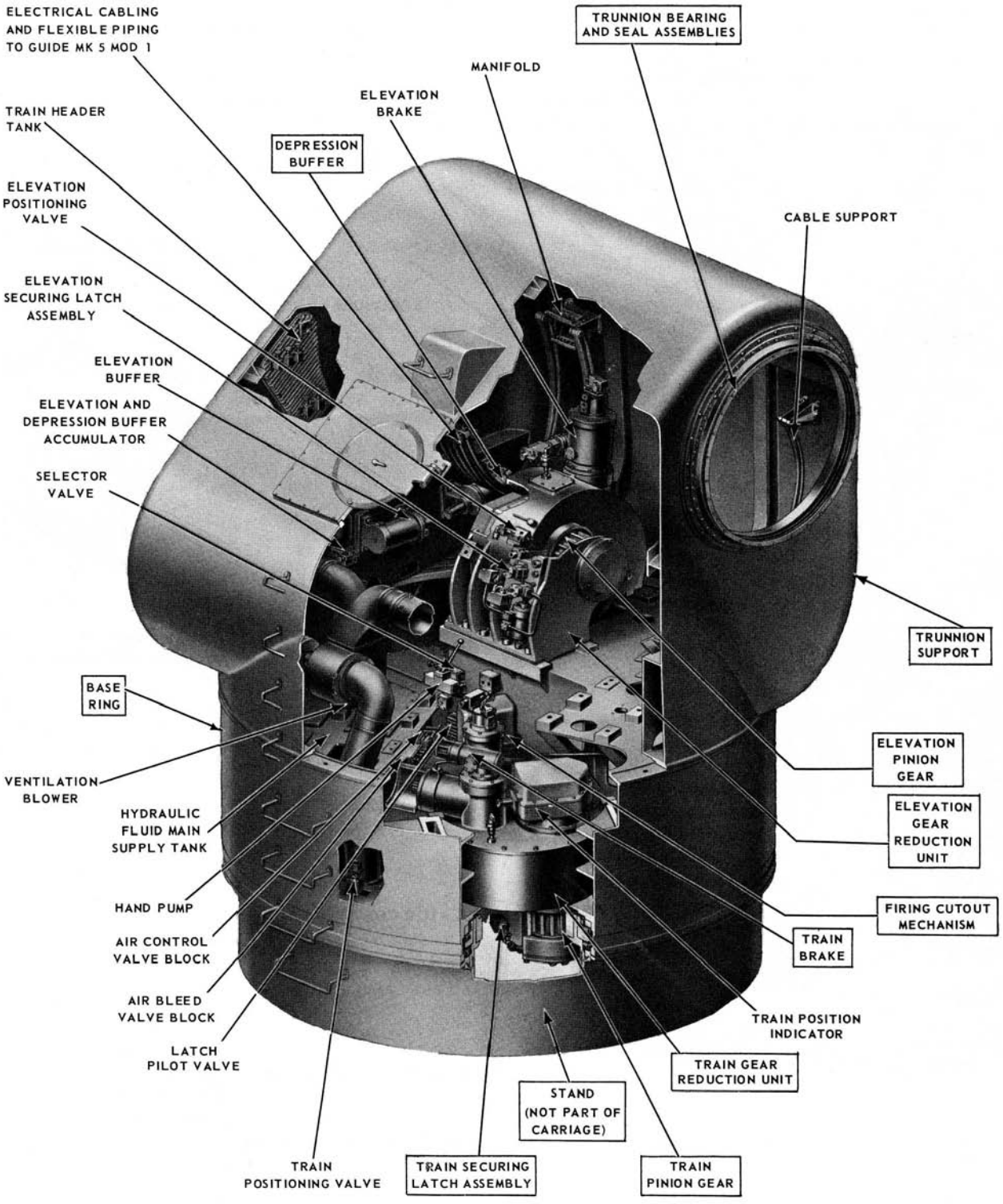
The carriage consists of two basic parts: the base ring, and the trunnion support. The base ring makes up the lower part of the carriage. The trunnion support fits on top of the base ring. The stand and carriage are joined together by the base ring, and the base ring sits on the stand.

The trunnion support holds up the guide. A long hollow tube (trunnion tube) is supported in bearing assemblies of the trunnion support so that the tube can be elevated and depressed. Attached to each end of the tube is a guide arm. As the tube is rotated, the guide arms follow this motion. The inside surfaces of the carriage provide mountings for other launcher components. The shell of the trunnion support protects units in the carriage assembly from the weather.

Guide Assembly

The guide assembly (fig. 5-23) provides the platform from which the missile is launched. It consists of four major parts: trunnion tube, two guide arms, and the guide power drive. The trunnion tube is mounted in bearings. A guide arm is attached to each end of the trunnion tube. An elevating arc is located at the center of the

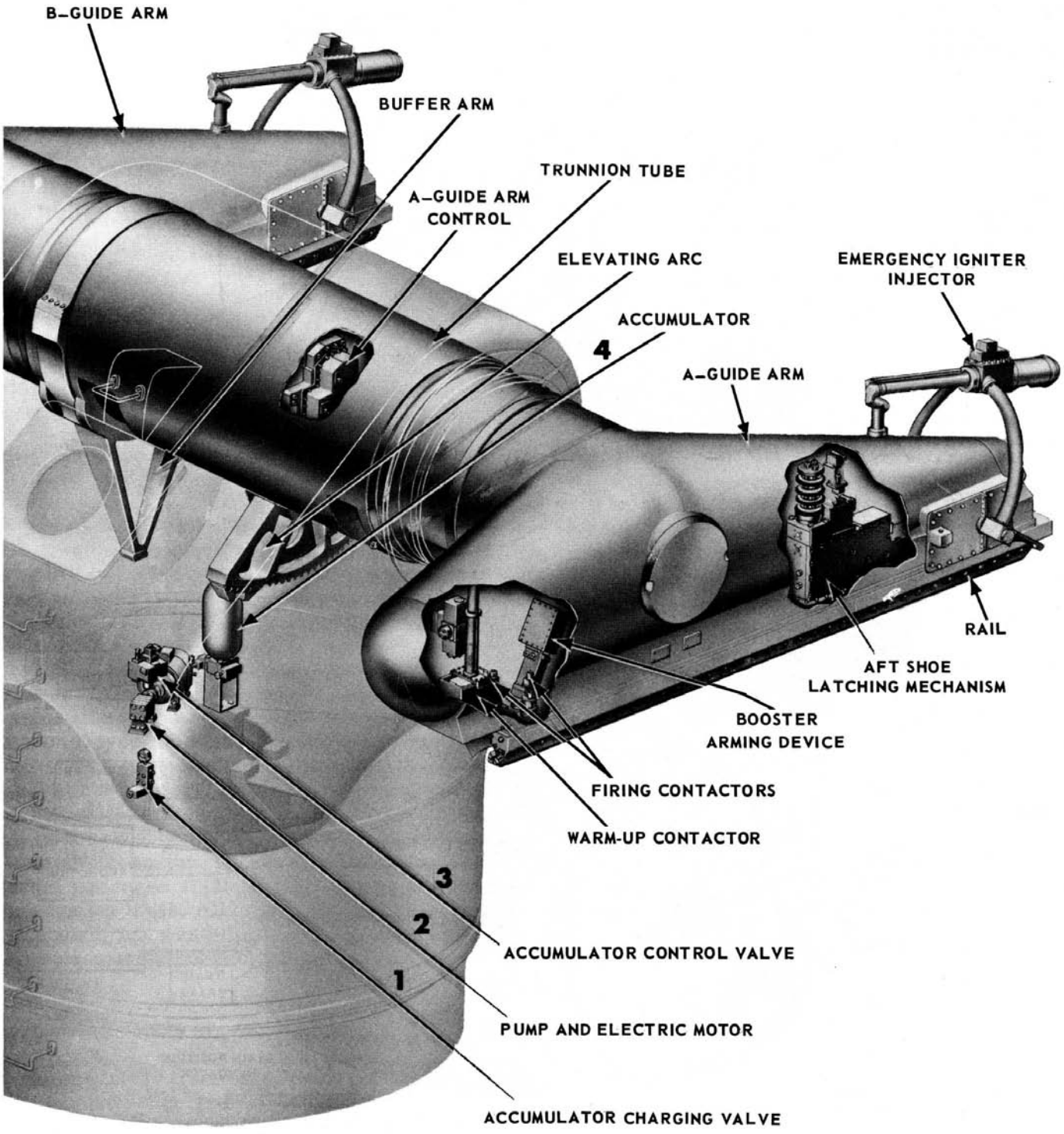
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Figure 5-22. — Carriage assembly for Talos missile system.

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Figure 5-23. — Major parts of the guide, Talos missile system.

tube. The arc is driven by the elevation power drive through a pinion gear which meshes with the teeth in the elevating arc.

GUIDE ARMS. - The guide arms are similar structures, so we will talk about only the A-arm. But what we say pertains to the B-arm also.

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The bottom of the arm is flat, and contains the rails. The weapons are suspended from the rails by shoes on the booster. At launch the rails provide guidance for a short distance.

The main operating (moving) parts of the guide arm (fig. 5-24) are:

1. Guide arm control (not shown in figure 5-24).
2. Aft shoe latching mechanism.
3. Warmup contactor.
4. Firing squib contactors.
5. Arming device.
6. Emergency igniter injector.

Guide Arm Control. - This is an electro-hydraulic assembly that controls the operation of the arming device, warmup contactor, and aft shoe latching mechanism. The emergency igniter injector has its own control assembly.

Aft Shoe Latching Mechanism. - The aft shoe latching mechanism (see the simplified diagram in fig. 5-25 is located at the aft end of the guide arm. The latching mechanism positions and retains the weapon on the guide arm by the aft booster shoe. The latching mechanism consists of two major parts: a forward motion restraining latch, and a reverse motion latch. The two latches simply pinch the aft booster shoe between them. The forward motion latch prevents the missile from moving forward until it is ready for launching. The reverse motion latch prevents the missile from falling off the rear of the launcher. During firing, the forward motion latch holds back the missile booster combination until the booster has developed enough thrust to overcome the restraining force of the latch. When this happens, the latch buckles (trips) and the weapon leaves the guide arm.

Other missile systems use the same type of mechanism for the same purpose.

Warmup Contactor. - Another component of the launcher guide arm, called the warmup contactor, prepares the missiles for flight. This device is located in the front of the guide arm. The expression "prepares the missile for flight" is very general; so we will explain it. Most Navy surface-to-air missiles contain some vacuum tubes. As you know, it takes time for vacuum tubes to heat up and to reach the temperature at which their operation becomes stable. To illustrate, it takes your home vacuum tube radio or TV set 20 or more seconds to warm up after you turn it on. Of course, a transistor set is in operating condition almost immediately after it is turned on. But RIMs are not completely transistorized, and they will have at least a few filament type tubes which require a warmup period.

Warmup power is also required for gyros. All Navy RIMs have gyros. These units must have their rotor wheels spinning at a specified number of revolutions per second to be effective. Otherwise the gyros will provide inaccurate

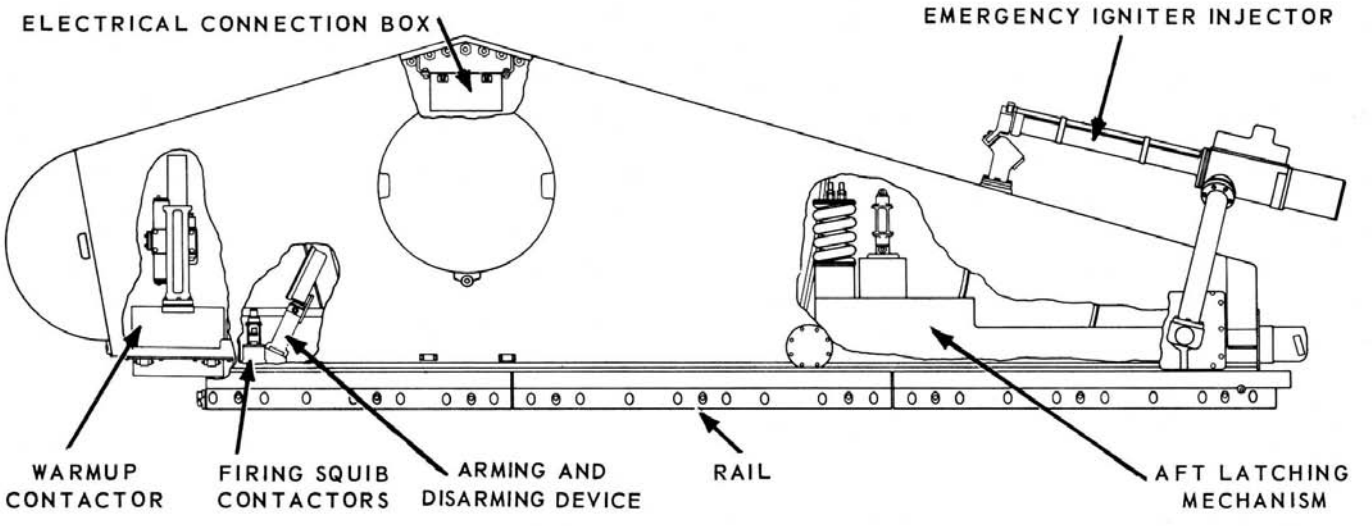


Figure 5-24.—Launcher guide arm, A-side, Talos missile system.

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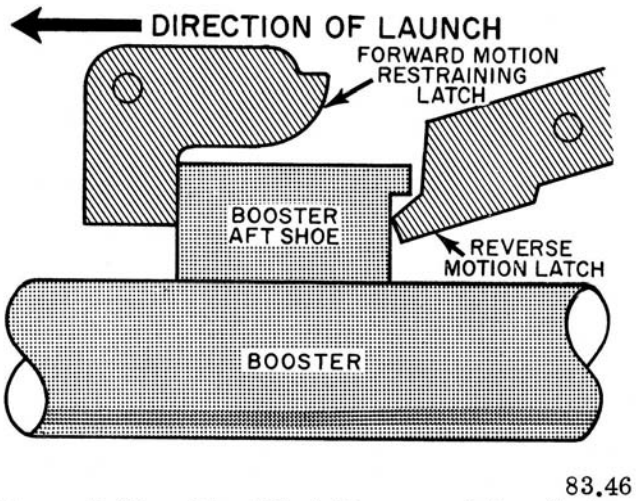


Figure 5-25. — Simplified diagram of the aft shoe latching mechanism.

references or information. If the gyro wheels are not spinning fast enough, the rotors will wobble.

The warmup voltage is supplied from a source outside the missile because we don't want to use up the power source inside the missile. The missile internal power supply is limited as to how long it will furnish power, and it would be foolish to use up any of its energy before flight.

Now back to the contactor. It applies external warmup electrical power to the missile while the missile is supported on the launcher guide arm. The contactor can be extended and retracted. When it is extended, a series of points on the contactor fit into a pad on the top rear of the missile. Current then flows through the contactor-missile connection to the missile electronic and gyro components.

The warmup contactor also provides an umbilical connection to pass information back and forth between the missile and the weapon control system.

Warmup contactors were mentioned several times in the discussion of the Terrier system, and you will also find them mentioned in regard to the Tartar system. Essentially, they are all electrical contacts to the ship's electrical system to warm up gyros and electronic components in the missile and the booster.

Firing Contactors. - All RIM booster propellants are ignited electrically and use igniters to start the propellant burning. Basically, an igniter (figs. 3-27, 3-29) consists of a charge of black powder and a small electrical heating element called a squib. When electricity passes through the heating element, enough heat is generated to start the black powder burning. The flame from the black powder shoots down the hollow center of the propellant grain and ignites it.

When a missile is on the launcher and the intent is to fire it, some device is necessary to bridge the gap between the launcher arm and the missile booster so the booster igniter firing circuit will have a circuit from the firing key to the squib. Look again at figure 5-24. It shows a cutaway view of the A-arm of the Talos launcher. Notice the booster firing contacts at the arm's forward end. These contacts engage similar contacts (called ignition contacts) on the top of the forward booster shoes. Electrical wires run from the booster contacts to the squib electrical heater. Thus when the firing key is closed, and all other required circuit closures are made, an electrical circuit is completed to the squib which ignites the booster propellant.

Firing circuits are interlocked mechanically and electrically. This means that certain events must take place in the weapon system, in the correct order, before the firing circuit will work. The fact that the events took place, and in their proper sequence, is indicated by the operation of electrical and mechanical devices. You are going to learn more about interlocking and firing circuit operation later in this course; but for the present just take our word that firing circuits are interlocked.

Booster Arming Device. - Another reason for interlocking firing circuits is for safety. Consider the booster. Boosters are not ready to fire when they are stowed in a magazine, or even when they are first put on the launcher. There is a chance that they might be accidentally set off. So boosters are put in a safe condition until immediately before firing. And how are they made safe? Just by the simple technique of opening the firing circuit inside the booster. Generally, the igniter is mechanically rotated in such a manner that the squib element's electrical contacts are physically disconnected from the rest of the firing circuit.

When a missile is to be launched, some device must be used to move the igniter back into its firing position. You can see now that another device is needed to bridge the gap between the launcher arm and the booster. The

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launcher we have used as a study example has a plunger type mechanism in the launcher arms. The plunger, when it is extended, connects with a system of levers and gearing in the booster in such a way as to rotate the igniter assembly into the proper firing position. This process is called booster arming.

In case it is decided not to fire the missile, the booster arming and disarming device can be used to disarm the booster before it is unloaded and then placed back into stowage.

Emergency Igniter Injector. - A hydraulically operated emergency igniter injector is mounted on the after end of each launcher guide arm, see fig. 5-23. This device inserts a high-explosive cartridge into the missile booster. The arrangement of injector and cartridge permits electrical firing from the control station when a misfire occurs.

The operation of the emergency igniter injector is normally controlled by the launcher captain from the EP2 panel.

The Talos system is the only one that uses this method of disposing of duds or misfires. Terrier and Tartar systems use the dud jettisoning device to place dud or misfire missiles overboard when it is necessary to dispose of a missile that cannot be fired from the launcher.

TRAIN AND ELEVATION POWER DRIVES

Two electrohydraulic power drives (fig. 5- 19) position the launcher. One trains the launcher by rotating the carriage, and the other elevates the guide arms by rotating the trunnion tube. Both the train system and the elevation system receive orders in the form of electrical signals, and act on these orders to position the launcher and guide arms accordingly.

The launcher can be positioned by either of two methods of control: remote order control, and local order control. In remote order control, signals are received from a missile fire control computer. Local order control is used to position the launcher from a local station in the launching system.

The train and elevation systems operate in a similar manner. In most cases they contain the same operating components. These components, with the exception of the magnetic amplifiers, are located within the launcher carriage.

The simplified schematic in figure 5-26 is provided to promote a general understanding of how the train drive responds to an input signal. Only the basic drive components are pictured.

Two channels of control signals are fed to the drive. One is a position order. This one will be discussed first. The order is a velocity order.

We will start with the synchro transmitter in the computer. It transmits a position order to the IXCT in the receiver regulator of the launcher. The stator of this CT is geared to the B-end of the hydraulic transmission. If the launcher is not positioned at the same bearing as the transmitted order, a voltage is developed on the rotor of the CT to represent launcher position error (angular difference between actual launcher position and ordered launcher position).

This error voltage is placed on the input terminals of a magnetic amplifier. The output position error signal of the amplifier is sent back to the receiver regulator. Through the receiver regulator, tilt is applied to the A-end of the hydraulic transmissions by an amount that corresponds to the strength of the error voltage. The receiver regulator, which is primarily a device to change an electrical input into a corresponding hydraulic output, is used to obtain the hydraulic pressure needed to stroke the A-end.

The A-end is driven by an a-c electric motor. The speed of the B-end rotation, which is governed by the amount of A-end tilt, is reduced by a gear reduction unit and applied to a drive pinion to rotate the carriage.

As the carriage rotates toward the ordered position, the launcher error, and therefore the error signal, decreases. When the launcher reaches the ordered position, the error will no longer exist and the A-end tilt will be reduced to zero.

Consider the situation where the position order is not static but is continually changing. This would be the case when the director is tracking a moving target. Here, movements of the director must be followed by the launcher with a minimum of error. This would be difficult to accomplish with only a position order channel, because an error would have to be developed to move the launcher. This problem is greatly reduced through the use of a velocity channel as an additional means of stroking the A-end.

The velocity order is a voltage received from the computer, which corresponds to the rotational speed of the director. This signal

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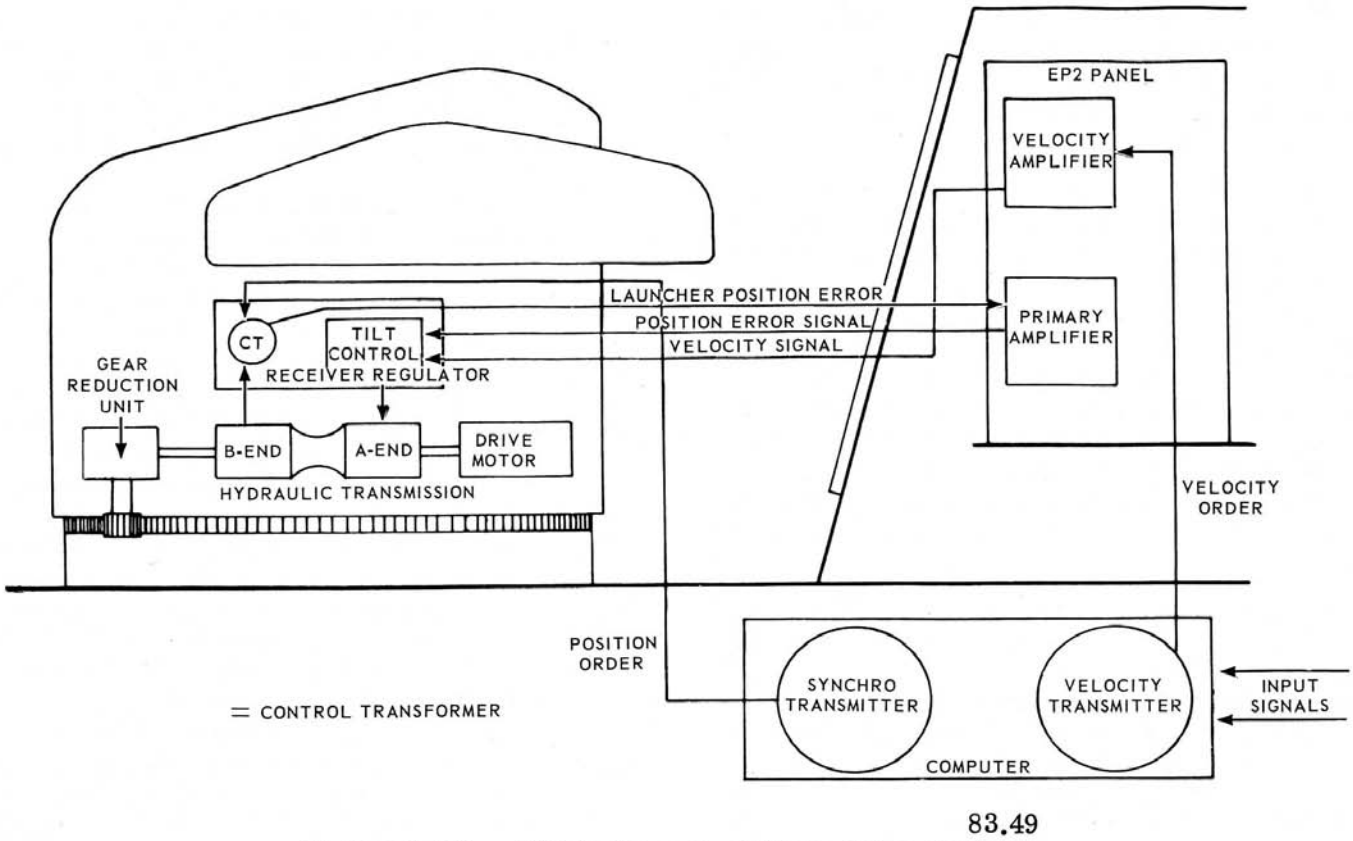


Figure 5-26. — Block diagram of train drive system.

is amplified by the velocity amplifier, and then sent to the receiver regulator in the launcher. The regulator acts on the signal by applying a proportional amount of tilt to the A-end.

With both channels controlling the launcher during a dynamic (moving) signal condition, the position channel is used to reduce the initial error.

The velocity channel is used to maintain rotation of the carriage so the position error will have little or no chance to develop. The small amount of position error that does develop is reduced by the position channel.

In the interest of simplicity, many refinements of the train drive system have not as yet been discussed. These refinements will be discussed through the remainder of this section which will deal with power drive refinements.

The refinements include the automatic tracking cutout system, the firing cutout system, and the limit stop system. These refinements impose limitations on the power drives when they respond to input orders.

The limit stop system restricts launcher movement to definite established limits, and prevents launcher components from being damaged. The system also halts the launcher if it loses power. The limit stop system is designed with a lead input which is proportional to launcher velocity. Therefore, the launcher movement can be stopped at the established limit regardless of its speed.

The automatic tracking cutout system works with the power drive to prevent the launcher from pointing into areas where a fired missile would hit the ship's structure, masts, or other parts of the ship.

The firing cutout system disables the firing circuit whenever the launcher moves into areas where a fired missile could cause damage to the ship structures.

The Terrier and Tartar systems also have these "refinements" in their train and elevation systems so the missile cannot be fired into own ship's structure.

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GUIDED MISSILE LAUNCHER FEEDER MK 11

Figure 5-1 shows the Launching System Mk 12 of which we have discussed the launcher. All Talos systems make use of the Mk 7 launcher, and there has been only one modification, Mod 1. The launching System Mk 12 Mod 0 and Mk 12 Mod 1 are identical except for the size of the two hoist magnetic controller panels (they are larger on the Mod 1) and the arrangement of cabling for the panels.

If you think about the name of this equipment group, you can get a picture of its main function. It simply feeds the missiles to the launcher. Of course, the feeder has other functions too, but we'll talk about them later.

Figure 5-27 A shows a pictorial view of the major units that comprise the Mk 11 feeder; figure 5-27B shows a block diagram of the feeder. Note that there are three main components; the magazine, the loader, and the assembler, each with its components.

The feeder is composed of two separate but similar parts. One part is associated with the A-arm of the launcher and the other part is associated with the launcher's B-arm. The part of the feeder that provides missiles to the A-arm is called the A-side, and the part that feeds the B-arm is called the B-side. (You can tell the side of the launcher or feeder by the conventional way. Just look in the direction of missile flight from the launcher or from the after end of the system, and the A-side is to your left. The B-side is to your right. This identification technique works regardless of the launching system's location on the ship.)

Although each side of the feeder operates independently, both sides usually work simultaneously, so that both launcher arms can be loaded at the same time. Since the A- and B- sides are almost identical, we shall describe only the A-side.

Guided Missile Magazine Mk 7

The components in this equipment group provide the stowage space for the missile- booster combinations. The magazine equipment also transfers the missile-booster combinations from their stowage positions to the loader, and puts them on it. Figure 5-27A shows the below-deck location of the magazine. It is placed below deck to prevent the entry of salt water and spray into the magazine spaces. Also, this location affords some protection from enemy gun and missile fire.

The main components of the magazine are:

1. Trays.
2. Tray supports.
3. Hoist and its power drive.
4. Lower buffers.
5. Magazine door and its power drive.
6. Spanner rails.
7. On-hoist power drive.

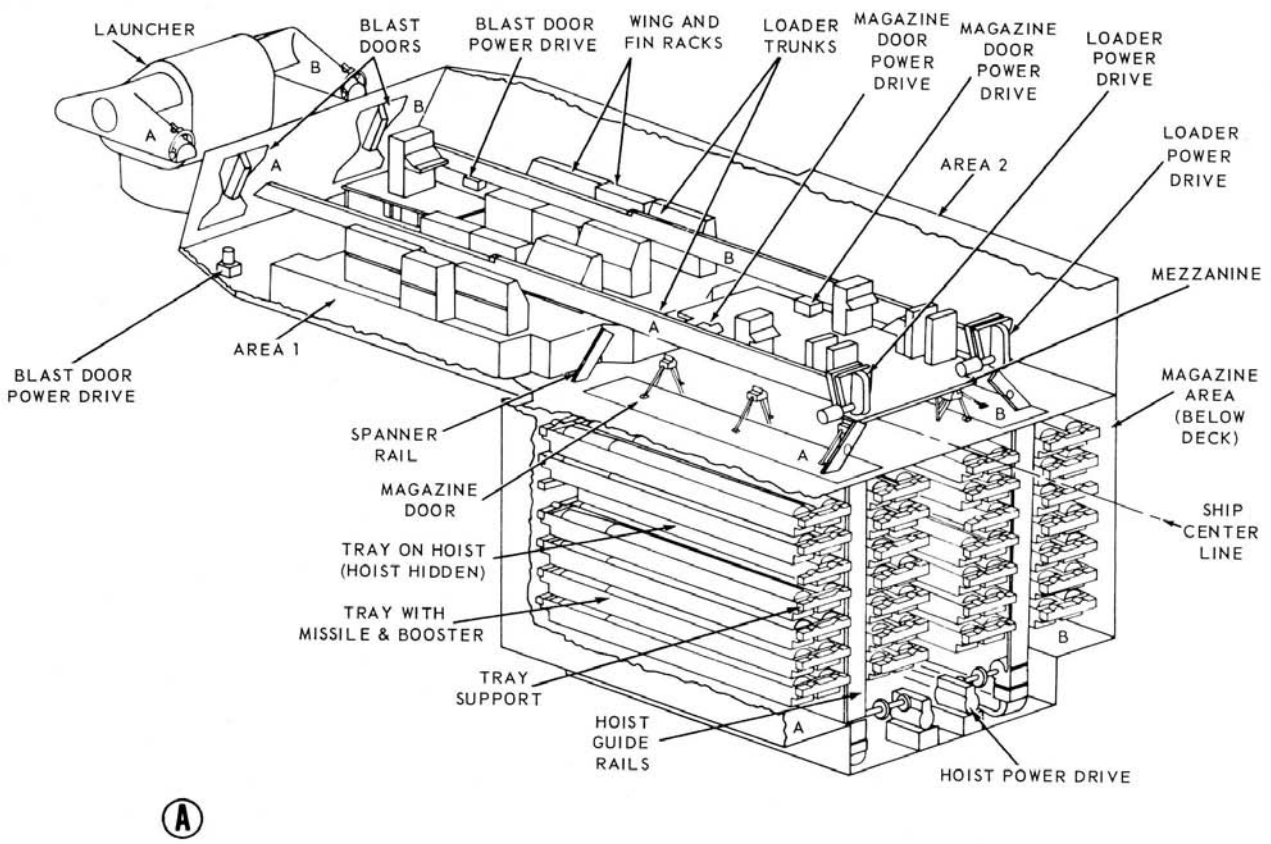
The magazine (A- and B-sides combined) can hold 52 missile-booster combinations. Keep in mind that a combination is a missile and booster' connected together and handled as a single-unit. The A-side magazine has 7 layers with space to stow four weapons at each level. Each weapon is placed in a long rectangular box called a tray. A hoist divides the magazine so that two trays are on either side of the hoist at each level. Vertical rails guide the hoist as it moves up and down. The vertical rails are at each end of the hoist. The hoist is used to raise a weapon and its tray up to the loader and to return an empty tray to the magazine. Notice the magazine door that separates the magazine from the loader. The door is a safety device. It is a flame and gas seal between the magazine and the deckhouse. Hoist spanner rails are linked to the door. When the magazine is opened, the spanner rails connect with the hoist vertical guide rails. Thus the spanner rails provide a vertical extension of the guide rails up to the loader. In other words, they span the gap between the magazine and the loader to give the guide rails a continuous track.

Now that you have a general idea of what units make up the magazine and what they do, we'll cover them in more detail.

TRAYS. - A typical tray is shown in figure 5-28. There are 26 of them in our magazine, one for each missile-booster combination. Each tray has a device for locking the weapon in the tray. Also, the tray is equipped with parts that help transfer the tray on or off the hoist.

In figure 5-28 you will see four rollers at the booster end of the tray. These four rollers engage the associated tray support. The two large rollers are mounted with their axes horizontal. They support the booster end of the tray. The two small rollers prevent the tray from moving back and forth. At the launcher end of the tray there are only two large rollers and these support that end. You can't see them in figure 5-28 but they are similar to the large rollers at the booster end.

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Figure 5-27. — The Mk 11 launcher-feeder system for Mk 12 launching system: A. Components of the launcher-feeder system; B. Block diagram of the feeder system.

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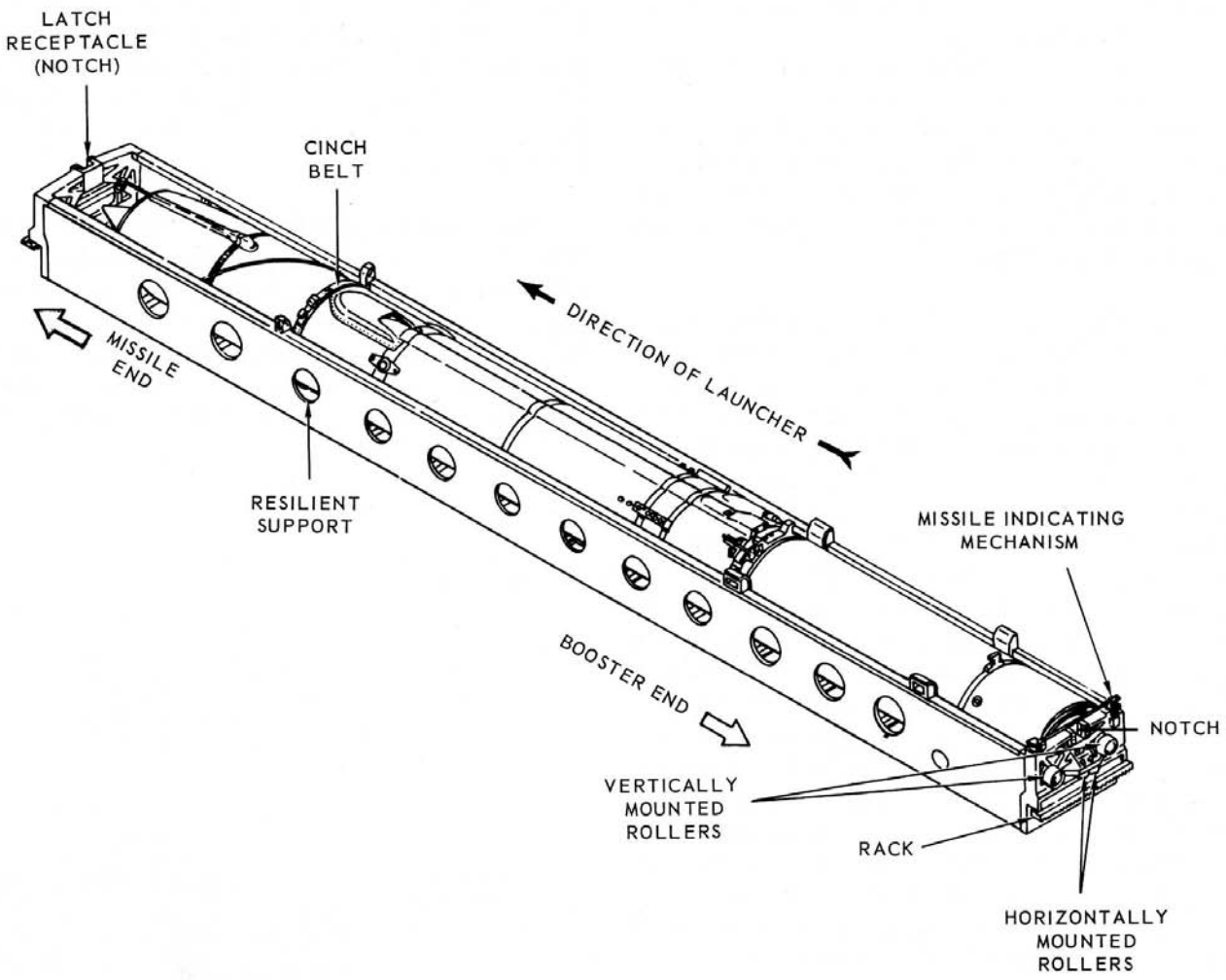


Figure 5-28.—Tray with Talos missile in it.

A shoe latch secures the missile-booster combination to the tray. The latch is inside the tray at the booster end. The latch is spring loaded and engages the bottom rear booster shoe. This prevents the missile from shifting its position within the tray. A hydraulic actuator on the hoist releases the latch when a weapon is to be transferred from the tray. The missile part of the combination is also secured to the tray. A cinch belt does this. It is located at the end of the tray that points in the direction of the launcher. When ramming action moves the combination forward, the cinch belt is automatically released. You'll see this action later when ramming in the tray takes place.

Now the missile is securely placed in the tray, but what prevents the trays from falling off their supports? On the top edge of each end of a tray is a notch. Latches on the tray supports fit into these notches (latch receptacles). This prevents the trays from rolling off the tray supports. The same type of arrangement is on the hoist. Both the tray support and the hoist latches are operated hydraulically. Each tray is kept latched in place, except during the time it is being transferred from the tray supports onto the hoist and from the hoist to the tray supports.

A rack, used for transferring the tray on or off the hoist, is located at each end of the tray. Pinion gears located on the tray supports and hoist mesh with the racks to provide necessary horizontal movement for affecting tray transfer. As the gears rotate, the tray moves linearly to transfer the tray to or from the hoist. These

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gears are driven by a hydraulic unit on the hoist. This unit is referred to as the on-hoist power drive (fig. 5-27A).

Missiles are not particularly rugged, and must be protected from shock and vibration. So each tray has a resilient support on which the missile portion of the combination rests. The resilient support is composed of hydraulic dampers and mechanical springs. This device acts like a shock absorber on a car.

TRAY SUPPORTS. - It takes two tray supports to hold up a tray, one at the launcher end of the tray and one at the booster end. Each set of tray supports holds up two trays. The tray supports are bolted to the magazine bulkhead. Each support contains the means for transferring trays to and from the hoist. Fig. 5-29 shows a tray support. Its location in the magazine is shown if figure 5-27 A. The on- hoist drive is coupled to the transfer clutch to provide a means for moving the trays. When the on-hoist drive moves, the pinion gears turn. These gears are meshed with the tray's racks. As the inboard tray is moved onto the hoist, the outboard tray is moved to the position originally occupied by the inboard tray. If you look closely at the right-hand end of the tray support, you can see the track in which the tray rollers ride. Similar tracks on the hoist line up with these, so a tray with or without its weapon can be taken off the supports.

HOIST. - The hoist (fig. 5-30) spans the length of the magazine. It is used to move trays up and down between the loader and the individual levels. The hoist is guided in its vertical travel by guide rails (fig. 5-27A). Each end of the hoist is fitted with rollers to make sure the hoist moves freely up and down the guide rail. A roller track at each end of the hoist receives tray rollers. When a tray is slid over onto the hoist, the tray is latched to the hoist so it won't falloff.

The hoist itself is latched when it is at the correct transfer position. This is the position where the hoist and a selected tray support are in almost perfect alignment, and a tray can freely move back and forth between hoist and support. Two locks at each end of the hoist hold it at the transfer position.

A power drive on the hoist provides hydraulic power to transfer a tray on and off the hoist, to lock the hoist to the guide rails, to latch a tray on the hoist, and to unlatch a missile- booster combination from the tray.

An electromechanical power drive lowers and raises the hoist. This drive is not on the hoist, but is located at the bottom of the magazine (fig. 5-27 A). Buffers on the hoist and at the base of the magazine prevent equipment damage when the hoist reaches either its upper or lower limit of travel.

MAGAZINE DOOR - AND SPANNER RAILS. - The door acts as a gastight and flametight seal between the magazine and the deckhouse space. (See figs. 5-31 and 5-27 A.) The spanner rails are not part of the door, but they are linked to it. When the door is opened, the spanner rails form extensions of the hoist rails. This permits the

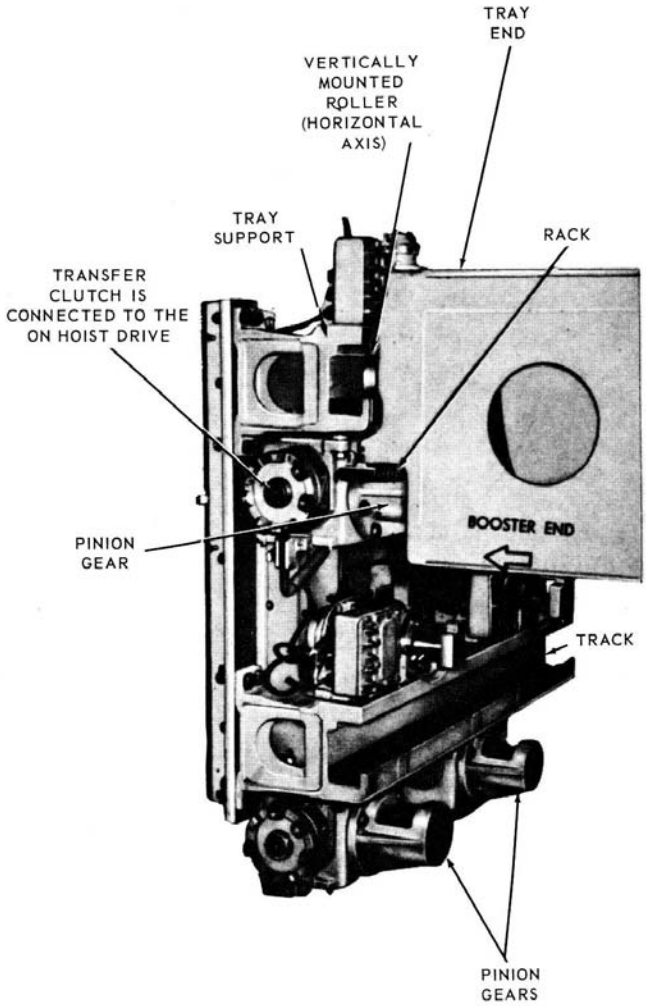


Figure 5-29. — Tray end and tray support in Talos magazine. 83.52

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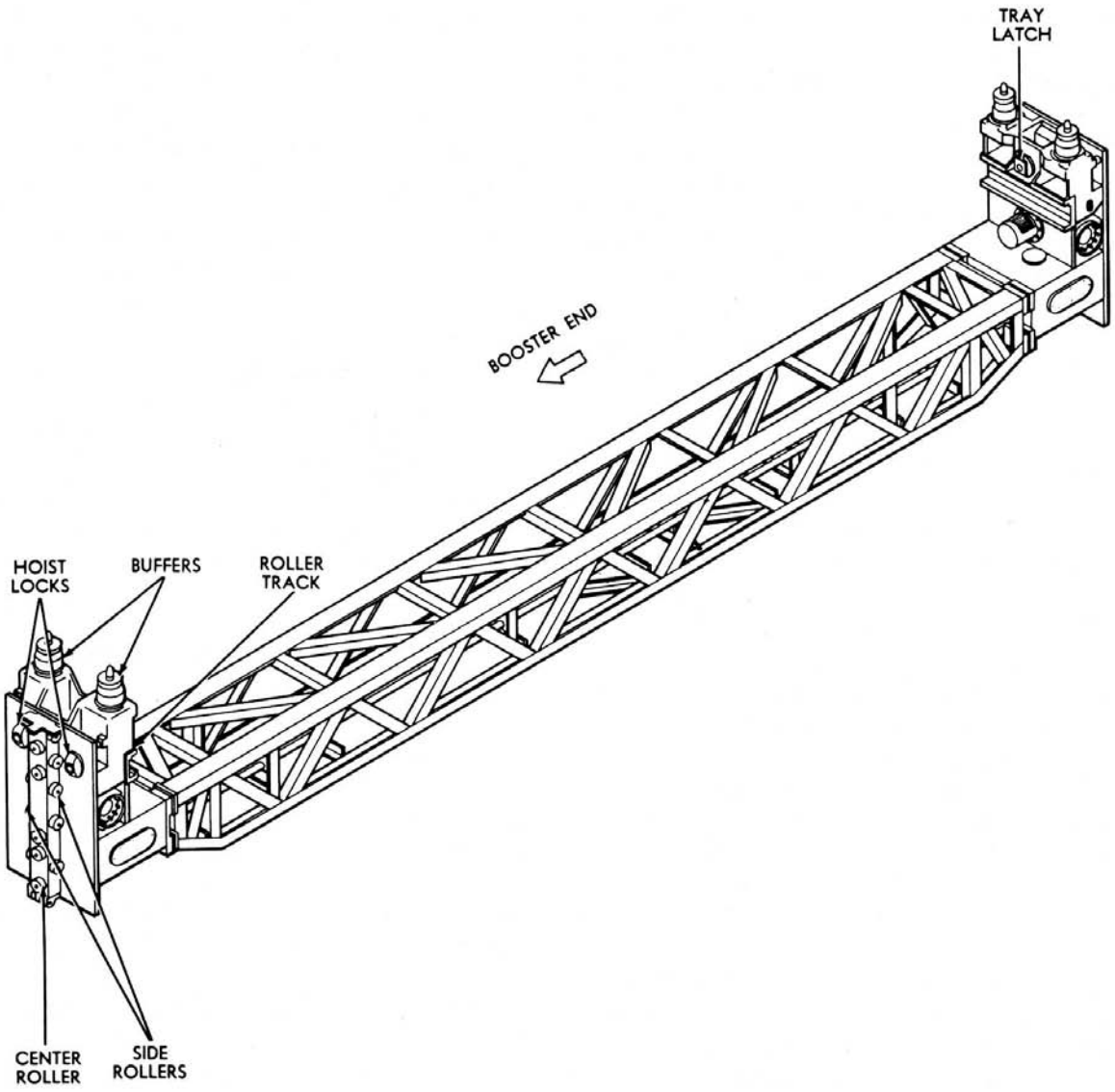


Figure 5-30.—Hoist in Talos magazine.

hoist to travel through the door opening to the loader. A hydraulic power drive (fig. 5-27A), provides the power to open and close the magazine door.

We have now brought the missile up from the magazine and are ready to move to the next area and the next steps in preparing the missile for firing.

Guided Missile Loader Mk 5

The loader is located in the deckhouse. You can see the loader in figures 5-1 and 5-27A, and in figure 5-32. The loader equipment transfers the weapon from the tray to the launcher.

During the transfer operation a device in the loader applies warmup power to the missile. The main components of the loader are:

1. Loader trunk
2. Forward and rear floating tracks
3. Saddle cart
4. Rammer
5. Positioners
6. Warmup contactor
7. Blast doors and span track
8. Power drives

When the hoist raises a weapon to the loader level, three units put the weapon on the loader

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trunk. These units are the floating tracks, saddle cart, and rammer. A power drive pushes the weapon along the loader trunk and stops it in the forward part of the deckhouse (the assembly area). Here, warmup power is applied and wings and fins are put on the missile. Just fins are attached to the booster. Then the blast doors are opened and the weapon is rammed onto the launcher guide arms. Now let's talk a little more about the principal units in the loader.

LOADER TRUNK. - This is a long metal structure composed of sections butted together and bolted to the underside of I-beams on the overhead of the deckhouse. The weapon is horizontally suspended from a rail on the loader. The top set of shoes on the booster are used to hang the weapon from the rail. You learned about these shoes in chapter 3. The forward handling shoe slides in skid tracks cut in the rail. The after handling shoe is retained in a saddle cart which also travels in the rail skid tracks. The cart is connected to a drive chain. The chain provides the means for moving the cart and weapon along the loader rail. A sprocket drives the chain. Connected to the sprocket is a drive motor. The drive motor is part of the loader power drive which controls the movements of the saddle cart and therefore the weapon.

FLOATING TRACKS. - Two floating tracks, (fig. 5-32) the magazine end of the loader trunk, raise the missile out of the tray and place it on the skid tracks. The floating tracks are designated as forward and rear to coincide with the forward and rear booster shoes on the Talos weapon. The tracks are designated "floating" because they can be raised and lowered.

When the missile-booster combination is ready for transfer to the loader, the floating tracks are lowered. Before the tracks are lowered, the forward part of the saddle cart is positioned on the rear floating track and is lowered with it. When the hoist raises the weapon to transfer it to the loader, the forward booster shoe projects through slots in the skid tracks and slots in the forward floating tracks.

The weapon is not on the loader yet. A rammer moves the weapon in the direction of the launcher while the weapon is still in the tray. Now the forward booster shoe is in the skid tracks and the rear booster shoe is moved forward onto the saddle cart.

After the ramming operation, the forward and rear floating tracks raise. The weapon is lifted out of the tray. Then the floating tracks are aligned with the loader trunk and the weapon can be moved along the loader trunk.

SADDLE CART. - The saddle cart (fig. 5- 33) rides in the loader skid tracks. Two metal latches on the cart hold the top rear booster shoe between them. These latches are called the reverse motion pawl and the forward motion pawl. The saddle cart is connected to the loader drive chain and provides the means of moving the weapon along the loader.

RAMMER. - This is essentially a hydraulically operated piston which is raised and lowered to transfer the weapon on to the loader. It pushes the weapon forward 4 inches, enough to slide it into receiving slots in the saddle cart and the track.

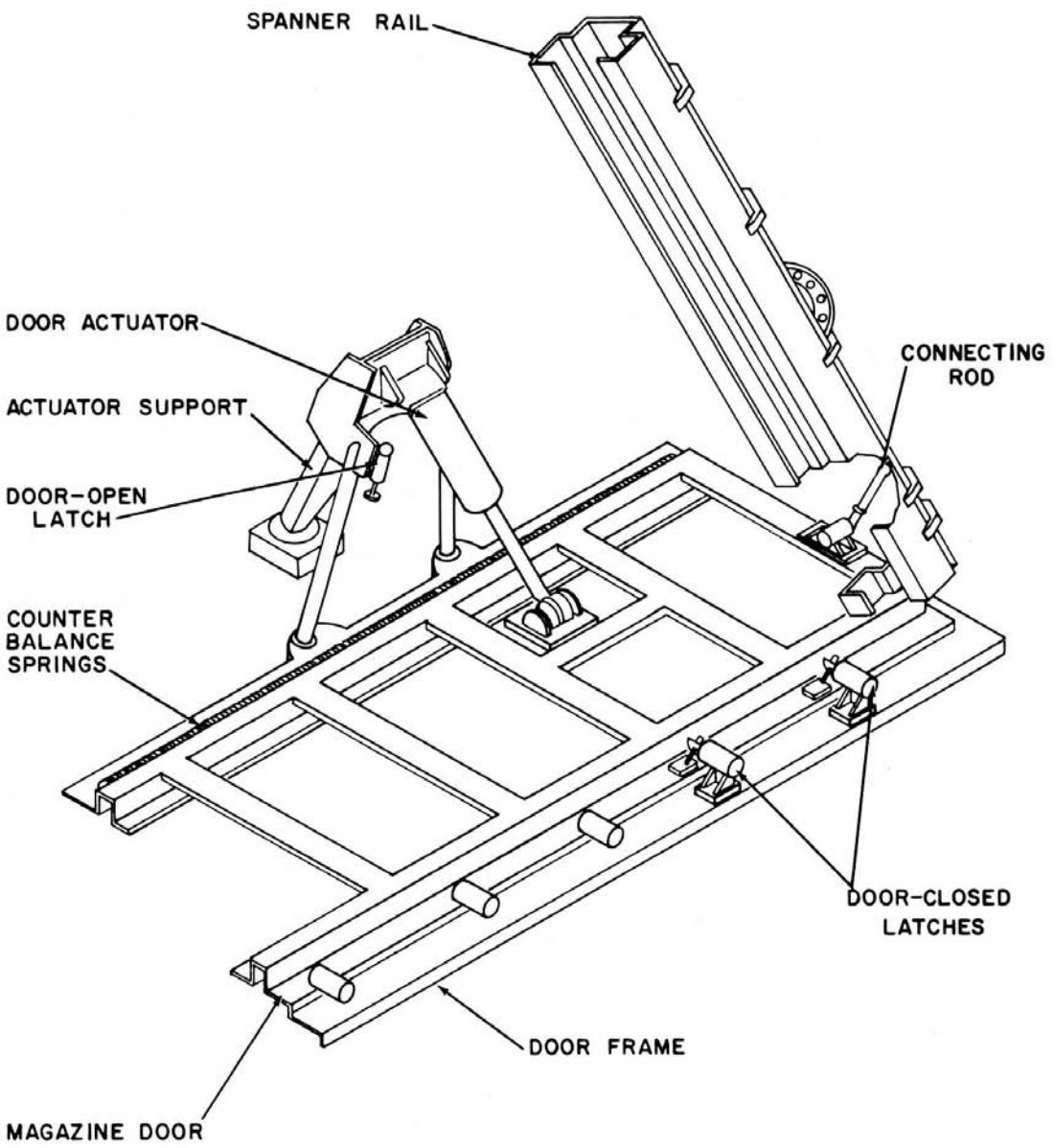
POSITIONERS. - Two hydraulically operated devices called positioners are on the loader. One is at the sprocket housing end of the loader; the other positioner is near the center of the loader trunk. Both of them position and lock the saddle cart. The positioner in the sprocket housing positions and holds the weapon on the rear floating track. The other positioner places the saddle cart so that the warmup contactor can mate with the booster warmup pad.

WARMUP CONTACTOR. - The warmup contactor is located near the center of the loader trunk in area 1 (figs. 5-1 and 5-27). The contactor applies electrical warmup power to the missile while the wings and fins are being put on. The contactor is controlled hydraulically so it Can be lowered to contact the pad on the booster.

BLAST DOORS AND SPAN TRACK. - There are two blast doors, one for the A-side and one for the B-side. Blast doors prevent hot gas and flame from fired boosters from entering the missile deckhouse. Of course, they also keep water from entering. When they are opened, they allow Talos weapons to be transferred from the loader to the launcher guide arm. Each blast door is composed of an upper and lower door. A span track is attached to the inside face of the upper door.

Both blast doors are mounted in a slanting bulkhead which forms the end of the deckhouse. You can get a general idea of what they look like in figure 5-27. When the doors are opened, the tracks connect the launcher rails with the

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Figure 5-31.-- Magazine door and spanner rail, Talos launching system.

loaders. This permits Talos weapons to be loaded on (or unloaded from) the launcher.

The upper and lower doors are hinged. The lower door is hinged to the bottom of the frame and the upper door to the top. Each door is opened and closed by two hydraulic pistons. The two doors do not open or close simultaneously, but act in sequence. The lower door opens first. When it is fully open, the upper door opens. When closing, the upper door closes and then the lower. Latches secure the door in the open or closed position. A deicing system prevents frozen water or spray from sealing the doors shut. A power drive on the main deck near the doors provides the power to operate the doors.

Guided Missile Assembler

Guided missile assembler is a fancy name for wing and fin stowage racks. The work done in this area is like that done in the Terrier assembly area.

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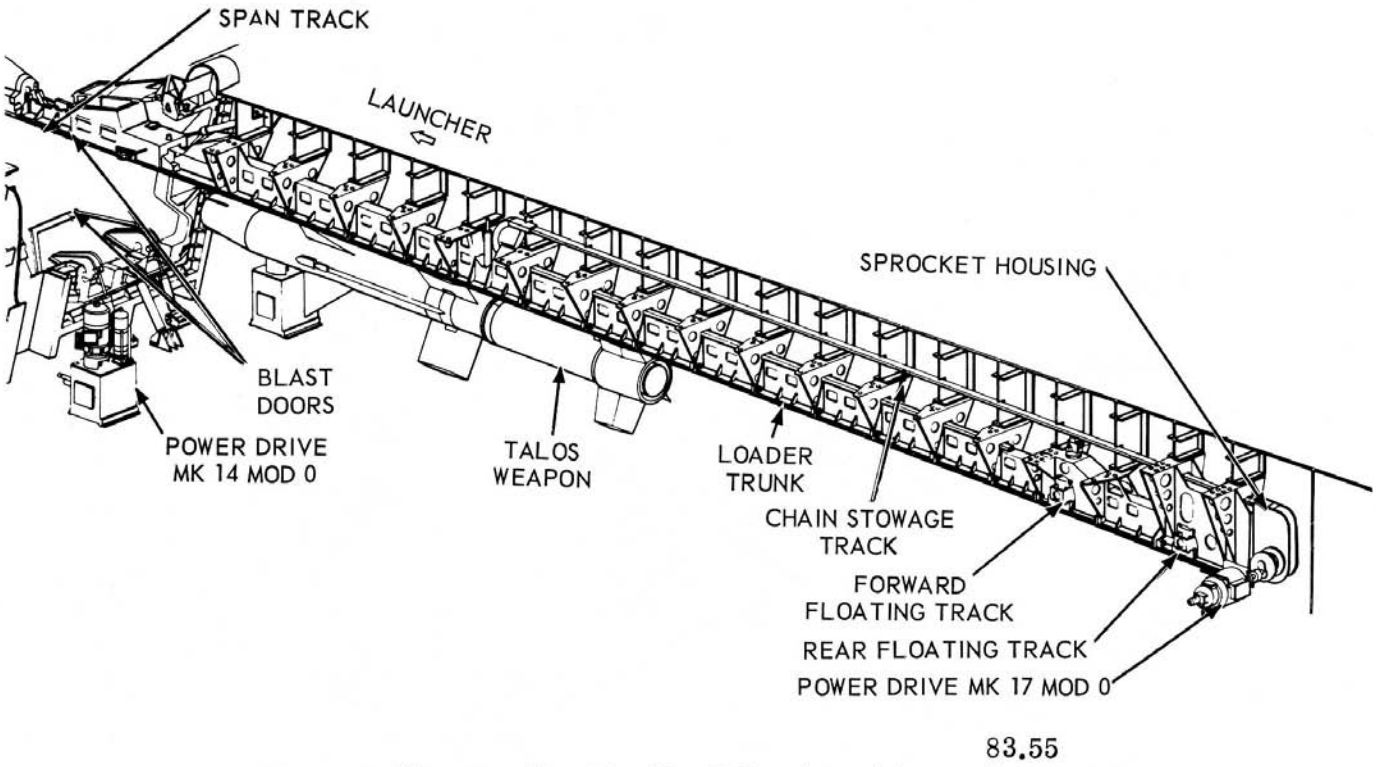


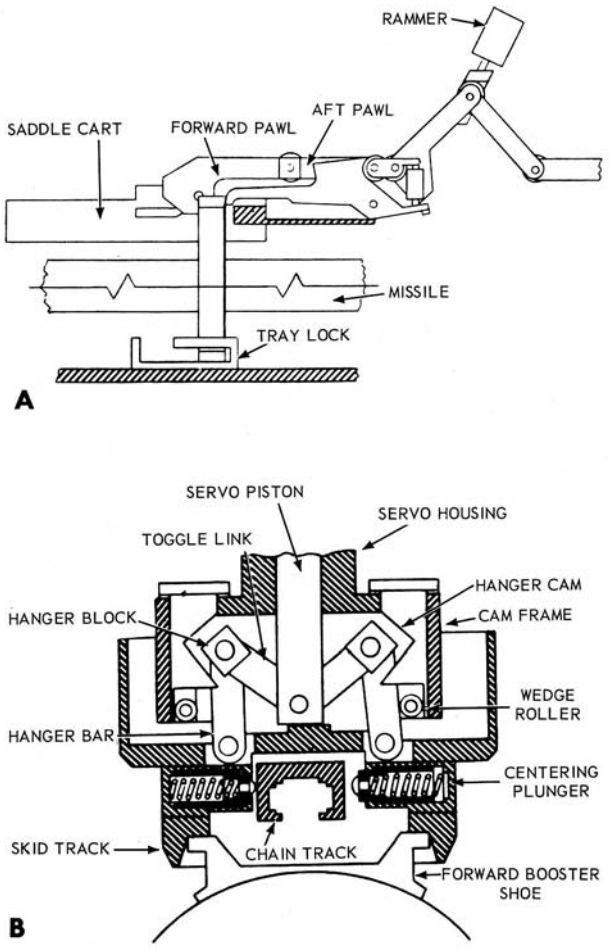
Figure 5-32. — Loader, B-side, Talos launching system.

MISSILE LAUNCHING SYSTEM CONTROL

A guided missile launching system is made up of many interrelated parts. All of these parts must work together as a whole to accomplish the purpose of the system - in this case, to stow, load, and fire missile weapons. To perform its mission, the system goes through a predetermined sequence of operations. For example, consider briefly how the loader works during loading. Loader equipment picks up the weapon from the tray and puts it in the loader skid tracks and saddle cart. Then the weapon is moved to the assembly area, where wings and fins are put on the missile-booster combination. Now the weapon is completely assembled. It is then rammed and attached to the launcher. The hardware that did the loading operation is brought back (retracted) and put into a position where it will grab another weapon and prepare to load it on the launcher. You can see that many events occur just in this small portion of the loading operation. Also, these events occur in a set sequence. If the equipment is working properly, nothing can happen out of step. But failures occur, and the launching system senses them when they happen. For instance, we forgot to open the blast doors in the above description of a loading operation. Well, a properly operating loader won't forget. It has electrical interlock circuits that indicate when a blast door is open or shut. If a door is open when it should be shut and the GMLS is ordered to load a weapon, the system will not obey the order. And you will agree this is a logical decision. Since the system as a whole must make thousands of logical decisions, electrical circuits have been designed to make them. These decision- making circuits are part of the system control. Also, the launching system control contains circuits that "keep tabs on" (monitor) the operation of the complete system. When an event takes place in the system, say the blast doors are opened, the completion of the event is indicated on a display panel. Almost every event that happens in the system is displayed visually on a panel. These panels are also part of the launching control.

Missile Launching Control Mk 10 consists of electrical switches, circuit breakers, relays, and other electrical devices that make up control circuits. Consoles and power distribution panels are also included.

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Figure 5-33. — Mechanics and hydraulics of the loader: A. Engagement of the aft booster shoe with the saddle cart; B. Floating track aligned to shoe.

Types of Control

The missile launcher train and elevation power drives are controlled through the launching system control. Also, the system control permits step and automatic control of the rest of the system. We had better define what we mean by "step" and automatic operation.

In step control each individual operation is started by a switch or pushbutton. In automatic control each step of an operation is performed automatically. Once a process has been started, it follows through without interruption; whereas, in step control the operation is performed in discrete steps.

Control Panels

The GMLS Mk 12 has 13 control panels. We are going to talk briefly about the more important ones. All of these panels together control, monitor, and test system operation. Also they provide a means for distributing electrical power. The location of these panels is shown in figure 5-34. These are in areas 1 and 2, or feeder and assembler areas.

POWER PANELS. - Panel EP-1A provides power distribution for the launcher power drives, missile warmup power, and electrical power to the launching system control circuits.

Power panel EP-1B distributes power to the magazine equipment, loader power drives, and the anti-icing equipment. The reason for two separate power distribution panels is that you don't want all your electrical eggs in one basket.

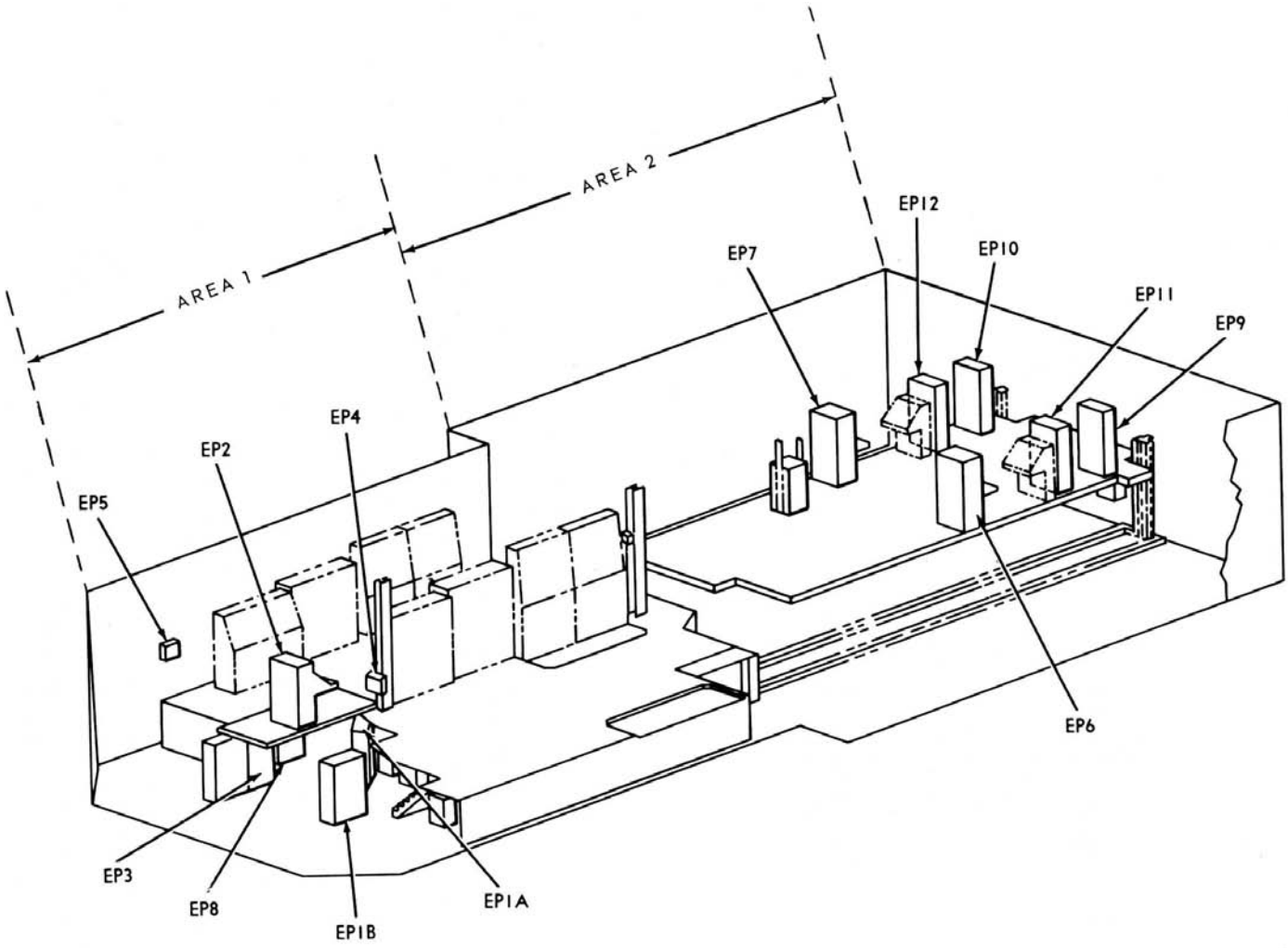
Launching System Panel EP2 contains switches, indicators, amplifiers, and relays needed to operate and control the launcher and feeder. Following are some of the functions that can be performed through the EP2 panel:

1. An operator, called the Launcher Captain, can select the launchers train and elevation signal source. If you want to control the launcher in train and elevation from a signal source other than the computer, you just throw a switch on the face of the EP2 panel to the appropriate position. You would do this if you wanted to test how well the launcher power drives were operating.

2. There are many lights on this panel. Some are red, some are green, and others are amber when lighted. A red indicator light might indicate there is a casualty in a hydraulic system, or that an electric motor is stopped. A green indicator light shows that a motor: is running. An amber indicator light might glow to show that a launcher rail has a missile on it and what type of Talos missile. A series of lights is used to monitor the movements of a missile as it flows through the launching system.

3. By throwing the right switches you can start electric motors as you need them. Under certain conditions you don't need all of them running at the same time, so independent start control is provided.

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Figure 5-34.—Control panels in the Talos missile launching system control.

4. The launcher captain can select one of several ways of operating the system. With switches he can put the system in the load method of control. In this operation the system takes a missile out of the magazine and puts it on the launcher. Sometimes it is necessary to remove a missile from the launcher. By throwing switches, this unloading operation is started. Then the system takes the missile off the launcher.

TEST PANEL EP3. - This panel contains switches, synchros, and jack plug connections to perform complete tests on the launcher power drives and to operate the launcher in local control. Dummy directors, signal generators, recorders, and other test equipment may be plugged into the panel to conduct tests.

ASSEMBLER PANELS. - Panel EP4 contains switches, relays, and indicators for monitoring and controlling the operation of the A-side of the assembler. EP5 panel is identical to, and has the same function as EP4 except that it controls the B-side of the assembler.

MAGAZINE PANELS. - EP6 panel provides for monitoring and controlling the" A" magazine mechanisms while in step control. Magazine Panel EP7 is the same as EP6 except that it controls the B-side magazine.

RELAY PANEL EP8. -This panel contains relays associated with launching system control.

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LOCAL CONTROL PANELS.-EP9 panel contains the equipment for the local control operation of the A-side loader power drive. The loader can be operated at variable speeds through controls on this panel. Panel EP10 is identical to Panel EP9 except for the fact that it controls the B-side loader power drive. Local Control Panel EP11 contains the equipment for local control operation of the A-side magazine hoist drive. The velocity and movement of the hoist can be controlled through this panel. Panel. Panel EP12 is identical to the EP11 except that it controls the B-side magazine hoist drive.

LAUNCHING SYSTEM FUNCTIONING

Now let's follow the functioning cycle of the Mk 12 launching system as it fires a round. Except for installing wings and fins, the cycle is completely automatic.

We begin the firing cycle when the weapon control station (WCS) gives the order for system alert followed by a load launcher order. The wing and fin assembly operators (12 of them) are alerted and the decision is made in WCS as to whether the first load to be put on the launcher is a double- or a single-rail loading and, when a single-rail loading is chosen, which side (A or B) is to be used. The launcher area is checked to see if it is clear, and the load launcher switch is moved to the load position. The WCS also selects the type of missile to be fired.

When the load order is given, the magazine hoist automatically indexes (moves up or down) to the selected tray position and removes around and its tray. With the round and tray on the hoist, the hoist moves upward to the standby position. The magazine doors open and the hoist rail spanner sections rotate to align with the hoist rail. The magazine hoist raises the round in the tray from the standby position to the load position, and the floating section of the loader rail lowers. The rammer retracts, engaging the aft booster handling (upper) shoes, and the missile unlatching actuator is extended, causing the shoe latch to retract. When the shoe latch has retracted, the rammer moves the round four inches, and the top booster shoes engage the floating rail portion to the loader track. As the missile-booster combination is moved forward by the rammer, the cinch belt (fig. 5-28) which holds the missile to the forward end of the tray is released automatically. The missile unlatching actuator retracts, and the floating rail elevates the round to the loader rail, about 2 inches.

When the floating rail has fully elevated and latched, the hoist lowers the empty tray into the magazine, the hoist rail spanner sections retract, the magazine doors close, the loader moves the round to the wing and fin assembly area (area 1), and the loader chain positioner locks the chain. The empty magazine tray is returned by the hoist to the stowage position, and the hoist returns directly to a standby condition, or it selects another round when ordered, and then returns to the standby position until the next cycle.

When the weapon arrives at the wing and fin assembly area, the positioner latches, and the electrical contactor extends to start missile warmup. When the magazine doors are closed, the blast door may be opened. However, normally the blast door opening is delayed for five seconds by a time delay relay, thus making sure that the door is open a minimum amount of time. Interlocks insure that the launcher is in the load position before the blast. doors open. The lower blast doors open first, and the upper doors and spanner rails raise and latch into the launcher rail, forming an inline extension of the launcher loader (feeder) rail system. Wing and fin installation (this operation should require a maximum of ten seconds) is completed, the arming plug installed, and 12 operators actuate their individual safety (hand) switches, indicating that each operator is clear of the round. External warmup power is removed, the missile switches to internal power, the electrical contactor retracts, the assembly area positioner retracts, and the round moves onto the launcher.

As the round reaches the launcher, the reverse motion latch extends and, when it is fully extended, the loader saddle cart returns to a position above the magazine, and the launcher electrical contactor extends. After the contactor is in place, missile internal power is removed and external power is again applied to the missile. The contactor also completes circuits for missile identification and type of warhead indication. As the loader saddle cart retracts past the upper blast door, the blast doors close. When the upper blast door is clear of the launcher, the train and elevation latches retract, and the launcher remains at the load position awaiting assignment; or it synchronizes with the launcher order signals from the computer if these signals are present (assignment has been made). After assignment has been made, the launcher trains and elevates to the firing position. The missile may now be fired by the WCS. The first loading operation requires approximately 57 seconds.

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Subsequent salvos usually require less time. The exact time varies with the location of the missile required.

TARTAR LAUNCHING SYSTEM

The Tartar missile launching systems are installed on guided missile destroyers. Tartar missiles are also used as backup missiles for the Talos systems aboard heavy cruisers. The Tartar Mk 11 launching system is used on DD3- and CG-class ships. This system has a two-arm launcher located over two rings of vertically stowed missiles. The Mk 13 launching system is used on small ships. It has a single launcher guide arm that loads in the vertical position. The missiles are stowed vertically in two rotatable ready service rings.

Tartar Launching System Mk 22 was developed for use on small ships where space and weight allowances were too limited to permit the use of the Mk 11 or the Mk 13 system. The Mk 22 system was designed to replace a 5"/54 gun mount. A single ready-service ring is located directly below the launcher with the missiles stowed vertically.

The main components of the Tartar launching system are the launcher, the missile magazine, and the missile launching control system. As Tartar missiles are completely assembled before stowage, and the folded tail surfaces are erected automatically after the missile is on the launcher, there is no need for an assembler. This also eliminates the space for the control panels, which have to be placed outside the launching system.

Figure 5-35 shows the Mk 11 launching system.

The launcher and magazine require no operating personnel; three men are required for the control panels.

During automatic operation, the launching system control initiates and controls the loading cycle, but the launcher is positioned and the missile is fired by the ship's fire control system

LAUNCHER

The Mk 11 launching system uses Launcher Mk 8, Mods 0, 1, and 3. The Mk 13 launching system uses Launcher Mk 116 Mod 0. Launching System Mk 22 uses Launcher 123 Mod 0. Figure 5-35 shows the Mk 8 launcher in the vertical position with a missile on each guide arm, before the launcher is trained and elevated to the correct launching position as ordered by the fire control system on the ship.

Guided Missile Launcher Mk 8 Mod 0

The missile launcher consists of a dual- arm launching guide, a rotating carriage with trunnions, a supporting stand structure, and a combination electric and hydraulic slipring assembly. The general layout is much like that of a gun mount. Both guide arms can be loaded from either the inner or outer ring of the magazine. The two arms are similar in construction, except for right- and left-hand parts. The launcher is remotely controlled by Missile Launching System Control Mk 9 Mod 0.

The major components of the launcher are the stand, the carriage, the missile launcher arms or guides, and the slipring assembly. The train and elevation power drives are components of the carriage.

The stand assembly includes a stationary training rack and hydraulic and mechanical components required to rotate and index the magazine cover.

The carriage is bearing mounted in the stand, is capable of unlimited train in either direction, and supports the bearing-mounted torque tube. Besides the carriage structure, the carriage assembly includes a hydraulic system, train and elevation power drives with associated control equipment, latches and securing pins, and the blast door operating mechanisms.

The train and elevation power drives are independent hydraulic drives each with its own electric motor. The pinion of the train power drive meshes with the stationary training rack of the stand and rotates to move the carriage in train. The pinion of the elevation power drive meshes with the gear of the elevation segment to rotate the torque tube in elevation.

The missile launcher includes the torque tube assembly, two guide arms, and a guide hydraulic system. The guide arms can extend for outer magazine loading and retract for inner ring loading. Launcher firing is always accomplished from the retracted position; dud jettisoning is always accomplished from the extended position. Each guide arm includes a missile ramming mechanism" Each rammer is a hydraulically operated chain hoist that can be extended into the magazine cells to hoist a missile to the arm. The rammer mechanism includes a hand drive for manual operation in the event of failure of hydraulic pressure.

Each guide arm incorporates a front, center, and rear guide. During loading or unloading, the missiles ride on a continuous rail from the magazine to the guide arm, composed of rails

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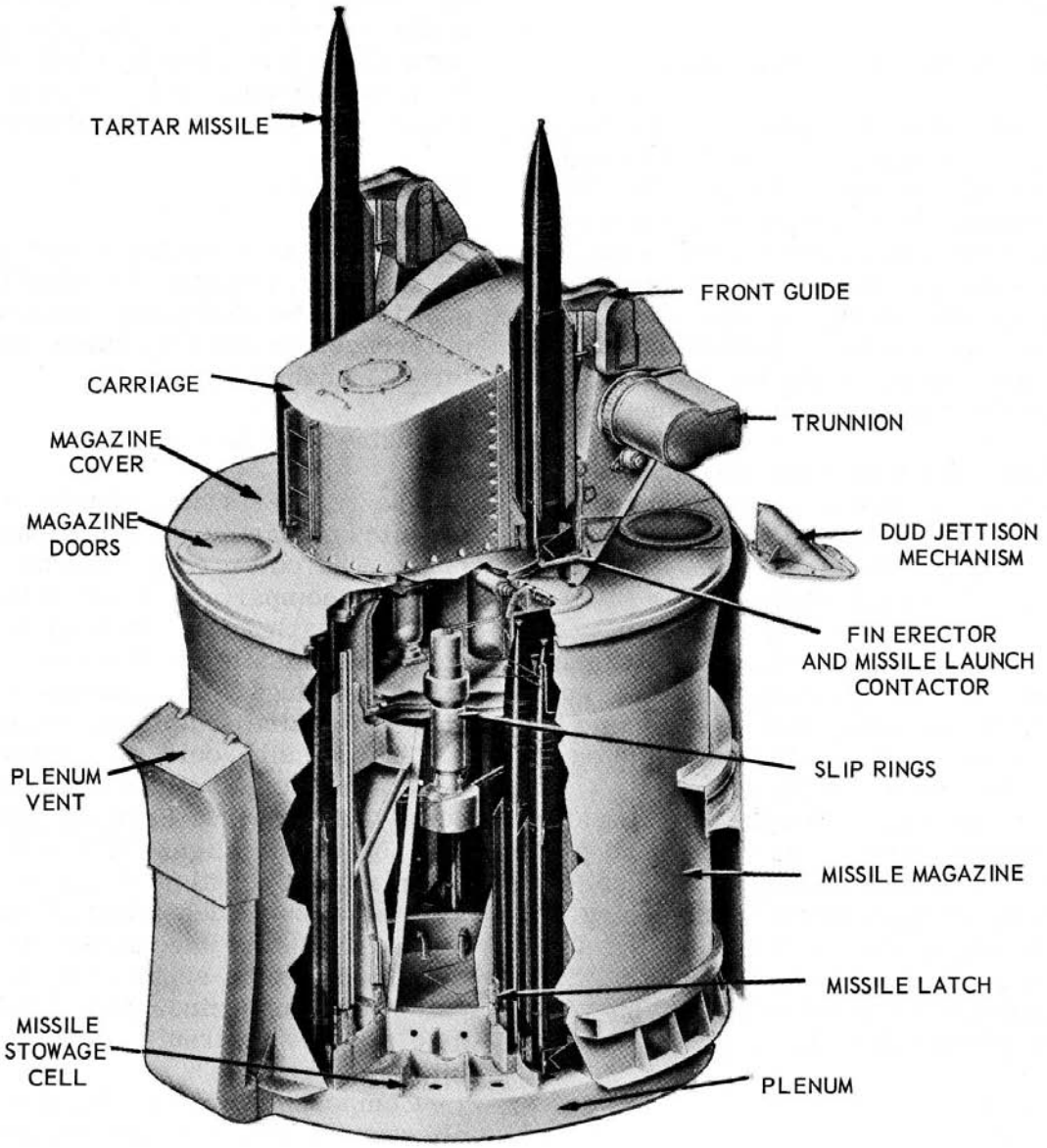


Figure 5-35.—Guided Missile Launching System Mk 11 (Tartar).

in the magazine cell, a segment of rail on the underside of the blast door, and the three guides on the guide arm. The rear guide extends and latches to the blast door when the door is opened. It is extended to latch to the transfer dolly during transfer operations. In automatic loading the rear guide remains extended until the missile is within a few inches of final rammed position. At this point the rear guide retracts and connects an electrical connector from the launcher to the missile. The rear guide incorporates four fin erectors for erecting the missile fins.

The slipring assembly is located on the vertical centerline of the launcher. The assembly transfers electrical power and signals, as well as hydraulic pressure and anti-icing circulating fluid between the rotating launcher and fixed structure of the missile launching system,

You will recognize many of the launcher parts which have the same names as in the Terrier and Talos systems. Some new names here are plenum and plenum vent, magazine cover, and fin erector. They are only on the Tartar system. The plenum and plenum vent

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are part of the safety system to carry off dangerous fumes in case of an accidental firing in the magazine.

Guided Missile Launcher Mk 116 Mod 0

This is the launcher used with the Mk 13 Tartar launching system. As you have seen in figure 5-2, it has but one guide arm for firing missiles. However, it can fire at a rapid rate. The missile magazine is directly beneath, and it holds 40 missiles, stowed in two concentric circles, called the ready service rings. The ready service rings can be indexed to the position beneath the blast door, ready for hoisting. The launcher can be positioned over either ready service ring.

The launcher assembly consists of the carriage and guide. A base ring and two trunnion supports form the structural units of the carriage (fig. 5-36). The blast door is part of the base ring. It opens only when a missile is being transferred from the magazine to the guide arm or is being put into the magazine. The carriage rotates (trains) and the guide pivots (elevates) to bring the missile into the ordered fire position. The missile is held on the guide arm by the retractable rail.

Mounted on the underside of the base ring are a power unit, cables, piping, and mechanical parts for electrical, hydraulic, and anti-icing functions, Inside the trunnion supports are cables, piping, and connections to supply the guide arm. In the righthand trunnion are the final drive components which include a chain-and-sprocket drive, a pinion, and a sector gear (elevation arc).

Mk 123 Launcher

The Mk 123 Mod 0 launcher is used with the Mk 22 Mod 0 launching system. It has a single guide arm, which is identical to the guide arm of the Mk 13 system. The base ring, on which the launcher is mounted, rotates to position the launcher over the selected missile in its cell. Within the carriage are the train/hoist and elevation power drives, a center column, service platform, train and elevation fluid supply tanks, and the hoist. The trunnion supports are on top of the base ring. The ship's ventilation system is used in the carriage to keep the air circulating.

The train/hoist power drive has a single electric motor-driven hydraulic transmission with separate controls and gear reducers for either training the launcher or driving the hoist chain.

The train/hoist system and the elevation system each have a receiver-regulator with a servoamplifier. Each system has an electric motor coupled to a variable-stroke hydraulic pump (A-end) which drives a fixed-stroke hydraulic motor (B-end). Each system has a power-off brake and associated mechanical drive trains.

MAGAZINES

All Tartar magazines are directly beneath the launcher, and stow the missiles in the vertical position. The following discussion points out differences in the magazines used with the different launching systems.

Magazine Mk 6 Mod 0

The ready-service missile magazine has 42 missile compartments arranged in two concentric rings. The outer ring contains 24 and the inner ring 18 compartments or cells. A set of two rails in each cell fits lugs on the missile to hold the missile in the cell. Latches secure the lower lugs. The individual cells are parts of the magazine and plenum structure.

The missile cells are closed at the top by a rotating cover, fitted with two inner and two outer blast doors. Each diametrically opposite pair of doors aligns with either an inner or outer ring. Operation of the magazine cover is automatic but independent of the launcher. The cover operating mechanism is driven by hydraulic pressure supplied by an auxiliary power unit in the magazine. This auxiliary power unit also supplies hydraulic pressure to operate the missile latches.

Components of the magazine control the application of warmup power to the missiles in the cells. The magazine includes a ventilating system, a sprinkling system to cool overheated missiles, an anti-icing system. and a CO_2 system for fire protection. The magazine has a flame barrier to isolate the missiles, and arrangements for safe collection and exhaust of resulting propellant gases if a missile ignites in its cell. This arrangement consists of the plenum chamber and plenum vent, shown in figure 5-35 and described later in this chapter.

Magazine Mk 8 Mod 0

The construction of the Mk 8 magazine, used in the Mk 13 launching system, is similar to the Mk 6, but is smaller since it serves only one launcher arm. The ready service rings, in two

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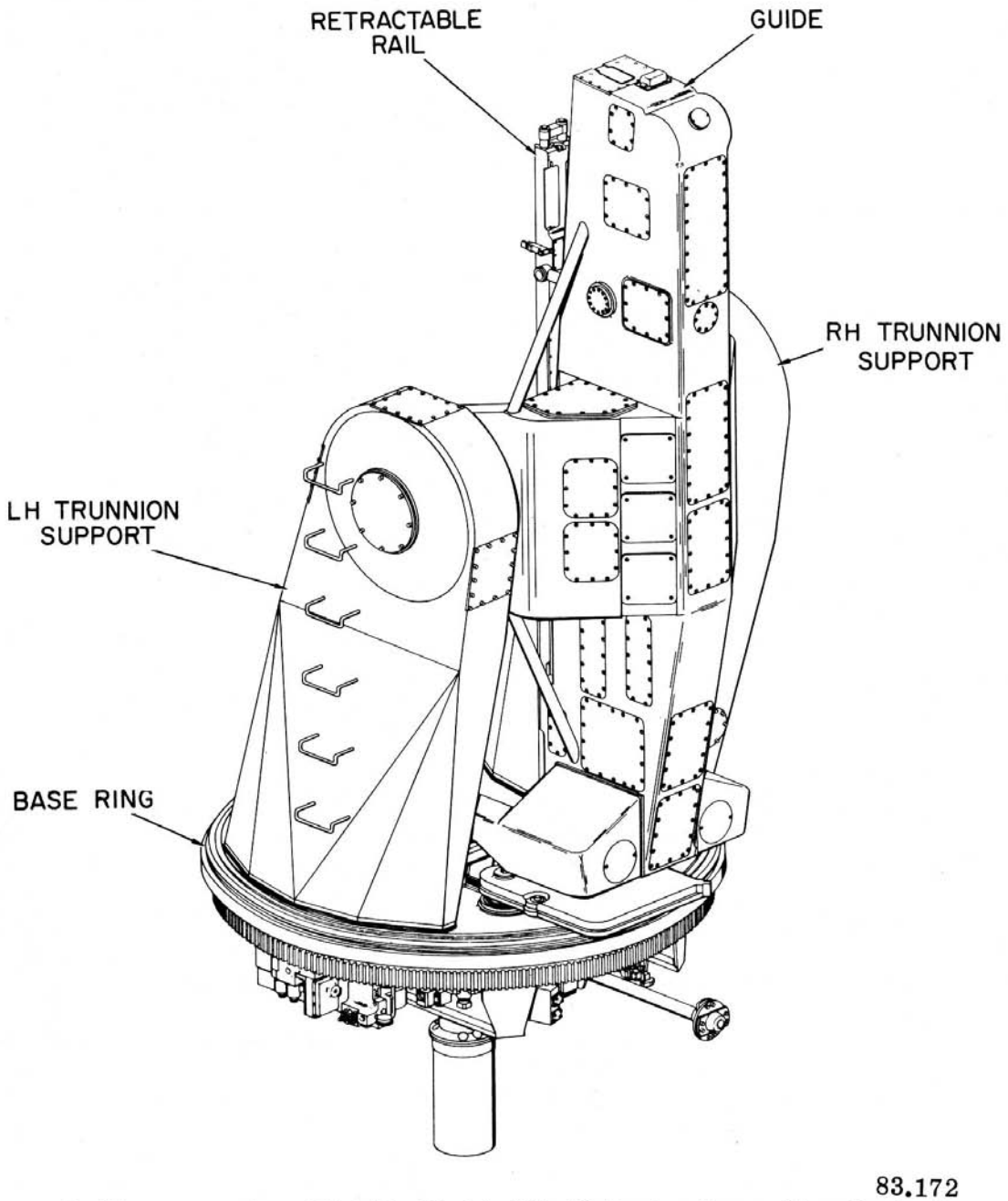


Figure 5-36.—Launcher Mk 116, Mod 0 (Mk 13 Tartar Launching System).

concentric circles, hold 40 missiles. In operation, the ready service ring rotates between the outer shell of the magazine and the inner structure to position the missiles at the hoist station for loading into the launcher. Each ring of missiles has a retractable rail just above the ready service ring. During the hoist cycle, the retractable rail extends and serves as a guide for the hoist chain and missile shoes. The magazine power supply, located in the inner structure of the magazine, rotates the ready service ring to the selected position, and drives (raises or lowers) the hoist.

Magazine Mk 9 Mod 0

The magazine for the Mk 22 launching system has a fixed single ring of 16 missiles. Instead of moving the selected missile to position beneath the blast door, the cover (mounting the launcher)

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is rotated until the blast door is directly above the selected missile, and then the hoist raises it to the launcher.

Associated Equipment

Some of the associated equipment in the launching system for the Tartar missile has been mentioned in the course of the discussion thus far.

WARMUP. - Warmup power is applied to the missiles while in the magazine, so the electronic tubes will be ready to operate when the missile is launched. The main components carrying the warmup power supply to the missile are the warmup contactors and the electrical contact -ring. As each missile is loaded into the magazine during strikedown, a warmup contactor in the cell enters a socket in the missile, establishing the circuit through which power will be applied when the missile is being readied to fire.

PLENUM CHAMBER. - Under the space or cell for each missile in the magazine is a space called the plenum chamber. If a missile should accidentally be ignited while in the magazine, the plenum chamber receives the exhaust gases and conducts them to the plenum vent to escape to the atmosphere. No matter where the missile is stowed, there is always a plenum compartment beneath it. Each compartment has a blow-in plate. Near the top of the magazine are four blowout plates, which release if pressure in the magazine builds up too much.

WATER INJECTOR. - Another system used only in the Tartar launching system is that of injectors. A total of 96 injectors are used, inserted into the base of the stand. Each injector is a standpipe threaded into the base, and a water injection detector nozzle. If a missile were accidentally ignited in the magazine, only the injector located under the missile will actuate to douse the ignited one. There is also a sprinkler system in the magazine to shower down water from above.

DUD JETTISON. - The dud jettison device used with the Mk 11 launching system is similar to that used with Terrier missiles. On the Mk 13 and Mk 22, however, the jettison mechanism is on the launcher arm, and can be operated by remote control from the EP2 panel.

CARBON DIOXIDE SYSTEMS. - An additional means of fire protection provided in the Tartar launching systems is carbon dioxide, supplied by two independent systems. One system protects the area where the missiles are stowed and the other protects the inner or center compartment of the magazine where the power units, receiver-regulators, and electrical units and cables are mounted. The carbon dioxide is supplied from pressurized cylinders of liquid carbon dioxide, secured in an off-mount location. Heat-sensing devices in the magazine detect overheating when a rapid rise in temperature causes the system to activate. Normal changes in temperature do not cause tripping of the actuating levers. Release of the carbon dioxide rapidly vaporizes it and it spreads all through the magazine and reduces the temperature rapidly and smothers any fire.

WARNING. - Although carbon dioxide is not poisonous to breathe, it shuts off all supply of oxygen and quickly smothers all oxygen-breathing life. Observe the precautions posted in and on the magazines wherever carbon dioxide is used.

ANTI-ICING SYSTEMS. -Anti-icing equipment is not unique to the Tartar launching system; Terrier and Talos launchers are similarly equipped to ensure operation of the launcher under low temperature conditions. Pipe lines for the circulation of heated fluid are attached to the launcher and exposed portions of the magazine, such as the blast doors. The anti-icing fluid is pumped from a reservoir tank heated by the ship's steam system.

LAUNCHING SYSTEM CONTROL PANELS

The compactness of the Tartar launching system installation leaves no room for the control panels and therefore they must be mounted nearby. Figure 5-37 shows the location of the control panels for the Mk 11 launching system. The control panels for the Mk 13 and the Mk 22 systems are similarly located in a control station off mount but as near as possible to the launcher and magazine.

Missile Launching System Control
Mk 9 Mod 0

The missile launching system control (fig. 5-37) regulates and directs operation of the missile launching system. The power distribution panel (EP1) controls the ship power inputs to

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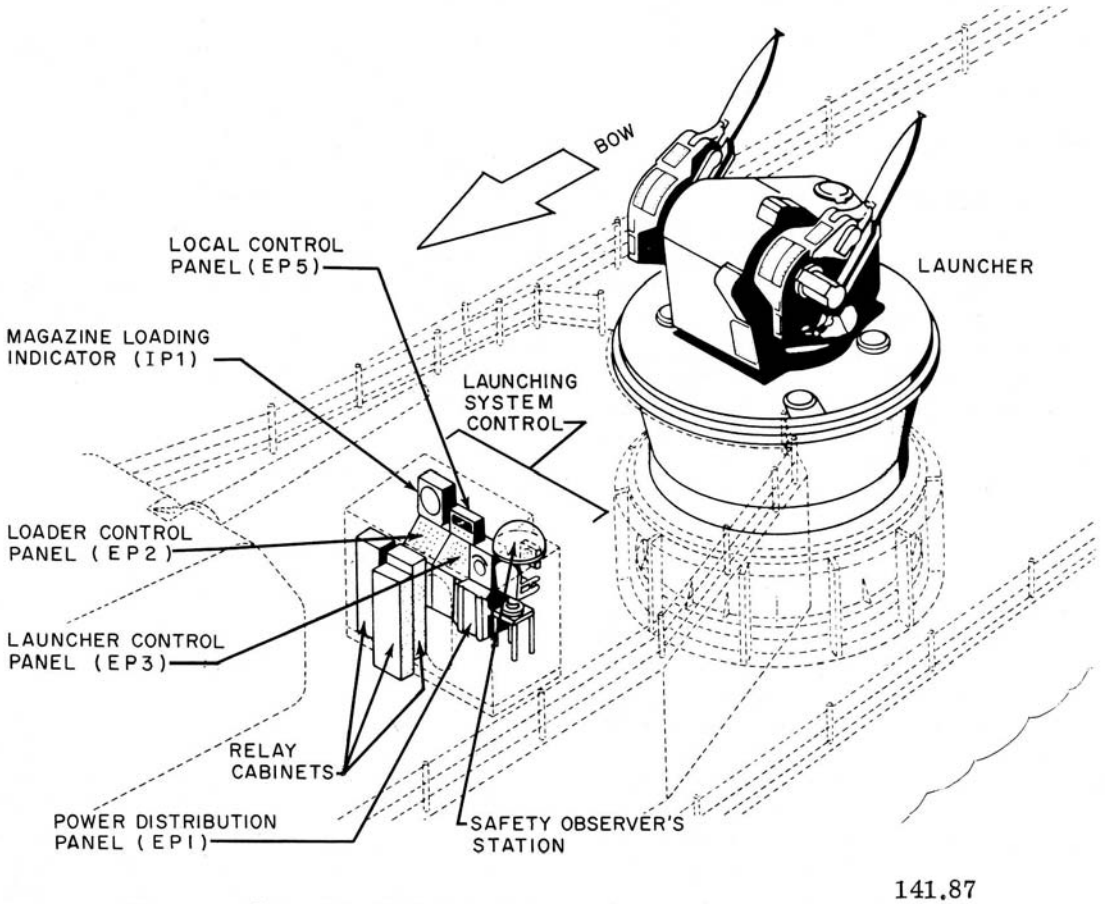


Figure 5-37. — Mk 11 (Tartar) launching system control station.

the missile launching system. The loader control panel (EP2) controls the movement of missiles between the magazine and the launcher guide arm. The launcher control panel (EP3) controls the launcher in loading, unloading, transfer, exercise, firing, and jettisoning. The local control panel (EP5) trains and elevates the launcher manually and displays an error indication to the launching system captain.

The magazine loading indicator (IP1), shows whether cells are loaded, if the warmup power is on, and if the missiles are latched or unlatched in their cells.

Control System Mk 13 Mod 0

The Mk 13 Mod 0 launching system has three remotely located control panels that are the control centers for the electrical circuitry. The EP1 panel is the basic distribution panel for all electrical power for the launching system. It contains circuit breakers, contactors, overload relays, fuses, switches, etc., for the electric motors and the supply circuits.

The EP2 panel is the operation control panel for the launching system and is manned by the launcher captain. It contains the switches and relays to select and control the type of operation, the lights to indicate the phase or sequence of operation, synchros for launcher load, dud jettison, strikedown and checkout positions, and amplifier and error meters for train and elevation.

The EP3 panel is primarily a test panel and is not manned during normal automatic operation. The launcher can be operated in local control from this panel and it contains the switches and jack plugs to perform tests on the launcher train and elevation systems.

Control System Mk 21 Mod 0

The control station of the Mk 22 Tartar launching system also has three control panels: EP1,

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EP2. and EP3. These have the same functions as the comparable panels in the Mk 13 system.

LAUNCHING SYSTEM FUNCTIONING

Mk 11 Launching System

In automatic operation, the launcher guide arms are elevated to vertical position and the launcher is rotated to position the arms over the selected missile compartments. A chain hoist rammer on each guide arm extracts a missile from the magazine compartment and raises the missile to the arm. On the arm, the folded tail surfaces of the missile open automatically, and connections are made automatically to transfer warmup power and control information to the missile, arm the missile, and complete the firing circuit.

In continuous operation the system is capable of firing a salvo every 20 seconds. Although ordinary operation is automatic, the system can be operated in manual step control. Safety and other interlocks ensure proper sequence of operation. The launcher and magazine require no operating personnel. The launching system control requires three men. Dud jettisoning units. one for each guide arm, are installed adjacent to the launcher. Auxiliary equipment provides for checkout, strikedown, and servicing of the missiles. The system, excluding missiles and auxiliary equipment, weighs approximately 66 tons.

Mk 13 Launching System

Like the Mk 11 launching system, the Mk 13 launching system can be operated in automatic or in step control. Automatic control, with orders coming from the weapons control station, is normally used for firing procedures, while step control is used for exercise, strikedown, and checkout procedures. Automatic control may also be used for unloading the missiles. Except for the fact that there is only one guide on the launcher, the steps in the loading and launching operation match those in the Mk 11 system. It has the same system, unique for the Tartar, for automatic erection of the fins on the missile after it is on the guide. When the missile is to be returned to the magazine, the fins must be folded before it can pass through the blast doors. The fins are folded by sending a crewman out on the launcher to do it; they are not folded automatically.

Mk 22 Launching System

A major difference between the Mk 13 and the Mk 22 is that the magazine structure of the Mk 22 is nonrotating, and the launcher is the rotating part. The launcher is positioned over the cell of the selected missile, which is then hoisted to the guide, and the launcher trains and elevates to the position ordered by the weapons control station. Operation can be automatic from the weapons control station or in step control from the control panels near the launcher, The launcher is activated from the EP1 power panel, and then it can be operated in automatic or step control.

SAFETY

The primary reason for the vast amount of information available on the subject of safety precautions is simply the desire to prevent accidents. Research has shown that a majority of all accidents come about through sheer carelessness. Not only is there a loss of time involved in an accident, but also there is an accompanying loss of either equipment, material, or, in the extreme case, life itself. Aside from these important considerations, there is a vast amount of money wasted in replacing damaged equipment, making investigations, paying for hospitalization or funerals, and for man-hours not worked during convalescence. These are but a few of the problems faced every day by the Navy because personnel fail to heed the posted and required safety precautions.

Practical safety features are incorporated into Navy equipment to eliminate potential hazards to personnel. Since familiarity with equipment leads to carelessness, observation of all safety notices and rules is mandatory. NO RELAXATION OF VIGILANCE SHALL EVER BE PERMITTED,

All personnel taking part in and observing operation of power equipment shall remain alert, keep clear of moving parts, and be thoroughly familiar with the safety precautions applicable to that equipment. At no time will skylarking be allowed in the vicinity of operating power equipment.

The following summary of safety precautions is intended to be general in nature but their importance should not be misunderstood.

Do not service or adjust live equipment without the presence of another person capable of rendering first aid.

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Never measure potentials over 600 volts by means of flexible test leads.

Do not tamper with interlocks or any other equipment safety feature.

If possible, use only one hand when working on live circuits.

Never use electrical or electronic equipment known to be in poor condition.

Do not allow unqualified personnel to operate the control panels. Trainees or other persons undergoing instructions shall operate only under the strict supervision of a qualified and responsible operator.

Except for General Quarters, always sound the train warning bell and get an all-clear signal before training and/or elevating the launcher (before each time the equipment is to be moved); likewise sound the loading horn before moving any of the feeder components (before each time equipment is to be moved).

Whenever any motion of a power drive unit is capable of inflicting injury to personnel or material, not continuously visible to the person controlling such motion, the officer or petty officer authorizing the unit to be moved by power shall insure a safety watch. The safety watch shall be omitted in general quarters, but must be maintained in areas where such injury is possible, both inside and outside the unit being moved. There shall be telephone or other effective voice communication established and maintained between the station controlling the unit and the safety watch.

Do not enter the train circle when the launcher train motor is running.

Do not load a live round for a nonfiring exercise.

Be sure that all personnel are located in safe areas before proceeding with such operations as extending or retracting a loader chain (when loaded), opening or closing either the blast doors or magazine doors, indexing a ready service ring, and transferring missile-boosters.

Do not enter a magazine while loading or unloading procedures are under way.

Be thoroughly familiar with all posted safety precautions and those listed in the OP pertaining to the equipment to which you are assigned.

SUMMARY

As you study the different missile systems you will notice that many of the mechanisms and the electrical and electronic components are the same and operate in the same manner. Not that knowing one system means you know them all, for there are differences, but by making comparisons and noting the ways in which systems are different, you will find it easier to understand the operation of the several systems.

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CHAPTER 6

A TYPICAL GUN AND MISSILE WEAPONS SYSTEM

This chapter will give you a brief overview of a typical gun and missile weapons system. The system described here is made up of elements that have been taken from Terrier and Tartar system. It illustrates the typical composition and functioning of gun and/or missile weapons systems (not including all weapons, such as depth charges, bombs, etc.). And it will provide the background that will lead to a better understanding of the system you have aboard ship.

WEAPONS SYSTEM CONCEPT

You have already studied the fundamental fire control problem. Now you will study some of the equipment used to solve that problem.

The effective use of any weapon requires that a destructive device (containing an explosive) be delivered to a target-usually a moving target. To deliver the weapon accurately, we must know both the location and the velocity of the target. Most targets now travel faster than sound, and must therefore be engaged at great distances. Against such targets, a weapon is most effective when it is used as part of a weapons system. A weapons system is the combination of a weapon (or multiple weapons) and the equipment used to bring their destructive power against an enemy.

A weapons system includes:

1. Units that detect, locate, and identify the target.

2. Units that direct or aim a delivery unit.

3. Units that deliver or initiate delivery of the weapon to the target.

4. Units that will destroy the target when in contact with it or near it. These units are usually termed weapons. Figure 6-1 illustrates these units and groups of units that make up a weapons system.

DETECTING UNITS

The first steps in using a weapons system and solving the fire control problem are to detect, locate, and identify the target. Initial contact with a surface or airborne target may be visual, or it may be made by radar. It is difficult to detect a target visually at long range, or even at short range when visibility is poor. For that reason, targets are usually detected by search radar. Search radars, as you know, keep a large volume of space around your ship under continuous watch. They give the ship fairly accurate information about the target's position, even when the target is hidden by fog or darkness. To determine a target's position we must know its range, its direction from the ship, and, for an airborne target, its elevation. Radar gives all three of these coordinates. (Radar has certain disadvantages, too. For example, it can be detected by an enemy at about four times the range at which it can pick up an enemy target.)

Optical devices are used as a supplementary source of information on slow-moving targets at relatively short range. They are useless against missiles or jet aircraft, which must be engaged while they are still beyond the range of optical instruments.

After we have detected and located a target, we must identify it. How can we identify a target that may be several hundred miles from our ship? The answer lies in a device called IFF (Identification, Friend or Foe). See Figure 6-1. Radar alone cannot tell the difference between friendly or enemy targets. But the IFF equipment can challenge an unidentified target, and determine from the answer whether the target is friendly. The equipment consists of two major units - the challenging unit which asks the question, "friend or foe," and the transponder which answers the question. IFF equipment is used in conjunction with search radar, and sometimes fire control radar. Briefly, this is how it works. To challenge a target you press a switch attached

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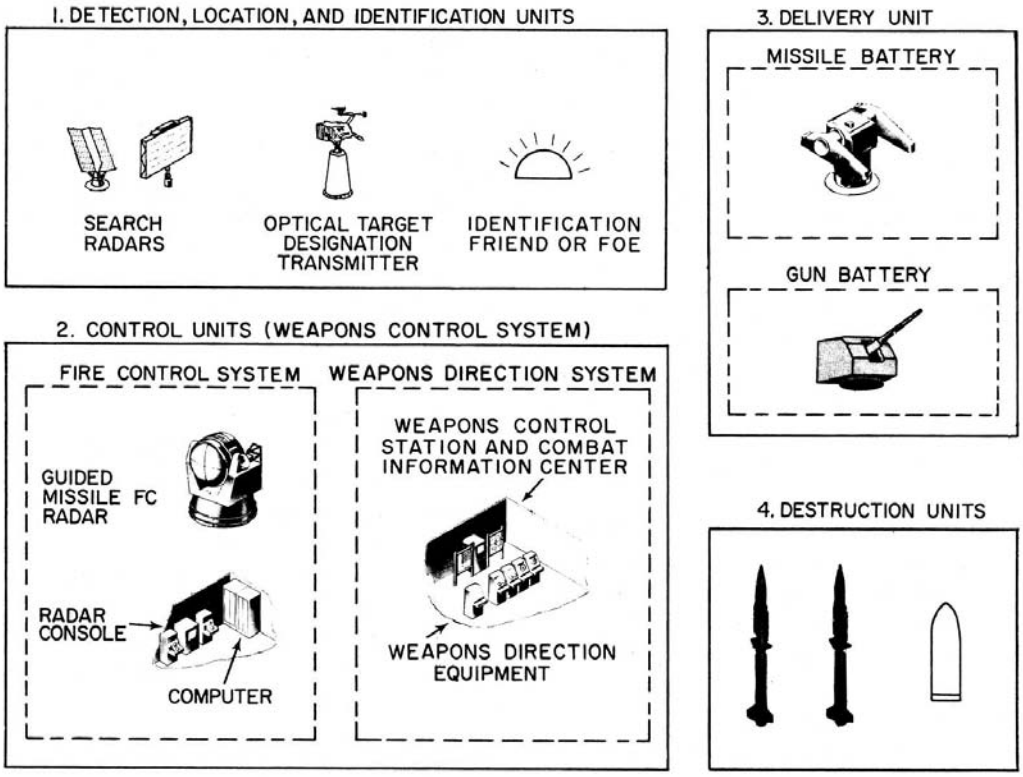


Figure 6-1. — Basic composition of a gun and missile weapons system.

to the radar. The transmitter will then send out a pulse of low power radio energy toward the target. If the target is friendly it will carry a transponder, which consists of a receiver and a transmitter. When the receiver picks up a challenge, it causes the transmitter to send out an answering pulse or pulses. The answer is usually a coded message. It is picked up by the challenging unit's receiver and sent to the indicator of the search radar. An enemy target will not know the code and therefore will not be able to answer the challenge.

CONTROL UNITS

Control units in a weapons system develop, compute, relay, and introduce data into a delivery unit, a weapon, or both. They direct, control, or guide the weapon (destructive device) to the target, and cause it to function in the desired way. These units form the heart of the weapons system. Note (fig. 6-1) that there are two groups of units in the control unit: Fire control system, and weapons direction system. These will be discussed in more detail later.

Types of Control Units

The devices that perform the control functions include:

DATA TRANSMISSION SYSTEMS that send target position information developed by the detecting units to the rest of the weapons system, and convey other data among the components of the weapons system. Examples are synchro, resolver, and potentiometer circuits.

COMPUTER DEVICES to process the input data from the detecting units and other sources, and put out the aiming and program instructions that cause the weapon to reach its target. Examples are rangekeepers and computers.

DISPLAY UNITS that display information at various locations on the ship. These are generally electronic or optical devices.

DIRECTING DEVICES which, with the aid of detecting devices, establish target location to a finer degree than the detecting devices alone. Directing devices can also function to directly or indirectly control missile flight. Examples are gun and missile directors, and radar sets.

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REFERENCE DEVICES such as stable elements, which establish reference planes and lines to stabilize lines of fire, lines of sight, and other references. These units are gyroscopically controlled.

DELIVERY UNITS

Broadly speaking, delivery units launch or project destructive units toward the target. Examples are guns, missile and rocket launchers, torpedo tubes, and depth charge projectors. Don't think of these devices as weapons. The term WEAPON is properly applied to the destructive unit that is launched or projected. Thus a guided missile launcher is not, strictly speaking, a weapon; the missile itself is the weapon.

To be employed effectively against their targets, all weapons must either be aimed at their targets or must be programmed during flight. They may require both aiming and programming. Programming is the process of setting automatic equipment to perform operations in a predetermined step-by-step manner. Aiming and programming are done at or before the time of launching, either by or through the delivery device. This function is characteristic of all delivery devices, even the simplest. Aiming the destructive device (weapon) at the target may be done simply by positioning the delivery device (a gun barrel or launcher guide arm, for example). Or it may be done without aiming the delivery device, by placing program instructions in the weapon. Some missiles are programmed to start searching for the target after the launching phase is over. Examples of other programmed functions that could be performed in the weapon are ignition of propulsion units and arming of the warhead after a designated number of seconds of flight.

Types of Delivery Devices

Guns direct (aim) the projectiles by positioning the gun barrels, and the propulsion energy is provided by the propellant charge, which may be a separate component as in bag guns and semi-fixed ammunition, or enclosed in the powder case which is crimped to the projectile.

MISSILE LAUNCHERS retain and position missiles during the initial part of the launching phase, and, by means of attachments to the launcher, feed steering, vertical reference, and program information into the missile up to the instant of launch. Of course there are other types of delivery devices, such as torpedo tubes, depth charge and thrown weapon projectors, and rocket launchers. But guns, and missile and rocket launchers are most important to you as a GMM. You will be required to understand their function in the weapons system. The GMGs are responsible for operation of depth charge and thrown weapon projectors, rocket launchers, and the Basic Point Defense Surface Missile System. When you are ready for E-8 you will need to know about those also, so do not evade learning about them as you go along. Use your opportunities for learning.

DESTRUCTIVE UNITS

The end purpose of detection units, delivery units, and control units is to cause the destruction unit to intercept or pass near the target. It is then the function of the destruction unit to destroy or inflict maximum damage on the target. Except for projectiles used in small arms, and some of those used in calibers up to 40-mm, weapons and projectiles used in combat are loaded with explosives, and equipped with devices to set off their explosion at the proper time. For some weapons and projectiles, the proper time is the instant the weapon makes physical contact with the target. For those designed to penetrate targets protected by armor or concrete, the proper time is after penetration. Still others are intended to explode when they reach the vicinity of the target.

In some special types, the explosive is intended only to rupture the container so the contents can be disseminated in the area selected. Examples of these are various types of gas bombs (lethal or merely disabling), biological warheads, and various chemical warheads. In these types, the explosive is not the destructive force.

BASIC WEAPON COMPONENTS

All weapons and projectiles have these components.

1. A CONTAINER or BODY which houses the internal components. The body may have such other functions as piercing armor, breaking up into high velocity fragments when the weapon or projectile explodes, or improving the weapon's ballistic characteristics by means of fins or streamlining.

2. A DETONATING DEVICE (called a fuze, exploder, detonator, etc.) which initiates explosion at the proper time, and includes safety devices to prevent premature explosion.

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3. A PAYLOAD which is the "reason for being" of the weapon or projectile. The payload usually consists of high explosive or nuclear material. Exceptions were mentioned above as special types.

Weapons of some types have their own propulsion systems. The outstanding examples are guided missiles, torpedoes, and rockets. With the exception of rockets, weapons that have a propulsion system also contain guidance and control systems.

To summarize the weapons system concept, we can say that any weapons system contains four major functional components, which are interrelated to make up the system as a whole (fig. 6-1).

REPRESENTATIVE SHIPBOARD WEAPONS SYSTEM

The equipments making up each of the four categories of functional components are enclosed in separate blocks (fig. 6-1). We will introduce and discuss the four groups of equipments in the order in which they operate to solve the fire control problem.

TARGET DETECTION, LOCATION, AND IDENTIFICATION UNITS

The first contact with an airborne target is usually made by air search radar. These radars are designed to keep a large aerial volume under nearly continuous observation. Jet aircraft travel at high speed, and may launch guided missiles against our ships from a great distance. This requires that our radar search be carried out to long range. To cover the necessary area, search radar uses a wide beam. In addition, most search radar antennas rotate as they search. Targets detected during this scanning process show up on the radar's target display indicators as alternately fading and brightening spots. It is difficult to determine target range, course, and speed from these spots. All of these factors limit the accuracy with which search radar can provide information about target position. For target information of the required accuracy, we must depend on fire control radars. We will discuss these radars later in this chapter.

After the search radar has detected a target and determined its approximate location, the next step in the development of the fire control problem is to identify the target. The problem of recognizing and identifying a friend or foe is as old as warfare. Passwords, flag hoist signals, and even the uniforms we wear are identification devices that have been developed through the years.

In modern warfare the identification problem is urgent. Radar systems present targets in the form of spots or spikes (called echoes) on a radar screen; but friendly and enemy targets look alike on the screen. Furthermore, high speed planes and guided missiles give us very little time to solve this problem. And when friendly fighter aircraft pursue enemy planes to within gun range of our ships, the identification problem is acute.

The safety of ships in a task force is another phase of this problem. If the enemy were able to use our identification system, he could make deadly approaches before his presence were known. In the past, enemy planes have actually followed our fighters to their mother ship and discovered the location of the carrier and her escorts. In such an instance the destruction of the enemy planes is vital, so that the location of the fleet will not be revealed.

Before we leave the subject of the major equipments that fall in the category of detection, location, and identification units, we want to emphasize that solution of the fundamental fire control problem begins with detection of a target. The next step is to locate it. And the final step in this initial phase is to identify it as friend or foe. These three steps combine to form the first phase in the functioning of a weapon system. At this point you should begin to see that you must think in terms of a complete weapons system in order to understand the functioning of each individual component in the system.

In the discussion above we have considered only air targets. Surface targets and underwater targets must also be detected and identified, and their location determined. A search radar is used to scan the area for surface targets; sonar is used for the detection of underwater targets.

Now let's consider the CONTROL UNITS in group (2) (fig. 6-1). These are not the control panels we described in chapter 5, which control only the missile launching system.

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CONTROL UNITS IN A WEAPONS SYSTEM (THE WEAPONS CONTROL SYSTEM)

Once the air search radar detects and roughly locates the target, and the IFF equipment has determined whether it is a friend or foe, the target information from these sources is sent to the equipments that we have called control units. These units include fire control radars, computers, weapon direction equipment, stable elements, and many other mechanical, electrical, and electronic instruments.

Traditionally, the systems of equipment used for the control of a particular battery of guns, torpedoes, or other conventional weapons, have been known as fire control systems. But the complexity of guided missiles has required the introduction of new fire control instruments, and new terms of describe them. In the following paragraphs we will define some of these terms.

All of the units that are enclosed by the solid line in block (2) of figure 6-1 form a WEAPONS CONTROL SYSTEM. A weapons control system is defined as a group of interconnected and interrelated instruments that are used to control the delivery of effective fire on selected targets. The system is composed of a WEAPONS DIRECTION SYSTEM and one or more Fire Control Systems. It includes all the equipment necessary to control target assignment for guns, missiles, and ASW weapons.

Weapons Direction System

Any WEAPONS SYSTEM begins to function as a system as soon as a target is detected. A FIRE CONTROL SYSTEM however, begins its functioning by determining target position with all possible precision, so that a line of fire can be established. Before a fire control system can establish a line of fire, certain preliminary processes must take place within the weapons system. These processes are:

1. Detection of a target by search radar or other devices.
2. Identification of the target by IFF or other devices.
3. Evaluation of the target.
4. Designation of the target to a fire control system.
5. Acquisition of the target by a fire control system.

The weapons direction system coordinates and monitors the operations of the missile launching system and the fire control systems.

The target position and identification information obtained during the first two processes is sent to the CIC (Combat Information Center), and to the WCS (Weapons Control Station, Fig. 5-7). These two organizations of equipment and personnel may be in the same compartment or in separate locations (fig. 5-8). Here, we will consider them to be in the same compartment. This compartment also contains the units that make up part of the Weapons Direction System (WDS). This particular group of equipments is known collectively as Weapons Direction Equipment (WDE). The WDE, and minor units that support its function, make up the Weapons Direction System of a ship.

The purpose of the WDS is to perform those functions that are required during three phases of a tactical situation. During the first phase, the equipment provides electronic means for the display of targets detected by search radars, and it provides devices for selecting and initially tracking the targets that show up on the displays. These displays are similar to the PPIs that you are familiar with or have read about in Basic Electronics, NavPers 10087-B. Targets show up as bright pips or dots on the face of the scope.

As the tactical situation develops, and the targets get closer, the system provides means for evaluating the situation and assigning a fire control system or systems to acquire and track designated targets. This is the second phase in the tactical situation. The third and last phase requires that weapons be assigned by the WDS to the fire control system that is tracking the target. Before weapons are assigned, the tactical situation must be reevaluated.

EVALUATION. - So far in this discussion, we have introduced three new terms: evaluation, designation, and acquisition.

In fire control, evaluation is concerned with these questions.

1. What does the target intend to do? Is it going to pass close to the ship for observing, or is it going to launch an attack?
2. How threatening to the ship's safety is the target? If its obvious intent is to attack, how much time does the ship have to launch a counterattack? And what weapons should the ship use to repulse the target?
3. What kind of attack is the target capable of launching? If the target carries missiles, the ship must launch weapons that will reach the target before it can launch its missiles.

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There are other factors involved in evaluating a tactical situation, but these sample questions should give you some idea of what the term "evaluate" means.

The equipment in the weapons direction system I presents a complete visual picture of the tactical situation, It displays all the targets that have been detected by the search radars. Each target must be evaluated with respect to the overall defense picture. The process of target evaluation is performed by ship's personnel with the help of equipment in the WDS, Decisions are made to bring the ship's weapons to bear on the most threatening targets. These selected targets must be assigned to the appropriate fire control systems. The assignment process includes two functions - designation and acquisition.

DESIGNATION. This is the step taken to assign the tracking element (director, radar, radar set) of a fire control system to a particular target. On the basis of target evaluation and the availability of fire control systems (some of which may be disabled, or busy with other targets), decision is made to assign a fire control system to the target. This is usually done by pressing a button to activate circuitry that transmits target position information from the weapons direction system to the antenna positioning circuits of a radar set, or the power drives of a director. These units automatically move the radar antenna to the position designated by the WDS. If the designation data is inaccurate the radar set must search for the target.

The searching process may last for a fraction of a second or longer, depending on the accuracy of the designation information and other factors. Once the fire control radar has found the target and starts to track, it can be said that it has acquired the target.

ACQUISITION. Acquisition by the tracking device is the process of accepting a designation from the WDS equipment which acquired the target, and starting to track it. A target is acquired when the radar has "gated" it, or the crosshairs in the director sights are on it.

In the preceding discussion we indicated that the WDS was further subdivided into the weapons direction equipment, and other equipment related to the overall function of the weapons direction system.

Fire Control Systems

A ship may have several fire control systems, depending on the number and type of weapons aboard. It may also have more than one missile or gun fire control system, or a combination of both. In addition, the ship may also have an underwater battery fire control system.

Missile fire control systems include directors, radars, and computers. The major functions of these components include tracking of the designated target, transmission of the target data to the weapons direction system, aiming of the launcher, and guidance of the missile to the target.

The GMM does not operate the fire control equipment but he needs to have some knowledge of what is taking place so he can cooperate intelligently with the FTs.

DELIVERY UNITS

Chapter 5 described the delivery units (launchers) for Terrier, Talos, Tartar, and Standard missiles. The launchers for Asroc Launching Group Mk 16 which incorporates the Asroc Launcher Mk 112, is the responsibility of GMTs and is not described in this text. Shipboard gun systems may include 3-inch, 5-inch, and 8-inch guns. These are the concern of the GMGs, but you need to know about them when your chance comes to make E-7 or E-8.

DESTRUCTION UNITS

A typical weapons system has gun projectiles and one type of missile; larger ships have more than one size and type of projectiles and two or more types of missiles. The different missile rounds of the Navy are described in other chapters of this text; other naval ordnance is described in Basic Military Requirements, NavPers 10054-C, with which you should be familiar.

In the following articles we shall describe the units that make up the weapons direction system.

TYPICAL WEAPONS DIRECTION EQUIPMENT

Some of the major tasks performed by the weapons direction equipment (WDE) are director-to-target assignment, launcher-to-director assignment, salvo select, missile warmup, missile firing, and emergency and dud firing. The WDE is the link between the search radars and the fire control system.

It is worth repeating that the weapons direction equipment includes displays and controls for the evaluation of target data, and for the selection and engagement of targets so as to ensure the

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most effective use of the gun and missile batteries. A typical WDE consists of one or more Target Selection and Tracking consoles, a Director Assignment console, a Weapon Assignment console, and the necessary cabinets to house power supplies and computer units.

TARGET SELECTION AND TRACKING CONSOLE

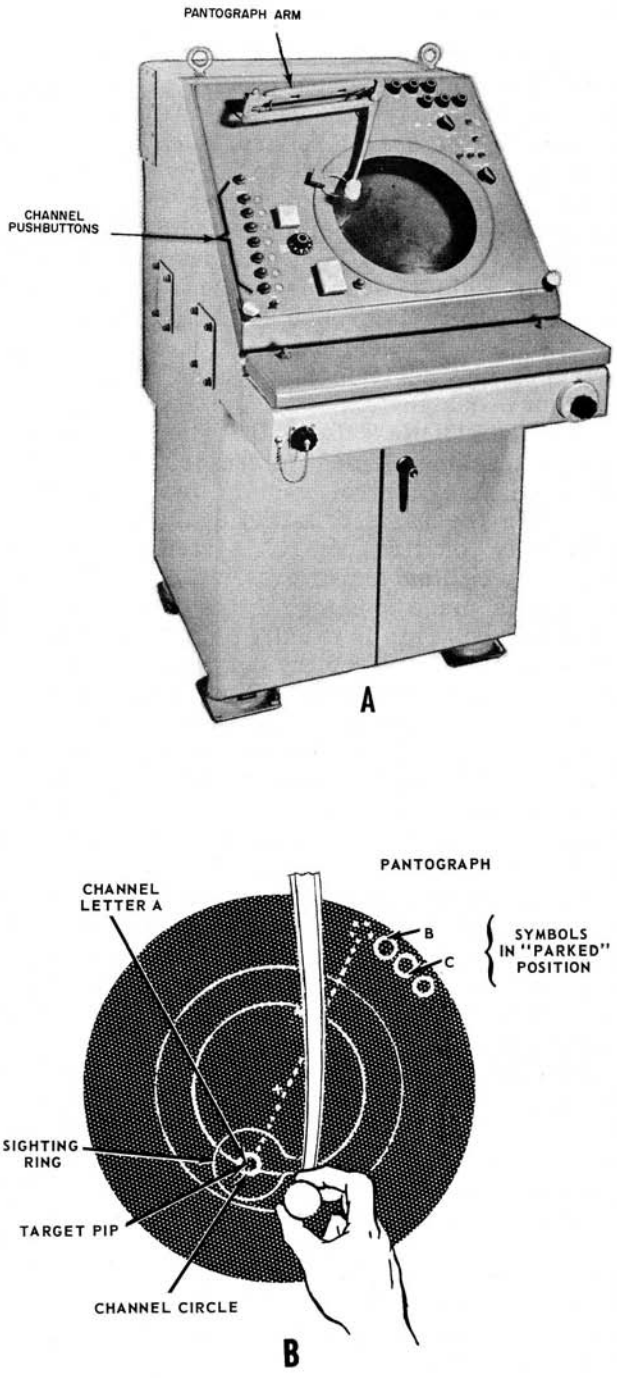
Figure 6-2A shows a typical target selection and tracking console. Regardless of the mark or modification, they all have the same general shape. The console is used for selecting and tracking targets detected by search radars. The principal indicator on a console of this type is a PPI (Plan Position Indicator) fig. 6-2B), that displays the bearing and slant range of all targets picked up by a selected search radar. The primary controls are a pantograph arm for selecting and tracking targets, and pushbuttons for assigning target-to-tracking channels. Other controls are provided for selecting various search radars for the PPI display, for selecting certain range scales, and for inserting target position and rate of movement data into the tracking channels.

Targets are displayed on the scope as radar video (pips). To select a target and assign it to a tracking channel, you position the pantograph sighting ring (fig. 6-2B) over the target pip and then press a channel button. Pressing the button gains electrical access to that channel, and simultaneously causes an identifying channel letter to appear next to the target pip. Successive corrections of pantograph position develop target course and speed data that are inserted into the tracking channels.

DIRECTOR ASSIGNMENT CONSOLE

The primary purpose of this console is to provide the information display and controls required to assign fire control systems to the targets being tracked by the target selection and tracking console operator, when it is determined that a specific target or targets should be engaged. Figure 6-3 shows the panel layout of the director assignment console for our basic WDE. Two plots are provided on the face of the console - a plan plot on the left, and a multipurpose plot on the right.

The plan plot (fig. 6-3A) Shows three range rings, and indicates true bearing with north at the top. Each target being tracked by that target selection and tracking console operator appears on



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Figure 6-2. — Typical weapons direction equipment: A. Target selection and tracking console; B. Plan Position Indicator (PPI) display on console.

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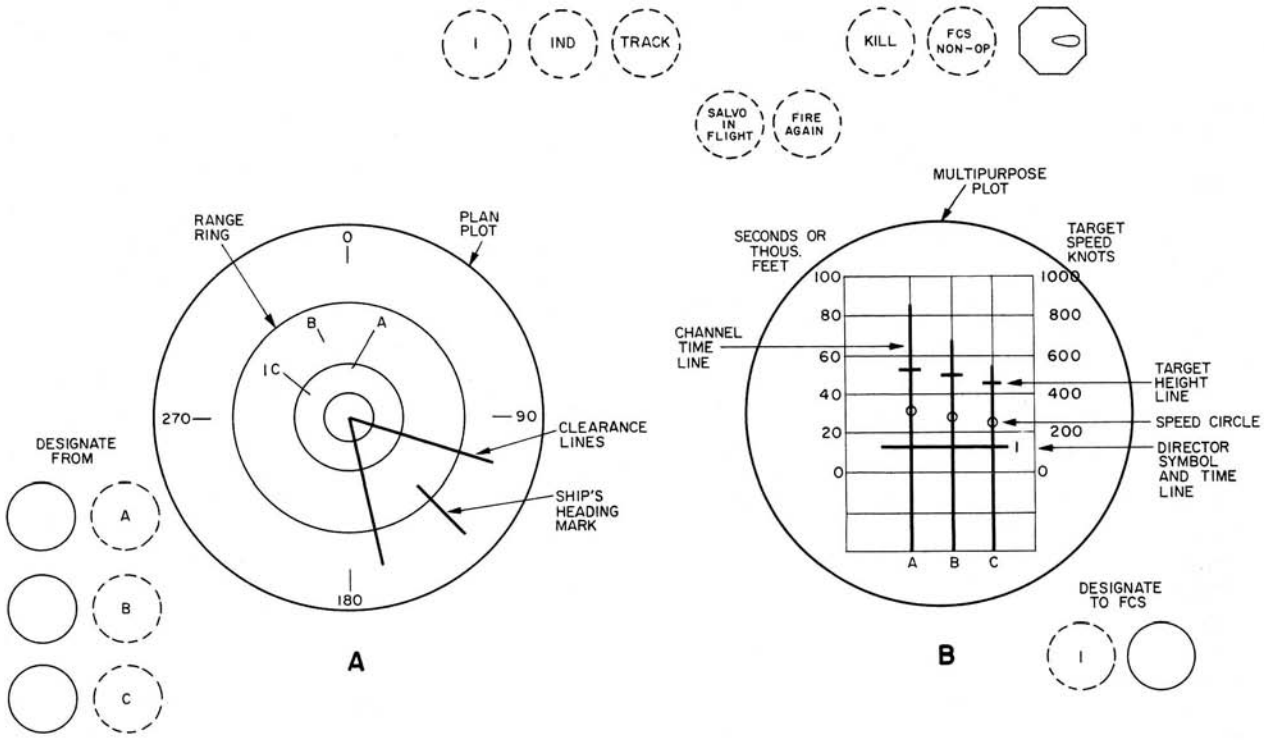


Figure 6-3. — Director assignment console display: A. Plan plot; B. Multipurpose plot.

the display as a letter, corresponding to the tracking channel from which it originates. The figure shows that tracking channels A, B, and C are tracking three separate search radar targets. The straight line associated with target A indicates the course and speed of this target. The number 1 indicates the position of the radar set in the basic fire control system. If the weapons control system had more than one fire control system, these additional system s would have associated numerals. A ship's heading marker, and radial clearance lines on either side of it, are presented electronically and rotate when the ship changes course. The sector between the two clearance lines indicates the region into which we may not launch missiles because of danger of striking the ship's superstructure.

The multipurpose plot (fig. 6-3B) is used primarily for making time comparisons. These comparisons help the operator to decide which of several targets to designate to a director, and to plan the future handling of targets that cannot be assigned immediately. Once the radar set acquires the target and begins to track it, the fire control system is busy solving the missile fire control problem. During this time the operator, with the aid of the information displayed on the plot, can decide which target is next in line for assignment to a tracking radar set.

The multipurpose plot is also used to indicate the speed and height of targets that are being tracked by the tracking channels. As you can see in figure 6-3B, it is divided into three vertical lines - each line representing a tracking channel. All changes in indications take place vertically, and you can read the values indicated as you would read a thermometer.

The vertical lines show, for each target, the time within which the radar set must be assigned and a missile fired in order to intercept the target before it can reach its Estimated Weapon Release Range (EWRR). The EWRR will vary, depending on the type of payload the enemy is carrying and on how accurately you guess what the payload is. This estimate range is manually inserted into the DAC and affects the length of the channel time line. The director symbol and time line (fig. 6-3B) comes into play only after the director is

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assigned. As this line decreases to zero level, it indicates the time left in which you have to make a target intercept at the maximum effective range of your system before he (the target) reaches the release range of his weapon. (For example, if you guess that the target's payload is an air-to-surface beam-rider missile, the EWRR might be on the order of 25,000 yards. At the left of the plot you can read how much time you have to assign the radar set so that it can acquire the target, track it, solve the problem, and load and fire a missile salvo, and have the missiles intercept the target before the target can release its missiles. This points up the need for quick evaluation. In conjunction with the plan plot, the multipurpose plot provides the necessary information to speed up this process. It relieves the human operator of the necessity of remembering how much average time each component in the weapon system requires to perform its function under varying conditions.

The scale used to measure assignment time is also used with the height line. The height line is a short horizontal bar which moves up and down the vertical channel line as target altitude changes (fig. 6-3B). In this case the number represents thousands of feet. To the right of the display is a target speed scale (marked knots) which is used in conjunction with the speed circle. The speed circle rides up and down to indicate target speed.

The long horizontal line shown in this plot represents busy time for the radar set. When the radar set is not acquiring or tracking, the time line and director symbol number rest at zero time. But when the radar set is assigned a target, the time line and symbol move up to indicate the time during which the set will be busy with that target; they slowly move down as time elapses. After a missile salvo is launched, the line and symbol continue to move downward until they reach zero. The missile should then have intercepted the target, and the radar set is ready to be assigned a new target.

Above the two display plots is a field of lamps relating to the gun and missile fire control system. The lamp with the numeral 1 in it is called the BUSY lamp. (If our basic weapon control system had more than one fire control system, each of them would be represented by a different lamp and number.) The BUSY lamp is sighted whenever the radar set is assigned a target. The IND lamp is lighted when the radar set is operating INDependently of the weapon direction equipment, as in tracking drill or radar calibration exercises. The TRACK lamp indicates that the assigned target is gated and is being tracked. The KILL lamp lights when a target has been destroyed. The observation of the kill is usually visual.

The FCS NON-OP lamp indicates that some part of the fire control system is not in operation. When missiles are launched, the SALVO-IN-FLIGHT lamp lights. If another salvo is ordered to be fired, the FIRE-AGAIN lamp lights to indicate that this order has been sent to the weapon assignment console, but that the salvo has not yet been fired.

The pushbuttons at the lower left labeled DESIGNATE FROM, and the pushbutton at the lower right labeled DESIGNATE TO FCS, are used in making assignments of the radar set to one of the three tracking channels, A, B, or C. The operator makes the assignments by simultaneously pressing the selected' 'designate from" button and the "designate to FCS" button until both lights function. This process connects the radar set to the selected tracking channel and slews the radar set automatically onto the target. At this time the radar repeat-back symbol moves until it is superimposed on the track channel symbol. This indicates to the director assignment console operator that the radar is tracking the proper target.

WEAPONS ASSIGNMENT CONSOLE

The Weapons Assignment Console (WAC), is designed to operate with the fire control system and launcher. It displays data from the fire control system, giving the target's present and predicted intercept positions, and information from the computer indicating whether or not missile intercept is possible. It also has a summary display of launcher information.

The missile firing key is located on the weapon assignment console. Decision of whether or not to fire is made from this station. The target may be out of range, for example, and this information would be shown on the console.

The console has a cathode-ray tube display showing a horizontal plot and true bearing, with own ship's position in the center. Around this plot is a fixed bearing ring. Radial lines from the center to the edge of the plot, generated electronically, indicate launcher unclear areas caused by ship's heading. These lines rotate with changes in ship's heading. This display is similar to the plan plot of the director assignment console (fig. 6-3A).

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The other indications on the cathode-ray tube display appear only while the fire control system is tracking a target. These indications are:

1. An "X" indicating target present position.
2. A small circle indicating target future position at the predicted point of intercept.
3. A large circle about the center, which indicates the maximum range the missile can reach at the target's predicted altitude at intercept.
4. A thermometer type display at the left hand edge of the plot, giving the target's predicted altitude at intercept (H).

LOCATION AND OPERATION OF CONSOLES

Directors, gun mounts, and missile launchers are mounted on the deck; search radars are above the deck. Normally, missile directors are not manned and have no optical tracking equipment. Full radar control is the only type of operation possible. There are no provisions for local operation in the director although the radar operator can position the director from the radar console. In both gun and missile directors, the optics and radar antenna are stabilized to a varying degree. Target data are transmitted to the computer.

Optics are used chiefly for gunfire control. Gunsights, gunsight telescopes, lead-computing sights, and optical rangefinders are examples.

Figure 5-8 shows the shipboard location of missile system components on three types of ships, CAG, CLG, and DLG. The search radars, high up on the ship's superstructure, scan the surrounding sea and sky for targets for all types of weapons. They transmit target data to the weapon direction equipment where the signals appear on the scopes, to be interpreted by the operators. The computer converts the radar signals for presentation on the PPI-scope (fig. 6-2).

In case of casualty to the primary search radar, a secondary source of target information may be available from other search radars. (Not all ships have a secondary source.)

If there are multiple targets, which is likely to be the case in an attack, the threat of each target must be evaluated. With today's supersonic planes, missiles, and swift ships and submarines, the time to make decisions is very limited, and a weapon director must be assigned very quickly to the most threatening target. The technicians and officers in CIC study the target's indications and movements even before the target video signals show on the weapon direction equipment, A target tracking radar is quickly assigned to pinpoint the location of the target, determine its speed, and height (for air targets). This information enables the weapons officer to determine which weapon is best suited to engage the target, and a director is assigned, either a gun director or a missile director. The positions of the targets in the tracking channels are transmitted continuously to the director assignment console. The console operator evaluates the targets on the basis of this information and assigns a fire control system. The weapon assignment console has charge of launcher assignment and selection of the missile. This time of missile firing is very important since we must strike for missile intercept before the target reaches its release point, and releases its own missile. This means that loading time must be precisely controlled. Each GMM must do his job with speed and precision.

Missiles must have a certain warmup period before being fired; but it must not be too long, or the electronic balance will be upset by the heat generated within the missile. This means that the missile cannot be energized well in advance of the expected launch. The WAC operator must make a decision as to when to begin warmup.

A TYPICAL FIRE CONTROL SYSTEM

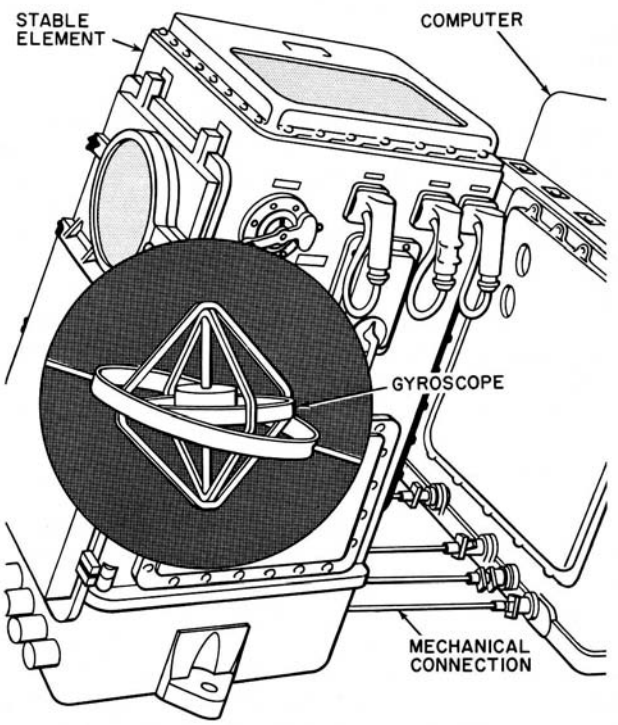
Gunfire control systems are adequately covered in the preceding chapters. In chapter 2 we discussed basic gun fire control principles and the elements of gun fire control systems; therefore these systems and equipments will not be discussed in detail here. In this section we will discuss only the equipments that make up the fire control system of a typical guided missile ship.

Look again at figure 6-1. We have assumed that the fire control system shown in the illustration is capable of controlling gun and missile batteries at the same time. This is a valid assumption because there are systems of this type in the fleet - Tartar, for example.

The fundamental fire control problem contains three basic elements - a line of sight, a prediction angle, and a line of fire. The line of sight is established optically or by radar, using a director or a radar set. A fire control computer produces the prediction angle in the form of gun and missile

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orders. These orders are transmitted to the guns and missile launchers to position these equipments along their respective lines of fire. The above statements indicate that there are two basic equipments needed to solve the fire control problem when guns and missiles are used as weapons. These two equipments are a director and a computer. You might add another instrument - the stable elements, but its function is sometimes performed by a device included in the director. So we can say that a complete fire control system contains a director, a computer, and a stable element which mayor may not be a separate unit. When separate, the computer and the stable element (fig. 6-4) always operate as a pair. Directors, gun mounts, and missile launchers, mounted on the deck, measure their position with respect to the deck plane. Ship's roll and pitch are independent of target position, and therefore affect all measurement of target's position and motion. Stabilization is needed to keep the line of sight on target and the line of fire on an aiming point in space. Corrections are needed by the computer for LOS and LOF.



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Figure 6-4. — The stable element is a gyroscopic device.

FUNCTIONS AND PROBLEMS OF FIRE CONTROL

Any combined gun and missile fire control system has four primary basic functions: to acquire and track targets; to develop launcher, gun, and missile orders; to guide missiles to the target; and, in some instances, to detonate the missile warhead.

Secondary functions of the system are to provide target information such as target speed, target course, range to the target, and system and weapon status information to the display units of the weapon direction system. This information is used to evaluate the tactical situation and to aid in the fire control system and weapon assignment

The Director or Radar Set

The director or radar set is the eyes of the fire control system. It can search for, detect, acquire, and track a target; and it can "capture" and guide a missile. At this point let's stop and consider the terms "director" and "radar set." There may be some confusion in your mind as to their exact meaning. The equipments perform the same functions in the weapon system, but they have different physical arrangements. A director contains a radar and/or optics for tracking and ranging, and it is usually manned (in gun or gun/missile fire control). A radar set has no optical tracking device or rangefinder. It is not manned in the sense that a man is located inside the antenna supporting structure. True, there is an operator in the radar control room; but his primary function is to monitor the equipment and make sure it is functioning properly.

In the rest of this chapter we will use the term "radar set," rather than director, because that name has been given to the newer equipments that perform the same function as a director.

The radar set described here, and illustrated in figure 6-1, is an automatic-tracking gunfire control and missile guidance radar. It receives target designation data from the weapon direction equipment, and uses this information to acquire and track a designated target. If guns alone are used to fire on the target, the radar set tracks the target to provide information needed to solve the gunfire control problem. If guided missiles are used, the radar not only tracks the target

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but transmits radar signals to capture the missile and guide it to the target (if it is a beam- rider or a command guidance missile).

Of course, as we have mentioned before, the radar set performs all these functions simultaneously if guns and missiles are used at the same time. Also, it can operate as a search radar if circumstances require.

The radar set can transmit simultaneously, on a common nutation axis (fig. 4-3), three distinct beams of radar energy-the tracking, capture, and guidance beams. A narrow tracking beam first acquires and tracks the target automatically. The wide angle capture beam captures the missile after launch, and holds it until it enters the narrow guidance beam (fig. 4-19) that guides it to the target. The capture and guidance beams are transmitted simultaneously; the missile distinguishes between the two because they are coded differently.

The radar set consists of two major groups of equipment: an antenna group, and a control and power group. The antenna group, which is located above deck, consists of a pedestal upon which are mounted the antenna and the necessary electrical and mechanical components required to stabilize and position the antenna. Housed inside the mechanical structure of the antenna group are the transmitting, receiving, and associated microwave circuits. Here, too, are located the gyroscopes that space-stabilize the antenna, and thus the radar beams, to compensate for the roll and pitch of the ship.

The control and power equipment group is located belowdecks in a compartment usually called the radar room. This room contains the radar consoles used to operate, monitor, and control the radar set. Also located in the radar room are the cabinets containing the power supplies that provide the operating voltages for the various units in the radar set.

Typical Gun and Missile Computer

The typical gun and guided missile fire control computer described here is an electromechanical type designed to operate automatically. No operating personnel are needed. It is located in the ship's plotting room, and is used with the radar set described previously. The computer is a dual ballistic computer. In other words, it solves the gun and missile fire control problems simultaneously.

The computer has three basic ways of operating. It can operate when designation is desired; then, after the radar set has acquired the designated target, the computer aids the radar set in tracking it. As soon as the guns and/or missiles have destroyed the target, the computer shifts to the air-ready method of operation. These different methods of operating are called modes. The various modes of computer operation can be briefly described as follows:

AIR-READY MODE.-In this mode the computer is energized, but is receiving no information. It generates orders only to put the radar set, launcher, and guns in predetermined air-ready positions. For example, the air-ready position of the radar set may be at zero° of train and 45° of elevation; the launcher air-ready position may be at 180° of train and zero° of elevation.

DESIGNATION MODE. - The computer goes into this mode of operation when it receives a "director assigned" signal from the director assignment console of the WDE. The computer directs the radar set to the designated target position so that the radar line of sight will point at the target. It also sends a search program to the radar set. The search program causes the radar beams to move in a preset pattern about the designated target position. The radar searches for the target, and when the target is gated the computer automatically goes into the track mode of operation.

TRACK MODE. - When the radar set acquires the target in range, bearing, and elevation, the track mode starts. The radar set then transmits an on-target signal to the computer. The computer sends signals to the radar set that cause it to drive at a rate that will keep it locked on the target. The computer determines the proper lead angles for the launcher and guns, and transmits these quantities to them in the form of electrical signals. These signals drive the guns and launcher to the proper aiming positions.

Before the missiles are launched, the computer determines and transmits to the missiles quantities that move the missile gyros to their proper positions. The computer also transmits, to the various display consoles of the WDE, tactical data such as present target position, future target position, and missile time to target intercept (time of flight).

DELIVERY UNITS IN A TYPICAL WEAPONS SYSTEM

The delivery units of a typical weapons system are the gun mounts and the missile launcher. This section sums up operation of a typical

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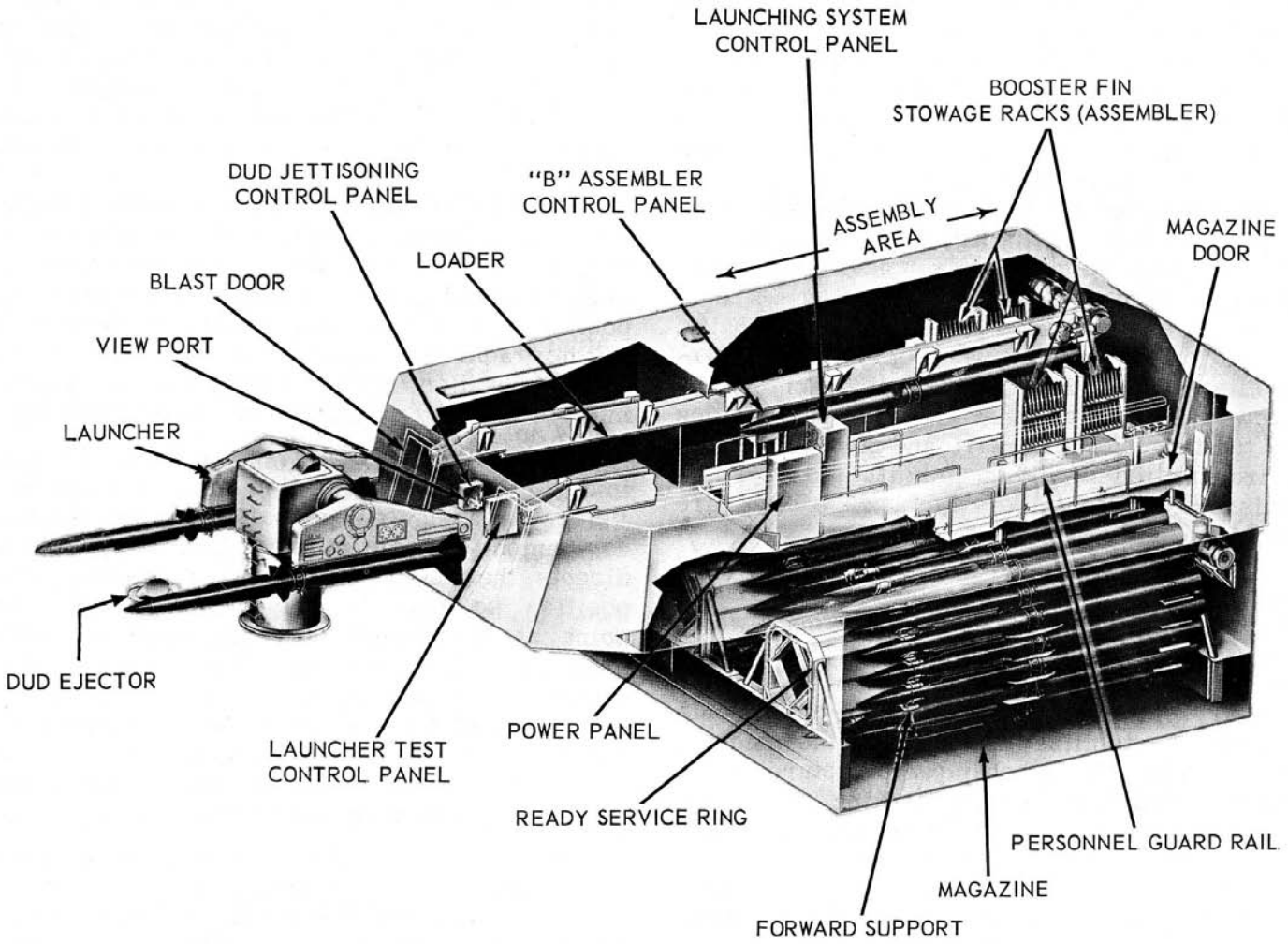


Figure 6-5. — Typical Terrier missile launching system Mk 10 Mods 0 to 6.

missile launcher and the equipments associated with it. Guns are covered in Military Requirements for PO 3&2, NavPers 10056-B, and Seaman, NavPers 10120-E.

Guided Missile Launching System

The guided missile launcher shown in figure 6-5 is part of a group of equipments that are known collectively as a Guided Missile Launching System. A guided missile launching system has three major components:

1. Guided missile launcher
2. Guided missile launcher feeder
3. Guided missile launching system control

The primary purpose of a guided missile launching system is to stow missiles until needed and then supply them to a launcher for firing. Its secondary function is to remove unfired missiles from the launcher and return them to the missile stowage area (or jettisoning them in case of dangerous misfire or a dud). In missile replenishment, too, the launching system equipment is used to strike the missiles below to the magazine, or to bring them up for unloading.

GUIDED MISSILE LAUNCHER. - All Navy missiles that are launched from ships (not including submarines) use short rail launchers. (These launchers are commonly called Zero Length launchers.) This type has one or two, usually two, launcher arms (or rails). The launcher shown in figure 6-5 is the dual-rail type. It receives

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and secures two complete missiles - one on each launcher arm... The launcher automatically trains and elevates in response to synchro signals (missile launcher orders) from the fire control computer. Through electrical connections on the launcher arms, the missiles (except Standard) receive warmup power before launch. Warmup power is used to bring the missile gyros up to speed, and to warm up the vacuum tubes, without taking power from the missile power supplies. Preflight information is also supplied to the weapon through contactors in the launcher arms, and the firing circuit is connected through the launcher to the missile's internal firing circuitry. The launcher can automatically return to a predetermined fixed position in which a new missile can be loaded on the launcher arm, or an unfired missile can be returned to stowage.

GUIDED MISSILE LAUNCHER FEEDER. - The purpose of this group of equipments is to stow guided missiles and their boosters in magazines, to remove them from the magazines, and to load them on the launcher arms. There are several types of feeders, but they all have these two purposes. The feeder described here is the most common type. The other systems are similar in operating principles.

The feeder consists of three functional groups of equipment - the magazine, the loader, and the assembler. Figure 6-5 shows the magazine area. The main piece of equipment in the area is the ready-service ring, in which the missile-booster combinations are stowed. The ring can rotate like the magazine of an automatic revolver. This rotating motion of the ring is called "indexing." The ring is indexed to position a missile round so that it can be placed under the loader. The loader provides a means for removing the missile rounds from the ring and loading them onto the launcher rails. Figure 6-5 shows one loader rail. Usually there are two of them. Continuous grooves in the rails function as tracks to support the booster shoes during loading operations. The booster shoes are T-shaped and horseshoe-shaped lugs. The rails of the launcher arms are also grooved to receive these lugs. During the loading or unloading operation, the launcher is positioned so that the loader rail and launcher rail form one continuous track. Missiles are loaded onto or unloaded from the launcher by a loader chain that is guided by a track in the loader rail. A hook, or pawl, attached to the chain, engages the rear shoe of the booster.

The third group of equipments that make up the feeder is called the assembler. The assembler is essentially a set of racks for stowage of the aerodynamic surfaces (booster fins and missile wings). The wings and fins are mounted on the booster and missile manually, by men assigned to perform this operation.

GUIDED MISSILE LAUNCHING SYSTEM CONTROL. - This equipment group includes the panels used to operate the missile launching system. The power panels contain circuit breakers, overload relays, and other electrical components required by the various power drives that control the movement of the launcher, rammer, and ready-service ring. Other panels contain operating controls that are used to start the system and control its operation. These panels normally respond to orders from the WDE. For example, the WDE may send an order to ALERT the missile launching system. An ALERT light on a panel flashes, indicating to the operator that WDE wants the missile launching system's equipment put into operation. The orders transmitted from the WDE to the missile launching system are of interest to the GMM, for he must learn to operate the control panel at any station in the launching system.

Types Of Orders. - The MISSILE SELECT order is transmitted from the WDE to the launching system to indicate the type of missile to be loaded on the launcher. There are several types of Terrier missiles. All of these types may be loaded together in a single magazine. This is called mixed loading. When the launching system has selected the type of missiles called for by the WDE, it sends back a signal indicating that the order has been carried out.

The LOAD order tells the launching system to start loading a missile or missiles. A load order may be "continuous," "single," or "hold." A "continuous" order causes missiles to be continuously supplied to the launcher. This operation is similar to "rapid or continuous fire" in conventional gunnery. The "single" order causes one missile per arm to be loaded on the launcher. The "hold" order holds the launching system in a ready-to-load condition.

When the launching system receives the UNLOAD order, it unloads any missiles that may be left on the launcher arms, returning the missiles to the magazine. In some mods, this can be done in automatic operation; in others it must be done in step operation.

The INTENT-TO-LAUNCH (ITL) is similar to the conventional "commence fire" order in

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one respect- it is transmitted by closing a firing key. But, while the gun firing circuit is completed almost instantly when the key is closed, there is a slight delay before a missile firing circuit is completed. This delay is necessary to establish certain operating conditions in the missile, and in other equipments in the weapons system. Before the missile can be fired, it must indicate that it is ready to be launched. This indication, "missile-ready-to-fire," is sent through the launching system control circuits back to the WDE. Almost every piece of equipment in the weapons system affects the operation of the firing circuit, either directly or indirectly.

Gun Battery

There are a number of situations in which a missile is not the best weapon. The target may be too close, or it may be too small to be worth expending a costly missile to destroy it. The search radars locate the targets, and the tracking radars (or directors) track the target and pinpoint its location. From the information shown on the display scopes in CIC, the weapons officer must decide what weapon to use against each target and must transmit his orders so action will be taken at once. Multiple targets may require the use of several kinds of weapons simultaneously. Radars can search and track more than one target at a time, and certain computers are capable of solving gun and missile fire control problems simultaneously.

DESTRUCTION UNITS IN A TYPICAL WEAPONS SYSTEM

As we mentioned earlier in this chapter, our typical weapons system is designed to control two weapons, the gun (projectile) and a homing or a beam-rider missile. These weapons have been discussed in this book, or in the books in the reading list. In addition to surface-launched weapons, there are air-launched and underwater-launched weapons. These are not discussed in this book, but you have been given basic descriptions in Seaman, NavPers 10120-E, and Military Requirements for PO 3&2, NavPers 10056-B.

WEAPONS SYSTEM FUNCTIONING

To provide a brief review of what you have studied so far in this chapter, we will list the principal steps or phases a typical weapons system goes through to accomplish its mission. The mission, of course, is to destroy the enemy or a practice target. The principal steps, in chronological order, are:

1. TARGET DETECTION. Search radars detect targets at long ranges, to allow time for the weapons system to go into action and complete its function.
2. TARGET SELECTION- From the information supplied by the search radars, the weapons direction system selects the targets that appear hostile, and that require missile and/or projectile interception, and inserts them into tracking channels. Target selection and tracking is performed by personnel assigned to the target selection and tracking console-a unit of the weapons direction equipment.
3. SEARCH RADAR TARGET TRACKING. The tracking channels (computing circuits) continuously track selected search radar targets to generate target rate of movement. This data appears as a symbol (letter) on the face of a large cathode-ray tube (scope). When the tracking channel has computed the correct target course, speed, and rate, the symbol on the scope will remain superimposed on the target echo supplied by the search radar. This computed target position and rate data are used for evaluation of the tactical situation presented to the ship, and for transmission to other units in the WDS - especially the director assignment console. Each target that is being tracked is assigned a different symbol to prevent confusion.
4. EVALUATION. The weapon system evaluates the threat of various targets, decides which should be engaged by guns and which by missiles, and decides which targets should be given the priority. The evaluation is performed by personnel, but they are aided in this process by the displayed information on the various consoles in the WDE and CIC.
5. DIRECTOR ASSIGNMENT. A radar set is assigned to the target having the highest priority. When a radar set is assigned, this implies that a fire control system has been included in the assignment.
6. ACQUISITION., The assigned radar set (fire control system) gets on the target.
7. TRACKING. The fire control radar tracks the target to provide precise target position and rate data. The computer associated with the tracking radar operates on the data from the radar set to provide the solution to the fire control problem. The computer answers are

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supplied to the guns and launcher as synchro signals to position these units in train and elevation.

8. REEVALUATION AND WEAPON ASSIGNMENT. The target that is engaged by the fire control system is reevaluated with respect to the tactical situation (this may have changed), availability of the launcher or gun, and the range limitations of the weapons.

9. LOADING. Missiles are loaded on the launcher, and the guns are prepared for firing.

10. LAUNCHER SYNCHRONIZATION OF MISSILE ORDER INPUTS. Synchro transmitters and receivers are inherently "self-positioning" or synchronizing. A synchro system is used to transmit a training order from the director to the launcher. The synchro transmitter, mounted on the director and geared to it, transmits the movement and position of the director. The dial of the synchro receiver in the launching equipment constantly indicates the director's position. The launcher will train to match the receiver dial. The synchros are connected electrically, but the launcher is moved in train and elevation by hydraulic power. The synchros actuate hydraulic pilot valves that actuate and control the hydraulic system.

The launcher is capable of unlimited train (unless located in a position where this is not possible). The guide rails may be elevated between -10° and +90° with respect to the deck (for Tartar systems) though the maximum angle of fire is 85°. "Stow" and "load" positions for Terrier Mk 10 systems both are between 1° and 3° (varies with Mod) elevation and 180° train, but Tartar systems load and stow at 90° elevation, Latches secure the launcher in the required load or stow position.

An ever-present problem is the limitation placed upon firing arcs by the ship's superstructure. The launchers guns are electrically cut out if they are aimed at any part of the ship. The mechanical actuator is the nonpointing zone cam, The cutout area is referred to as the blind zone for the weapon. An aft gun or launcher cannot fire dead ahead at low elevation angles, and a forward gun or launcher is cut out directly aft, except where the gun or the launcher guide can be elevated above the firing cutout zone.

Synchronizing networks or circuits may use relays, diodes (semiconductor and vacuum tubes), and gas tubes (thyratron or neon). The purpose of the synchronizing circuit is to prevent overspeeding of the drive where large changes are necessary. If a large error signal is allowed to drive the equipment at an excessive speed, and there is a radical change of target speed or direction, the inertia of the moving heavy equipment could be so great as to drive past synchronism. The time required for the launcher to synchronize is about 5 seconds. Upon assignment, the loaded launcher synchronizes in train and elevation with the launcher orders generated by the computer. The Launcher Status Console operator supervises missile and launcher readiness, noting that the launcher is synchronized and that missiles are warmed up and ready to fire. The sequence of operations is similar for all surface launched missiles. After the missile is on the guide arm and the blast doors are closed, the launcher train and elevation latches retract. The launcher starts to synchronize to the director and synchronizes to the firing position. The salvo firing circuit is closed and the missile is activated. The arming tool winds and retracts, the guide arm contactor retracts and the booster is ignited.

The missile clears the guide arm rails. Then the missile on the other guide arm is fired. If the order is for continuous firing, other missiles are brought up from the magazine, the wings and fins attached, and warmup applied. As soon as both guide rails are empty, the launcher synchronizes to load position, and the cycle is repeated.

11. LAUNCHING AND FIRING. The missiles are launched at the proper time and in the proper direction. The guns are loaded and fired.

12. MISSILE GUIDANCE. The fire control radar guides each missile to the target being tracked. Gun projectiles, of course, receive no guidance.

13. TERMINAL PHASE. When a missile or projectile approaches to within lethal range of the target, a VT fuze detonates its destructive charges. This is the "moment of truth" for the weapons system.

INTERSYSTEM COMMUNICATIONS

All the information gleaned by radars and computed by computers is of no value if it is not available to decision-making personnel. The information must be available instantly to officers, petty officers, and other men who have the knowledge and competence to interpret and apply it. A complicated network of communications, with duplicate equipment to take over in case of failure or damage, is necessary to keep data transmission a continuing process. Figure 6-6 is a simplified schematic of the flow of data in

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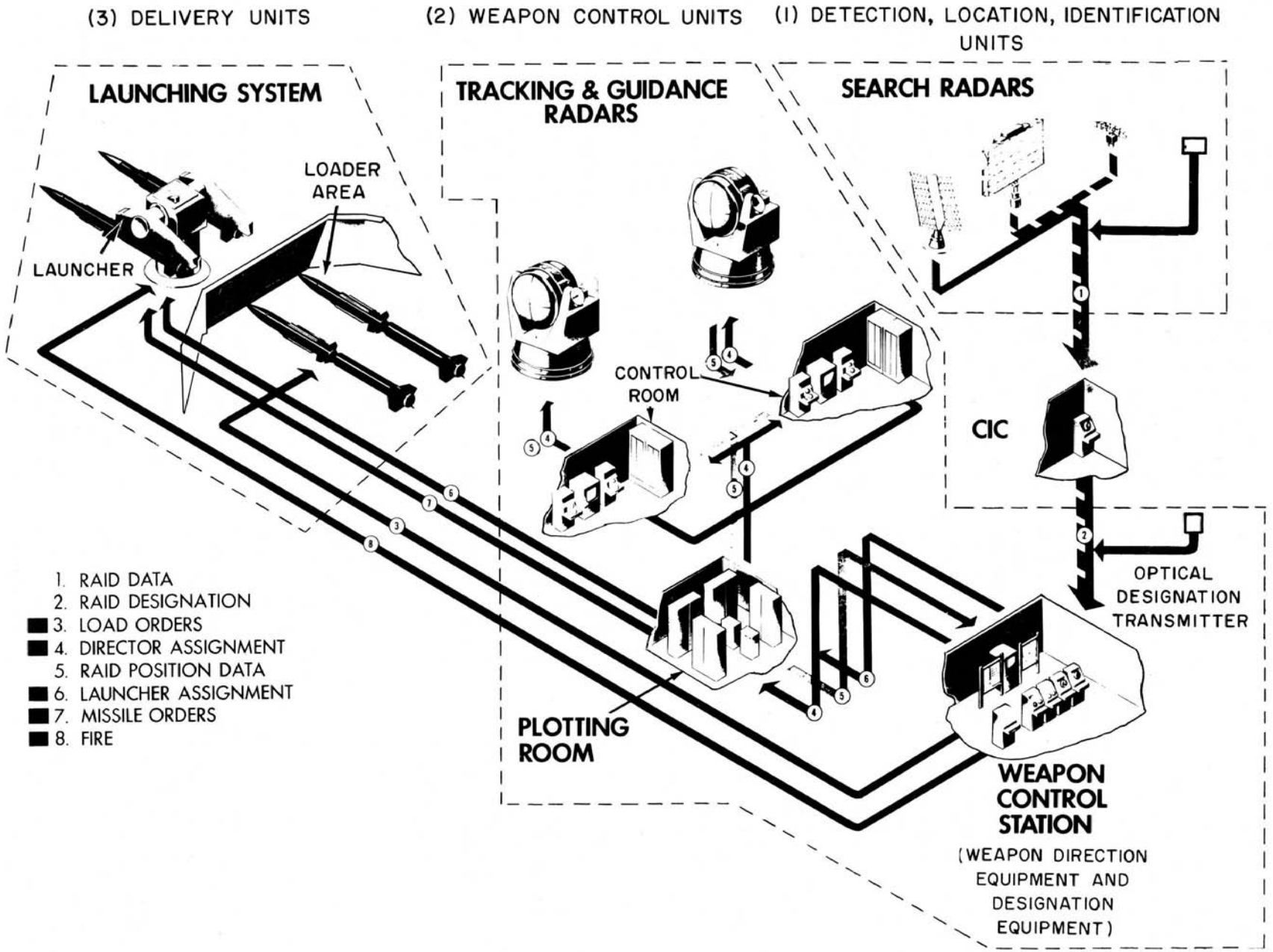


Figure 6-6. – Flow of data and orders in Terrier weapon system; simplified schematic.

a Terrier weapon system. Let's follow through on the flow of data in a typical weapon system.

The search radars in figure 6-6 include a surface search radar (AN/SPS-10), a primary search radar with pencil-beam for long-range scanning (AN/SPS-26), and a fan-beam radar for long-range aircraft detection (AN/SPS-29). Targets not identified by the radars are challenged by IFF. Results are relayed to CIC, the Pilot House, and the Weapons Control Station, where they are displayed on scopes. IFF is normally controlled from CIC. By switching at the radar distribution switchboard, the radars can be connected directly to the target tracking consoles. The optical designation transmitter is used if there is failure of the search radars or if the target is too low for detection by search radars.

The designation equipment has a target selection and tracking console in WCS and another in CIC. From the information displayed on the PPI-scope, CIC assigns tracking channels for the targets in the order of their apparent threat. Telephone communications are available for all personnel in the system. so decisions and changes can be given verbally to supplement (or replace) pushbutton signals.

The operator of the Director Assignment Console (in WCS), on the basis of information from the tracking radars and director displayed on his console, assigns a missile launcher or a gun system +.0 a particular target.

The operator of the Weapons Assignment Console (in WCS), studying the display of information on his scope, selects the missile rail to be loaded, the method of loading (single or continuous), pushes the button that initiates warmup power to the missile, selects the number of missiles to be fired per salvo, and assigns the launcher to a fire control system. He can also cancel the launcher assignment.

At the control panel in the launcher system, the operator watches the succession of lights and, if anything is wrong, he immediately notifies CIC. It may be necessary to select another missile or even assign another launcher; the target does not wait for repairs to be made.

The whole operation takes less time than it takes to tell about it. Each man must be master of his job.

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CHAPTER 7

APPLICATIONS OF SERVOMECHANISMS

Servomechanisms, called servos for short, are the basic building blocks of power drives. In this manual what we mean by a power drive is an electric or electrohydraulic machine which positions a launcher or other device in accordance with a relatively weak electrical signal. We will consider a power drive as a big servo made up of smaller ones.

First we will define a servo and talk about its characteristics. Then we will describe some of the devices used in servos. Then we will put these devices together to form a basic power drive. And finally, we will cover some techniques used to make power drives more accurate.

The principles of servomechanisms are discussed in your basic text, Synchro, Servo, and Gyro Fundamentals, NavPers 10105. The uses of servos in missiles and missile launching systems concerns us most in this chapter. The review material will serve to relate the principles to the missile applications.

WHAT IS A SERVO?

Figure 7 -1 shows a block diagram of an elementary servo. It consists of two blocks and some connecting lines. If you are not familiar with it already, study the diagram carefully and memorize it. From this simple concept of a servo will spring one of the most important ideas you will ever encounter in your naval career as a technician - the feedback principle. Not only is feedback important in understanding servos, but it also has important applications in the electronic and hydraulic fields. Therefore, if you know how feedback is used in servos, you can better understand how it is used in electronics and hydraulics.

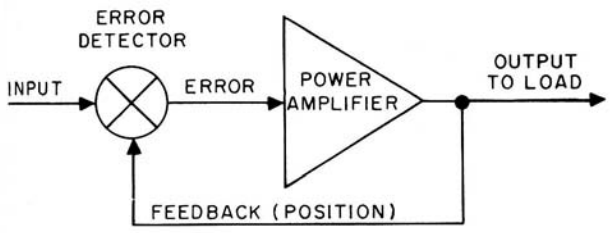
At this writing there is no standard definition of a servo. (Chapter 4 quotes one definition.) For the purpose of this chapter, we will call a servo any electrical, electronic, mechanical, or hydraulic system which uses feedback. But a rigorous definition is relatively unimportant. What is important is that you know what makes a group of parts a servo. Regardless of their physical form - electric, electronic, mechanical, hydraulic, or combinations of these - all servos have the following characteristics.

A SERVO IS A CONTROL DEVICE. - The basic job of the servo in figure 7-1 is to position a load. The load can be a launcher guide or carriage, a rammer, a hydraulic valve or piston, a dial, an electric motor, a mechanical linkage, etc. The load is attached in some manner to the output of the servo. Consider a launcher guide. Its position is controlled in accordance with launcher train and elevation orders which are inputs to the servo.

A SERVO IS A POWER AMPLIFIER. - The input to a servo is usually a very small signal. It is too weak to move the load by itself, so some sort of power amplification must take place within the servo. Again take as an example a servo used to position a launcher guide. The input to the servo is sometimes so small it can be measured with a milliammeter. To develop enough power to move the great weight of a guide arm requires currents in the ampere range. Therefore, every power drive you will work with has one or more amplifying stages in it. The amplifier may be electrical, electronic, hydraulic, or one or more of these types of amplifiers in combination.

A SERVO IS A CLOSED LOOP SYSTEM. - A servo is called a closed loop system because it uses feedback. Feedback is a principle upon which the operation of all servos is based. Look again at figure 7-1. You can see that the feedback line runs from the output to the block marked error detector. This feedback is a communication channel which reports the condition (speed, position) of the output back to the error detector. To see how feedback works,

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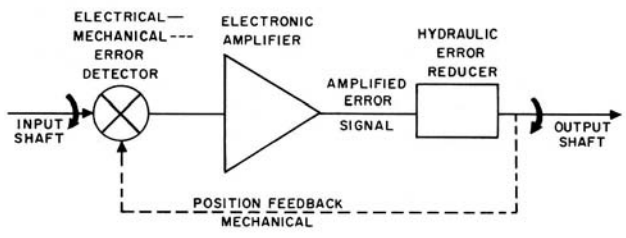
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Figure 7-1. — Elementary servo in its simplest form; block diagram.

assume the input is a mechanical signal telling the output to move to a certain position. If the output is not at the ordered position, the feedback signal reports the position of the output to the error detector. The error detector measures the difference between the ordered position (input) and the actual position of the output. Also, the error detector performs a simple mathematical operation: it subtracts the output from the input to get the amount of difference, or error, as it is called. Thus the error is the actual input to the amplifier, not the quantity marked input.

Also notice that when the feedback equals the input, the error signal is zero and no signal is given to the servo. But whenever the feedback differs from the input, an error signal is developed. The error signal drives the output in such a manner as to reduce the error signal.

Since the principle of feedback is used in servos, they are often called closed loop systems or servo loops. Keep in mind that feedback can be transmitted electrically, hydraulically, or mechanically in a servo. Feedback is also called response by many technicians. When the feedback line defines the position of the servo's output shaft or its load, the feedback is called position feedback.



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Figure 7-2. — Elementary electromechanical servo.

A SERVO IS AN ENTIRE SYSTEM. - It cannot consist of a single component. It must have the minimum number of components we have shown in the block diagram in figure 7-1. There is no law against a servo having more sections than the ones we have shown. And they usually do. But regardless of the number of parts in a servo, they all work together as a system or team. And this system concept is important. A servo is not an isolated motor or power amplifier, but must be considered as an entire system of interconnected components. Together, these components measure, transmit, compare, amplify, and control quantities.

EXPANDED VERSION OF A SERVO

So far, we have talked about the essential elements in servos, the "bare bones" of a servo, so to speak. We reduced a servo to its minimum number of functional blocks and still made it work. But this compressed view of a servo does not allow us room to expand the discussion of its operation. So we will expand our servo horizon by increasing the number of working blocks from two to three and then discuss each in turn.

Figure 7-2 is a block diagram of the elementary servo shown in figure 7-1. Instead of two functional blocks, there are three. Each is labeled with a name that aptly describes the block's function.

Our new block diagram of an elementary servo differs from the previous one in that the power amplifier has been divided into two parts: an AMPLIFIER and an ERROR REDUCER. The amplifier increases the weak error signal, and it controls the error reducer. We have coined the term error reducer because the name closely describes the function of this servo section, which is to drive the output of the servo until it is equal to the input, thus reducing the error toward zero. Keep in mind that there can never be zero error. The error reducer must receive an error signal before it can control the output. However, the error signal should be kept as small as possible.

Also notice that we have identified each part in the servo as either electrical, mechanical, electronic, or electromechanical. The input, output, and feedback devices are mechanical shafting; the error detector is an electric-mechanical

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device; the amplifier is an electronic type; and the error reducer is an electrohydraulic unit.

Earlier, we described a servo as any device that uses the principle of feedback. It can also be defined as a mechanism whose output faithfully tries to reproduce its input. Let's look at how the servo blocked out in figure 7-2 works, based upon this point of view. Assume the input shaft and the output shaft are at the same position. When this is so, there is no error between them and so there will be no error signal to the amplifier. Therefore, the error reducer will not receive a correcting signal and the servo will not move. But if the input shaft is suddenly turned to a new position, there will be an instantaneous angular difference between the positions of input and output shafts. Where is this difference discovered (detected) and measured? The answer is, of course: at the error detector. The input and feedback shafts are both inputs to the error detecting device, which, as we said before, is an electromechanical device. Since the feedback shaft is geared to the output shaft, the feedback shaft duplicates any position and motion of the output shaft. In other words, knowledge of what the output shaft is doing is fed back over the feedback line to the error detector. Here, the positions of the input shaft and output shaft are compared. The error detector measures any difference between them and then it does something more. It transforms (changes) mechanical position error into an electrical error signal. The electrical error output of the error detector is directly proportional to the angular difference between the input and output shafts.

The electrical error signal is relatively weak. So, it must be amplified. This may be done by a vacuum - tube amplifier, a magnetic amplifier, or a combination of these. After it is amplified, the error signal is sent to the error reducer. Here, it is changed from its electrical form to a proportional hydraulic signal. Now the error reducer drives the output shaft in a direction which reduces the error between the output and input shafts. As the output shaft turns, so does the feedback line. But it turns in a direction that reduces the angular difference between the input and output shafts. When the output and input shafts are in agreement, the output of the error detector is zero. The amplifier "sees" no signal and its input, and the servo stops.

Now if we turn the input shaft at a constant velocity, the output shaft should turn to the same position as the input shaft, and follow it at the same speed and in the same direction. If the input shaft were to speed up, then reverse its direction, the output shaft should faithfully reproduce these mechanical gymnastics; and all the while the two shafts should remain closely aligned. If at any time they do not, then the error detector will produce an error signal. This signal is amplified and sent to the error reducer. It then drives the output shaft until the error between the input and output shafts is as nearly zero as possible. When this condition exists, the servo is said to be "nulled." Other terms that describe zero or nearly zero error are: synchronized, in synchronism, or in correspondence.

COMPONENTS OF A LAUNCHER POWER DRIVE

To understand power drive operation, you must have background knowledge of servos. In the preceding pages of this chapter we have given you a general idea of the functional sections and what they do. You learned that the input is the controlling quantity. We described it as the displacement of a shaft. In practical servos or power drives the input is generally an electrical quantity which represents a shaft position. The servo error is the difference between the input and output of the servo. The error detector is the device which compares the input with the servo output. The error reducer is essentially the prime mover of the servo. It is controlled by the amplifier section, which simply increases the size of the error signal so that it is strong enough to actuate some device in the error reducer. The load mentioned earlier, strictly speaking, is not a component of the servo. However, load characteristics (size, weight, etc.) have an important bearing on the design and operation of the servo.

Now we will discuss some of the components that make up each block of a power drive. We'll start off with the error detector, and synchro data transmission.

ERROR DETECTOR

In the operation of automatically controlled equipment such as launcher power drives, it is necessary to have angular motion of a shaft

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to the electronic amplifier. The amplifier amplifies the input from the CT and applies the amplified error signal to an electrohydraulic servovalve. The servovalve converts the electrical error signal to a proportional hydraulic signal. The hydraulic output of the servovalve flows to the A-end stroking pistons. The stroking pistons move the A-end tilt plate off neutral, and the A-end pumps fluid to the B-end. The B-end then turns and supplies a mechanical output which trains or elevates the launcher in the direction indicated by the error signal. Any B-end output (drive shaft rotation) is transmitted through feedback $hafting to the CT rotor. This feedback completes the servoloop. When the launcher train or elevation position agrees with its position order, the synchro rotor will be in a position which produces minimum output voltage across its rotor leads (R1 and R2).

We will not cover synchro transmitters and control transformers here because they are treated in detail in the Military Standardization Handbook (Synchros), MIL-HDBK-225 (AS) and in the basic training manual Synchro, Servo and Gyro Fundamentals, NavPers 10105. If you need a review about how synchro transmitters and control transformers work, individually or as a team, you should read the texts listed above before continuing this present chapter. Here we will present additional or amplifying information about CTs and synchro systems that is not included in the previously mentioned courses.

Synchro Errors

A perfect synchro has never been made. Synchros will always contain some errors due to manufacturing inaccuracies and assembly. As you know, for every physical position of a synchro rotor there is a corresponding electrical position. For example, if you put the rotor of a perfect synchro transmitter at 30°, as shown in figure 7-4A, the voltages you will read across the stator terminals will be as follows:

S1 to S2 - 90 volts and 180° out of phase with R1-R2.
S1 to S3 - 45 volts and in phase with R1-R2.
S2 to S3 - 45 volts and in phase with R1-R2.

These stator voltages and phase relationships are unique for 30° rotor position. (See fig. 7-4B.) You won't get these quantities at any other position of the rotor. But, as we said before, synchros are not perfect. Any difference between the actual physical position of the rotor and the electrical position is known as electrical error. (Sometimes the electrical error is called static accuracy.) It is possible to get the voltage readings and phase relationships listed above when the rotor of a real synchro is at, say, 30° and 18 minutes. Therefore the synchro has an electrical error of 18 minutes. This is a typical error for a control transformer. The electrical error for synchro transmitters can be that high, but usually it is in the order of 8 to 15 minutes.

Consider a practical synchro system consisting of a control transformer and transmitter like the system shown in figure 7-3. If both units have an electrical error of 18 minutes, the total possible electrical error is 36 minutes, or a little over half a degree.

What can cause errors in synchros? Briefly, here are some of the causes:

1. It is impossible to make the three stator windings the same. Each winding could have a different number of turns, for example.
2. The rotor and stator assemblies must be exactly round. If they are slightly elliptical, an electrical error results.
3. The rotor of a synchro must be put in the exact center of the stator bore. If the rotor is off center by just a small fraction of an inch, then there will be an electrical error.

A servo is only as accurate as its error detector. If there are electrical errors in the servo's data transmission system, the servo output will reflect the electrical error. Now let's see how electrical errors show up in a simple synchro system.

The pictorial diagram in figure 7- 5A shows a synchro transmitter and control transformer connected in the conventional way. We will assume it is a perfect system. It has no electrical error. Both units are perfect. Notice particularly that all gear ratios are 1:1. That is, if we turn the transmitter handcrank one revolution, the transmitter rotor will turn one revolution (360°). Similarly, if you turn the CT's handcrank one revolution, the control transformer rotor will turn one revolution. Furthermore, assume that the dials on both rotor gear faces are so accurate that we can read angular position of the respective rotor in minutes of arc as well as degrees of rotor angular position.

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follow accurately the motion of another shaft some distance away. In earlier chapters of this book you learned that launchers are normally controlled by launcher order signals that originate in fire control computers. These orders are transmitted over synchro data transmission circuits. Figure 7-3 shows a typical launcher train order synchro system. The system contains a synchro transmitter (CX) which is inside the fire control computer, and a control transformer (CT) located at the launcher. These two units, together with their connecting wires, are called a synchro data-transmittion system. Synchro systems are described in Synchro, Servo and Gyro Fundamentals, NavPers 10105, so we won't cover their basic operating principles here. But we will see how a synchro system is used in launcher power drives. The synchro transmitter changes the movement of its rotor shaft into equivalent electrical signals. These signals represent the position of the rotor shaft and are sent over the three stator wires to the synchro control transformer. The CT has a dual role in this particular circuit arrangement: It acts as an error detector and also as a receiver. Because this unit is the heart of most servos, and especially of power drives, we should closely examine its purpose.

Control Transformer

Look at the block diagram shown in figure 7-3 and you will see the major components in a launcher power drive. Take particular notice of the control transformer. The synchro transmitter in the fire control computer supplies launcher position order to the control transformer. The CT compares the orders with the actual position of the launcher, and determines the error. The electrical error signal is fed

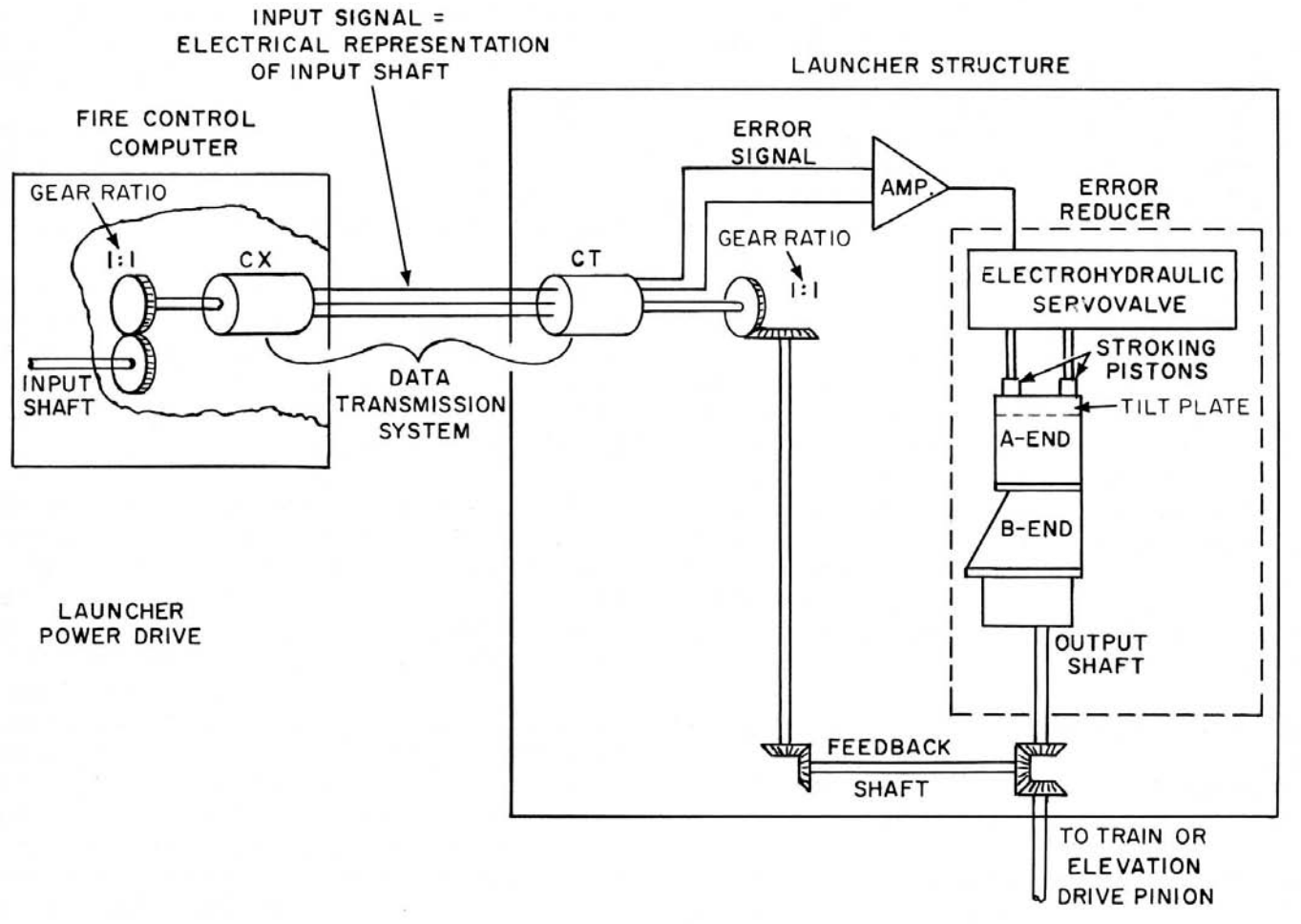
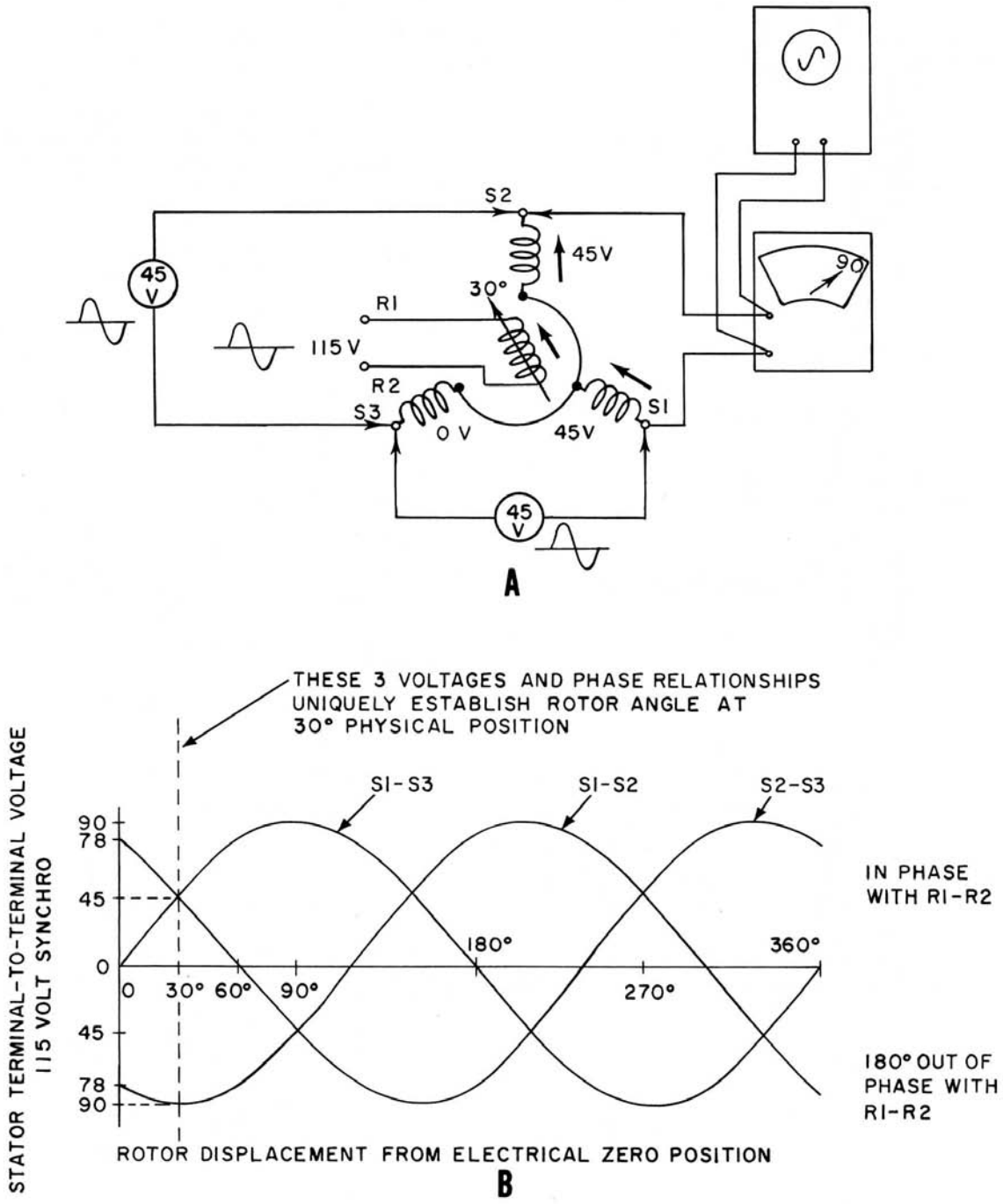


Figure 7-3. — Typical synchro data transmission system (train or elevation launcher orders).

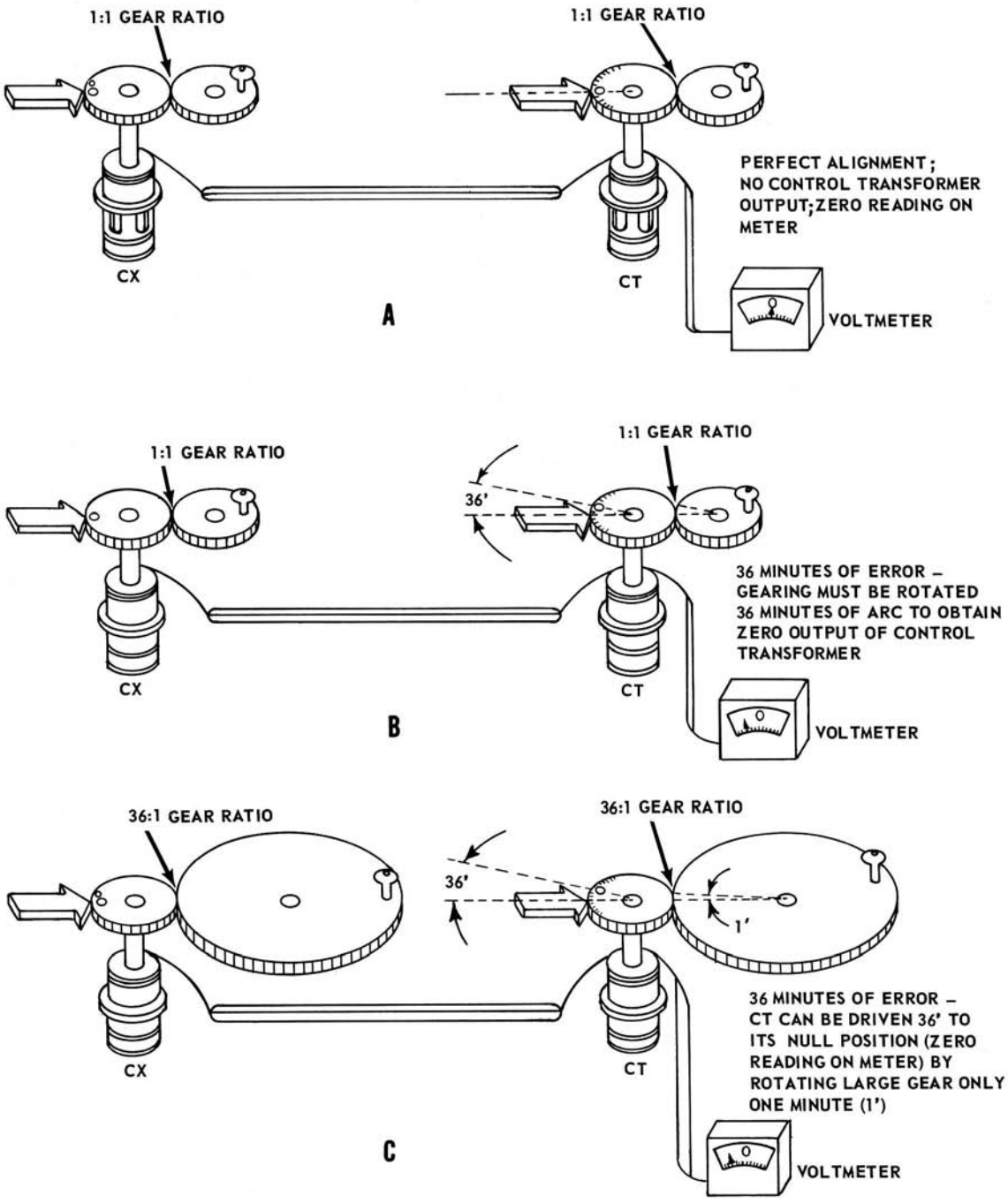
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Figure 7-4. — Synchro electrical error: A. A perfect synchro transmitter at 30°; B. "Error" or rotor displacement from electrical zero position.

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Figure 7-5. — Electrical error in a synchro system: A. A perfect synchro transmitter connected to a perfect control transformer; B. Synchro transmitter and control transformer each with electrical error of 18 minutes; C. "Fine" synchro system using 36:1 gear ratio to reduce error.

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Since we have a perfect system, if we put the rotor of the transmitter on zero, and then turn the crank at the CT end of the system, a voltmeter connected across the CT R1-R2 leads will read zero when the CT dial reads zero. If we turn the rotor of the transmitter to 5°, as read on the CX rotor dial, and then turn the control transformer handcrank until the voltmeter reads zero volts, a glance at the CT dial will show that it reads exactly 5 degrees. You can repeat this experiment for every position of the dial and the result will be that the transmitter rotor is at a selected position, the CT rotor will be at the same position when the voltmeter reads zero. In other words, we have perfect transmission of data.

But now look what happens when we use actual synchro units in the system. Assume that the synchro system contains an accumulated electrical error of, say, 36 minutes. The pictorial diagram in figure 7-5B shows the same setup as we had before. But instead of perfect synchros, we have replaced them with ones that have an electrical error of 18 minutes apiece. If we put the dial of the transmitter at zero, we will transmit what we think is an electrical signal proportional to zero degrees. But to get a null (minimum or zero reading of the voltmeter), the CT rotor must turn through an angle of 36 minutes. At null it is obvious that the two rotors are not in the same angular position. The transmitter rotor is at its zero position and the control transformer rotor is 36 minutes away from zero. Now turn back to figure 7-3. Assume that the data transmission system shown there also has a 36 minute electrical error. If the launcher order computing section in the missile fire control computer turned the CX rotor shaft to the position corresponding to zero launcher train order, the power drive servo would position the launcher at zero degrees and 36 minutes. The launcher is certainly not at the ordered position. It is close to it, maybe, but it is not exactly on. For this reason the system we are talking about here is called a COARSE system. It transmits approximate angular position information because the system contains electrical error. But launcher power drives must receive very accurate aiming information so that the launcher guide can be pointed in the right direction. Therefore, an additional synchro system, called the FINE system, is used along with the coarse system.

Operation of a FINE Synchro System

To show how a fine system works we can make one out of the coarse system we've just talked about simply by changing gear ratios.

In figure 7-5C we have done just that. Instead of a 1:1 gear ratio between the synchro rotors and their handcranks we have installed gears with a ratio of 36:1. If we turn either handcrank one revolution, its associated rotor will turn 36 times. Also, it follows that if we turn either crank one minute, then the rotor geared to the crank will turn through 36 minutes of arc. Now mentally place both dials at zero. Assume that we have a 36 minute electrical error in the synchro system. With the increased gear ratio, we have to move the control transformer handcrank only one minute to null the voltmeter, even though we have a 36 minute error in the system. So, by increasing the gear ratio we have reduced the effect of the error 36 times. Remember, in an identical situation using a coarse (1:1 ratio) system we had to move the CT rotor 36 minutes to get system null.

In the preceding discussion about synchro system electrical error we have taken the part of a servo. We manually turned the CT handcrank which moved the CT rotor until we saw a zero reading on the meter dial. Now let's replace the human operator with a servo and show how increased gear ratios improve the accuracy of the synchro system and its associated servo. The diagram in figure 7-6 shows a launcher power drive servo controlled by a fine synchro system. Assume there is a 36 minute accumulative error in the synchro system. If we put the input shaft (CX rotor shaft) at its ZERO physical position and the launcher at its zero position, the servo will drive the launcher through a ONE minute angle. But, because of the 36:1 stepped-up gear ratio between the launcher and the CT's rotor, the rotor of the CT will turn 36 minutes, canceling out the 36 minute electrical error. At this point, the voltage at the amplifier input is zero, and the servo stops. The important point is that the launcher has moved only one minute even though the error in the synchro transmission system is 36 minutes. Or, you can say the angular position between the input and output of the system (data transmission system and servo) is one minute. If we had used a coarse transmission system with a 1:1 gear

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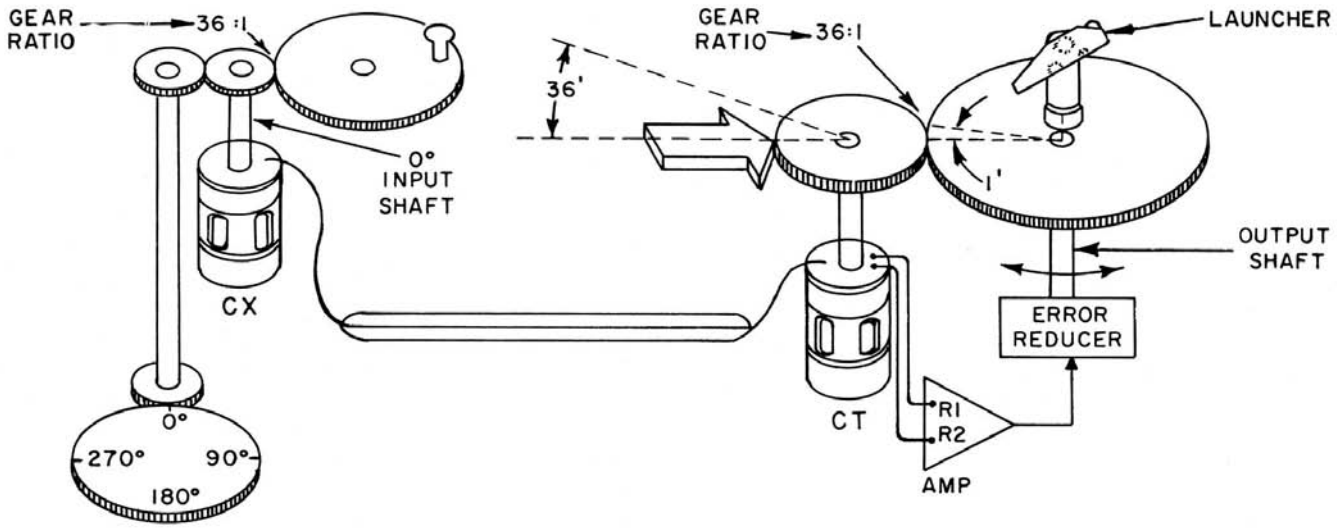


Figure 7-6. — Launcher power drive using a fine synchro system.

ratio, the difference between the input shaft and the output shaft would have been 36 minutes when the servo stopped driving the launcher.

DISADVANTAGES OF 36:1 SYNCHRO TRANSMISSION

The main disadvantage of the 36:1 transmission is that the servo is no longer self-synchronous. In the 1:1 transmission system the output shaft is synchronized with the input shaft at only one point. In other words, there is only one position the output shaft can assume which will allow correspondence between the rotors of the CT and the transmitter. However, in the 36:1 transmission system the output shaft can be in correspondence at 36 different positions for any one position of the input shaft. For example, if the rotor of the transmitter is at 0° (see fig. 7-7), the output shaft, and consequently the launcher, could be synchronized at 0°, at 10°, at 20°, and so on, in steps of 10 degrees. In each of these positions of the output shaft, the position of the control transformer is stepped up 36 times so that it is an integral multiple of 360°, thus bringing the CT into false correspondence with the transmitter in each case.

Combining the Fine and Coarse Systems

Although the fine system provides high accuracy in a power drive servo, it is never used by itself, since, as you have seen, it does not provide true synchronization of the input and output at all times. We certainly would not want a launcher pointed at 80 degrees, when the synchro transmitter rotor shaft was at, say, 10 degrees. Therefore, the fine system is always combined with a coarse system. The fine synchro system provides a very sensitive control at times when the error between the order signal and the servo output is small. Since this is a 36-speed synchro, however, it can bring the launcher to anyone of 36 positions. It is the job of the coarse synchro system to bring the launcher close enough to the true synchronous position so that it is within the range of the fine synchro.

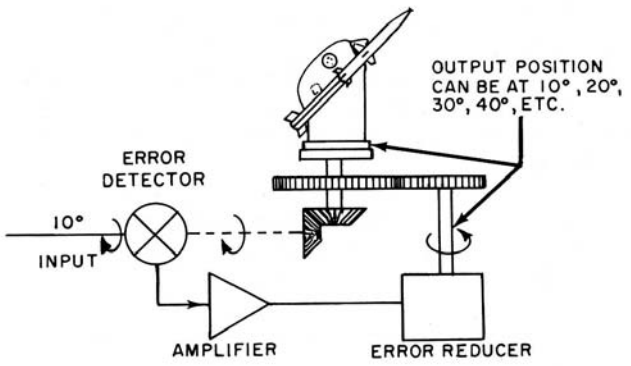
Therefore, you must have some way for the coarse synchro to take control and drive the launcher into correspondence whenever the error exceeds a certain amount - in most cases about 2 degrees. The circuits that accomplish this have many names. Some of these are:

1. Synchro changeover network or circuit.
2. Synchro crossover network.
3. Synchronizing circuit.

Figure 7-8 shows where these circuits are located in a typical power drive servo.

Since a switching function is called for in these circuits, what more perfect devices could be used than relays and diodes.

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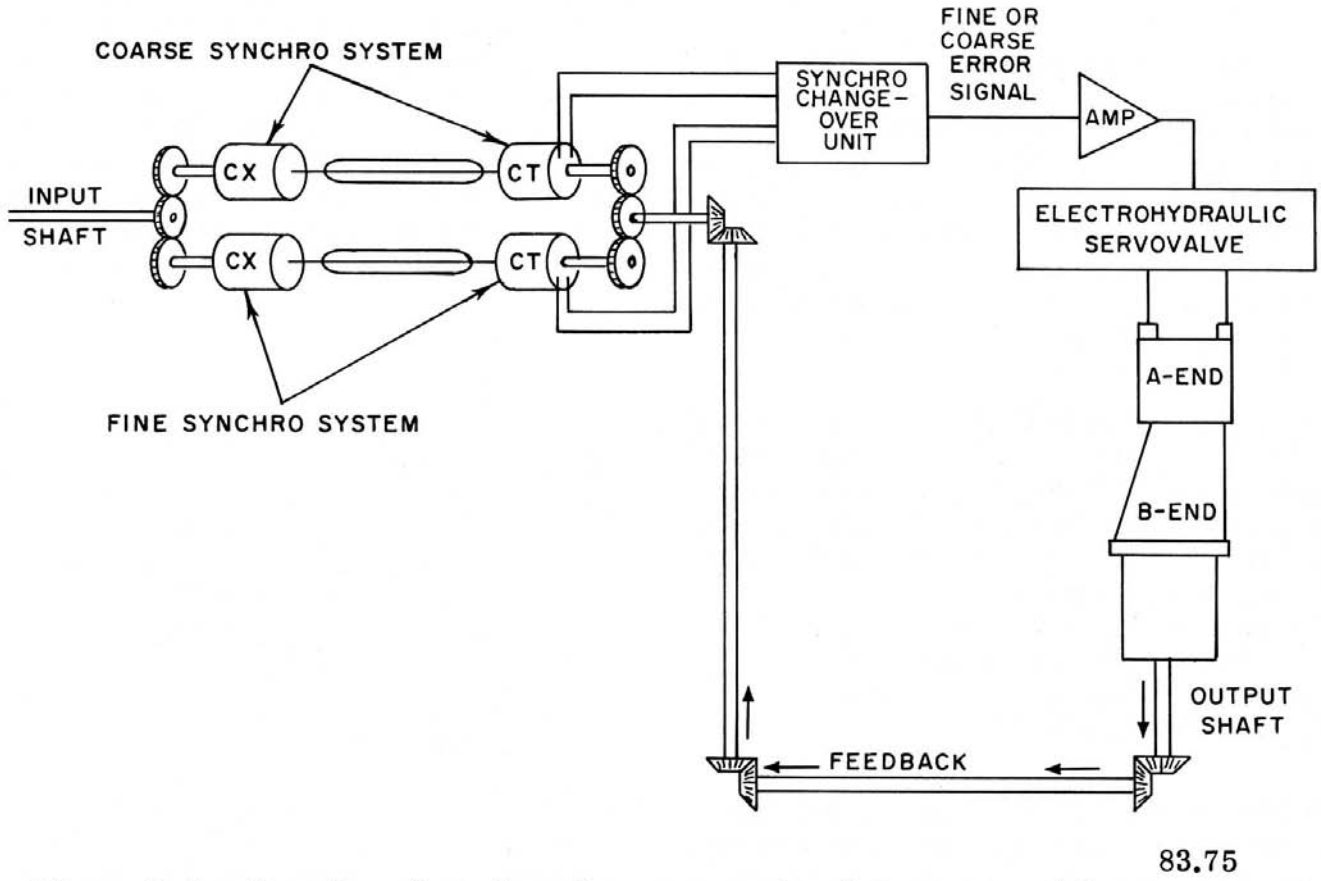
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Figure 7-7. — Fine synchro system (36:1 gear ratio) causes launcher to synchronize at any multiple of 10 degrees.

Figure 7-9 shows a schematic of a typical synchronizing network which uses a relay to switch the fine and coarse synchro control signal inputs to the servoamplifier. Follow the two signal paths from their control transformers to the amplifier. Notice that both signal circuits are opened and closed at the contacts controlled by the relay.

Start out by tracing the fine signal from the fine CT to the servoamplifier. In figure 7-9 it looks as if the fine signal isn't going anywhere. However, the relay coil pulls the contact arm down. This closes the upper contact, and the fine signal is fed directly to the servoamplifier. You may be wondering how the relay was energized to pull the arm down.

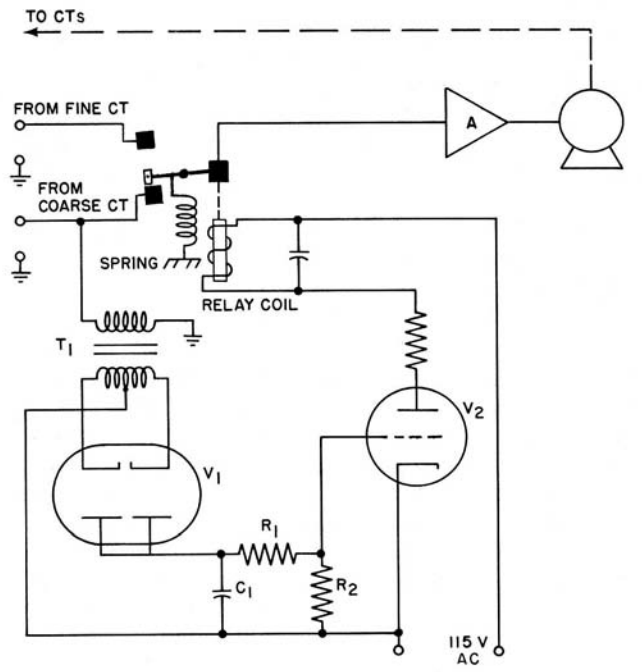
Before you can answer that, you'll have to remember what you've learned about the operation of a triode tube. You will recall that the potential on the control grid determines whether or not the tube will pass current. With a strong negative potential on the grid, the tube has a high resistance, and very little current passes. With a weak negative potential on the grid, the tube has a low resistance, and current flows across the tube whenever the plate goes positive. The grid potential is developed across R2. It is this voltage across R2 that determines whether or not the tubes will pass current.



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Figure 7-8. — Location of synchro changeover network in a power drive servo.

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55.30
Figure 7-9. — Relay synchro changeover circuit.

Now trace the coarse signal circuit. The coarse signal appears across the primary of the transformer, TI. The secondary voltage of TI goes to VI for full-wave rectification. The rectified output of VI is filtered by RI-R2 and CI. Part of the rectified and filtered coarse signal is developed across R2, making the top of R2 negative. Thus the coarse signal controls the grid bias of V2.

When the coarse signal is small, the bias at R2 is small; V2 conducts current on every positive alternation of the supply voltage. This current flows out of the V2 plate, through the relay coil, and back to the source of supply. Then the relay pulls the contact arm down and closes the upper contacts. The fine signal goes to the amplifier. The capacitor in parallel with the relay keeps the relay operated during negative alternations of the supply voltage.

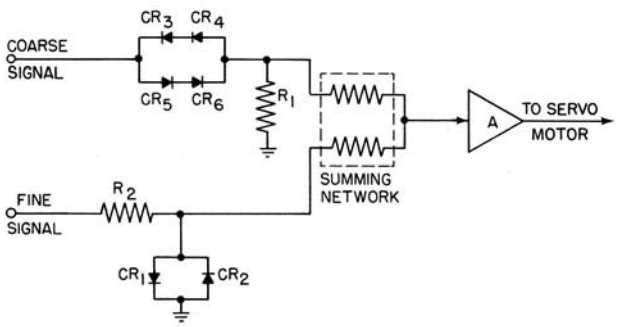
When the coarse signal is large, the bias at R2 is large and V2 conducts very little current. With very little current through V2, the relay coil releases the contact arm and opens the fine signal circuit. Then the spring pulls the contact arm down and closes the lower contacts. The coarse signal is then fed to the servoamplifier.

(If you've forgotten the meaning of any of the electrical symbols used in figure 7-9 and other figures, review the basic texts referred to previously.)

OTHER SYNCHRONIZING NETWORKS. - There are many variations of the circuit just described, but they all operate in much the same manner.

The semiconductor diode synchronizing network is fairly common, so let's take a look at another circuit using this technique. This circuit is illustrated in figure 7-10. Within a range of approximately 2° on either side of the synchronizing point, the coarse signal is effectively blocked because of the high impedance of the series diodes, CR3, CR4, CR5, and CR6. With the coarse signal blocked, the fine signal is fed into the summing network and is in control of the servo. However, this signal is limited to a very low voltage by the parallel diodes, CR1 and C R2.

Both the fine and coarse voltage inputs will increase as the error in correspondence is increased. Remember that the resistance of the diode rectifier decreases with an increase in current flow across it. CR1 and C R2 develop the fine signal. A point will be reached (about 3° error) when CR1 and CR2 will be incapable of dropping a voltage greater than the coarse voltage. Any increase in current gives us a decrease in resistance and a decrease in the fine voltage output to the summing network.



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Figure 7-10. — Semiconductor diode synchro changeover network.

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Now let us look at the coarse signal. In figure 7-10 you will notice that the coarse signal is developed across R1. Also notice that the diode network of CR3, CR4, CR5, and CR6 is in series with R1. Errors in correspondence which are less than 2° will cause some current to flow across R1 and the diode network. However, this current is small and will cause the diode network's resistance to be high. Therefore, most of the coarse signal voltage is dropped across the diode network and very little voltage is developed by R1. In this condition the resultant voltage in the summing network is predominantly from the fine synchro. As we get further out of synchro correspondence, the current through the coarse signal diode will increase resistance, causing a decrease in the diode network's voltage output. A smaller percentage of voltage will be dropped across the diode network and thus more signal voltage developed across R1. Circuit resistance is selected so that the voltage developed across R1 (coarse signal) will override the voltage across CR1 and CR2 (fine signal) when the synchro correspondence error is 2° or more. The coarse signal now has control of the servo. When the servo error becomes less than 2°, the fine signal resumes control.

SERVOAMPLIFIER SECTION

So far you have seen how two small signals (coarse and fine) control a servo and its load- a launcher in most of our examples. You know where they come from originally - from a synchro control transformer. The output of such a synchro is a single alternating voltage, normally very weak. The size of the voltage indicates the size of the error-the difference between launcher or other load position and the order signal. The direction of the error - right or left; elevate or depress- is indicated by the phase of the small voltage. If it is in phase with the 115-volt a-c synchro supply, the error is in one direction. If it is out of phase, the error is in the other direction.

The principal job of the amplifier section is to make the error signal bigger. However, this section may have other jobs to do. For instance, if the output of the amplifier controls a d-c device, then the a-c error signal must be converted into a d-c voltage somewhere in the amplifier section. Sometimes, servo designers select an a-c amplifier to amplify the error signal. Then the amplified signal is converted into d-c after it is amplified. This technique is illustrated in figure 7-11A, The electronic stage in the amplifier section that changes the a-c signal into d-c is called the demodulator. On the other hand, the designers may change the error signal first to d-c, and then use a direct coupled (d-c) amplifier instead of an a-c amplifier. This arrangement is shown in figure 7-11B. Part C illustrates another method of changing signals from one form to another as they pass through the amplifier section. A demodulator changes the a-c error signal to a direct one because the amplifier has a network which operates on direct voltage. The d-c output of the network is fed to a modulator, which changes the d-c voltage to an alternating one. The a-c error signal is then amplified to operate an a-c control device.

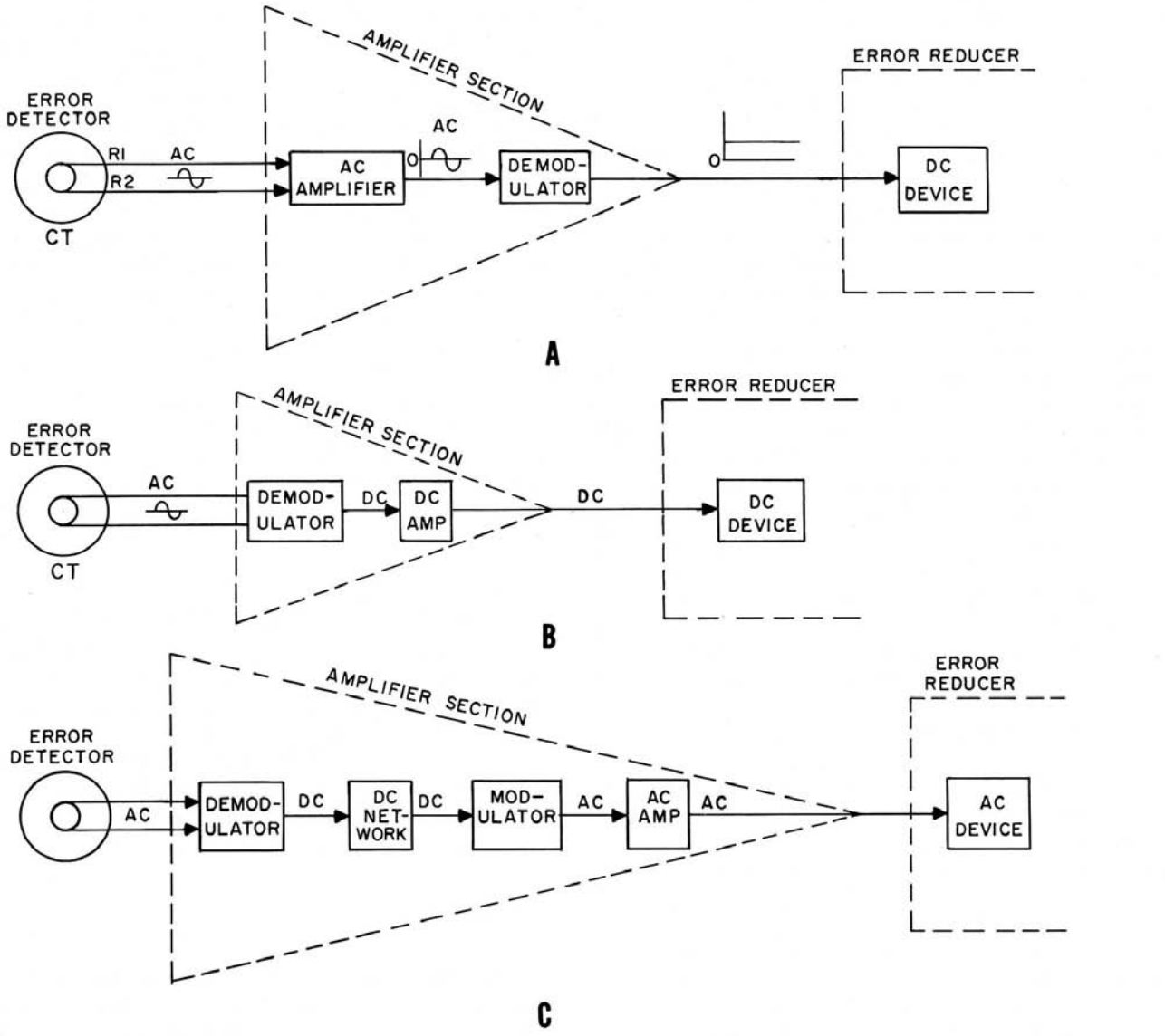
Now you can see that electrical error signals in a servo can be either a-c or d-c. Since some system components may require d-c, and other components in the same loop may require a-c, it is desirable to have some devices which can convert signals from a-c to d-c, and vice versa.

In this section we will show how modulation and demodulation work. We will not include material about the actual stages in the amplifier that amplify signals, because these stages are discussed in detail in the basic electrical and electronic courses. Power drive servos use vacuum tubes, tubes, transistors, or magnetic amplifiers. And you will find all the information you need to know about them in the basic courses mentioned previously.

Modulators

In some power drive servos the error signal may take several forms before it reaches the error corrector. The error detector, as we said earlier, is usually a control transformer which of course, is an a-c device. So its output is an alternating voltage. But there are cases when a circuit which operates on d-c is placed between the error detector and the amplifier. (Look again at figure 7-11C.) Then the a-c error voltage must be changed to direct current. A demodulator performs this voltage conversion. Its output is the error signal in d-c form. The d-c error signal is fed into, say, a stabilizing network that operates on direct voltage. If designers have chosen an a-c amplifier, the d-c output of the stabilizing network must be changed to alternating current. Modulators change d-c signals to alternating ones.

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Figure 7-11. — Changing the form of the error signal: A. A-c amplified signal converted to d-c; B. D-c signal amplified; and C. A-c error signal changed to d-c, then changed to a-c and amplified.

Don't get the idea that modulators are only used to change the form of error signals. Modulators, as well as demodulators, are also used in feedback and auxiliary circuits in servos.

When a d-c signal is converted to a-c, both direction (Polarity) and magnitude of the d-c signal must be contained in the alternating output. The circuit or device that changes (converts) a d-c voltage to a-c is called a modulator. Modulator circuits use elements that act as synchronous switches. Examples of these elements are crystal diodes, vacuum tube diodes, triodes, transistors, and mechanical contactors (vibrators). The "switches," regardless of type, are operated at the supply voltage frequency (the frequency of the reference voltage, usually 60 or 400 hertz and the resulting a-c is a series of pulsating voltages with amplitudes proportional to the d-c error voltage. The phase of the a-c output corresponds to the polarity of the d-c input voltage.

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CRYSTAL DIODE MODULATORS.-A typical crystal diode modulator is shown in figure 7-12. This circuit, or a variation of it, is found in power drive servos. This particular circuit is called an electronic chopper or ring modulator. The main parts of the modulator are the reference transformer (T1), output transformer (T2), and a crystal diode bridge consisting of two sets of diodes. One set, CR1 and CR4, work together; the other set, CR2 and CR3, also form a team.

The diodes hold the key to circuit operation. Each set of diodes can be compared to a switch that opens and closes at the frequency of the alternating reference voltage. On one half-cycle of the reference voltage, CR1 and CR4 conduct and act like a closed switch. Then on the next half-cycle, CR2 and CR3 conduct and simulate a closed switch.

If we apply a 60 or 400 hertz reference voltage to the circuit, the diode pairs will open and close at 60 or 400 hertz. This vibrating action will allow an applied d-c signal to pass through the bridge when either set of diodes conducts. Notice, too, that when either set conducts, they connect the top terminal of the d-c input to one or the other ends of the output transformer (T2). These ends have the terminal markings of A and B. As the diode switches open and close, they alternately connect the A and B terminals of T2 to the d-c input's ungrounded terminal. When a diode pair conducts, it acts as a closed switch, and any d-c voltage appearing at the d-c input terminal is alternately placed at, say, first point A, and then at point B, back to point A, and so forth. The effect of this vibrating switching action produces an alternating voltage in the primary of T2. This is what we want. The modulator has taken a DIRECT VOLT- AGE and changed it into a ALTERNATING output which has the same frequency as the reference voltage.

Now that we have the overall idea of what the modulator is supposed to do, let's see how it does it. When the instantaneous polarity of the reference transformer is as shown in figure 7-12A, CR2 and CR3 conduct, and act like closed switches. At this point, the d-c error signal voltage is placed at point A on the output transformer. Figure 7-12B shows the electro- mechanical equivalent of circuit conditions at this point. Neglecting d-c voltage drops across resistors, diodes, and windings (these parts have low ohmic values anyhow), point A is at about the same potential as the error signal.

On the next half-cycle of the reference voltage, the polarities at the reference transformer change, and CR1 and CR4 conduct. Now point B of T2 is at the same potential as the d-c error signal. Look at the equivalent circuit in figure 7-12C to see this instantaneous action. You can see now that on successive alternations of the reference voltage, the d-c error potential is transferred from one end of the output transformer primary to the other. Thus the voltage induced in its secondary is an alternating voltage corresponding to the d-c error voltage.

ELECTRONIC (VACUUM) TUBE MODULATORS. - You learned in your basic courses that electron tubes may be vacuum type or gas-filled type, and that the vacuum type is most commonly used. The operation of both types and of variations of each, such as diode, triode, pentodes, and others, is described in Basic Electronics, NavPers 10087-B. Chapter 1 of Basic Electronics describes the operating principles of electron tubes, and chapter 10 explains their application in modulation and demodulation. To qualify for E-4 you must know the function of electronic circuit components, and the operating principles and characteristics of electron tubes. Since all this information is available in your basic texts, it will not be repeated here.

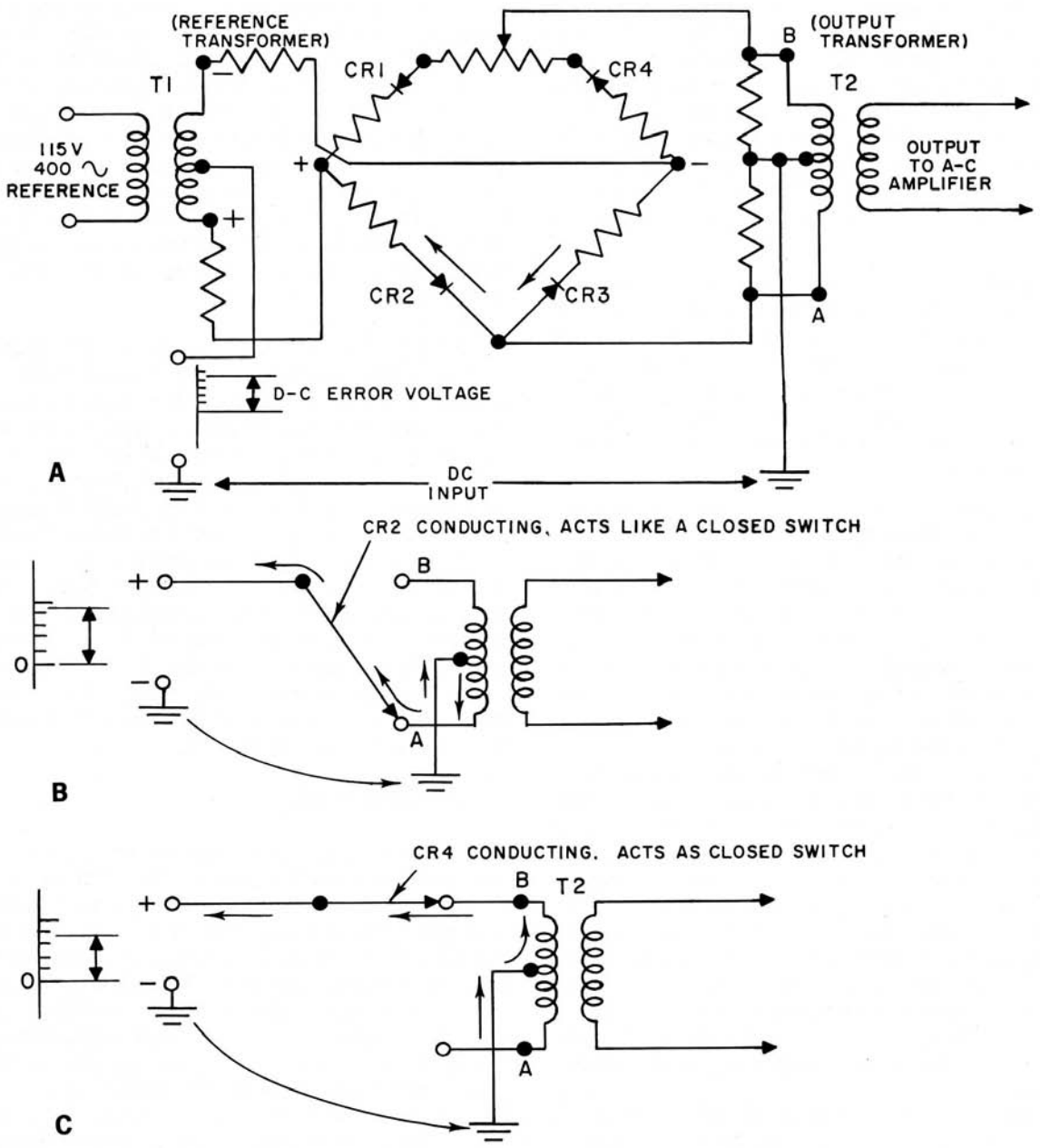
DEMODULATORS

Some devices that control the error reducer operate on direct current. But the input signal to the servoamplifier is usually an a-c synchro voltage. Therefore, the a-c signal must be converted to direct current. A demodulator is used to accomplish this. Demodulators are often referred to as phase-sensitive rectifiers, phase- sensitive detectors, phase discriminators, converters, discriminators, or simply detectors. These are high-sounding names for a circuit that is fairly simple. If you understand the operating principles of modulators, demodulators will be easy for you to learn.

Diode Demodulators

A typical diode demodulator (phase detector) is shown in figure 7-13. As illustrated, an a-c supply voltage serves as the reference voltage for the detector. This voltage must come from the same source that is supplying a-c excitation to the synchro system, or whatever type of a-c error detector is used, and must be in phase

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Figure 7-12.—Modulation operation: A. Acting as closed switches, CR2 and CR3 conduct; B. Electromechanical equivalent of circuit conditions in A; C. Equivalent circuit when CR1 and CR4 conduct.

with the common supply voltage. This permits a phase comparison of the error voltage with the reference voltage. The plates of the two diodes are supplied with this reference voltage so that the two plates will be in phase. Assume that there is no error signal from T2 to the plates of the diodes at the time the plates are on a positive half-cycle. The two diodes will conduct equally. The voltages produced across R1 and R2 are equal, making the cathode of V1 and

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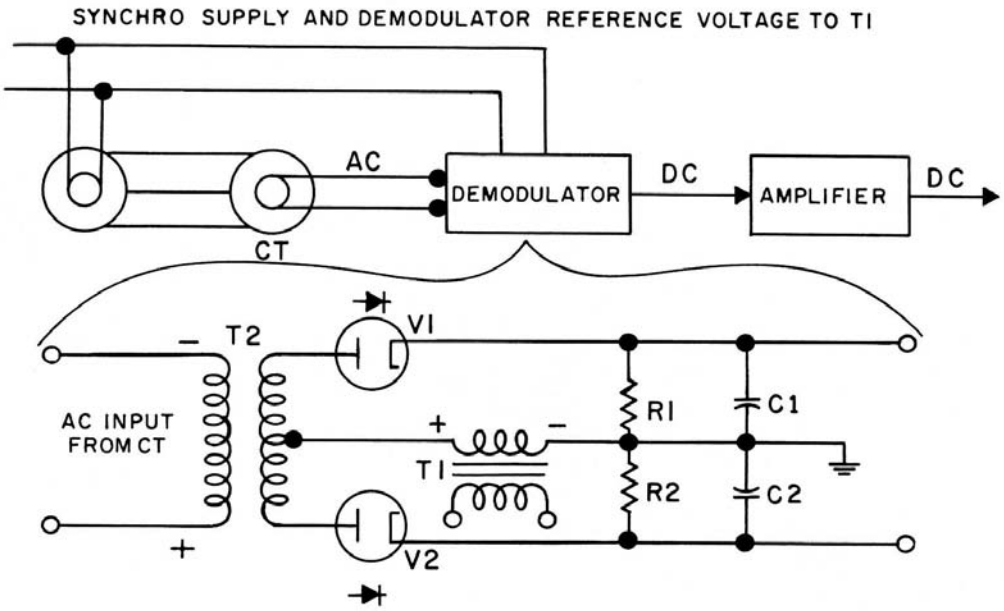


Figure 7-13. — Diode vacuum tube demodulators.

V2 at equal potential with respect to ground. With the two output terminals at the same potential, the output voltage will stay at zero as long as no error signal is applied.

If an error signal is applied to T2, making the plate of V1 positive at the same time that the reference voltage on the plates of V1 and V2 is on its positive half-cycle, V1 conduction will be increased and V2 conduction decreased over the no-signal condition. The top of R1 would become more positive and the bottom of R2 less positive. This would result in a positive output at the top with respect to the bottom. Since the voltages applied to the plates are both alternating, the voltage developed across R1 and R2 would also be alternating. However, R1-C1 and R2-C2 have a long time constant compared to the input frequency, and therefore filter most of the ripple, giving a d-c output.

If the error signal applied to T2 is changed by 180 degrees, V2 would now increase its conduction while the conduction of V1 would be reduced. This would result in an output voltage of reversed polarity. Variations of the diode phase detector may be encountered. You will find that some demodulators use crystal diodes instead of vacuum tube diodes. However, they all work on the same basic principle.

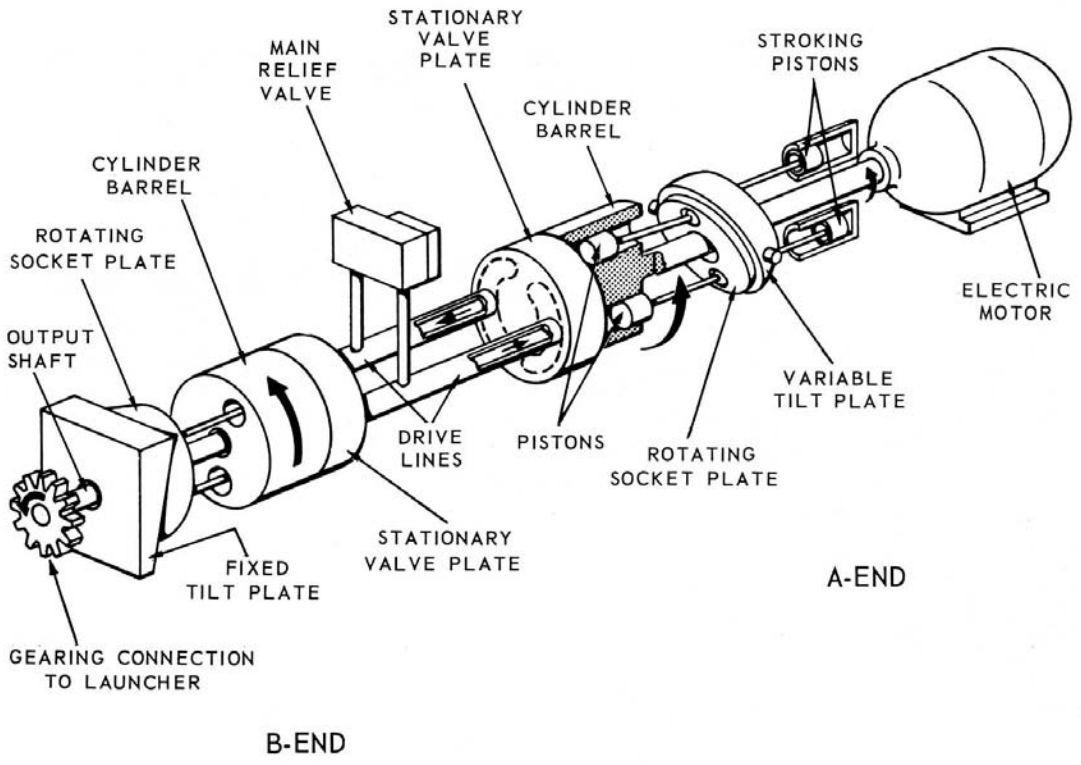
Triodes too, are similar to diodes, but have the additional ability to amplify. Amplifiers are explained in the basic courses in electricity and electronics, and will not be covered here. Transistors also are described in those texts. Transistors are able to do many of the things for which electron tubes have been used, and their small size makes them preferable in many instances.

THE ERROR REDUCER

The devices which you will study in this section are those which belong in the third block of figure 7-2. We gave the functional name of error reducer to this block. Here you will find the components that accept the amplified error signal and then change it from its electrical form into mechanical or hydraulic action. This action, in turn, controls the tilt of a hydraulic A-end. An axial-piston pump (A-end), as you know from your study of Fluid Power, NavPers 16193 (current revision), is a variable delivery hydraulic pump. The A-end applies hydraulic fluid pressure to a hydraulic motor called the B-end which, in turn, converts the hydraulic pressure into a rotary motion. Output of the B-end is mechanically coupled to the train and elevation drive gears that position the launcher.

Figure 7-14 shows an A-end and B-end that is enclosed in the same housing and are separated by a common valve plate. This type unit is a

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Figure 7-15. — Type-K installation.

by a universal joint, to the drive shaft, the shaft rotates with it. Through gearing, this moves the launcher.

As the unit continues to rotate, the piston moves uphill, sliding deeper into its cylinder, forcing low pressure fluid into the return transmission line.

If the direction of fluid flow from the A-end were reversed, the low pressure return line would become the high pressure line, and vice versa. Rotation of the B-end would reverse.

The A-end is constructed somewhat like the B-end, except that the tilt of the socket ring is variable, not fixed. In action it is just the reverse of the B-end. Its input is mechanical and the output is fluid pressure. Very simply, it operates like this:

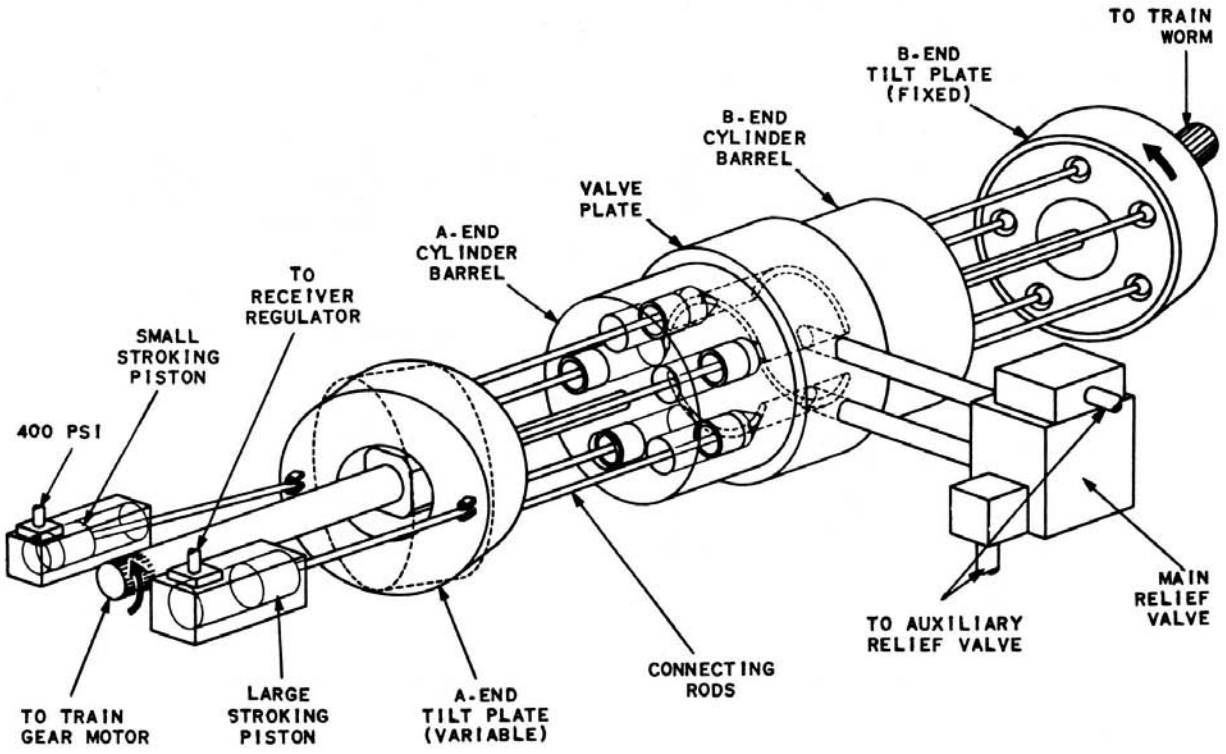
In figure 7 -16 tilt has been applied to the A-end. As piston A rotates upward, it is forced into its cylinder, pushing oil ahead of it. The other pistons as they ride up this half turn will do the same. The oil is collected at the sausage-shaped port and sent out through the transmission line marked HIGH PRESSURE to the B-end, where it forces the hydraulic motor to rotate. Piston B, as it rotates downward, is drawn outward from its cylinder. This helps draw oil in from the return line.

If the tilt of the A-end is removed entirely (0° tilt) the pistons will continue to be rotated by the electric motor, but they will not move back and forth in their cylinders. This means no fluid flow, and the system is at neutral. If the tilt box is tilted on past neutral in the opposite way from +.hat in the illustration, the pressures in the lines reverse. The line which has been the high pressure line becomes the return line and vice versa. This changes the direction of B-end rotation and the direction of launcher movement.

Control of the tilting plate then controls launcher movement. The stroke piston (or pistons) (fig. 7-18) is the connection between our amplified order signal and the A-end tilt box. Figure 7-18 shows two methods used in power drive servos to control A-end tilt, and both function on the differential working area principle.

In figure 7-18A you can see that the' stroke piston is being acted upon by two hydraulic pressures. The 1000-psi side is held constant and

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Figure 7-14. — (combination A-end and B-end).

Type-C or CAB (combination A-end and B-end) installation which is most frequently used in launcher train and elevation systems. (See figs. 5-19A and 5-19B for location of train and elevation CAB units in Talos launching system, and fig. 5-26 for a block diagram of the train drive system.)

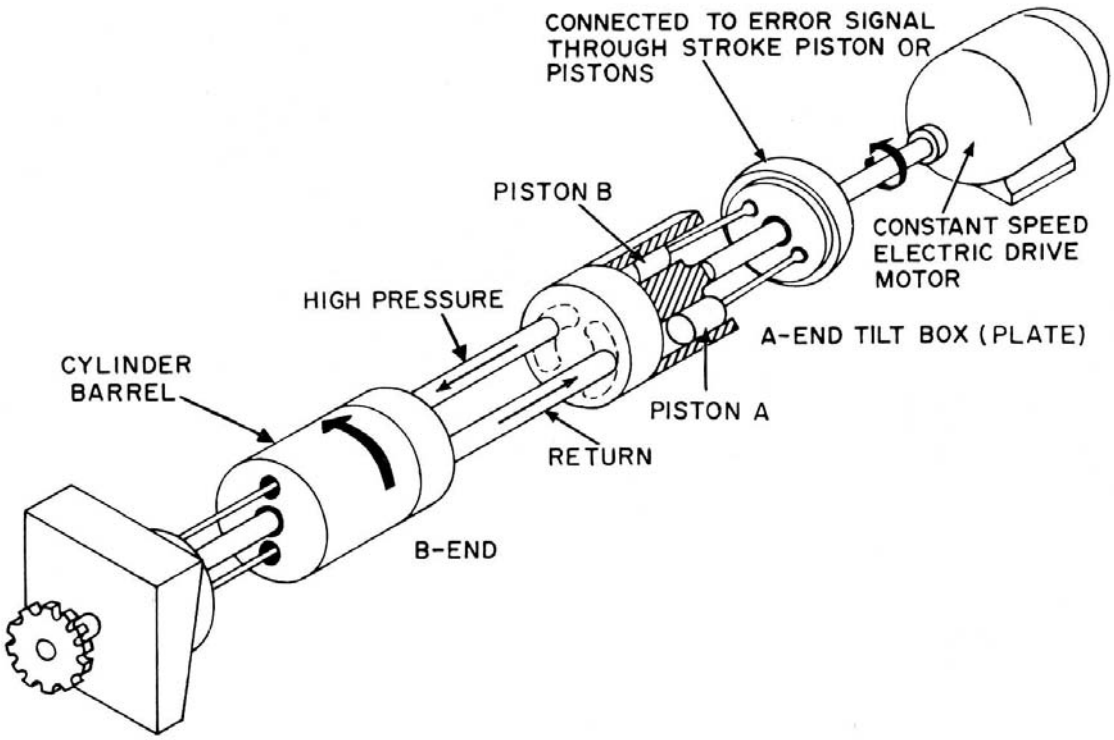
There are times when it is convenient to install the two units in separate spaces. In this case the units are connected by piping with each unit having its individual valve plate. This is the Type-K installation (fig. 7-15). Regardless of the physical arrangement, each installation works similarly to the system we will discuss in the following paragraphs.

Hydraulic A-end and B-end Type

The major elements of this type of drive are shown in figs. 7-15 and 7-16. The A-end (pump) is driven by a constant-speed electric motor. The output is made variable by action of the tilting plate or box, which is moved by the stroke piston (or pistons). In figure 7-3 you can see that the stroke pistons are, in turn, controlled by the electrohydraulic servovalves when they are actuated by error signals from the amplifier. The B-end (motor) is driven by the fluid output of the A-end. The speed of the B-end is dependent on the amount of fluid pumped by the A-end pistons. The more tilt applied to the A-end the m,:)re fluid pumped by the pistons and therefore the Greater the speed of B-end rotation. The direction of rotation of the B-end is determined by which transmission line is high pressure and which is return. The output of the B-end is mechanical rotation. In the case of a launcher it is directly connected to the launcher train or elevation gearing. The unit that moves the launcher in train is geared to the training circle (fig. 5-20) and the elevation unit is geared to the elevation arc (fig. 5-18). The same type of system is used in gun mounts and turrets to train and elevate guns.

B-end operation is demonstrated in figure 7-17. Only two pistons (usually there are nine) are shown. High pressure fluid from the A-end is shown being applied to the top of the piston. The force is carried through the piston rod to the tilted ring. The only way for the socket ring to yield is downhill. This causes the socket ring to rotate. Since the socket ring is joined,

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Figure 7-16. — A-end and B-end operation.

works on a certain size piston face area. The left side of the stroke piston is acted upon by a force made variable by our error signal. This force works on twice the stroke piston face area as that of the constant 1000 psi. In this case 500 psi would balance it, and the stroking piston would remain motionless. Raising the pressure on the left side of the piston above 500 psi moves the piston right, and puts tilt on the A-end. Reducing the pressure below 500 psi shifts the piston and the tilt box the other way, reversing the direction of fluid flow.

In figure 7-18B you see practically the same actions. Here are two stroke pistons. The face of the larger one is twice the size of the smaller one. Hydraulic pressure on piston A is held constant, and varying the smaller pressure acting on piston B will cause tilt to be applied.

Electrohydraulic Servovalve

Train and elevation power drive servos have hydraulic error reducers. So, the principal power units in this section are hydraulic. But you will always find some electrohydraulic device which converts the electrical output of the servoamplifier into a proportional hydraulic fluid flow. An electrohydraulic servovalve performs this function. It is made up of two basic sections: a force motor and a hydraulic amplifier. The output of the unit ports hydraulic fluid to the two stroking pistons which position the A-end tilt plate.

Figure 7-19 shows a typical electrohydraulic j servovalve. Hereafter we will call it simply a servovalve. The main hydraulic unit is a spool valve which is positioned by a hydraulic circuit. The fluid flow in this circuit is controlled by a reed flapper valve. A small unit made up of a force motor and two permanent magnets control the reed. The spool valve is free to move in the enclosing cylinder, subject to the restraining forces of the centering springs. The spool valve moves in one direction or the other when unbalanced pressures are developed in the two pressure chambers. A chamber is located at each end of the spool.

How The Servovalve Works

There are several variations of the servo-, valve but they all work on the basic principle described in the following paragraphs.

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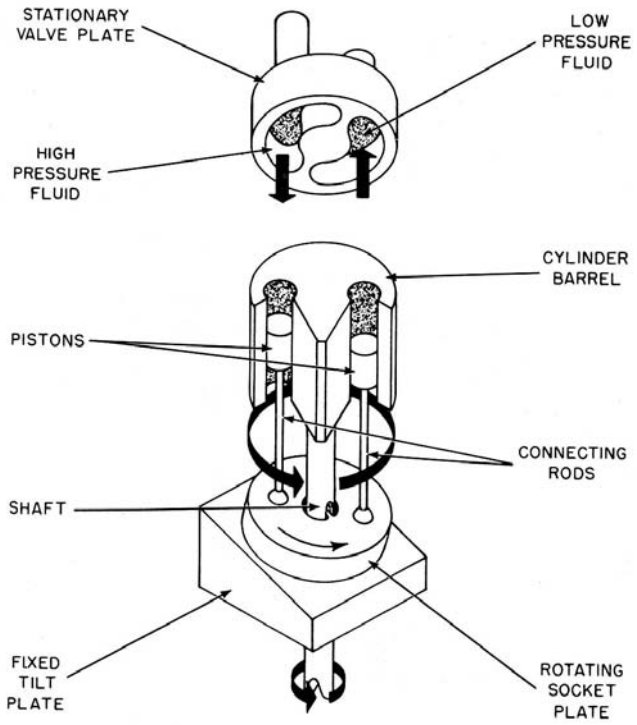


Figure 7-17. — B-end operation.

The electrohydraulic servo-valve shown in figure 7-19 converts an electrical signal to proportional hydraulic order. A servovalve consists of a force motor and a hydraulic amplifier. The force motor transforms the electrical output, a differential current, into a proportional force on the motor reed.

The force motor consists of two permanent magnets, two pole pieces, two coils, and the reed. The reed can be pivoted in a flexture tube, which serves as a centering device, or in a flapper valve that is clamped at one end. The reed extends through the solenoid windings of the force motor into the mixing chamber between the nozzles. Position of the reed is changed according to the differential of current flowing in the coils. You will recognize this as push- pull action.

The position of the reed regulates the flow of fluid through the nozzles. For example, if the reed moves toward the right, the flow through the right nozzle is restricted, while the fluid flow through the left nozzle increases.

The fixed orifices work somewhat like a current-limiting resistor in an electric circuit. The resistor develops a voltage drop proportional to the value of current through it. Similarly, the fixed orifices function as restrictions and develop pressure drops proportional to the rate of fluid flow in the lines containing them.

The action of the reed, nozzles, and orifices is as follows. When the reed moves to the right, blocking fluid flow to tank through the

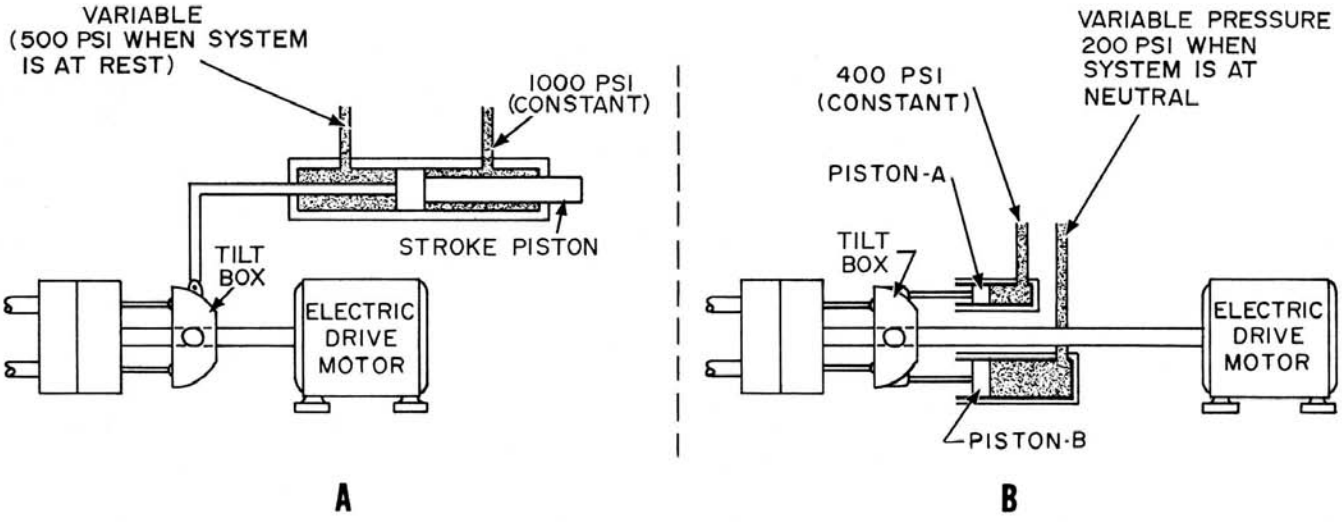
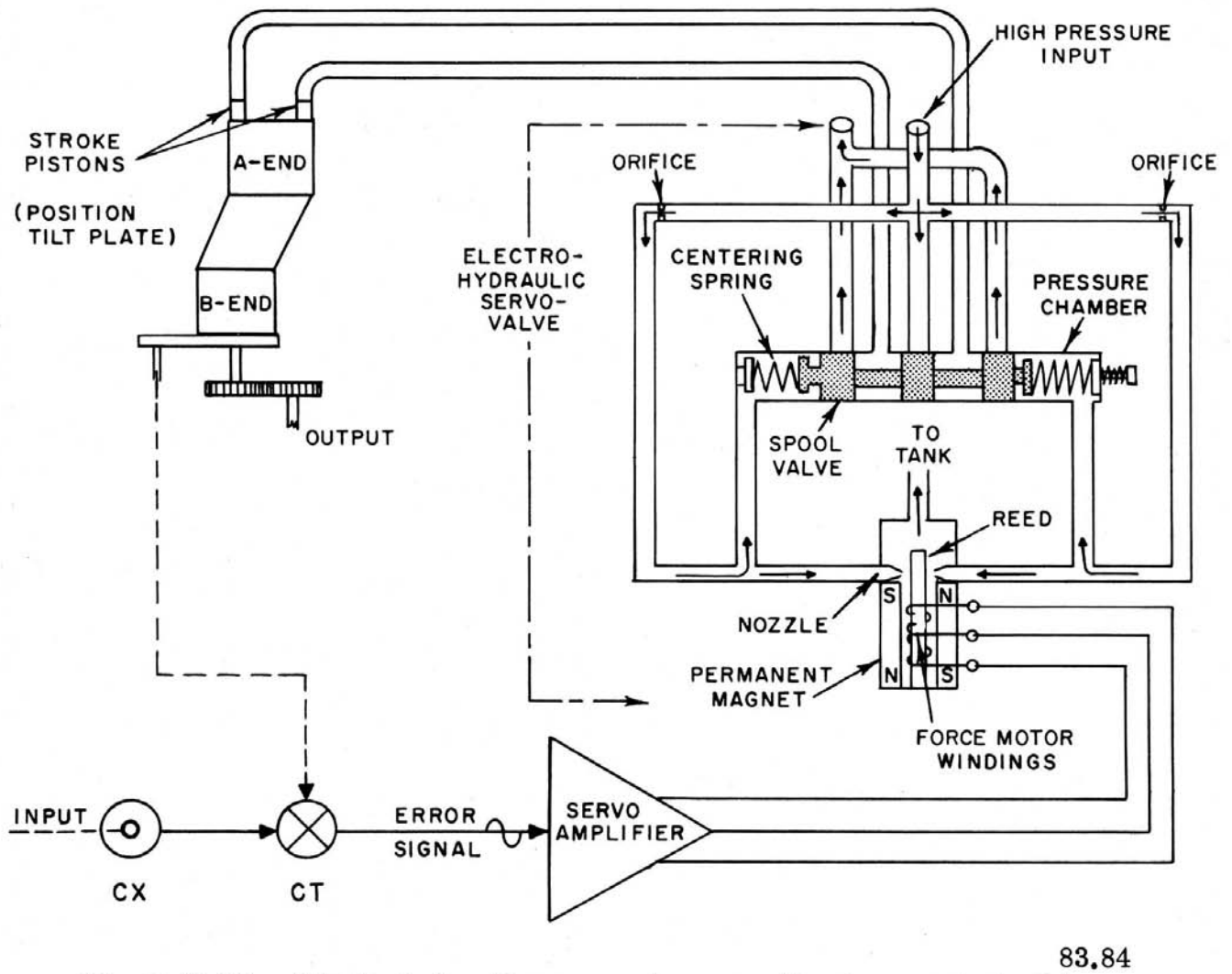


Figure 7-18. — Putting tilt on the A-end: A. Pressure on one piston; B. Pressure applied to two pistons. 83.83

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Figure 7-19. — Electrohydraulic servovalve operating in a control system.

right nozzle, fluid pressure in the right pressure chamber increases. At the same time, the fluid flow through the left nozzle increases. Fluid pressure in the left pressure chamber cannot be maintained due to the restriction to fluid flow of the left orifice. The differential in pressures set up at the ends of the spring- centered spool valve upsets the balance of the valve, causing it to shift to the left. The motion of the spool valve is reversed when the reed moves toward the left nozzle since this causes higher pressure in the left-hand pressure chamber than in the right. In this manner the spool valve is centered or moved to the right or left, depending upon the position of the reed.

When in the center, or neutral position, the spool valve prevents liquid from entering either of the two lines leading to the A-end stroking pistons. This action puts the A-end tilt plate on neutral and there is no B-end output. When the spool valve moves to the left, for example, the center land of the spool valve admits high- pressure fluid to the right stroke piston line: while at the same time the left land opens the low-pressure line to the left stroke piston line. This puts tilt on the A-end. Motion of the spool valve in the opposite direction results in a reversal of connections so that A-end tilt responds in the opposite manner.

IMPROVING THE QUALITY AND PERFORMANCE OF SERVOS

A power drive servo must operate smoothly, rapidly, and with as few errors as possible. Ideally, the motion and position of the output, shaft should duplicate the motion and position of

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the input shaft. But we never get ideal performance from servos because they do not react immediately to a changing input signal. The output will always lag the input. Any action, regardless of what it is, requires time to take place. The action of a servosystem is no exception to this principle. The electrical, mechanical, hydraulic, and pneumatic reaction times in a servo cause the output to lag behind the error signal producing it. Any slack or bending in mechanical linkages will produce a delay. A hydraulic unit will produce a delay. Expansion and contraction of hydraulic lines will cause a lag. Also, it takes time for fluid to flow through valves and lines. Air is compressible, and this causes a delay. Electric and hydraulic integrators produce delays. In the electrical parts of the system, any components that affect the phase of an a-c signal have some effect on the response time of the signal. For example, all coupling and filter capacitors and inductances contribute to a time difference between the input and output.

One method of increasing the speed with which a servo answers an input signal is to increase the gain of the servoamplifier. But if the gain is made too high, the servo output will oscillate. We can reduce the servo's tendency to oscillate by decreasing the gain of the amplifier. But if we cut it down too far, the servo will overshoot the input signal. Therefore, servos are provided with devices that directly and indirectly control automatically the gain of amplifiers. In this manner servos are prevented from overshooting and oscillating. Let's explore the meaning of these two terms further because they are very important in the study of servo operation.

OSCILLATING

Oscillating, frequently called hunting, occurs when the output shaft drives back and forth across the ordered position in short rapid swings, as though the output shaft were looking for a place to stop but never finds it. Hunting is also characterized by its continuous action; it never stops or dies out. And it can be dangerous. If the output shaft oscillates at a rapid rate for a long time, it is possible to shake a launcher or other load to pieces. Oscillation can take place when a launcher is synchronized with a fixed or a moving order signal. But you won't see its effects in a properly designed and adjusted power drive servo.

Overshooting

Overshooting is similar to hunting. But the oscillations of the output shaft die out after a short period of time. They start out as large over-travels and progressively get smaller until eventually the output shaft stops.

To get a better idea of overshooting, we will look at how a servo without damping reacts to a fixed input signal. Assume that the input shaft - (synchro transmitter rotor shaft) is stationary and at zero degrees, and the output shaft is positioned at, say, 10 degrees. The output of the error detector is an electrical signal proportional to 10 degrees. When the servo is energized, the error reducer will drive the output shaft to reduce the error to zero. The error reducer continues to drive the output shaft until the desired position is reached. At this point, the error is zero, or as some technicians say, the system is nulled. But because the load and error reducer have inertia and momentum, the output shaft continues driving beyond the desired position. When the output shaft crosses the desired position, the error detector generates an error signal which tends to reverse the direction of the output shaft. However, it takes the error signal some time to bring the output shaft and load to a stop. In other words, because there are components in the servo that do not react immediately to a signal, some time elapses before the output shaft can respond to the error signal. During this response lag the output shaft continues to drive in the original direction. When it does stop, the error signal immediately starts it back toward the desired position. At correspondence the output shaft and the load have acquired enough speed in the reverse direction to again pass the desired position. The result is a series of progressively smaller over-travels until finally the servo stops.

REDUCING OSCILLATION

To reduce overshooting and hunting, servos are provided with damping devices or circuits. These circuits are frequently called stabilizing or antihunt circuits, and usually use some form of feedback. Feedback, you will remember, is the method by which a sample of an output is returned or fed back to the input to be added to or subtracted from the input, thereby changing and controlling the output. The damping or stabilizing circuits in power drive servos are capable of acting as positive

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feedback to increase the gain of the servo amplifier when the error signal is increasing. It also acts as a negative feedback to reduce the gain of the amplifier when the error signal is decreasing. In this manner servos are prevented from overshooting and oscillating.

We will talk about three of the many methods of reducing overshooting and hunting in power drive servos. First, we will cover the technique of using a control transformer with a movable stator to prevent a launcher from overshooting a fixed order signal. Then we will explain the use of a tachometer generator for damping out oscillations. Finally we will cover integration control, which increases the ability of a servo to follow slowly changing error signals and reduces velocity error. Usually you will find all three methods used in a servo, in addition to others which we will not cover here.

Movable CT Stator Method

So far in our discussion of servos we have assumed that the stator of the control transformer error detector is fixed. The CT rotor, of course, is driven by the feedback line. When the output shaft, and thus the load, is at the ordered position, the electrical output of the CT is zero volts. And the load stops.

In figure 7-20A, however, you see a different setup. Here there are two responses to the CT. The stator is geared to B-end output launcher position feedback (response) and the rotor is geared to the rotary piston. The purpose of having two responses is to cause the A- end tilt plate to start removing tilt before the launcher arrives at its ordered position. The following is a brief discussion of how this is accomplished.

As in a conventional CT, the error signal is produced by rotating a resultant of the three CT stator field voltages. The error voltages induced into the rotor windings are sent to an amplifier and on to a torque or force motor. Rotation of the generator moves a rotary valve. This switches hydraulic circuits to the rotary piston, causing it to turn in a direction equivalent to the desired movement of the launcher (train or elevation). Rotary piston movement sets the hydraulic regulating devices in motion, causing tilt to be put on the A-end pump. This, you will recall, causes the launcher to move.

Even while this is happening, however, the moment the rotary piston moves, it turns the rotor of the CT in such a direction as to cancel out a portion of the original error. Now, as the launcher moves toward its ordered position, B-end response moves the CT stators, also in a direction to cancel out the error. When the stators overtake and pass the rotor, a phase shift occurs in the signal voltage. The result of the phase shift is an output from the rotor in an opposite direction from the first error signal. In other words, if the first signal called for right train and tilt is put on the A-end, the electrical phase shift will cause the error signal to call for, in effect, left train. Hydraulic actions reverse in the regulator, and tilt begins to be removed from the A-end. Theoretically, the A-end tilt box should reach neutral when the launcher arrives at its ordered position. As you can see, these actions will prevent any prolonged overswings of the launcher. Figure 7-20B shows in four steps the action described above.

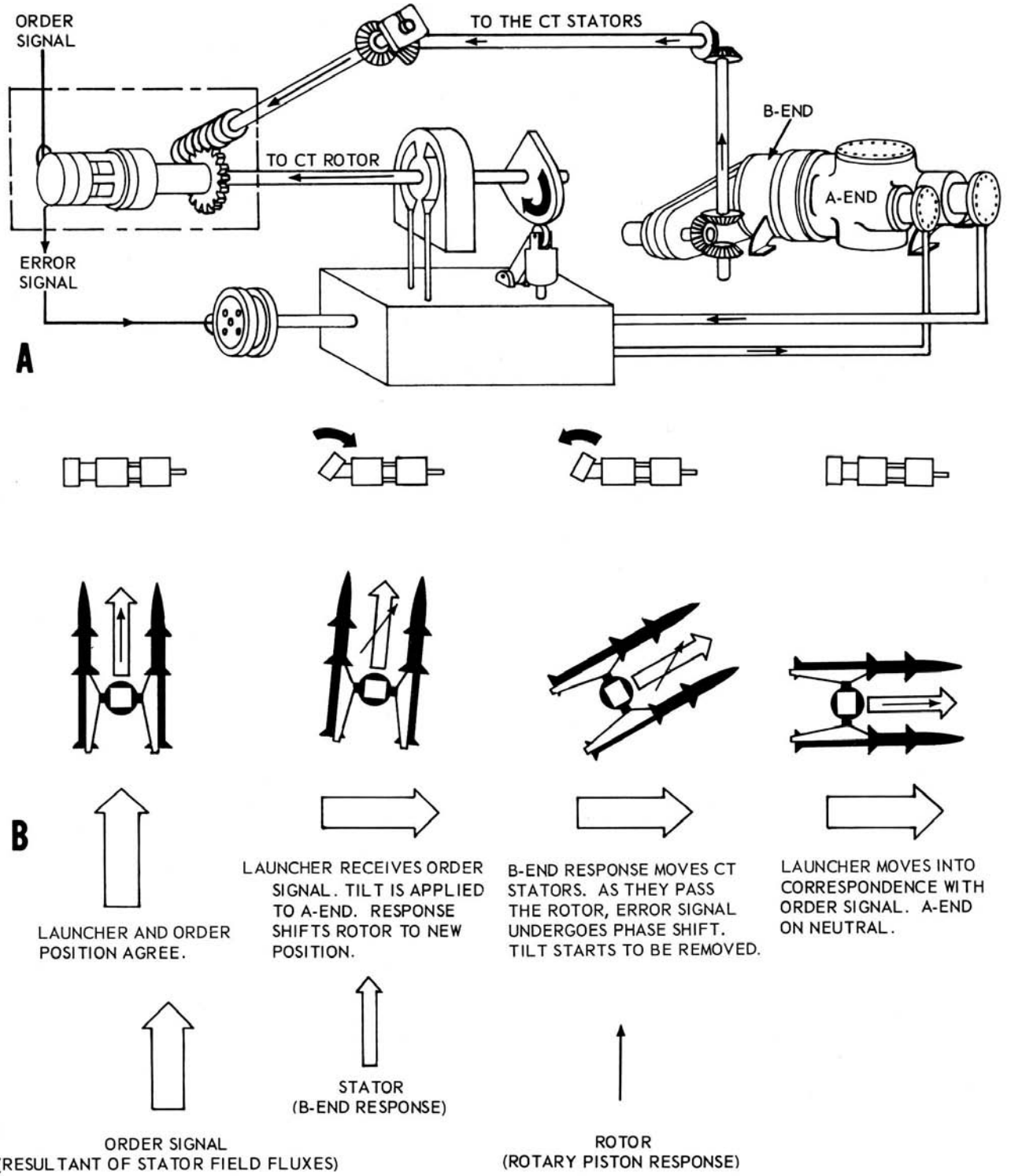
Output-Rate Damping (Feedback Method)

Feedback is commonly used to reduce overshooting and hunting. One method of providing feedback is to use a d-c tachometer generator. This device is commonly called a "tach". Its application is shown in figure 7-21A, The tach is geared to, and rotates with, the servo's output shaft. The tach's output is a d-c voltage whose amplitude is proportional to output shaft speed. Also, the polarity of this voltage indicates the direction of output shaft rotation. Therefore, the output of the tach represents load velocity (rate). This velocity voltage is connected to the amplifier so that it opposes the error signal. Whenever the error signal changes, the rate feedback signal opposes any change in the error signal. In other words, the error signal is damped. The effect on the servo is as though you increased the friction on the output shaft.

This method of using a feedback signal proportional to the velocity of the output of a servo is also called velocity feedback. It is used in some missile and rocket launcher power drive servos to prevent overshooting when the launcher is synchronizing to a fixed input order signal (STOW, LOAD, DUDJET). Under these circumstances, launcher velocity increases as it approaches synchronism and, therefore, the effect of velocity feedback is to slow down the launcher before it approaches this point.

Figure 7-21B shows another method of using velocity feedback to prevent overshooting. Instead of a tach, a potentiometer whose slider is connected to the A-end stroke mechanism provides a velocity signal which opposes any

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Figure 7-20. — Reducing hunting and overshooting of power drive servos: A. By using control transformer with a movable stator; B. As launcher synchronizes, CT acts to remove tilt.

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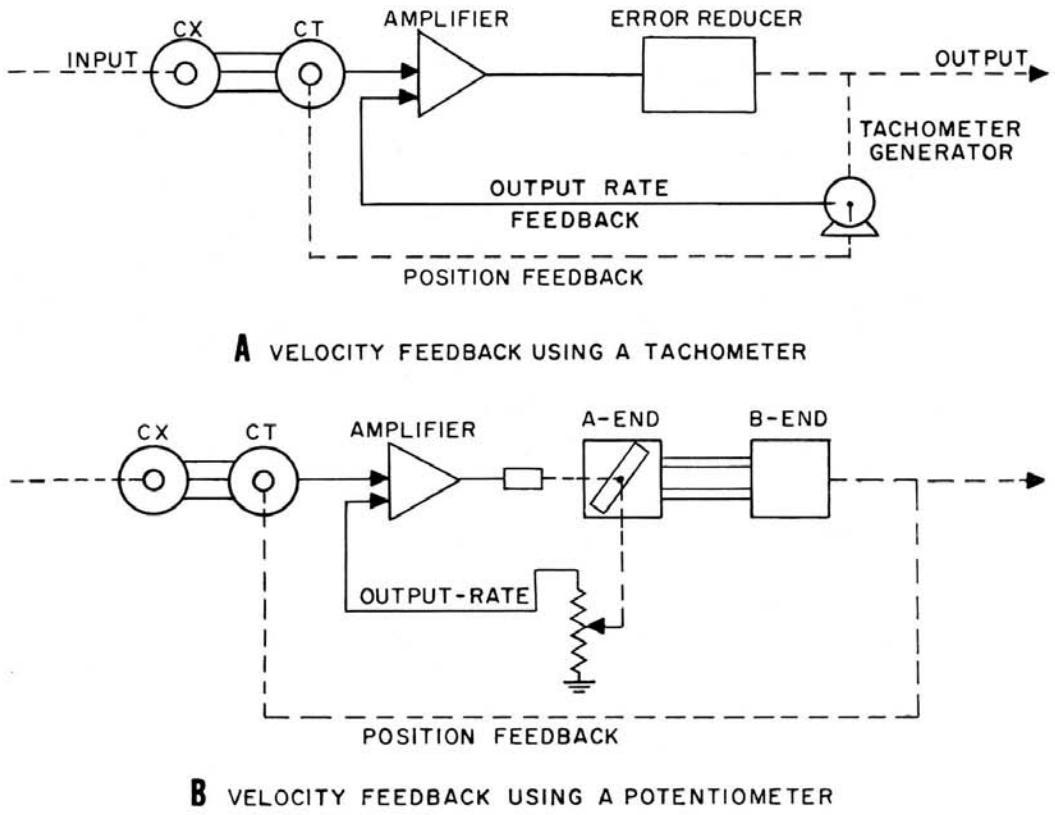


Figure 7-21. — Feedback method to reduce overshooting and hunting: A. Velocity feedback using a tachometer; B. Velocity feedback using a potentiometer. 83.86

change in the position error signal. Since the direction and amount of A-end tilt is a close approximation of launcher velocity, a pot can be used in place of a tach to get the same damping effect. Both methods produce the same result -they slow down the load before it reaches synchronism.

Acceleration Feedback

When you solve one problem, usually another arises. Such is the case with velocity feedback. It causes velocity error. Here's why. When the servo is following a CONSTANT VELOCITY input signal, the tach or the pot puts out a velocity signal even if the input and output shafts are in agreement. At this point there is no position error signal, but there is a velocity feedback signal at the input of the servoamplifier. And this velocity signal causes the output shaft to lag the input. The faster the constant velocity signal, the faster the servo moves, and the greater the velocity feedback signal, and, therefore, the further the output shaft will lag behind the input shaft. This velocity lag problem can be solved with integral control circuits (you'll study them next) which are used in conjunction with velocity feedback circuits. But there are other ways of skinning a cat. We can use the same feedback arrangement illustrated in figure 7-21A, and insert a simple resistor- capacitor network between the tach and the amplifier. Our new circuit is shown in figure 7-22. Also, it has a new name - acceleration feedback. But it is still classified as output-rate damping because the tach senses the output velocity of the servo.

The resistor is connected across the output of the tach, and the capacitor is in series with the tach. The capacitor is the key to circuit operation. When the servo is following a constant velocity input signal, the output of the tach is a steady d-c voltage. Now from your study of electricity you know that a capacitor blocks

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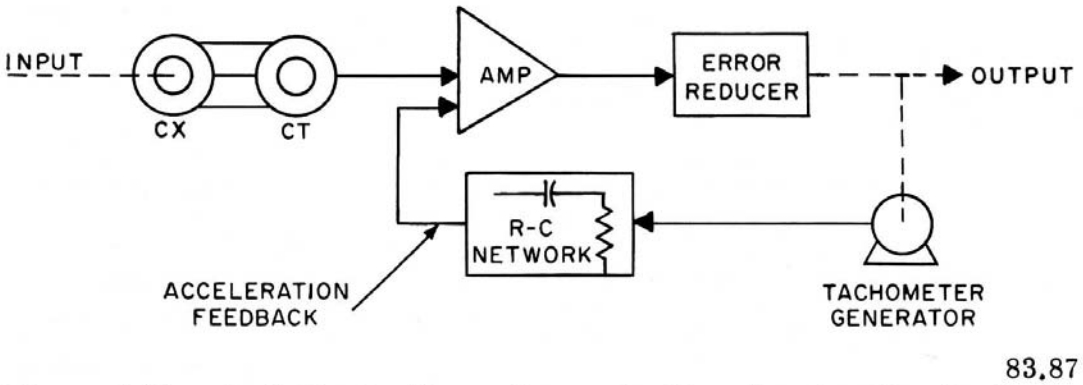


Figure 7-22. — Reducing hunting and overshooting: Acceleration feedback.

the flow of direct current. Therefore, no velocity signal gets through to the amplifier when the output shaft is moving at the same speed as the input shaft. The velocity feedback signal from the tach is blocked, and does not oppose the error signal. But if the output shaft suddenly changes its speed (accelerates), then the tach puts out a fluctuating d-c signal which looks like a-c to the capacitor, and it passes the feedback signal on to the amplifier. Here the feedback signal opposes any change of error signal. Thus the output shaft is restrained from changing its speed (accelerating).

Integral Control

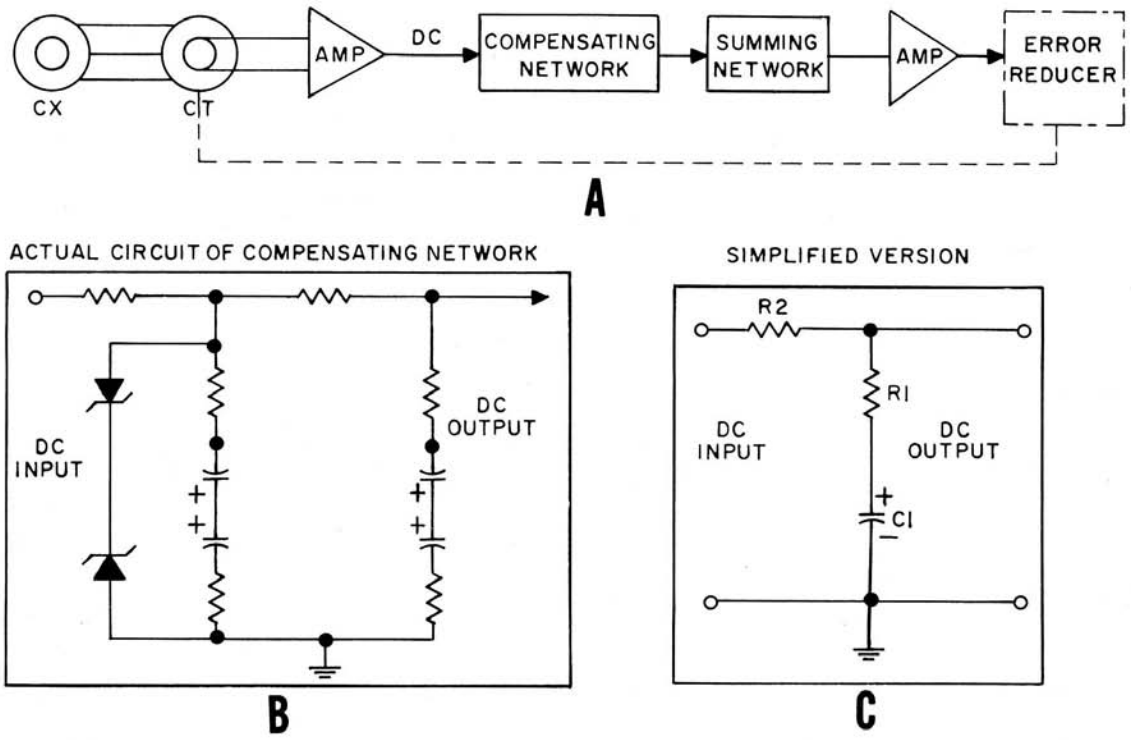
Power drive servos, as we've said before, are sometimes required to follow constant velocity order signals. These signals occur, for example, when the tracking radar is following a target whose speed and range remain fairly constant. The input shaft of the launcher train order transmitter turns at a constant velocity (speed and direction) for a substantial percentage of time. Therefore, the power drive servo must respond to this type of input with as small an error as possible. But because there is always friction present in the servo, a velocity error will be present: the output shaft position lags the position of the input shaft when both shafts are rotating at the same velocity. For instance, the input shaft is rotating at 10°/sec and the output shaft is moving at the same velocity but the angular position between them is, say, 1 degree.

To correct for velocity error, servos use integral control circuits. This type of circuit, like the output rate method, reduces velocity error to a minimum. The integral circuit modifies the error signal so that it is proportional to the length of time it exists, multiplied by the amplitude of the error signal. For example, suppose the output of the circuit is four volts and it was produced by a constant error signal which lasted for one minute. If the same error signal had lasted for only one-half minute, the output would have been two volts. You can see that if an error signal exists for a long time its amplitude increases. Therefore, the amplifier output increases and an exaggerated error reducing action takes place. Or, to say it another way, the servo overcorrects the error. The speed of the output shaft increases more than it normally would and thus it catches up with the input shaft.

Figure 7-23A shows a simplified block diagram of an actual power drive servo. Figure 7-23B shows an integral control circuit (also called a compensating network) used in the servo in fig. 7-23A. We have reduced this circuit to its simplest form as shown in fig. 7-23C. Briefly, here is how the circuit works.

The integral control circuit is made up of a combination of two resistors and a capacitor. Notice that the network is in series with the error detector and the servoamplifier. Since the integral control circuit operates on direct voltage, the amplifier must contain a demodulator to change the a-c error signal to a proportional d-c form. The size of the components in the network is such that the capacitor voltage does not change when the error voltage changes rapidly. Only that portion of the changing error signal developed across R1 is impressed on the amplifier. But, with an error signal of longer duration, the capacitor will charge, increasing the voltage input to the amplifier. Therefore,

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Figure 7-23. — Integral control: A. Simplified block diagram of power drive servo; B. Integral control circuit of compensating network; C. Simplified circuit of compensating network.

this circuit is sensitive to constant or slowly changing error signals of the type you would expect from a velocity error.

On the other hand, the integral control circuit ignores rapidly changing error signals. Remember, the higher the frequency of the voltage impressed across an R-C circuit, the more the capacitor acts like a short circuit. Rapidly fluctuating d-c signals will be split between R1 and R2 because the capacitor acts like a short circuit or zero resistance. R2 is much larger than R1, so most of the fluctuating voltage is dropped across R2. A much smaller portion of the rapidly changing error signal appears across R1. Since R1 is in parallel with the input to the amplifier, only a small signal voltage is applied to the amplifier.

Now look what happens in the circuit when the error signal is steady or changes slowly. This is the kind of signal you would get when a velocity error exists. Initially, all of a constant error voltage would be distributed between R1 and R2. But the longer the error voltage is applied, the more C1 charges up. The increasing voltage drop across C1 adds to the drop across R1 and. since these two components are in parallel with the amplifier, their combined voltage will appear at the input terminals of the amplifier. In effect, the error reducer will overcorrect the error signal and the output shaft will catch up with the input.

In many power drive servos, hydraulic devices perform the same function as integral control circuits. When hydraulic integral control is used. a potentiometer picks off a voltage from the hydraulic integrator and feeds this signal to the servoamplifier. But regardless of the technique used - hydraulic or electrical - the main purpose of integral control remains the same - to minimize the effect of velocity error on servo operation. Also, you will generally find that integral control circuits and devices operate on the fine error signal and not the coarse.

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CHAPTER 8

HYDRAULICS AND PNEUMATICS IN MISSILE SYSTEMS

INTRODUCTION

You have been using hydraulic, electrohydraulic, and pneumatic power to operate different equipments almost from the day you entered the Navy. Deck equipment for loading and unloading, and equipment for raising, lowering, or otherwise moving heavy objects such as anchors, use hydraulic power. Your basic military texts (Seaman, NavPers 10120-E; Basic Military Requirements, NavPers 10054-C; Military Requirements for Petty Officer 3/2, NavPers 10056-C) did not tell you how these equipments were powered. But now you need to understand the power behind the machine. Look at the quals on hydraulics and pneumatics. Note that all of the knowledge factors are required of the E-4 and E-5. Much of this information that you need may be found in Fluid Power, NavPers 16193-B. We will try to show how fluid power is used in missile systems. The preceding chapter told how fluid power is actuated through servomechanisms. Wherever you need a large force, controllable by a small force, hydraulic power can fill the need. It is the chief source of power for operating equipment and machinery used by the GM ratings. Keeping the hydraulic systems in peak operating condition is a major part of the GMM's work. The more you understand about how hydraulic systems work the better able you will be to keep them working.

HYDRAULIC TERMS COMMONLY USED BY GMMs

The terms defined may be used as an introduction to the subject of hydraulics, and for later reference. These terms may have more than one meaning, but we will give only the meaning which applies to hydraulic systems.

ACCUMULATOR. - A device for storing hydraulic fluid under pressure. It is usually a spherical or hemispherical hollow object (fig. 8-1) with diaphragms, bladders, valves, and other accessories to control the fluid. Its purpose is to store enough fluid at, or close to, the working pressure of the system to meet short demands for excess fluid. It also smoothes out surges and pulsations in the hydraulic system, and meets low-capacity demands without operating the high-capacity pump (except intermittently to charge the accumulator).

AIR BREATHER. - A device which allows air to enter or leave a hydraulic tank as the oil level changes. An air filter is normally installed in the breather. See figure 8-8.

ANNEALING. - Method of softening pipe and tubing so that it can be bent or formed more easily. Only copper tubing is annealed. The process is also used to restore flexibility to tubing to prevent splitting or cracking.

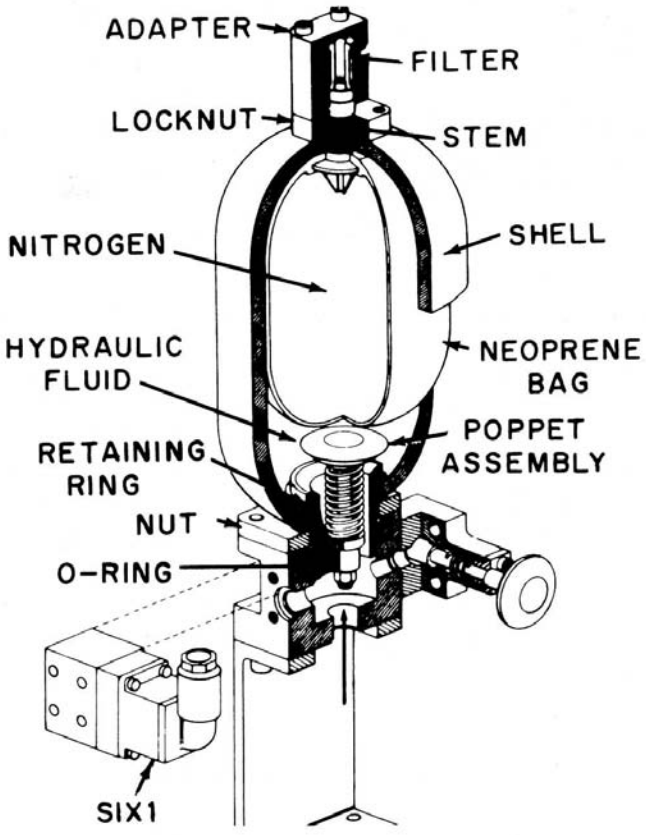
BAFFLES. - Plates or partial plates which extend into hydraulic tanks to reduce sloshing and foaming and to aid in cooling the fluid.

BUFFER. - A mechanism used to retard moving equipment or bring it to a smooth stop. See figure 8-2. It is not necessarily a hydraulic device, but may be pneumatic or mechanical. In the buffer illustrated, forcing the fluid through the deceleration grooves causes the slow down.

CAB UNIT. - Combination A-end and B-end. The A-end and B-end are located in the same housing and are separated by a valve plate (fig. 7-16).

CAVITATION. - Partial vacuum in hydraulic fluid caused by lack of full volume of fluid at the pump intake. Collapse of such cavities produces very large impulsive pressures that may cause considerable mechanical damage to neighboring solid surfaces.

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Figure 8-1. — Bag type amcumulator.

CONTROL FLUID. - (Control pressure). Hydraulic fluid, other than transmission fluid, under pressure and used to control the operation of the hydraulic power unit.

CYLINDER AND PISTON. - A linear motion device for converting fluid energy into mechanical energy (fig. 8- 3).

DASHPOT. - A device to cushion the last portion of the stroke and prevent metal-to-metal contact of pistons and plungers when they reach the ends of travel (fig. 8-4).

DRAIN LINES. - Lines that return hydraulic fluid to the sump, supply, or header tanks.

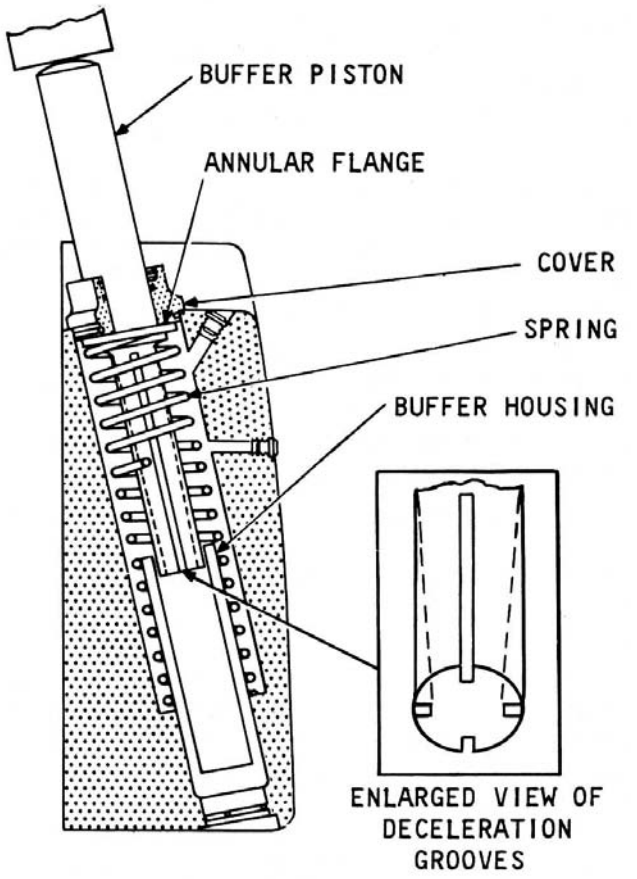
DRAIN PLUG. - Plug used to drain hydraulic fluid from a hydraulic system or tank. See figure 8-8B.

FILTER. - A device for removal of dirt, sludge, and lint from a hydraulic fluid where the resistance to motion of such solids is in a tortuous path. (Compare with Strainer.) Filters are installed at various points in the hydraulic system. See figure 8-5. The one shown has a single element of the "micronic" type, constructed of a pleated cellulose material, to be discarded when clogged.

FITTINGS. - Devices used to interconnect hydraulic pipes and tubing. Fittings may be screwed, flanged, or compression type. See Fluid Power, NavPers 16193-B, and chapter 12 for different types and uses of each.

FIRE POINT. - The temperature at which a substance, if ignited, will burn for at least 5 seconds. The fire point is always higher than the flash point.

FLASH POINT. - The temperature at which a fluid (such as gasoline) gives off sufficient vapor to form a flammable mixture with air.



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Figure 8-2. — Hydraulic buffer.

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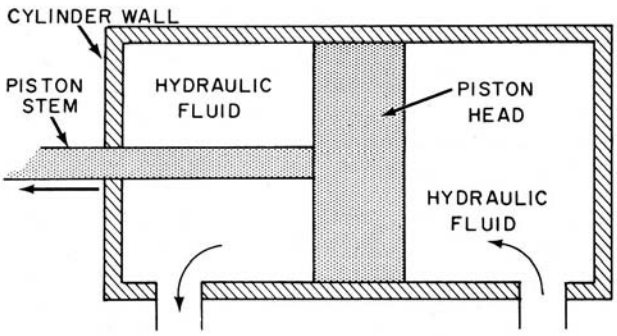


Figure 8-3. — Cylinder and piston.

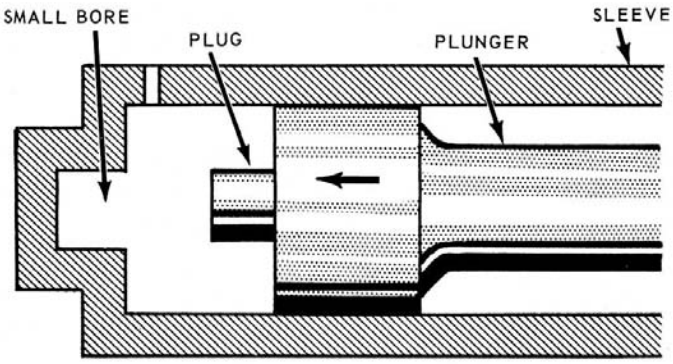


Figure 8-4. — Dashpot.

FLOW RATE. - The number of units of volume of fluid passing through any channel in one unit of time. See Volume of Flow.

FLUID LEVEL GAUGE (GAGE). - An instrument which indicates the fluid level in a hydraulic system.. Sometimes called Tank Window. Refer to figure 8-8.

GASKET. - Material placed between mating surfaces of hydraulic fittings (flanges, etc.) to increase tightness of the seal.

GPM (GALLONS PER MINUTE). - The normal way of measuring the volume of flow rate in a hydraulic system.

HEAD OF FLUID. - Hydraulic fluid in a system that is maintained above the power drive level.

HOSE. - Flexible hydraulic lines.

HYDRODYNAMICS. - Study of liquids in motion.

HYDROSTATICS. - Study of liquids at rest, particularly regarding pressure and equilibrium.

INHIBITORS (OR ADDITIVES). - Chemicals added, during the manufacturing process, to hydraulic fluid to improve its ability to retard corrosion and foaming and to resist oxidation.

JIC SYMBOLS. - Graphic symbols for fluid power, used on hydraulic schematic diagrams. These symbols were originated by a Joint Industrial Conference of manufacturers of commercial hydraulic equipment. They are now included in MIL-STD-17B-2.

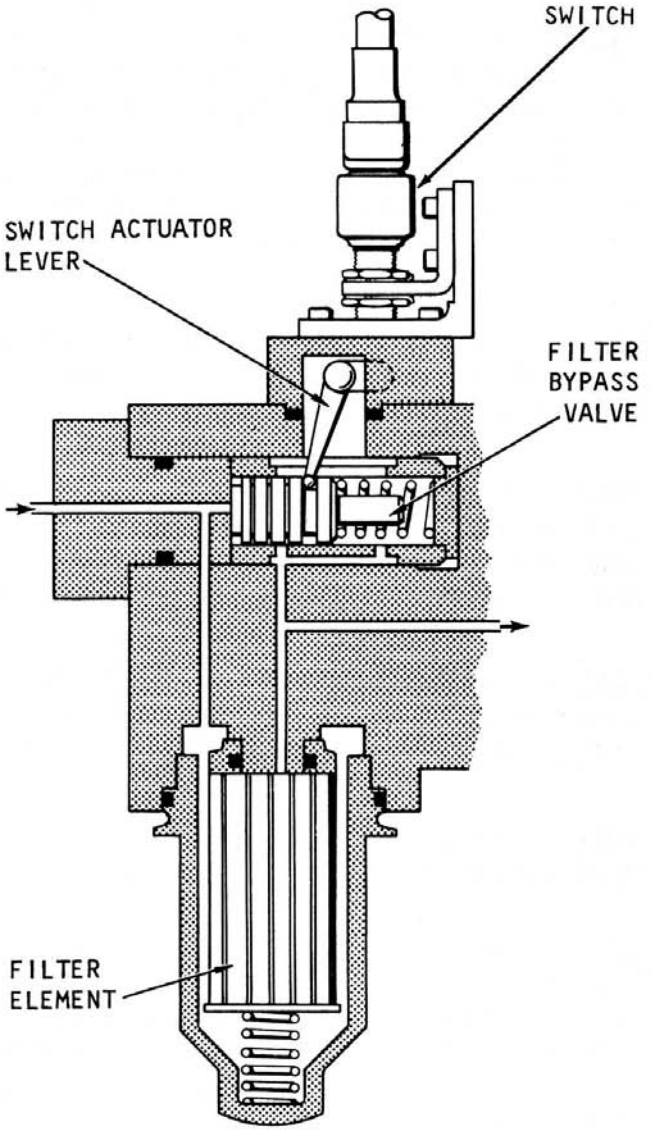


Figure 8-5. — Filter.

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ORIFICE. - An opening of relatively small size in a fluid passageway that controls or limits the rate of flow; a restriction. See figure 8-9D.

OXIDATION. - Chemical change in hydraulic fluid caused by oxygen which combines with the fluid during high temperature operation.

PACKING. - Hydraulic seal to prevent leakage around a moving part) such as a piston rod.

PASCAL'S LAW. - This law states that pressure applied anywhere to a body of confined fluid is transmitted undiminished to every portion of the surface of the containing vessel. This transmission of pressure through a fluid is the principle on which all hydraulic operation is based.

PASSAGE. - A machined hole or channel which lies in or passes through a hydraulic component and acts as a conductor of hydraulic fluid.

PICKLING. - A method of removing scale from the inner surfaces of piping and tubing. It is described in Fluid Power, NavPers 16193-B.

PISTON, CYLINDER OR BUFFER. - The moving part of a hydraulic cylinder or buffer. See figures 8-2 and 8-3.

PISTON, PUMP OR MOTOR. - The mechanical component of a pump or motor. The piston works in a cylinder and either moves the hydraulic fluid or is moved by it. Refer to figure 8-3.

PORT. - Opening in a surface of a component, usually where hydraulic fluid enters or leaves the mechanism" such as a valve, piston, or pump.

POUR POINT. - Lowest temperature at which a liquid will pour or flow.

PSI. - Pounds per square inch (pressure).

PUMP. - A device which converts mechanical energy to hydraulic energy. Following are short definitions of several kinds of pumps used in hydraulic systems.

Constant Delivery Pump. - A pump that delivers a fixed volume of fluid in a given time.

Axial Piston Or Parallel Piston Pump. - A pump in which the pistons rotate on a shaft in such a way that the pistons are driven back and forth in their cylinders in a direction parallel to the shaft. See figure 7-15.

Gear Pump. - A constant delivery pump with two or more intermeshing gears acting as the pump rotor (fig. 8-6).

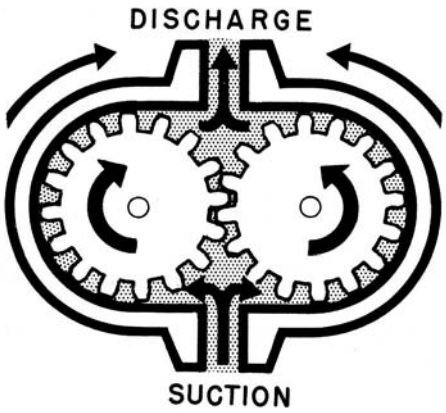
Positive Displacement Pump. - A pump that discharges the fluid in volumes separated by a period of no discharge. A definite volume of liquid is delivered for each cycle. Pump types such as axial piston, gear, and vane may be considered to be several separate positive displacement pumps combined in one unit to smooth surges caused by periods of no discharge.

Rotary Pump. - A pump with rotor which carries the fluid from intake to discharge on a curved path. Vane and gear pumps (fig. 8-6) are classified as rotary pumps.

Variable Delivery Pump. - A pump that delivers a variable volume of fluid without changing the speed of rotation of the source of power..

REPLENISHING FLUID. - (Also called Supercharge Fluid.) Fluid that is used to replace any volume loss in power drive transmission lines (lines between A-end and B-end).

RESTRICTION. - (Also called Choke or Orifice.) A device which produces a deliberate pressure drop in a line or passage by means of a reduced cross-sectional area (fig. 8-9D).



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Figure 8-6. — Gear pump.

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SEAL. - A part or assembly of parts used to prevent leakage of hydraulic fluid. Compare with Gasket and Packing.

SERVO FLUID. - Control pressure fluid in the hydraulic portion of the servosystem.

SLUDGE. - Gummy deposit caused by hydraulic fluid breakdown, mainly due to oxidation.

STRAINER. - A device for removal of dirt, sludge, and lint from fluid wherein the resistance to motion of such solids is in a straight line, as when pouring fluid into the system. A strainer is sometimes called a screen (fig. 8-7). It may be simply a funnel with a 200-mesh wire screen fitted in it.

STROKE PISTON. - Normally, a hydraulically controlled piston that controls the output of an axial piston variable delivery pump (fig. 7-15).

SURGE. - A transient rise of hydraulic pressure in a hydraulic system.

TANK. - Container for the hydraulic fluid in the system. Several types are described below and illustrated in figure 8-8.

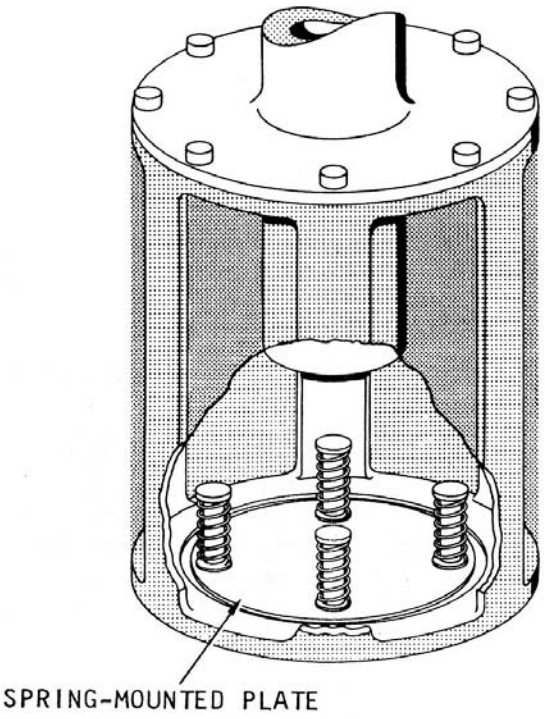


Figure 8-7. — Pump intake strainer (screen).

Expansion Tank (Header Tank). - This tank, located above the hydraulic system, provides space to allow for expansion and contraction of the hydraulic fluid in the system due to temperature changes. It also maintains a head of fluid to prevent entry of air into the system.

Reservoir. - (Also called Supply Tank.) The power drive tank used to maintain a supply of working fluid which may be drawn from as needed.

Sump Tank. - A tank usually enclosed within a power drive reservoir or supply tank to ensure available space for drainage from the receiver regulator.

TILT PLATE (OR TILT BOX). - The plate which is suspended by two trunnions and is moved by the stroke piston(s) to control the output of a variable delivery radial piston pump (fig. 7-14).

TRANSMISSION FLUID. - Hydraulic fluid located in the lines between the A-end and the B-end.

TUBING. - Copper, brass, or steel hydraulic lines. It is common practice to call small hydraulic lines tubing and large lines piping. However, there is no official distinction made.

VALVE. - A device for controlling flow rate, flow direction, or flow pressure. Some types of valves commonly used in hydraulic systems are described below. Numerous variations are designed for specific applications.

Valve Block. - Several closely associated valves can be organized into a valve block so they can be more readily controlled, and coordinated. Many combinations are possible.

Bypass Valve. - A valve used to let a volume of fluid bypass a hydraulic component (fig. 8-5).

Check Valve. - A device which permits hydraulic fluid to flow in one direction only (fig. 8-9A).

Directional Control Valve. - A valve which directs the flow or passage of fluid in a hydraulic system (fig. 8-9B).

Dump Valve. - A valve which, when actuated, dumps hydraulic fluid trapped in an accumulator system. It is normally manually operated. (See fig. 8-9C). The fluid is returned to the supply tank.

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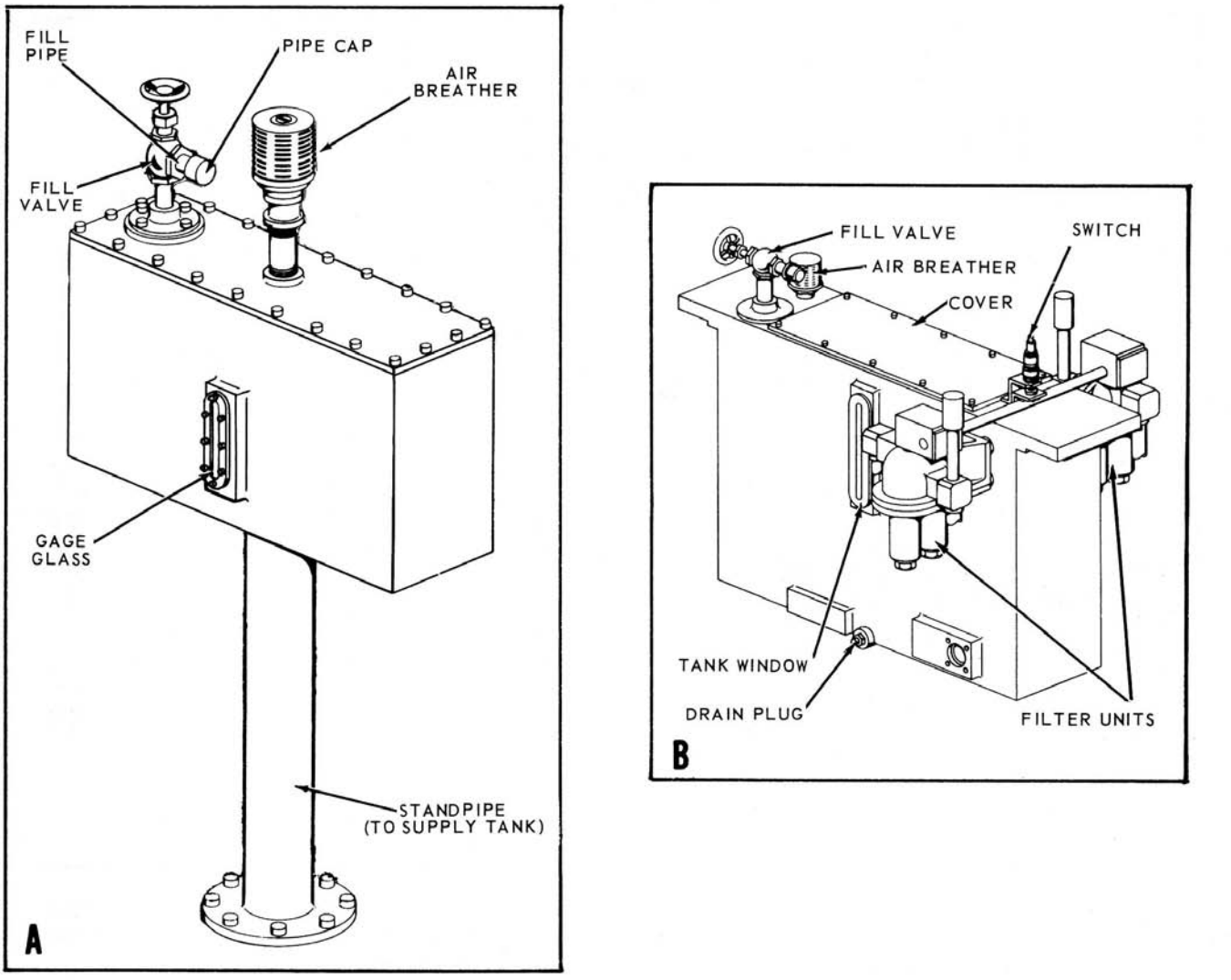


Figure 8-8. — Types of hydraulic fluid tanks in missile systems: A. Expansion (header) tank; B. Reservoir (supply tank). 83.178

Flow Control Valve. - This valve maintains a preset rate of flow regardless of pressure variations at the inlet or outlet (fig. 8-9D).

Gate Valve. - A manually operated valve that controls the flow of fluid by means of wedge (gate) which can be moved up or down across the line of flow. It is usually operated by a hand- wheel.

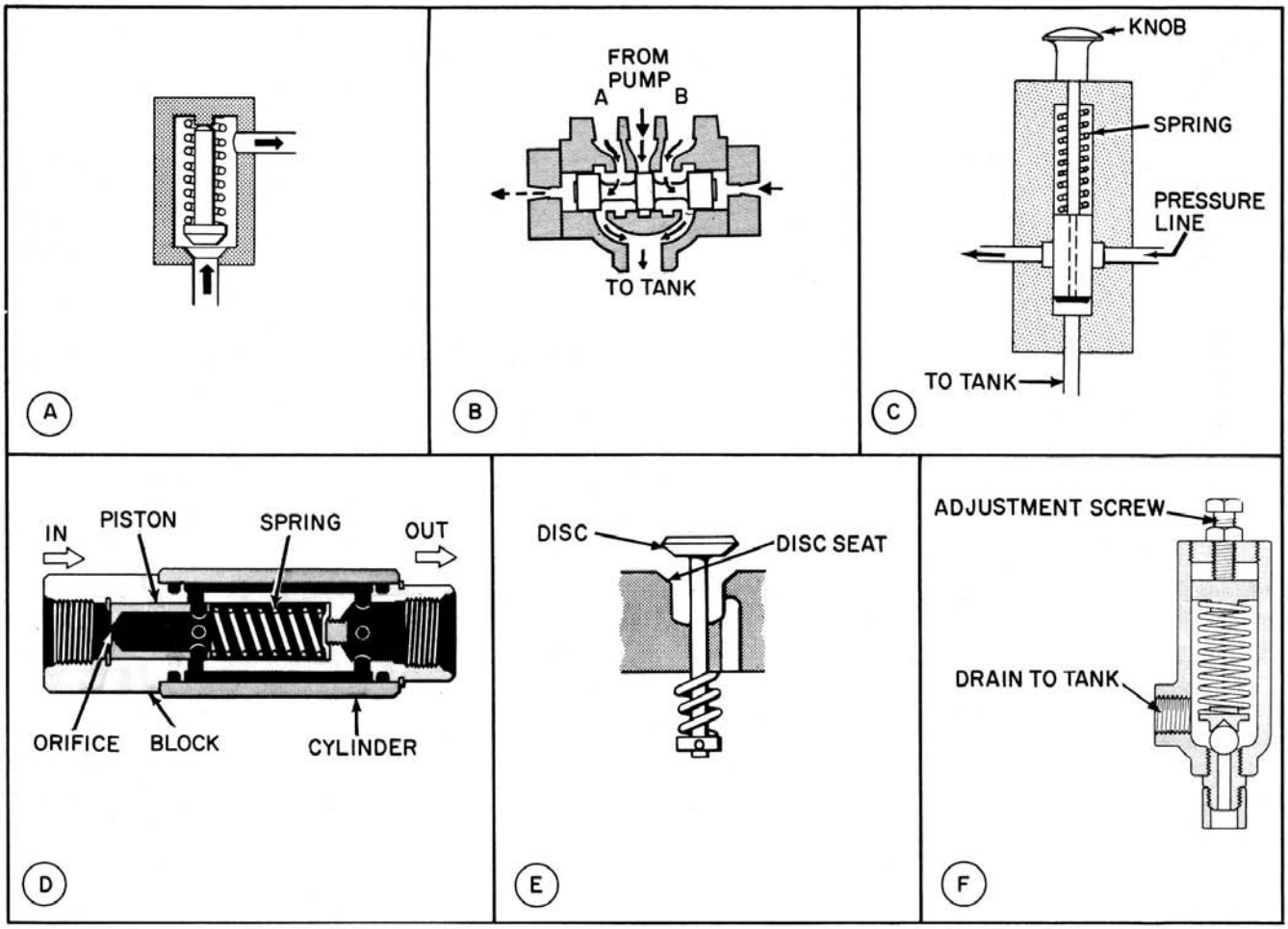
Globe Valve.-A manually operated valve that controls the flow of fluid by means of a plug, ball, or disk, which may be raised from or lowered into the valve seat.

Pilot Valve. - A valve that controls the action of another valve.

Poppet Valve. - A valve in the hydraulic end of a bag accumulator (fig. 8-1). It prevents the synthetic bag (containing the pressurized gas) from extending into the hydraulic manifold when there is no (or very little) hydraulic fluid in the accumulator flask. See fig. 8-9E.

Relief Valve.-A valve which limits the maximum pressure applied to the portion of a hydraulic system to which it is connected. If the

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Figure 8-9. — Some common types of valves: A. Check valve; B. Directional control valve; C. Dump valve; D. Flow control valve; E. Poppet valve; F. Simple relief valve.

pressure exceeds this limit, the valve opens and releases some of the hydraulic fluid. Figure 8-9F shows a simple relief valve.

Servo Valve. - Also called Pilot Valve or Control Valve. This valve is in the hydraulic portion of a servosystem that is normally controlled by an electrical error signal and that originates the hydraulic control signal.

Unloading Valve. - A valve used in accumulator power drives. It directs pump output to the accumulator or tank, in accordance with system demand. Fluid in excess of pressure requirements is returned to the tank.

VELOCITY. - Rate or speed at which fluid is moving at a given point in a hydraulic system.

VENT (Verb). - To remove air from a hydraulic system.

VENT (Noun). - A threaded plug or needle valve used to remove air from a hydraulic system.

VISCOSITY.-Measure of a hydraulic fluid's resistance to flow. Temperature affects the viscosity of hydraulic fluids.

VISCOSITY INDEX (V.I.). - Rate at which the viscosity of a fluid changes with the temperature.

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VOLUME. - Quantity of hydraulic fluid.

VOLUME OF FLOW. - The quantity of fluid, usually measured in gallons per minute (GPM) that passes a given point in the hydraulic system in a given time.

LAUNCHER POWER DRIVES

Chapter 7 discussed the launcher power drives from the standpoint of electrical and electronic action required. The hydraulic components were given only incidental mention, with the exception of the operation of the A-end and B-end. This chapter will emphasize the work of the hydraulic parts of the power drives.

MAIN COMPONENTS OF POWER DRIVE SERVOLOOP

As described and illustrated in chapter 7, you know that there are two separate systems for moving the launcher; one power drive system moves the launcher in train, another system moves it in elevation (or depression). Each one has a prime mover (which is an electric motor) an A-end hydraulic pump, a B-end, mechanical shafting and gearing, and means of transmitting signals received. The operation of the A-end and the B-end was described in the preceding chapter and in Fluid Power, NavPers 16193-B, so there is no need to repeat it here.

Electric Motor

The electric motor not only drives the A-end but also the replenishing pump, the control pressure pump, and the sump pump and oscillator. Since the speed of the A-end is much less than that of the electric motor, it is necessary to use reduction gears between them. (Basic Machines, NavPers 10624-A, explains how reduction gears work.) Reduction gears are also used between the electric motor and the pumps it operates.

A-end and B-end Response Linkage

The response is the quantitative output resulting from the input. If the response is linear, the output is the same quantity as the input.

The transmission lines between the A-end and the B-end are the hydraulic lines that carry the hydraulic fluid, and the valves and gears that control the quantity of flow. Pipes, tubing, and passages (defined at the beginning of the chapter) form part of the transmission lines.

Components of Components

Each of the main components of a hydraulic system is made up of many parts, similar in many respects in different systems. A supply of hydraulic fluid is required; the tank containing it may be called a reservoir or a supply tank. See figure 8-8B. As the system operates, the fluid becomes heated and expands. An expansion tank receives overflow of fluid so that pressure does not build up in the lines. See figure 8-8A. Leakage can drain into a sump tank. Filters are located at several points. Filters have to be cleaned when they become clogged; follow the instructions in the applicable OP when you need to do this. Some filters have a replaceable filter unit that is discarded when it becomes clogged. If it is not possible to take care of the filter at the time, the filter assembly valve block will bypass fluid around the filter element to the system to prevent starving the system of fluid. When this occurs a filter bypass switch actuated by the bypass valve will close, to complete a circuit to a filter clogged indicator light on the control panel. The trouble should be remedied as soon as possible, for unfiltered fluid can cause further trouble such as scored valves which, then must be removed and repaired or replaced.

The definitions at the beginning of the chapter listed and illustrated several kinds of valves and briefly gave the function of each type. This is far from a complete list; many more are described in Fluid Power, NavPers 16193-B. Some of them operate automatically, as when pressure reaches a certain point; others are operated manually. The operating power maybe hydraulic, pneumatic, or electrical which may use mechanical devices to actuate the valve. A spring- actuated valve is an example of use of a mechanical device to open or close a valve. The successful operation of any hydraulic system is dependent on its valves. You need to learn the location and use of each valve in the system on which you work. Whenever a hydraulic system is not operating properly, one of the first things to do is to check the valves involved. You need to learn how to dismantle, clean, and reassemble valves. Some general instruction on the installation and maintenance of valves may be found in Fluid Power, NavPers 16193-B, but you need the appropriate OP for your equipment for directly applicable instructions.

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When reading chapter 5 you may have noticed how many of the launching system components are operated hydraulically- magazine rail latch, positioner, hoist, speed reducer, retractable rail, power-off brake, and many more. To be operated hydraulically, each part must be connected to pipes or lines that carry the hydraulic fluid. That means there are a great many connecting lines behind the scene. You can see why you need to know types and uses of pipes, fittings, seals, and gaskets. Replacement of gaskets and seals or sections of pipe are frequent assignments for the GMM.

Gear Pumps

The dual gear pump (fig. 8-10) is operated by the electric motor. It draws hydraulic fluid from the supply tank and supplies both servo and supercharge pressure fluids. A dual gear pump actually consists of two gear pumps in one housing. The gears differ in width, which allows for difference in fluid volume, although both are driven at the same speed. It is also called an auxiliary gear pump, and it ports the hydraulic fluid to the control mechanism.

Control Mechanism

The control mechanism is not actually a part of the power drive itself but is directly related to its operation. It governs the operation of the CAB unit. It uses the pressure fluid ported to it by the gear pump. The servo pressure is used to shift valves, release the power-off brake, and position the stroking pistons. The supercharge pressure is used to replenish fluid lost through slippage and leakage and to supply the main relief valve. The control mechanism is mechanically linked to the A-end and the B-end and continually receives indications of tilt angle and B-end motion. When the control assembly receives a signal (from the computer) ordering the driven equipment to a new position, it establishes the difference between the existing position of the equipment and the ordered position.

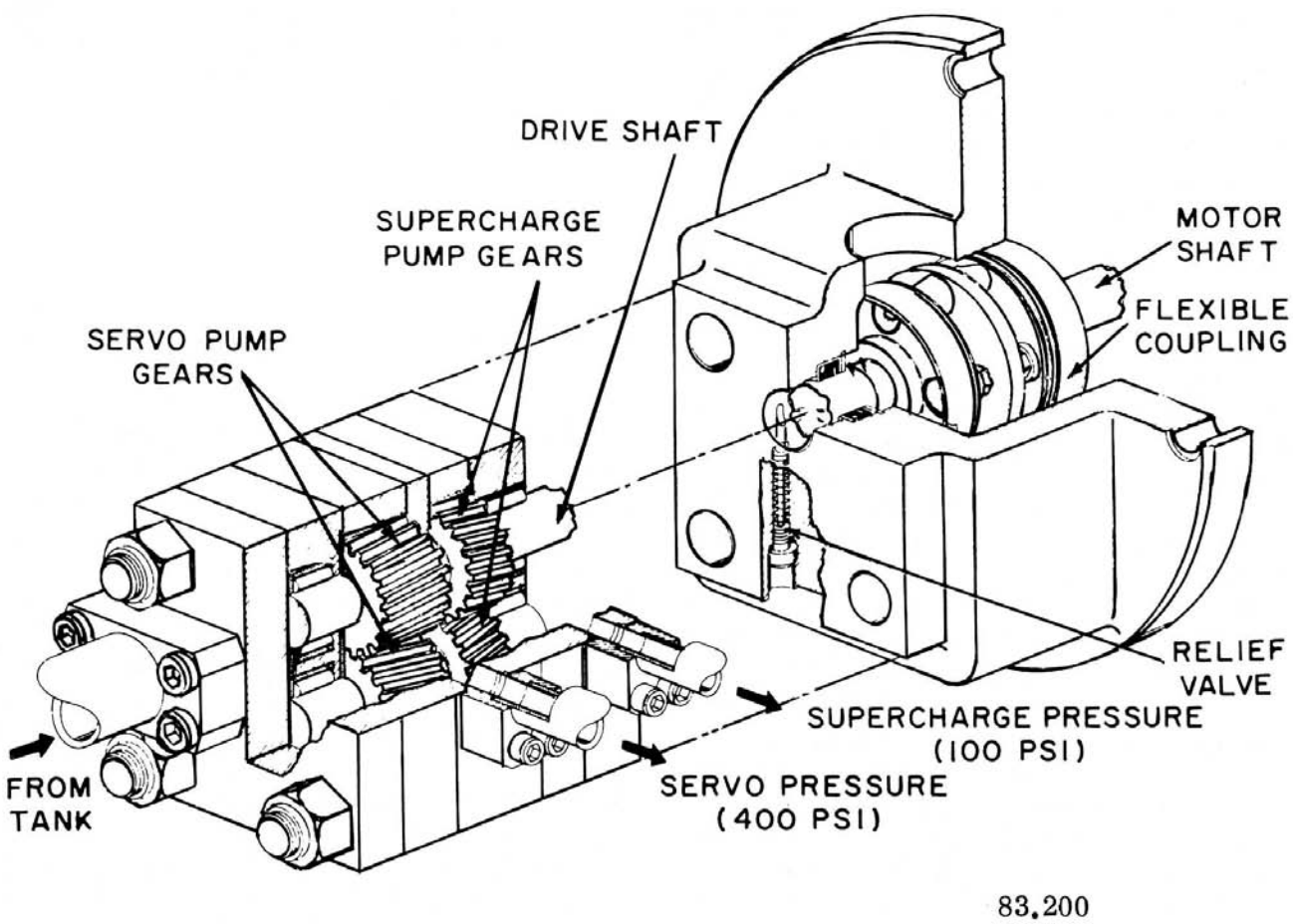


Figure 8-10. — Dual gear pump on typical CAB power drive.

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This error is then translated into valve movement. Regulated pressure fluid is ported to the stroking pistons. This moves the A-end tilt plate to the desired angle. The A-end then supplies pressure fluid to the B-end, which drives the equipment to the ordered position.

Control assemblies are generally mounted on top of the power drive, but may be mounted on the side.

Main Relief Valve

This valve is connected to the two lines between the A-end and the B-end (fig. 7-15). It is a compound valve designed to prevent excessive pressure in the high pressure line or A-end discharge line. When the pressure in one line exceeds the preset limit, the valve ports the excess to the other, or low pressure, line.

Power-Off Brake

The power-off brake, an associated component of the CAB unit, secures driven equipment against pitch and roll of the ship when the system is inactive, holds and secures the equipment in event of a power failure, and provides a manual means of operation (handcrank or air motor) for emergency operation, or installation and maintenance procedures. The brake usually is located adjacent to the B-end, fig. 8-11, and mounted to a geared speed reducer coupled to the B-end drive shaft. The brake shaft is driven by the speed reducer' shaft before the gear train increases the torque.

Figure 8-12 shows a cut-away of a typical power-off brake. Principal components of the brake assembly are the brake shaft, friction disc, disc housing, the worm and worm wheel, the worm shaft and clutch assembly, brake release piston, and the brake housing.

One end of the brake shaft is geared to the B-end output shaft. The other end, as shown in fig. 8-12, is splined to the inner discs. These inner friction discs alternate with the outer friction disc, and the outer disc are splined to the disc housing.

Since the disc housing is fastened to the worm wheel and can only be turned through handcrank operation, the outer friction disc are classed as stationary (whereas the inner friction discs rotate with the brake shaft).

Braking occurs when the spring-loaded pressure plate presses the rotating discs into contact with the stationary discs. Since the brake shaft has a positive gear-drive relationship with the B-end output shaft, this action also holds associated driven equipment.

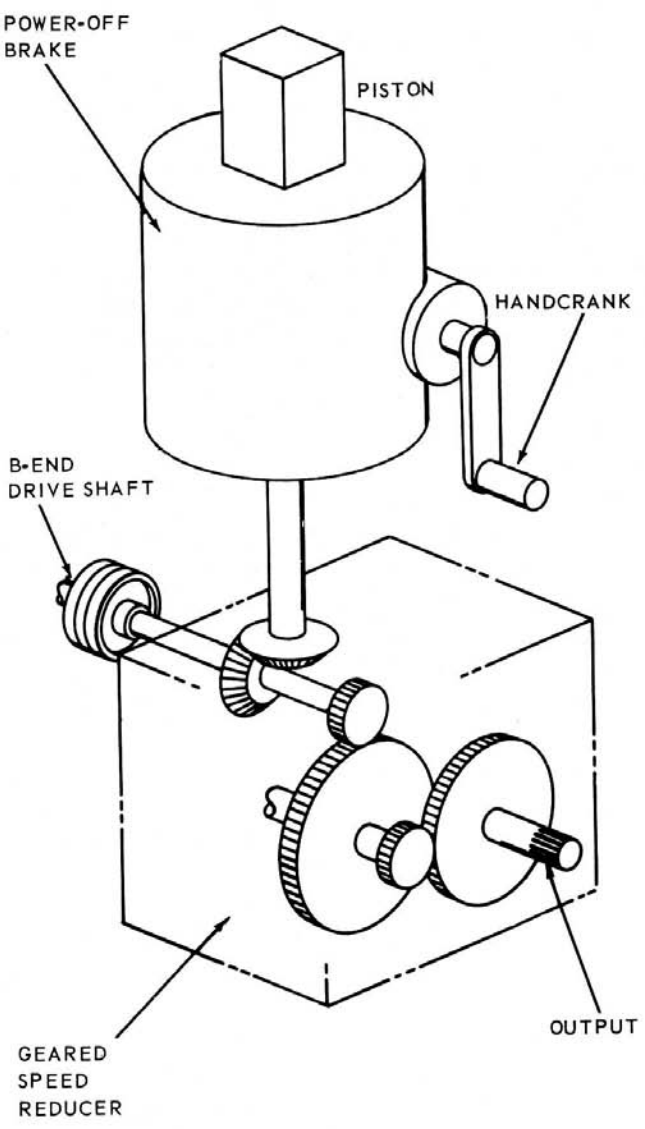


Figure 8-11. — Power-off brake location.

During normal CAB unit operation (B-end rotating), hydraulic pressure is ported to the power-off brake and acts on a brake-release piston which is attached to the pressure plate through a connecting rod. The subsequent force exerted by the piston compresses the pressure springs. This action releases the friction discs to permit free rotation of the brake shaft.

When the CAB unit is shut down, the resultant pressure drop to the release piston allows the spring-loaded pressure plate to force the friction disc into braking engagement.

Whenever the brake is set, the worm wheel is connected (through disc contact) to the brake shaft. Consequently, the brake shaft can be turned only by handcrank rotation of the worm.

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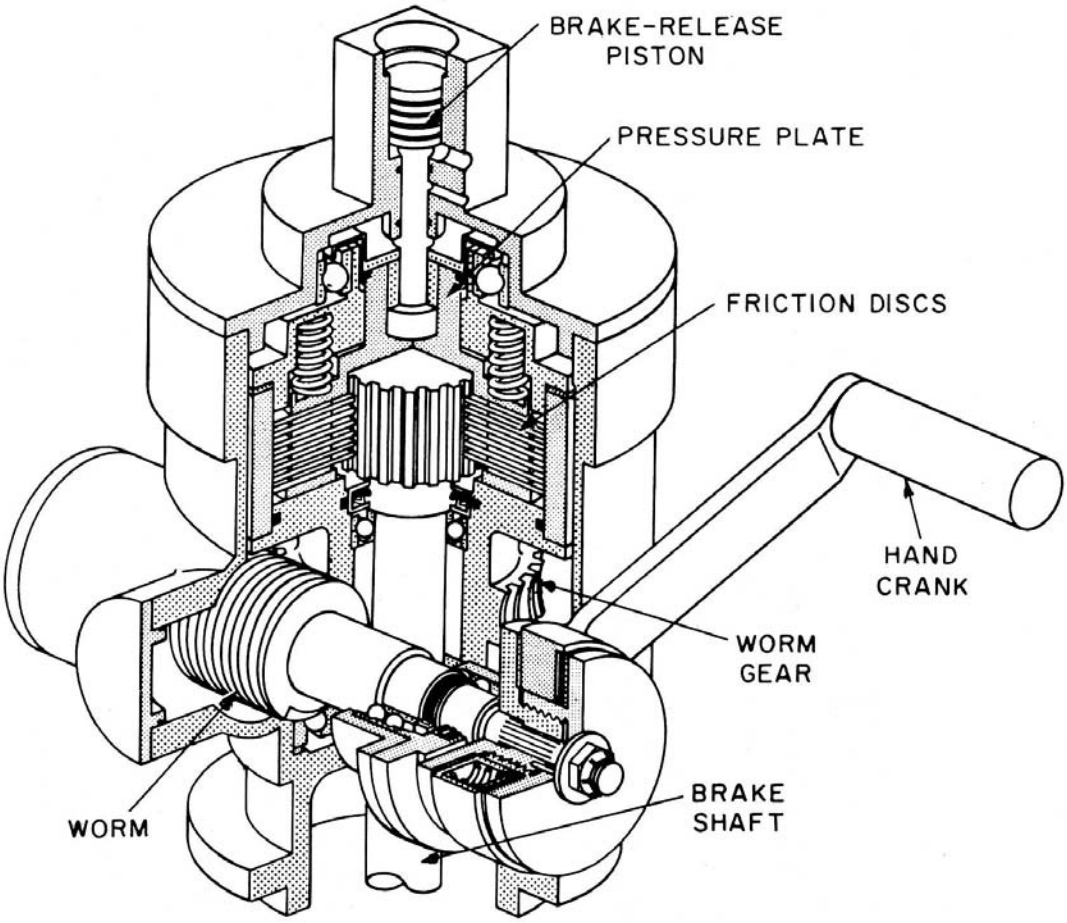


Figure 8-12. — Power-off brake (typical).

The worm is the mechanical counterpart of the hydraulic check valve. Both transfer motion in one direction but not in the reverse direction. The worm self-locks in one direction of motion because of the low helix angle of the worm thread.

Most power-off brakes are designed with a manual drive input to which a handcrank or air motor may be attached for emergency operation, or for installation and maintenance procedures. The train and elevation system have separate power-off brakes. The brakes differ somewhat in different applications. The number of friction discs varies with different mods but they function in the same manner.

LAUNCHER RECEIVER-REGULATORS, TRAIN AND ELEVATION

A receiver-regulator is a component of a gun mount or launcher power drive that receives order signals from a remote or local station, compares these signals with the train and elevation positions of the launcher (or gun), and generates error signals to control the movements of the power drives to correct the launcher position. Most of the receiver regulators used with launchers are similar in design and operation.

In normal operation, remote orders are supplied by the assigned fire control system. The principal function of the receiver-regulator and the servo amplifier is to convert electrical order signals into hydraulically powered movements. These movements control the velocity, acceleration, deceleration, and position of the launcher carriage and guide arms. The B-end output of the train system .drives the launcher carriage, while the B-end output of the elevation system drives the launcher guide. When the launcher is synchronized to the director orders, the missile is ready to be fired.

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The launcher receiver-regulators (train and elevation) are part of the basic power drive servoloops, each of which also includes a hydraulic pump (A-end), hydraulic motor (B-end), and the A-end and B-end response linkage.

The receiver-regulator is mounted on a stand, directly over the A- and B-ends (CAB unit). In outward appearance, the receiver-regulator is a metal box with connections to other units, and a dial (fig. 8-13). The inside is packed with

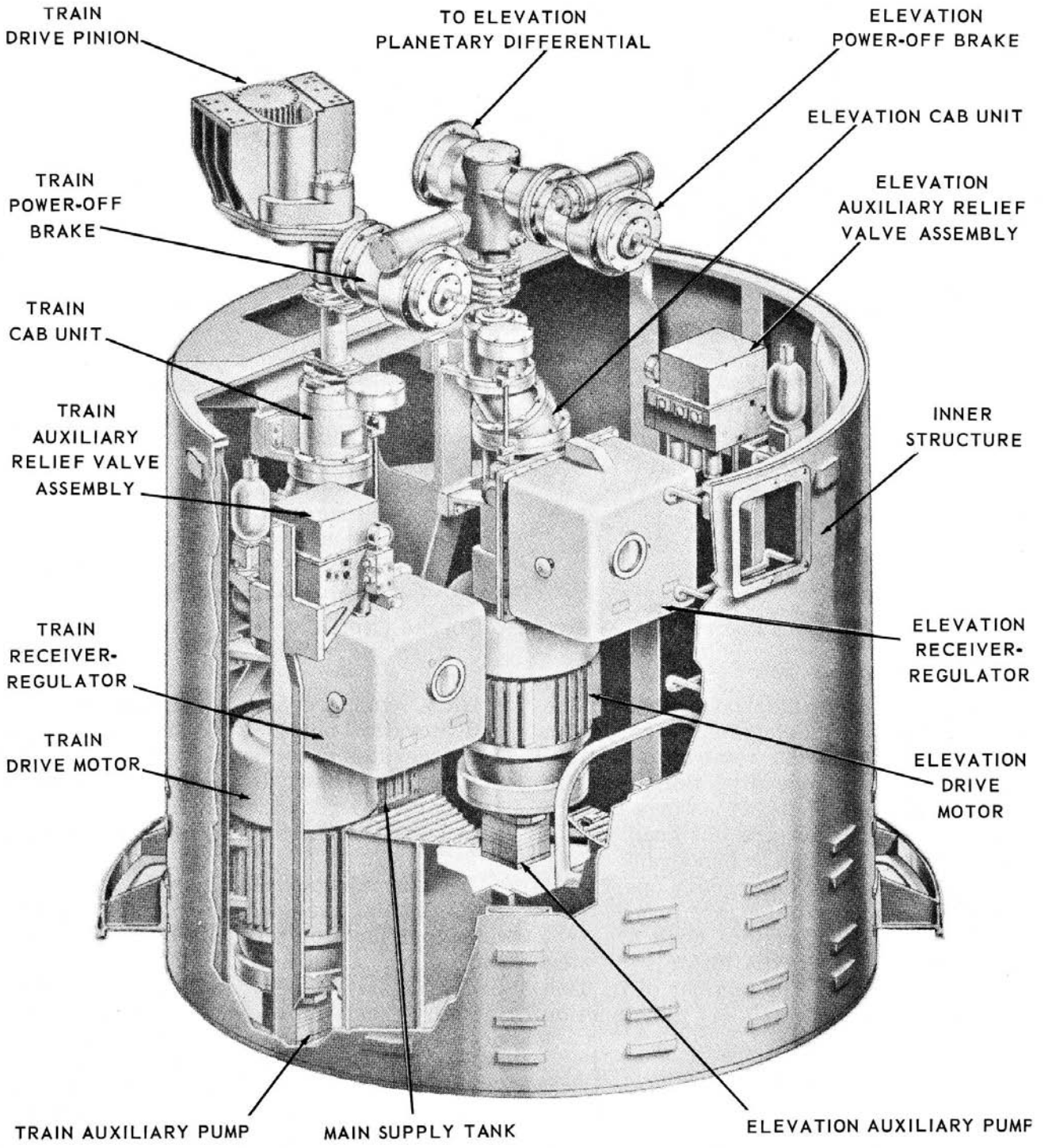


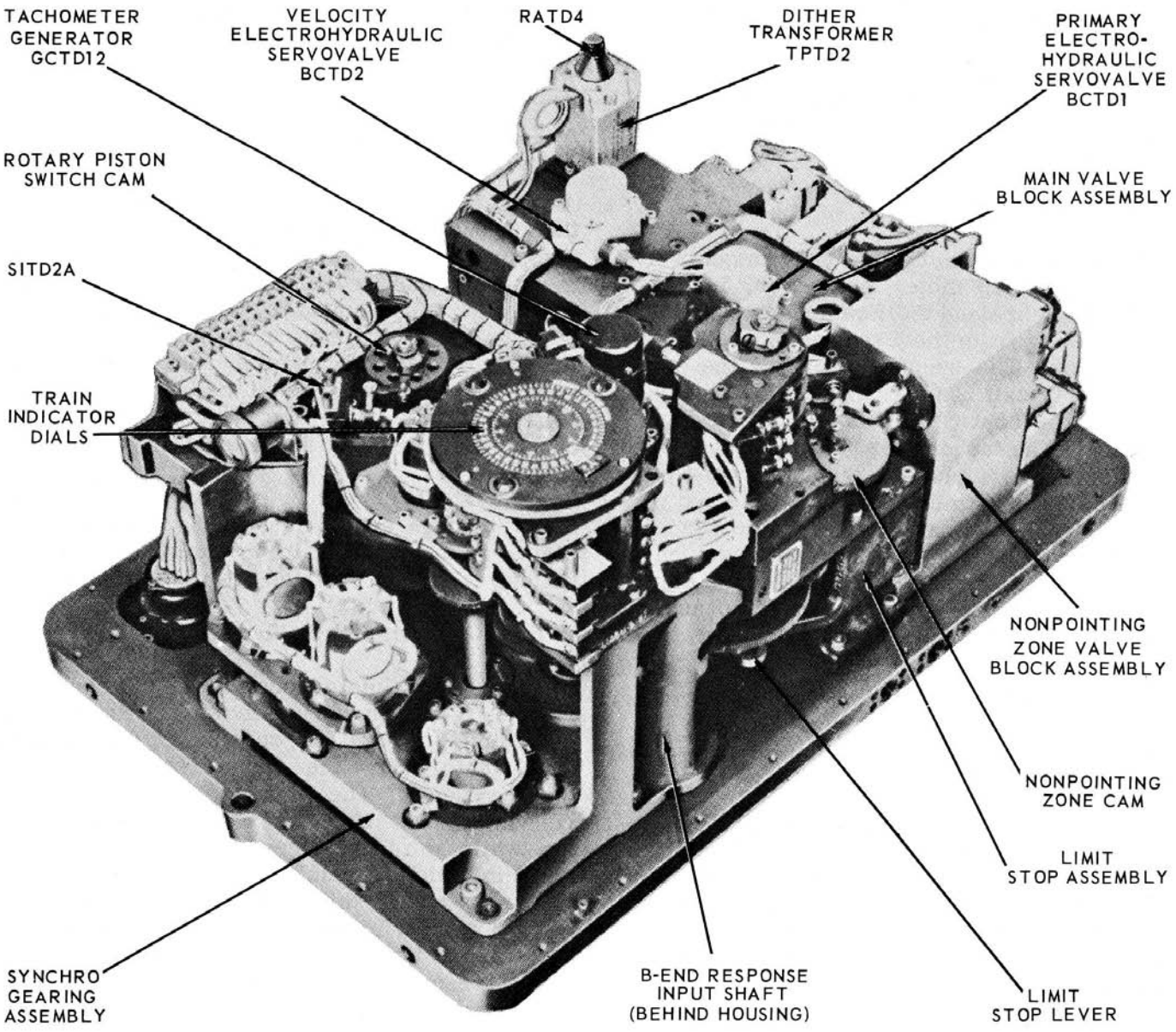
Figure 8-13. — Train and elevation power drives, Mk 13 Mod 0 launching system (Tartar).

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an assortment of complex equipments. In figure 8-14, locate the parts described in the next few paragraphs. These components are connected to components outside the receiver-regulator to perform their functions. The operation is intricate and we will give only briefly the work of the main components.

Main Valve Block

The main valve block of the receiver regulator contains the components (valves, pistons, switches) that are used by the primary, velocity, integration, and stroke servosystems. Only a few of the parts (there are about twenty valves, etc.) are visible in figure 8-14. The dither transformer (TPTD2) is mounted on top of the valve block along with its adjustment, the dither potentiometer (RATD4), which controls the amplitude of the dither input. The stroke control and integration actuating levers, not seen in figure 8-14, are mounted on the right-hand end of the valve block. The primary electrohydraulic servovalve (BCTD1) converts the amplified primary electrical error signal to a hydraulic signal.



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Figure 8-14. — Train receiver regulator, Mk 5 launcher, Mk 10 launching system (Terrier).

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The velocity electrohydraulic servovalve (BCTD2) converts the amplified electrical velocity and integration signal to a hydraulic signal.

Rotary Piston

The rotary piston is located below the rotary piston switch cam. It consists of a cylinder, piston vane, piston stop, piston cam, two response gears, and a switch cam with its associated switch. Two hydraulic fluid ports lead to the piston cylinder which is divided into two hydraulic chambers by the piston vane and piston stop. If the pressure is equal in both chambers, the piston vane remains stationary. If the pressure is unequal, the cam moves toward the lower side. This moves the rotor shaft which is connected to the rotors of the 1-speed and 36-speed control transmitter (CX). The indicator dials show what movement has taken place.

Synchro Gearing Assembly

The synchro assembly (fig. 8-14) mounts five synchros, the tachometer generator, indicator dials, the switches and their cams, a transformer, and the gearing from the B-end response and the stroke piston. The synchros receive the order signal (electrical) and transmit the launcher position to the control panels and the fire control system. The tachometer generator transmits a launcher speed (velocity) signal for test purposes. The transformer steps down the a-c voltage for dial illumination. The indicator dial indicates the launcher position and is driven by the B-end response. The switch cams are driven by the B-end response and are used to actuate the switches that indicate the launcher train position. Although train and elevation synchro assemblies appear identical, there are differences.

Limit-Stop System

The train limit-stop system includes the limit-stop assembly, the nonpointing zone valve block, and a part of the A-end response assembly. This system acts as a safety device to stop launcher movement whenever it is necessary for safe or proper operation. The elevation limit-stop assembly is similar to the train limit-stop assembly except that it has a gear and rack (instead of a nonpointing zone cam). The cams must be designed and cut for each ship so the missiles will not be pointed into any part of the ship's structure.

Non-Pointing Zone Valve Block

This is also known as the tracking cutout valve block. It contains nonpointing zone pistons and their associated valves and solenoids. The limit stop actuating shaft leads through the base of the valve block and connects to the servovalve linkage. Each piston is controlled by one of the nonpointing zone solenoid valves; the train valve block has two and the elevation valve block has three.

The nonpointing zone components prevent the launcher with loaded guide arms from training or elevating into any part of the ship's structure, stopping the train power drive if necessary and introducing an elevation order that elevates the launcher above the nonpointing zone.

A-End Response Assembly

Figure 8-14 does not show the lead-in for the A-end response assembly but does show components to which it transmits. The movement of the A-end tilt plate is transmitted to the limit stop assembly and the train limit stop valve. The A-end response also positions the sleeve of the stroke control servovalve and a switch cam. When it is not necessary to operate the limit-stop systems, transmission of launcher position and launcher velocity continue.

The shaft of the A-end response assembly leads through an opening in the regulator base plate, approximately in the center of the regulator, inboard of the limit-stop assembly.

B-End Response Assembly

The approximate location of the B-end response input shaft is shown in figure 8-14. It extends through an opening in the regulator base plate near the lower center section of the regulator. The lower gear of the B-end response input shaft drives the synchro gearing while the upper gear of this shaft drives the limit-stop assembly. When the B-end rotates, it drives the launcher, through a gear reduction unit, at the speed and in the direction determined by the error signal. A mechanical B-end response signal is fed back to the CTB stator in the receiver regulator. This response signal cancels the order signal when the order has been satisfied. The B-end response is often referred to as "position."

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OTHER POWER DRIVES IN LAUNCHING SYSTEMS

Not all the hydraulic systems in the launching system belong to the A-end- B-end type. Hydraulic power for operation of the launching system is not furnished by one big hydraulic system, but by several independent systems. Several of these systems are of the accumulator type. The main components of the accumulator type are: (1) electric motor; (2) gear pump; (3) control valve block; (4) accumulator; and (5) accumulator charging valve and pressure gage. See figure 8-15. Of course, it also has to have a supply tank for the hydraulic fluid. An important difference between the accumulator type and the CAB type described previously is in the use of accumulator flasks, such as the one shown in figure 8-1, to keep a supply

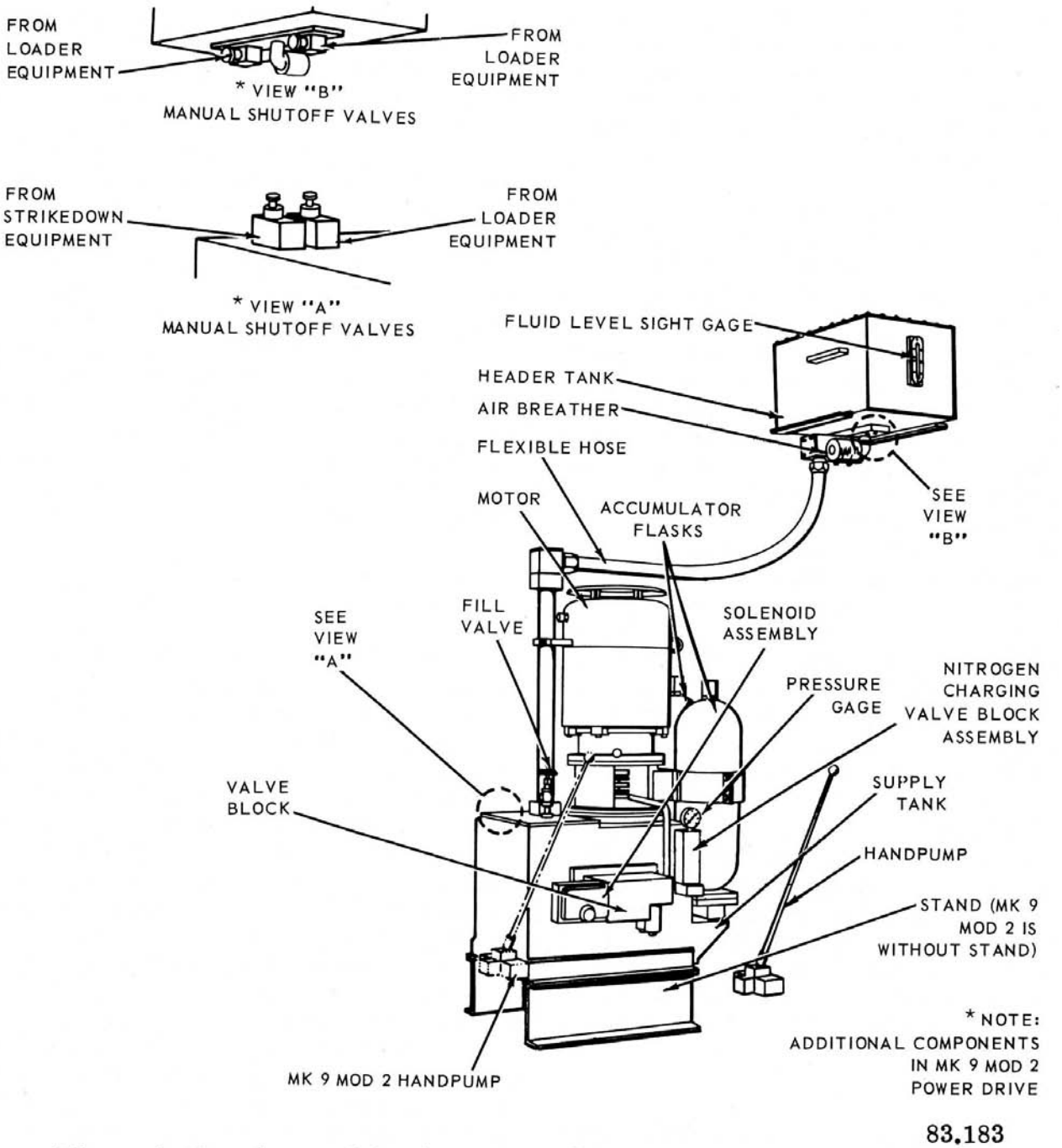


Figure 8-15. — Accumulator type power drive system for loader (Terrier).

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of hydraulic fluid ready for instant use at the desired pressure. Most systems have two or more such accumulator flasks. The accumulators are pressurized with nitrogen. The bladder inside the flask is charged with nitrogen through the nitrogen charging assembly (fig. 8-15). Nitrogen is used because it is not a fire hazard where oils are used.

On Terrier systems, the loader has two types of power drives, a CAB type which operates the loader chain, and an accumulator power drive, which is in the strikedown area and provides power for the spanning rail, blast doors, floating tracks, tilting rail, and other loader components. The magazine power drive is also of the accumulator type. It supplies the power to the ready service rings, tray shifts, hoist drive, load status recorder, magazine doors, and, in the Mk 10 Mod 7, to the lower ready-service ring under inter-ring transfer conditions.

The guide arm components on the Mk 5 launcher (used in the Mk 10 launching system) are operated by an accumulator type hydraulic system. Its electric motor is sometimes called "launcher rails motor" on electrical diagrams. Older mods of the accumulator had manually operated shutoff or dump valves, but Mk 5 Mod 3, and later launchers, have solenoid operated dump valves for the accumulators. Functionally, the different mods are the same and use the same major components.

A load status recorder was mentioned above. There is a load status recorder for each ready service ring in the magazine. It shows what type of missile is loaded in each space in the ready service ring. If a missile is moved from a tray, the change is shown on the recorder (also called an indicator). No personnel are stationed in the magazine so these indications on a recorder in the magazine are of no use is anyone. The information must be displayed where it will be of use; this is on the control panels. "Load status" indication is not shown as such on any panel except through the various circuits which may, in turn, indicate loaded, empty, or dud stations on the circular light patterns on the panels (EP2 and EP4, EP5). See figure 5-17. The load status recorder is operated hydraulically and mechanically but the information is sent to the panels through electrical relays.

POWER DRIVES FOR SMALLER LAUNCHING SYSTEMS

"One-armed" launchers such as the Mk 13 and the Mk 22 (Tartar) might be considered "smaller" launchers. They use hydraulic power for the same operations as the largest launching systems although they do not need as many systems nor such large ones. The power supply for the magazine of the Mk 13 system uses one A-end hydraulic pump to drive two B-end hydraulic motors. One B-end drives the ready service ring and the other drives the hoist chain, but not simultaneously. The train and elevation systems on the launcher each have an A-end and a B-end type power drive to train and elevate the launcher, but share one header tank, which is mounted in the stand. (The header tank for the magazine power supply is also mounted in the stand.) In the Mk 22 launching system, the train power drive system also drives the hoist and operates the associated latches and pawls. The train system and the hoist system have separate controls and separate gear reducers but one power drive system. During hoisting operations the training mechanism is latched, and vice versa.

The Mk 13 (Tartar) system has an additional power system to operate the launcher guide arm and the blast door. The header tank is a part of the guide arm; the main tank is a part of the base ring, and the other components are mounted to the underside of the base ring weldment. There is an electric motor which drives the rotary gear pump, the control valve block and three accumulator flasks, a solenoid valve assembly, and a plunger. The rotary gear pump is submerged in the main tank.

HYDRAULIC POWER IN STRIKEDOWN, MATE, AND LOADING OPERATIONS

The same power system is used for loading a missile on the launcher and for returning it to the ready service ring. Automatic unloading in just a matter of reversing the steps (Each installation has charts posted at the control panel, listing each step.) However, if the missile is to be struck down to any other area, such as testing and checkout areas, other power systems are involved. Periodic tests are required for all is just a matter of reversing the steps in the loading process. (Each installation has charts posted at the control panel, listing each step.) However, if the missile is to be struck down to any other area, such as testing and checkout areas, other power systems are involved. Periodic tests are required for all missiles and, for these, the missile must be unmated from the booster (except Tartar and Standard) (MR). This work is done in the strikedown and checkout area. This

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area has been identified in several illustrations.. See figures 5-1, 5-4, 5-8, and 5-11. The location with relation to the rest of the launching system varies with the weapon system and the ship, but it is as close as possible to the ready service rings. (The Tartar systems do not have such an area as the weapons are checked out on the launcher arm.)

As you can see in figure 5-4, a missile brought up from the magazine (ready service ring) can be sent to the strike down and checkout area instead of to the launcher. Step control must be used for this operation. The loader trunk sections extend into the strikedown area (fig. 5-11). Here the strikedown car receives the weapon. The hoists, cranes, checkout car, booster cart, and other equipment in the strikedown area are operated from ship's power source which can be either electric, pneumatic, or hydraulic.

The checkout mode is also used for removing missiles from the ship. Terrier and Talos rounds must be unmated and the missiles and boosters transferred separately.

When received by the ship, Terrier, Standard (ER) and Talos missiles and boosters are in separate containers, except when transferred by Fast system, in which case they are not containerized. They are moved to the strikedown and checkout area by a hydraulically operated elevator where they are handled with the aid of the checkout car and the booster cart.

Chapter 14 will tell you more about your work in this area. This will include missile replenishment, missile mating and unmating, and preparing missiles for tests.

PNEUMATIC POWER

Although hydraulic power is used for moving most of the parts of a missile launching system, from positioning heavy missile launchers to nudging tiny valves to open or close, there are some items that use pressurized air for power. Connections to the ship's pressurized air system are available in some of the spaces, especially where testing and checkout are to be done. Cylinders of compressed air may be used in some instances.

AIR OPERATED POWER UNIT

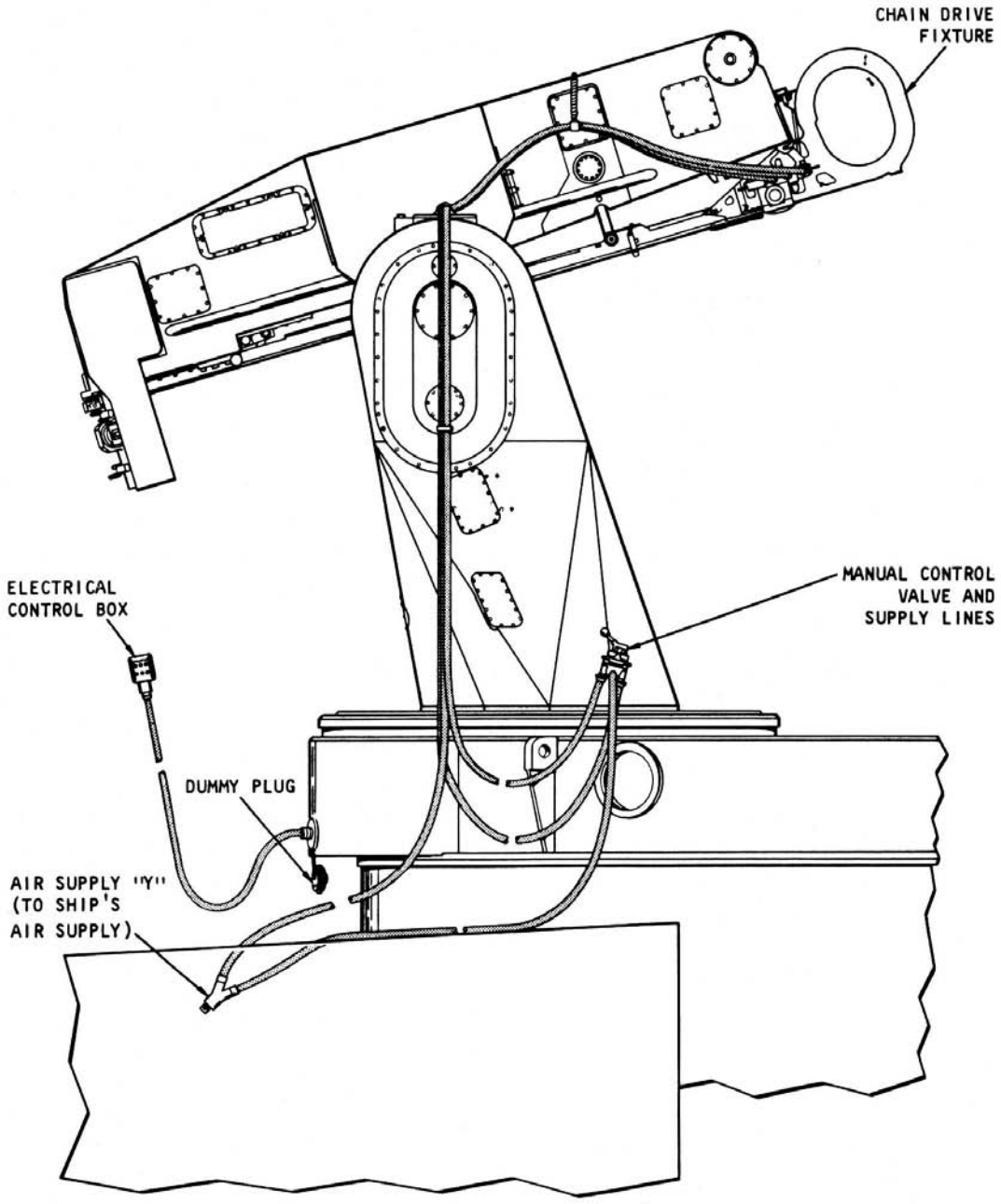
When Tartar missiles are struck down to the magazine for replenishment or are off-loaded, the launcher is used but auxiliary equipment is needed. The strikedown gear used (fig. 8-16) with the Tartar missile consists of an air-driven chain fixture, a manual control valve (portable), and an electrical control box. The electrical control box is a hand-held, portable apparatus that permits the launcher captain to be on deck in full view of the launcher while controlling the launcher by means of the pushbuttons and switches on the control box. It is used for positioning the launcher during strikedown, checkout, or E-section removal. Illustrations may be seen in the OP. The strikedown gear is removed and stowed when not in use.

The power for the unit is supplied by the ship's compressed air system. Flexible hoses are used to make the connection to the ship's supply.

The compressed air is not used directly in the same form in which it is stored but is converted to mechanical energy. The potential energy in the compressed air is changed to mechanical energy through an air motor, located adjacent to the chain drive, where it drives a gear train. An air motor, when coupled to an electric generator, may also be used to supply the electrical energy to drive a hydraulic system.. Figure 8-17 A is a sketch of a basic pneumatic system. The air is led from the compressed air flask or the ship's supply line, through a pressure reducer, then to the air motor or air turbine. On the Tartar strikedown unit shown in figure 8-16, the pressure regulator reduces the air pressure to 20 psi.

The air motor shown in figure 8-17B works on the principle of differential areas. (This is not the one used in the Tartar system.) The motor consists of a rotor with freely sliding vanes mounted in recesses around its outer edge. The rotor is eccentrically mounted in its housing as shown in the figure. When the rotor is in motion the vanes tend to slide outward due to centrifugal force. The distance they can. slide is limited by the eccentricity of the rotor housing. When the compressed air is ported into the inlet, its pressure is exerted equally in all directions. Since area "A" is greater than area "B", the rotor will turn counterclockwise. Each vane in turn assumes #1 and #2 positions and the rotor turns continuously. The potential energy in the compressed air is thus converted into kinetic energy. The air at reduced pressure is exhausted to the outside. The shaft of the motor is directly coupled through gearing to the unit it is to drive (in fig. 8-16, the chain drive unit).

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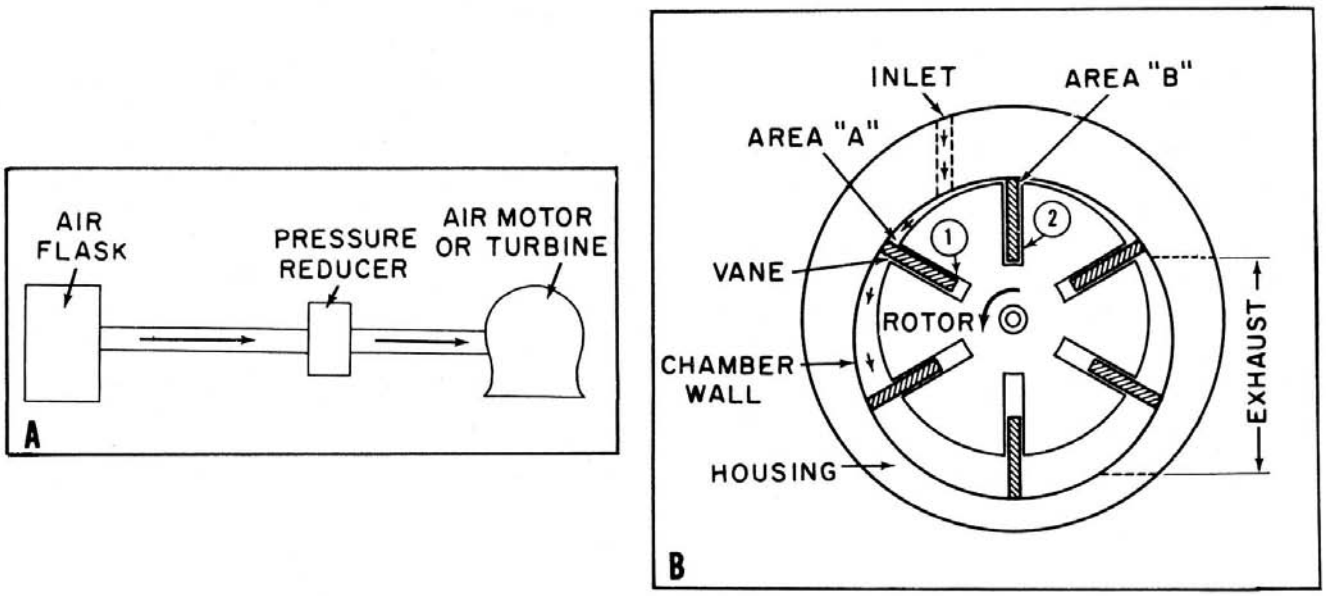
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Figure 8-16.—Strikedown gear attached to Tartar launcher (Mk 13 Mod 0 system).

DUD JETTISON DEVICES

There are several methods of disposing of dud missiles. Most often the missile is returned to the magazine to be checked out, tested later, and defective parts replaced. When it is necessary to rid the ship of a dud missile, the launcher is used with the dud jettisoning unit. The Talos system uses an emergency igniter injector on the launcher (fig. 5-23), but other systems have a jettisoning unit that pushes the missile overboard without firing it. The Terrier systems and the Tartar Mk 11 system use dud jettison units that are hydro-pneumatic systems powered by compressed air from the ship's high pressure air supply. The Mk 13 launching system (Tartar) uses compressed nitrogen from an accumulator. The installation arrangements vary

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Figure 8-17.—Pneumatic power: A. Basic pneumatic system; B. Air motor.

for the different Terrier mods but the operating principles are the same. The deck location of the dud ejector is shown in figure 6-5. and in several of the illustrations in chapter 5. The major portion of the dud ejector is below deck when not in use (not extended). The launcher holding the dud missile is trained and elevated to align with the dud ejector. The dud jettison unit is operated from the dud jettison control panel (fig. 6-5) when orders have been received to use it. The compressed air is used directly, without conversion to electrical energy; that is, it is a static system.

PNEUMATIC OPERATED HANDLING EQUIPMENT

The cranes and hoists used to handle missiles on deck and below deck are under the cognizance of Naval Ships Systems Command. Descriptions of these equipments may be found in NAVSHIPS publications. You will be using cranes and hoists in handling missiles during replenishment and in off-loading. Some of them are operated by the ship's compressed air supply. Guided missile handling equipment such as missile skids, handling dolly, transfer dolly, handling attachments, storage cradles, hoisting slings, and similar machines are described and illustrated in OP 2173, volumes 1 and 2, Handling Equipment for Ammunition and Explosives.

Apart from the cargo handling gear listed above, the strikedown car, booster cart, receiving stand, and transfer car are used for missile checkout. The installations vary on different ships. You are responsible for safe attachment of the missile or booster, and you operate the equipment, but other personnel are responsible for the maintenance and repair of the equipment. All Talos, Terrier and Standard (ER) missiles must be unmated (separating the booster from the missile) each time they are checked out, and mated again for return to the ready service ring. (Talos missiles and boosters are stowed separately except those that are in the ready service.) The electrically operated checkout car in the Mk 10 launching system is used to receive missiles and boosters from the strikedown elevator and to move these components to the loader rail. A movable platform on the car is used for missile and booster mating/unmating operations. Not all the handling equipment is power operated. The transfer car and some of the handling hoists for the Tartar missiles are operated by hand power. On a CV A you will have an elevator to move the missiles to the checkout room.

PNEUMATIC TEST SETS

Testing of missiles aboard ship is done at prescribed intervals, according to the appropriate OP for the equipment. Special test sets have been developed for each type missile. The Guided

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Missile Test Set (GMTS) programs the missile through a simulated flight sequence, comparing missile response to known standards. A missile systems test is made up of a number of individual tests. The test set is in the checkout room.. Chapter 14 has an illustration (fig. 14-23) of a missile with connections to the test set. There are electrical, hydraulic, electronic, and pneumatic connections to be made (which you do) ~ There is also a pneumatic test set that is used to test certain internal components of missiles. It uses high pressure air but controls it and reduces it to the pressure needed.

Example of the carrying out of the tests will be given in chapter 14. As a GMM 3 or 2, you will prepare the test setups, making the connections to the power source and to the proper component of the missile.

MAINTENANCE OF PNEUMATIC SYSTEMS

In general the same periodic inspection and precautions required for hydraulic systems are also valid for maintenance of pneumatic equipment. The micronic filter elements of a pneumatic system must also be inspected for cleanliness and replaced at regular intervals. Pneumatic units which become contaminated cannot be flushed as can hydraulic systems but must often be disassembled and cleaned as described in the appropriate maintenance publications.

Leaks in air or nitrogen systems can usually be found with the aid of a soap solution applied to the joints. The presence of a leak is revealed by the formation of bubbles. Tightening of connections or replacement of O-rings usually takes care of the leakage problems. A bit of dirt in a valve may require dismantling of the valve to clear it.

HYDRAULIC PNEUMATIC POWER USED INSIDE MISSILE

CONTROLLER DEVICES

In earlier chapters, statements were made about control surfaces moving a certain way upon signal, and about other movements in the missile. There has to be some power to cause these movements. Hydraulic power is used for many of them. It should be remembered that hydraulic fluid contains no energy in itself. It merely provides a means for transferring energy within a mechanism. Since, for all practical purposes, hydraulic fluid is incompressible, it can be used to transfer energy with negligible losses.

Since hydraulic fluid normally moves through a closed system, several methods have been devised for moving it. Axial piston and rotary hydraulic pumps, driven by turbines, are commonly used in guided missiles. The hydraulic pumps are of the same types as those used in the launching systems, though not of the same size. The principles of a simple hydraulic system are shown in figure 8-18. The reservoir or sump acts as a storage tank for the hydraulic fluid. A motor or other prime mover is connected directly to the hydraulic pump. The relief valve ports excessive pressure to the sump.

ENERGY CONVERSION

To cause the work piston to move up, we must position the directional valve as shown in the upper portion of the figure. This permits the oil to exert pressure against the bottom of the work piston, causing an upward movement. The oil on the top side of the work piston is returned to the sump as shown.

The lower portion of the figure shows how we can cause the work piston to move down. In this case, we must move the directional valve to the left so that the oil will be forced to take a path leading to the top of the work piston. This will cause the work piston to move down. The oil on its lower side will pass back to the sump.

In both cases the controlling factor was the position of the directional valve. In the operation described, the hydraulic fluid, which has no energy of its own, merely translated rotary motion of the motor to linear motion at the work piston. This is one form of energy conversion unit used in the auxiliary power supply (APS) of missiles to provide a source of power to the many devices required for successful flight of the missile. The APS is in addition to the main missile engine (propellant) required for thrust.

Early mods of the Terrier missile used compressed air cylinders as the source of power, but these limited the range and also gave a slow reaction due to the time it takes to compress the air in the actuator to a pressure sufficient to move it. Hydraulic power

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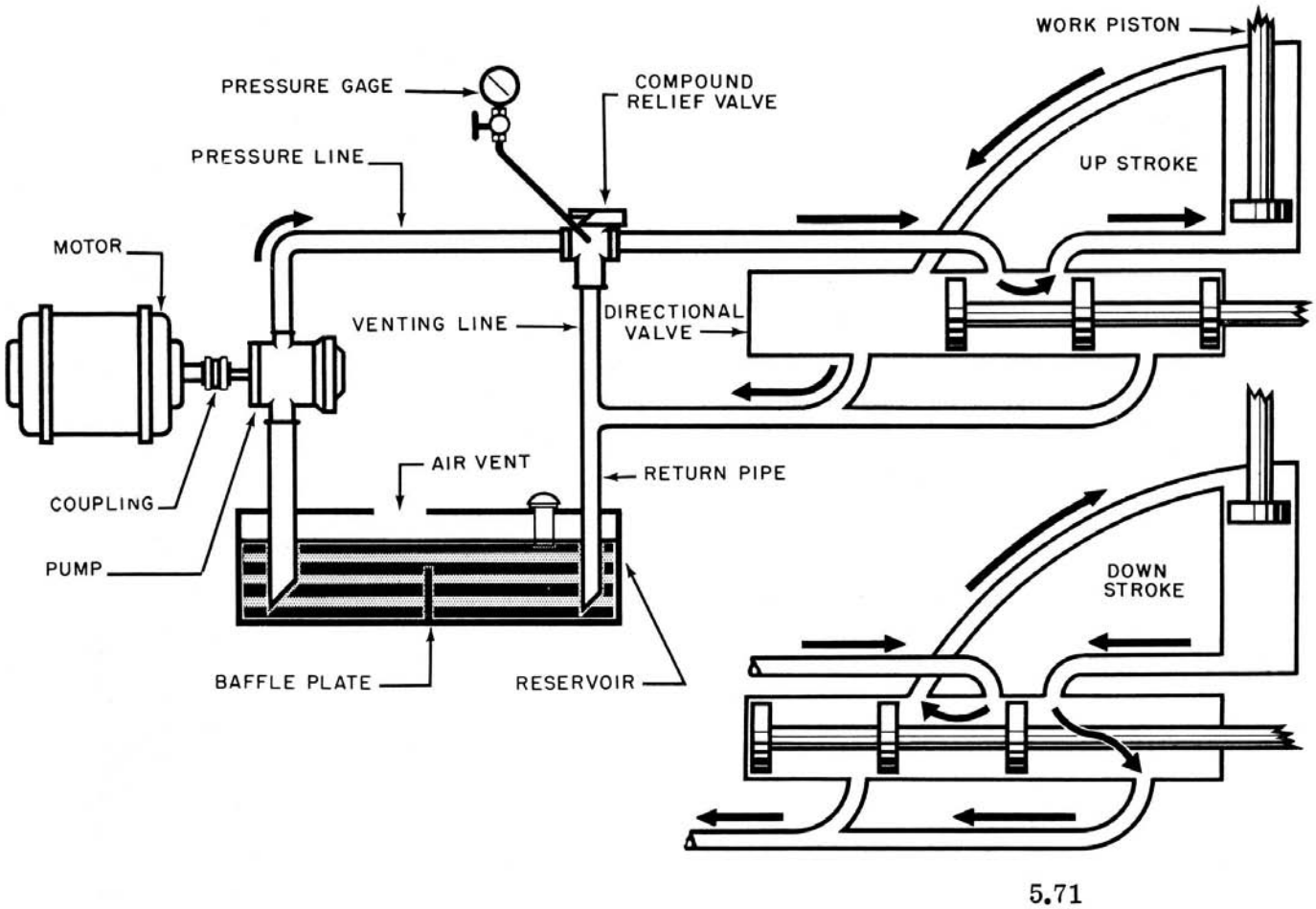


Figure 8-18. — Transfer of power in a simple hydraulic system.

will produce a faster reaction on an actuator. as hydraulic fluid transmits the power almost instantly.

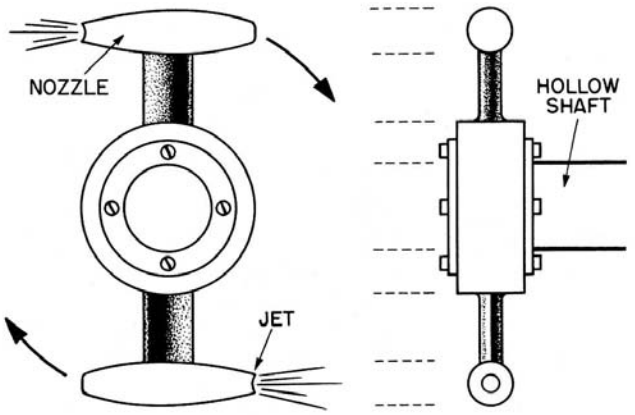
Turbines

Turbines may be driven by air or by hot gas. Both Terrier and Tartar missiles use auxiliary hot-gas systems. The Terrier and Tartar missiles have two hot-gas generators. each with its package of solid propellant. The hot gas exhaust from one is fed to the missile's turbohydraulic system and the other goes to the turboelectric system. They are placed in the aft section, near the tail, which is controlled by the hydraulic system. The Talos missile uses an air-driven hydraulic pump that makes use of air taken in through the diffuser section in the missile nose.

AIR TURBINES. - One type of air turbine is the pinwheel turbine shown in figure 8-19. This turbine is a mechanical jet similar in principle to a garden sprinkler. Compressed air is led into the pin wheel hub through the hollow shaft. It eventually passes through the diametrically opposed nozzles where its velocity is increased. The reaction to the exhaust causes a rotation of the pinwheel just as the reaction to the ejection of exhaust gases causes thrust in the main propulsion system. As with the air motor, the shaft of the air turbine is coupled to another device- usually an electric generator.

HOT GAS OR COMPRESSED AIR TURBINES. - Hot gas turbines are used in dynamic systems in which the energy source is solid or liquid fuel. These turbines may also be used to convert the potential energy in compressed air to kinetic energy. One type of turbine found in these systems is the Terry turbine, shown in figure 8-20B. The turbine wheel is a solid piece of steel having semicircular recesses (buckets) milled into its

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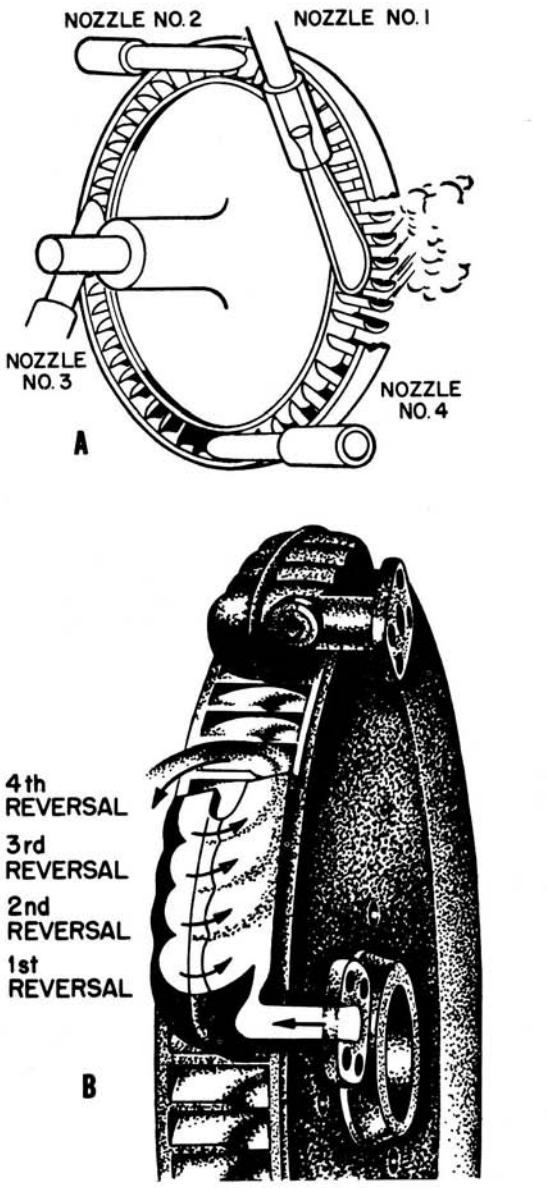


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Figure 8-19. — Air-operated pinwheel turbine.

periphery. Mounted on the casing around the wheel are four nozzles spaced 900 apart. Within the casing are a series of stationary semicircular reversing chambers. The products of combustion are led through a gas manifold ring and pass through the nozzles. The gases then impinge at high velocity on the buckets. In passing through the buckets the direction of flow is reversed 180 degrees. The gases are then caught by a semicircular reversing chamber in the casing, where they are again reversed 1800 and returned to the wheel. The process is repeated five times through a 900 arc of the turbine housing, after which the gases are exhausted. Reversing the hot gases several times gives a multiple-stage effect, thereby using more of the potential energy in the gases.

Another type of turbine is the single-stage impulse turbine shown in figure 8-20A. In this turbine the gases expelled through the nozzles are not reversed in direction, but make only one pass through the turbine blades. You will find variations on the turbines discussed, but their basic principles of operation will remain the same. Both Terrier and Tartar use this type in their APS systems.



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Figure 8-20. — Turbines used in auxiliary power supply (APS) A. Impulse turbine; B. Terry turbine.

Governors

As mentioned earlier, turbines are often coupled to an a-c or d-c electric generator. To provide a constant electrical output, a governor is commonly used to control turbine speed within very close tolerances. One type which may be used is the moving shutter governor, which controls the speed of the pinwheel turbine.

MOVING SHUTTER GOVERNOR. - The moving shutter governor is mounted in the hub of the pinwheel turbine, as shown in figure 8-21A and 8-21B. Compressed air entering the turbine through the hollow shaft must pass through the

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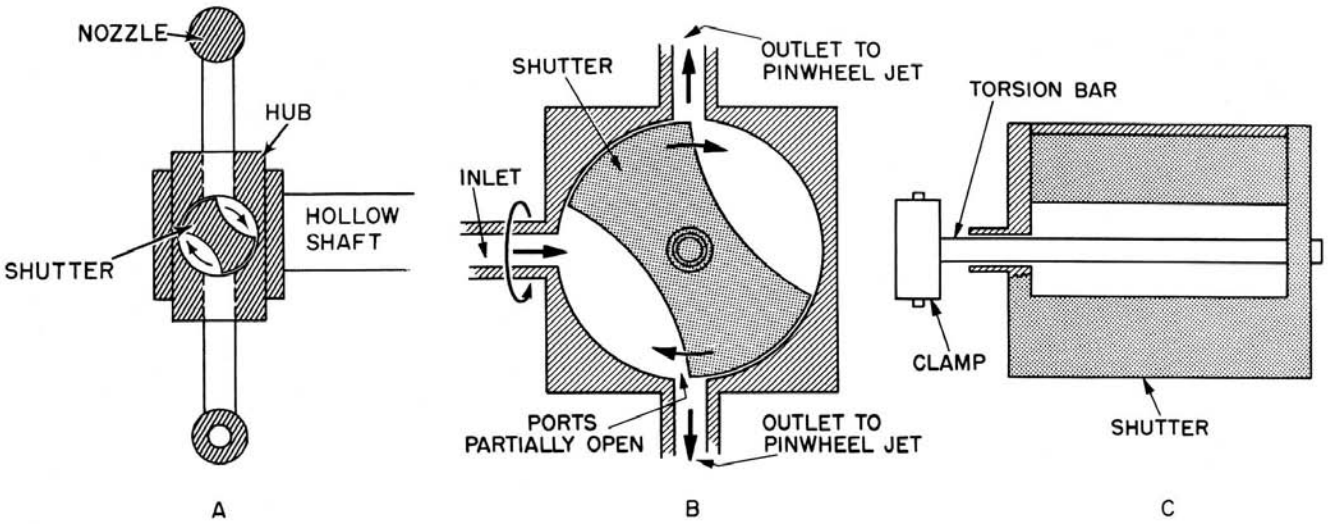


Figure 8-21. — Moving shutter governor.

governor before it can pass through the jet nozzles. The governor consists of a shutter secured to a torsion bar (fig. 8-21C). As the turbine rotates, centrifugal force causes the shutter to attempt to align itself in the plane of turbine rotation. In figure 8-21B the shutter tends to turn clockwise and block the flow of air to the nozzles. The torsion bar restrains the shutter from blocking the outlets. As turbine speed approaches a specified limit, the force on the shutter begins to overcome the restraint of the torsion bar, thus permitting the shutter to turn clockwise and partially block the outlets to maintain speed at the specified limit. If turbine speed decreases, the torsion bar overcomes the centrifugal force, and the shutter moves counterclockwise to uncover the outlets. Thus the moving shutter governor continuously controls turbine speed by metering the airflow to the nozzles.

FLYBALL GOVERNOR. - A very common type of turbine governor is the flyball governor shown in figure 8-22. The coiled springs provide a restraining force on a pair of pivoted counterweights mounted on the turbine shaft. When shaft speed reaches design speed, centrifugal force overcomes spring tension. The counterweights pivot, causing the brake shoes to bear on the brake drum. When design speed is exceeded, the centrifugal force and the braking action increase. At decreasing speeds the centrifugal force lessens, and the braking action decreases. Thus a constant turbine speed is maintained.

Another type of flyball governor controls turbine speed by metering the flow of air or hot gases to the turbine. Its springs and counterweights are coupled to a valve on the input side of the turbine. Centrifugal force causes the weights to open and close the valve, thereby controlling turbine speed directly.

Miscellaneous Devices

Devices other than those described in this chapter are found in many APS systems. For example, air systems may include dehydrators which prevent moisture from reaching system components. Hydraulic systems contain devices for bleeding off entrapped air. (Entrapped air in hydraulic lines can cause serious problems. System failure often results because of the compressibility of air.) Sight gauges are often provided for indicating pressure and fluid levels. Speed reduction gears are often found between high speed turbines and the machinery they drive. The technical manuals concerning the missile you are working with will describe the applicable APS system in detail.

Certain auxiliary devices are included in all APS systems to aid in smooth and safe operation. These devices include check valves, starting valves, reducer valves, filters, and various types of flow regulators.

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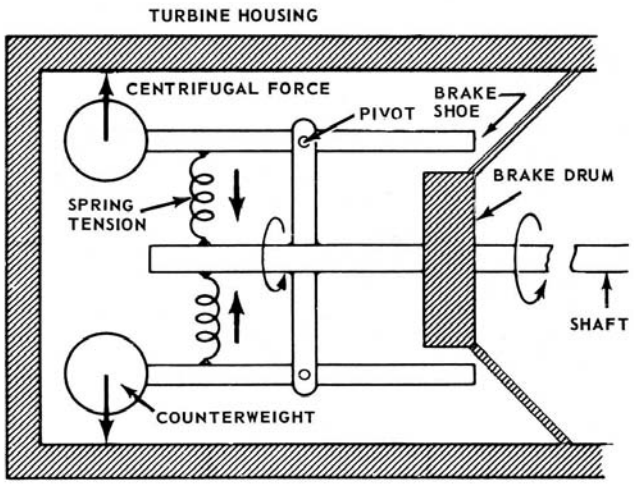


Figure 8-22. — Flyball governor.

One of the simplest devices for restricting or regulating flow is a fixed orifice or restriction in the hydraulic line. A more complex device is an adjustable orifice restrictor, such as a needle valve.

ADVANTAGES AND DISADVANTAGES

The disadvantages of compressed air power for movement of control surfaces of missiles were mentioned earlier. Hot gas APS systems took the place of the compressed air systems. All of them actuated a hydraulic system to cause the movement of control surfaces as required for missile flight. A disadvantage of the hydraulic system is that it is bulky and heavy. This offsets the advantages of smooth, speedy response. The new missiles are being equipped with all-electric systems to replace the hydraulic components.

MAINTENANCE OF HYDRAULIC AND PNEUMATIC EQUIPMENT

The maintenance and repair of hydraulic and pneumatic units in missiles and in missile test equipments pose no special problems if the instructions given in the appropriate maintenance publications are followed closely. However, there are two general precautions of importance which apply to work with fluid systems. The first of these is the need for cleanliness of work areas, tools, and related equipment. The second (but not second in importance) is the need for constant observance of safe work practices.

The need for cleanliness results from the fact that the moving parts of hydraulic and pneumatic devices are machined to very close tolerances and must be perfectly free of foreign matter. The smallest impurity in these systems can damage the precision components, impair the operation of the overall system, and cause missile failure.

PERIODIC INSPECTION

To prevent impurities from entering missile fluid systems, inspections are made of hydraulic and pneumatic equipments at regular intervals. Both the units which supply fluids for testing the missile and those which charge it prior to actual flight are closely inspected.

At intervals specified by technical manuals, and as summarized and codified in the 3-M system, the input and output filters of missile hydraulic systems should be removed and examined. The filters are usually of the micronic type mentioned earlier in this course. The elements in these filters cannot be cleaned. If there are signs of excessive impurities, they must be replaced.

SYSTEM FLUSHING

Flushing of test equipment pumping systems is performed to remove any contamination which might be present. This is always done both after the initial fluid system installation, and following any major repair in which the principal connections have been broken and remade. When the initial system installation has been completed and given an electrical checkout, or when repairs have been completed, the equipment is turned on and the hydraulic fluid is allowed to circulate for a specified period of time.

The equipment is then turned off an the fluid is removed from the system and discarded. The input filters are then replaced and the reservoir refilled with the proper fluid. When the reservoir is filled to the correct level, the system is then ready to supply oil to the missile for testing purposes or for charging the system for flight.

If hydraulic components within the missile become contaminated, they must be removed and reworked in a repair shop. This type of repair is done only at a major shore repair station-not aboard ship. A unit, such as shown in figure 4-33, is removed in its entirety and is replaced with a new unit.

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HYDRAULIC TROUBLESHOOTING

Except for the electrohydraulic components, most troubleshooting in hydraulic systems is accomplished by visual means. The most frequent cause of trouble is leakage caused by poor connections or faulty O-rings. When a connection shows evidence of leaking, tightening will usually stop the loss of fluid. When the leak results from a bad O-ring, it may be necessary to disassemble the unit and replace the ring. If a leak cannot be repaired by one of these methods, the faulty section is usually replaced.

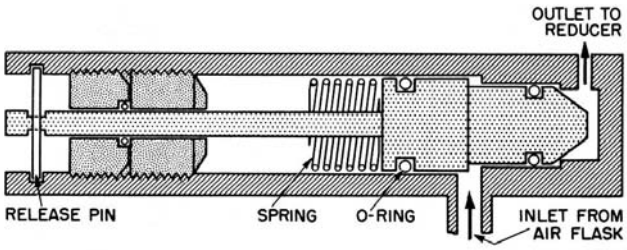


Figure 8-23. — Starting valve.

CARE OF PNEUMATIC EQUIPMENT

As in the case of hydraulic components in the missile faulty pneumatic components may be removed in their entirety and sent to a repair facility.

VALVES

Many types of hydraulic valves are described and illustrated in Fluid Power, NavPers 16193-B plus general instructions and cautions for installing and maintaining such valves. That material will not be repeated here as the basic text should be readily available to you.

Pneumatic systems use many of the same type valves as those used in hydraulic systems, but there are some that are special for use with air systems, either compressed or free air.

Starting Valves

Starting valves are commonly used in pneumatic systems. These valves provide a positive block on the discharge (output) side of the air flask. Many of these are designed to be opened by retracting a pin, either by hand or electrically. Retraction of the pin permits air to pass from the flask, thus starting operation of the pneumatic system. Figure 8-23 shows the operation of a starting valve. When the pin is released, inlet pressure acting on the valve shoulder causes piston movement to the left. The function of the spring is merely to absorb the shock of the rapid piston movement.

Relief and Safety Valves

Relief valves and safety valves (fig. 8-24) are used in all closed systems. Their function is to prevent excessive pressures from rupturing hydraulic and air lines, or damaging machinery. Most of these are spring-loaded valves in which spring compression is set according to the maximum allowable pressure in the system. If pressure becomes excessive, the spring is compressed and the excess pressure is vented to the atmosphere. An adjusting screw is normally provided to set the spring pressure.

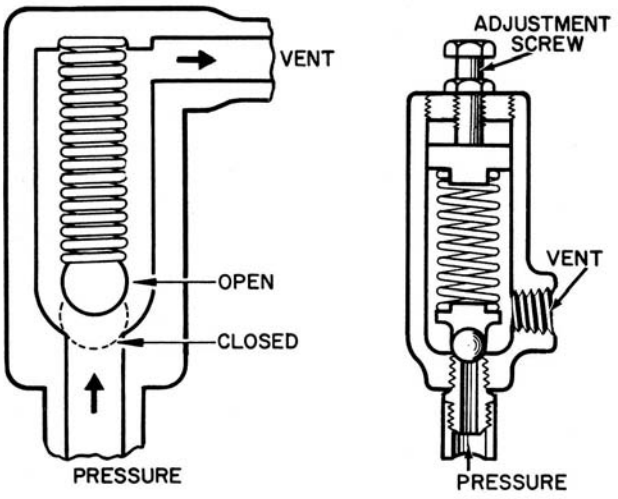
Although safety and relief valves operate on the same principle, their function is slightly different.. Relief valves are usually small in comparison to safety valves, and are designed to relieve occasional excess pressures during normal operating conditions. Safety valves are designed for emergency or breakdown, and can take care of the entire load.

Air Pressure Reducer Valve

It is usually necessary to reduce air flask pressure (about 3000 psi) to a much lower operating level.

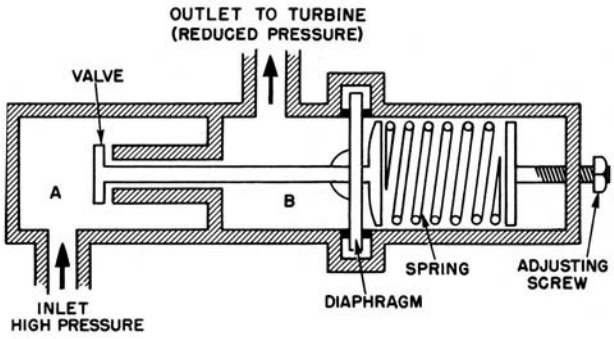
In the reducer valve shown in figure 8-25 pressure is reduced to 300 psi prior to reaching the turbine. To start with, assume that atmospheric pressure exists in chambers A and B before the starting valve is opened. At this time, the spring pressure against the diaphragm holds the reducer valve open. At the instant the starting valve is opened, air at 3000 psi rushes into chamber A and passes through the valve into chamber B. The pressure in chamber B immediately begins building up from atmospheric pressure. When it exceeds 300 psi it is sufficient to overcome spring tension; thus the diaphragm moves to the right, compressing the spring, and the valve closes. Note that the spring tension is set by the adjusting screw so that pressure in chamber B must exceed 300 psi to move the diaphragm to the right, permitting the valve to close. If the pressure in chamber B drops below 300 psi,

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Figure 8-24. — Relief of safety valves.



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Figure 8-25. — Air pressure reducer valve.

spring pressure pushes the diaphragm to the left, causing the valve to crack open, admitting air to chamber B. When the pressure in chamber B is exactly 300 psi, a point of balance is reached wherein the valve will remain open just enough to permit constant pressure in chamber B. Although it may appear that the spring pressure would be insufficient to overcome the high pressure in chamber A to open the valve, the valve is designed so that even a relatively low spring pressure will crack it against 3000 psi in chamber A.

This valve will maintain a constant outlet pressure of 300 psi as long as the inlet pressure exceeds 300 psi.

Although pneumatic systems have been designed for missile control systems, none is in use. The valves described above are types that may be used in other applications, as in a pneumatic-electric control system. The illustrations of the basic parts of each type can help you when you have to dismantle and clean a valve. You need to have the parts drawing that will show all the parts, not just the main parts as in these sketches but, if you understand how the valve operates, it will help you to put it together correctly.

A pneumatic valve that you need to know is the PRP valve in the sprinkling system in the magazines. (It will be described in detail in chapter 10 and illustrated in fig. 10-35).

SAFETY

Safety is everybody's job. Awareness of danger, knowledge of how to avoid it, and constant vigilance are the three basic requirements for the prevention of accidents while you are working on or operating a launching system.

Safety is both a result and a reflection of good training. The crews of missile launching systems may be trained so that every man thoroughly knows how to do his job; however, the crew still cannot be considered well trained unless every man is safety conscious. Safe working habits must be impressed upon every crewman through proper instructions, constant drills, and continuous supervision. Carelessness, cockiness, and lack of training have led to disaster while working with all types of ordnance equipment and material.

Each piece of ordnance equipment has a specific list of safety precautions to be observed during operation and/or maintenance. Study these thoroughly before attempting to operate or repair any piece of equipment with which you are not familiar.

Hydraulic systems operate under hydraulic pressures ranging from approximately 100 psi to 2,000 psi. Some pneumatic systems operate in approximately the same range of pressures as hydraulics. These pressures are dangerous and can be hazardous to personnel.

The following safety rules are but a few of the many that must be observed when operating or working on hydraulic or pneumatic systems.

Never disconnect hydraulic lines or disassemble hydraulic equipment when the hydraulic system power motor is running.

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Never disconnect hydraulic lines or disassemble hydraulic equipment until the accumulators have been manually dumped to tank.

Never manually actuate switches, solenoids, relays, or valves on hydraulic systems under pressure unless you are competent and qualified to perform these actions.

Report hydraulic leaks immediately so that they may be repaired at the first opportunity.

If clothing becomes drenched with hydraulic fluid, immediately change into dry clothing for hydraulic fluid is injurious to health when in prolonged contact with skin. It is also a fire hazard. Immediately wipe up all spilled fluid.

Do not direct a high-pressure air jet at any part of the human body; this may be fatal.

Safety precautions must be observed when performing maintenance, testing, and operating ordnance hydraulic and pneumatic equipment. The high pressure liquid or air can cause major injuries to your face, hands, and other parts of the body by jets of air or liquid escaping from valves or pipe connections which are highly pressurized.

Don't think that once you have learned all applicable safety precautions you can sit back and take things easy. Review them periodically, particularly those for jobs seldom performed. Try to improve upon any rules in effect. Safety is everyone's responsibility, not just those who drew up the regulations. Most accidents are caused by men who are so familiar with their job they think they can take short cuts; by men who don 't know the applicable precautions; by practical jokers; or, in the majority of instances, by plain carelessness.

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CHAPTER 9

ELECTRICAL DEVICES USED IN LAUNCHING SYSTEMS

INTRODUCTION

In this chapter we discuss the basic operating principles of switches and relays. Also, we take up the application of these units in launching system control circuits. To maintain electrical and electronic circuits efficiently and effectively, you must have this background knowledge.

In most missile launching systems, the equipments are normally located at considerable distances from each other. For example, the launcher captain's control panel is more than 50 feet from the launcher, yet he must be able to control the launcher without leaving his station. How is this particular problem solved? Remote control is the answer. Remote (indicating and control) circuits are made up of switches, relays, and other devices, which control the output from the ship's generators and utilizes this source for GMLS motors and control circuits.

> NOTE: The use of d-c motors and generators in GMLS is in the form of synchros or tachometers, except Mk 12 which has motor, generator sets.

The electrical components mentioned above are explained in detail in Basic Electricity, NavPers 10086-B.

Remote control circuits not only eliminate the wasted energy of rushing about from equipment to equipment, but they also permit equipment to be operated from several control points about the ship. Thus, the missile launching process can be started by closing a key in the weapons direction system or by turning a switch on a panel at the launching site.

Missile launching operations (loading, unloading) are normally performed automatically. But other types of control are also available. Most systems can operate in "Step" control. System operation in this mode is in a series of interlocked steps and individual parts of the installation can be used without "cutting in" the entire system. Relay and switch arrangements provide switching from one type of control to another.

Some launching systems are capable of stowing mixed loads. For example, several kinds of Terriers such as BT-3 and HT-3 are stowed in the same ready service ring. Mixing of missiles implies that some method is provided to locate and to select a desired missile for loading and firing. Special devices, which incorporate switches and relays, are used to perform the missile stowage locating and selecting function. The Mk 9 GMLS uses a stepping switch to select a cell from which a missile can be selected. In the Mk 10 GMLS, this action is one of the functions of the load status recorder, and in the Mk 13 GMLS a ratchet relay is utilized. Though the names of these devices differ, they all operate to perform the same general purpose.

SWITCHES

A basic understanding of switches and their function in control circuits is most important. Circuits using switches are sometimes more complex than electronic circuits. Therefore, to troubleshoot effectively you should have some background knowledge of switches. In this chapter a great deal of simplification has been used. And, in general, only the less complex switches and switching circuit arrangements are included here. But enough basic information is included to give you the necessary background for further study about the subject.

A switch is a device used for making, breaking, or changing the connections in an electric circuit. Switches are used extensively in launching-system control circuits to start and stop motors, to turn indicating lights on and off, to channel information from one point in the system to another, and to shift system mode of operation, to name a few of their many uses.

An essential function of any switch is to maintain a good, low-resistance contact when

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the switch is closed. A poor connection between switch elements produces considerable resistance. This results in overheating the contact area. When heavy current is being carried by the switch, and the switch contacts are opened, an arc is produced. Therefore, switches should be opened and closed quickly to minimize arcing. Usually, they are designed to have snap action.

Switches are frequently classified by the number of poles, by the throw, or by the number of positions. The pole of a switch is its movable blade or contactor. A switch may have one or several poles. The throw of a switch indicates the number of circuits each pole can complete through the switch. The number of positions a switch has in the number of places at which the operating device (toggle, shaft, plunger, and so on) will come to rest, and, at the same time, open or close a circuit. As you can see in figure 9-1, switches through which only one circuit can be completed are called single-pole, single-throw switches. Switches with two poles, through each of which one circuit can be completed, are described as double-pole, single-throw switches, while those with two poles through each of which two circuits can be completed are described as double-pole, double-throw switches.

Another way of classifying switches is by the method of actuation, that is, pushbutton, toggle, pressure, and the like. Switches can also be classified by using the trade name of the manufacturer. Two examples are: Micro, and Iron Fireman switches.

ROTARY SWITCHES

A rotary switch can take the place of several switches. As the knob or handle of a rotary switch is rotated, it opens one circuit and closes another. This can be seen from an examination of figure 9-2. Most rotary switches have numerous layers, called wafers or pancake sections. By adding wafers, the switch can be made to operate as a large number of switches. Rotary switches are used in launching system equipment to select modes of operation and for many other functions.

Type J Rotary Switch

The type J rotary switch (fig. 9-2) consists of an equal number of rotors and pancake sections. The number of sections required in the switch is determined by the application. A shaft with an operating handle extends through the center of the rotors. The movable contacts are mounted on the rotors, and the stationary contacts are mounted on the pancake sections. Each section consists of eight stationary contacts, designated A to H, and a rotor with two insulated movable contacts spaced 180° apart.

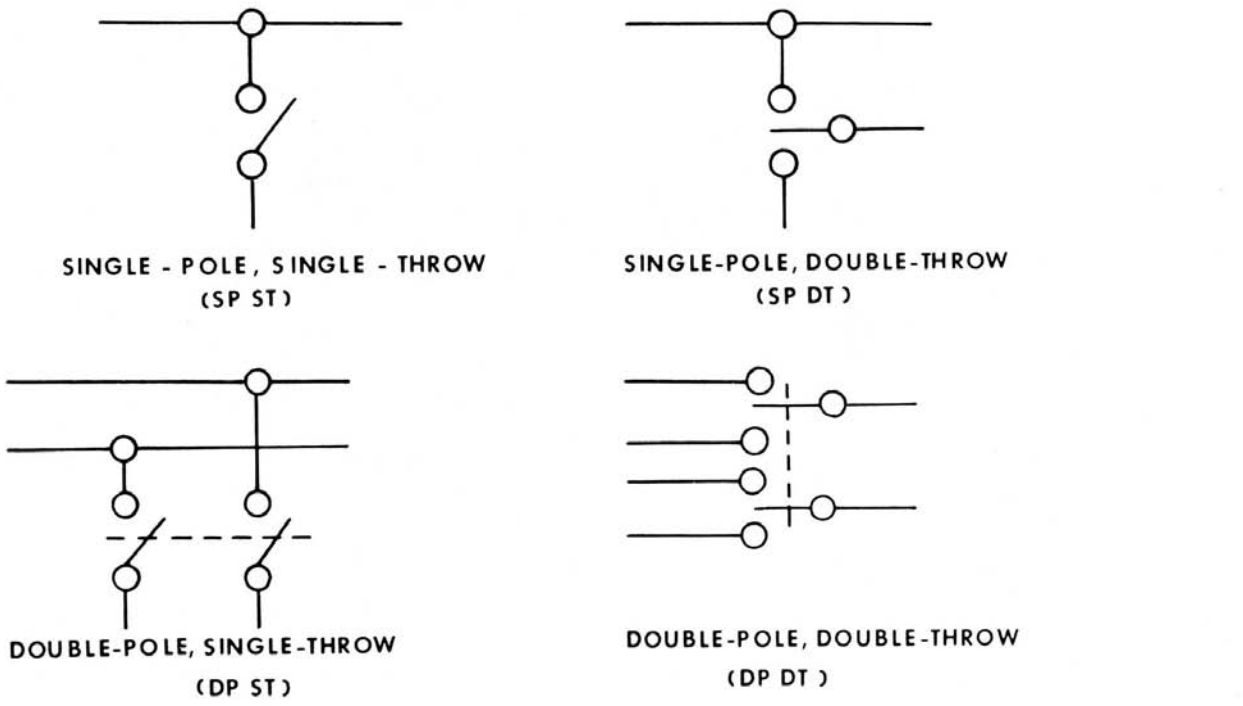
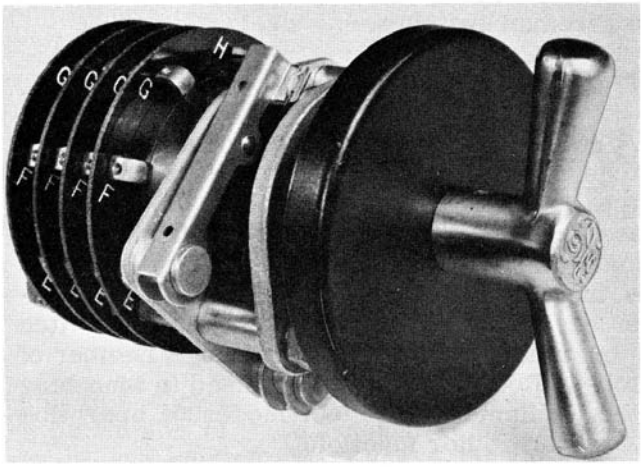


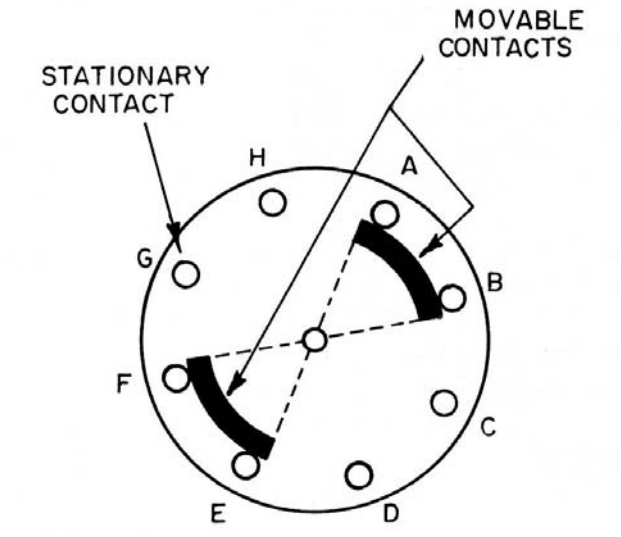
Figure 9-1. — Switch classification according to number of poles and throws. 12.66

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12.70
Figure 9-2. — Type "J" multipole rotary switch.

Figure 9-3 shows the contact array for all pancake sections. Each movable contact is arranged to bridge two adjacent stationary contacts. The switch has eight positions. A detent mechanism properly aligns the contacts in each position of the operating handle. In one position, the rotor contacts bridge segments A-B and E-F; in the next position, the rotor contacts bridge segments B-C and F-G. Diagonally opposite pairs of contacts are subsequently bridged for the



83.89
Figure 9-3. — Type "J" switch contact arrangement.

remaining positions. The various circuit leads are connected to the proper pancake terminals. To transfer circuits you just turn the handle.

JR Type Of Rotary Switch

The letters JR are the designation for a family of rotary switches. These switches (fig. 9-4) control by a single motion a number of switches, called pancakes or wafers, located on the same shaft. To do this, the switch is built in layers, or wafers, along the shaft of the switch handle (fig. 9-4A). Each wafer is in itself a separate switch. See figure 9-4C. The number of contacts determines the type of switching circuit. Usually all the wafers in the JR type switches are identical. That is, they may be all make-before-break or break-before-make (fig. 9-4B).

Make-before-break means that as the switch is rotated, the rotor contacts touch the next pole before breaking the previous contact. Break-before-make means that as the switch is rotated, the rotor contacts leave the original pole before the movable contacts touch the new pole. In rare cases you will find a switch on which a few wafers permit break-before-make while the rest are of the other type. Extra wafers are provided for use as spares.

As the handle of the switch is turned, the rotor blades in all wafers turn simultaneously to make and to break the circuits. A detent wheel is incorporated in each switch assembly to ensure proper positioning. Also, a stop plate (fig. 9-4A), limits the rotation of the switch by means of a stop pin. The pin is fixed in the stop plate to prevent overtravel.

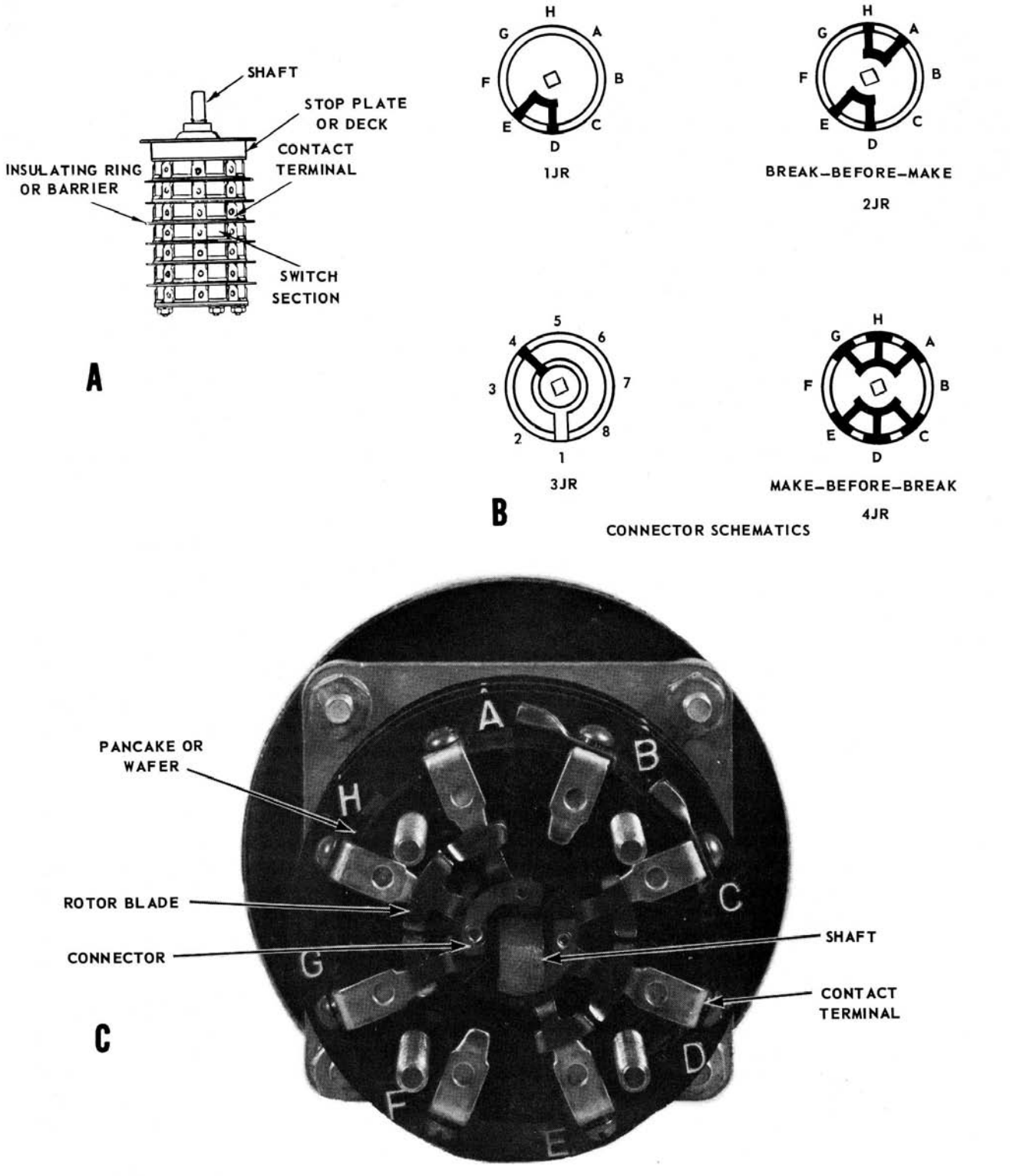
The JR switch is smaller in size and more readily disassembled than the J switch. These features result in a saving of space and also facilitate repairs. The JR switch is classified as 1 JR, 2 JR, 3 JR, or 4 JR type.

The 1 JR switch has only one movable contact per section. This movable contact bridges two adjacent stationary contacts.

The 2 JR switch is the same electrically as the J switch and is the type used for general ordnance applications. The 2 JR switch has two movable contacts per section, 180° apart. Each movable contact bridges two adjacent stationary contacts.

The 3 JR switch uses one of the stationary I contacts as a common terminal. This stationary contact is connected in turn to each of the other stationary contacts of the section by a

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Figure 9-4. — JR rotary switch: A. Typical rotary switch arrangement; schematic; B. JR switch contact arrangements; C. Face view.

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single wiper contact. The 3 JR is used for selecting one of several (up to seven) inputs.

The 4 JR switch has two movable contacts in each wafer. The movable contacts bridge three adjacent stationary contacts.

The JR switch is stacked in multiples of 5 sections (up to 25 sections). In some cases, a switch with a number of sections (not a multiple of five) has been installed. If this switch must be replaced, a switch with the next largest number of sections that is a multiple of five should be installed if space permits. It is preferred to have all sections of a switch the same, but, if absolutely necessary, a switch with some sections of one type and some sections of another type can be provided.

Type JR switches are rated at 115 volts, 60 hertz, and 10 amperes. The switch should not be used on d-c circuits because of the possibility of severely burned contacts when operated slowly (teased). The switch is of the non-shorting type.

Barriers are also provided between sections to prevent terminals from turning and shorting to adjacent terminals.

If the sections are not uniform the switch will be designated "JRSP", followed by the number of sections.

The stop deck on the JT switch (fig. 9-4A) permits setting the switch to the number of positions desired. By inserting pins or screws in the stop deck immediately after the desired last position, you can keep the switch from moving beyond that point.

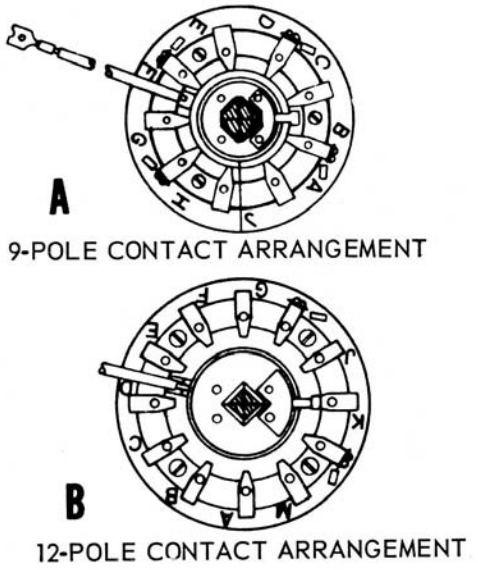


Figure 9-5. — Barrel switch contact arrangement: A. 9-pole contact arrangement; B. 12-pole contact arrangement.

Barrel Switches

Barrel switches are used in some ordnance installations. The contactor-carrying shaft on this type of switch is manually rotated. Each contact wafer level has an external electrical input to a slip ring. (Slip rings have been mentioned several times in preceding chapters.) From the slip ring, electrical distribution is made to the contactor blade and then to the contact for the external distribution.

There are three types of contactor blades used in barrel type switches: double, offset, and straight.

Figure 9-5 shows a straight blade arrangement for 9-pole and 12-pole barrel switches.

INTERLOCK SWITCHES

Interlock switches include a large group of switch types that are actuated by mechanical linkage or hydraulic fluid. They act as control or protective devices and are numerous in missile launching systems. Their use permits action to take place only in the ordered sequence. For example, switch SI102 cannot be actuated ahead of SI101.

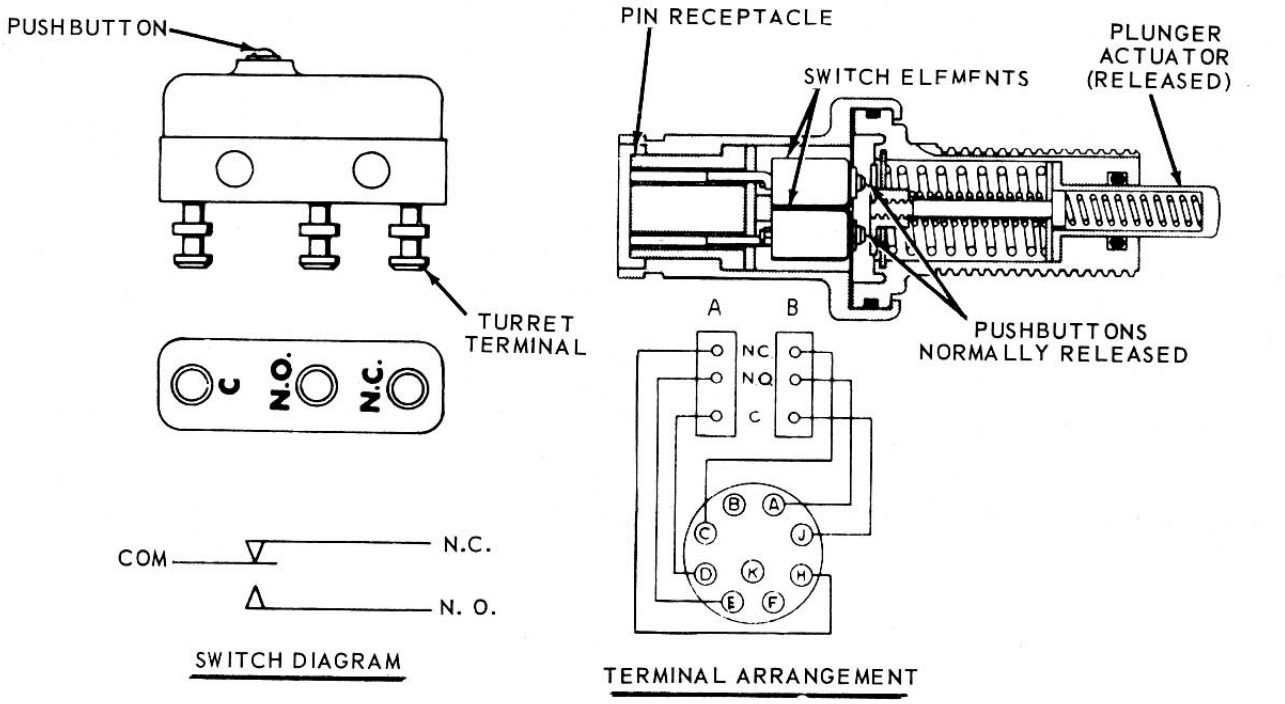
Sensitive Switches

The most common type of interlock switch is the sensitive switch. There are various kinds of sensitive switches with different means of actuation.

These are small, short-traveling, snap-action switches. See figure 9-6. They are manufactured as normally open, normally closed, and double throw. The latter has no OFF position. The Microswitch is frequently used in referring to this type of switch. The term Micro is a trade name for the switches made by the Micro Switch Division of Minneapolis Honeywell Regulator Company. However, many other companies also make sensitive switches.

Sensitive switches are usually of the push-button variety and are often used as interlock switches. These switches usually depend on one or more springs for their snap action. For example, the heart of the so-called Micro switch

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Figure 9-6. — Sensitive switch, showing terminal and element contact arrangement.

is a beryllium copper spring, heat-treated for long life and reliable action. The simplicity of the one-piece spring contributes to the long life and dependability of this switch.

When a sensitive switch is used as an interlock, the plunger (pushbutton) is actuated by mechanical means. The device for moving the plunger can include either a rotating cam, lever, wedge, or bellows arrangement. Figure 9-7 shows some of the ways of applying operating force to the plunger.

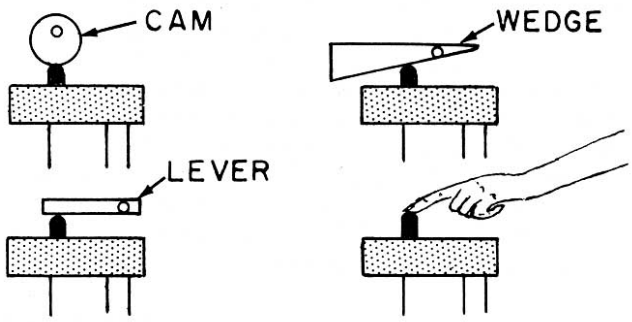
Other Types of Interlock Switches

A snap or snap-lock switch is another type of interlock switch. It is used mostly on older ordnance equipment. It is usually actuated by a mechanical cam. The contact lever snaps into contact with the stationary contacts, as the torsion spring inside the switch overcomes the latch. See figure 9-8.

The stepper switch, sometimes called a stepping relay, is a rotary switch driven by a coil and latching arrangement. This combination switch and relay is used in the missile selection circuits of launching systems. Its action is described in the section on relays.

RELAY PRINCIPLES

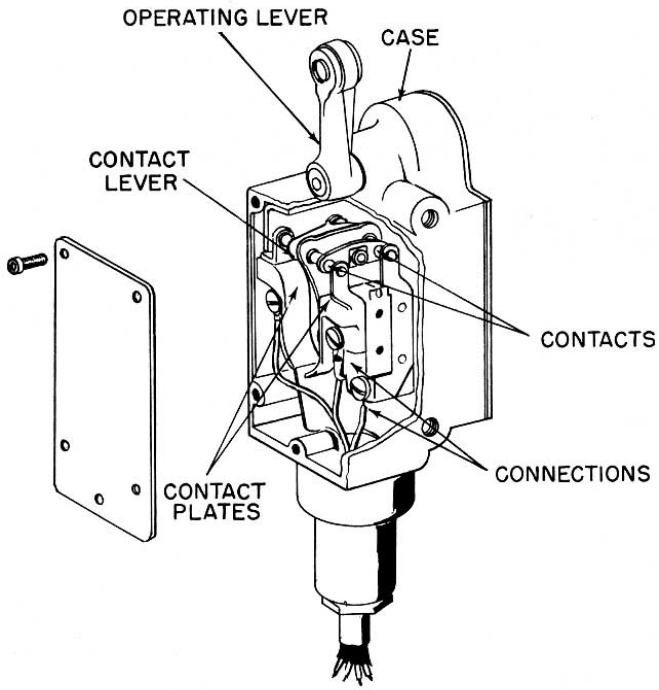
A relay is simply an electromagnetically operated switch. It is designed to open or close a circuit when the current through its coil is started, stopped, or varied in magnitude. The main parts of a relay are a coil wound on an iron core and an armature that operates a



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Figure 9-7. — Methods of applying operating force to pushbutton (sensitive) switch plunger.

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Figure 9-8. — Snap-lock switch.

set of contacts. A simple relay and circuit are shown in figure 9-9.

If you close switch 81, current flows through the coil, energizing the electromagnet, and drawing the armature upward. The action of the armature closes the contacts and power is applied to the load. More contacts can be added to the armature so that other functions may be accomplished.

The operating speed of a relay is determined by the time between the closing of the coil circuit and closing of the relay contacts. In small, specially designed relays, like the ones in launching system control circuits, the operation speed may be as low as one millisecond. The operating speed of a relay may be increased by any technique that reduces eddy currents in the core. Making the core of laminations is one method of reducing eddy currents and thus increasing the operating speed of a relay.

Another method is to place a resistor in series with the relay coil and increase the operating voltage. This will increase the speed of closing because at the instant power is applied to the relay all the voltage will appear across the coil and the magnetic field will build up faster. The speed of relay operations can be reduced by placing a heavy copper sleeve over the core of the coil. This has the effect of a shorted turn. Current flow in the sleeve opposes the field in the coil as it builds up or collapses, thus delaying the relay's operation.

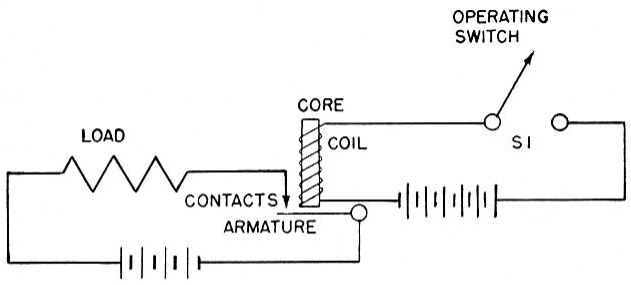
The type of material used for contacts depends on the amount of current to be handled. Large power relays usually have copper contacts and use a wiping action to make sure of a good connection. Small relays may use silver or some silver alloy, while in some applications tungsten or some very hard material may be used which will prevent contact burning or oxidation. In general, relays that open and close with a fast positive action cause much less trouble than those that operate slowly. Relays that malfunction or fail completely should be replaced. It is not good practice to repair them.

POWER RELAYS OR CONTACTORS

Heavy-duty relays called contactors are used extensively for remote control switching of high voltage and current. A case in point is the application of 440 volts to an electric motor. For this application and similar ones, a relatively small amount of control power (generally 115 volts) may be used to energize the coil of a contactor whose contacts are made heavy enough to handle the required amount of power.

Figure 9-10 shows a typical contactor of the armature type. This type contactor comes in three sizes and all are for 440 volt, 60 hertz operation.

Main components of the contactor are a 115 volt coil, a magnet, an armature, a stationary four contact assembly, a movable four contact



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Figure 9-9. — Simple relay circuit.

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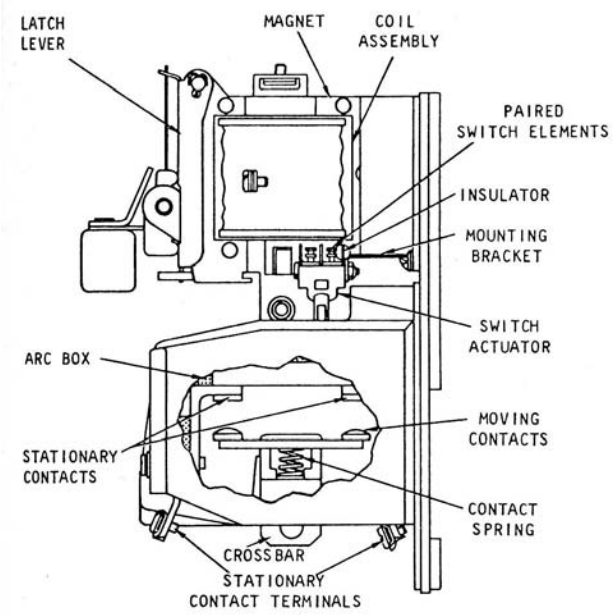


Figure 9-10. — Size 1 contactor.

assembly that is linked to the armature through a crossbar, two switch elements, and an inertia- type shock latch.

When the coil is energized the armature movement pulls the crossbar which in turn moves the contact assembly to close the motor circuit.

When the coil is deenergized, a kickout spring breaks all the contacts.

The inertia latch prevents the contactor from closing (if deenergized) or opening (if energized) under shock. In the event of shock, the weight on the latch moves a slider bar to momentarily lock the contactor plunger in position.

Figure 9-11 shows another type of contactor known as the solenoid relay. It operates with a vertical motion. When the coil is energized, the plunger or armature snaps upward, closing the contacts. These are mounted on springs to ensure an even pressure where more than one set of contacts are used. Contactors of this type usually have silver alloy contacts which do not oxidize easily and so require little attention.

CIRCUIT BREAKERS

Circuit breakers (fig. 9-12), used in launching systems, are comparatively small devices that play the role of guardian over the electrical system" The circuit breaker is designed to open the circuit automatically under short circuit or overload conditions without injury to itself. Thus it performs the same function as the fuse, but has the advantage that it is capable of being reset and used again. Like the fuse, the circuit breaker is rated in amperes and voltage. The thermal-magnetic breaker permits temporary light overloads. such as an in rush starting current; permits medium overloads for predetermined lengths of time; and trips instantly on exceedingly high overloads. There are three basic types of circuit breakers, thermal, magnetic, and thermal-magnetic. The thermal type is the most universally used.

In their usual forms the circuit-breaker contacts are closed by a hand operated lever. Since some form of automatic switch opening device is needed to replace the human operator. a switch tripping device is included in the circuit breaker. The complete contact assembly consists of the main bridge contacts and arcing contacts (fig. 9-12).

Trip Mechanism

The trip mechanism is actuated by a release. or relay. Release devices are a combination of

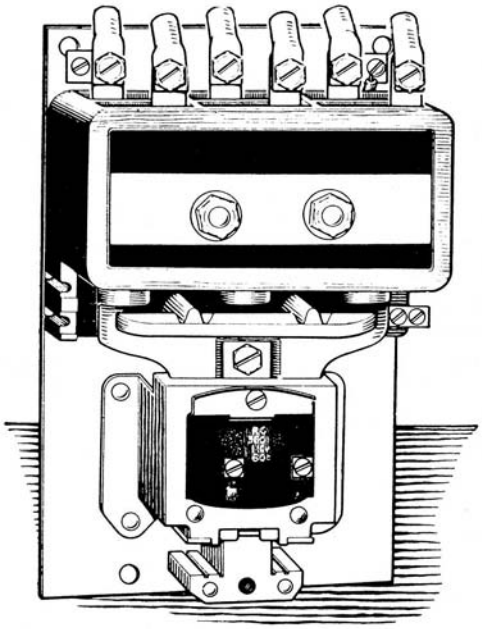


Figure 9-11. — Power contactor, solenoid relay type. 83.94

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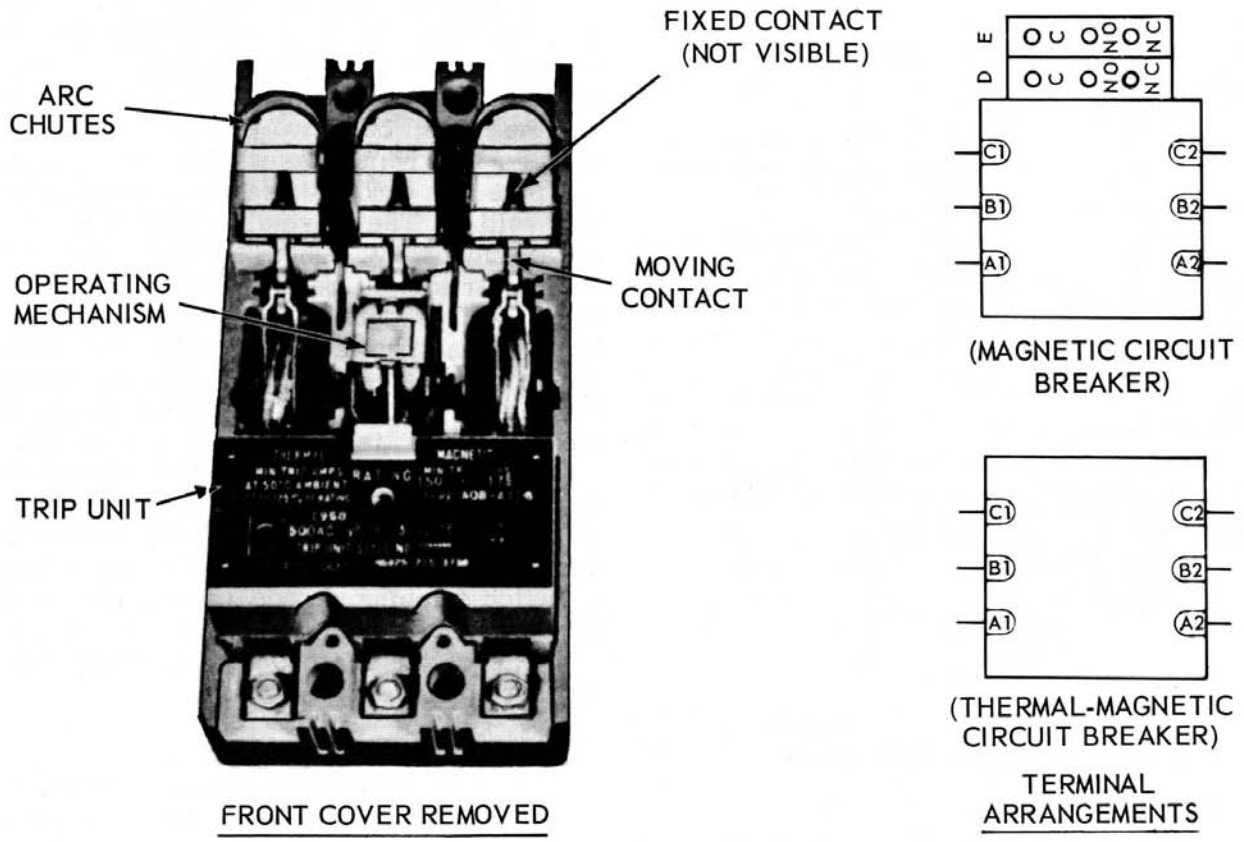


Figure 9-12. — Circuit breaker: A. Front cover removed; B. Terminal arrangements.

the thermal and magnetic types. A thermal release is used for overload protection, and depends upon the deflection of a bimetallic element that is heated by the circuit current. As current flows through the bimetallic strip, heat is generated and the strip bends. Under sufficient heat it bends enough to interrupt the circuit by releasing a trip, which opens the contacts. The magnet release uses an electromagnet which acts directly on the trip mechanism of the circuit breaker. The magnetic part operates on short circuits. Most circuit breakers also have a manual means of resetting.

Another type of thermal circuit breaker is shown in figure 9-13. This breaker consists of a conductive bimetallic snap-acting disk which bridges two electrical contacts. When the disk is heated by an excess current, it snaps into reverse position, opening the contacts and the circuit. In circuit breakers having low ampere and voltage ratings, a resistance wire is inserted in the circuit. The resistance wire provides the heat necessary to snap the disk. The breaker is reset by pressing the button which restores the disk to its original position. Once this type of circuit breaker is closed it cannot be reopened manually. They are also nonindicating; that is, the position of the breaker (open or closed) cannot be determined by visual inspection.

The automatic-reset type circuit breaker is similar to the bimetallic disk type just described, except that it has no reset push-button; it resets itself automatically. After a short time, when the disk has cooled sufficiently. it will bend back and close the circuit, resetting itself. If a constant overload exists, the breaker will intermittently break the circuit.

Besides the protection against high current overloads, many circuit breakers can be opened or closed by means of a switch or lever to isolate circuits for maintenance or repair purposes.

An electromagnetic circuit breaker is described and illustrated in chapter 8, Basic Electricity. NavPers 10086-B.

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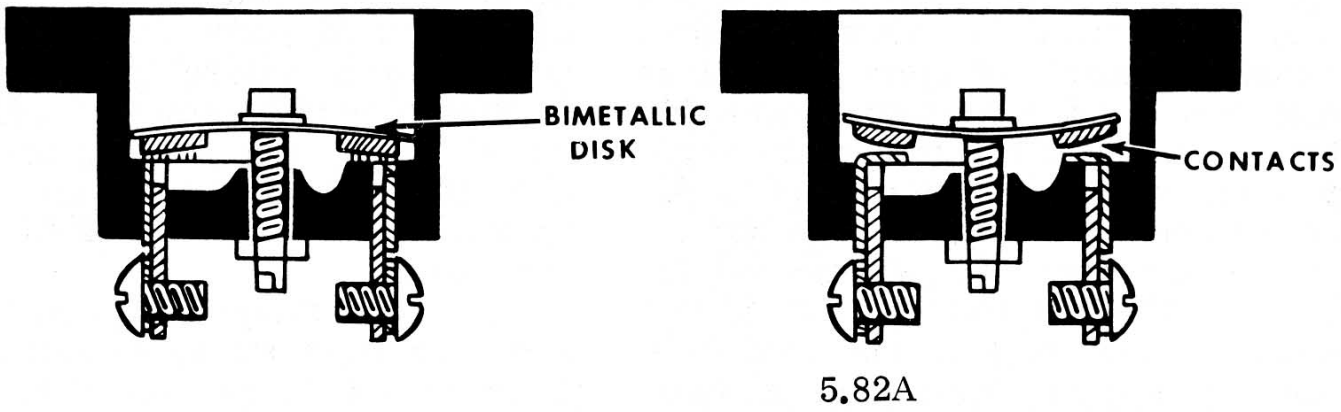


Figure 9-13. — Thermal circuit breaker.

STEPPING RELAYS

Stepping relays are used in control circuits to locate, to identify, and to select missiles for warmup and loading. Figure 9-14 shows a simple stepping relay assembly and its principle of operation. It consists of two principal parts: a relay and a rotary switch. Stepping relays are sometimes called stepping switches or stepper switches.

To start stepping, the relay coil is energized. The Y-shaped pawl is attached to the relay armature and the pawl is moved about its pivot. When this happens, the left prong of the pawl presses the ratchet tooth in a counterclockwise direction. The ratchet gear also turns counterclockwise. Consequently, the shaft of the wiper arm which is attached to the ratchet gear turns through the same angle and in the same direction. As the ratchet tooth passes the end of the pawl, the interrupter contacts open. These contacts are connected in series with the relay coil. When the interrupter contacts open, the relay is deenergized. The pawl is then returned to its manual position by the spring.

The right prong of the pawl engages the ratchet tooth which has been moved. Thus the right prong holds the ratchet gear locked in its new position. But when the pawl is in this position, the interrupter contacts close again and the switch takes another step.

When the stepping process is repeated, the left prong of the pawl engages the next ratchet tooth. Since the ratchet gear in our example has ten teeth, the ratchet and shaft have ten specific positions. This indicates that 10 external circuits can be connected to and controlled by the switch. Each step cycle makes a different switch contact. In a missile launching system, the cycle continues until the proper switch connections are made for the type of missile selected.

Control Relays

Control relays are used where circuit functions become so numerous that throwing switches manually would be complicated and time-consuming. Performing switching operations with relays causes the various functions to take place automatically and in the proper sequence.

Control relays come in a wide variety of sizes and shapes. Since there is such a wide variety, we will discuss only some of the more common ones. These are:

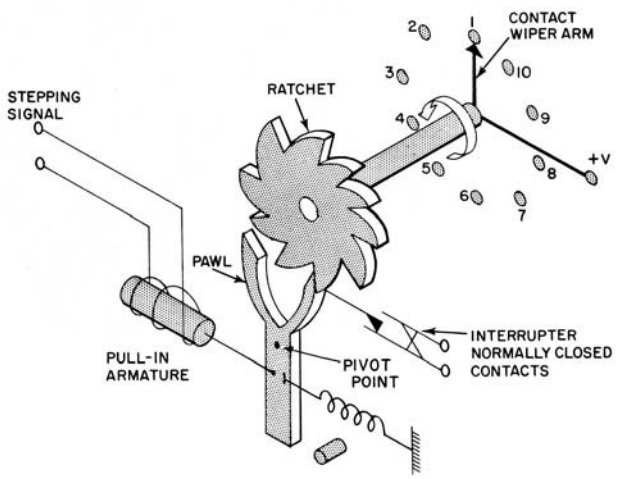


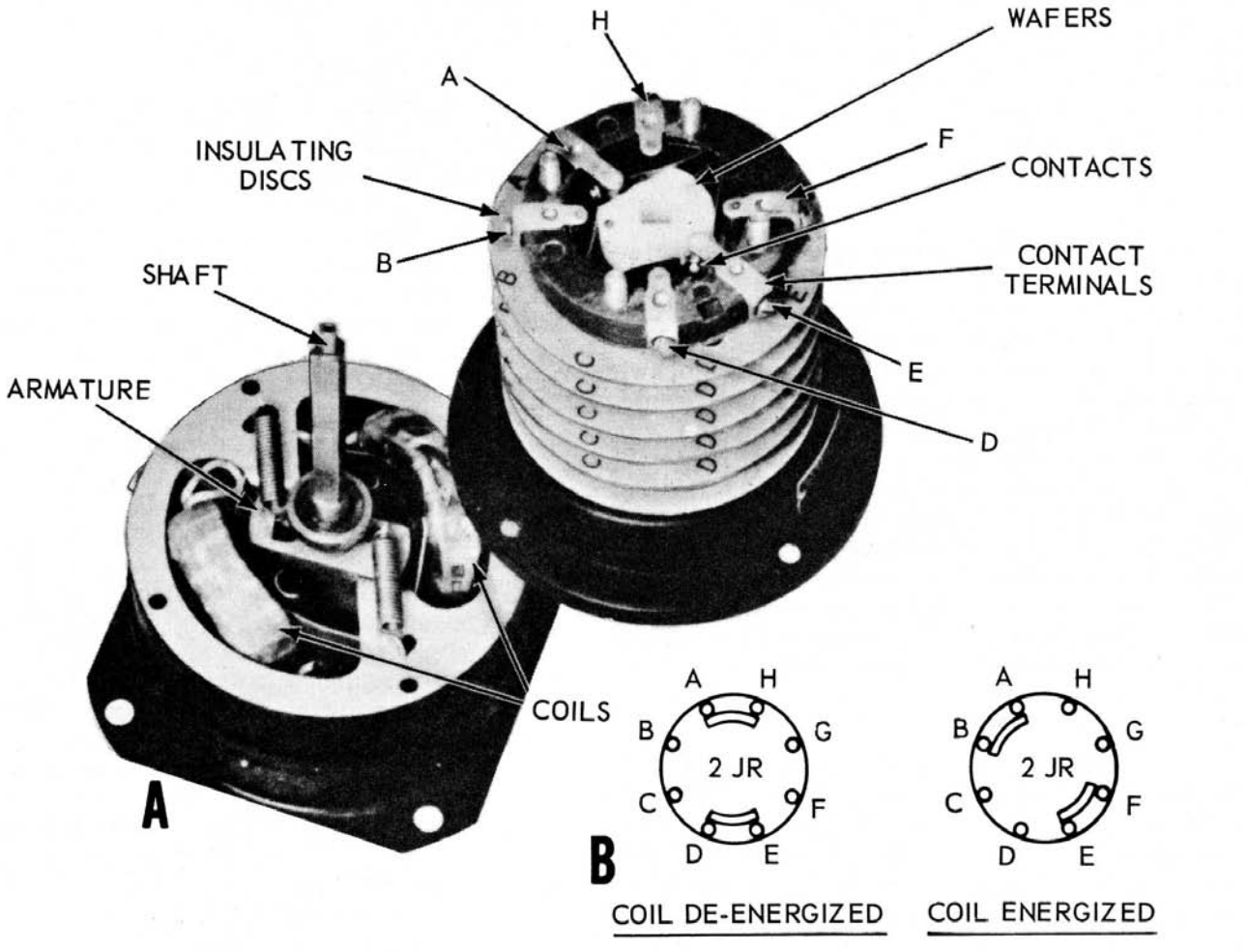
Figure 9-14. — Stepping relay operation.

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1. The rotary-type control relay. Figure 9-15 shows a typical rotary relay. You can see that it is heavily constructed to withstand shock. The coil housing consists of steel laminations with external coil input terminals. A movable coil armature is attached to a contactor-carrying shaft that extends through the contact levels. (Notice that the contact arrangement is similar to the manually operated JR switches we described earlier.) Each of the stacked contact levels (wafers or pancakes) is insulated from the other and has an eight-pole contact arrangement. When the contactor or shaft is moved, the contactor at each position provides a shorting path between two or more contacts. Deenergizing the coil allows the armature to spring back to its original position, if the relay is a nondetented type like the switch illustrated in figure 9-14. If the relay is a detented type, a second set of coils (instead of a spring) returns into armature to its former position.

Figure 9-15B shows a nondetented relay in its energized and deenergized positions. When it is deenergized, the HA and DE elements are closed, when energized, the AB and EF elements are closed.

2. Rotary relays also come in miniature and microminiature sizes. Functionally they are the same as the large rotary type we just talked about. The main difference is that the miniature and microminiature relays can be plugged in like a vacuum tube. The plug-in type is also much smaller. It has a lower current capacity and is hermetically sealed (air tight) in a can.



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Figure 9-15. — Typical rotary relay: A. Nondetented type; B. Position of elements in energized and deenergized states.

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Another type of miniature relay, not as widely used as the plug-in type, is a solder-in type known as the hi "G" relay. This relay is extremely rugged and operates on 115-v, 400-hertz current. As indicated in the schematic in figure 9-16, this relay contains only two normally closed contacts. When the relay is deenergized, a red dot is visible at the relay base.

OVERLOAD Relay

An overload relay is designed to break a circuit when the current through it reaches a predetermined value. An overload relay (fig. 9-17 shows a typical one) consists of a coil and a plunger. The plunger is attached to a disc. The disc itself is enclosed in an oil-filled chamber called a dashpot. You learned about dashpots in Fluid Power, NavPers 16193-B, so we won't cover the operating principle here.

The coil is connected in series with the device the relay is to protect. During normal operation, the magnetic flux induced by the coil is not enough to raise the plunger. But if there is an overload, the current increases through the coil. Increased current induces a stronger magnetic flux (field) in the coil and the plunger is drawn upward. If the plunger is fully drawn up into the frame, the attached disc pushes the normally closed contact for the control circuit upward. This action opens the control circuit which, in turn, controls a contactor relay in, say, the 440-volt supply to a motor. You'll see more clearly how this works when we cover the application of relays and switches in typical circuits.

During an overload, the circuit is not broken instantaneously, although the greater the overload, the faster the relay action. Since the oil holds back disc movement, the size of the disc orifice through which the oil must pass determines the delay time for a given amperage. The size of the orifice can be adjusted by turning the cap at the top of the relay housing. (See fig. 9-17.)

A thermal overload relay has a heater element (instead of a dashpot) which deflects when heated by the current passing through it, and triggers the trip latch that opens the overload contacts. As soon as the cause of the overload is corrected, the relay must be reset. Reenergization of the motor run or "start" circuit energizes the reset relay coil, and solenoid action moves the plunger, resetting the tripping latch mechanism.

Overload relays may be single or double coil. The single coil overload relay may be obtained with or without a manual latching control.

TIME-DELAY RELAYS

The time-delay relay is used to provide a time interval between separate operations. One common form of time-delay relay uses a bimetallic element which bends as it is heated. The element is made by welding together two strips of metals having different expansion rates. A heater is mounted around or close to the element. Contacts are mounted on the element itself and, as the element is caused to bend by the different expansion rates, these contacts close to operate a relay (fig. 9-18). The delay

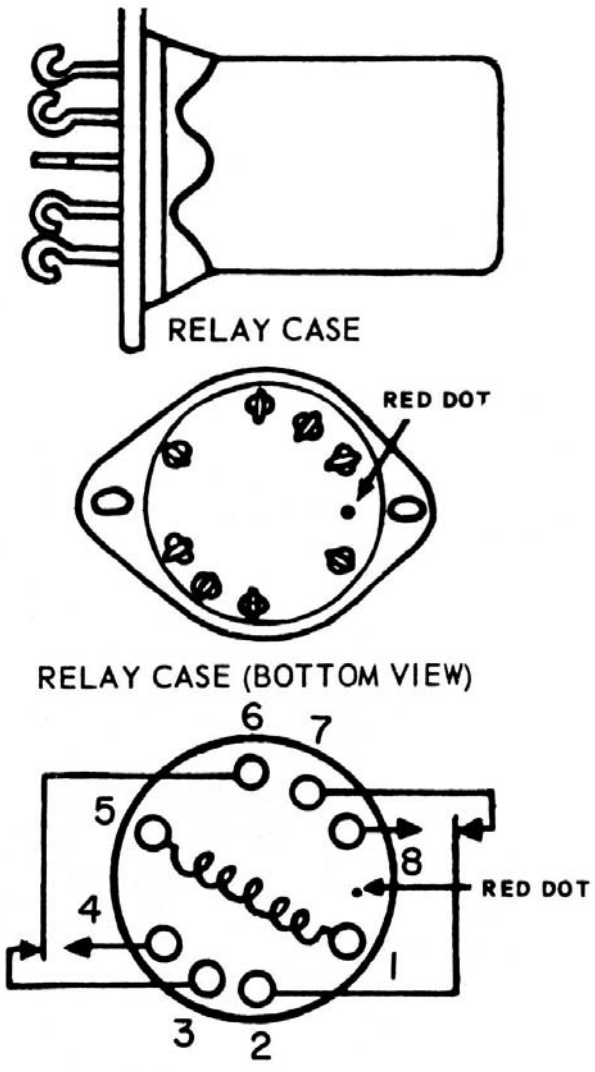
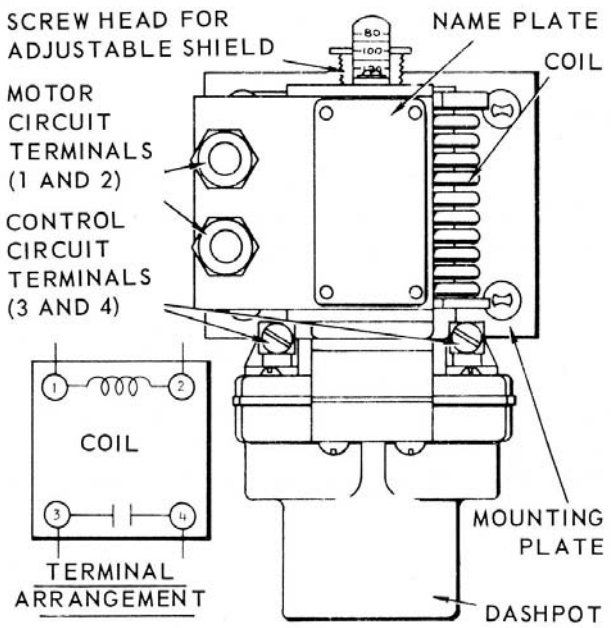


Figure 9-16. — Hi "G" relay.

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Figure 9-17. — Typical magnetic overload relay.

time for bimetallic strips is usually from 1/2 to 1 1/2 minutes and is varied by using metals with different expansion rates or by increasing or decreasing the distance between the fixed and moving contacts.

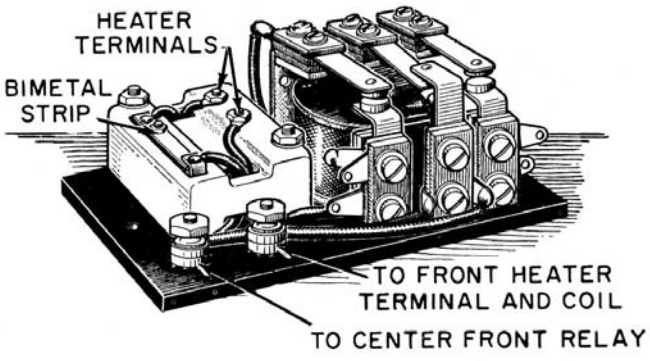
Motor-driven time-delays are frequently used. This type of relay employs a small synchronous motor and a gear train to obtain the desired delay time. A set of movable contacts is mounted on the last gear of the train, and the circuit is closed when this set of contacts is turned enough to touch the stationary contacts (fig. 9-19). Other motor-driven time-delay relays utilize a spring action to close the relay contacts. The spring is released by the gear train after a given time interval.

The air dashpot type (fig. 9-20) is used in many time-delay applications. It has many applications in missile launching systems. A magnetic coil pulls a plunger through a dashpot filled with air, the air passing through a small hole in the plunger. The time delay can be varied by changing the size of the hole in the plunger. To make a relay of this type trouble-free, a snap action of some kind must be provided for closing the contacts.

Sensitive Meter Type Relay

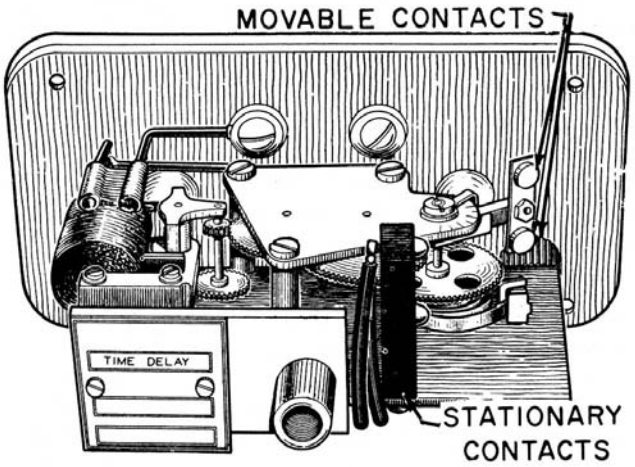
Meter relays are used in synchro changeover circuits and rocket firing. This type of relay has a moving element similar to the D'Arsonval element in a voltmeter. The moving element consists of a signal coil, a locking coil, and a contact arm.. Meter relays are extremely sensitive and accurate. Because they are used in rocket firing circuits to prevent firing a rocket whenever the launcher fine error signal exceeds, say, 20 minutes of arc, no inaccuracy can be tolerated.

Figure 9-21 shows the parts and operating principle of a typical meter relay. The relay is shown in its deenergized position. Deflection of the contact arm is proportional to the



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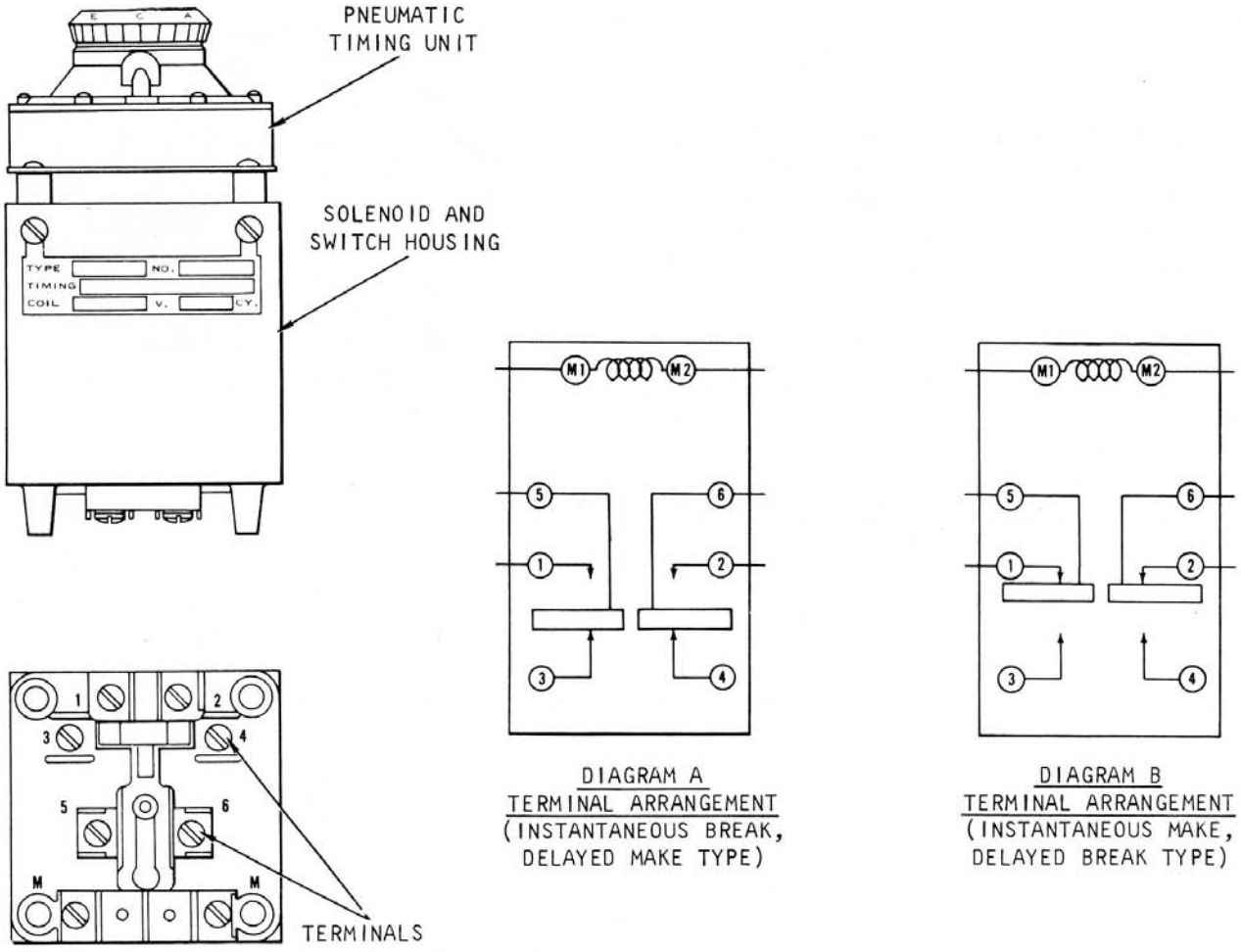
Figure 9-18. — Bimetal time-delay relay.



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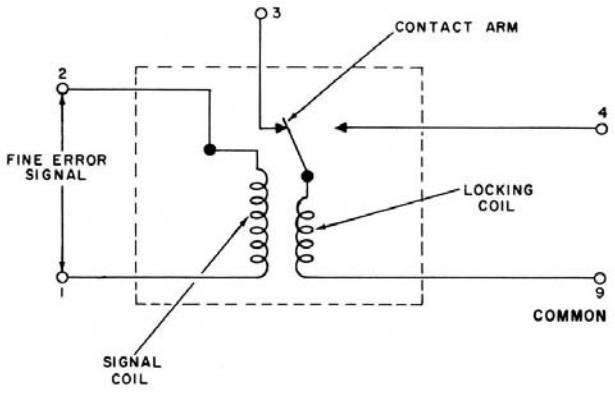
Figure 9-19. — Motor-driven time-delay relay.

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Figure 9-20. — Air dashpot time-delay relay.



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Figure 9-21. — Meter type relay; schematic.

current flow through the signal coil. The contact arm will not make contact with contact 4 until a certain current is reached. In a firing circuit the amount of current that will move the arm to contact 4 (and therefore lock out the firing circuit) is proportional to 20' of launcher position error. The locking coil helps to increase contact pressure between the contact arm and contacts 3 and 4. When either contact is made, the locking coil is energized, and this increases contact pressure.

Automatic Reset Timing Relays

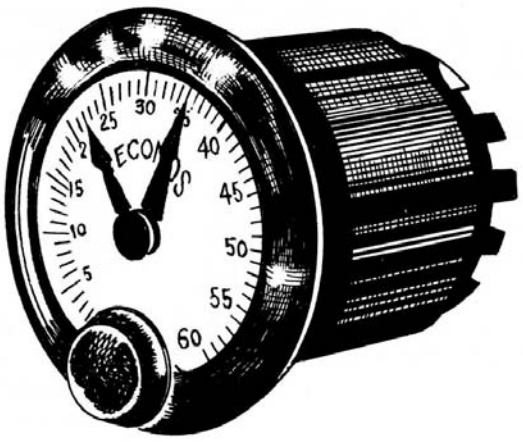
In some missile launching systems, such as GMLS Mk 11, automatic reset timing relays are used to provide accurate, adjustable delay periods between operation of a control circuit and subsequent closing of one or more load circuits. This relay can also be used as an automatic

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reset, as an interval timer, or for opening an electrical circuit at a selected interval after simultaneously energizing the load and control circuits.

This type of relay is a precision-made timing instrument. It consists primarily of a synchronous motor, a coil-operated clutch, a motor switch, a reset spring, a timing-gear-reduction unit, a red and a black pointer (fig. 9-22), a calibrated dial, and a knurled adjusting knob. Two types of timers are in use. One type resets when power is interrupted and the other type resets when power is applied.

The timing pointer (black) starts moving away from the manually preset pointer (red) when the coil-operated clutch shifts to connect power to the synchronous motor. When the black pointer reaches zero, the delay circuit is restored. The time delay may be reset immediately, or reset may be delayed until the starting impulse for the next delay cycle arrives.



83.187

Figure 9-22. — Automatic reset timing relay.

LAUNCHING SYSTEM CONTROL CIRCUITS

As you know, a guided missile or rocket launching system usually consists of three major components:

1. Launcher
2. Feeder
3. Launching system control

The latter component is made up of electrical panels, relays, solenoids, switches, and other electrical devices located throughout the launching equipment. All the mechanical, electrical, and hydraulic mechanisms in a launching system are electrically controlled by the action and interaction of the various relay and solenoid circuits of the launching system control subsystem. The control circuits regulate the application of power and the time it is applied to motors and to solenoid-operated hydraulic valves. Operation of the launching system is performed sequentially. No action - hydraulic or electric - can occur out of sequence because of the interlocking arrangement of switches and relays.

We can't show in this chapter all the various types of control circuits. There are hundreds of them in a single launching system. But we can discuss some typical examples, and show you the application of switches and relays in these circuits.

Here we will discuss a circuit using most of the basic electrical devices described earlier. In this way you will see how a circuit which looks fairly complicated at first glance is actually made up of smaller circuits. These, in turn, are made up of just a few electrical devices and their associated wiring.

POWER CONTROL CIRCUIT

The circuit we will talk about is a power control circuit. Its job is to connect or disconnect the weapons system 440-v, 60-hertz power to start and stop a motor. In figure 9-23 the power control circuit is shown in its deenergized state. You can see that all the individual circuits are arranged in ladder fashion across 440-volt a-c, and 115-volt a-c control supply lines. No electric action can take place until certain conditions have been met. Now, assume we want to start the motor. Before we can do this, all conditions imposed by the circuit must be satisfied. For example, all relays with normally opened (NO) contacts must be energized. And we must close all switches with normally opened (NO) contacts. Also, all relays with normally closed (NC) contacts must remain deenergized. When these and other conditions not mentioned are fulfilled, the circuit between the supply lines is completed. The motor then energizes and starts turning.

Let's go through the diagram step-by-step, starting from the 440-volt supply at the top of the illustration. Keep in mind as we trace through the circuit that our objective is to apply power to the motor. The first element is CBZ2,

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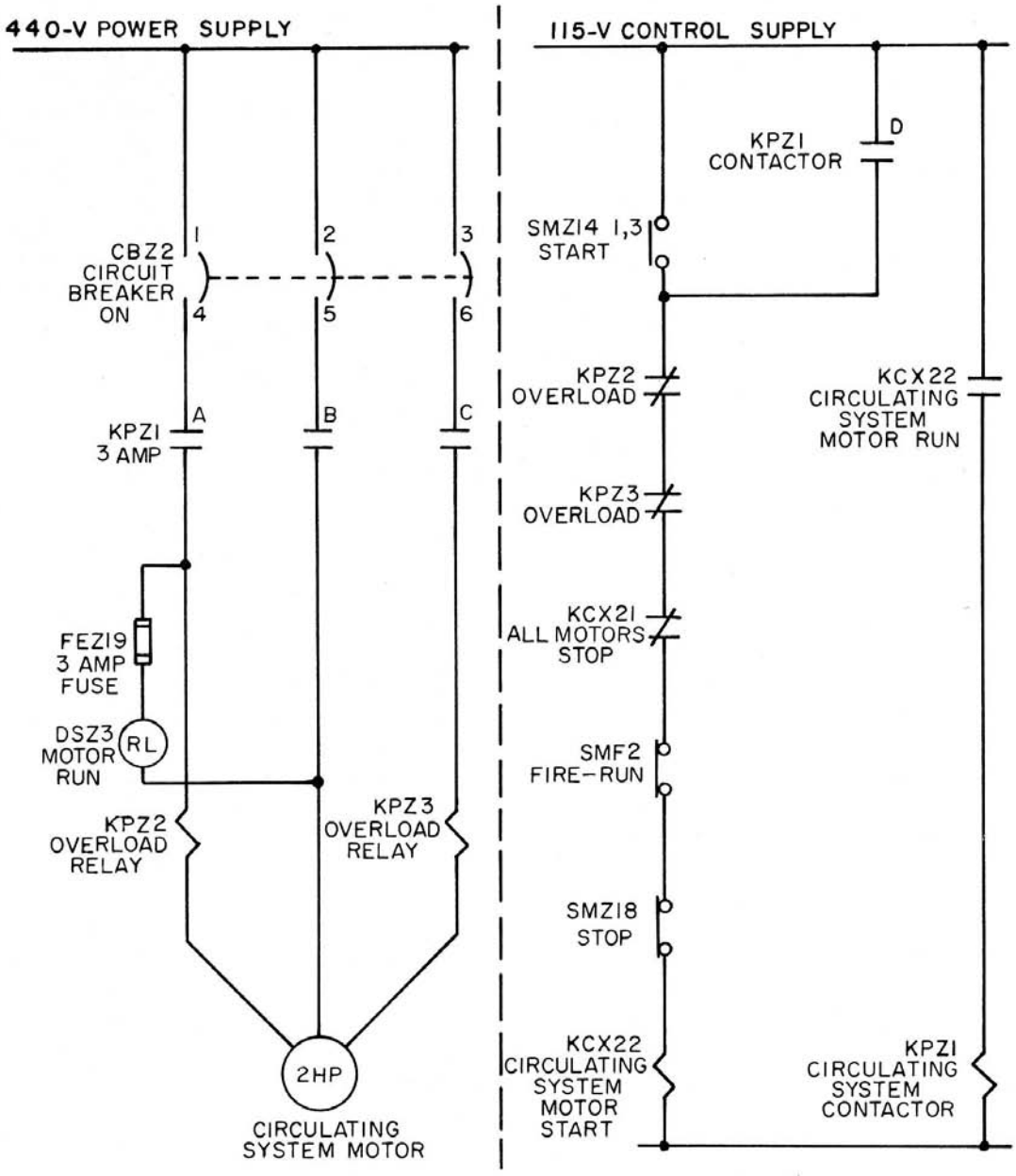


Figure 9-23. — Typical power control circuit (motor start-run circuit).

a circuit breaker. You will remember that this electrical device provides overload protection for the motor. The 440-volt supply lines are sometimes called feeders. Notice that there are no fuses between CBZ2 and the motor. The circuit breaker in our circuit is used instead of fuses because it can operate a great number of times without injury. Then, too, the action of the circuit breaker may be controlled to a greater degree of accuracy than a fuse. Fuse FEZ19, protects the light, not the motor.

CBZ2 is hand operated. It has a handle which can be turned to either one of two positions, ON or OFF. For easy access, the handle of the circuit breaker is on the front of an electrical power panel. If we turn the handle to the ON position the three sets of contacts, 1-4, 2-5, and 3-6, will close.

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The trip device in CBZ2 is a combined thermal and magnetic type of unit in which the thermal part operates on sustained overloads, and the magnetic part operates on short circuits. The tripping action allows momentary surges of current. When the motor is first started, it draws a lot more current than when it is running at normal speed. Therefore, the circuit breaker is designed so that it will not trip open when the motor is first started and line current surges. But if the circuit is overloaded for a sustained period of time, the thermal part of the tripping device will open the circuit. On the other hand, if a short circuit is present, the magnetic part of the tripping device will act instantaneously.

When an overload of any kind trips the circuit breaker, the handle moves to a point between the ON and OFF positions. The breaker is reset by moving the handle first to the OFF, and then to the ON position.

So far, we have 440-volt power to contacts A, B, and C of KPZ1, an electrically operated power contactor. Before we can apply power to the motor, we must close these contacts and then the 440-volts will have a clear path to the motor. Since KPZ1 is a line contactor, its operation is controlled from the 115-volt control circuit. You will find the coil of KPZ1 at the bottom right-hand side of the drawing. A glance at KPZ1's circuit shows that it is controlled by the normally open contacts of KCX22. Therefore, the next step in our circuit tracing procedure is to find the coil of KCX22. It is directly to the left of the coil of KPZ1.

A quick study of KCX22's circuit shows that it is a simple series-parallel circuit containing contacts of relays in the 440-volt circuit (KPZ2 and KPZ3) and in the 115-volt control circuit (KPZ1). Also included in the circuit are several switch contacts and the normally closed contacts of "All Motor Stop" relay, KCX21.

You can see now that to energize KPZ1 which, in turn, will start the motor through the closed contacts of KPZ1, we must energize KCX22. If we start tracing KCS22's circuit you can see that the contacts of the first five elem.-ants in the circuit are normally closed.

SMA18 is a pushbutton actuated sensitive switch. It is shown in its normally closed position. (The motor stops when the switch is open.) SMF2 is in its FIRE-RUN position as indicated in the drawing, and its contacts are closed. KCX21 is controlled by a switch not shown in the diagram,. and the contacts of this relay are also normally closed. Finally, the contacts of KPZ3 and KPZ2 are closed. The coils of these overload relays are in the 440-volt power circuit to the motor, as you can see at the left side of figure 9-23. Since no current is flowing at present in the motor circuit, these thermal overload relay coils should be cool, and the contacts associated with them should be closed. And they will stay closed when the motor is energized unless there is an overload in the motor or in its power circuit.

Now we have reached a point in KCX22's circuit where we can branch. We can go to the right, or we can go directly ahead to reach the high side of the 115-volt control supply. Let's go to the right. And if we do, we are immediately stopped by the open contacts of KPZ1. This relay is not energized yet. It is controlled, as you saw a moment ago, by KCX22. So, obviously we have no other choice but to back up and then go through the other parallel branch. To get through this leg of the circuit, we must close SMZ14. It is another pushbutton switch. And its contacts are spring loaded to the open position.

If we press it, its contacts close and the switch is in the start position. Turning SM Z14 to START sets off a relay chain reaction; KCX22 energizes. And its contacts in the KPZ1 circuit close. Then KPZ1 energizes. Now the normally open A. B, and C contacts of KPZ1 in the motor 440-volt supply lines close and the 440-volt supply is impressed across the motor. Then it starts rotating. Also, the light, DSZ3, glows, indicating to an operator that the power circuit to the motor is completed.

So far, so good. We have the motor running, which was our original objective. But if we release the pushbutton on SMZ14, the motor would stop if it were not for the holding circuit that bypasses SMZ14. Remember that the contacts of this switch are normally open because it is spring loaded to its OFF position. Therefore, when SMZ14 is released, it springs from its closed or RUN position to its normally open or OFF position. But releasing the switch does not stop the motor in our circuit. Notice that the D contacts of KPZ1 are in parallel with the contacts of SMZ14. So, if you release the pushbutton of SMZ14, KCX22 will remain energized, thus keeping the 440-volt supply to the motor through the contacts of KPZ1, because KCX22's circuit remains completed through the D contacts of KPZ1.

In review, there are several ideas you should remember particularly from this discussion. First, the power control circuit in figure 9-23

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is typical of the ones you will find in missile launching systems. Some power control circuits will differ in the number and types of components. But, by and large, these circuits operate on the same general principles.

Second, the power circuit is interlocked with the control circuit, and vice versa. You will find contacts of devices operated by the heavy power current in the lighter control circuit, and conversely, contacts of control circuit relays are in the power circuits. Thus, the operation of one circuit affects the operation of the other.

Third, most power control circuits will contain a holding or lock-up circuit so that the start button or switch can be released and be in a position where it can initiate another start cycle.

Finally, notice that in the circuit we have been talking about, as well as others like it, the energizing and deenergizing of relays occur in a certain order, or sequence. For example, after we manually turned the circuit breaker, CBZ2, to its ON position and then pressed SMZ14 to START, KCX22 energized. Then KPZ1 picked up (energized), and the motor started. Based on this description, you could call our network of switches, relays, and other electrical devices, a sequencing circuit.

TYPICAL FIRING CIRCUIT

Firing circuits, as you know, are used to launch missiles. Before these weapons can be launched, certain conditions in their respective weapon systems must be met. Take a missile firing situation, for example. A launcher with both arms loaded slews to synchronize with the train and elevation orders generated by the missile fire control computer. When the launcher is synchronized with the orders, a light glows on a panel within the launching system, and on the Weapons Assignment Console (WAC) at the Weapons Control Station. These burning lights indicate that the launcher is pointing the missiles in the direction ordered by the computer and not at some part of the ship or into the sky. Missiles still cannot be launched, however, unless other conditions are met. For instance, the blast doors must be shut. The launcher must be in a safe firing zone. The launcher contactor must be extended and the missiles must have been receiving warmup power for a specified length of time, 20 seconds or so. When all of these conditions exist in the missile, launcher, and feeder, another light (Ready To Fire) glows on the Weapons Assignment Console.

Now the weapons control officer can make a tentative decision to fire. He checks the tactical situation and the panel face of the WAC. And, if everything is in order, he signals the WAC operator to fire. The operator sets the Salvo Select switch, and closes the firing key. The missiles are now activated. This term means that the missiles shift from ship's warmup power generated by the missiles. Also each missile goes through a set sequence of operations preparatory for flight. Then, when the missiles are ready, the boosters are ignited. But booster ignition does not occur at the same time for each missile. First the A rail is activated on intent to launch and the time delay is activated on A rail clear (empty), 2.5 seconds later the B rail is activated. Both missiles are indicated "Ready" prior to closing the firing key.

We've just described, in a very sketchy way, equipment, circuit, and tactical conditions that must exist before missiles can be fired. To perform and to indicate that the events have taken place to meet firing conditions, thousands of major and minor physical operations (hydraulic, electrical, mechanical, and to a lesser degree, pneumatic) must take place within the launching system as a whole. Each of these operations is interlocked with another. And to describe each operation and how it affects overall system operation takes hundreds of pages of written material and many drawings.

Obviously, we cannot cover an entire missile firing operation here. Numerous circuits must be activated to get the missiles in position for firing. The firing circuit is the electrical method for igniting the primer, which, in turn, ignites the propelling charge.

Tartar Firing Circuit, General

In the Tartar GMLS, the common firing circuit includes an auxiliary power supply (APS) squib firing circuit, an intent-to-launch firing circuit, and a missile motor-squib firing circuit.

The intent-to-launch and auxiliary power supply firing circuits are applied to the missile through the launcher-to-missile connector located on the inboard fin erector arm.

The missile motor squib firing circuit is completed by the firing contacts located on the front guide. When the guide arm is loaded, the firing contacts on the front guide mate with identical contacts on the missile.

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The intent-to-launch circuit consists of the power supply for the APS squib firing transformer and the APS isolation transformer.

When the APS squibs are ignited, the missile starts operating on its own internal power, independent of the ship's power supply. When the necessary conditions within the missile are met, intent-to-launch and APS firing voltage is available to the missile motor squib firing transformer, and ignites the missile motor squib. The motor squibs ignite the booster propellant in the missile. When enough thrust is produced by the burning propellant to overcome the restraining force of the forward motion latch (about 0.03 sec.), the missile is launched.

The same sequence is followed for the missile on the other arm, which is fired shortly after the first. The missiles are not fired simultaneously, but the interval is short.

Tartar Mk 13 GMLS Firing Circuit

This rundown on the firing sequence ignores the action of the electrical components. To illustrate further how relays and switches are used to interlock and sequence events, we have taken a segment of the "Big Missile Firing Picture." Figure 9-24 shows a portion of the Mk 13 GMLS firing circuit. We have drawn only that part of the firing circuit needed to fire a Tartar missile from the arm of the launcher. For simplicity, firing mode switching circuits have been deleted. The circuit that remains performs a single function. It initiates the firing process of a Tartar missile from the arm of the launcher.

The main event in the operation of any missile launching system is the launching phase. Just before launch the missile is an integral part of its launching system. Only after launch is the weapon no longer married to the launching complex. How does this divorce take place? You will remember from chapter 3 that to ignite the booster the firing squibs are set off electrically. Squib ignition, in turn, ignites booster propellant and the resultant thrust sends the missile on its way.

Before we start discussing the circuit, we'll make a few assumptions:

1. The entire launching system is ready for operation. All power buses are energized, and hydraulic pressures are available.
2. A Tartar (DTRM) missile-booster combination has been loaded on the arm of the launcher.
3. Only a single salvo will be fired.
4. The blast door is closed.
5. The launcher is following a remote signal in train and elevation.

When the firing key on the WAC is closed, the normal firing channel is enabled. The APS electrical and hydraulic squibs will be ignited through the normal firing channel if the launcher has been assigned to a fire control system, safe firing conditions exist, and the launching system is ready to fire. The following launcher conditions must be present before the ready-to-fire relay can be energized:

1. Launcher synchronized.
2. Fins unfolded.
3. Blast door closed.
4. Launcher rail extended.
5. Launcher in safe firing zone.
6. Launcher assigned minimum of 1.8 seconds.
7. Missile warmup applied on launcher or at least 1.8 seconds.
8. Launcher warmup power enabled for 24 seconds.
9. Launcher power unit pressure normal.
10. Proper code matching between missile and selected FCS-2 or FCS-3 local oscillator in signal comparator.
11. DUD firing not ordered.

All these conditions must be fulfilled before there can be a complete path through SMF2 and SMF3 to energize KCF11.

With the Tartar missile on the launcher rail, the firing safety switches closed at the EP2 panel and at the Safety Observer's position, and the launcher assigned and synchronized to the remote signal, the electrical sequence of normal firing is as shown in figure 9-24.

Now we can start tracing the circuit. We must state that our ultimate objective is to ignite the squibs shown in the lower part of the drawing. We could start from the squibs and work back as we trace the flow of current but, by convention most GMMs start at the high side of the line, shown at the top of the page. Then they trace through the maze of switch and relay contacts until they reach the common or low side of the line. Starting at the top, left side, of the drawing the first break in the circuit is the open contacts of switch SMF2. We will consider the contacts closed because it is standard procedure for the launcher captain to turn this switch to the FIRE position after he has started up the system.

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The contacts of SMF1 are also closed. SMF1 is in its normal position because this is a normal firing situation, not an emergency one. This takes us through the first and second steps in the electrical sequence.

1. With the conditions in circuit 3-3A satisfied, the ready-to-fire relay (KCF11) is energized, and this is indicated on the EP2 panel and in Weapons Control.
2. Circuit 2 is closed by Weapons Control by closing the Normal Firing Key. This energizes relay KCF7.

Now let us look at the conditions set in circuit 3B. When the contacts of relay KCY5 are closed, it indicates that the launcher is synchronized with the computer order signals, and the firing key on the weapons assignment console is closed. Again, logical events have taken place. No one in his right mind would give the order to launch a $25,000 missile if he didn't know where the launcher was pointed. But the Navy leaves very little to chance. People do get excited when under stress and then they do some illogical things. Therefore, a "launcher- is-synchronized" interlock circuit is provided. This circuit' 'tells" the firing circuit that the launcher is, or is not, pointing the missile in the proper direction to score a hit.

As we trace further down the page we run into the contacts of KCM2 (blast door closed). On a launcher with two guide arms, the blast doors for both must be closed. Interlock switches, closed when the blast door closes, indicate to the firing circuit and other circuits that the blast door is closed.

There are several obvious reasons for interlocking the blast doors in the firing circuit. If a missile were fired with them open, blast, flame, and hot particles from the booster's jet could enter the missile magazine. The result of this we will leave to your imagination. Also, it is possible for the launcher as it trains and elevates with a missile sticking out from the arm to hit an opened blast door.

The electrically controlled, hydraulically operated fin openers automatically erect the missile control fins before the firing sequence through relays KCU3A and B. A contactor in the right-hand opener housing supplies external electrical power to the missile on the launcher.

When relay KCF2 energizes, it indicates that the launcher is pointed in a safe firing zone. Closing of the firing key indicates to the firing circuit that a human decision to launch a missile has been made. In other words, there is an "intent-to-launch" present in the firing circuit. Whether this intent will be carried out is up to the missile and various components in the launching system. In fact, as you will soon see, the missile tells the launching system and the weapons direction equipment that the missile is ready to fire.

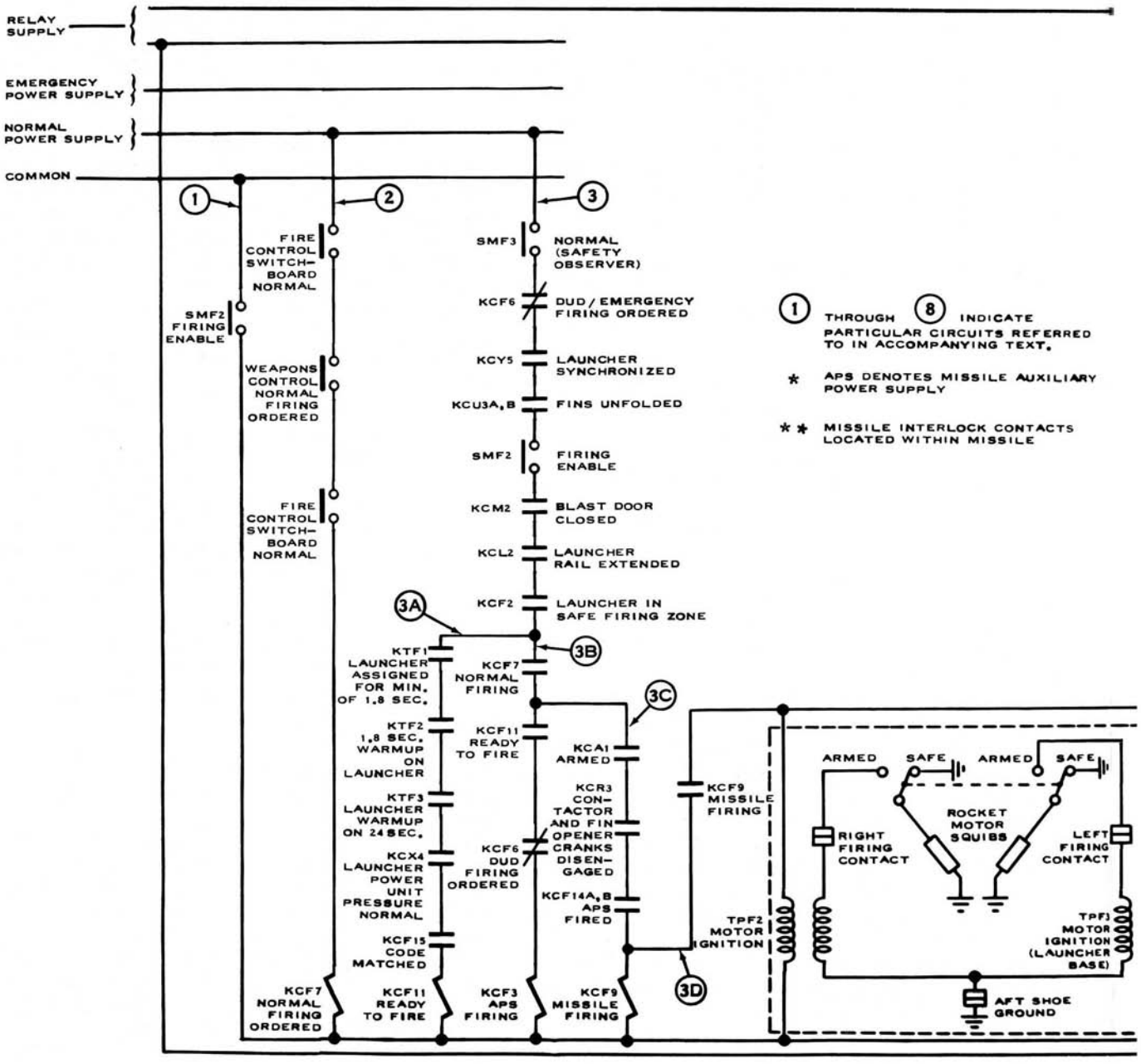
So far, we have traced the circuit up to the ready-to fire point. It is apparent that this part of the circuit is a series circuit. Also, the circuit tells a story about events that happen in the launching system. Notice that the story up to now can be told like this: When SMF2 is positioned at "FIRE", AND SMF1 is on NORMAL, AND KCM2 is energized, AND KCU3A, B and KCL2, and KCY5, are energized, AND KCF2 is energized, there is a complete path for current from the high side of the line to circuit 3B. You can see that in our short summary of circuit operation the connective word AND was used frequently. It was used to connect the description of a series of logical events that must take place before a closed path is available for current to flow from one point to another. This type of circuit is called an AND circuit. It is a term frequently used in the digital computer field and you will hear of it more and more in the missile launching system literature of the future as digital techniques continue to invade your technical area.

This brings us to step 3 in the Tartar firing circuit.

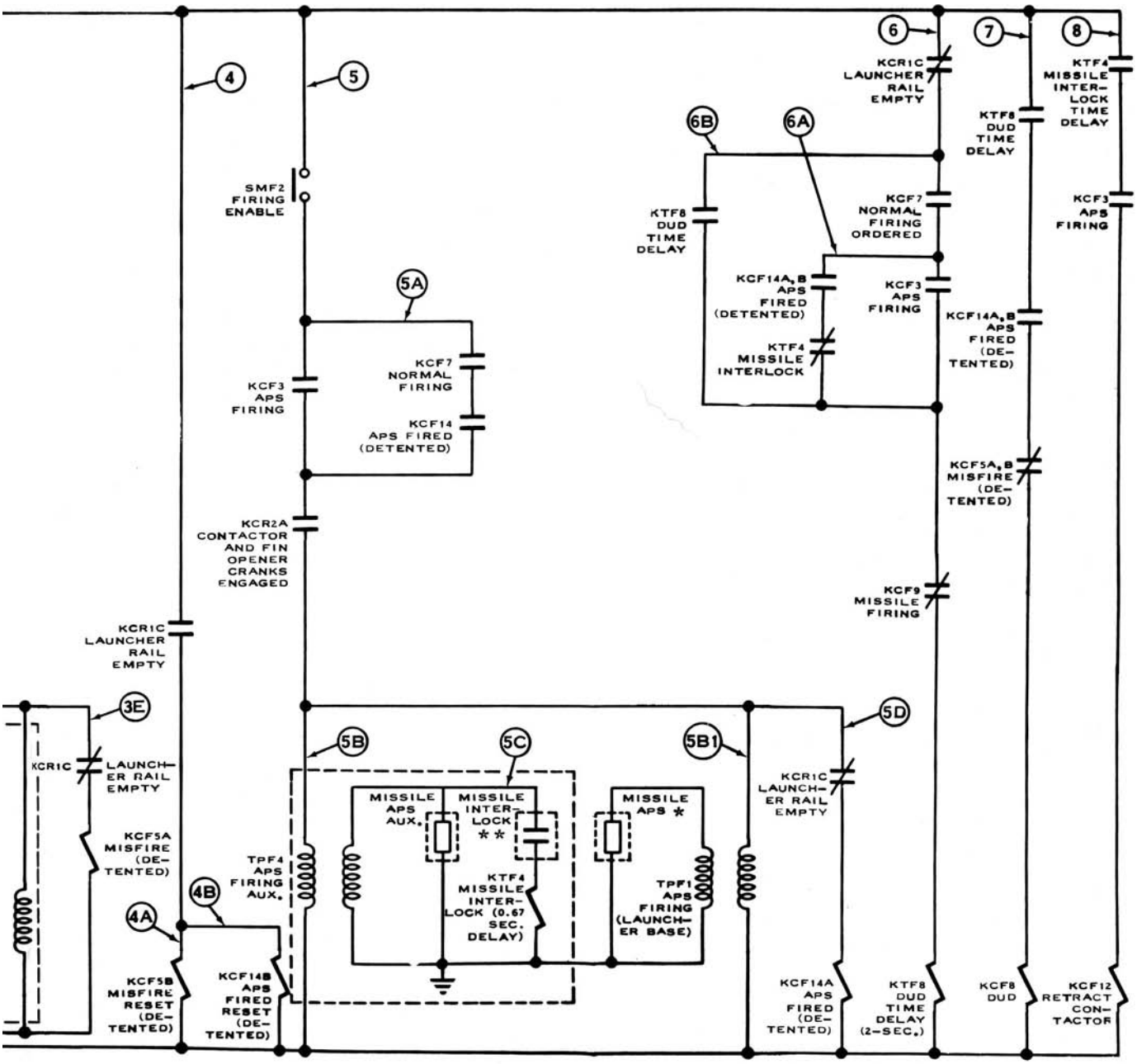
3. With the conditions in circuit 3B satisfied, relay KCF3 is energized, causing four simultaneous operations: firing of the missile APS activation squibs (circuit 5), arming of the missile and releasing the lock for the forward motion latch (circuit 3C), energizing relay KCF14A in the detented position to record that the missile squibs have been fired (circuit 5D), and energizing relay KTF8 (circuit 6) to start timing a 2-second delay. If the rocket motor squibs fail to fire within the 2 seconds, the missile is considered a dud. The dud relay is energized and the dud indications appear on the EP2 panel and in Weapons control.

The Missile Activate relay (Intent-To-Launch (ITL) relay), when energized, indicates to the missile that it should begin getting itself ready to fly. As soon as the launcher is loaded with a missile, the arming tool engages the missile arming lever on the forward shoe. When KCA1

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Figure 9-24. — Normal firing circuit, Mk 13 Launching System (Tartar).

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picks up, its normally open contacts in the parallel branch (circuit 3B) close. When contacts for KCR3 (contactor and fin opener cranks disengaged) are closed, then the launcher-to- round contactor is joined with the warmup pad (missile-to-launcher connector) on the top, located between, and aft of, missile fins Nos. 3 and 4. You remember from chapter 3 that while a missile is on the launcher waiting to be fired, the missile receives warmup power and information from sources outside itself. When KCF1 picks up, this tells the missile to get ready to switch from external power and start generating its own power.

When KCF3 picks up, it starts a lot of activity in the missile. The squibs in the missile's APS ignite (Don't confuse these squibs with the rocket motor squib), and the missile begins the power changeover process.

4. If the missile is not a dud (is activated), the firing sequence continues. The missile interlock in circuit 5C is closed which activates relay KTF4 and starts timing the O.67-second delay. This delay permits the weapon seeker head to stabilize along the axis of the missile before contactor retraction is initiated.

5. After the delay, relay KCF12 in circuit 8 is energized to retract the contactor.

6. With the missile activated and armed, and the contactor retracted, it is time to energize the firing relay, KCF9 in circuit 3C. Circuit 3D is closed to ignite the rocket squibs.

When the missile has developed enough internal power to operate efficiently, it shifts to its own power and signals this to the launching system and Weapons Control.

When the missile gives the ready-for-flight signal, the arming tool winds. This winding or rotating action arms the booster firing circuit. Completion of the arming process is indicated by the closed contacts of circuit 3E. If there were no indication to the firing circuit that the booster was armed, it would be possible to attempt to fire an unarmed booster. The Launcher Assignment Console operator would make frantic attempts to fire, but nothing would happen as he repeatedly closed his firing key. Little would he know that the booster firing circuit was open because it failed to arm. But as the circuit stands now, he knows, and the closed contacts of circuit 3E tell him that the booster firing circuit has been armed.

The contacts between the booster squibs and booster shoe firing contacts are closed when the arming tool completes its winding operation. At the end of the arming process, the arming tool and the launcher contactor retract. Now these two devices are clear of the missile and safely housed inside the launcher arm, the contacts are closed, indicating that these two events have taken place.

We assumed in the beginning of our discussion that the launcher was in a clear firing zone. So these contacts are closed. Now there is a clear field ahead for current to flow. The only resistance in its path is the coil of the booster firing relay. Now the coil energizes, and the relay picks up. To the right of the relay you will see a transformer.

When the relay is energized, a sudden surge of current flows through the primaries of both firing transformers. Then, voltage is induced in the secondaries of the firing transformers. This voltage flows through the booster shoe's firing contacts and the closed booster armed contacts to the booster firing squibs. The squibs ignite the booster propellant, and the missile round leaves the rail. (In the Tartar missile, the booster propellant is in the center of the DTRM.)

It takes only a fraction of a second for the burning propellant to build up sufficient thrust (about 2300 lbs) to overcome the restraining force of the forward motion latch and send off the missile. When the missile has left the launcher, the rail-clear lights on the EP2 panel and in Weapons Control go on.

If there is any failure, the sequence stops and appropriate action m"-1st be initiated. If the missile is a dud, it may be returned to the magazine or it may be dud fired. If it is a misfire (The APS squibs fire but the rocket motor fails to ignite.), the missile must be handled as determined by ship's doctrine.

Loss of launcher synchronization will break the firing sequence. This may occur while clearing the blind zone. If synchronization is regained in a short time, the firing operation resumes where it left off but, if the loss of synchronization is for an extended period of time, it may be necessary to fire the missile. The decision will be made by Weapons Control.

Several times we have "back-tracked" to take up the details of a portion of the complete circuit. The sequence of action is similar in different firing systems, but some may have more switches and relays than others. If you have a good concept of order of action, you can follow the action on any circuit.

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SAFETY

Probably more deaths occur from electrical shock than from anyone type of accident aboard ship. Preventing electric shock necessitates strict compliance with all safety requirements for the various work areas and strict' adherence to all prescribed safety precautions for the type of job concerned.

Current flow through the body is the cause of electrical shock. Factors determining the extent of the body damage due to electrical shock are the amount and duration of the current flow, the parts of the body involved, and the frequency of the current if a-c. In general, the greater the current or the longer the current flows, the greater will be the body damage. Body damage is also greatest when current flow is through or near nerve centers and vital organs. Sixty- hertz current is considered slightly more dangerous than current of lower frequency or d-c. This difference is small, however, and the same precautions that apply to 60-hertz a-c also apply to d-c.

Men differ in their resistance to electric shock. Consequently, a current flow that may cause only a painful shock to one man might be fatal to another. After an accident has happened, investigation almost invariably shows that it could have been prevented by the exercise of simple safety precautions which are then posted for future guidance, but which never undo the consequences of the accident that has gone before. Always observe safety precautions and keep accidents from happening.

Always remember that:

1. Electricity strikes without warning.
2. Hurrying reduces caution and invites accidents.
3. Taking time to be careful saves time in the end.
4. Taking chances is an open invitation to trouble.
5. If you do not know the safe way, it pays to find out before exposing yourself to danger.
6. Every electrical circuit, with but insignificant exceptions which definitely do not include circuits even as low as 35 volts and possibly even lower, is a potential source of danger and must be treated as such.
7. Except in cases of emergency, never work on an energized circuit. It must be considered that the circuit is energized until a personal check has been made to see that the switch is opened and tagged, and the circuit has been tested with a voltmeter, or voltage tester.

The following additional safety precautions should be helpful to you in avoiding injury to yourself and to others and in preventing damage or loss of equipment.

Always have one person available who is familiar with first aid procedures for electrical shock. See OP 2645 for first aid instructions.

Before undertaking maintenance work on launching system components, except where power-on condition is needed, position power-transfer device to OF F. This cuts off the 440- volt power source.

When working on live circuits, exercise as much care to avoid contact with low voltages as with high voltages. Assign the responsibility of energizing the equipment to a qualified operator.

Avoid unnecessary disassembly or adjustment of equipment. And when disassembling or adjusting equipment, follow instructions given explicitly.

When such items as switches, relays and solenoid coils malfunction, do not attempt to repair them. Simply replace the faulty unit with a functional spare.

Before performing work on electrical components, check yourself-wear no articles that might catch on equipment or act as a conductor.

Check the working area-be sure the deck is clean and dry; if possible, stand on a special insulator such as a rubber mat.

Check procedures - study the entire procedure before taking the first step; consult circuit diagrams frequently; know what is in the equipment.

Be aware that high voltages may be present (because of equipment breakdown) across terminals that are normally low voltage.

In general, use only one hand when servicing live equipment.

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CHAPTER 10

EXPLOSIVES, PYROTECHNICS AND MAGAZINES

One of the most important developments in the history of ordnance was the discovery of explosives. Explosives have advanced from the weak and unstable gunpowder of Roger Bacon to many types of specialized explosives. This chapter will give you a brief history and discussion of the characteristics, uses, and handling of explosives currently used by the United States Navy. It is expected that when you have learned the characteristics of the principal military explosives and something about how they work, you will handle them with respect.

It could be said that naval ordnance is the science of delivering a large quantity of explosives to the enemy and making the material explode where it will do the most damage. Your duty as a GMM in time of war will be to have the missiles assembled and checked and the launching system in top working order to launch warhead-carrying missiles.

What do you do in peacetime? You keep your skills and knowledge abreast of the system so you can keep the missile system in a "go" condition, ready for any service use.

You may already have had experience in handling explosives. You probably have operated the equipment that handles explosive-loaded missiles and their explosive components. If you are stationed where there are other types of explosives, you have probably helped with torpedo warheads, gun type ammunition, and bombs. In any case, it is wise for you to know something about explosives, as you will be associated with them throughout your career as a GMM.

Some general safety precautions to be observed in the handling and stowing of explosives are given in chapter 8 of Seaman, NavPers 10120-E. It's a good idea to review them.

DEFINITIONS

NONMILITARY EXPLOSIVES

The popular nonmilitary definition of an explosion is anything that goes BANG. It is caused by the rapid expansion of gas, accompanied by a noise. For example, when you inflate a tire, you compress the air in it. If you should have a blowout, the air expands again, and you have a small explosion.

In a nonmilitary sense, a mixture of two gases can sometimes explode. An explosive mixture can be formed by hydrogen and air. When you ignite this mixture the reaction gives off gas and heat, and the heat makes the gas expand rapidly, causing an explosion similar to a blowout.

Your car runs by BURNING a mixture of gasoline vapor and air. But under some conditions, this mixture will EXPLODE in the cylinder of your car. When a cheap gas is used, the mixture will start to burn in the cylinder when the spark ignites it. But as the gas burns, pressure inside the cylinder increases. And when this pressure reaches a certain point, the rest of the mixture explodes, making the motor "knock."

You may ask, "What's the difference between burning and exploding?" They both release energy. But the difference is in the SPEED at which they release the energy. A pound of coal has a lot more energy than a pound of TNT. But a missile warhead filled with coal would be a dud. The coal cannot release the energy fast enough to cause an explosion.

Sometimes, however, coal dust (or any other dust that will burn) can explode if it is suspended in the air. Maybe you've read about dust explosions in coal mines, flour mills, or threshing machines.

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MILITARY EXPLOSIVES

None of the examples we have given are military explosives. What, then, is a military explosive? Many explosives have been studied for possible suitability for military use. But only a few of them can meet the requirements. Some desirable properties of a _military explosive are:

1. Relative insensitivity to friction and shock; not liable to be detonated by small arms fire.
2. Proper detonating velocity for intended purposes.
3. High power per unit weight.
4. Sufficient stability to retain usefulness for a reasonable time in any climate.
5. High density (weight per unit of volume).
6. Positive detonation by easily prepared primers.
7. Suitability for underwater use.
8. Convenient size and shape to facilitate packaging, shipping, and handling.

PROPELLANTS

The term PROPELLANT is frequently used in connection with guided missiles and space craft. Often it is called fuel. In older military texts it was called a low explosive. As such, it was defined as a slow-reacting explosive which burned rather than exploded. In missiles, the booster propellant is what gives the push or boost to the missile to start it on its way to the target, and the sustainer propellant carries on after booster burnout. Actually, it is not slow at all, it only seems slow in comparison with a high explosive. The example of the Tartar, in the previous chapter, illustrates this. A buildup of nearly 2300 lbs. thrust in a fraction of a second of burning is not slow. A propellant must burn, however, and not explode. The amount of thrust per unit weight of propellant varies with the type of propellant. See chapter 3 on thrust buildup. The search for a more powerful propellant is continuous, and is needed especially for space launchings.

In addition to being powerful, the propellant must be safe to handle and store. With few exceptions, solid propellants have been used in missiles because they are easier to handle and store than liquid propellants.

Now that you know some of the properties of a military explosive, let's take a quick look at the development of explosives.

HISTORY OF EXPLOSIVES

For many centuries black powder was the only known explosive. It was in the 13th century that Roger Bacon, an Englishman, discovered black powder. There is evidence that the Chinese knew the effects of gunpowder several centuries before this era. The Greeks used a product related to gunpowder, called Greek fire, and a number of experimenters in Europe had made combinations of chemicals that made explosive substances, but the mixture made by Roger Bacon was the beginning of our modern product.

In the 14th century. Berthold Schwarz. a German, invented a gun and used black powder to propel stones from it. This may be considered the real beginning of the history of military explosives. In spite of other developments, black powder remained a major military explosive through the 19th century.

Modern history of explosives began in 1838 when Pelouze, a French chemist, prepared nitrocellulose by nitrating paper. But it was not until. 1845 that Schoenbein, a German chemist, discovered guncotton. He found that nitrated cotton burns quietly in the open, but when confined in a small space, it can explode violently.

Shortly after the discovery of guncotton, Sobrero, an Italian chemist, experimented with nitroglycerin. He found that even a small shock or jar would make it explode. This sensitivity factor makes nitroglycerin useful commercially, but of no use for the military.

But in 1866, Alfred Nobel of Sweden found that he could make nitroglycerin safe to handle by soaking it up in Kieselguhr - a porous kind of earth. He called the mixture DYNAMITE. Today there are many types of dynamite, but they are all nitroglycerin soaked up in some kind of porous material. Dynamite is one of the most important commercial explosives today, but it has little military value.

Black powder has many disadvantages as a projectile propellant. For one thing, it made big clouds of black smoke that blocked the gunner's view of his target, and interfered with his aim for his next shot. For another, it fouled the gun barrel with unburned particles and with glowing coals that made reloading dangerous. It also revealed the location of the gunner.

So chemists began trying to make a smokeless powder that would not foul the gun bore. The Prussians were the first to succeed. About 1884, the French produced the first practical

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military smokeless powder. They called it Poudre B. It consisted of nitrated cotton, gelatinized and mixed with paraffin or vaseline.

In 1887, Nobel invented BALLISTITE, a double-base smokeless powder made of nitrated cotton and nitroglycerin.

(This is the Alfred Nobel who set up the trust fund and established the conditions for the Nobel Peace Prize awarded each year to some person adjudged to have done outstanding work in the promotion of peace.)

In the same year, the British began producing CORDITE. Cordite has the same ingredients as ballistite, with vaseline added.

Picric acid was probably the first high explosive to be used extensively as a bursting charge. For over a hundred years after it was discovered (1771), picric acid was used as a yellow dye, before it was found that it was a high explosive. During World War II, the Japanese used picric acid as their favorite bursting charge. The American Forces used a related compound - ammonium picrate, better known as Explosive D.

Prior to World War II, all mines, depth charges, depth bombs, and torpedoes were loaded with TNT. To provide a larger explosive force, Torpex was developed; it is far more powerful than TNT. Torpex proved to be unstable and was replaced by HBX. The need for powerful blast effect led to further developments of such explosives as Tritonal, Minol, and RDX. RDX is used extensively in mixtures with other explosives as a filler for missile warheads.

The expanding techniques of modern warfare lead to more and more specialized requirements for explosives. Future developments may be chiefly mixtures of currently known explosives with other materials. But in some cases, the requirements can be satisfied only by new and more powerful explosives, which are presently being sought.

CHEMICAL NATURE OF AN EXPLOSION

The chemical reaction that takes place during an explosion can be either of two types, depending on the nature of the explosive.

Black powder, for example, explodes by oxidation. As you've probably heard, it's a mixture of potassium nitrate, charcoal, and sulfur. All three are solids. To produce an explosion, you apply heat to the mixture. What happens? At the point where you apply heat, the potassium nitrate (KNO_3) gives up its nitrogen and part of its oxygen. The sulfur and charcoal combine with oxygen to form sulfur dioxide, carbon dioxide, and carbon monoxide. All three of these are gases.

In burning, the sulfur and oxygen release heat that does two things. First, it increases the pressure of the gases. Second, it spreads the reaction to all the nearby particles of powder. The reaction continues through the mixture, at the rate of several hundred feet a second, until all the powder has burned.

Other explosives, such as TNT and nitroglycerin, have a different reaction. Each is a chemical compound, rather than a mixture. (In a mixture, two or more ingredients are commingled but not changed; in a compound there is a union of two or more ingredients in a definite proportion, resulting in a new substance.) But the molecules of the compound are highly unstable. You might say there's a "tension" inside them. You start an explosion by applying a shock or a sharp jolt, rather than heat.

When it gets jolted, the unstable molecule flies apart, releasing energy in the form of heat. It usually releases two gases - nitrogen and nitrous oxide. It may also release oxygen, which combines with hydrogen and carbon in the molecule to form gases. The heat not only increases the pressure of the gases, but converts all the other products of the reaction into gas. The sudden release of energy applies a jolt to all the nearby molecules, so that the reaction travels through the whole mass of explosive. (In TNT and other high explosives, the reaction travels through the mass at a speed of several miles a second.)

CLASSIFICATION OF MILITARY EXPLOSIVES

We can classify military explosives by their composition, the nature of their reaction, their sensitivity, the way we initiate the reaction, and by the way we use them in service.

COMPOSITION

By composition, we can divide military explosives into two groups - explosive mixtures and explosive compounds.

An explosive mixture always includes a substance that can burn (such as carbon or sulfur) and a substance that can supply the oxygen for burning (such as a nitrate or a chlorate). We can change the characteristics of the explosive, within limits, by changing the proportion of its ingredients. The most familiar example of an explosive mixture is black powder.

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An explosive compound has a fixed chemical composition. So we can't change its characteristics by changing the proportion of ingredients. (But both the degree of purity and the size of the particles affect its explosive characteristics.)

To make these explosive compounds, the manufacturer usually starts with a hydrocarbon- an organic compound of hydrogen and carbon. He then makes the molecules unstable by a process called nitration, which adds nitrates or nitro compounds to various parts of the molecules. A detailed description of the manufacturing process, replete with pictures, is given in OP 5, Vol. 2, Ammunition Ashore, Production and Renovation. Familiar examples of explosive compounds are TNT, cellulose nitrate (used in making smokeless powder), ammonium picrate, and tetryl.

(There are some explosives that won't fit in either of the above classes. For example, dynamite is a mixture of nitroglycerin and some absorbent substance such as sawdust. Ballistite (used as a rocket propellant) is a mixture of nitroglycerin and cellulose nitrate.)

NATURE OF THE REACTION

We can divide military explosives into low and high explosives, according to the speed at which the reaction takes place.

In low explosive, the change to gas is comparatively slow; actually, it's fast burning. We call this reaction deflagration. In this reaction, the particles burn in rapid succession. The heat from one burning particle ignites the unburned particles next to it, and so on until all the explosive has burned. Black powder, smokeless powder, and ballistite are all low explosives. The term low explosive, however, has been dropped from military terminology in favor of the term propellants. Propellants are distinguished from explosives (in military usage) by their function, which is to propel projectiles, rockets, guided missiles, depth charges, and other munitions from guns or launchers, to the target. They can be made to burn at controlled, predetermined rates to produce the gases which develop the high pressure and provide the propulsion force. Propellants can be made to detonate under certain conditions, mentioned below.

When you set off a high explosive, the first particles to explode send a shock wave through the whole mass of explosive, and the change to gas is almost instantaneous. We call this reaction detonation. Dynamite, nitroglycerin, TNT, HBX, and RDX are all high explosives.

The violence of an explosion depends on how fast the explosive detonates, how much gas it produces, and how hot the gas is. The speed of detonation depends on the kind of explosive, how dense it is, and how tightly it is confined. For example, a thin layer of black powder in the open will burn without exploding. In the barrel of a torpedo tube, an impulse charge of black powder will burn fast enough to furnish the necessary push for firing the torpedo. But if it's very tightly confined, black powder will sometimes detonate like a high explosive.

When a low explosive (propellant) deflagrates, the hot gas gradually builds up pressure and applies a pushing force to anything around it. When a high explosive detonates, the pressure builds up so fast that it has a shattering effect, rather than a pushing effect. The shattering effect of an explosion is often called brisance. A brisant explosive is one in which the pressure builds up rapidly.

SENSITIVITY

Explosives differ greatly in the amount of energy it takes to set them off. The most sensitive explosives will detonate if you give them a small jolt. The least sensitive will usually absorb a lot of punishment without detonating. (But you can't depend on it; all explosives must be handled carefully.)

A good example of an insensitive explosive is ammonium picrate (Explosive D), which is used to fill armor-piercing projectiles. An armor-piercing projectile must not explode until it's detonated by its fuze, after it has penetrated the enemy armor. Ammonium picrate is insensitive enough to resist the shock of firing from a gun, and the shock of impact against armor plate. But when it does go off, it's almost as powerful as TNT.

Some of the most powerful explosives are among the least sensitive. HBX, for example, is a powerful explosive, but it usually takes a severe shock to make it detonate.

When we select an explosive for any special purpose, sensitivity is an important thing to consider. The main charge in a warhead must be fairly insensitive, so that it will be reasonably safe for you to handle. A booster charge must be more sensitive than the main charge. And a primer or a detonator must be quite sensitive, so that a fairly small shock will start the explosion.

But even primers and detonators can't be too sensitive. They must be safe to handle; and in a missile warhead, they must resist the shock of

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launching. A few explosives are too sensitive to be of any military use at all. Nitrogen tri-iodide, for example, is so sensitive it will explode if you touch it.

Figure 10-1 shows you the explosive train that takes place in an armed missile warhead when the firing system is actuated by a proximity fuze. (The proximity fuze is actuated by the target.) The detonator is then fired by the electric current from the fuze. The detonator in turn fires the booster charge. The shock from the booster causes the disrupting (main) charge to explode, causing the explosion that destroys the target.

The safety and arming device (S&A) makes sure that the warhead cannot detonate until the missile is a safe distance from the ship.

METHOD OF INITIATING THE EXPLOSION

The two most common ways to initiate an explosion are by heat and shock. We use heat to initiate the low explosives used for propellants and impulse charges. In guns, torpedo tubes, and depth charge projectors, the flash of flame from a primer provides the heat. The primer contains a small amount of extremely sensitive explosive. It may be set off by a spark from an electric squib, by the shock of a firing pin striking it, or by other means. The flash of flame ignites the propellant. A primer may be used to initiate a detonator.

Only the most sensitive of high explosives can be reliably detonated by heat alone. To initiate the high explosive charges of projectiles, torpedoes, depth charges, and missile warheads, we apply a strong, sudden shock. To provide the shock, we use a smaller charge of a more sensitive high explosive, either in contact with the main charge (burster, fig. 10-1) or very near it. The smaller charge can be detonated by heat, or by the shock of a firing pin.

AUXILIARY CHARGES

In many instances an intermediate or auxiliary charge is needed between the initiator and the main

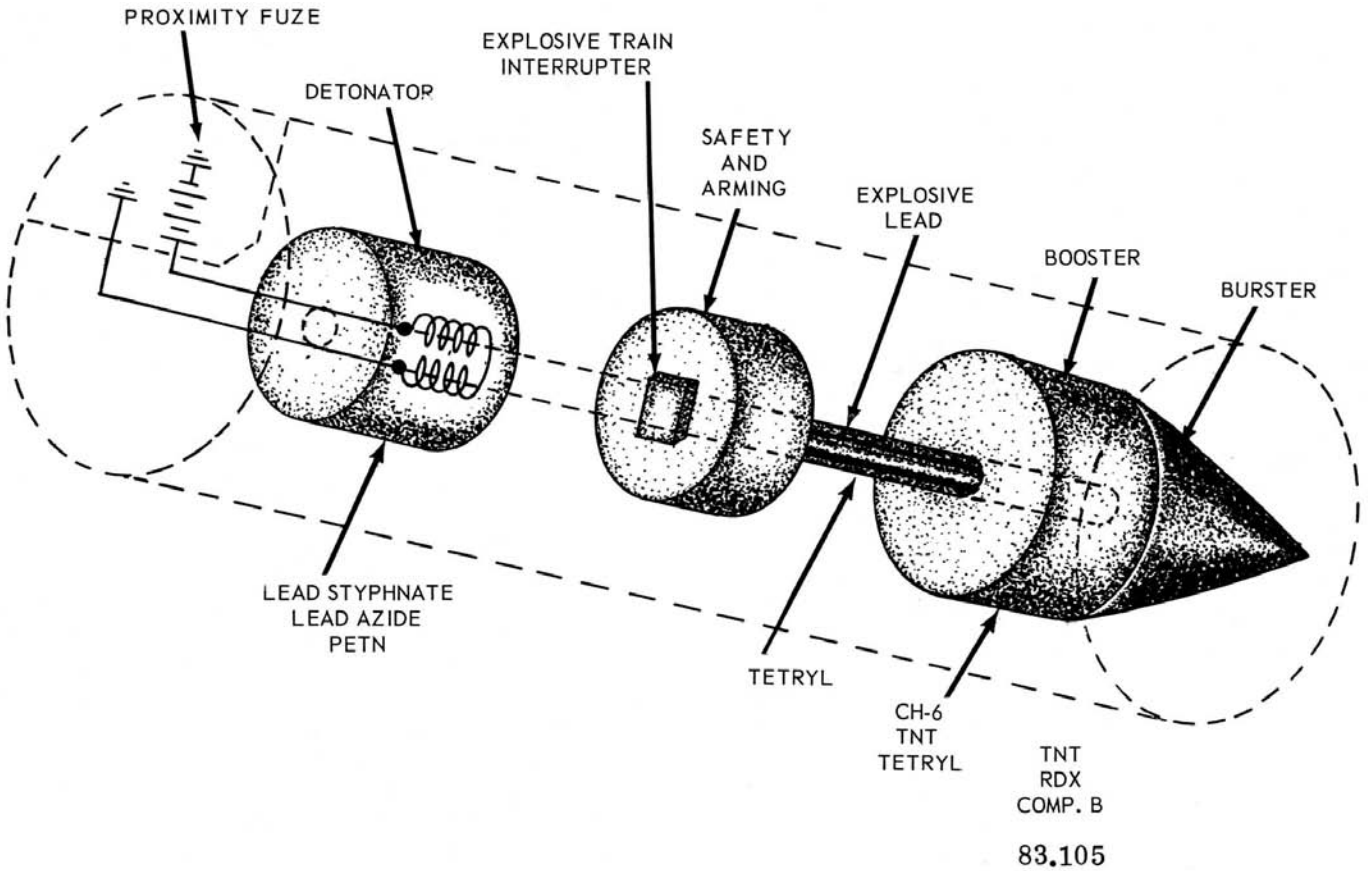


Figure 10-1. — Explosive train in a missile warhead system.

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charge of explosive to ensure successful initiation. An auxiliary charge used with a bursting charge is called a booster (fig. 10-1). It consists of a moderately sensitive high explosive to increase the shock of the detonator. Thus, the basic high explosive train consists of the detonator, booster, and bursting charge, but often there are auxiliary parts. Such a train might include a primer, delay pellet, detonator, booster, auxiliary booster, and burster.

INFLUENCE DETONATION

A third way to initiate an explosion is by influence. You can sometimes detonate a charge of a high explosive by exploding another charge near it. In that case, we say that the second charge explodes by sympathetic detonation. (But it is the shock provided by the first explosion that causes the second one.) This is the technique used in missile warheads.

The distance at which an influence explosion can occur depends on several things: first, the amount and brisance of the first explosive; second, the sensitivity of the second explosive; and third, the material that lies between the two charges. For example, the shock wave will travel a considerable distance through steel, a shorter distance through water, and not far at all through air.

SERVICE USE OF EXPLOSIVES

According to their use in service, military explosives can be divided into four classes:

1. Propellants and impulse explosives
2. Disrupting explosives
3. Initiating explosives
4. Auxiliary explosives

We use propellants and impulse explosives when we want a steady PUSH. For example, when we fire a projectile from a gun we want a pushing force. We want this force to continue as long as the projectile is in the bore, so we use a low explosive-smokeless powder. For the impulse charge in torpedo tubes and depth charge projectors, we use black powder, another low explosive. To propel a missile, we use a double-base compound; that is, a combination of two propellants bound together by small amounts of other ingredients. Figure 3-23 shows different shapes of propellant grains and the text discussed methods of controlling burning rate.

We use a disrupting explosive when we want a shattering effect. When we fire a missile at an aircraft, we want the missile's warhead to shatter into fragments, so we use a disrupting explosive.

High explosives such as TNT J RDX, and HBX are all disrupting explosives.

We must choose explosives carefully, so that each will do the job we want it to do. Both a low and a high explosive may release the same amount of energy, but there is a difference in how fast they release it. Here is an example. Suppose your car is stalled with a dead battery, and you ask your friend for a push. What you need is a steady push, applied over a distance of 20 or 30 yards, so that you can accelerate to starting speed. Your friend could apply the same amount of energy to your car by crashing into the back of it at 50 miles an hour, but that wouldn't help you get started.

For this same reason, you wouldn't use TNT for a propelling charge in a missile booster. If you did, it would blow the booster case to bits. You'd think twice before you tried it again, if you were still alive.

As we explained earlier, you must apply energy to make a charge explode. For that purpose we use an initiating explosive. To ignite a propellant, we need a flame. To detonate a disrupting charge, we need a shock. We often use lead azide mixed with some flame producing material as an initiator for both propellants and disrupting charges, because it produces both a shock and a flame.

We use a primer to ignite a propellant. A common primer is a small container that holds a pellet of fulminate of mercury and a small charge of black powder. When you fire it, it produces a long spear of flame that ignites the propellant.

We use a detonator to set off a high explosive charge. The detonator usually contains a charge of lead azide or fulminate of mercury, either alone or combined with granular TNT or tetryl. When it's fired, it provides the shock that detonates the main charge.

With a big charge of propellant explosive, or with relatively insensitive high explosives such as TNT, we need an auxiliary explosive between the initiator and the main charge. The auxiliary explosive provides enough heat or shock to make sure the main charge goes off properly. The intermediate charge we use with propellants is called an ignition charge. It consists of granular black powder. With high explosives, the intermediate charge is called a booster.

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It consists of a moderately sensitive high explosive, such as granular TNT, tetryl, or CH-6 (fig. 10-1).

Look back at chapter 3 and 4 and the illustrations of the main components of missiles. Several of the pictures point out the booster, which contains propellant. Figure 3-27 shows the location of the igniter in the BT-3 missile. Figures 3-30 and 3-31 show the booster propellant and the sustainer propellant in the Tartar missile. The booster, sustainer, and warhead are pointed out in several of the drawings in chapter 4.

CHARACTERISTICS OF MILITARY EXPLOSIVES

Here are some of the most common military explosives, and some of their characteristics. Many of them you will actually handle, either as impulse charges or in the warhead, booster, or detonator of missiles. We've included a few others in the list, just to give you some background information on other explosives the Navy uses. The list is in alphabetical order, so you can use it for future reference.

AMATOL is a high explosive, made by mixing TNT and ammonium nitrate in various proportions. The Navy has used it from time to time as a bursting charge for projectiles. A 50-50 mixture is just as powerful as TNT, and it's cheaper. Its chief disadvantage as a projectile filler is that it is very hygroscopic (absorbs moisture readily), although it stores well if protected against moisture. When fired, it makes practically no smoke. A TNT explosion produces a cloud of black smoke, which makes spotting easy. In wartime, if there were a shortage of other high explosives, the Navy could use amatol as the main charge in mines.

AMMONIUM NITRATE is a high explosive. The Navy has little use for it, except in making amatol. Ammonium nitrate is quite insensitive, yet it is a powerful explosive. It is used extensively in making commercial dynamite.

AMMONIUM PICRATE. (See Explosive D.)

BALLISTITE is a low explosive mixture, of almost equal parts cellulose nitrate and nitroglycerin. It was one of the first military smokeless powders, and at one time it was widely used as a propellant. But as a propellant, it causes serious erosion of the gun bore. The Navy no longer uses it, except as a rocket propellant and in some guided missile boosters and sustainers.

It is very useful for that purpose, since it burns evenly and uniformly at the low pressures developed in a rocket motor.

BLACK POWDER is a low explosive mixture that burns very fast when it's confined, even slightly. For many years black powder was the universal military explosive. It served not only as a propellant, but also as the bursting charge for projectiles and torpedo warheads.

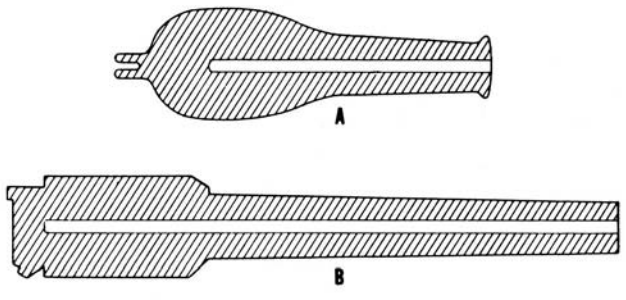
Black powder is now obsolete for both these uses. As a propellant it burns too fast; as a bursting charge it burns too slowly. Figure 10-2A shows a profile of one of the old-time guns that used black powder. The breech end of the barrel had to be thick, to keep the sudden force of the explosion from breaking it. And the barrel had to be short; the gas from a black powder explosion can't maintain its pressure for any great distance of projectile travel.

Figure 10-2B shows the profile of a newer gun. Since smokeless powder burns slower than black powder, the thick breech is no longer necessary. And the barrel is much longer.

The Navy still uses black powder for some purposes. You can change the burning speed to some extent by changing the size of the grains. The bigger they are, the slower they burn.

At present, the Navy uses five different sizes of black powder grains. The largest ones are 6-sided grains with rounded ends. The next smaller size is called cannon powder. We use it as an ignition charge for turret-gun powder bags. We use the three smaller sizes either alone or combined with other explosives - as burster charges for special projectiles, in primers, and in fuze delay trains.

If kept dry, black powder will remain stable almost forever. Moderately high temperatures don't affect it. But black powder deteriorates when it's damp.



4.39

Figure 10-2.—Gun barrel profiles: A The old look, for black powder; B. The new look, for smokeless powder.

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When it's exposed, black powder is probably the most dangerous explosive you'll find aboard a Navy ship.

It's extremely sensitive to shock, friction, and sparks - including those too small to see. If spilled on the deck, you can ignite it by walking On it. So, if you should spill any, you'll have a dangerous situation. Wet the powder immediately, scoop it up, and heave it overboard. Be sure the powder is thoroughly wet before attempting removal. A small spill can be covered with a dripping wet cloth to saturate it before wiping it up. All work in the area must be suspended until the powder is cleaned up.

CH-6 is a mixture of RDX (97.5%), graphite, and other chemicals which reduce the mixture's sensitively.

COMPOSITIONS A, B, C, (See RDX.)

CORDITE is a smokeless powder. It is the standard British propellant. It is cheaper than our smokeless powder, and it has a more uniform action in the gun. But we don't use it because it quickly wears away the gun bore.

CORDITE N (SPCG), a later development, avoids this drawback. Cordite N is very cool burning with very little smoke and no flash. It is a triple-base propellant, rather new in the U. S. Navy. It is an opaque, chalk-white color, and yellows with age.

CYCLONITE. See RDX.

DYNAMITE is too sensitive for military use. We rarely use it even for demolition work, because a stray rifle bullet could make it detonate.

EXPLOSIVE D (ammonium picrate) comes in the form of red or yellow crystals. It's almost as powerful as TNT, but not nearly as sensitive. That makes it useful as a burster charge in armor-piercing projectiles and armor-piercing bombs. (A projectile gets a very severe shock when it strikes armor plate. But, to be effective, it must not detonate because of that shock. It must be detonated only by its fuze, after the projectile has penetrated the armor.)

For a long time the composition of Explosive D was a secret. That is why we spoke of it in code, rather than by its right name.

FULMINATE OF MERCURY (mercury fulminate) is a yellowish-white crystalline powder. It's the most sensitive explosive in common service. We can use it for only one purpose: to initiate the action of other explosives, either directly or through an auxiliary explosive. In primers, it may be mixed with other flame-producing materials.

GUNCOTTON, a form of cellulose nitrate, was the first modern bursting charge. Its early uses included loading into mines and torpedo warheads. Because of its sensitivity when dry, its susceptibility to deterioration, and its relatively low power, guncotton has generally been replaced by TNT and other explosives.

HBX is one of the most important developments in the field of explosives. It was developed by the U. S. Navy to take the place of torpex because torpex is too sensitive. HBX is very nearly as powerful as torpex, but much less sensitive. It is chemically stable and noncorrosive, and is in the same general class as TNT for safety in handling. HBX-1 and HBX-3 are used as explosive fillers in underwater ordnance, replacing TNT filler.

LEAD AZIDE has a high temperature of ignition and is less sensitive to shock and friction than mercury fulminate. The brisance of lead azide increases as the pressure applied to it increases. It is less brisant and has less explosive power than mercury fulminate.

Lead azide is poisonous, slightly soluble in hot water and in alcohol, and very soluble in a dilute solution of nitric or acetic acid in which a little sodium nitrate has been dissolved. Lead azide reacts with copper, zinc, cadmium, or alloys containing such metals, forming an azide which is more sensitive than the original lead azide. Because it does not react with aluminum, detonator capsules for lead azide are made of this metal. The hygroscopicity of lead azide is very low. Water does not reduce its impact sensitivity, as is the case with mercury fulminate. (See OP 5, Vol. 1 for instructions if you must destroy some lead azide. Ammonium acetate and sodium dichromate are used to destroy small quantities of lead azide.) The velocity of detonation of lead azide is approximately 17,500 feet per second. Its color varies from white to buff.

Lead azide may be used where a detonation is caused by flame or heat. It has been adopted as the detonator of major caliber base-detonating fuzes, of point-detonating fuzes, and of auxiliary-detonating fuzes. It is also used in priming mixtures.

Lead azide is completely stable in storage, even at high temperatures. However, it produces an intensely poisonous, highly flammable gas when enclosed.

LEAD STYPHNATE comes in two forms - (1) the normal, which appears as six-sided monohydrate crystals, and (2) the basic, which appears as small rectangular crystals. Lead styphnate is particularly sensitive to fire and the discharge of static electricity; when dry,

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styphnate can be readily ignited by static discharges from the human body. The longer and narrower the crystals, the more susceptible the material is to static electricity. Lead styphnate does not react with metals. It is less sensitive to shock and friction than mercury fulminate or lead azide. Lead styphnate is very slightly soluble in water and methyl alcohol and may be neutralized by a solution of sodium carbonate. The velocity of detonation is approximately 17,200 feet per second. The color of lead styphnate varies from yellow to brown. Lead styphnate is used as a component in primer and detonator mixtures. It is stable in storage, even at high temperatures.

NITROGLYCERIN is a colorless, oily liquid, a little heavier than water. It is very simple to make; and after it is made, it is very easy to blow yourself to pieces with it. Some experimenters say it takes a small jolt to detonate nitroglycerin; others say it takes only a dirty look.

Nitroglycerin is an important commercial blasting explosive, but it is too sensitive for military use. It is, however, one ingredient of double-base powder, which is colloided so that the nitroglycerin is desensitized. These powders are used by the U. S. Navy as gun and rocket propellants. It is also colloided with guncotton or mixed with inert material to make commercial dynamite, frequently used for construction blasting.

PETN (pentaerythritoltetranitrate) was one of the compounds developed in the search for an explosive more powerful than TNT. It is one of the most powerful of all modern high explosives. The Navy sometimes uses it in detonating and priming mixtures. PETN is used in the explosive train detonators in many U. S. Navy missile warhead systems. It is often used in primer or detonating cords in demolition work. During World War II, a mixture of PETN and TNT was sometimes used as the main charge in mines and torpedoes.

PICRIC ACID (tri-nitro-phenol) comes in pale yellow crystals. It was probably the most important projectile-bursting charge used during the Spanish-American War and World War I. Since its melting point is too high for safe casting, it was usually mixed with other explosives to lower the melting point. When it was used alone, it was press-loaded in the projectile cavity. The British call picric acid lyddite. The French name is melinite; the Japanese name is shimose, the Italian name is pertite. It is most generally used in its converted form, ammonium picrate, or Explosive D.

RDX is a powerful high explosive, of greater brisance than TNT. In pure form, it is too sensitive for military use. To make RDX safe for military use, it is mixed with oils, waxes, or less sensitive explosives. It is important because of its high power and good chemical stability.

The Navy uses different mixtures containing RDX:

1. Composition A is a mixture of RDX and wax. This mixture has about the same sensitivity as Explosive D, but it is more powerful. It is beginning to replace Explosive D as a projectile filler.
2. Composition B is a mixture of RDX, TNT, and wax. It is used for filling projectiles, bombs, and missile warheads.
3. Composition C is a plastic explosive mixture - you can mold it by hand into any desired shape. It is often useful in demolition work, since you can mold it around the object you want to destroy. Composition C-4, the one you'll most likely find in use, is white in color and has a texture like putty. Composition C-4, like Composition C-3, is manufactured in 2 1/2- pound blocks. But C-4 does not exude oil like other Composition Cs do. These compositions are about 25% stronger than TNT.
4. HBX, described earlier, contains 40 percent RDX, plus TNT and some other ingredients.
5. Another explosive has been developed, designated H-6. It is similar to HBX but is considered superior to it. It is used in bomb type ammunition, and is a cast filler.

SMOKELESS POWDER is a low explosive. It is the standard propellant for all Navy guns. It comes in the form of cylindrical grains, in a variety of sizes, with one or more perforations running the length of the grain to increase its burning rate (fig. 10-3). When they're fresh, the grains are gray or buff colored, with a translucent, horny appearance. Older powder may be brown or black.

Chemically, smokeless powder is cellulose nitrate, or pyrocotton, prepared by putting ordinary cotton through several processes, then colloiding with ether and alcohol.

The manufacturer of smokeless powder, after washing and boiling the pyrocotton, extracts as much water as possible by passing it through wringers. He then adds alcohol, and extracts the remaining water. After removing the excess

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Figure 10-3. — Smokeless powder grains.

alcohol, he adds the proper amount of ether. The ether and alcohol, working together, soften the pyrocotton into a colloidal mass. This soft material is then extruded in the form of perforated rods, which are cut into grains of the desired length. These grains of smokeless powder must dry for several months before they're ready for service use.

The stability and useful life of smokeless powder are affected adversely by moisture and heat. The storage conditions for smokeless powder are therefore very important.

TETRYL comes in yellow crystals or granules. Its chemical name is tri-nitro-phenyl-methyl-nitramine. It's a high explosive, more powerful and more sensitive than TNT. The Navy uses tetryl extensively as a booster, especially in mines, and torpedo and missile warheads. A mixture of tetryl with fulminate of mercury is sometimes used as a detonator. Tetryl is also used in explosive leads.

Tetryl is a derivative of methyl-aniline and is classified as a nitro aromatic compound. It is a fine crystalline material practically insoluble in water, but soluble in acetone, ammonia, ether, carbon tetrachloride, and benzol. Tetryl melts at about 130°C. Heated above its melting point, it undergoes gradual decomposition, and explodes when exposed to a temperature of 260°C for five seconds. Tetryl will corrode steel when in the dry or moist state. It is practically nonhygroscopic (after proper drying) but moisture does interfere with its effectiveness. Tetryl is chemically stable at ordinary temperatures. It is more sensitive to shock or friction than TNT, arid more powerful than TNT. Tetryl is more sensitive to detonation by mercury fulminate or lead azide than TNT and is readily exploded by penetration of a rifle bullet. It can be initiated from flame, friction, shock, or sparks, burns readily; and is quite likely to detonate if burned in large quantities. The velocity of detonation of tetryl is approximately 24,400 feet per second. When pure, tetryl is light yellow, but is usually gray after loading because of the graphite mixture used in the loading process.

Tetryl is sensitive to mechanical shock, and it is used as a booster charge between the fulminate of mercury or lead azide detonators and the high-explosive bursting charge. It is also used as a filler in small-caliber projectiles. Tetryl is loaded in pellet form, the pellets being pressed after being mixed with small quantities of graphite which serves to lubricate it while it is being pressed.

Tetryl is poisonous when taken internally and causes dermatitis on contact with the skin. Precautions are therefore necessary regarding the handling and packing of the dry material. Special precautions must be taken to prevent ignition or explosion from friction or blows resulting from rough handling. Tetryl should be kept dry and protected from high temperature and sparks.

TNT (trinitrotoluene) is probably the best known of all military high explosives. When it is pure, TNT is a white crystalline substance. When impurities are present, its color varies from yellow to dark brown. It is chemically stable as long as you protect it from moisture and extremely high temperatures. You can store it for years without any chemical change. And, compared with most high explosives, TNT is relatively insensitive and safe to handle.

An advantage of TNT is its low melting point. It can be melted and poured into mines, torpedo warheads and projectile cavities, where it will harden when it cools. In its cast form, TNT is hard to detonate. It needs a powerful booster of tetryl or granular TNT. However, components containing TNT, such as bombs, depth charges, warheads, and similar munitions containing TNT bursting charges, are subject to sympathetic detonation. This makes it necessary to store such munitions separately, especially away from fuzes, detonators, and fire hazards that could start a detonation. Also, it cannot be roughly handled without danger.

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Instances on record show that it can be detonated very easily if the combination of conditions is just right for it.

WARHEADS AND FUZES

Like any other vehicle, the guided missile must carry some form of useful burden if it is to accomplish the intended objective. In missile terms, the useful burden is called the payload. Physically, the payload merely occupies one or more of the sections of the airframe, and it contributes nothing to the functions of the vehicle, such as guidance, propulsion, or control. But in the total system, it is the component of greatest value, since all the actions of the missile serve as the means for ensuring the effective delivery of the payload.

In research and test missiles, the payload often consists of telemetering units, which collect data during flight, convert the information into radio signals, and transmit them to receivers at a recording site. In some test missiles, dummy payloads are carried which have the same physical characteristics as the corresponding devices which the missile will carry as an operational weapon. But in its military role, the guided missile is launched with a payload composed of one or more warheads and one or more fuzes. The warhead is a device capable of destroying or damaging an enemy target. The fuze is a triggering mechanism used to initiate the actions of the warhead and determines the exact moment of release of the destructive forces.

In the discussion of explosives you have seen two spellings, FUSE and FUZE. The Navy makes a distinction in their meaning. Fuze was defined earlier. A FUSE is a protective device inserted in series in an electrical circuit. An explosive fuse is a conduit that leads fire from one place to another. A firecracker fuse is a familiar example. Primacord, used to detonate explosives in mining and quarrying, or for demolition is another example. When the fuse is lighted, the flame follows the train of powder in the center of the cord.

The fuze used to detonate weapons is a mechanical or electrical device but may include a fuse train of black powder.

TYPES OF WARHEADS

Many of the warheads developed for other kinds of weapons can be modified or adapted for use in guided missiles. Some of these may present special problems to the missile designer, but almost any sort of destructive device employed in conventional weapons may also be carried by guided missiles. Among the types of warheads which might be used are: external blast, fragmentation, shaped charge, explosive pellet, biological, and atomic.

External Blast Warheads

This type of warhead causes damage by means of a high pressure wave, or blast, which results from the detonation of an explosive substance. When set off by a suitable impulse, the explosive material undergoes a sudden chemical change in which energy is released almost instantaneously. Gaseous products are formed and large quantities of heat are generated. The destructive effect results from the high pressure produced by the rapid heating of the gases.

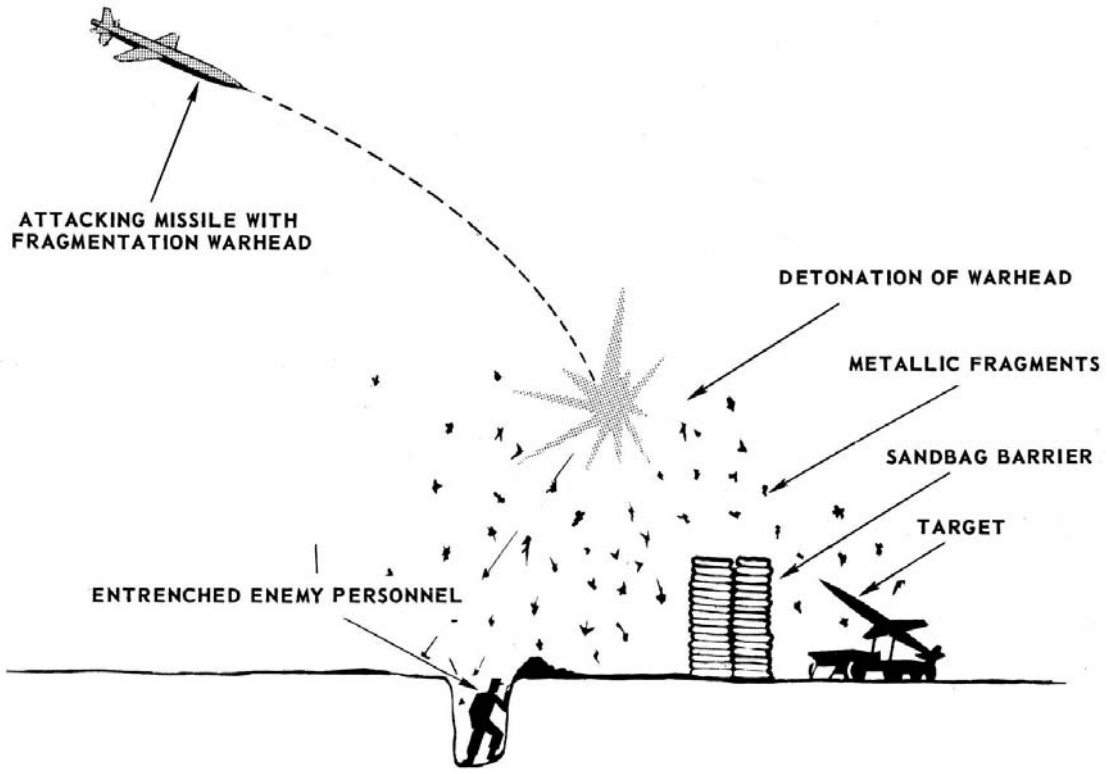
Blast warheads are very effective against ground targets, and have been used in many surface-to-surface and air-to-surface missiles. They are less effective against aircraft, since in the atmosphere the pressure wave dissipates rapidly with distance, and the explosion must take place very near the aircraft in order to damage it. Large blast warheads can cause great damage to ground installations, which must be of special construction to withstand them; and damage occurs hundreds of feet from the point of detonation. The V-1 buzz bomb, which carried a warhead consisting of about 2,000 pounds of high explosive, caused destruction and damage over an area equal to an average city block.

Torpedoes use a blast type of warhead. Since water is incompressible and relatively dense, the pressure waves created by the explosion are transmitted to the target practically undiminished, and damage it.

Fragmentation Warheads

These warheads operate by bursting a metal case containing a high-explosive charge. Upon explosion, the container is shattered into hundreds of fragments which fly out at high velocities; and these are capable of damaging targets at considerable distances from the point of detonation. For this reason, this sort of warhead is very effective against aerial targets and is often employed in air-to-air and surface-to-air missiles. Usually the warhead does not penetrate the target but is detonated by the fuze at some distance from the target. This increases the chances of a hit. See figure 10-4.

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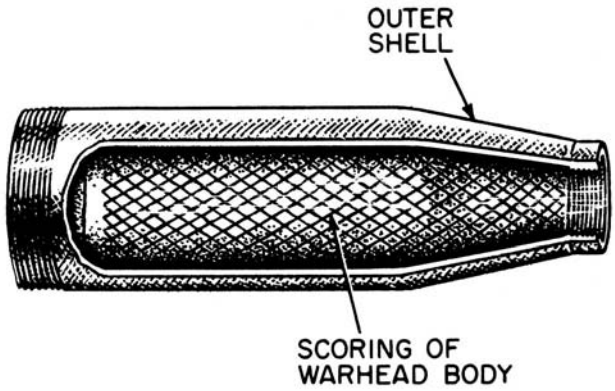
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Figure 10-4. — Effect of fragmentation warhead on surface target.

The factors which influence the destructive action of the warhead are the size of the fragments, their velocity, and the angle at which they ~re ejected. Fragment size is controlled by the designer by weakening the case at certain points. The fragment velocity is controlled by the shape of the container, the ratio of explosive weight to metal weight, and by the type of explosive used. The angle at which most of the fragments are emitted depends on the shape of the container and the point within it at which the detonation takes place. On modern missiles fragmentation is not a hit-or-miss affair. Theories are checked out on scale models and test firings substantiate the value of controlled designs. Various shapes and sizes of fragments have been tested against different targets. Figure 10-5 depicts one type of controlled fragmentation warhead.

Shaped Charge Warheads

Shaped charges, also called cavity charges, make use of the Munroe effect, in which the explosive power is concentrated by shaping the explosive material. Experiments show that if a regular cavity such as a conical hole is molded into the side of an explosive charge nearest the target, the effect on the target is increased over the effect obtained with the same charge without the cavity. The presence of the hole brings about a concentration of the



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Figure 10-5. — Controlled fragmentation warhead.

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explosive force similar to the way in which light can be focused into an intense beam by a glass lens.

In the explosion of a shaped charge, a beam of very hot gas, called the jet, is ejected. In it, the gas particles have an extremely high velocity. If the cavity is lined with some material that can be broken into small pieces or can be melted by the explosion, the efficiency of the charge is greatly increased. The small particles of the liner are carried by the jet, which is increased in weight, and as a result, it can penetrate a thick target, acting somewhat in the manner of a needle. Among the applications of the Munroe effect are the Army's bazooka projectile and also certain types of demolition charges used to blow holes through reinforced concrete structures.

When employed in guided missile warheads, shaped-charge explosives have possibilities of great effectiveness against both aircraft and heavily armored surface targets.

Explosive Pellet Warheads

A warhead of this type contains a number of small explosive charges, or pellets, each of which is separately fuzed. When the main warhead is detonated, the pellets are ejected but withstand the force of the explosion and are hurled intact toward the target. The pellets then detonate either on impact or after penetrating the target skin. The total destructive effect combines both blast and fragmentation effects, since blast damage is great when the individual charge is exploded, regardless of whether the explosion occurs at the skin of the target or after penetrating it.

The explosive pellet is an ideal weapon for use against enemy aircraft. Its full development is dependent upon perfecting a fuze for the individual charges that can withstand the initial blast of the principal warhead while still ensuring explosion on or within the targets.

Chemical Warheads

This type may contain either war gases or incendiary materials. Warheads containing gases may liberate any of the well-known types such as mustard gas, lewisite, or some newly developed chemical. The effects produced are either denial of the use of the target area or personnel casualties within the area. Missiles equipped with chemical warheads also serve as possible counterthreats to initiation of gas warfare by the enemy.

A variety of disabling gases have been developed. The length of disability and the type of disability can be varied with the type of agent used, the method of application, the terrain, the weather, and other factors. Agents dispersed as a vapor or aerosol usually have a short period of effectiveness. In the category of riot-control chemicals are the tear gas type and those that produce nausea and vomiting.

The most important advantages of chemical agents are the area coverage and penetration effects. Agents dispersed as gas or aerosol penetrate structures and incapacitate hidden enemies that could not be reached by conventional weapons. At the same time, the lives of the innocent are spared. The effects of the disabling chemical wear off before long, and without after effects. This is far different from the gas warfare of World War I, when deadly chlorine gas and mustard gas were used.

It takes no great depth of thought to realize that it is much more humane to overcome the enemy by disabling him temporarily (and maybe making him uncomfortable for a few hours) than by blasting him to bits.

Another type of chemical warhead is the incendiary warhead. It contains a material that burns violently and is difficult to extinguish, while covering a large area after release from the warhead. Incendiary weapons are useful principally against ground targets. There are several types of chemicals used to cause fires, and different rules for handling apply to each.

There are many more chemical agents used in warfare. Disaster Control (Ashore and Afloat), NavPers 10899-B, has a lengthy chapter on the different types of chemical agents used, their effects, and how to protect yourself against them. Reading that chapter can be very enlightening. You may be sure that all major nations have an arsenal of chemicals to use in warfare. You need to know how to protect yourself against the different varieties.

Biological Warheads

A biological weapon delivered by a missile would contain living organisms capable of disrupting personnel activities in the target area by causing sickness or death to the inhabitants. Not only can micro-organisms be used against people, but also against animals and vegetation. Such use could destroy or greatly reduce the food supply and the raw materials for factories. Water supplies can be contaminated. Biological agents are difficult to detect. For a revealing

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discussion of the possibilities of this type of warfare, plus methods of detection and protection, read chapter 4 in Disaster Control (Ashore and Afloat), NavPers 10899-B.

Atomic and Thermonuclear Warheads

In this type, destruction and damage result from the processes of atomic fission or fusion. The destructive effects are blast, heat, and liberation of radiation. The detonation results in death, sickness, and the denial of the use of large areas as a result of the release of radioactive elements.

Volumes have been written about the effects of nuclear weapons, all based on the results of the two bombs dropped on Japan in World War II. Some information has been added from the experimental tests made since then but the statistics of human and material destruction hark back to the original drops. All other figures on human destruction are estimates of what could happen, however accurate those estimates might be. We know that nothing can survive at ground zero, where the weapon strikes. The area of total destruction varies with the size of the weapon. Beyond this area of complete devastation, shelters can save the lives of many, by protection against falling buildings, fires, thermal radiation, and nuclear radiation. One of your basic texts, Basic Military Requirements, NavPers 10054-C, devotes a chapter to Nuclear, Biological, and Chemical (NBC) defense.

Several of our Navy missiles are capable of carrying a nuclear warhead. This means that we can send this destructive force far into enemy territory, away from our own personnel. We know, too, that other major powers have nuclear missiles. Therefore, you must learn what means of protection against their effects you have aboard ship, as well as how to fire the lethal missiles.

Continuous Rod Warheads

Fragmentation-type explosive devices such as fragmentation grenades, bombs, and projectiles are well known and have a long tradition of use in conventional weaponry. They are effective, but they do leave something to chance. The pattern of fragment distribution is necessarily random, and the fragments tend to be irregular in size (and hence in lethality) in spite of pineapple like or waffle-like patterns in the fragmenting body.

The purpose of the continuous rod warhead is to menace aircraft within a lethal radius. In this type of warhead, the warhead energy is used to expand rods radially into a ring of metal which can lengthen and thus increase its diameter rather than produce an expanding shell of small fragments. Upon detonation the continuous rod warhead expands radially into a ring pattern. The intent is to cause the connecting rods, during their expansion, to strike the target and produce damage by a cutting action.

Other Types of Warheads

Several other types of special warheads may be used. These include: radiation, anti radiation, illumination, psychological, exercise, and dummy warheads.

RADIATION warheads may use radiological material in the same manner as chemical or biological agents, scattering the radioactive material according to plan. The possibilities and ramifications of this type of warfare will not be explored further here.

ANTIRADIATION WARHEADS carry material that will jam enemy radars. The Shrike missile is of this type. It is intended to home on enemy radar installations and silence their transmitters. The ARM-l missile being developed is similar to the improved Shrike.

ILLUMINATING warheads have long been used in projectiles during night attacks to point out or silhouette enemy fortifications or other targets. This has been especially useful during shore bombardment. Illuminating warheads are also used in aircraft bombs and rockets to assist in the attack on ground targets and submarines. No application has been made in guided missiles.

PSYCHOLOGICAL warheads do not carry lethal or destructive agents, but carry material designed to create a psychological effect on the enemy, rather than actual physical damage. Payloads may be propaganda leaflets, mysterious objects that appear dangerous, or inert or dummy warheads. Decoy warheads may carry "window," which causes false radar echoes or noise-makers to confuse sonar operators of antisubmarine ships.

A dummy warhead has only the outward appearance, the size, shape, and weight of a real warhead. It is used in training and practice operations.

EXERCISE or training warheads do not contain any explosive material but otherwise contain

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parts of a real warhead, so they can be assembled, disassembled, tested for electrical continuity, and other wise used for training exercises.

The ASROC (Rocket Thrown Torpedo) uses a torpedo for its warhead.

TYPES OF FUZES

The missile warhead is activated by tile actions of one or more fuzes, which release tile destructive forces after certain conditions have been fulfilled. The type of fuzing employed determines whether tile warhead is detonated at a distance from the target, upon impact with it, immediately following penetration, or at some fixed time after penetration of tile target skin. The missile warhead is generally detonated in one of the three relations with the target shown in figure 10-6.

The most effective type of fuze for a given missile depends upon the nature of tile target and the possibilities of tile warhead for causing damage. The type often employed in missiles are the impact, time ground-controlled, and proximity fuzes.

Fuzes may also be classified according to their location, as nose fuzes, tail fuzes, or other.

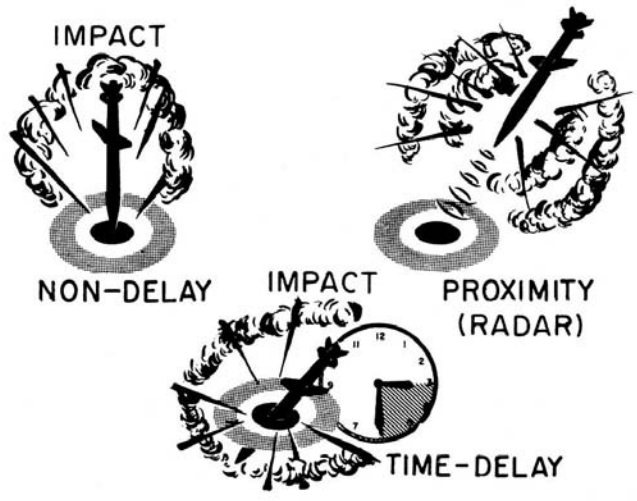


Figure 10-6. — Types of missile fuzing.

Impact Fuzes

Impact fuzes are actuated by the inertial force exerted when the missile strikes the target. If detonation takes place at the moment of impact, the fuze is of the non-delay, or instantaneous type. If the detonation takes place some time after impact the fuze is said to be of the delay type. This short delay time permits the weapon to penetrate the target before it explodes. Impact fuzes are also called contact fuzes.

Ground-Controlled Fuzes

In ground-controlled fuzes, some device is used for measuring the distance from the missile to the target. The control device is not mounted in the fuze but on the ground; and when the proper space relationship exists between the missile and its target, a signal is sent to detonate the fuze from the control point on the ground.

Time Fuzes

Time fuzes, or time-delay fuzes are fuzes that are preset to detonate the warhead after a specified lapse of time after launching. One type has a burning powder train' another type has a clocklike mechanism. In either type, the time cannot be changed after the missile is launched. A missile may have to maneuver to intercept its target, and the variation in time, however slight, precludes the use of a fuze with preset timing. However, Subroc uses a timer that closes the firing contacts when the preset time (in the water) has elapsed. The timing device is actuated when the depth bomb strikes the water.

Proximity Fuzes

Fuzes of this type are actuated by the influence of some property of the target and are detonated at a distance which allows maximum damage to take place. Five general classes of proximity (also called VT, or variable-time) fuzes can be distinguished according to the property to which the device responds. These are electromagnetic (radar and radio), pressure, acoustic, photoelectric, and electrostatic fuzes.

ELECTROMAGNETIC FUZES. - These fuzes may operate with radio, radar (microwave), infrared, or ultraviolet waves. The basic proximity fuze must have a transmitter-receiver, a means of amplifying the return signal so it will be

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strong enough to activate the detonator, electrical safety devices to prevent premature detonation, and a power supply to set off the fuze. The miniature transmitter in the fuze transmits high-frequency radio waves, which are reflected from the target as the missile approaches it. Because both the missile and the target are moving with respect to each other, the reflected signal, as received at the missile, is of a higher frequency than the transmitted signal. The two signals, when mixed, will generate a Doppler frequency, the amplitude of which is a function of target distance.

At the proper time, the action of the reflected waves causes an electronic switch to close and fire the detonator. Fuzes of this kind have been developed to a high degree of accuracy and dependability. They operate effectively both in darkness and daylight and in all kinds of weather. However, they are subject to jamming by false information from the target. This can make the fuze inoperable or, worse yet, cause it to detonate before it comes within lethal range of the target. Some counter-countermeasures have been devised to offset the effects of enemy countermeasures. One method is to add a contact fuze so that if the proximity fuze fails the other fuze will act. Two of our missiles, Sidewinder and Sparrow, use such a system.

PRESSURE FUZES. - The pressure that activates these fuzes may be air pressure or water pressure. Those that are actuated by water pressure are called hydrostatic fuzes. Some of our depth charges have fuzes preset to actuate at a certain depth, where the preset pressure is reached. Another type is actuated by the variations in pressure in the ocean caused by the passing of a ship or submarine. They must be so designed that they will not be set off by the natural movement of the waves.

Fuzes that are actuated by air (barometric) pressure might be used against stationary ground targets. As barometric pressure over different parts of the earth is subject to frequent change, it is difficult to use a preset altitude (or barometric pressure) as the triggering quantity for a guided missile whose target may be a considerable distance from its launching point. Polaris is one missile that is detonated at a preset height above the target, with the fuze activated by the barometric pressure.

Fuzes acted upon by the surrounding medium (air or water) are also called ambient fuzes. Proximity fuzes which respond to changes in pressure generally lack the sensitivity and reliability required for guided missile applications, but in some cases they are useful against surface targets.

ACOUSTIC FUZES. - These are actuated by sound waves from the target. They must react only to specific sounds, not to all sounds. The problems of the acoustic proximity fuze were studied by the Germans at Peenemunde to determine the characteristics of these devices in supersonic missiles. Their wind-tunnel experiments proved that sound waves can be received readily by missiles traveling at speeds in excess of sound velocity. The acoustic fuze has the valuable property of all-weather, day-or-night effectiveness; but it also has the disadvantage that it is subject to local vibration and noises generated within the vehicle as well as to the sound waves by which it senses the target. The need for sensitive but selective acoustic fuzes is one of the reasons for the Navy studies on sounds made by fish and sea mammals. Acoustical sensors are still used to activate mines and torpedoes.

PHOTOELECTRIC FUZES. - Photoelectric fuzes react to external light sources, and ordinarily they are inoperable at night or in conditions of low visibility.

ELECTROSTATIC FUZES. - The Germans also investigated the possibilities of the electrostatic system of fuzing in which the detonating influence is the electric field of the target. Attempts to develop the fuze were unsuccessful - probably because of the variable nature of the electrostatic field surrounding possible targets, Air targets become electrostatically charged as they pass through the air, but water vapor or rain dissipates much of the charge, which poses a problem for the fuze. Electrostatic fuzing has application over short distances.

MAGNETOSTATIC FUZING. - Magnetic sensors measure changes in the earth's magnetic field or the presence of a source of magnetic flux. The magnetic field of the earth at any given point remains practically the same unless disturbed by some other force. Any steel ship has a permanent magnetic field of its own, peculiar of itself. Such a ship passing over a magnetic mine would detonate it. Degaussing or deperming was made a requirement for all Navy ships to reduce losses from mines. These processes remove much but not all of the magnetic charge of a ship,

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Magnetostatic fuzing is being developed for use in missiles. Equipment to measure the intensity of the earth's magnetic field at a point or in a reference frame is still in the developmental stage. It would be used with the guidance system.

Of these various types of proximity fuzes, the radio system appears to be the most reliable and effective for missile applications. Future developments may change this.

SAFING AND ARMING (S&A) DEVICES

Each fuze has a safing and arming (S&A) device to control the detonation of the payload so that there will not be a premature detonation, or a dud. The safety devices included in the S&A must prevent accidental activation, so the missile can be transported, stored, handled, tested, and launched. The purpose of the primary safety mechanism is to prevent accidental activation. The secondary safety device must overcome countermeasures and false signals and permit activation only upon receipt of the specified signal. The increase in enemy countermeasures has made this more complex.

Since the arming device is actuated by a specific signal, such as radar waves from a target, the countermeasure may supply a false signal by a decoy or some other method to deceive the arming device. The safety device must prevent arming by the false signal. This is a complex problem that requires constant study. To increase the chances of detonation at the best time and place, the weapon designer may put in duplicate systems (redundancy), or he may put in two types of fuzes so that if one fails there is another to take over.

PYROTECHNICS

PYROTECHNICS is a Greek word for fireworks. The Navy uses fireworks not for celebration, but for illumination, screening, marking, and signaling. An example is the illuminating projectile or star shell (SS) used to illuminate targets for gunfire. This is actually a pyrotechnic device, even though it is encased in a projectile body of standard external shape, and is fired from a standard rifled gun.

In the following sections we shall take up pyrotechnics launched by hand or from special projectors, or simply held by hand. All the pyrotechnics we shall study here are intended for signaling.

The Navy issues pyrotechnics not only for use aboard its surface combat ships, but also for use by aircraft, submarines, motor torpedo boats, and merchant ships, as well as for use ashore. However, we can here discuss only those issued as ship's pyrotechnics. For the others, see OP 2213 (second revision) Pyrotechnic, Screening, and Marking Devices.

The pyrotechnic units we shall take up are-

1. Markers, location, marine
2. Signal lights, and the pyrotechnic pistols and projectors used in firing them
3. Distress and hand signals
4. Navy lights
5. Flash signals
6. Smoke and flare markers

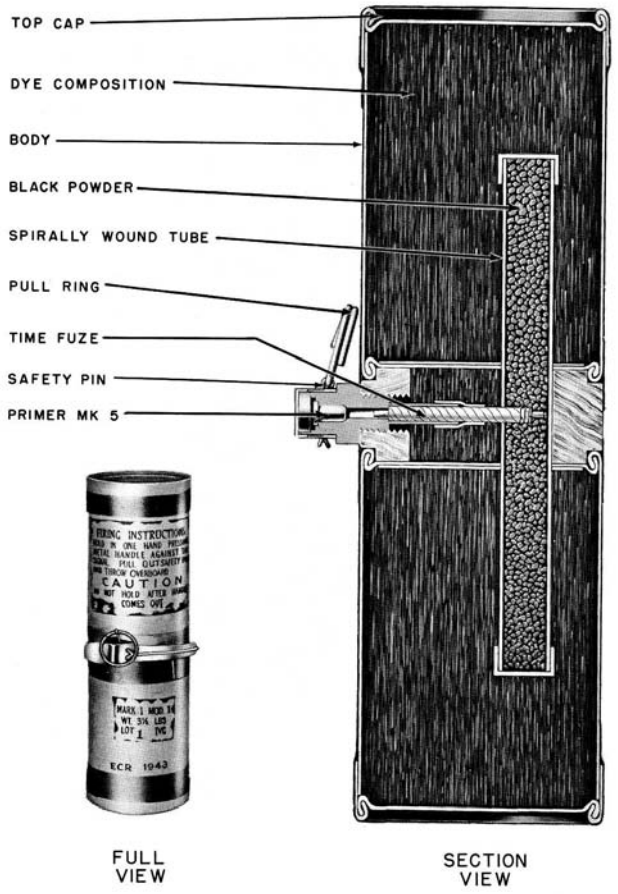
MARKERS, LOCATION, MARINE

Markers, location, marine (formerly called Depth Charge Markers) are of two general types - those for day use (Mk 1 Mod 3) and those for night use (Mk 2). The marker for daytime use spreads a patch of chrome yellow dye on the water; the night type burns with a yellow flame for 45 to 55 minutes. Both types are used to indicate the point of discharge of depth charge barrages and to provide a reference point for further antisubmarine attack. (A Mk 1 Mod 2 marker, still occasionally used, has green dye. It should be used only for practice sessions since green is the distress signal used to mark downed aircraft in search and rescue operations at sea.)

The Marker, Location, Marine Mk 1 Mod 3 (fig. 10-7) is a cylindrical waterproofed container about 12 inches long and 3.5 inches in diameter. When you pull the ring attached to the safety pin and release the safety lever, the primer ignites the time fuze. Fifteen seconds later the black-powder charge bursts the two dye containers and scatters the dye. The marker is dropped about 25 yards from the actual point where the depth charge itself was launched, so that the depth charge's "boil" when it bursts will not dissipate the slick of dye. Never pull the pin until the marker is to be launched. After the pin is pulled, keep the safety lever firmly against the marker body until it actually leaves your hand.

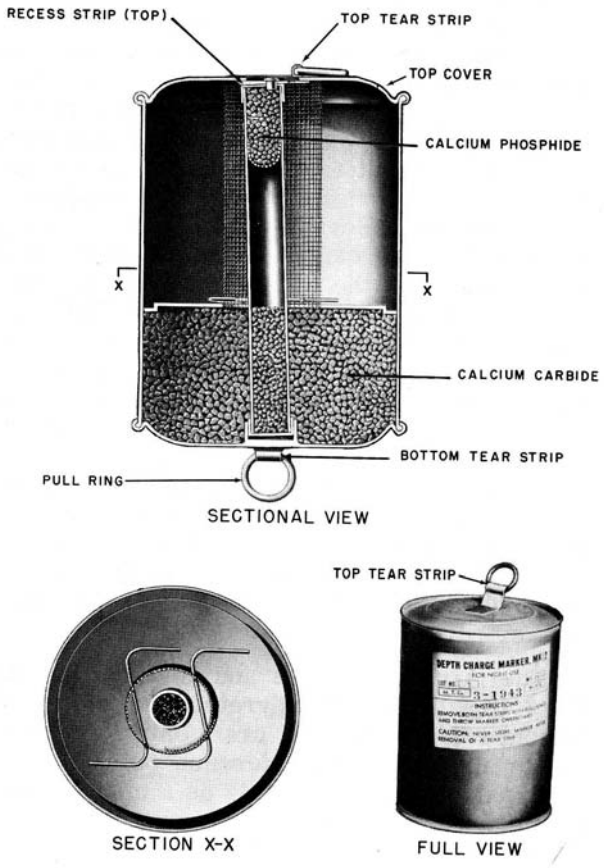
WARNING: If the marker is accidentally dropped after the pin has been pulled, clear the area. Don't try to retrieve the marker and make it safe again; it cannot be done.

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83.107

Figure 10-7. — Marker, location, marine Mk 1 Mod 3 (day).



83.108

Figure 10-8. — Marker, location, marine Mk 2 (night).

If exposed to moisture, the dye in the marker cakes and doesn't spread very well in the water. The markers should, therefore, be kept dry. Markers, location, marine can also be launched from aircraft.

The Mk 2 (night) marker is a sealed metal cylinder 7 inches high and 5 inches in diameter, shown in figure 10-8. It contains two chemicals. One of them is calcium carbide, used back in the horse-and-buggy days for carriage lamps. When wet, calcium carbide gives off acetylene, a gas that smells bad but burns well. The other chemical (calcium phosphide), when wet, gives off a gas that ignites by itself, without help from matches, ignition charges, or the like. This ignites the acetylene, which burns with a white flame.

To operate the marker, pull the rings on the marker to open the holes which allow water to get to the chemicals. Then throw the marker overboard, allowing a short time lag, so as to avoid the depth charge "boil." The flame should appear within no more than 90 seconds. Don't remove the tear-strip rings until ready to cast the marker overboard. Never handle or carry the markers by their tear-strip rings.

The Mk 2 (night) marker should be inspected while in stowage for damaged tear strips. Markers with damaged strips should be disposed of immediately as unserviceable.

This marker may also be launched by hand from aircraft at altitudes up to 3000 feet.

SMOKE AND FLARE MARKERS

For night or day reference marking on the ocean's surface, Marker, Location, Marine Mk

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58 Mod 0 is used chiefly by aircraft patrols in ASW but also is used for search and rescue operations, man-overboard marking, and similar applications. It can also be dropped over the side from surface ships. It is approximately 21 1/2 inches long and weights about 12 3/4 pounds. It contains a battery that is activated by sea water, an electric squib, some starter mix, two pyrotechnic candles, and a transfer fuse between the two candles. Before launching, the tear tapes over the water port must be removed so that the sea water can enter to activate the battery. The battery current then energizes the electric squib which ignites the starter mix, which in turn lights the pyrotechnic candle. When the first candle has burned out, in about 20 minutes, the second candle is started by the transfer fuse. Figure 10-9 illustrates this marker. Several other types of markers are in use, but the present modifications require launching from aircraft to provide the force needed to rupture the dye marker or to activate the smoke and fire marker.

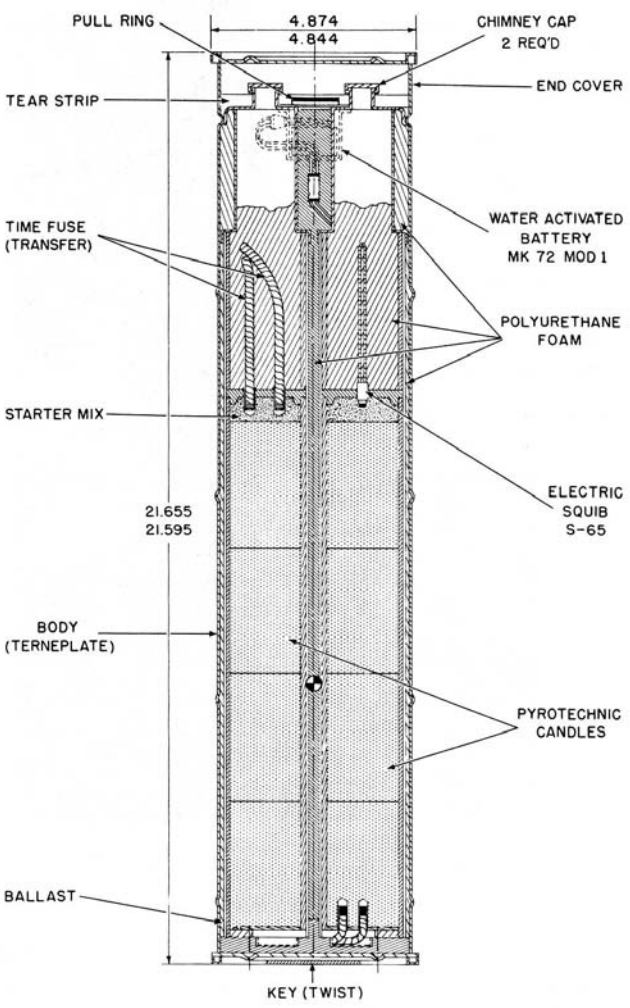


Figure 10-9. — Cross-section view of Marker, location, marine Mk 58 Mod 0.

The Aircraft Smoke and Illumination Signal Mk 6 (fig. 10-10) is a pyrotechnic device that is launched from surface craft only to produce a 4 day or night floating reference point. One of its ~ principal particular uses is as a man-overboard ~ marker. It was previously approved for launching from low performance aircraft as a long-burning marker but has been superseded for these purposes by Marine Location Marker Mk 58.

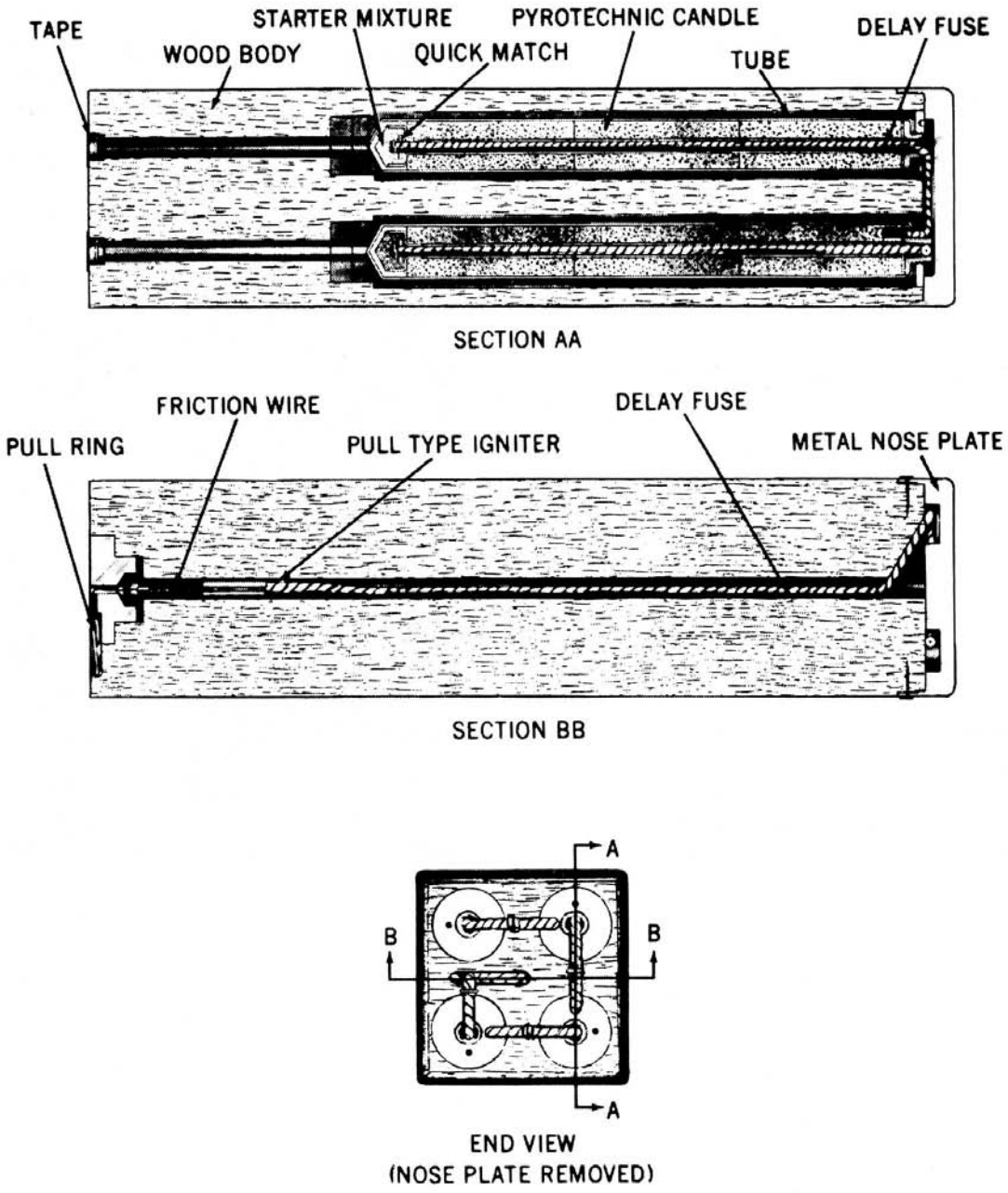
This device consists of a wooden body with a flat, die-cast metal plate affixed to one end to protect it from water impact damage and to maintain it in the correct floating attitude. There are four flame and smoke emission holes in the opposite end, each capped and sealed with tape. The pull wire ring, also at the emission end, is likewise covered with tape.

The Mk 6 signal has a direct-firing ignition system. Ignition results from pulling the pull ring. The pull ring is pulled by hand, and the device is thrown into the water immediately. The pull wire ignites a 90-second delay fuze which ignites the quickmatch at the top of the first of four candles. The quickmatch ignites the first candle starting mix which, in turn, initiates burning of that candle. Expanding gases of combustion force the cap and tape from the emission hole, allowing smoke and flame to be emitted. When the first candle is nearly burned out, a transfer fuze carries the ignition to the quickmatch of the next candle in series. This process continues until all four candles have burned. The yellow flame and gray-white smoke are produced for a minimum of 40 minutes.

After the tear strip on the shipping container has been removed, the following rules shall apply:

1. The tape over the pull ring shall not be disturbed until immediately before hand launching the signal. This tape not only prevents an accidental pull on the pull ring, but also protects the igniter assembly from moisture which might render the signal useless.

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83.203

Figure 10-10. — Aircraft smoke and illumination signal Mk 6.

WARNING: This signal is initiated by the physical movement of a friction wire through ignition compound. Extreme care must be taken to prevent tension on the pull ring during all handling operation.

2. If this device is prepared for launching and is not launched, the pull ring must be securely retaped into position at the top of the signal without exerting any pulling force on the pull-wire igniter.

3. Under no circumstances shall these signals be stowed or restowed with their pull rings exposed or with any wires, strings, or other material of any kind joined to their pull rings.

All safety precautions pertaining to this signal shall be observed. In addition, the following specific rules apply:

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1. Do not remove the tape over the pull ring until immediately before launching.

2. The Mk 6 signal must be thrown over the side immediately after pulling the pull ring. This device contains a maximum 90-second delay element between initiation and candle ignition.

3. In all handling, extreme care must be taken to avoid pulling on the pull ring. Any slightest movement of the friction igniter may start the ignition train.

SIGNAL LIGHTS

Signal lights, often called Very lights (not because they are very light. but because that is what they were called by the French. who originated them), are similar to standard shotgun cartridges in appearance. When fired from the proper pistol or projector, a burning star (somewhat like a star from a Roman candle) shoots high into the air, as shown in figure 10-11. The one shown also has a tracer.

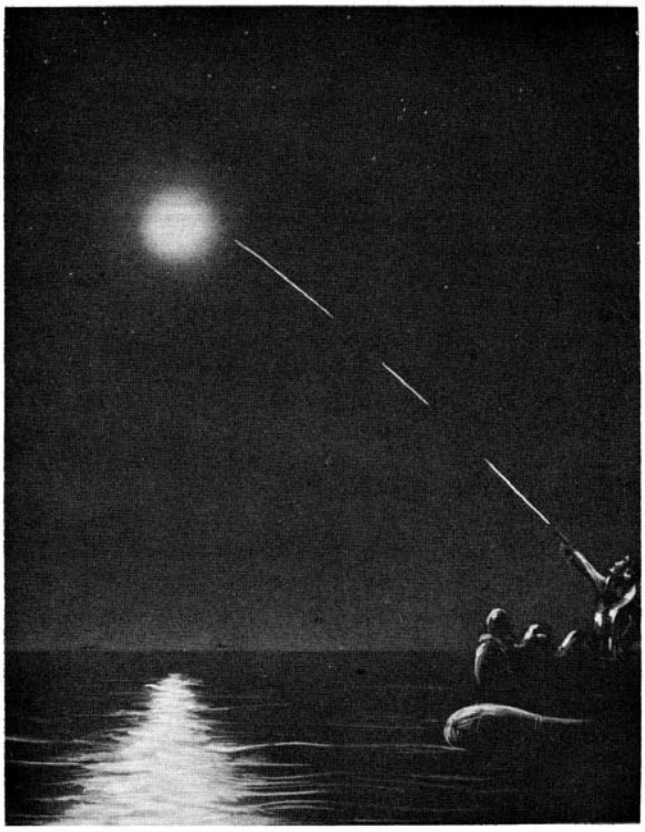
The Mk 2 signal light is available in three colors - RED, GREEN, and WHITE. Each cartridge has a percussion primer and a propelling or expelling charge of ten grains of black powder, which projects the burning star to a height of about 200 feet. The star charge is a tightly packed cylinder wrapped with a quick match (a fast-burning fuse), which ignites it when fired. The star charge is separated from the expelling charge by a shock-absorbing wad of hard felt. The cartridge is closed by a wad which is marked so that the color of the star can be determined by feeling it, as shown in figure 10-12, so the correct shell can be selected in the dark.

The RED star may be identified by its corrugated closing wad, the GREEN star has a smooth closing wad, and the WHITE star has a small conical boss on its closing wad. Each of the three colors may also be identified by the corresponding color of the paper on the cartridge.

The burning time for each of the stars is approximately 6 seconds.

The lights are available in combination kits known as Service Box, Signal Pistol Mk 5; and Reserve Box. Signal Pistol Mk 5. Unless packed in kits, signal lights are packed in a metal can in units of ten; and 100 cans, or 1,000 signals, are packed in a wooden case for shipment purposes.

Signal pistol Mk 5, for firing signal light Mk 2, is a single-barrel, breech-loading pistol,



83.109

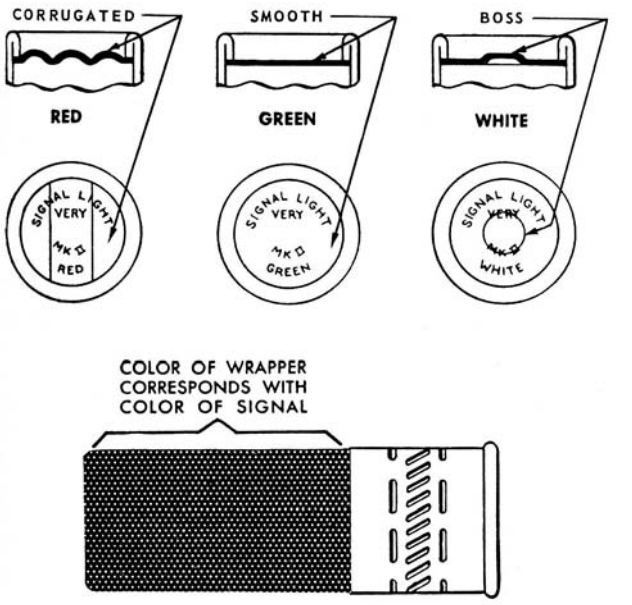
Figure 10-11. — Signal light with tracer, fired from a pyrotechnic pistol.

11 inches long. Metal parts are mounted on a plastic frame. A cartridge belt (Mk 1) and holster are issued for use with the pistol. Figure 10-13 shows how to use the pistol.

1. To load the pistol, depress the latch button below the barrel. At the same time pull the barrel downward, as in part A of the figure. Then insert the signal light shell (as in part B of the figure). Push the barrel upward again until it latches closed. The pistol is now ready to fire.

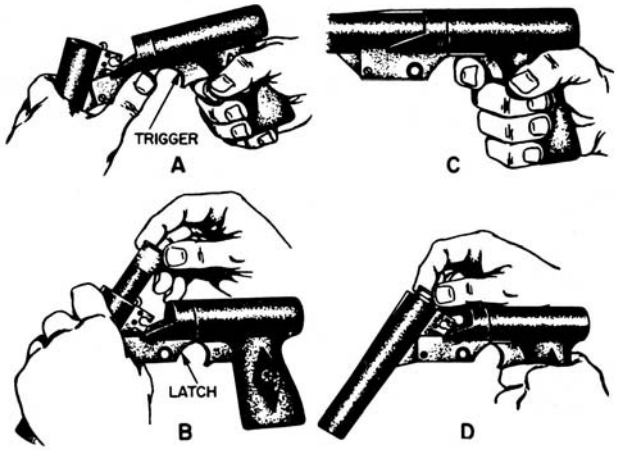
2. To fire the pistol, aim it upward at the desired angle, but clear of other ships or personnel. Pull the trigger, as shown in figure 10-13C. Keep your elbow slightly bent when firing, to absorb the shock of recoil without having the pistol knock itself out of your hand.

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83.110

Figure 10-12. — Markings on Signal light Mk 2 Mod 0 (Very light).



83.111

Figure 10-13. — Operation of Signal Pistol Mk 5: A. Depress latch and pull down barrel; B. Insert Signal Light Mk 2; C. Barrel latched closed, finger on trigger; D. After firing, open pistol and extract shell.

3. To extract the expended shell, break the pistol open again as in step 1, and pull it out of the chamber, as in figure 10-13D.

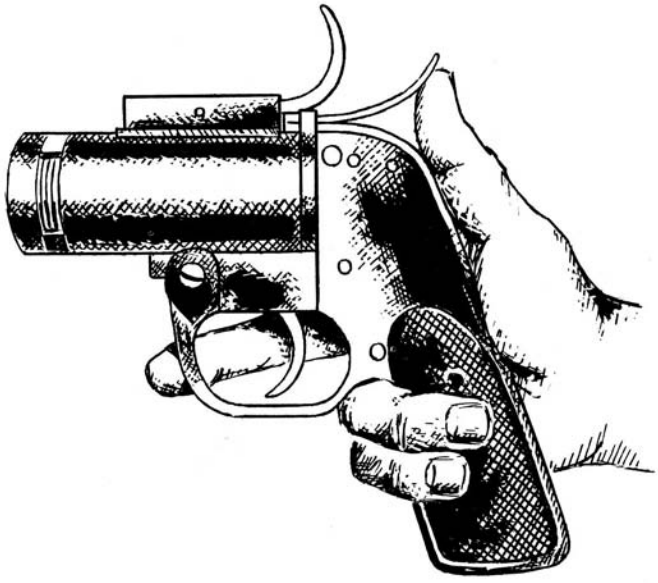
Signal pistol Mk 5 must be kept in serviceable condition at all times. Clean it thoroughly after each time it is used. Wipe down all parts with a cloth impregnated with light machine oil. After assembly, wipe the exposed parts with a dry cloth. Swab the barrel with a cloth dampened with acetone or other solvent to remove powder residue.

While loading, firing, or unloading a pyrotechnic pistol, care must be taken to avoid pointing the muzzle in the direction of the users body, other personnel or vessels.

If a pyrotechnic pistol is loaded and not fired, it must be unloaded immediately because it has no positive safety features. The pistol is always cocked as long as the breech is closed.

Pyrotechnic Pistol AN-M8

A pistol similar to the Mk 5 signal pistol is Pyrotechnic Pistol AN-M8 (fig. 10-14). It can be used with a number of signal lights of shotgun-shell shape. Some of these shells



83.190

Figure 10-14. — Pyrotechnic Pistol M8; tripping breech lock.

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have paper cases and some have aluminum cases. Aircraft Red Star Parachute Signal M11 is fired only to denote aircraft distress, but the other signals that can be fired from Pyrotechnic Pistol AN-M8 are used for signal and identification purposes, and may be fired from aircraft or surface ships. The use of the different colors of signals was outlined in the text Seaman, NavPers 10120-E, particularly with regard to their use in lifeboats.

DISTRESS SIGNALS

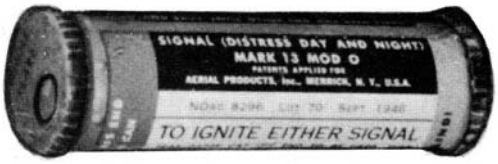
There is something Biblical about the distress signal Mk 13 Mod O. Like the famous pyre in EXODUS, it provides by day a pillar of smoke, and by night a fiery light. It's mighty comforting to have in a life raft or life vest. The signal kit in inflatable lifeboats has 12 of these signals.

The Mk 13 Mod 0 signal (fig. 10-15) is a metal cylinder about 5 1/8 inches long and 1 5/8 inches in diameter. It weights between 6 and 7 ounces. One end contains a canister which, when ignited, produces orange smoke for about 18 seconds. The other end contains a pyrotechnic flare pellet which will burn 18 to 20 seconds.

Each end of the metal tube is enclosed by a soldered cap with a pull ring through which you can put your finger. When you pull the cap loose, a brass wire attached to its inside surface moves through a cap coated with a composition that ignites by friction, setting off either the flare or the smoke canister (depending on which ring you pull). The metal caps of the signal are covered with paper when issued; you must remove the paper before the pull rings are accessible.

The signal body carries illustrated instructions for use. The flare end has embossed projections extending around the case to identify it as the right end to use at night. When you use the signal, point it away from the face and hold it at arm's length at a 30° angle after it ignites. After one end of the signal has been used, douse the signal to cool the metal parts. Keep it so that the other end can be used if necessary. Each end is separately insulated and waterproofed. N ever try to use both ends at once. When using the smoke signal, keep it to leeward.

These signals are shipped in wooden boxes containing 100 units, and are also available in metal cans containing four units, for stowage in life boats, floater nets, etc. Avoid rough handling. Stow in a cool, dry place, in accordance with standard pyrotechnic stowage rules.



3.246

Figure 10-15. — Distress Signal Mk 13 Mod 0.

Signal, Illumination, Marine AN-M75 is an emergency rescue signal small enough to be carried in the pockets of life vests or flight suits and on liferafts. It contains two pyrotechnic stars that are projected by ejection charges. The igniter assembly is thrown about 10 feet from the signal, and the first delay charge is ignited. This ignites the expelling charge for the first star. After ignition, the first star burns 4 to 6 seconds. The used signal (or one that fails to fire) should be thrown overboard.

NAVY LIGHTS

Navy lights are hand torches which burn with a brilliant light visible at night up to 3 miles away. They come in three colors; blue, white, and red. Navy blue light Mk l Mod l burns between 60 and 90 seconds; Navy red light Mk 1 Mod 0 burns between 150 and 180 seconds, and Navy white light Mk 1 Mod 2 burns 60 to 70 seconds. The three lights are similar in appearance and construction (fig. 10-16).

Navy lights consist of a paper tube, which contains the pyrotechnic substance, with a wooden handle at one end, and at the other end a cover with an exterior coating of abrasive like that on the scratching side of a safety match box. A tear strip protects the cover's exterior.

The upper end of the paper tube, beneath the cover, is capped by a fabric impregnated with igniting compound similar to that on the head of a safety match.

To ignite the Navy light, tear off the protective strip, remove the cover, and scrape the inverted cover across the top of the paper tube. When you do this, it's advisable to hold the light pointing AWAY from you at an angle of about 45°, to avoid contact with hot particles falling off the pyrotechnic candle. Hold the light at that angle throughout the burning.

Navy lights Mk 1 Mods 0, 1 and 2 are shipped in metal containers with 6 or 12 lights packed in

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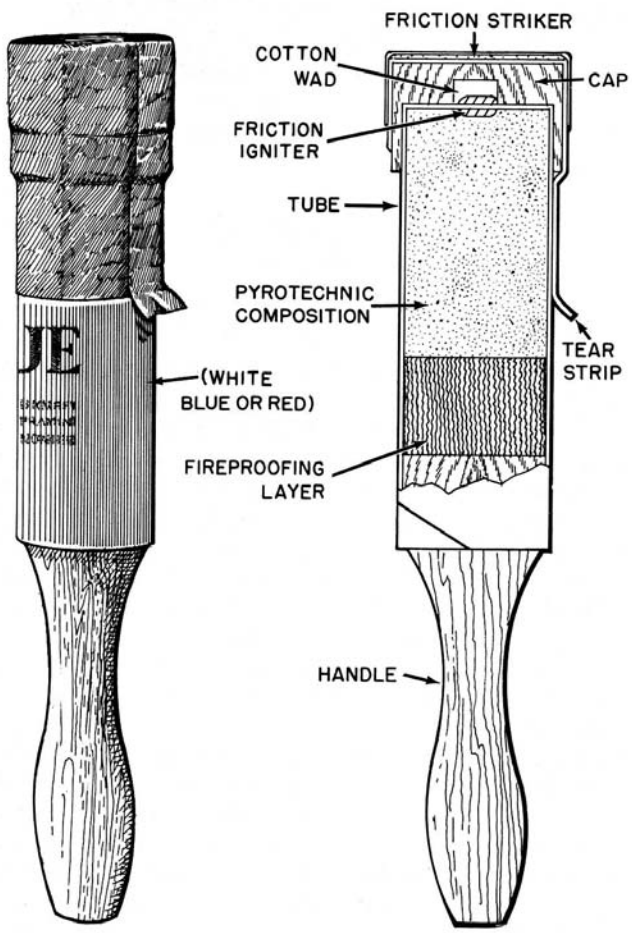


Figure 10-16.—Navy lights.

each, and enclosed in cardboard cartons holding 12 boxes (72 to 144 lights). Navy blue light Mk 1 Mod 1 is also shipped as part of the Reserve Box, Signal Pistol Mk 5. These lights deteriorate when exposed to moisture. Do not remove them from their containers until ready for use. For the same reason, keep them away from water or moisture. Lights which have been left in open containers for more than 6 months should be turned back to the nearest ammunition depot or magazine at the earliest opportunity. Lights which have become chemically encrusted, or which give off an acetic acid (vinegar) odor, should be immediately disposed of. Put them in a weighted sack and dump them overboard in 500 fathoms of water and 10 miles from shore. Note the following SAFETY PRECAUTIONS in the use of Navy lights:

1. Select carefully the place at which the lights will be burned, because burning particles dropping from the lighted candles can start fires.
2. Always hold the light up at an angle of 45° and point it to leeward while it's burning.

It must be remembered that all pyrotechnic and screening devices, while designed and tested to be safe under normal conditions, are subject to accidental ignition because of a wide variety of circumstances. The general rule to follow is: "Be constantly aware that pyrotechnics contain chemical components that are intended to burn with intense heat, and act accordingly."

FLASH SIGNALS

Missile targets used in training are expensive. To prevent destroying a practice target, an exercise head is put in a missile in place of a warhead. Since we want to know if an exercise missile has approached within lethal range of a target, flash signals are installed in the exercise head. These signals contain pyrotechnic material. When the material is ignited it produces puffs of smoke, and you get a visual indication that the missile has passed close by the target. The flash signal contains a primer and some flash powder. At intercept, an electrical impulse from the fuze ignites the primer, which fires pyrotechnic material (black powder and coated magnesium powder).

STOWAGE OF PYROTECHNICS

The dangerous nature of pyrotechnics was appallingly demonstrated by the catastrophic fire on the USS Oriskany, which started from a pyrotechnic flare, dropped in handling.

The extreme sensitivity of pyrotechnic material makes it mandatory to store it in special pyrotechnic lockers away from other ammunition. Pyrotechnics are, in general, a fire hazard. Many of them deteriorate under high or variable temperatures. Some are badly affected by moisture. The storage place must be dry, well ventilated, not subject to direct rays of the sun or other heat source, and must have firefighting equipment handy. Since many pyrotechnic items can be set off by a blow, they must be handled with great care. Be very careful not to bump or drop them; remember the Oriskany. Flash signals and flares can be set off by electromagnetic radiation. They must not be exposed

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in line with radars or other sources of electromagnetic radiation. (The radiation is also harmful to you; see chapter 12.) Missiles are .not stored with the flash signals in them. The flash signals must be installed just before the missile is to be used for practice, and if not expended, must be removed before the missile is returned to the magazine. The men who do this work must be instructed in the precautions necessary. See OP 4, Ammunition Afloat, Volume 2, (second revision). (Flash signals are restricted to research and development use.)

Pyrotechnic and screening devices are normally equipped with some type of safety pin, lock, or tape that is designed to prevent accidental activation of the initiation mechanism. Such equipment must not be tampered with, struck, bent, or otherwise damaged or removed until immediately before it is intended to launch the device. Any devices that show signs of damage to safety features are considered unserviceable and must be carefully segregated for prompt disposition in accordance with current instructions.

If a pyrotechnic device should be accidentally ignited, its functioning will, in all cases, result in a fire hazard. In a confined area, the gases generated by this combustion could present a serious toxic hazard. Signaling devices containing propellant charges which are designed to propel the pyrotechnic candle into the air create an extremely dangerous missile hazard if they are accidentally ignited. Pyrotechnic compositions characteristically contain their own oxidants and therefore do not depend on atmospheric oxygen for combustion. For this reason, the exclusion of air, by whatever means, from a pyrotechnic fire is usually ineffective. Many pyrotechnic mixtures" particularly illuminating flare compositions, burn with intense heat (up to 4500°F). Normally available extinguishers are of little or no value in fires of this kind. Carbon dioxide extinguishers, in addition to being ineffective, are potential sources of danger in that they tend to produce oxygen which supports combustion. Foam type extinguishers are equally ineffective because they work on the exclusion-of-air principle. It is recommended, therefore, that water, in flooding quantities and at low pressure, be used to cool the surrounding area and thus prevent spread of the fire.

Pyrotechnics that are activated by water, such as markers, location, marine, must not be stowed in compartments where there are sprinkler systems. Do not fight fires in them with water.

As most pyrotechnics deteriorate with age, the oldest ones should be stowed nearest the front of the locker so that they will be used first.

APPLICATION OF EXPLOSIVES IN RIM

So far in this chapter we have discussed the "raw materials" used in explosives. Also we have covered, in a general way, types of warheads and fuzes. With this background, we can turn our attention to specific applications of explosives in missile components. Figure 10-17 shows a breakdown by sections of the TERRIER BT-3 missile round. The complete round is designated as Mk 2, and is made up of Guided Missile Mk 10 Mods 0,1, or 2 mated with booster Mk 12. The numbers of the round, sustainer, and missile used with improved versions of the BT-3 missile (BT-3A, and BT-3B) are indicated on the illustration, but the basic outlines of components are not changed. The HT-3 and HT-3A use the same booster and sustainer but have a different missile, which is not indicated on the illustration. One of the big differences not shown in figure 10-17 is the fact that the BT-3A and BT-3B can carry a nuclear warhead. Because the BT-3 and its later versions are widely used in the fleet, we are using it as a study example. Other TERRIER types, TARTAR, TALOS, and STANDARD missiles contain functionally similar components; so what you learn here also applies to these missiles.

MISSILE SECTIONS AND THEIR EXPLOSIVES

The BT-3 is composed of six sections:

1. Nose section
2. Fuze section
3. Warhead section
4. Electronic section
5. Sustainer section
6. After section

Explosives are used in all sections except the nose and electronic sections. The fuze section

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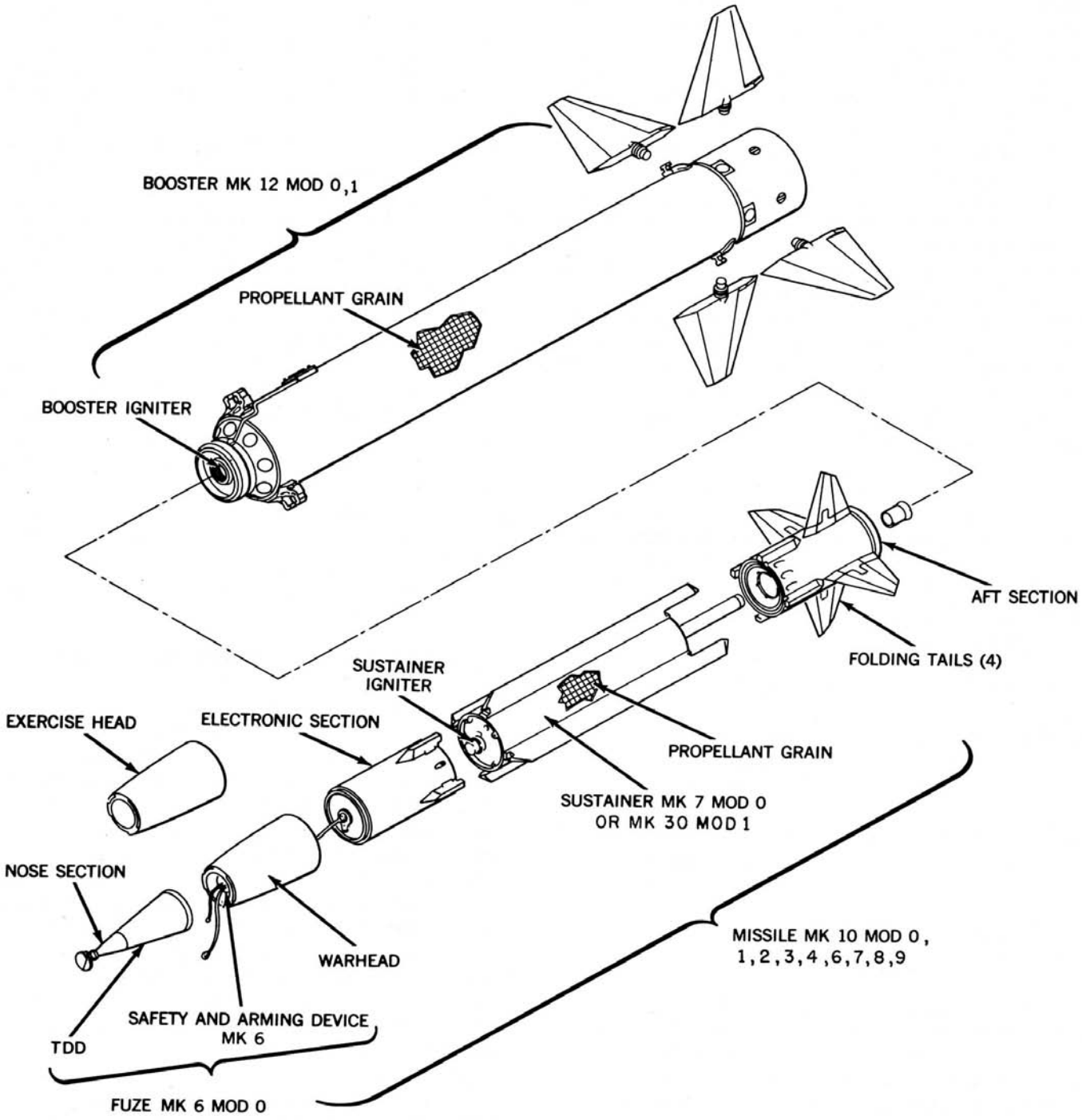


Figure 10-17. — Location of explosives in Terrier BT-3 (and modifications) missile rounds.

contains the Target Detecting Device (TDD for short). Inside the warhead is the Safety Arming Device (more frequently called the depth charge S&A device). The S&A device is electrically connected to the TDD. These two units make up the fuze. As you learned earlier, the sustainer contains the propellant that keeps the missile flying after booster burnout. The aft

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section contains two gas generators. One generator drives a hydraulic pump which provides hydraulic power for the steering control system. The other generator drives an electrical alternator which provides electrical power to electrical and electronic circuits in the missile.

Table 10-1 lists some of the explosives, propellants, and pyrotechnics in the principal hazardous units of the BT-3. We have not listed all the hazardous units but just enough of them are mentioned to show the application of the . basic explosive compounds you studied earlier in this chapter. For a complete list, look in the OP for the missile weapon system on your ship. One volume is devoted to general and specific safety precautions applicable to missile components. Here you will find a table which lists all the hazardous components in the missile of interest and the type of explosive in each component. pyrotechnic magnesium powder

Table 10-1. — Explosive, Propellant, and Pyrotechnic Material of BT-3 Round.

ITEM	DESCRIPTION
1. Warhead explosive charge	Composition B
2. Fuze booster	CH-6
3. Sustainer igniter	Composition B — KNO_3 (potassium nitrate)
4. Flash signal pyrotechnic	Black powder and magnesium powder

BT-3 FLIGHT TERMINATION SYSTEM

Before we leave the subject of explosives, we should discuss in more detail warheads and fuzes. Earlier we discussed the many types of warheads and fuzes, but now let's look at a specific application for them. The BT-3 is still a good representative example, so we'll stick with it. Other missile warhead systems are similar to the BT-3s. They differ only in detail.

Flight Termination with a Warhead

A warhead system consists of a warhead and a fuze. The warhead system is only part of a larger system called the Flight Termination System. As its name implies, the purpose of the flight termination system is to end a missile's flight. And it usually does, with a big bang. When the missile intercepts the target, a firing pulse from the fuze sets off the warhead. Also, should the flight of the missile become uncontrolled for any reason, a firing pulse from the flight limiter circuit will detonate the warhead. Figure 10-18 shows a block diagram of the flight termination system. In the diagram you will find the two units - flight limiter and fuze - that start the action to detonate the warhead. The flight limiter will send out a firing pulse if there is a failure in the missile receiver or missile power supply, or if the missile flies out of the beam. These are unplanned failures, but you can deliberately make similar failures occur. For instance, you can cut off guidance beam transmission at the radar. The missile does not see a beam and the flight limiter circuit senses a receiver failure. The warhead is subsequently detonated. You can see that essentially the flight limiter is a safety device. If a missile goes out of control, it will automatically destroy itself before it endangers your ship or others in the task force.

Flight Termination with an Exercise Head

The same principle applies if the missile is fitted with an exercise head instead of a warhead. An exercise head is used for missile flight evaluation. The exercise head contains telemetering equipment which sends information about the missile's performance back to the firing ship. This type head contains a small destructor charge. When this charge is detonated, the force from the charge blows out bits of the exercise head. These jagged edges of the exercise head left after the explosion make the missile aerodynamically unstable. The surface of the missile is no longer streamlined, and the missile is torn to pieces by the force of the air stream.

When the exercise head is used, the fuze firing pulse (at intercept) ignites two pyrotechnic flash signals. These signals are mounted in the exercise head and give visual indication of target interception. Sometime later the flight limiter circuit initiates the explosive train to detonate the destruct charge. This destructor charge in the exercise head is not the same as the self-destruct unit in the warhead which destroys the missile if it gets off course (or if for some other reason the missile will miss

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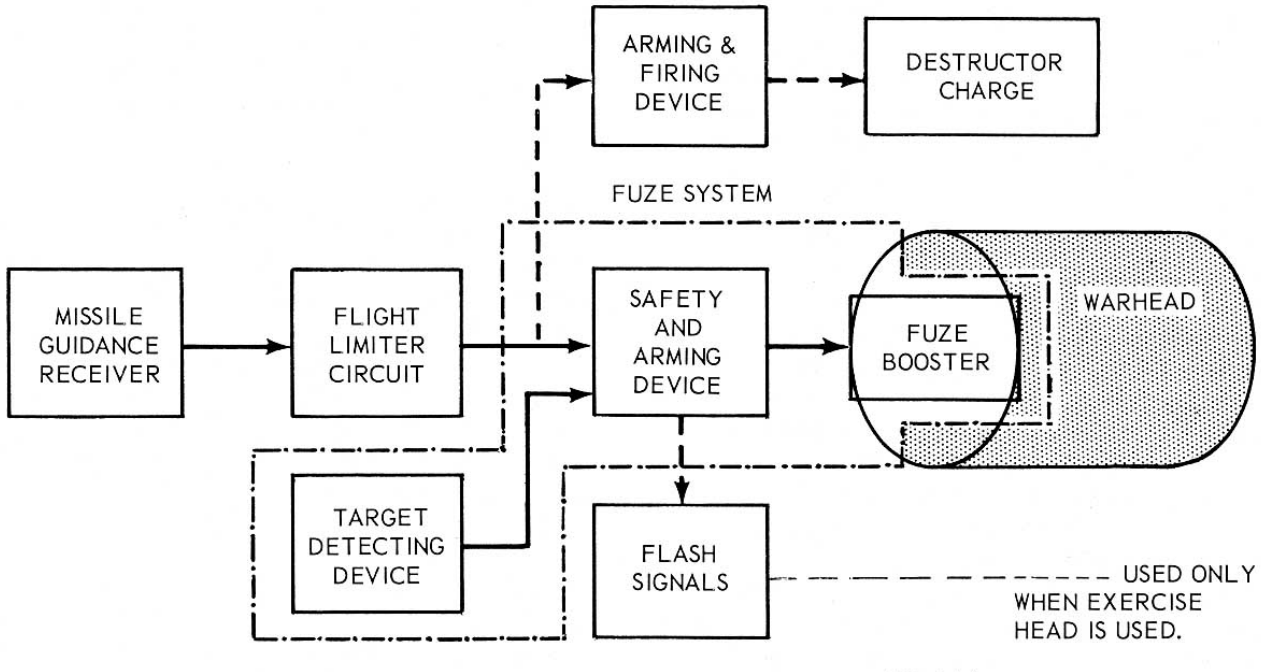


Figure 10-18. — BT-3 flight termination system.

the target and must be destroyed). Some recoverable missiles have been designed for training use, and they represent a great saving. They are especially useful for antimissile target practice.

DISPOSING OF DAMAGED OR DEFECTIVE EXPLOSIVES

In the paragraphs above we talked about missiles destroying themselves, and you have read in the newspapers about destruction of the huge rockets used in satellite launching. Is it the fault of the explosive or of some part of the mechanism, electrical or electronic systems? Can the flaws be determined and corrected before launch? We will consider here only the possibilities with explosives.

You cannot test an explosive because to do so would destroy it. You can look at it, feel of it, smell it, but you cannot try it out. Your missiles come aboard with the explosives enclosed, so you cannot see the explosive nor feel it. Visual surveillance is all the inspection you can give it. Examine the exterior of the rocket motor, the sustainer, and the warhead for any signs of exudates or corrosion. Also take note of any dents or breaks in the container. A dented component may have to be returned to the depot. With care, corrosion, if not too deep, can be removed. The removal of exudates is more of a problem. Low grades of TNT exude a dark oily substance that is highly flammable. It is much more sensitive than the TNT itself, especially if it is absorbed by wood, rags, or other cellulose material.

Since most of the TNT now used in explosives is high grade, there is little likelihood of exudates. If you find any, carefully collect a sample to be sent to the U.S. Naval Ordnance Station, Indian Head, Maryland, for analysis. Use a wooden spatula to scrape up your sample; scraping with metal can cause an explosion. Exudate can be washed off with acetone or alcohol, but IN NO CASE should soap, washing compound, or other alkaline substance be used. In the meantime, separate the components in question from other explosives until you receive word about what to do with them.

The solid propellants used for rocket motors and sustainers in missiles are as stable as smokeless powder or more so. No tests are authorized for shipboard use. Proper stowage conditions, careful handling, and visual inspection are required. If a case has been punctured or severely dented, or has been dropped (specified in the OP; usually over 5 feet), it shall not be used but must be returned to the depot. If it is considered too unsafe to hold until it can be

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shipped it should be dumped in deep water without delay, or segregated until safe disposal is possible. A warhead that shows signs of physical damage or corrosion should be returned to the depot. If an exercise head is accidentally dropped, it should be sent to the depot.

Very Sensitive Explosive Components

Fuzes, S&A devices, and pyrotechnics are more sensitive than propellants. A fuze or an S&A device that has been dropped from a height of over 5 feet shall not be used; return it to the depot with a written explanation of what happened. If a fuze or an S&A device becomes armed, it must be dropped in deep water (over 500 fathoms deep and at least 10 miles from shore).

Any pyrotechnic material that appears damp or deteriorated must not be returned to the locker but must be expended as soon as possible by dumping in deep water or by returning it to the depot. You remember that we covered pyrotechnics that may not contact water. Smoke- making devices that have been in the water or have misfired may not be taken on the ship.

Signals with cracked bodies, bent fins, deformed tail tubes, or with any other visual defect that might make them unserviceable must be discarded for disposal, either by deep water submergence or return to depot. Do not attempt to disassemble or repair faulty signals.

MAGAZINES

The term "magazine" applies to any compartment, space or locker which is used, for the stowage of explosives or ammunition of any kind.

The term magazine area includes the compartments, spaces, or passages on board ship containing magazine entrances, which are intended to be used for the handling and passing of ammunition. The term is also used to denote areas adjacent to, or surrounding explosive stowages, including loaded ammunition lighters, trucks, and railroad cars, where applicable safety measures are required.

Since missile magazines are not common cargo or living space, but are used for storage of missile rounds, they are protected by their location in the ship, usually below the waterline. They are insulated against moisture and excessive heat. Besides, they are equipped with sprinklers for protection against fire and possible explosion, as well as for emergency cooling. Smothering equipment is provided to put out electrical and oil fires. And they may be equipped with heating and air-conditioning units to keep the spaces within certain temperature limits.

No matter how effectively the above systems work, the only way you can be sure of safe missile stowage is by routine effective inspection and maintenance of the magazines.

The magazine is intended for storage of live missile rounds and for the equipment used to handle them - and for these only. It is no place for empty paint or grease cans nor for stowing paint brushes, oily waste rags, or similar fire hazards. And what goes for material also goes for men. Nobody but those authorized should ever be admitted to a magazine. Even they should be there only when they have business there, a magazine is no place to sit around and "shoot the breeze."

Missile magazine maintenance is chiefly a matter of inspections, cleaning, sprinkler and smothering systems testing, and occasional painting, replacement of lights, fixtures, etc. Magazines are inspected daily; other magazine work is done in accordance with rules laid down by the weapons officer, and will vary from ship to ship.

MAGAZINE TEMPERATURE CHECKING

The main item of daily routine inspection is to check the most important and single factor that affects powder and propellant stability - the temperature - and record it.

To check the temperature, you need a thermometer, of course. But an ordinary thermometer won't be enough. Temperature readings are customarily taken in magazines only once a day. The common type of thermometer tells you what the temperature is at the time you read it. But what was it when you weren't around? You need a thermometer which can record the HIGHEST temperature reached up to the time the reading was taken.

You'll find on the magazine bulkhead, therefore, a MAXIMUM-MINIMUM THERMOMETER (fig. 10-19). This instrument is a U-shaped mercury-filled glass tube with two bulbs. It shows the extreme temperatures, both high and low, indicated since the thermometer was last ZEROED.

You read the PRESENT TEMPERATURE on the instrument by noting the level in either arm of the tube. (Both sides should read approximately the same.) The temperature recorded

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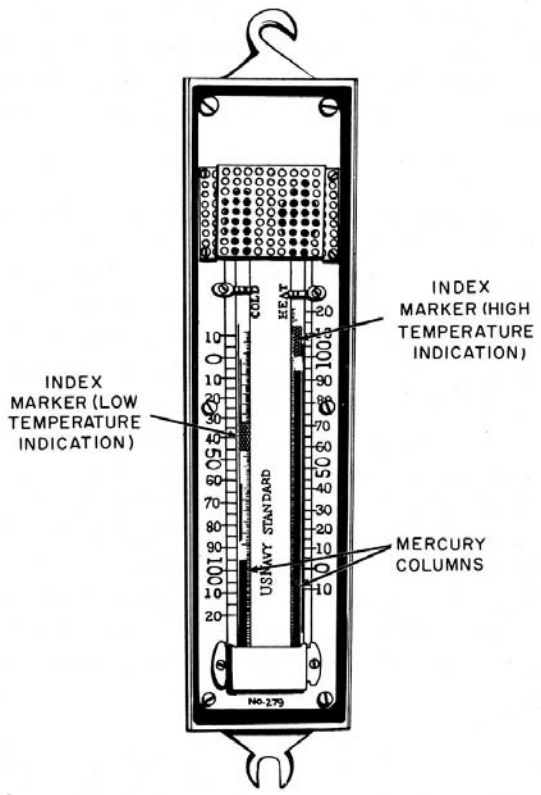


Figure 10-19. — Maximum-minimum thermometer. 5.65

in the pictured instrument is around 95°, which would call for some drastic action if it were actually on a magazine bulkhead.

You read the MAXIMUM TEMPERATURE by noting the level of the BOTTOM edge of the little steel index marker against the right-hand scale, which increases UPWARD. (The picture shows it at just over 100°, another excessive temperature for a magazine.)

You read the MINIMUM TEMPERATURE (here a little over 45° similarly, on the lefthand scale against the bottom edge of the little steel marker. The minimum scale increases DOWNWARD.

To zero the instrument, you run a little horseshoe magnet against the glass tube to draw each steel index marker down to the level of the mercury. Zero the thermometer on both sides AFTER you have recorded the maximum and minimum readings.

Magazines are usually equipped with two maximum-minimum thermometers - one in the coolest part of the magazine, and one in the warmest. Others may be used where it is considered necessary to have additional data on parts of the magazine that may get too warm-bulkheads near steam lines, for example.

RELATIVE HUMIDITY INDICATORS

Because many types of explosives are adversely affected by humidity, there must be some form of humidity control in the storing of guided missile explosive components. Many of the individual components, before assembly into the missile, are packaged in sealed containers in which there is a quantity of desiccant, usually silica gel, to absorb the moisture. Each container has a humidity indicator which changes color as the humidity increases. If the container has been properly sealed there should be no appreciable change. If there is no directive or instruction that specifies, your officer will decide whether to ret-urn the component to the depot or to repackage it. The OP for your missile prescribes the frequency of inspection (perhaps weekly), and gives instructions for replacing the desiccant.

The humidity of the magazine must also be checked regularly. One method is by use of a wet-bulb thermometer or psychrometer. The thermometers must be calibrated, and if properly used, they can give fairly accurate results.

ALARM AND SENSING DEVICES IN MISSILE MAGAZINES

Alarm systems are provided on most ships to indicate the presence of fires, overheated conditions in the magazine, or water leakage through the sprinkling system main control valve. The alarm indicator may be a buzzer, a light, or a small drop type enunciator. The water leakage alarm system is activated by a water switch on the dry side of the sprinkling system main (group) control valve.

Another type of alarm system used is actuated by heat. The alarm sounds when the temperature in an ammunition storage area rises to a danger point. Due to this warning, the temperature can be reduced before sprinkling becomes necessary.

A later development in alarm system now in use is the pry-a-larm. This system functions according to an entirely different principle: The trigger of the pry-a-larm detector is activated by minute particles of combustion. NOTE; Formation of combustion particles occurs in all types of fires and in smoldering or overheated materials. The small combustion particles are invisible, but they are usually present before there is any other evidence of fire; the larger particles are visible in the form of smoke.

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However, most of the particles are too small to be seen by the naked eye.

The pry-a-larm system has several advantages which are as follows:

1. The system provides an early warning which permits safe evacuation from the damaged area and gives the damage control time to fight the fire while it is still small and controllable.
2. The system may be adjusted (calibrated), to ensure proper operation, regardless of its location onboard ship.
3. A standard two-wire circuit is used with the electrical circuit associated with the pry-a-larm system. Due to the low current used in the circuit, a thin-walled conduit can be used.
4. Any failure of wiring or of other essential parts is immediately indicated on a trouble board.

The most important part of the pry-a-larm warning system is the sensing element called the detector head. Basically, the detector head consists of two ionization chambers and a cold-cathode tube.

The specially designed cold-cathode tube is connected in parallel with two ionization chambers. The trigger-electrode of this tube is connected to the junction point of the two chambers. When combustible particles are present, the current in the outer chamber decreases, causing the voltage at the trigger-electrode of the tube to increase. The increased voltage on the trigger-electrode causes the tube to conduct sufficient current for operating the alarm system.

An automatically operated alarm system is tripped when the temperature reaches a preset degree, or, in another system, by the rate of rise of the temperature.

In some magazines the sprinkler system is turned on automatically when the temperature reaches a certain point. A pneumatic release pilot valve (PRP) opens the valve to the sprinkler pipes when the temperature reaches the critical point. The valves for electrical operation are motor operated, with hand-controlled or thermostatically controlled switches. If water-activated explosives have to be stowed in a magazine where there is a sprinkler system, the sprinkler system must be secured so there cannot be accidental sprinkling.

Testing Alarm Systems

On a periodic basis, sprinkling system alarm circuits should be tested. These tests involve checking the electrical continuity of the switch circuits. The leakage alarm (water switch) shown in figure 10-20 is activated by water, when water enters the switch housing the contacts of the switch are shorted and the alarm is energized. To test this type of switch proceed as follows:

1. Notify all personnel concerned that a test of the alarm system is being conducted.
2. Obtain a bulb-type battery filler, and a small container in which to catch water.
3. Partly fill syringe with fresh water.
4. Remove drain plug on water switch (fig. 10-19) and place syringe stem flush against the drain opening. Slowly squeeze the syringe to force enough water into switch housing until the two contacts are shorted. This will energize the leakage alarm; the alarm should be located in the ship's damage control central.
5. When verification from D.C. central has been received that the alarm system is working properly, drain the switch housing and replace drain plug.

Moisture within the switch housing can cause the alarm system to be activated. Ensure that the water switch (leakage alarm) is completely dry after testing.

FIRE SUPPRESSION SYSTEMS

In the following discussions the Mk 13 launching system will be used as a representative example of fire suppression systems because the magazine contains three of the four systems we will describe. The fire suppression system in the missile magazine consists of two carbon dioxide systems, a sprinkling system, and a missile water injection system. Fire or extreme heat in either of the protected areas activates the associated carbon dioxide system, blanketing the equipment or missiles with carbon dioxide. The sprinkling system sprays seawater on all missiles in the magazine during a fire or extreme heat. This system activates only if the temperature continues to rise after the carbon dioxide system activates. The missile water injection system directs a stream of water into the rocket motor of any missile that inadvertently ignites in the magazine.

Three of the fire suppression systems described in this chapter activate automatically and all four are independent of each other. In addition, the carbon dioxide systems and the

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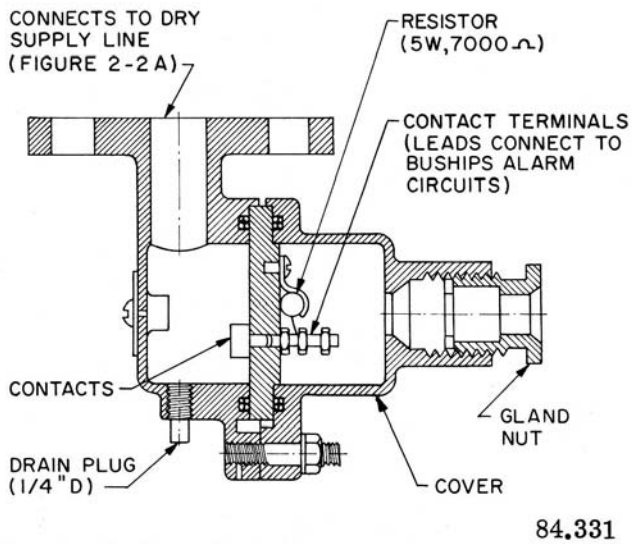


Figure 10-20. — Sprinkling system water switch SIZ2.

sprinkling systems have independent controls for manual activation.

SPRINKLER SYSTEMS

The sprinkling system in the magazines below decks for the spare components is usually part of the sprinkling system that includes the ammunition magazines. The piping system technical manual or the damage control manual should be consulted for information on the specialized systems provided for missile spaces.

The sprinkling systems are supplied from the firemain. The efficiency of operation depends on maintaining full working pressure in the firemains and keeping the system free of debris. Marine growth can foul the firemains, particularly in tropical waters, where weekly flushing may be necessary. Acid cleaning of firemain piping is done at overhaul.

Magazine sprinkling systems consist of the following components: a gate (root) valve provided with a device (not a padlock) for securing it in the open position, a globe valve type sprinkling valve (normally closed), either a separate test casting or a testing feature incorporated in the sprinkling valve, a sprinkling alarm device (circuit FH), and the distribution piping in the form of a grid. The magazine group control valve may serve one or more magazines and may be located either in the handling room, in the adjacent passageway, or in one of the magazines. Whenever a group control valve serves more than one magazine, a stop valve and check valve or stop-lift-check valve is provided in each branch line. This prevents back flooding through the system in the event one of the magazines of the group becomes flooded as result of damage. The valve can also be used for isolating the sprinkling system in a particular magazine when desired. The stop-lift-check valves should be locked (not padlocked in the check position).

SPRINKLERS IN MISSILE MAGAZINES

As a typical example of the sprinkling systems installed in missile magazines (for the assembled rounds), the Mk 13 launching system, Guided Missile Magazine Mk 8 Mod 0, will be used. The system may be actuated automatically by one or more heat-sensing devices, or manually by local or remote controls. The sprinkler heads shower salt water spray down into the ready service area. The pneumatic release pilot (PRP) valve is connected by pneumatic lines to the heat-sensing devices (of which there are 12). Normal temperature variations do not cause the PRP valve to open, but a sudden rise in temperature will. When the sprinkling system is actuated, a sprinkling alarm sounds. If there is leakage into the dry supply line, a leakage alarm sounds. Figure 10-21 shows schematically some of the components of the sprinkler system in this magazine. The piping can deliver 10 gallons of water per minute to each sprinkler head, and the whole ready service area can be quickly saturated. Drains at the base drain off the water.

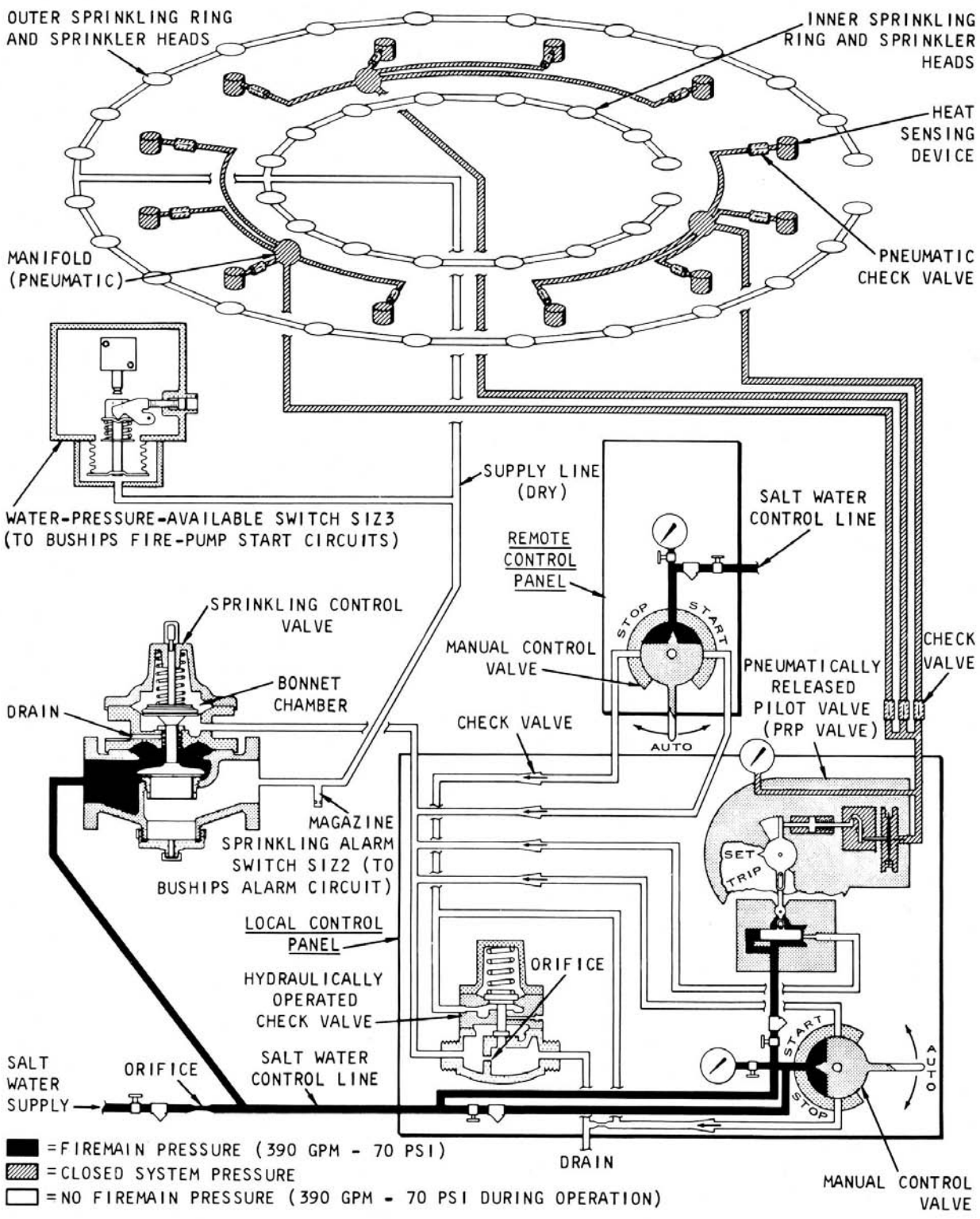
SALT WATER SPRINKLING SYSTEM

The main control valve in the salt water system shown in figure 10-22 functions similarly to the valve operated by hydraulic fluid used in most gun and turret sprinkling systems except that the salt water operated valve cannot be opened or closed mechanically. The water operated valve contains a sight tube that indicates the condition (open or closed) of the valve.

Note: On some ships the salt water system was installed without changing the main control valve.

A local control panel for a typical missile magazine sprinkling system mounts four manually operated valves: a manual control valve, a pressure cutoff valve, an automatic operation cutoff valve, and a pressure gage cutoff valve.

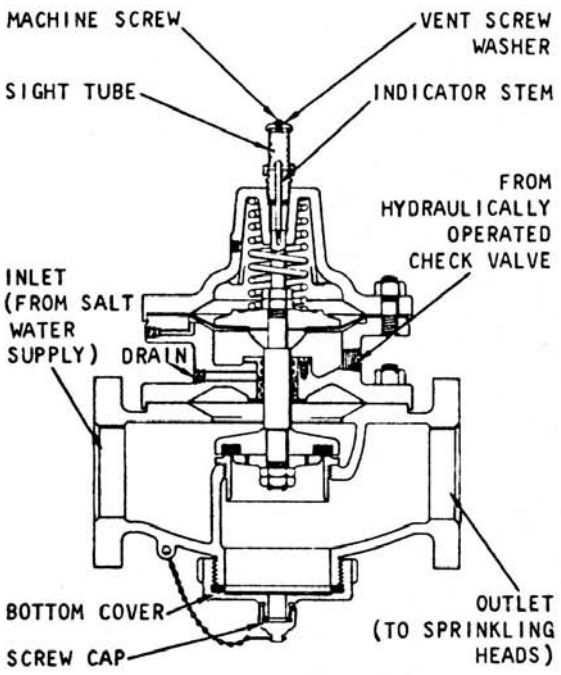
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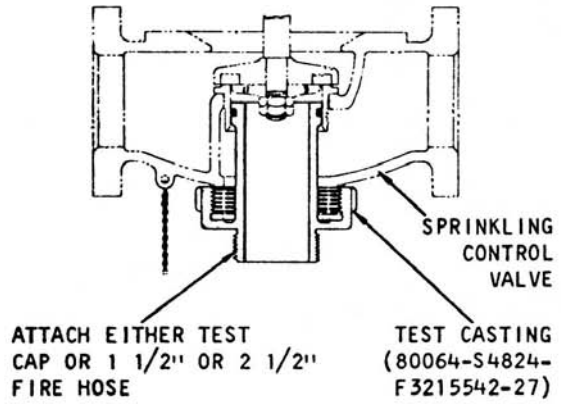
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Figure 10-21. — Sprinkler system operation (schematic), Guided Missile Magazine Mk 8 Mod 0. Launching System Mk 13 Mod 0.

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VIEW A-CONTROL VALVE WITH BOTTOM COVER ATTACHED



VIEW B-CONTROL VALVE WITH TEST CASTING ATTACHED

Figure 10-22. — Salt water operated sprinkling (main) control valve. 84.314

The panel shown in figure 10-23 also mounts five 1-way check valves, a hydraulically operated check valve, a pneumatically released pilot (PRP) valve, and a pressure gage.

The manual control valve is a 3-position and a 3-way valve. The three positions and functions of the valve are as follows:

1. AUTO - Permits automatic operation by blocking the passage of water through a manual control valve.
2. START - Permits water from the firemain to be ported up through a one-way check valve to the piston of the sprinkling system main control valve located in the magazine, thus initiating sprinkling action.
3. STOP - Permits water from the firemain to be ported down through a one-way check valve to the hydraulically operated control valve (pressure-operated check valve). With firemain pressure on this valve, the pressure from the sprinkling system main control valve piston is vented to tank, thus preventing any further sprinkling.

The pneumatically (air operated) released pilot (PRP) is normally closed. When actuated, it directs water from the firemain to the piston of the sprinkling system main control valve. The pilot valve is actuated by sensing devices in the magazine area (see fig. 10-21). This valve and the sensing devices will be described later in this chapter.

The pressure gage at the control panel shown in figure 10-23, indicates the firemain pressure. A manually operated cut off valve and a vent plug are provided to isolate the gage and to vent any air trapped in the pipe leading to the gage.

Salt water strainers are provided in the firemain input line and in the line to the automatic pilot valve (PRP). Drain cocks are usually provided to drain off any sediment collected in the strainer.

The remote control station shown in figure 10-24, which works in conjunction with the local control station, consists of a gage, firemain water pressure connection, strainer, two cut off valves, and a three-way manually operated control valve.

The three-way manually operated control valve of the remote control station functions like the manual control valve of the local control station and is operated in the same manner.

To follow the operation of the sprinkling system refer to figure 10-21. Firemain pressure which operates the main sprinkling control valve is shown leaving the wet side of the main control valve and passing through a cut off valve and strainer to the three-way manually operated control valve and the PRP valve. If the automatic pilot valve is actuated or the three-way valve is positioned to START, firemain pressure

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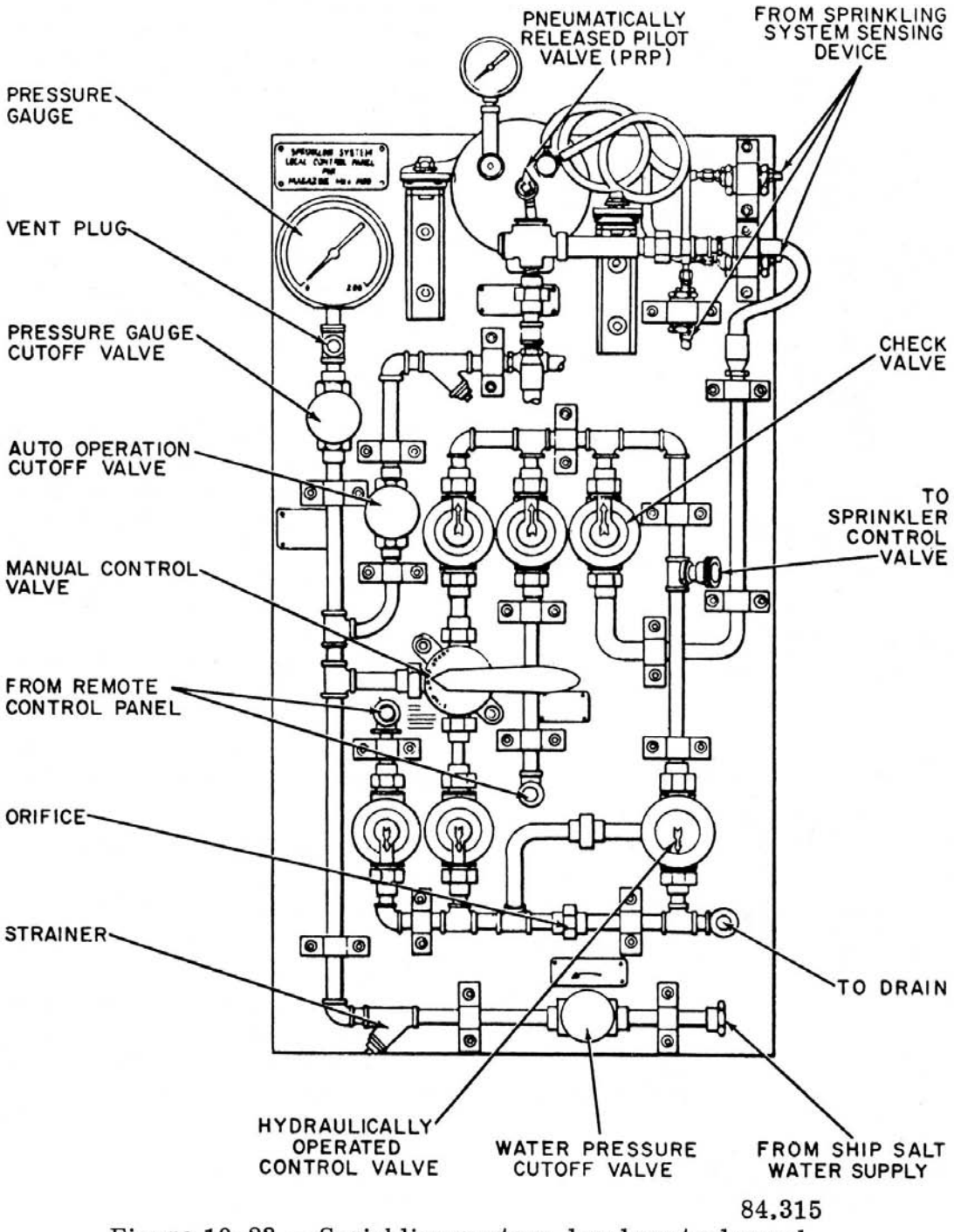


Figure 10-23.—Sprinkling system, local control panel.

is ported through a one-way check valve to lift the main sprinkling control valve and activate the sprinkling system.

Once the sprinkling system has been activated, it can be stopped by positioning either one of the three-way control valves to STOP. This action ports water from the firemain to the hydraulically operated check valve, causing the check valve to lift and connect the line from the main control valve to drain. Note there is no stop line from the PRP valve to the hydraulically operated check valve; therefore, if the sprinkling system is activated by the PRP valve, it must be manually stopped by one of the three-way control valves.

The orifice that connects the main sprinkling control valve and the three-way control valves to

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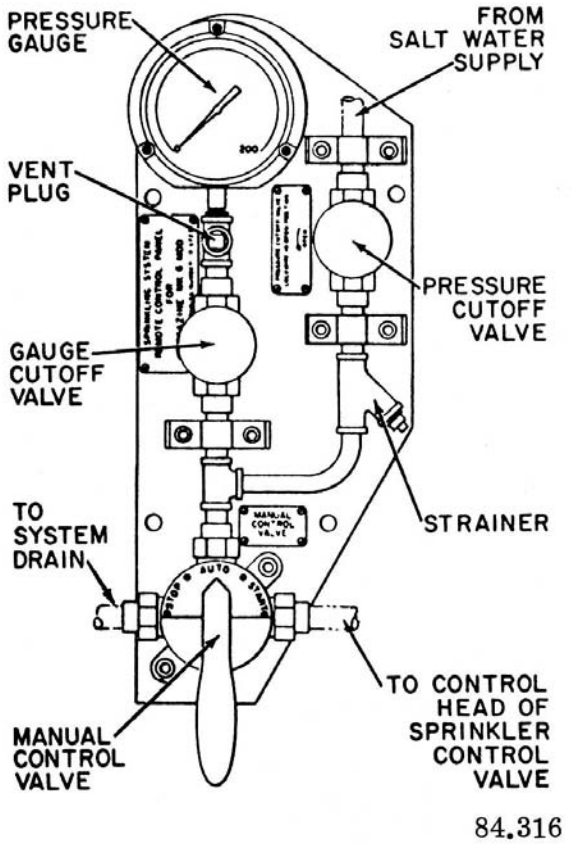


Figure 10-24. — Sprinkling system, remote control panel.

drain is too small to prevent operation of the sprinkling system, but large enough to prevent possible leakage around the three-way control valves and PRP valve from building up pressure and activating the sprinkling system.

The function of the pressure switch, leakage alarm, and air-charged lines will be described later in this chapter.

The latest improvement in automatic sprinkling systems involves the use of firemain pressure to activate a wet type system. The wet type sprinkler system differs from the dry type, in that the sprinkler pipes between the magazine sprinkling control valve and the sprinkling heads are filled with nonpressurized fresh water. A combination valve and sprinkler head replaces the open orifice type of spray head. The sprinkler head valve is held closed by 50 psi water pressure which is supplied from a 20 gallon fresh water accumulator tank. Actuation of the PRP valve or operation of the manual three-way valve, immediately releases the 50 psi control pressure and blocks off the accumulator tank. At approximately the same time, the main sprinkling control valve opens allowing water at firemain pressure to wet down the magazine.

Testing The Sprinkling System

Once a month air test the pneumatic lines in the sprinkling system for tightness and operability of the heat-sensing devices, and test the sprinkling system for proper operation of the valves.

Once each quarter, air test the dry lines for unobstructed flow between the sprinkling control valve and the sprinkling heads, flush the associated firemains for unobstructed flow, clean the salt water strainer and clean the drain hole in the sprinkling control valve.

Of course, you are not going to turn on the sprinkling system and wet down the magazine each time you test the sprinkling system. For both the airtightness test and the operational test you will need a test casting, a spanner wrench, a firehose or a test cap of the correct dimensions (fig. 10-22), and a small container to catch any salt water drip. The OP for the system will tell you the items needed. The OP also gives the step-by-step instructions for each test.

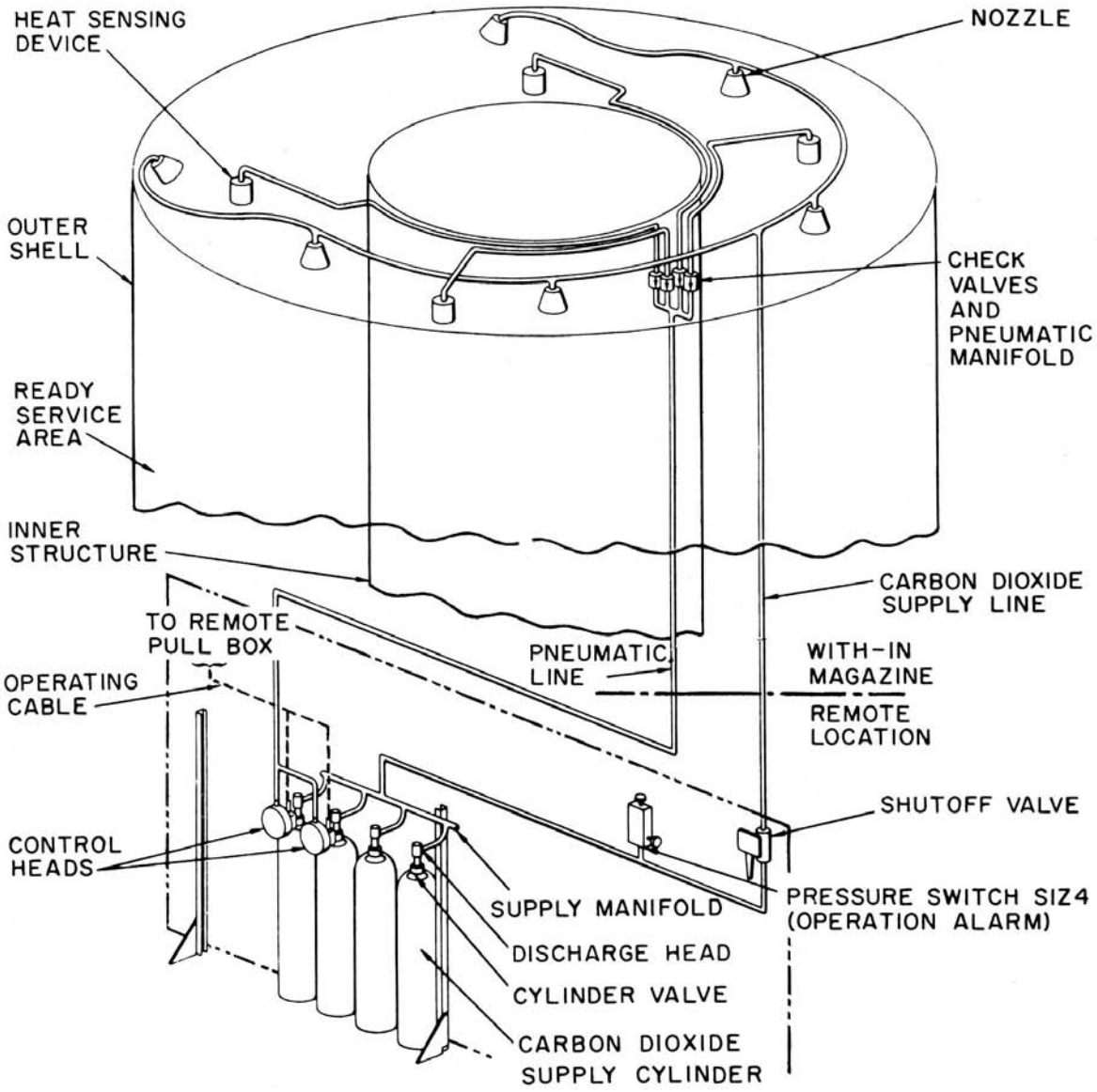
The man doing the testing must be inside the magazine and therefore the magazine must be immobilized until he is finished with the test and is out of the magazine. [Before entering the magazine, position the Magazine Safety Switch on SAFE and remove the switch handle so the magazine power drive cannot be inadvertently started. Also, close the two shutoff valves that serve the magazine carbon dioxide systems. These valves are located adjacent to the magazine access land are normally locked open; unlock and close them before entering the magazine.

When automatic sprinkling systems on ships are performing improperly, assistance from the designated contractor may be requested according to NavShipInst 9480.13.

CARBON DIOXIDE (CO_2) SYSTEMS

The primary components of the carbon dioxide systems are six heat-sensing devices, six supply cylinders, three pneumatic control heads, eight discharge nozzles, two shutoff valves, two operation alarm switches, and two remote control pull boxes. The components of the outer and inner carbon dioxide systems are identical; the systems differ only in the number of components that are needed.

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Figure 10-25. — Outer CO_2 system arrangement, Mk 13 Mods 0, 1, 2, and 3 launching system, Guided Missile Magazine Mk 8 Mod 0, and Mk 108 Mods 1, 2, and 3.

The magazine of the Tartar launching system has an installed carbon dioxide system, which is really two independent systems, one for the inner ring and another for the outer ring of the magazine. The outer system has more components than the inner system because it covers a large area. Each system automatically floods its area with carbon dioxide if its heat-sensing devices detect excessive temperatures. Each system can also be manually or remotely actuated.

The carbon dioxide supply cylinders, figure 10-25, located below decks near the magazine structure, contain liquid carbon dioxide at 850 psi at 70°F. Each cylinder has a 50-pound capacity and weighs approximately 165 pounds when fully charged. Each cylinder is equipped with a discharge head to which is connected a supply hose that leads to a common manifold. Control heads are installed on two of the four discharge heads. Pneumatic lines connect the

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control heads to a pneumatic manifold. Pressure originating in one or more of the heat-sensing devices is transferred through the pneumatic manifold to the control heads on two of the cylinders.

Each control head has a lever for manual operation. A safety locking pin secures the operating lever. A line to the top of each control head contains an operating cable that goes to a remote control box shown in figure 10-25.

When tripped, a discharge head on each cylinder directs carbon dioxide into the supply manifold and on to the discharge nozzles. The control heads trip the discharge heads on the control cylinders. Carbon dioxide flowing through the supply manifold trips the other two discharge heads.

When carbon dioxide is released, it operates a pressure switch outside the magazine; the switch operates an alarm. The pressure switch can also be operated manually and reset. As the liquid CO_2 is released from the orifices it becomes "snow" which quickly cools the magazine and puts out the fire. (The "snow" will blister the skin; do not touch it.) WARNING: Close shutoff valves (one for the inner system and one for the outer system) on carbon dioxide systems before entering the magazine. Areas flooded with carbon dioxide cannot sustain life.

WARNING: If a fire occurs in the installation. do not enter it, do not open hatches, and do not start the ventilating system for at least 15 minutes after the system has been flooded with carbon dioxide. After the 15-minute wait for the cool-off period, thoroughly ventilate the installation for 15 minutes before entering. Post another person outside as an observer and standby. If it is necessary to enter the magazine before it is thoroughly ventilated, wear a fresh-air mask or other type of self-contained breathing apparatus. Do not use a filter type mask or a canister gas mask.

The entire supply of carbon dioxide is released when the system is activated. Afterward, the empty cylinders have to be replaced with filled cylinders, and the control heads (fig. 10-26) have to be reset manually. A large screwdriver is needed to turn the reset shafts clockwise until the arrows point to SET.

Although the base structure of Magazine Mk 108 Mods 1, 2, and 3 has been extensively redesigned, there has been no change in the carbon dioxide system.

Testing CO_2 Systems

Carbon dioxide systems must be inspected and tested monthly. Inspect for breakage in tubing, pipes, and hoses. Check that all tubing is properly supported and strapped in place. Replace any damaged parts immediately, using only the special, heavy tubing required for the pneumatic lines.

Air testing the CO_2 systems for tightness and operability of the heat-sensing devices also checks the automatic operation of the alarm switches. Checking the manual operation of the alarm switches is done separately. The operability of the control heads and the pneumatic check valves is also tested.

No carbon dioxide is used in making the tests - the CO_2 supply must be closed off before beginning the tests. To perform the air test you will need test caps for all the nozzles, an air pressure gage, a hand pneumatic pump, an adapter to connect the ship's air supply line and air gage to the Navahos carbon dioxide supply manifold, and an adapter to connect" the air gage and the pneumatic hand pump to the pneumatic line.

The outer and inner carbon dioxide systems are tested separately. Remove the nozzles and insert the test caps. Disconnect the discharge heads on the CO_2 cylinders and connect the air gage and the ship's air supply line, using the adapter, to the carbon dioxide manifold, apply 20 psi air pressure to the carbon dioxide line. This should activate switch SIZ4 (fig. 10-25), an audible alarm should sound, the visual alarm should light, and the ventilation systems should shut down. If any of these do not function, you will need to get the NavShips instructions for repair, and correct the trouble. Next, apply 90 to 100 psi air pressure, secure the air supply, and hold for 5 minutes. If there is any drop in pressure, look for leaks by applying soap suds at the joints of fittings. Replace leaky parts and test again.

When testing the operation of the control heads on the carbon dioxide cylinders and the pneumatic check valves, be sure to observe all the cautions in the instructions in the OP, and perform the steps in the order given. Do not let the carbon dioxide discharge from the cylinders during the test.

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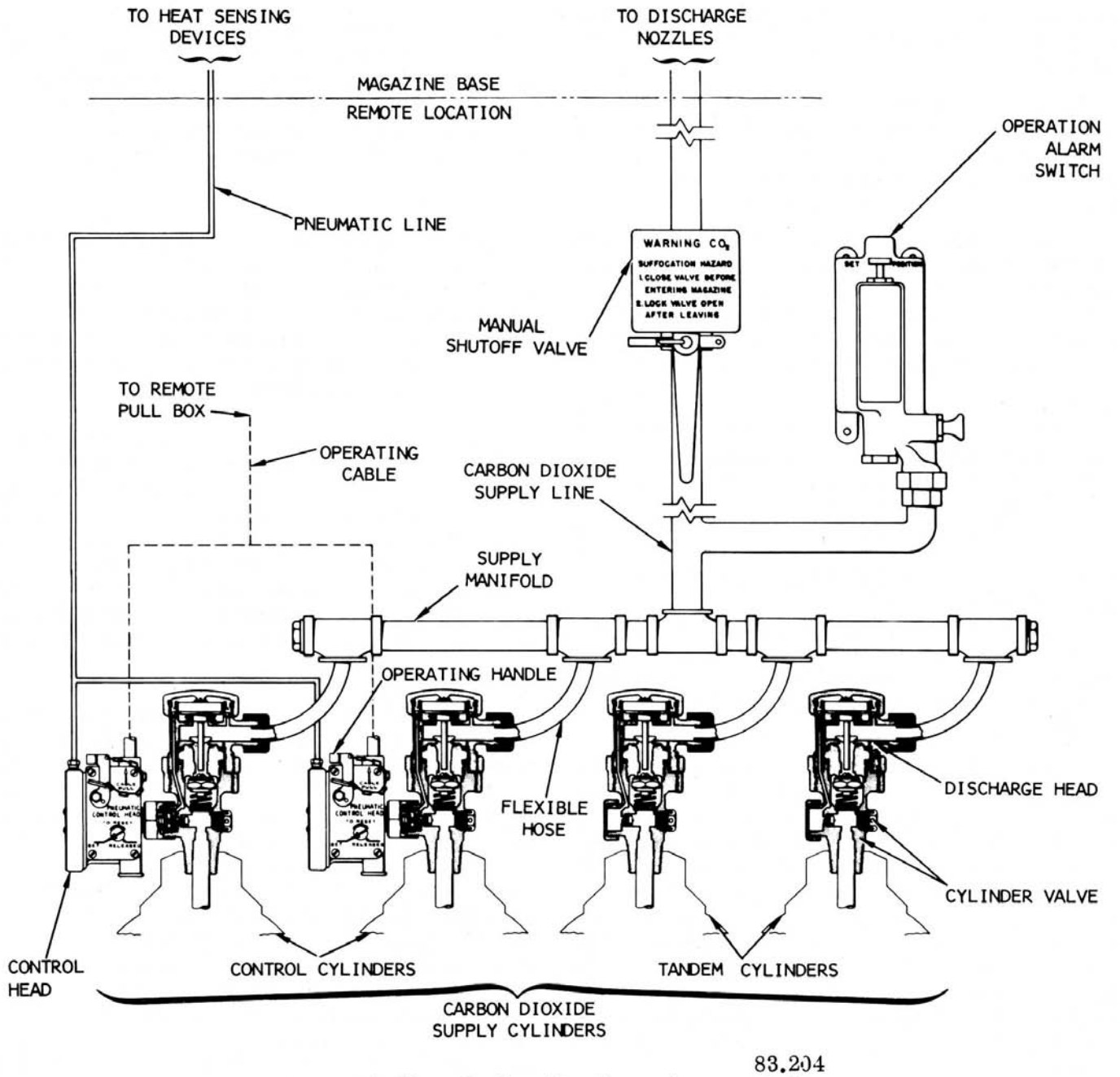


Figure 10-26. — Carbon dioxide system controls.

USE OF FOAM IN FIREFIGHTING

You learned about the use of foam on class B fires (involving substances like oil, gasoline, kerosene, other liquid fuels, and paint) when you studied Basic Military Requirements, NavPers 10054-C, and you have had training in using the foam equipment. In addition to the standard oils and liquid fuels, various rocket fuels now have to be considered in the same fire category. For fighting fires in some type of nuclear warheads, a blanket of foam has been found most effective.

Foam protection is provided for Talos magazine areas, assembly areas, and mating and checkout areas by means of nozzles near the

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deck level, supplied through a fixed piping. A cutout and a visible indicator are provided. The foam systems are not automatic in operation. On CG class ships, foam is provided to the magazine deck only.

For the Terrier missile system, nozzles near the deck level, supplied through fixed piping, give foam protection to the magazines. Foam protection for the assembly compartments and for the strikedown and the checkout compartments is provided by foam hose lines. Foam systems are nonautomatic; but they are interlocked with the access door, and have interior and exterior indicators.

Mechanical foam is produced by mechanical mixing of foam fluid dissolved in water with air, making a tough blanket of air-filled foam bubbles. Chemical foam is the result of a chemical reaction between chemical powders in contact with water, or by mixing two fluid chemicals. The foam-producing equipment is under NavShips cognizance, and descriptions of installation will be found in NavShips publications. Chapter 93 of NavShips Technical Manual 0901-930-0003 (formerly NavShips 250-000, now issued as a pamphlet) describes the methods of producing foam for firefighting. It also describes the use of spray or fog in firefighting. These two methods, foam and fog, are used most on deck and on hanger decks and elevators. The fog is very effective in cooling and smothering a fire but there is danger of the fog nozzle coming into contact with electrical equipment.

WATER- INJECTION SYSTEM

The purpose of the water injection system is to provide an instantaneous and continuous jet spray of water toward the exhaust of any missile accidentally ignited in the magazine.

In the Mk 13 Mod 0 launching system the missile water injector system contains 96 water injector units (fig. 10-27) in the magazine base. Each unit consists of a standpipe, that is threaded into one of the Circular water mains, and a water injection nozzle threaded into the standpipe. A fresh water tank is charged at approximately 200 psi until injector actuation at which time pressure is reduced to firemain pressure. The connecting line from the fresh water supply to the firemain contains a check valve as does the firemain line. Water from the fresh water tank or the firemain goes through a water main to a manifold, which distributes water into the two circular water mains in the magazine base. The mains supply water to the standpipes and detector nozzles.

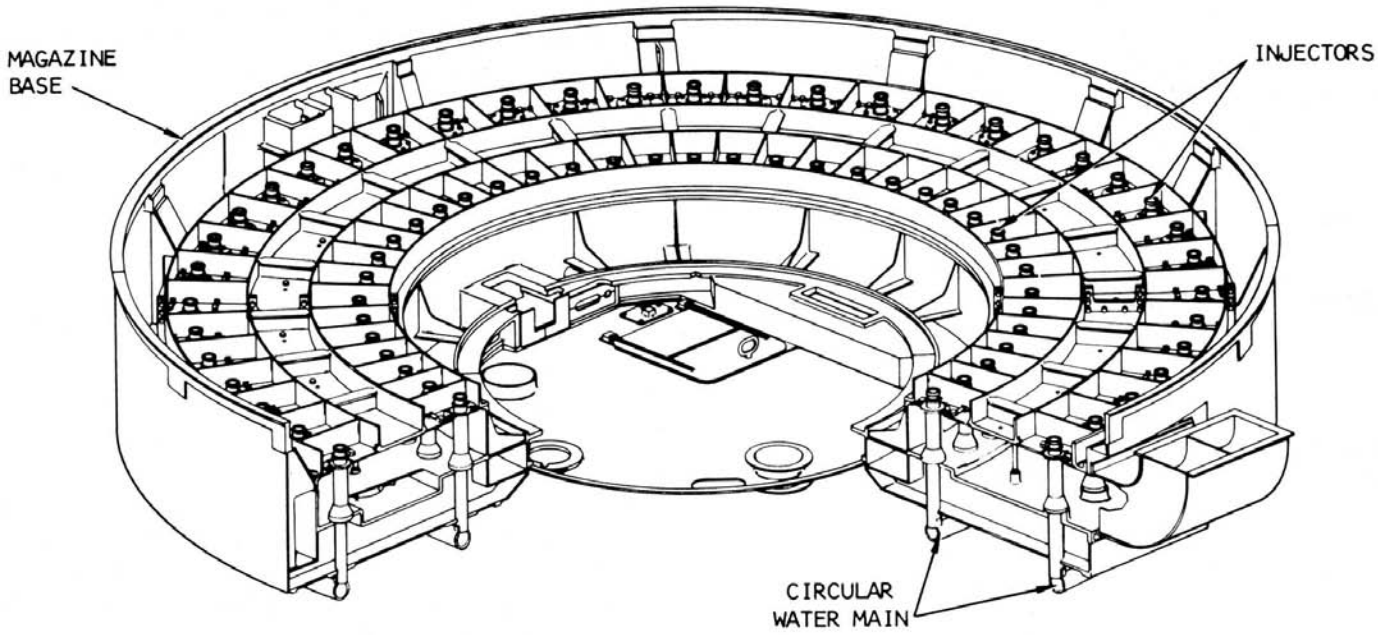


Figure 10-27. — Base of magazine Mk 8 Mod 0, launching system Mk 13 Mod 0, showing water injectors.

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The nozzle body contains a closure piston, an actuation piston, lock balls, and a cover diaphragm secured by a cover sleeve shown in figure 10-28. Three lock balls in the throat of the nozzle hold the closure piston in place against water pressure from inside the nozzle. This piston blocks the flow of water out of the nozzle until the system activates. A gold-wire spring holds the actuation piston in place above the closure piston until missile exhaust activates the system and breaks the spring. A cover diaphragm keeps the nozzle clean.

If a missile ignites in the magazine, exhaust from the missile exerts pressure on the actuation piston in the nozzle. This pressure breaks the gold-wire ring, allowing the actuation piston to move down. The three locking balls then fall out of the throat and into the center of the nozzle.

As the locking balls disengage from the nozzle throat, water pressure from the fresh water tank forces the closure piston, the lock balls, and the actuation piston out of the nozzle, along with the stream of fresh water. A flow detector, in the line between the fresh water tank and nozzles, responding to the flowing water, closes contacts in the circuit to start the firepump, to energize the alarm system, and to activate the drain eductor system.

With the firepump started sea water is available to the injection system. When the water pressure from the tank decreases to firemain pressure, sea water from the firepump opens a check valve and starts flow into the injection system. At 70 psi firemain pressure, the injector nozzle will discharge at the rate of 180 gallons per minute.

During burning of an electrically ignited missile motor, the missile exhaust is forceful enough to prevent water flow for a fraction of a second. During this brief period, the injection system obstructs the missile exhaust flow. For this reason the nozzle has been made small and the cover sleeve purposely made of a material (nylon plastic) that will break away when subjected to the exhaust stream.

To stop the flow of water into the water injection system, a remote shutoff valve must be closed, and the firepump circuit must be opened at the switchboard. After components of activated nozzles are replaced and the compression tank is filled and recharged, the system must be reset.

The water injection detector nozzle in the Mods 1, 2, and 3 is the same as in the Mod 0, but the stand pipes and associated piping have changed due to the changes in the base structure of the magazine. The stand pipes extend below the bottom plate of the base structure. The associated piping is below the base structure, passing under it, not through it. The base structure has been strengthened and provisions made for mounting the elbow-shaped exhaust duct for the plenum chamber.

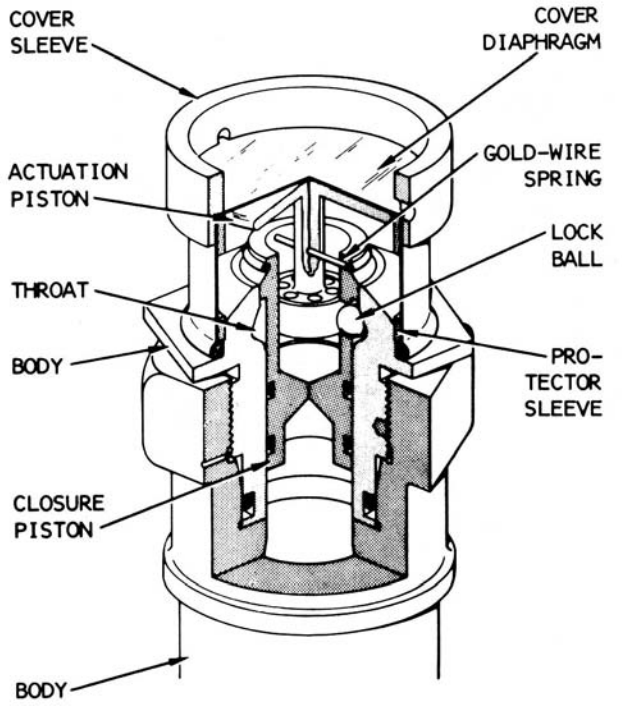


Figure 10-28. — Water injection detector nozzle.

Testing Water Injection Systems

The injection system has to be inspected and tested at intervals determined by ship's policy. Maintenance is then performed as shown necessary by the inspection and tests.

The inspection of the nozzles has to be performed inside the magazine, working in an empty cell. If no cell is empty at the time, hoist one missile onto the launcher. Then set the Magazine Safety Switch to SAFE on the panel to inactivate the power drives, and remove the switch handle from the panel. Also, before entering the magazine, close the shutoff valves on the CO_2 system, and shut off the water pressure in the firemain leading to the injectors.

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One crew member, on instructions from the man in the magazine, manually indexes the ready service ring to position him over the next nozzle, and so on until all nozzles have been inspected. Each nozzle is removed for inspection, using a special wrench. Be careful not to apply force or drop anything on the nozzle end. A force of 16 pounds will trigger it.

After all nozzles have been inspected, turn on the water pressure in the firemain and proceed to bleed each standpipe. To do this, loosen the nozzle with a special wrench, two or three turns, until water appears. Then, tighten the nozzle again until leakage stops. Inspect the rubber cover on the face of the nozzle, and replace it if it is damaged. It is cemented in place.

When all this is completed, recharge the compression tank (62-1/2 gallons of fresh water and 200 psi air pressure). When the crewman is out of the magazine, return the switch handle to the panel, replace the handcrank on the power-off brake, open and lock the two shutoff valves on the C~ system, and, if a missile was placed on the launcher to empty a cell, return it to the cell.

If there is a drop in the air pressure in the fresh water compression tank, check for leakage in the system by checking each nozzle and standpipe. Observe the same precautions for working in the magazine as you did for inspecting the operability of the nozzles and standpipes.

Some instructions require only a spot check of nozzles, and a complete check is not made unless one or more faulty ones are found in the spot check. Review the latest instructions for your system.

AUTOMATIC CONTROL DEVICES

Most missile magazine sprinkling systems are equipped with some type of automatic control device. These control devices are actuated by heat-sensing elements in the magazine area.

The automatic control devices actuate the same sprinkling system main control valve which is operated by the remote and local control stations. The devices are designed to actuate when a rapid rise in temperature occurs or when the heat exceeds a fixed temperature.

PRP Valve

The PRP valve assembly (fig. 10-29) consists of a bronze case which encloses a release diaphragm, chamber, linkage, springs, and a pilot valve shaft and levers. The shaft and levers are connected to the PRP which opens and closes to control the main control valve. The shaft and levers are arranged so that any sudden pressure

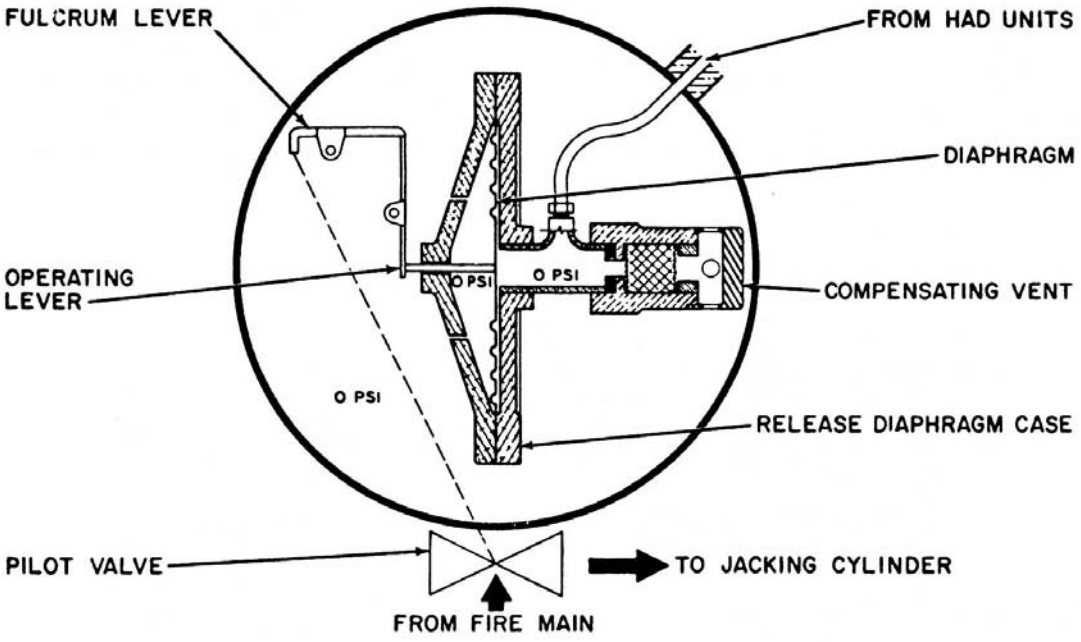


Figure 10-29. — Pneumatically released pilot valve (PRP) schematic.

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increase causes the diaphragm to extend into the diaphragm chamber and to trip the operating lever out from under the fulcrum lever. When the fulcrum lever is released, the pilot valve is opened by spring action.

Slow changes in pressure between the inside and outside of the diaphragm chamber are equalized by the compensating vent shown in figure 10-30. This vent is installed in the line connecting the manifold fitting to the inside of the diaphragm chamber and discharges into the bronze case on the outside of the diaphragm chamber.

One side of the release diaphragm case is open to the interior of the bronze pneumatically released pilot valve case. The other side of the release diaphragm is connected to the tubing from the compensating vent fitting and from the HAD's.

A lever is provided on the front of the PRP case to reset the PRP after operation. An air valve and gauge are also provided on the front of the PRP case to pressurize the system by means of a hand pump when testing for air leaks. The cap covering the adjustment for water side of the PRP valve is locked in position by the manufacturer so that valve setting cannot be tampered with and the cap will not vibrate loose. A metal tag is also attached to the case by the manufacturer warning personnel not to open casing for adjustment.

HAD Unit

The earliest application of automatic control for sprinkling systems is the heat actuated device (HAD) shown in figure 10-31. The device, encased in wire guards, is a pneumatic thermostat which consists of a hollow brass-chamber whose capacity is about 14 cubic inches. One or more HAD's are located in the protected compartment and create the pressure necessary to actuate the PRP valve when the rate-of-rise of the temperature becomes excessive.

The excessive heat is absorbed by the HAD and is utilized to heat the air trapped in the system. The heated air expands and creates a pressure which is transmitted through 1/8 inch tubing to the PRP diaphragm, causing the PRP valve to trip and actuate the sprinkling system. The device functions when the internal pressure is equivalent to the pressure produced by 6 to 10 inches of water within 10 seconds after the HAD has been exposed to external heat.

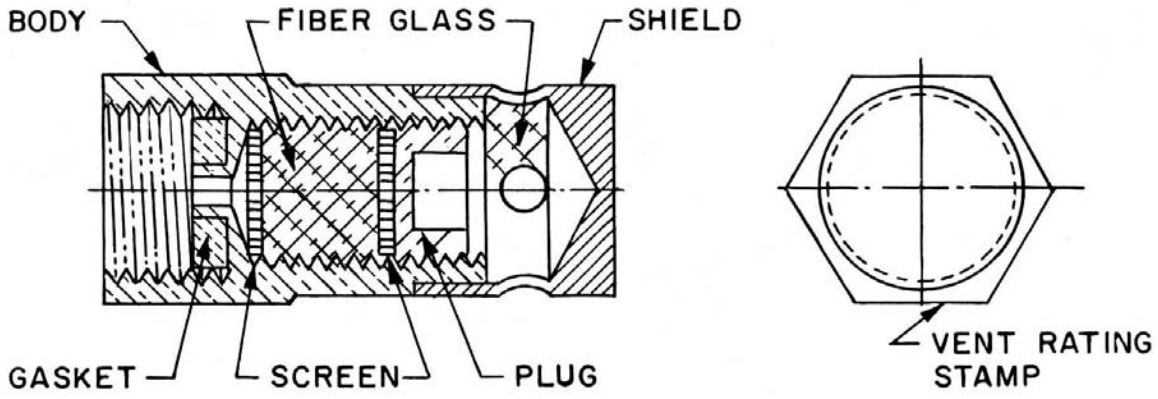
When the heat is absorbed by the device at a slower rate than the one previously mentioned, the system does not function, since provision is made within the pneumatic release pilot valve (PRP) to allow for normal temperature changes within the compartment.

Fixed Temperature Unit

The fixed temperature units (FTU's) are designed to actuate the automatic control device when the temperature reaches a predetermined value.

Note: The temperature rise must be slow, otherwise the HAD unit will actuate the automatic control device before the FTU can function.

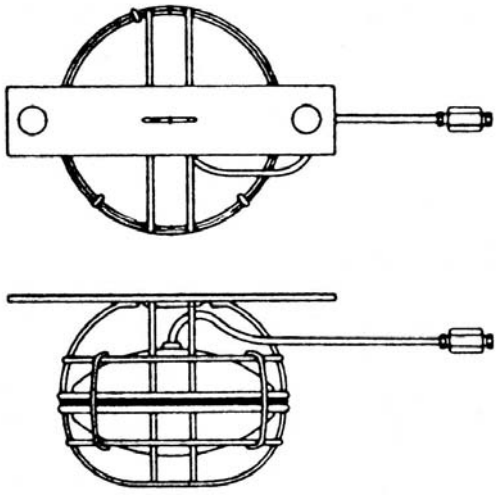
An FTU shown in figure 10-32, consists of a spring-loaded cap which is held in place by indium solder. This solder is made of such material that it melts at the predetermined maximum setting for the protected compartment.



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Figure 10-30. — Compensating vent.

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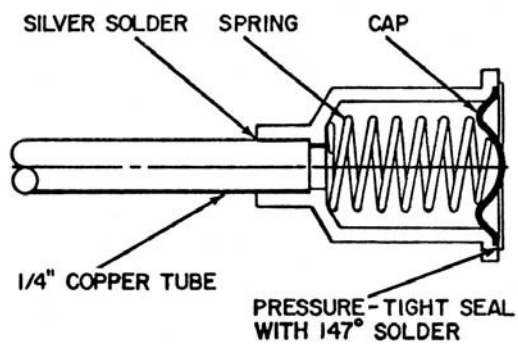


84.321

Figure 10-31. — Heat actuated device (HAD).

When the FTU cap is freed, the pressure in the PRP valve case is released, causing the automatic control device to actuate.

A schematic of an automatic control system consisting of a PRP valve, HAD units, and FTU units is shown in figure 10-33. In figure 10-32 it is assumed that the temperature in the protected compartment rises at a slow rate. As the temperature rises, the HAD's respond by transmitting the heat in the form of air-pressure to the PRP diaphragm. Since the air-pressure rise is slow, it is equalized within the PRP diaphragm case by the compensating vent, thus preventing the PRP valve from being actuated. However, when the temperature in the protected compartment reaches the predetermined maximum level, the FTU opens and vents the air pressure built up in the diaphragm case, causing the PRP valve to trip.



84.326

Figure 10-32. — Fixed temperature unit (FTU).

Thermo-Sylphon Unit

The latest control device for automatic sprinkling systems combines the features of a HAD and an FTU. This device, known as the thermo-sylphon heat sensing device, is used on many of the newest types of sprinkling systems.

A thermo-sylphon heat sensing device shown in figure 10-34, consists of a bellows normally enclosed in a mesh cage. The bellows are expanded and held by a fusible link against spring pressure. The device, automatically actuates a PRP valve when there is a rapid temperature rise or when the fusible link melts.

When a rapid temperature rise occurs in a magazine or ready service area, the resultant sudden pressure increase in the bellows is transmitted to the PRP valve causing it to activate the sprinkling system. Normal temperature changes also cause air in the bellows to expand and contract. However, these normal pressure changes are vented by the compensating vent in the PRP valve.

When the temperature in a magazine area reaches a predetermined value, it causes the fusible link to melt, releasing the compressed spring, and causing the bellows to collapse. As the bellows collapse, a pressure is developed that actuates the PRP valve.

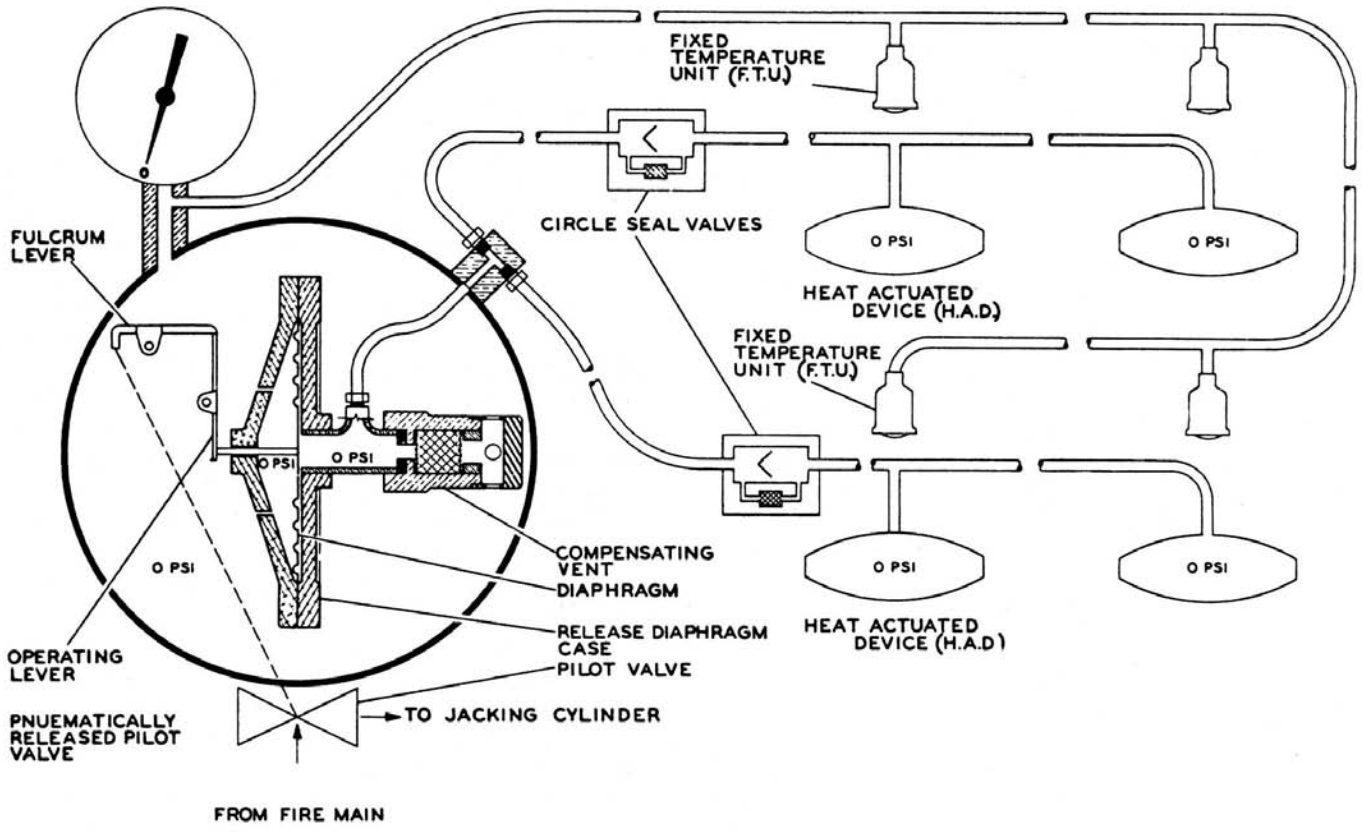
Note: The fusible pin (link, lug, slug) of a heat-sensing device, in a particular sprinkling system, will melt at a predetermined temperature. For example; the Mk 13 launching system magazine has sixteen heat sensing devices. Twelve of these devices are used with the salt water sprinkling system. The fusible pins in these devices will melt at 174 degrees F. The four remaining heat-sensing devices are used with the carbon dioxide (CO_2) system. The fusible pins in these devices will melt at 158 degrees F.

It is imperative that when replacing a fusible pin on a device that has been activated, a pin with the same melting point as the original pin must be installed.

TEST SPRINKLING SYSTEM

Once a month (1) airtest the pneumatic lines in the sprinkling system for tightness and operability of the heat sensing devices, and (2) test the sprinkling system for proper operation of the valves.

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Figure 10-33. — Sprinkling system automatic control system, schematic.

The once every quarter airtests of the dry lines for unobstructed flow between the sprinkling control valve and control heads and flushing the firemains for unobstructed flow was covered earlier in this chapter.

Airtest (Tightness)

To airtest the sprinkling system monthly for tightness and operability of the heat sensing devices, proceed as follows:

1. Obtain the following equipment:

   a. A test casting
   b. A spanner wrench
   c. A hand pneumatic pump
   d. Either a 1-1/2 inch fire hose or a test cap (2-1/2 - 7-1/2 N.H. thread) having a petcock
   e. A small container in which to catch salt water

2. Using the spanner wrench, remove the bottom cover of the sprinkling control valve. Then screw in the test casting, shown in figure 10-22B.

3. To the threaded end of the test casting, attach either a fire hose or, if available, the test cap. If the fire hose is used, the hose should be led to a convenient drain.

4. Close the normally locked open globe valve in the 3-1/2 salt water supply main.

5. Connect pneumatic pump to air valve on PRP valve (fig. 10-35). Remove cap at the bottom of gage to get to the air valve to connect pneumatic pump to PRP valve.

6. Slowly pressurize system until a pressure of at least eight ounces is obtained. Because of the slow passage of air through the vents, some additional pumping of air may be required before obtaining a balance.

7. After the balance is obtained, stop pumping and hold the pressure for five minutes. The pressure should not drop during this period - even the slightest drop in pressure is serious,

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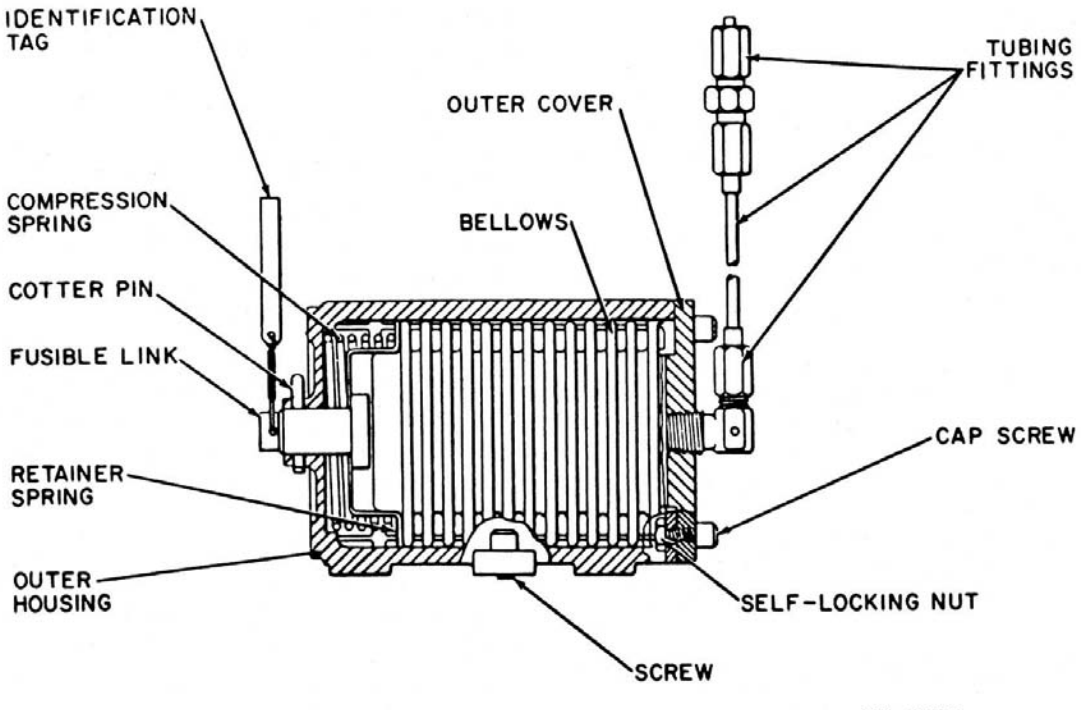


Figure 10-34. — Thermo-sylphon heat sensing device.

for it indicates a leak which may prevent automatic operation of the system at the time of a fire. If the gage does not retain eight ounces of pressure for five minutes, first check the fitting on the hose line for the pneumatic pump to be sure it is not the type that holds the air valve open, thereby permitting pressure to escape. Look for a leak by applying soap suds to the fittings near the PRP valve and subsequently at the fittings near the heat sensing devices. Do not use a movable jaw wrench when tightening fittings. NOTE: If the leak is within the PRP valve, replace this valve with a new unit. Do not open the PRP valve case under any circumstances. Turn in defective valve to the nearest naval stocking activity. Repeat airtest with replacement valve.

8. To test action of the heat sensing devices, punch the air valve fully open. Sudden release of pressure in the PRP valve case and pneumatic lines should trip the sprinkling main control valve; allowing water to flow into the test casting. (Actuation of the PRP valve simulates the condition created when the sealing disc (cap) of an FTU is ejected when the indium solder melts or the bellows of the thermo-sylphon device collapses due to melting of the fusible link.)

9. Wait about two minutes (see note below), and then reset the tripping mechanism on PRP valve by gripping the reset lever with the reset key and turning the lever to SET (fig. 10-35). Be sure the lever latches at SET before removing key. Note: The two minutes wait is necessary to allow time for pressure on both sides of the valve diaphragm to equalize. Unless the pressure is equalized the PRP valve will not latch at SET. If after two minutes the valve does not set, again slowly pressurize the system as in step 6, wait five minutes, then punch the air valve wide open. Wait another two minutes, and then reset the valve. If the valve still fails to reset, or will not trip to begin with, replace it with a new unit. DO NOT OPEN THIS VALVE UNDER ANY CIRCUMSTANCES. Turn in the defective valve to nearest naval stocking activity. Repeat airtest with replacement.

10. With the PRP valve reset and the air vented from the system, totally immerse the most remotely located accessible HAD in a container of water. (Water temperature should be at least 200° F.) The PRP valve should trip in a maximum of 5 seconds. Check the sprinkling main control valve to ensure that it is open. To expedite the test, cool the HAD with cold water or ice. Reset

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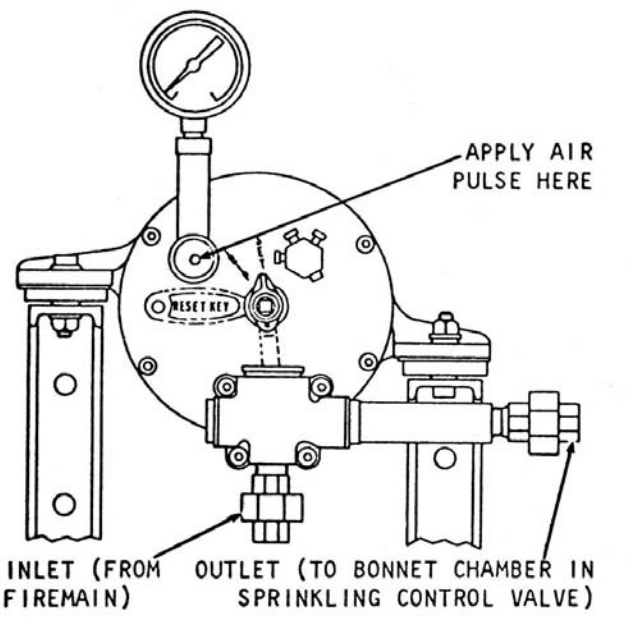


Figure 10-35. — Pneumatically released pilot valve.

the PRP valve and check to ensure the sprinkling main control valve is closed.

10a. (Figure 10-35 apply air pulse here approximately 8 ounces). This does the same thing as if the heat actuated device (HAD) had functioned or the thermo-sylphon device had functioned due to a fast rise in magazine temperature.

11. Open globe valve in the 3-1/2 inch salt water supply main and lock open. Remove fire hose or test cap from the test casting on the sprinkling main control valve. Have a small container available to catch salt water trapped within test casting. Then remove test casting, check to see that there is no leakage past valve seat, and screw on the bottom cover to the valve, using the spanner wrench.

GENERAL INSTRUCTIONS AND SAFETY

In a study of safety precautions, it is difficult to cover every possible situation that may arise and which, if improperly handled, may produce serious results. However, if a thorough understanding of the basic ideas behind the precautions is developed, unsafe conditions can be recognized and corrected and further suitable action can be taken instinctively when the unexpected occurs.

Safety is everyone's responsibility. Awareness of danger, knowledge of how danger can be avoided, and constant vigilance are the three basic requirements to prevent accidents when working with explosives, including missiles and missile components.

Safety precautions, rules, and regulations for handling explosives should be made the subject of frequent instruction, and the necessity for strict compliance with these procedures should be so firmly fixed in the minds and habits of new men that they will invariably and subconsciously thereafter react in an emergency according to the instructions previously received. Attention is especially invited to the fact that in the early stages of the use of explosives, experience was gained at a great price- not only in dollars, but in human lives.

No relaxation should be tolerated, since this tends to create the impression that the rules are arbitrary. Men tend to become careless and indifferent when continually engaged in work with explosives and, as long as no incident occurs, are inclined to drift gradually into neglecting the necessary precautions. Nothing but constant vigilance on the part of officers and petty officers in charge will ensure the steadfast observance of the safety rules and regulations which experience has taught to be necessary.

It is of primary importance in the safety program that all persons should be thoroughly indoctrinated before their first occasion of working with explosives. This indoctrination must include personal safety, material protection, accident prevention, and initial actions to be taken if a dangerous situation starts to develop. THERE IS NO VALID REASON FOR FAILURE TO COMPLY WITH SAFETY REGULATIONS.

Missiles, as well as gun ammunition, bombs, rockets, and torpedoes, are extremely dangerous; therefore, constant vigilance and intelligent supervision must be exercised during handling and storage of these items.

Handling of missiles and explosives shall be kept to a minimum and performed only with authorized handling equipment. Live missiles shall never be used to check out the equipment.

Missile boosters shall be handled with extreme care. A slight blow may crack the propellant grain and cause an explosion when the weapon is fired. Care shall be taken that no heat is applied to or near boosters.

Missile warheads are classified as bomb-type ammunition; therefore all general safety

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precautions for handling high explosive and bomb-type ammunition shall be exercised when warheads are being handled.

Warheads must be grounded at all times when outside their shipping containers. The container shall be grounded before it is opened prior to removal of the contents. Empty containers must be grounded before a warhead is inserted. Physical contact of a container to ships metal deck would be an adequate ground.

Steel instruments or tools that may cause sparks shall not be used for cleaning or scrapping exudite from, or for assembly or disassembly of warheads.

A warhead that is cracked, dented, bent, or that otherwise shows signs of physical damage or corrosion shall not be used. Warheads that cannot be used should be returned to a depot.

Only authorized personnel shall remain in the area when a warhead is being installed or removed.

When fuzing a warhead, ensure that the threads are clean and in good condition; the fuze must not be forcibly screwed into or out of, its cavity. Place a light film of silicone grease on threads and fuze body for lubrication; do not use an excessive amount of grease.

Any warhead, live or inert, that fails to mate for any reason should be returned to a depot.

Exercise heads shall be handled in accordance with the greatest hazard posed by the material contained within.

If an exercise head is accidentally dropped, it should be returned to a depot.

A fuze or an S&A body that is cracked, dented, bent, or that shows other signs of physical damage shall not be used; it should be free from rust or other corrosion.

An S&A device shall be in the SAFE condition before installation. It shall not be installed into a warhead unless the warhead is assembled in a missile, except where otherwise directed.

Any fuze or S&A device that has been dropped from a height of over five feet shall not be assembled to a missile or warhead, but should be returned to a depot, with attached explanation.

Fuzes and S&A devices shall not be tested aboard ship; neither shall they be disassembled for any reason. They are a sealed assembly and shall not be repaired, modified, or broken down.

Fuzes, boosters, detonator, etc. are loaded with explosives which are sensitive to shock and friction. They must be handled with care at all times.

No explosive shall be removed from a wooden container by inserting a wire, nail, or sharp instrument.

No explosive component shall be disassembled, nor shall any attempt be made to modify or repair it, except by specific approval from NavOrd.

As explosives go, black powder is one of the most dangerous. It must always be handled with the greatest care. A few of its properties and precautions that should be observed in handling it are:

1. It possesses practically unlimited stability if stored in tight containers and kept dry. (Black powder, and assemblies containing it, should be regarded as unserviceable if they have become damp or wet.)
2. It deteriorates irregularly when moist.
3. It is not affected by moderately high temperatures. 4.

It is highly flammable and sensitive to shock, friction, and sparks.

5. If you can, avoid opening containers of black powder in the presence of other explosives or ammunition. The maximum limit that you can expose in a magazine is 25 pounds.

Pyrotechnics and pyrotechnic ammunition (except illuminating projectiles) shall be stored in cool, dry magazines below decks, preferably above the water-line, or in special pyrotechnic lockers located on the weather decks of surface ships. Submarines shall stow pyrotechnics and pyrotechnic ammunition in approved designated places.

If the quantity of any type pyrotechnic ammunition is large, it shall be stored separately from other types of pyrotechnics.

That part of signaling pyrotechnics for boats shall be packed in watertight boxes and may be stowed in boats as required by existing instructions.

Smoke bombs, float lights, smoke boxes and similar pyrotechnic smoke-making ammunition shall be stored, preferably, in dry, cool locations above decks, owing to the difficulty of combating the objectionable smoke in case of fire in these materials.

Chemical ammunition, as a rule, shall be stored in dry, well-ventilated enclosures on the upper decks, convenient for jettisoning in an emergency.

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The different types of chemical ammunition shall, if practicable, be stowed separately. Separate stowage is mandatory if the quantity of any type chemical ammunition is large.

Smoke signals are subject to spontaneous combustion if they become moist. Their stowage in compartments below the waterline is, in general, undesirable because of the relative inaccessibility of many such compartments.

Aboard ship, smoke and gas producing pyrotechnics should be stowed above decks. Pyrotechnics such as Marker, Location, Marine Mk 2 and others which generate flammable gases when moist, should also be stowed topside and separate from other pyrotechnics.

NUCLEAR SAFETY PRECAUTIONS

Since the warheads of some of your missiles contain a nuclear component, you need to know how to handle nuclear materials. The nuclear component is enclosed in explosives, so the rules for safety in handling explosives are applicable. If something happens that causes the explosive to detonate, some nuclear material will be released and there will be a radiation problem. If there is a fire it can cause the explosives to detonate and thus break the container of nuclear material. This does not mean there will be a nuclear explosion. The chances of full nuclear detonation occurring unintentionally are almost infinitesimal, but there can be an escape of some nuclear radiation in an accident or incident. Observe the two-man rule whenever you assemble, disassemble, test, package, unpackage, or handle a weapon containing a nuclear component. Wear your dosimetric device (film badge or other personal type dosimeter) to measure any radiation present. If there is a nuclear accident or incident. get out of the area quickly, holding your breath to avoid inhaling particles, and secure the area. Call for the decontamination team to take care of the radiation problem.

The rules for procedures in case of nuclear accident or incident are given in OPNAVINST 8110.16C. Part of it deals with procedures in case of nuclear-loaded plane crash-lands and burns. First, rescue personnel if at all possible. Then proceed with firefighting. A GM T should safe the fuzing and firing system as quickly as possible. If the fire cannot be controlled before it engulfs the weapons, push the weapons overboard.

In summary. THINK SAFETY. Study the intent of safety regulations.

Safety is a state of mind, develop it so safety becomes second nature to you in your work as a GMM.

It is well known in the Navy that almost all fatal accidents are caused by carelessness on someone's part. A man who violates safety rules risks not only his own life, but the lives of his friends and shipmates.

Remember. "ETERNAL VIGILANCE IS THE PRICE OF SAFETY."

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CHAPTER 11

SMALL ARMS, LANDING PARTY EQUIPMENT AND DEMOLITION

Although ground force operations are secondary duties for naval personnel, each ship of cruiser size and larger maintains a state of readiness for such action. Fleet ships maintain an organized landing party, for limited ground force operations, military police duties, parades and ceremonies. The Navy might be asked to land an armed force in a foreign country when there is a political disturbance and local authorities are unable to give adequate protection to life and property; or a landing party might be called upon to perform riot duty when there is widespread disorder which the civil authorities cannot control. Landing parties frequently give assistance in civil disasters, such as fires, floods, and hurricanes.

Because someday you may be assigned to a landing party, now is the time to learn how to handle small arms. After studying this chapter you should know what safety precautions to observe while handling small arms, and how to field strip, clean, and reassemble them.

You will also study how to use landing party equipment, and how to assemble, issue, and maintain the equipment.

The information contained in this chapter on demolition is meant only to familiarize GMMs with the equipment, material, and safety precautions connected with demolition work. It is in no way intended to train GMMs to become demolition experts. Demolition work is a skill that is acquired only through intensive training and should not be attempted by untrained personnel.

This chapter also contains information on the procedures for using hand grenades including the types of hand grenades now in use, the various methods of throwing grenades, and safety precautions when using hand grenades.

SMALL ARMS

Small arms have been defined as guns with a bore of 0.60 or smaller. They include hand guns and shoulder weapons which are fired from the hand, such as the pistol and revolver; or from the shoulder, like the rifle, carbine, submachine gun or shotgun.

NOTE: Shotguns have bores somewhat larger than 0.60-inch, but they are considered small arms never the less.

Machine guns of small caliber, such as caliber .30 and caliber .50, technically may be classed as small arms on the basis of their bore diameter, though they usually are fired from a bipod or tripod, instead of from the shoulder. Often they are called light machine guns. Few of these machine guns are in use on ships, and they will be given only very brief treatment in this chapter.

The line-throwing gun is fired from the shoulder, but it is not a weapon. It is used to fire a projectile to carry a line when the distance is too great for the line to be thrown by hand.

Most small arms used by the Navy are basically standard Army weapons using Army ammunition. Therefore Army nomenclature and terminology are used with small arms. For example, instead of mark and mod numbers, the Army uses the letters M and A. Thus, "Carbine M1A2" would mean, in Navy language, "Carbine Mk 1 Mod 2." However, in discussing small arms we stick to the Army language; both the Army and the Navy call the weapon "Carbine, Cal. .30, M1A2."

Reference publications such as technical and training publications are issued by the Army in two principal series - Field Manuals (FMs) and Technical Manuals (TMs). Field manuals are intended for the man in the field; they cover basic operations, elementary maintenance, marksmanship, and tactics. Technical manuals, however, are more like OPs: they contain technical data

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on maintenance and repair. An index of Army FMs and TMs is found in O.D. 39397 and Army Pamphlet 310-4 Title, Military Publications.

Much of the confusion surrounding small arms terminology lies in cartridge or round designations. For example, what is the difference between a .30-30 and a .30-06 round of ammunition? Actually, a .30-30 means that the cartridge has a caliber of .30 inch and contains 30 grains of propellant powder. The .30-06 cartridge, for which the M1 rifle is chambered, also has a caliber of .30 inch but the numbers -06 in this case mean the round was standardized in 1906.

The diameter of a shotgun's bore is referred to as the "gage", which is not a measurement of inches or millimeters. Instead, it means the number of lead balls of that particular diameter required to make a pound. For example, if you measured the diameter of the bore of a 12-gage shotgun, you would find it to be 0.729 inch. If you were to make a number of lead balls of this diameter and weigh them, you would find that 12 of them would make a pound. So, the larger the bore of a shotgun, the smaller the gage number. A 16-gage shotgun has a smaller bore than a 12-gage.

AUTOMATIC AND SEMIAUTOMATIC FIRING SYSTEMS

Small arms weapons use fixed case ammunition. The ammunition may be loaded and the case ejected by operating the gun mechanism by hand, or the gun may perform these functions automatically.

Revolvers and some shotguns require manual ejection of empty cases. All other modern small arms weapons are loaded and their empty cases ejected by mechanical devices powered by the energy of the burning propelling charge. This mechanical action may be either automatic or semiautomatic.

A semiautomatic weapon unlocks, extracts, ejects, cocks, and reloads automatically. However. the trigger must be pulled each time to fire a round. The .45 cal. pistol is termed "automatic" but-actually it is semiautomatic, as are the .30 cal. M1 rifle and M1 carbine. A fully automatic weapon continues firing as long as the trigger is kept pulled. Submachine guns and the BARs are automatic.

Weapons which are capable of both automatic and semiautomatic fire are the 7.62-mm M14 rifle, .30 cal. M2 carbine, and the .45 cal. submachine gun M1.

SMALL ARMS OPERATING PRINCIPLES

Automatic and semiautomatic weapons are classified on the basis of how they obtain the energy required for operation. Fundamentally, small arms obtain the energy from the forces that accompany the explosion created when a round of ammunition is fired. The use of these forces does not reduce the effectiveness of the weapon, but utilizes wasted energy that has been put to good use. There are three primary methods in which the wasted energy can be used to operate the weapon. Figure 11-1 shows the three methods in which the pressure from the exploding cartridge is used to operate a weapon, they are gas operated, recoil operated, and blowback operated.

Gas Operated

Gas operated weapons directly utilize the expanding gases produced by the burning propelling charge to actuate their mechanisms. A portion of the expanding powder gases behind the bullet is diverted into a gas cylinder located beneath the barrel. In this type weapon, there is a port opening just aft of the muzzle that connects the barrel to the cylinder. As the bullet passes this port opening, gases enter the cylinder behind a piston, and push the piston rearward.

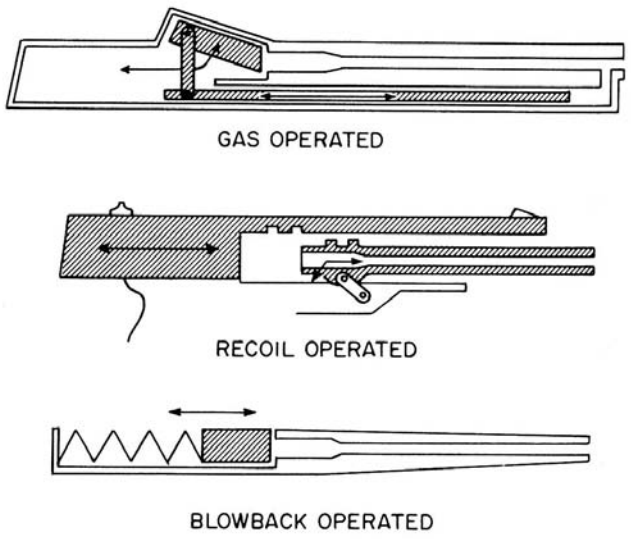


Figure 11-1.— Types of operating systems.

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The piston is connected by a rod to the operating mechanism of the weapon, such as the bolt. The piston carries the bolt aft with it, unlocking, extracting and ejecting the cartridge, and cocking the weapon. Examples of gas operated weapons are the .30 cal. Ml rifle, Ml carbine, and the BAR.

Recoil Operated

As a round is fired, high pressure is developed behind the bullet. This pressure serves a two- fold purpose, to force the bullet down the barrel and to force the breechblock (bolt) to the rear. If the barrel and bolt were secured together (as in the old time cannon), the entire force of recoil would be felt by the shooter's arm and shoulder. By designing the barrel and bolt so they slide in a frame or receiver, the rearward force of the pressure on the shooter is lessened, and the energy can be used to compress springs and move levers, etc., necessary to complete the cycle of operation.

In recoil operated weapons, the bolt and barrel move rearward together for a short distance. The barrel then stops and the bolt (now unlocked) continues to the rear against spring pressure until the empty case is ejected. The force of recoil is also used to cock the weapon and compress the spring which returns the bolt to its firing position, chambering a new round in the process. The .45 Cal. pistol and Browning machineguns are examples of recoil operated weapons.

Blowback Operated

There are similarities between the recoil and blowback operated weapons. There are, however, several major differences. In recoil operation, the bolt and barrel move to the rear as one unit until the bullet leaves the barrel and most of the recoil is spent. The combined thrust of the recoiling barrel, bolt, and other parts is used to operate the weapon. In blowback operation, the bolt moves to the rear against spring pressure just as the bullet leaves the muzzle. The barrel does not move in recoil. The bolt is held closed by spring pressure and the mass of the breechbolt. The force of the exploding cartridge starts the bolt moving rearward. However, the weight of the bolt prevents the chamber from opening entirely until the round has left the muzzle. The recoil spring stops the bolt and returns it to closed position, chambering a new round in the process.

The weight of the breechbolt is an important factor in the design and operation of a blowback operated weapon. When used with low powered ammunition, it is a suitable arrangement. The .45 cal. submachinegun is an example of a blowback operated weapon. A military rifle, however, using the standard .30 cal. cartridge and blowback action, would require a 27-pound breechblock.

HANDGUNS

In your basic training manuals you studied in some detail the .45 cal. pistol. In this portion of the chapter we Will discuss in detail field stripping, maintenance, and safety precautions pertaining to hand guns.

There are two handguns in general use in the Navy at present, the .45 cal. automatic pistol, and the .38 cal. Smith and Wesson revolver. The .45 cal. automatic M1911A1 is the standard service pistol used by sentries, watchstanders, and some members of the landing party. The .38 cal. revolver, because of its lighter weight, frequently is issued to flight personnel, instead of the bulkier .45 cal. pistol.

.45 CALIBER AUTOMATIC PISTOL

The .45 cal. automatic pistol, often called the "Colt", was designed and patented by John M. Browning who was probably the world's greatest inventor of automatic weapons. The original model 1911 differs only in minor detail from the current model 1911A1. Operation of the two models is identical. Figure 11-2 shows the pistol with nomenclature for some of the external parts.

The caliber .45 pistol M1911A1 is a recoil-operated, semiautomatic, magazine-fed, self-loading hand gun with fixed sights. It is often called an "automatic pistol," but, according to our previous definition, it is a true semiautomatic weapon. The magazine holds seven rounds when fully loaded; one round is fired with each squeeze of the trigger. Rifling in the barrel is left hand twist (the only Navy weapon with left hand rifling). Empty, the pistol weighs approximately 2-1/2 pounds. It has a maximum range of a little over 1600 yards, and an effective range (in the hands of troops) of about 50 yards.

DISASSEMBLY

Care of the pistol includes daily preventive maintenance, prefiring cleaning, and postfiring

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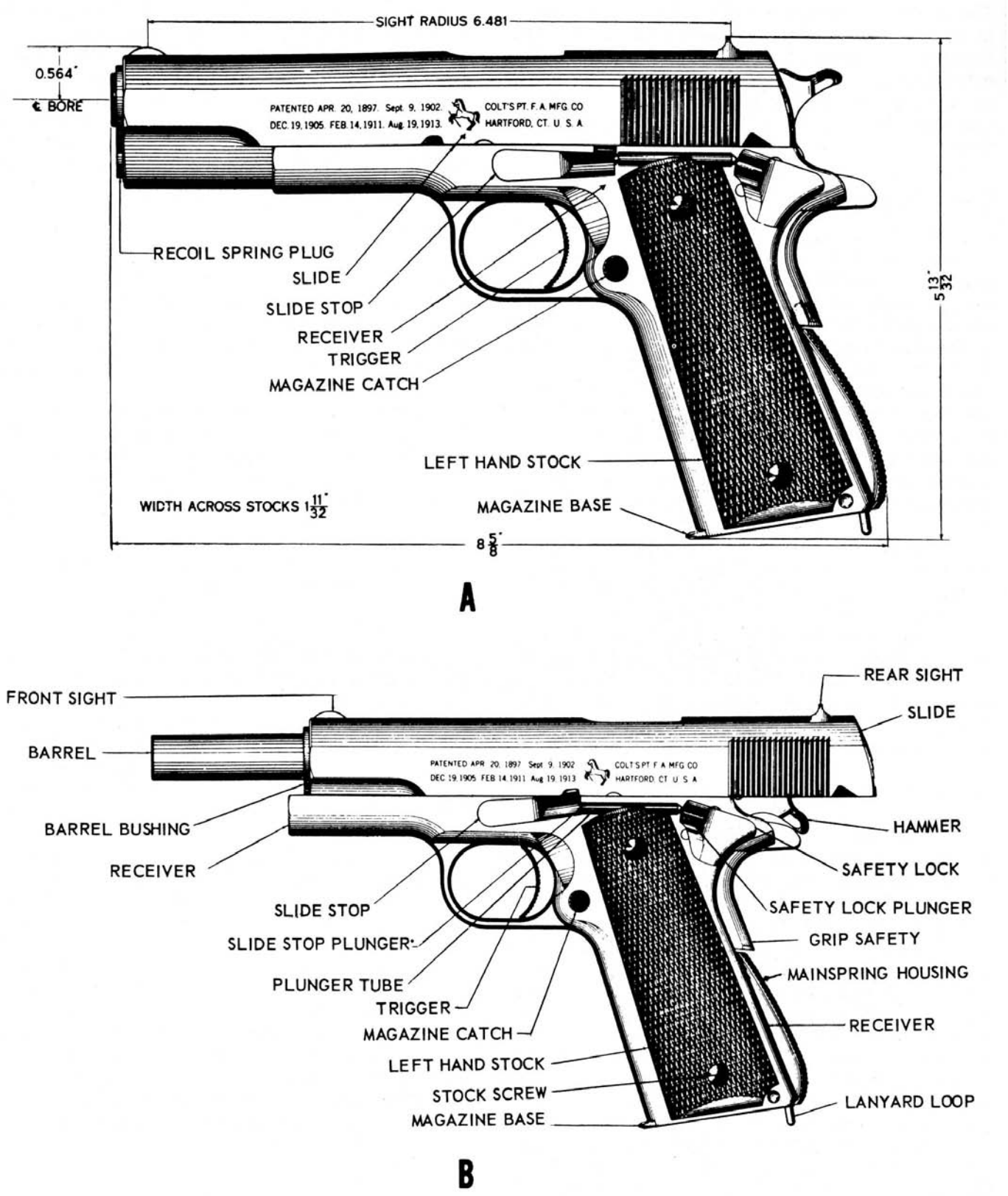


Figure 11-2.–Automatic pistol, caliber .45, M1911A1. A. Slide closed. B. Slide open. 17.42

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cleaning. For daily maintenance the pistol need not be disassembled but, for the prefiring and post-firing cleaning the pistol should be disassembled.

There are two phases of disassembly for the pistol, general disassembly (field stripping) and detailed disassembly. General disassembly (fig. 11-3) is the disassembly necessary for normal care and cleaning and after the weapon has been fired. This is the extent of disassembly that is generally explained to personnel such as watchstanders. The detailed disassembly of the receiver group (fig. 11-4) is the job of the Gunner's Mate during periodic cleaning and repair.

To do a good job of cleaning and repair, it is essential that you know the names of the parts of the weapon. The nomenclature of parts of the pistol should be learned while practicing disassembly and assembly. As each part is removed and replaced, the nomenclature is repeated until known. While studying the disassembly and assembly of the pistol, refer to illustrations showing the parts by name and description. Become thoroughly familiar with them and their functions. Knowing the names of the parts also will help you understand the operation of the weapon.

General Disassembly

Prior to performing any work on the pistol, remove the magazine and pull the slide to the rear and inspect to see that the weapon is clear. Then perform the following steps:

1. Cock the hammer and put the safety lock in the up, or SAFE, position. Depress the recoil spring plug and turn the barrel bushing about a quarter turn clockwise. Allow the recoil spring to expand slowly, under control, to prevent injury or loss of parts. Turn the recoil spring plug counterclockwise and remove it from the recoil spring. Move the safety lock back down to its FIRE position.

2. Push the slide to the rear until the half- moon recess (on the slide) is directly above the

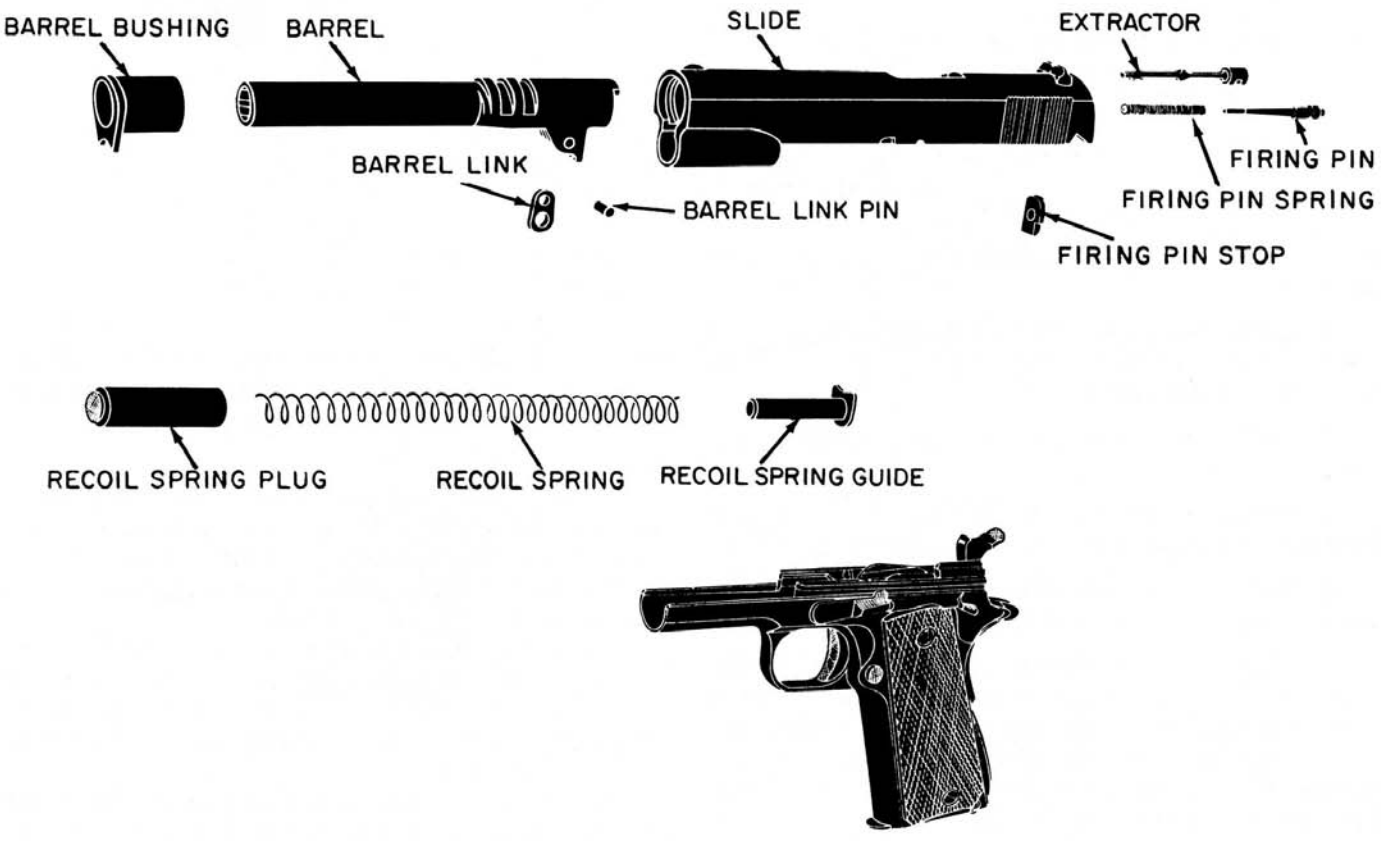
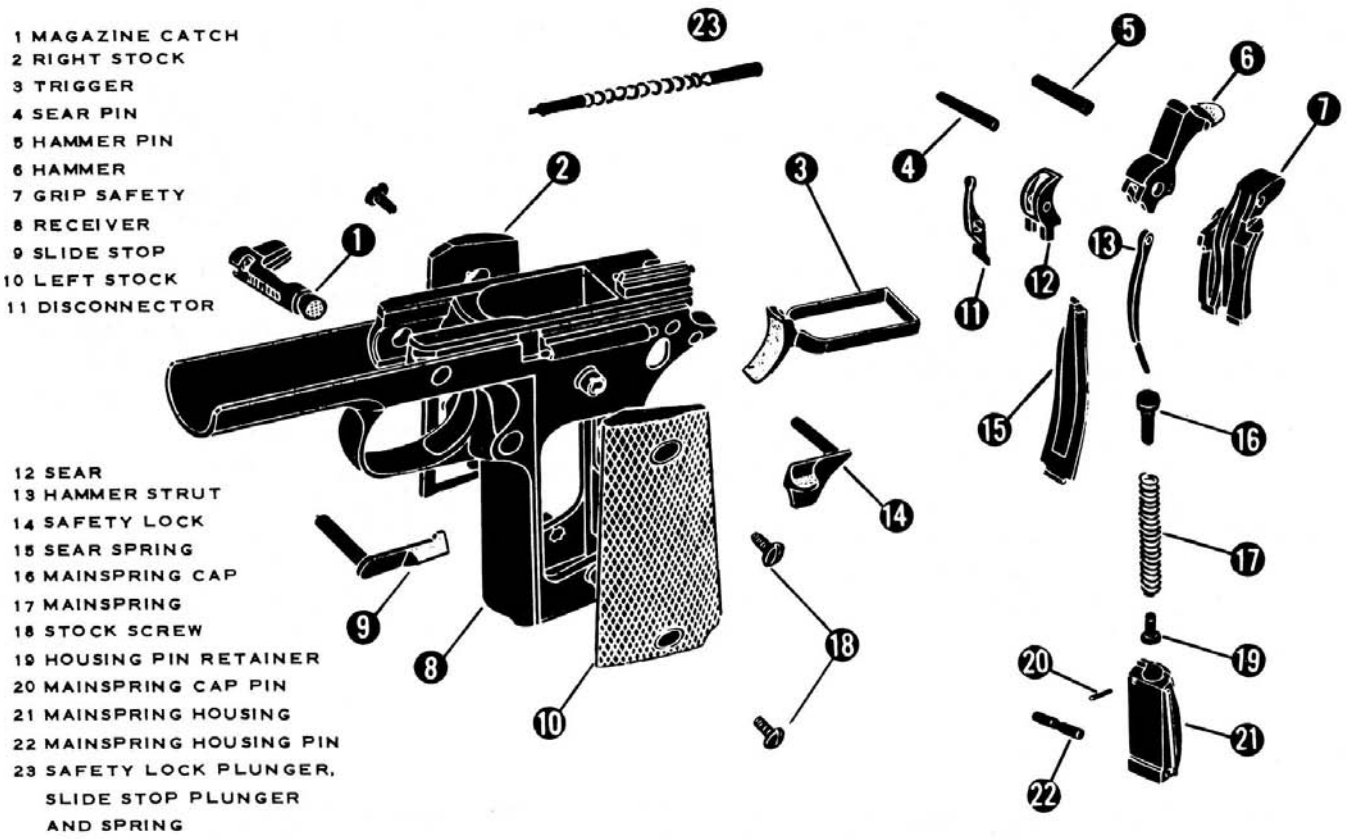


Figure 11-3. — The pistol in a field stripped condition.

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17.42.2

Figure 11-4. — The receiver group.

projection on the slide stop. Push out the slide stop from right to left.

3. Turn the pistol upside down and pull the receiver rearward to separate it from the slide. Lay the receiver down.

4. Pull the recoil spring and guide to the rear, free of the slide.

5. Remove the barrel bushing by turning it counterclockwise and pulling it from the slide.

6. Lay the barrel link forward and pull the barrel out of the muzzle end of the slide.

7. Take out the firing pin. Press in on the rear of the firing pin with any pointed object until you can slide out the firing pin stop. Keep your fingers over the firing pin, allowing the spring tension to ease; then lift both the firing pin and spring from the slide.

8. Pry the extractor out of the rear of the slide.

Detailed Disassembly Of The Receiver Group

Follow these procedures for the detailed disassembly of the receiver group. Individual parts in this group are shown in figure 11-4.

1. With the hammer in the cocked position, remove the safety lock by moving it up and down while exerting pressure outward. After removal of the safety lock, squeeze the trigger and allow the hammer to EASE forward.

2. Using the safety pin as a drift, press out the mainspring housing pin. This may require a good deal of pressure so place the receiver on a sturdy supporting surface while pressing out the pin.

3. To remove the grip safety, slide the mainspring housing down about 1/2 inch and lift out the grip safety. Remove the mainspring housing and sear spring.

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4. Using the firing pin as a drift, punch out the hammer pin; then lift the hammer from the receiver.

5. Drift out the sear pin from right to left and let the sear and disconnector drop out into your hand.

6. Press the magazine catch until it is flush with the left side of the receiver. Using the short leaf of the sear spring, turn the magazine catch lock one quarter turn counterclockwise, the lock should turn easily. Lift the magazine catch from the right side of the receiver.

7. Remove the trigger from the rear of the receiver.

ASSEMBLY

Assembly of the pistol also is accomplished in two phases: First the receiver group is assembled. After this phase, the weapon is in the field stripped condition. Then the field stripped weapon is assembled.

Both phases of assembly are accomplished by performing the disassembly procedures in reverse order. Here are four hints that should be helpful in assembling the pistol-

1. All pins are inserted from the left to right.

2. Place the sear and disconnector in the receiver as one unit fitted together as shown in figure 11-5.

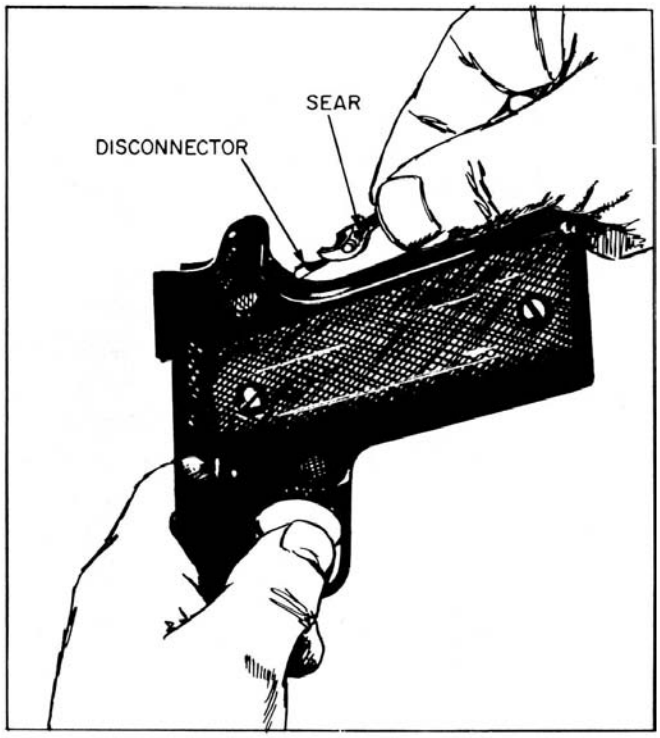
3. When you place the sear spring in position, have the mainspring housing ready to slide up about three quarters of the way into the receiver, to hold the spring in place.

4. Before sliding the mainspring into place, check to see that the hammer strut is resting in the well of the mainspring housing. It is possible for the strut to catch on top of the well instead of properly seating in the well recess.

SAFETIES

There are four safety devices on the pistol. The two manual safeties are the safety lock (sometimes called the thumb safe) and the half- cock notch. The two automatic safeties are the grip safety and the disconnector. Although the disconnector is classed as a safety, it is not considered a positive safety, as are the three safeties mentioned above, since it is designed to cause the pistol to fire semiautomatic fire and cannot be controlled by the shooter.

The safety lock positively locks the slide in the forward position. In addition, a stud on the safety lock (fig. 11-6A) blocks the shoulders



17.42.3

Figure 11-5.—Replacing the sear and disconnector.

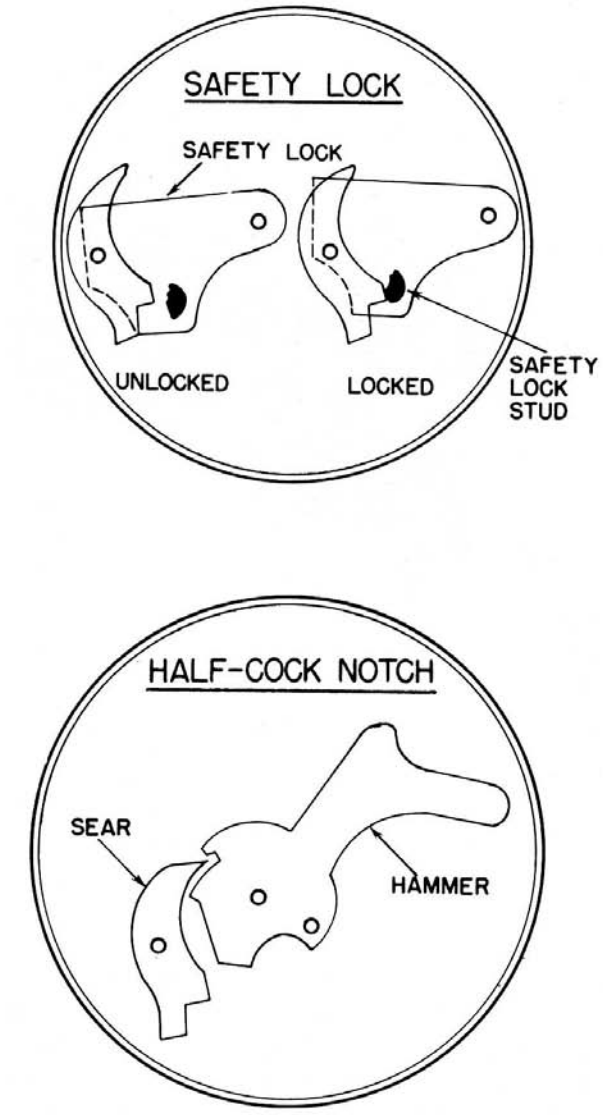
of the sear to prevent any movement of the sear out of the full-cock notch of the hammer.

The half-cock notch is the notch just above the full-notch. It has a lip which prevents movement of the sear from that notch when pressure is applied to the trigger. (See figure II-6B.)

The grip safety (fig. 11-7 A) indirectly stops any movement of the sear by blocking trigger movement. If the trigger cannot be actuated, the sear cannot move, and the hammer will not fall.

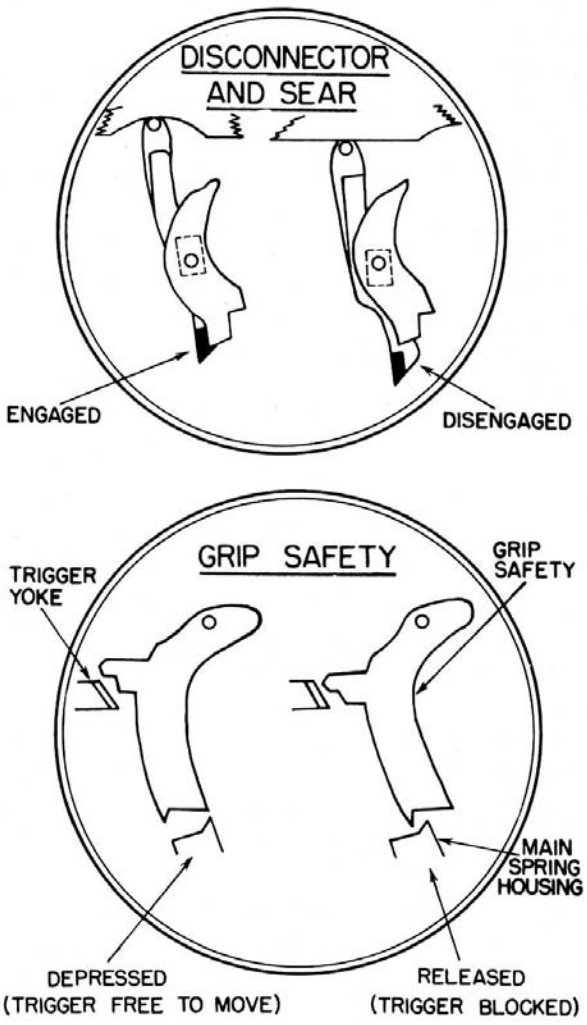
The disconnector (fig. II-7B) prevents firing unless the slide is fully forward and locked. When the slide is forward, the disconnector rides up into a recess on the underside of the slide. The spade of the disconnector (dark area) bears against lugs on the sear. When the trigger is pulled, the trigger yoke pushes back against the disconnector spade, which transmits the motion to the sear, rotating the sear nose out of the full-cock notch of the hammer, and the weapon fires. Any time the slide is not fully forward, the nose of the disconnector is forced downward. In this condition the disconnector spade does not contact the sear when the trigger is

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17.42.4

Figure 11-6. — Manual safeties.



17.42.5

Figure 11-7. — Automatic safeties.

pulled. When the trigger is pulled, the disconnector will be pushed to the rear but the sear remains in position, holding the hammer to the rear.

CYCLE OF OPERATION

Refer to figure 11-2 as we explain the functions of the pistol. We will assume that a loaded magazine is in the weapon, a round is in the chamber, the grip safety is depressed, the trigger has been squeezed, and the round ignited. The cycle of operation now begins.

As the powder gases burn and expand, the bullet is forced down the barrel while the same force is directed rearward against the slide. The slide and barrel are locked together at this point, and both are forced aft. The barrel link is attached to the stationary receiver so the barrel is moved downward as well as to the rear. As the barrel locking ribs are disengaged from the recesses in the slide, unlocking is completed.

As the slide moves aft in recoil, the extractor pulls the empty case along with it. Extraction is completed when the cartridge clears the chamber.

Ejection occurs when the cartridge strikes the stationary ejector, pivots on the extractor, and flips from the weapon through the ejection port.

Cocking began as soon as the slide started its recoil movement. The hammer is moved rearward and the hammer strut is pushed down against the mainspring, compressing it. When the slide strikes the recoil spring guide collar, its rearward movement is stopped. The recoil spring then causes the slide to begin its forward

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movement. The hammer follows the slide for a short distance. Then the sear, which bears against the hammer through the action of the sear spring, enters the full-cock notch of the hammer and holds it in a cocked position.

Feeding starts as soon as the slide, moving to the rear, clears the top of the magazine. The magazine follower, under pressure from the magazine spring, forces the top round against the lips of the magazine. This places the top cartridge in position to be picked up by the face of the slide during its forward movement.

Chambering occurs when the forward moving slide pushes a new round into the chamber. As the bullet is pushed up the ramp into the chamber, the base of the cartridge slides up the face of the slide. As this happens, the groove on the base of the cartridge is engaged by the hooked extractor.

After chambering, the slide continues forward a small distance, pushing the barrel ahead of it. As the barrel moves, it pivots up and forward on the barrel link. The locking ribs on the barrel enter the locking recesses in the slide, thereby locking the two together.

Firing will start the cycle all over again. When the grip safety is depressed and the trigger is squeezed, the trigger yoke presses against the disconnector, which pushes aft on the sear. The sear rotates on its pin, disengaging from the notch on the hammer. The mainspring pushes up on the hammer strut, rotating the hammer forward. The hammer strikes the firing pin, which in turn strikes the cartridge primer.

.38 CALIBER SMITH AND WESSON REVOLVER

The .38 cal. revolvers are found primarily in armories at shore activities. In this portion of the chapter we will discuss the .38 cal. Smith and Wesson Special (fig. 11-8). This weapon primarily is used by personnel assigned to guard duty or police work, but it is frequently issued to flight personnel. A revolver utilizing the caliber .38 special cartridge is considered a more practical close-quarters defense weapon than the bulky caliber .45 pistol. The .38 has about the same maximum and effective ranges as the .45 cal. automatic, 1600 and 50 yards, respectively.

The caliber .38 S&W revolver is a single- shot breech-loading hand weapon. The cylinder of the weapon has six chambers and revolves around a central axis. Six shots can be fired without reloading. When the cylinder is closed the weapon is ready to fire. Fired cases are extracted manually.

This weapon is designed to fire the cartridge, ball, caliber .38 special. The action of cocking the hammer causes the cylinder to rotate counterclockwise and align the next chamber with the barrel. Squeezing the trigger all the way back cocks the hammer, or the hammer can be cocked with the thumb. Note that all these operations are manual. The revolver is not an automatic or semiautomatic weapon in the technical sense.

One other caliber .38 revolver that is also used in the Navy (but less commonly) is the Colt. This weapon is in structure almost identical with the S&W. One structural difference is that the Colt has a shorter barrel than the S&W. The main functional difference is that the Colt's cylinder rotates clockwise when being fired; the S&W cylinder rotates counterclockwise. Both use the same ammunition.

Figure 11-9 shows the parts of the revolver and the disassembly to the extent required for normal care.

Operation

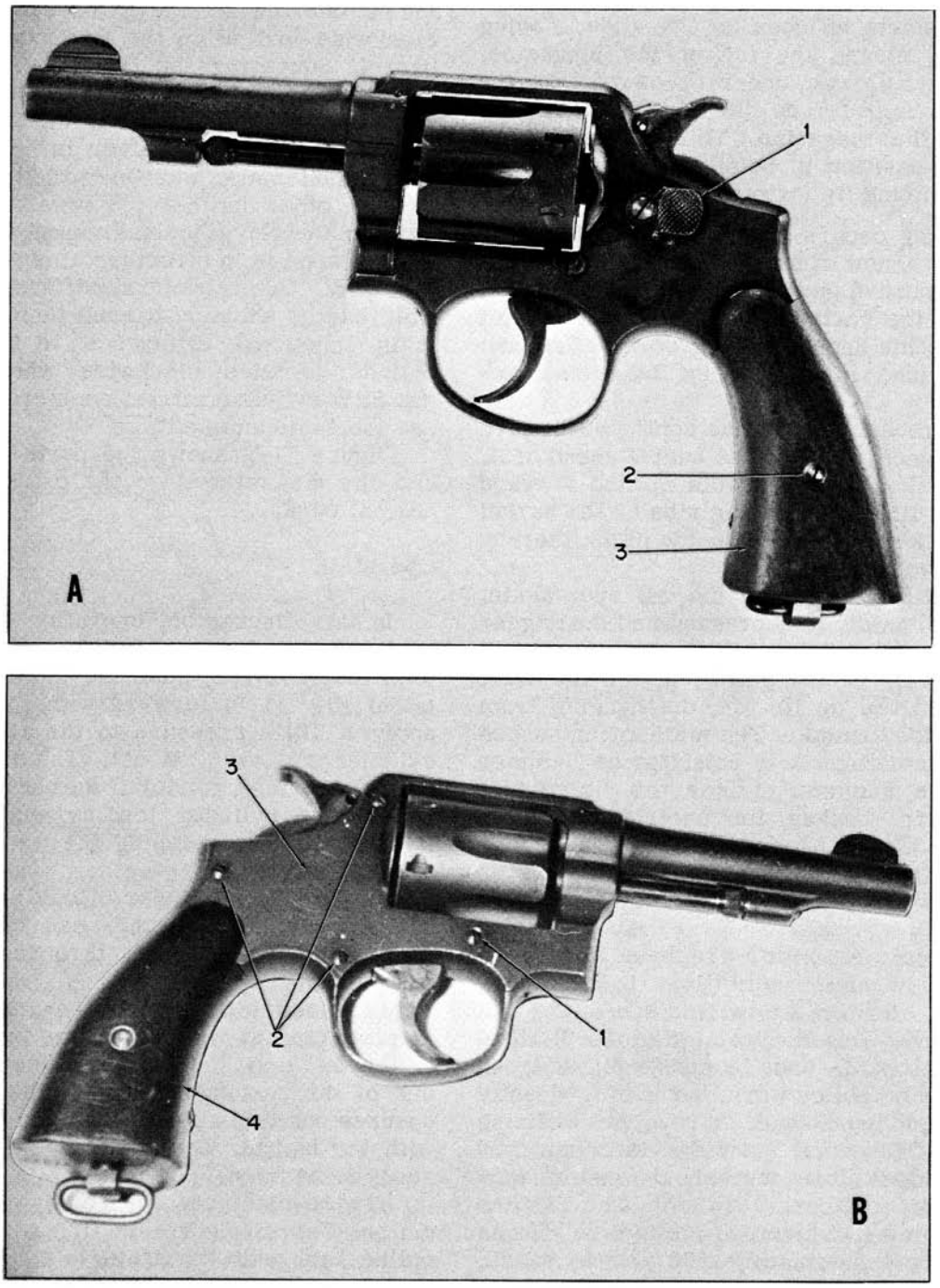
In this discussion, operation of the revolver is limited to loading, firing, and unloading. To load the revolver, push the thumb piece (thumb latch) (fig. 11-8) forward with the right thumb. apply a little pressure to the right side of the cylinder and swing it out. (The thumb piece will not release the cylinder if the hammer is cocked.) Rotate the cylinder loading each chamber as it comes on top, keeping the weapon pointed in a safe direction.

NOTE: The cylinder should not be flipped out sharply because this can cause the crane (fig. 11-9) to be bent, throwing the cylinder out of timing.

To close the revolver, swing the cylinder in place and at the same time turn the cylinder to the left until the ratchet in the frame engages one of the rectangular cuts in the cylinder. This ensures positive alignment of one of the chambers with the barrel. The weapon is now loaded and ready to be fired.

The revolver can be fired by single or double action. For single action firing, the hammer is pulled back with the thumb to the full-cock position for each round, this action also rotates the cylinder. The hammer is held in the cocked position by the sear until released by the trigger. In double action firing, pulling the trigger causes the hammer to be raised to nearly its full-cock

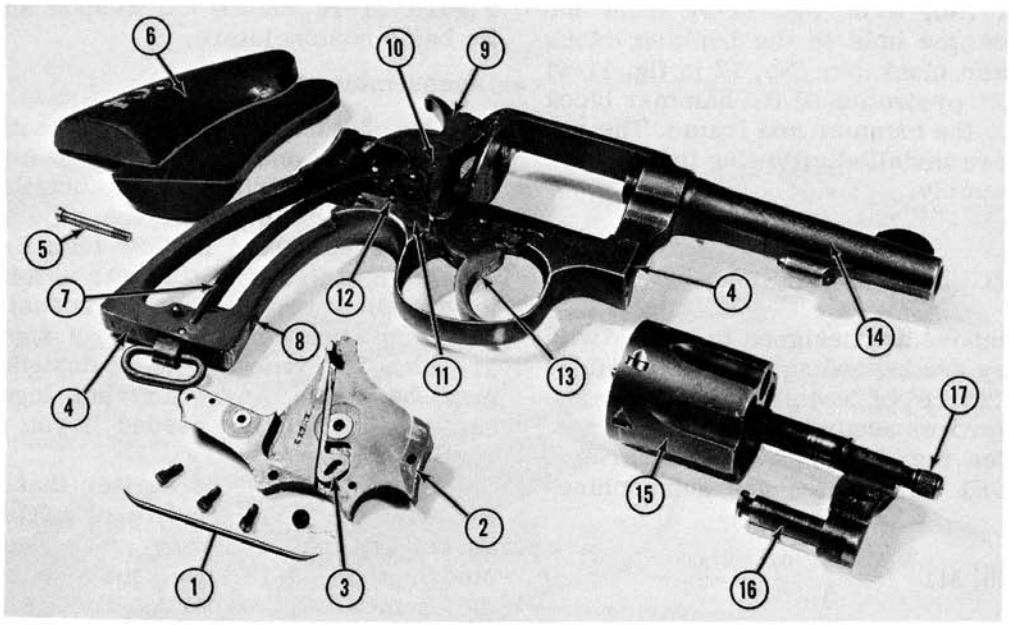
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Figure 11-8. — Smith and Wesson revolver, caliber .38 special. A. Left side: 1. Thumbpiece (cylinder release). 2. Stock screw. 3. Stock. B. Right side: 1 and 2. Sideplate screws. 3. Sideplate. 4. Stock.

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Figure 11-9.—Smith and Wesson revolver, caliber .38; right side view with cylinder and ejector group, side plate, and stocks removed. 1. Sideplate screws. 2. Sideplate. 3. Hammer block. 4. Frame. 5. Stock screw. 6. Stocks. 7. Mainspring. 8. Mainspring strain screw. 9. Hammer. 10. Sear. 11. Rebound slide. 12. Hammer block pin. 13. Trigger. 14. Barrel. 15. Cylinder. 16. Crane or yoke. 17. Ejector plunger.

position. The hammer strut will then escape the trigger, and the spring-loaded hammer will fall and strike the cartridge. In double action firing, the cylinder is rotated by pulling the trigger. Since it requires slightly less trigger pull for single action, this method should produce better accuracy.

The empty cartridges are ejected by swinging out the cylinder to the left and pushing the extractor plunger toward the rear of the cylinder.

There are two built-in safeties on this revolver - the hammer block and the rebound slide. The hammer block prevents the hammer from going far enough forward to strike the cartridge primer when both the hammer and trigger are in the forward or uncocked position. Thus, if the revolver were dropped or otherwise struck on the hammer, the round would not be fired. The rebound slide actuates the hammer block to prevent the hammer from traveling far enough to strike the primer should the hammer slip from the thumb while being manually cocked.

Disassembly and Assembly

The following steps should be followed in the disassembly and assembly of the revolver.

1. Push forward on the thumb piece (fig. 11-8A) which actuates the cylinder latch, and swing the cylinder out to the left. With a small screwdriver remove the sideplate screw (No. 1 in fig. 11- 8B) located directly under the cylinder. This screw retains the crane (or yoke) of the cylinder and ejector group.
2. Remove the cylinder and extractor group by pulling the cylinder forward.
3. Remove the three remaining sideplate screws (No. 2 in fig. 11-8B).
4. Remove the sideplate. Do not pry the sideplate off. Use a wooden handle to tap the plate and frame until the sideplate loosens from its seating.
5. Remove the stock screws and lift off the stocks.

The disassembled weapon appears as shown in figure 11-9. The parts can be inspected and lubricated as necessary.

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To assemble the weapon, first remove the hammer block (No. 3 of fig. 11-9) from the sideplate. Place the hole in the hammer block over the hammer block pin (No. 12 in fig. 11-9) so that the "L" projection of the hammer block will fit between the hammer and frame. The remaining parts are installed following the reverse order of disassembly.

SHOULDER WEAPONS

Shoulder weapons are designed to be held with both hands; they are braced against the shoulder to absorb the force of recoil and steady the weapon to improve accuracy. This group of weapons includes the .30 cal. M1 rifle, carbine, M14 rifle, M16E1 rifle, BAR, and submachinegun.

RIFLE, CAL. 30, M1

This rifle is the basic weapon currently used by personnel assigned to the ship's landing party. Its effectiveness was proved in World War II and in Korea. It is a semiautomatic, gas-operated weapon with a maximum effective range of about 500 yards. When fitted with a special launcher, it can fire rifle grenades. Figure 11-10 shows the weapon and points out its basic nomenclature.

Disassembly and Assembly

The .30 cal. Ml rifle, as is the case with most other weapons, is disassembled in two phases - field stripping and detailed stripping. For normal maintenance the rifle will not have to be disassembled further than field stripping as shown in figure 11-11A. As a GM you must be prepared, however, when the occasion arises, to strip the weapon in detail as shown in figure 11-11B. The rifle has been designed so that it may be taken apart and put together rather easily. No force is needed if you strip it correctly.

It was pointed out earlier that it is helpful to know the nomenclature of parts in the disassembly and assembly of a weapon. While studying the Ml rifle, make sure you learn the names of the parts. The parts generally are named for the job they perform.

Field Stripping

There are three major groups in the field stripping of the Ml rifle - the trigger housing

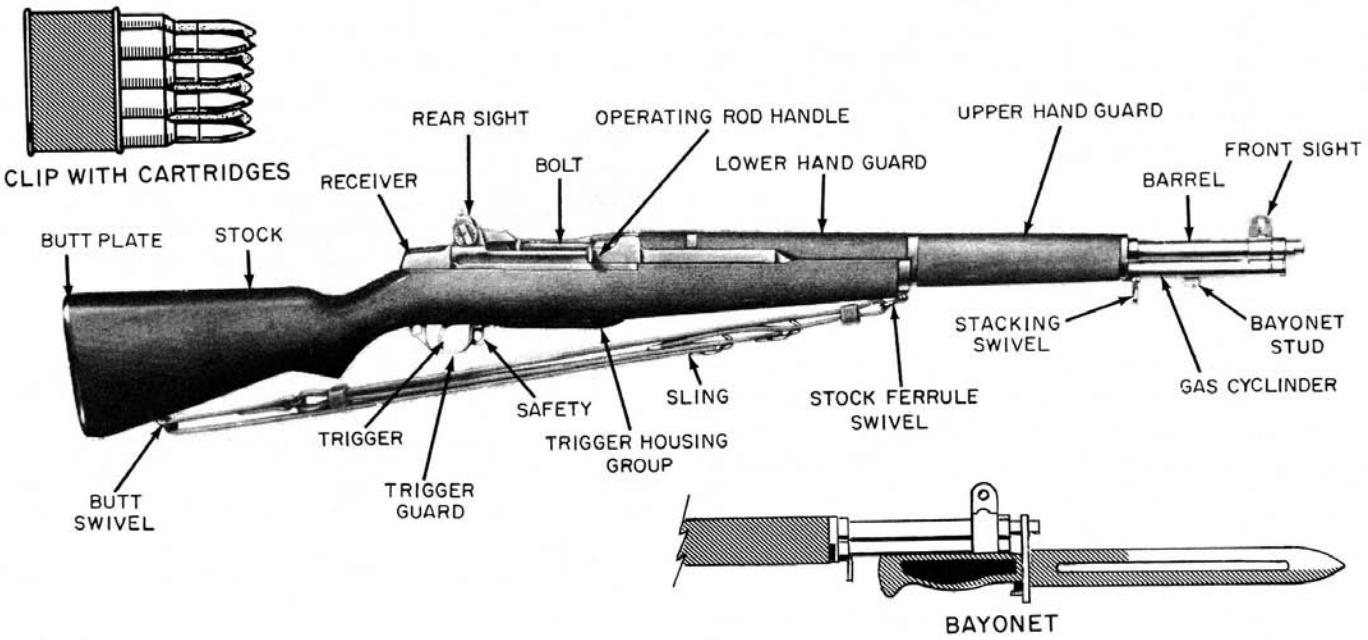
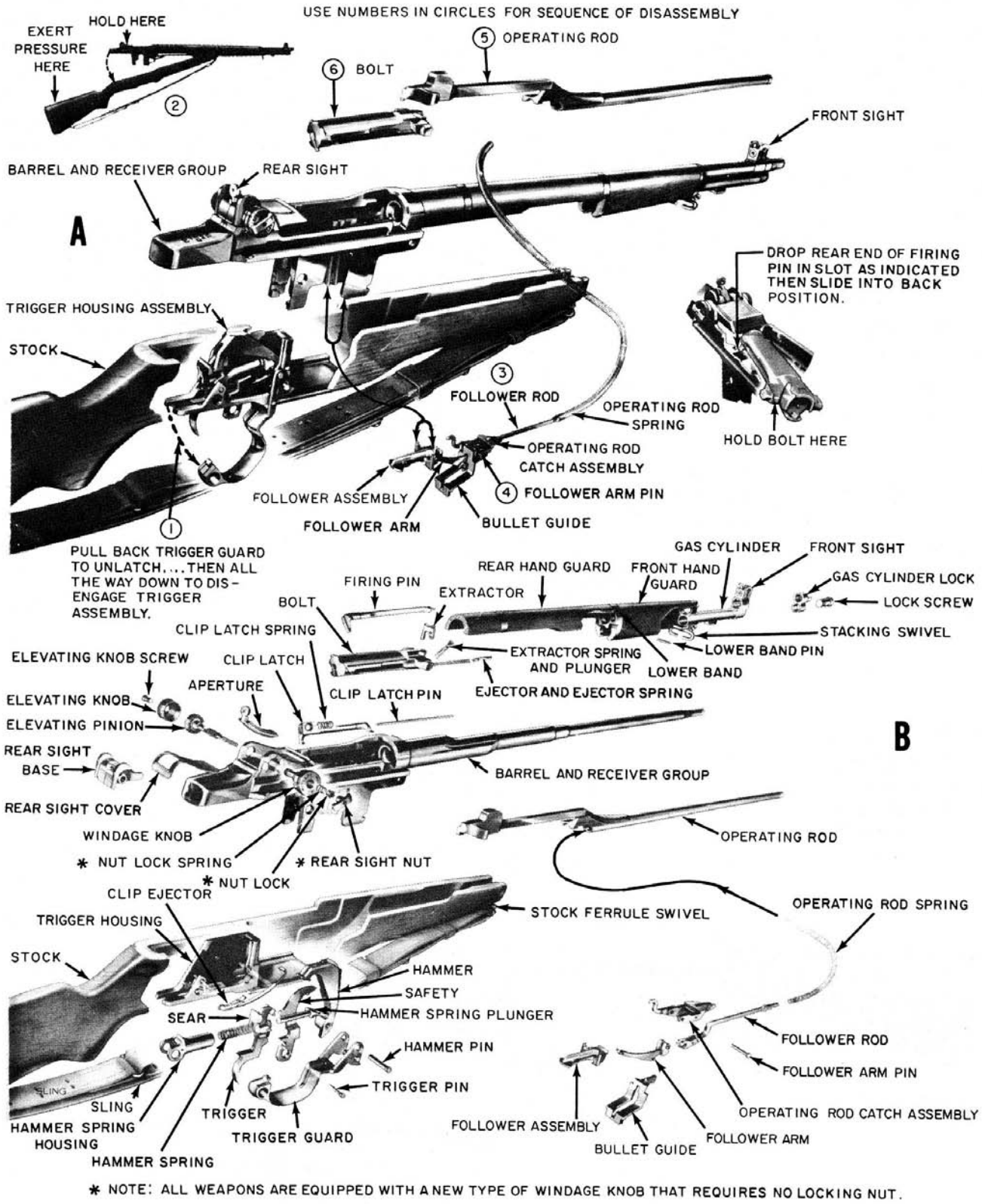


Figure 11-10.— Basic nomenclature, U. S. Rifle, caliber .30, Ml.

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Figure 11-11.—Disassembly of .30 caliber rifle M1. A. Field stripped. B. Detail stripping.

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group, the barrel and receiver group, and the stock group. To disassemble the rifle into these three groups, grasp it with the left hand so that the base of the trigger housing is included in your grip. Place the rifle butt against the left thigh, with the trigger group toward you. With your right hand pull the trigger guard downward and outward. Swing the guard out as far as it will go, then lift out the trigger group. Next, grasp the rifle at the rear of the receiver with your left hand, muzzle to the left. With your right hand palm, give a downward blow to the small of the stock, grasping it as you do. This separates the stock group from the barrel and receiver group.

Detailed Stripping

Place the barrel and receiver group so that the sights are down, muzzle pointing to the left. With the thumb and forefinger of your left hand, grasp the follower rod and disengage it from the follower arm. Remove the follower rod and operating rod spring by withdrawing them to the right. Push out the follower arm pin from its seat and remove it.

Grasp the bullet guide, follower arm, and operating catch rod catch assembly, and lift them out of the assembly together. Next, lift out the follower assembly. Do not separate the slide from the follower.

Turn the barrel and receiver group over so that the sights are up, muzzle pointing away from you. Pull the operating rod to the rear until the rear of the handle is directly under the forward edge of the windage knob. With an upward and outward pressure, disengage the guide lug of the operating rod through its dismount notch on the receiver. Remove the operating rod.

Grasp the bolt by the operating lug and, while sliding it forward, lift it upward and outward to the right front with a slight rotating motion.

Hold the bolt in your left hand with your thumb over the ejector. This is important because the ejector will fly out and possibly be lost while removing if you do not hold it with your thumb. Remove the extractor and the extractor spring and plunger. Lift out the ejector and its spring. Do not separate the ejector from its spring or the extractor from its spring.

To disassemble the trigger housing group (fig. 11-12), close and latch the trigger guard and release the hammer to the fired position. Hold the trigger housing group with the first finger of the right hand on the trigger and the

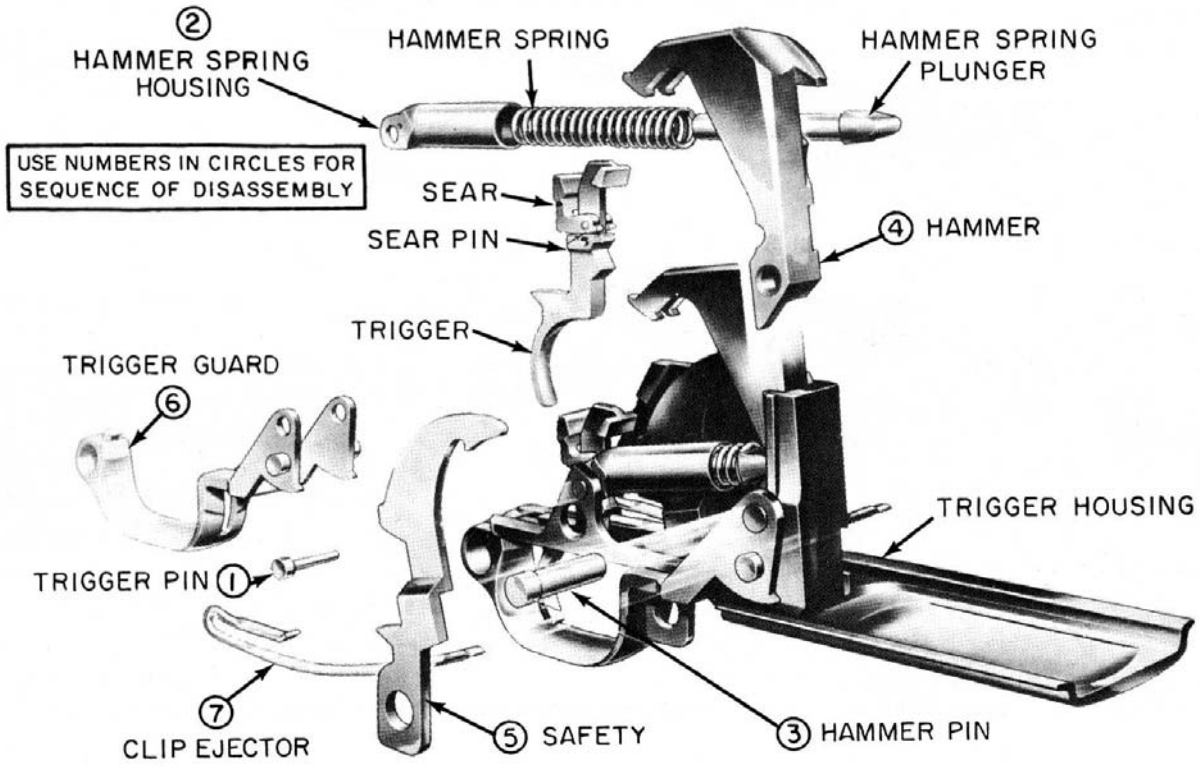


Figure 11-12. — Disassembly of trigger housing group.

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thumb against the sear. Place the trigger housing against a firm surface, press on the sear with the right thumb, then push the trigger pin out from left to right. Slowly release the pressure with your thumb and finger allowing the hammer spring to expand.

Lift out the trigger assembly and separate the hammer spring plunger, hammer spring, and the hammer spring housing. Do not remove the sear pin or sear. Push out the hammer pin from left to right and remove the hammer.

Unlatch the trigger guard and lay the trigger housing on its right side. Push out the stud of the safety. Remove the safety by lifting it from its slot in the base of the trigger housing.

Holding the rear of the trigger housing in your left hand and the trigger guard with your right hand, swing the trigger guard to the open position. Slide the trigger guard to the rear until the wings of the trigger guard are aligned with the safety stud hole. Rotate the trigger guard to the right and upward with your right hand until the hammer stop inside of the right wing clears the base of the trigger housing. Remove the trigger guard.

Assembly

The rifle and its component groups are assembled in the reverse order of their disassembly. First, assemble the trigger housing group, then the barrel and receiver group. The rifle is now in the field stripped condition of three main groups as shown in figure 11-11A. The stock group and the barrel and receiver group are fitted together, then the trigger housing group is inserted. The assembly is completed by closing and latching the trigger guard.

To test the assembly of the rifle, pull the operating rod to its rearmost position. The bolt should stay open. Close the bolt and snap the safety to its locked position, and squeeze the trigger. The hammer should not fall. Push the safety forward and squeeze the trigger. The hammer should fall.

Operation

By studying the disassembly and assembly of the rifle, you now know the parts. It is important that you understand how the parts function. There are eight steps in a cycle of operation of the Ml rifle. You will better understand the operation of the Ml if we first look at the functioning of several individual parts. First, the trigger group will be discussed, then the actions that take place upon loading a clip are shown. A complete cycle of operation will be explained, then we will see what happens when the last round of a clip is fired.

Trigger Housing Group

Refer to figure 11-13 as we explain how this group functions. Take the trigger housing out of the rifle (close and latch the trigger guard and cock the hammer). You can see that the hammer is held in a cocked position by the trigger lugs engaging the hammer hooks. Hold the hammer with your left thumb and slowly squeeze the trigger. You will see the trigger lugs move forward, releasing the hammer hooks. The hammer will rotate forward under pressure of the hammer spring. Now, release the pressure on the trigger and again cock the hammer, you will see the trigger lugs engaging the hammer hooks to hold it cocked.

However, there must be a way of preventing the hammer from going forward even if you keep pressure on the trigger after each shot. This is done by the sear, which catches on the rear hammer hooks. Now squeeze the trigger and hold it to the rear. Cock the hammer slowly and see how the sear catches on the rear hammer hooks and holds the hammer back. Slowly release the trigger and you will notice that the sear will release the hammer hooks. Now the hammer hooks catch on the trigger lugs and hold the hammer in the cocked position. This combination holds the hammer to the rear each time a round is fired.

Action on Loading a Full Clip

Before a clip can be loaded into the rifle, the operating rod and the bolt must be all the way to the rear. The follower is all the way up in the receiver, due to the pressure being exerted by the operating rod spring through the follower and follower arm, against the follower. The hump of the follower rod has contacted the 45° camming surface of the operating rod catch, pushing it toward the barrel and causing its undercut hook to engage with the hooks on the operating rod. This keeps the bolt and operating rod to the rear against pressure of the compressed operating rod spring. You can find the parts mentioned in figures 11-11, 11-14, and 11-15.

As a full clip is placed on the follower and pressed down, the follower arm moves down rotating around its pin. The follower arm being

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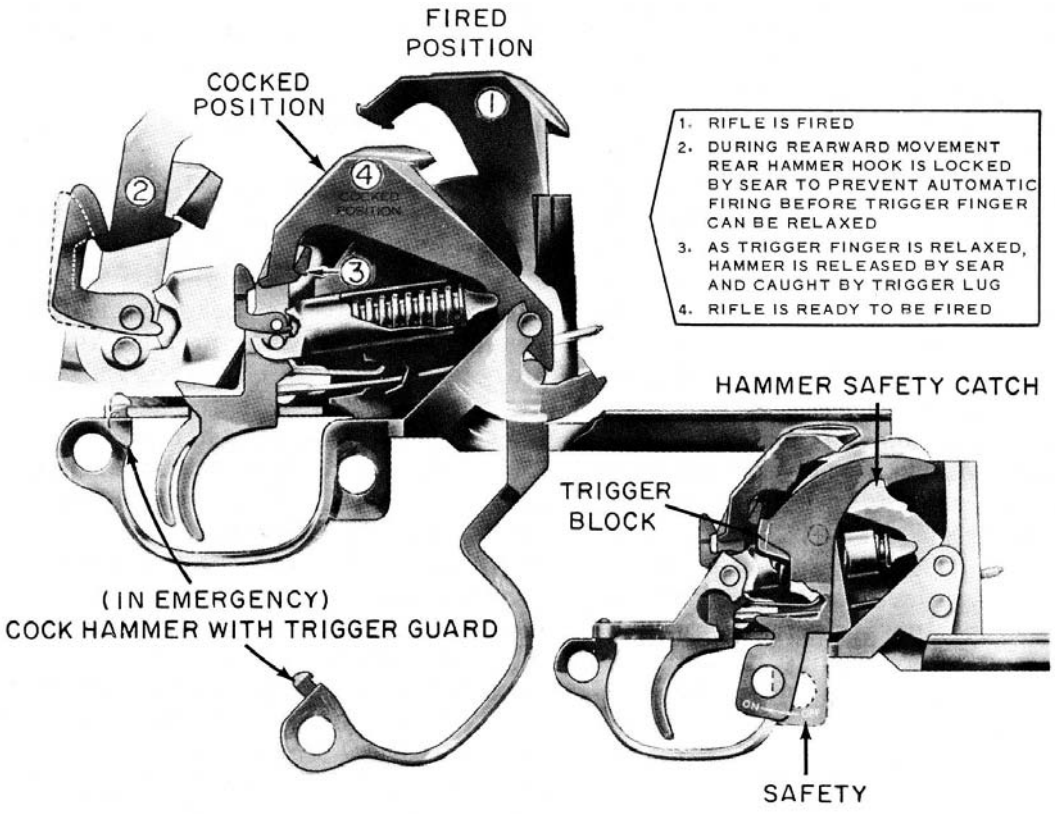


Figure 11-13. — Trigger housing group functioning.

connected to the follower rod, pushes the rod towards the muzzle. This moves the hump of the follower rod away from the 45° camming surface of the operating rod catch.

As the follower reaches its lowest point in the receiver, the square shoulder on the follower arm contacts the rear lip of the accelerator, forcing it upward toward the barrel. Between its lip and the point where it is fastened by its pin to the operating rod catch, the accelerator bears on and pivots about the toe of the bullet guide. Since the guide is stationary, the accelerator forces the front end of the operating rod catch downward, separating its hook from the hooks of the operating rod. The operating rod and bolt are now free to move forward under the action of the operating rod spring.

NOTE: The accelerator functions only once during the cycle of operation - when loading a full clip.

As the forward end of the operating rod catch moves downward away from the barrel, the long rear arm of the catch moves upward and away from the front stud of the clip latch (fig. 11-11B). This allows the clip latch spring to. expand and force the rear stud of the clip latch into a notch on the clip. The stud holds the clip in the receiver against the action of the compressed clip ejector. The operating rod catch is held away from the hooks on the barrel by the front stud of the clip latch, which is continually pushing against the catch's long rear arm. This allows the bolt to move back and forth freely until the last round is fired.

An explanation will be given of the actions that occur upon firing the last round, after we go through a complete cycle of operation.

Operating Cycle

Feeding takes place when a cartridge is moved into the path of the bolt. With the bolt retracted and a full clip in the receiver, the follower exerts pressure on the bottom round in the clip. Pressure is exerted on the follower by the operating rod spring through the follower rod and follower arm.

Chambering is the action that takes place when moving a round into the chamber. As the

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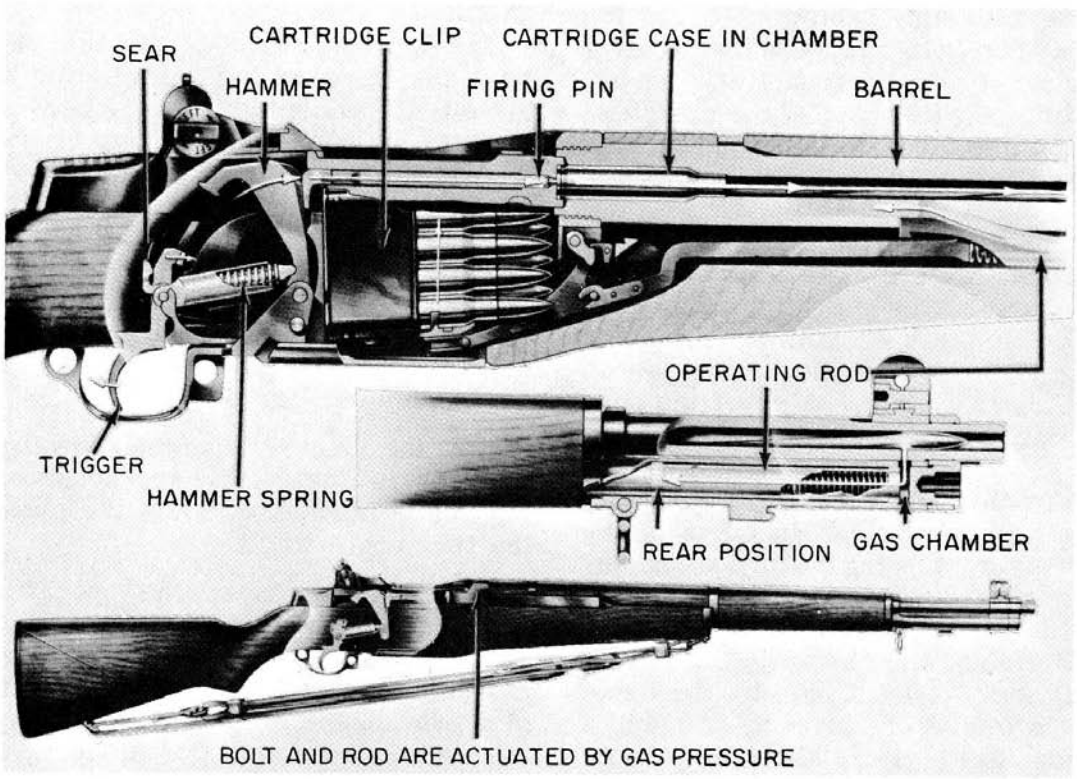


Figure 11-14. — Basic functioning 84.244

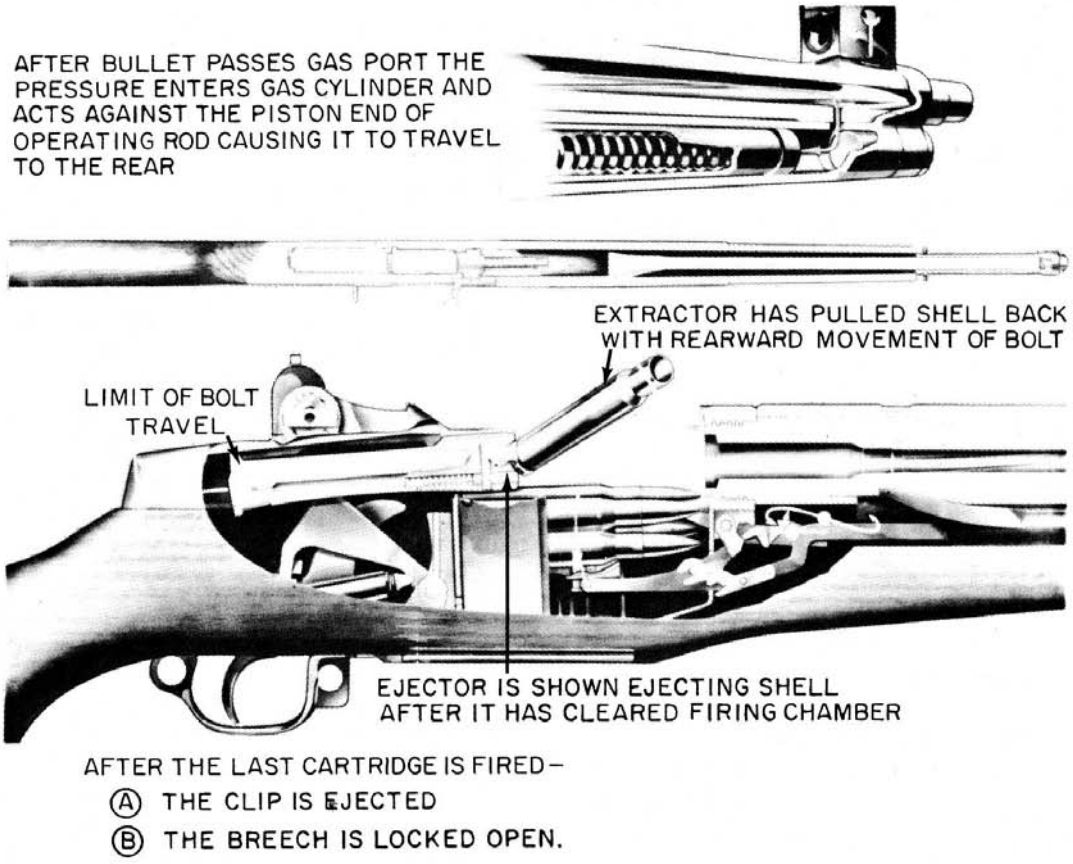


Figure 11-15. — Bolt and gas cylinder functioning. 84.245

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bolt moves forward, it rotates and engages the top cartridge in the clip, ramming it into the chamber. When the bolt reaches its forward position, the rim of the cartridge is gripped by the extractor, and the base of the cartridge forces the ejector into the bolt, thus compressing the ejector spring.

Locking of the bolt is accomplished when the bolt is all the way forward. The rear camming surface in the hump of the operating rod forces the operating lug of the bolt downward, causing the bolt to rotate clockwise. The bolt is locked by the locking lugs on both sides of the bolt, engaging in the locking recesses in the receiver.

Slightly before the bolt reaches its foremost position, the tang of the firing pin contacts the bridge of the receiver, stopping the forward movement of the firing pin. When the bolt is turned and fully locked, the tang of the firing pin is lined up with the slot in the bridge of the receiver and may be driven home by the hammer. This is a safety feature to prevent a round from being fired before the bolt is fully locked.

As the round is fired and the bullet nears the muzzle, a portion of the gases produced by the burning powder expand through a gas port into the gas cylinder, striking the piston head and driving the operating rod to the rear. The camming surfaces of the operating rod force the operating lug on the bolt upward, disengaging the bolt from the receiver. As the bolt rotates counterclockwise, the firing pin tang contacts the bridge of the receiver, camming the firing pin to the rear into the face of the bolt.

You recall that the extractor gripped the rim of the cartridge as the bolt moved forward, it remains in this grip while it is in the chamber. As the bolt moves to the rear, the empty case is withdrawn from the chamber by the extractor.

When the empty case clears the chamber, the ejector (which has been continually pushing against the base of the case) ejects the empty case from the receiver by the action of the expanding ejector spring.

Cocking occurs as the bolt continues to the rear, riding over the hammer, forcing it rearward and down. The hammer is caught by the sear, if the trigger is still being pulled, or by the trigger hooks if the trigger has been released.

Action Following Last Round

As the last round is fed into the path of the bolt, the hump of the follower rod moves closer to the 45° camming surface between, the front arms of the operating rod catch.

While the last round is in the chamber, the follower is against the bottom of the bolt. When the last round is fired, the bolt comes to the rear and the follower is moved all the way up in the receiver. At the same time the hump of the follower rod contacts the 45° camming surface of the operating rod catch and pushes the catch up toward the barrel.

As the catch is cammed toward the barrel, its hook is engaged by the hooks of the operating rod. This action holds the operating rod to the rear and the bolt open.

When the front of the operating rod catch is cammed toward the barrel, the catch pivots on the follower arm pin and the long rear arm moves downward against the front stud of the clip latch. The clip latch rotates, withdrawing the rear stud from the notch in the clip. The empty clip is then ejected by the expanding clip ejector.

CARBINE. CALIBER .30 M1

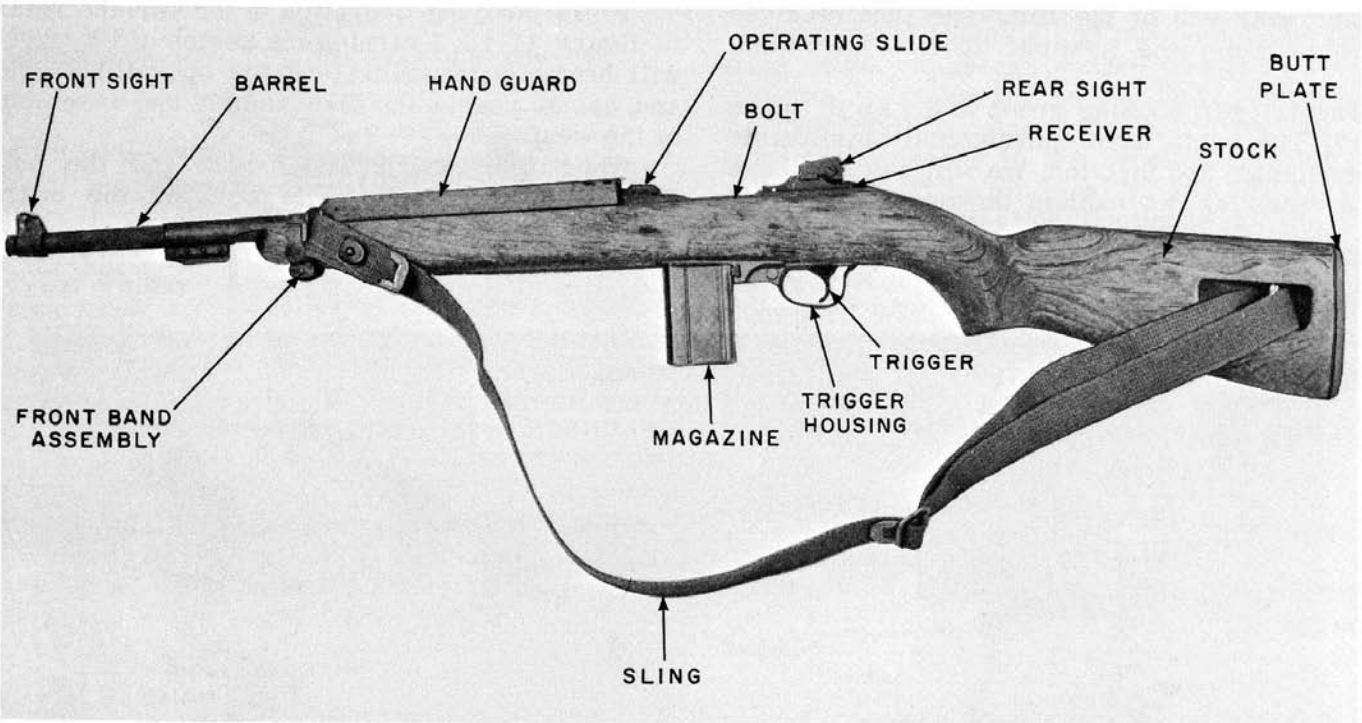
The carbine cal. .30 M1 was developed during World War II and was used extensively by the Army and Marine Corps, and various units of the Navy. The carbine does not have the stopping power of a .45 cal. weapon but its 300 yard range makes it a much more useful weapon than the pistol in the hands of a man who has received normal marksmanship training.

Other models of the carbine include the M1A1, M2, and M3. The M1A1 is identical to the M1 except for a separate grip and a metal skeleton folding stock extension hinged to the grip and rear end of the stock. The M2 is the M1 with parts modifications and changes. These changes allow the M2 to be fired in automatic or semiautomatic fire by adjusting a selector. The M3 is identical to the M2 except that the top of the receiver is designed to accommodate special sighting equipment (sniperscope).

In this chapter we will discuss the carbine Ml because this is the model you are most likely to see on board ship.

The Ml carbine (fig. 11-16) is a gas-operated, self-loading, air-cooled shoulder weapon delivering semiautomatic fire, and is fed by a 15-round box type magazine. The carbine uses caliber .30

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Figure 11-16. — Carbine, caliber .30, M1.

ammunition, which however, is NOT interchangeable with ammunition of other caliber .30 weapons.

The first M1 carbines (and there are probably still some around) were issued with an L-type sight. Both the long and short arm of the sight have a peephole. With the short arm raised into position, the sight is preset for 150 yards range. The longer arm is raised for shooting at targets 300 yards away. There is no in between and there is also no provision for windage. The later M1 has an adjustable sight graduated in 50-yard increments from 100 to 300 yards and it also can be adjusted for wind.

Nomenclature

The gas cylinder and piston are located under the barrel forward of the receiver. The gas cylinder and piston operate in the same way as for the M1 rifle in that they transmit the force developed by the fired round to operate the weapon. The after end of the piston extends out of the cylinder and rests against the forward end of the operating slide. Though the piston moves to the rear only 9/64 inch, it strikes the operating slide hard enough to drive it to its full recoil position.

The bolt is actuated by the operating slide which slides back and forth under the barrel. The rear portion of the operating slide projects back along the right side of the receiver, ending in a hook shaped projection (operating handle). A hump in the operating slide is cut out to form the bolt camming recess. The bolt operating lug rides in this recess and is cammed up or down to unlock or lock the bolt.

Power for counterrecoil action is provided by the operating slide spring which surrounds the spring guide. The after end of the guide fits into a well in the receiver. As the weapon is fired and recoils, the guide moves into the receiver. The spring being too large to fit in the well is compressed, storing energy to return the slide to its forward position after the force of recoil is spent.

The bolt contains the firing pin, extractor, and ejector. During its movement to the rear, the bolt cams the hammer back and down to its cocked position. As the bolt moves forward it forces the next round into the chamber.

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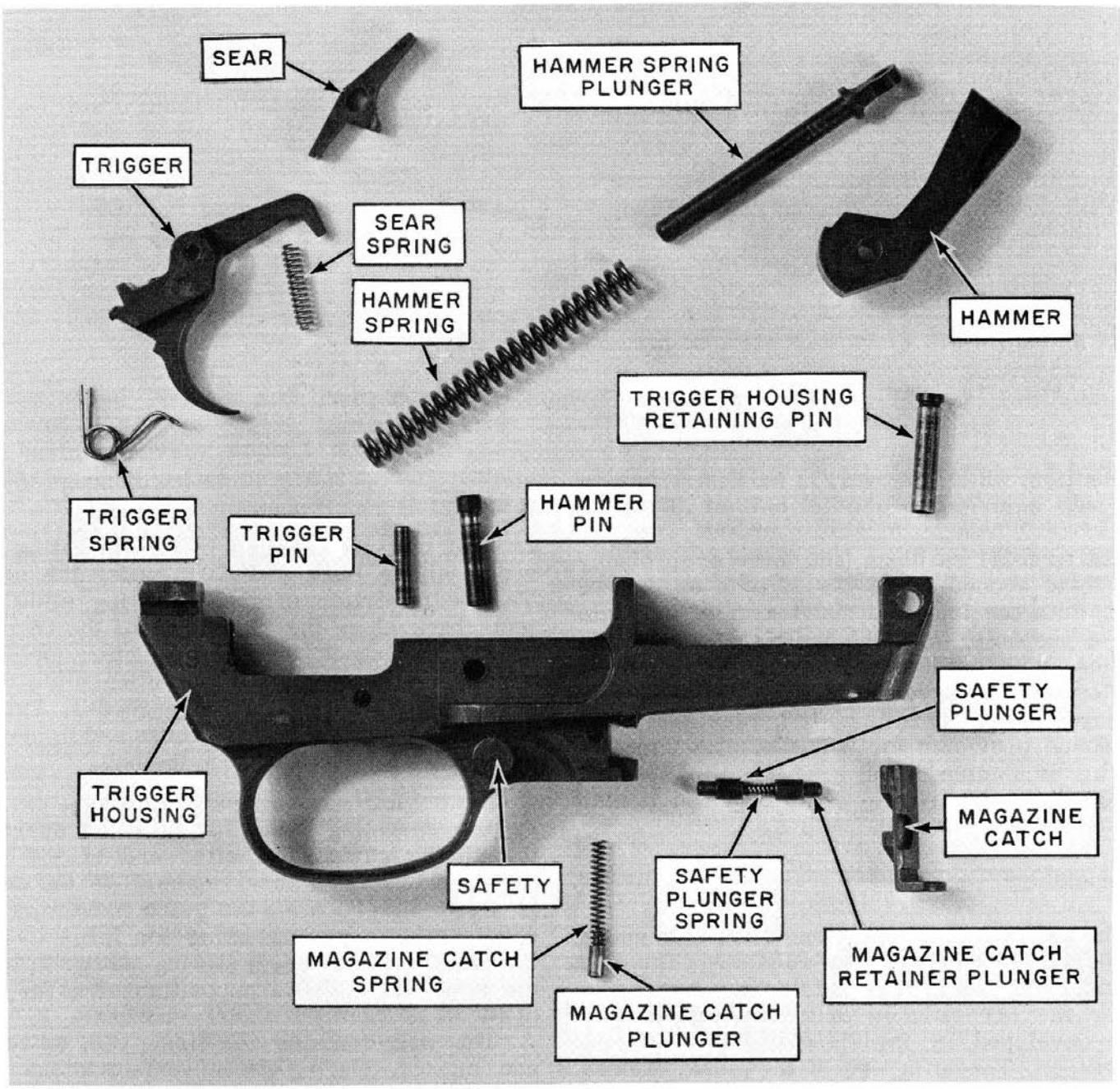
The firing pin fits in a hole drilled in the bolt. A tang on the end of the firing pin extends out the rear end of the bolt. The tang receives the blow from the hammer to fire the round.

The trigger housing group is shown in figure 11-17. The parts have conventional small arms nomenclature and function. We will see how these parts work as we explain the operating cycle.

Operating Cycle

While studying operation of the carbine refer to figure 11-18. Learning the names of the parts will help you to understand the operating cycle and assist you in the disassembly and assembly of the weapon.

When the carbine is loaded and the bolt is closed, the hammer is held by the sear.



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Figure 11-17. — Trigger housing group, M1 carbine.

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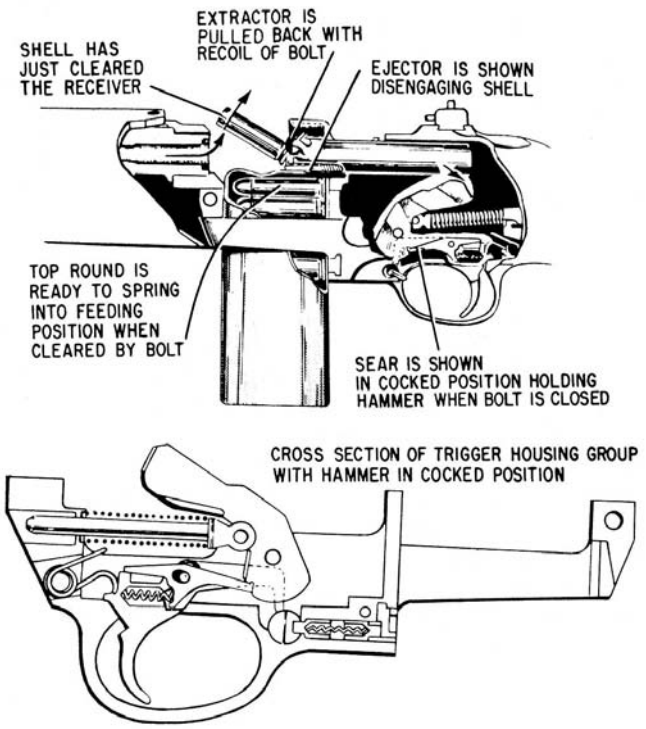


Figure 11-18. — Trigger and bolt functioning, M1 carbine.

When the trigger is pulled, it pivots around its pin, raising at the rear and rotating the sear with it. As the sear pivots around the trigger pin its front end goes down, disengaging the sear notch of the hammer. This releases the spring-loaded hammer to move forward and strike the cartridge primer.

The bolt must be fully rotated into its locked position before the hammer can move forward. Unless the bolt is locked, the tang on the firing pin is blocked by the bridge of the receiver. When the bolt is locked. the tang is aligned with a slot in the bridge.

As the bullet is forced down the barrel, it passes a gas port. Some of the expanding gases go through this port to the gas cylinder and strikes the piston. The piston is driven to the rear approximately 3/16 inch where it strikes the operating slide driving it to the rear in recoil. The operating slide moves to the rear independently of the bolt for the first fraction of an inch. The lug on the bolt merely rides in the straight section of the recess in the operating slide during this movement. This delay in the unlocking process allows the projectile to leave the muzzle, relieving barrel pressure before the bolt is opened.

At the end of this slight movement, the operating slide camming surface comes in contact with the operating lug on the bolt. This rotates the bolt and disengages the bolt's locking lugs from the recesses in the receiver. As the bolt rotates, the firing pin is withdrawn into the bolt.

The operating slide continues to the rear carrying the bolt with it. As the bolt moves to the rear it withdraws the empty case from the chamber. When the cartridge mouth clears the breech, it is ejected from the weapon by the ejector which has been continually pressing on the base of the cartridge.

As the bolt rides over the hammer it forces it back. The sear comes into contact with the sear notch of the hammer, and is carried forward slightly. This causes the sear after end to ride off the lip of the trigger.

When the bolt completes its rearward movement, the operating slide spring being compressed, forces the bolt forward carrying a new round into the chamber. The hammer, under its spring pressure, rides on the bottom of the bolt and tends to follow it. The hammer only rotates a short distance before it is brought up by the sear. When pressure on the trigger is released, the hammer spring imparts a slight forward motion to the hammer. The hammer pivots enough to push the sear slightly backward, causing its rear end to ride up over the trigger lip. This completes the cocking action.

When the bolt reaches its forward position, the rim of the cartridge is gripped by the extractor. The base of the cartridge forces the ejector into the bolt, compressing the ejector spring. When the bolt is all the way forward, the rear camming surface in the hump of the operating slide forces the operating lug of the bolt down, making the bolt rotate clockwise. The bolt is locked as the locking lugs on both sides of the bolt engage the locking recesses in the receiver. The forward movement of the operating parts ends when the inside of the heavy portion of the operating slide has driven the piston into the gas cylinder. The carbine is now ready to be fired again.

Disassembly

For cleaning and inspection, the carbine is first disassembled into three main groups- barrel and receiver group, trigger housing group, and the stock and handguard. To do this, loosen

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the front band screw and slide the band (fig. 11-16) off the stock. Remove the handguard. The barrel and receiver group and the trigger housing group can be lifted out of the stock as one unit.

Next, remove the slide spring and guide by disengaging the guide from its seat on the slide and withdrawing it to the left. out of its well in the receiver.

The trigger housing group is then separated from the barrel and receiver group. To do this, cock the hammer by pulling the operating slide to the rear and pushing it forward again. Take out the trigger housing pin and remove the trigger housing group by sliding it toward the muzzle. Next, take out the operating slide and bolt.

This is the extent of the disassembly for normal cleaning and inspection. For more detailed instructions refer to the Army Field Manuals for the .30 carbines. FM 23-7; TM-9- 1276 and TM-9-1005-210 (Series).

Assembly

The carbine is assembled in reverse order of its disassembly, following the additional procedures below.

Hold the bolt by its operating lug so that the tail of the firing pin is opposite its notch in the receiver. Then lower the bolt into position.

Now hold the forward end of the slide in the right hand, palm up. Slide the bolt forward until its forward end is about 1-1/2 inch from the chamber; hold it in this position with the left thumb. Engage the operating lug of the bolt in the operating cam groove of the slide.

Raise the forward end of the slide so that the dismounting lug on its left side is opposite the notch in the left groove on the under side of the barrel. Then, by slightly twisting the slide to the right, engage the operating lugs of the slide in the operating grooves of the barrel. Move the slide and bolt to the rear until the operating slide lug is seated in its groove in the receiver; then close the bolt.

Place the barrel and receiver on their left side, muzzle to the left. Replace the trigger group assembly by engaging its grooves with the corresponding grooves in the receiver, and then replace the retaining pin.

Insert the small end of the guide rod in the loosely coiled end of the operating slide spring. Insert the loosely coiled end of the spring into its well in the receiver. By pressing on the shoulder of the guide rod, compress the spring until the end of the guide rod can be inserted into its seat in the slide.

Next, Make certain the safety is to the left. Place the barrel and assembled groups in the stock. Replace the handguard. Slide the front band down over the end of the handguard and stock until it is engaged by the restraining spring. Then tighten the front band screw.

THE M14 RIFLE

The M14 rifle (fig. 11-19) is a light-weight, air-cooled, gas-operated, magazine-fed shoulder weapon. It is designed primarily for semiautomatic fire, or full automatic fire at the cyclic rate of 750 rounds per minute. The rifle is chambered for 7.62 cartridges and is designed to accommodate a 20-round cartridge magazine, the M2 bipod, the M76 grenade launcher, and the M6 bayonet. At the time of this writing, the M14 is being used primarily by the Marines and Seabees. It is not a general issue rifle so will not be discussed at this time. Further information on the M14 may be found in TMs and FMs for the rifle.

THE M16E1 RIFLE

The rifle, M16E1 (fig. 11-20), is a 5.56-mm (about .22 caliber) magazine-fed, gas-operated, air-cooled shoulder weapon. It is designed for either semiautomatic or full automatic fire through the use of a selector lever. The rifle is equipped with a flash suppressor which also serves as a stationary piston permitting the launching of rifle grenades without the use of supplementary attachments.

A "clothespin" type bipod, can be attached and be used in prone and foxhole positions.

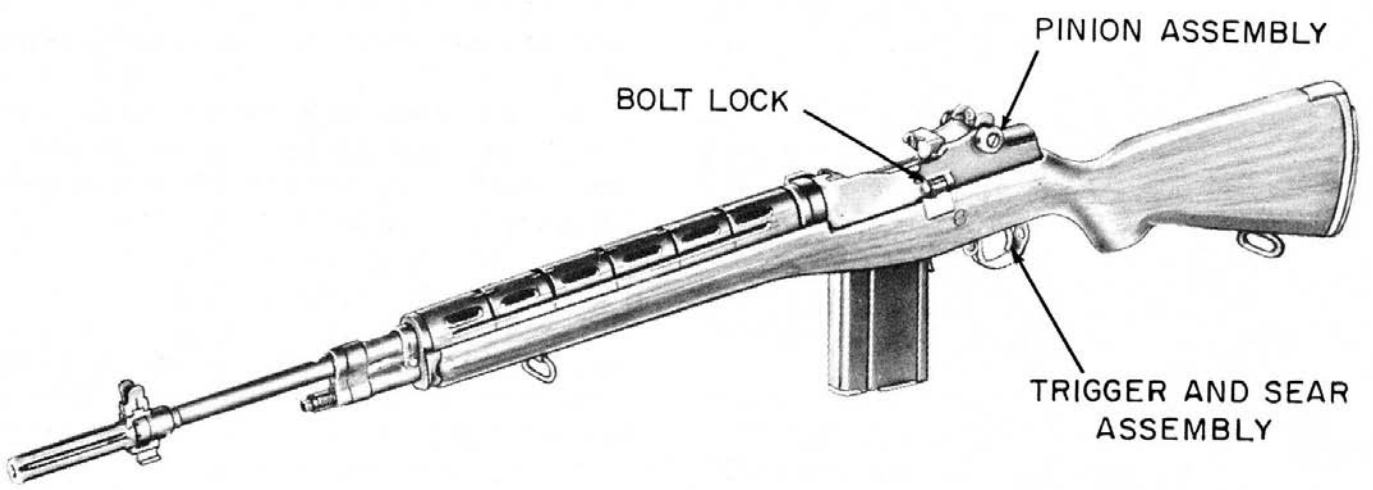
Clearing the M16E1 Rifle

The first consideration in handling any weapon is to make it safe by clearing it. To clear the M16E1 rifle, place the butt against the right thigh and proceed as follows:

1. Attempt to point the selector lever toward SAFE, the position shown in figure 11-21. If the weapon is not cocked, the selector lever cannot be pointed toward SAFE. If this is the case, do not cock the weapon at this time; instead, go on to the next step in clearing.

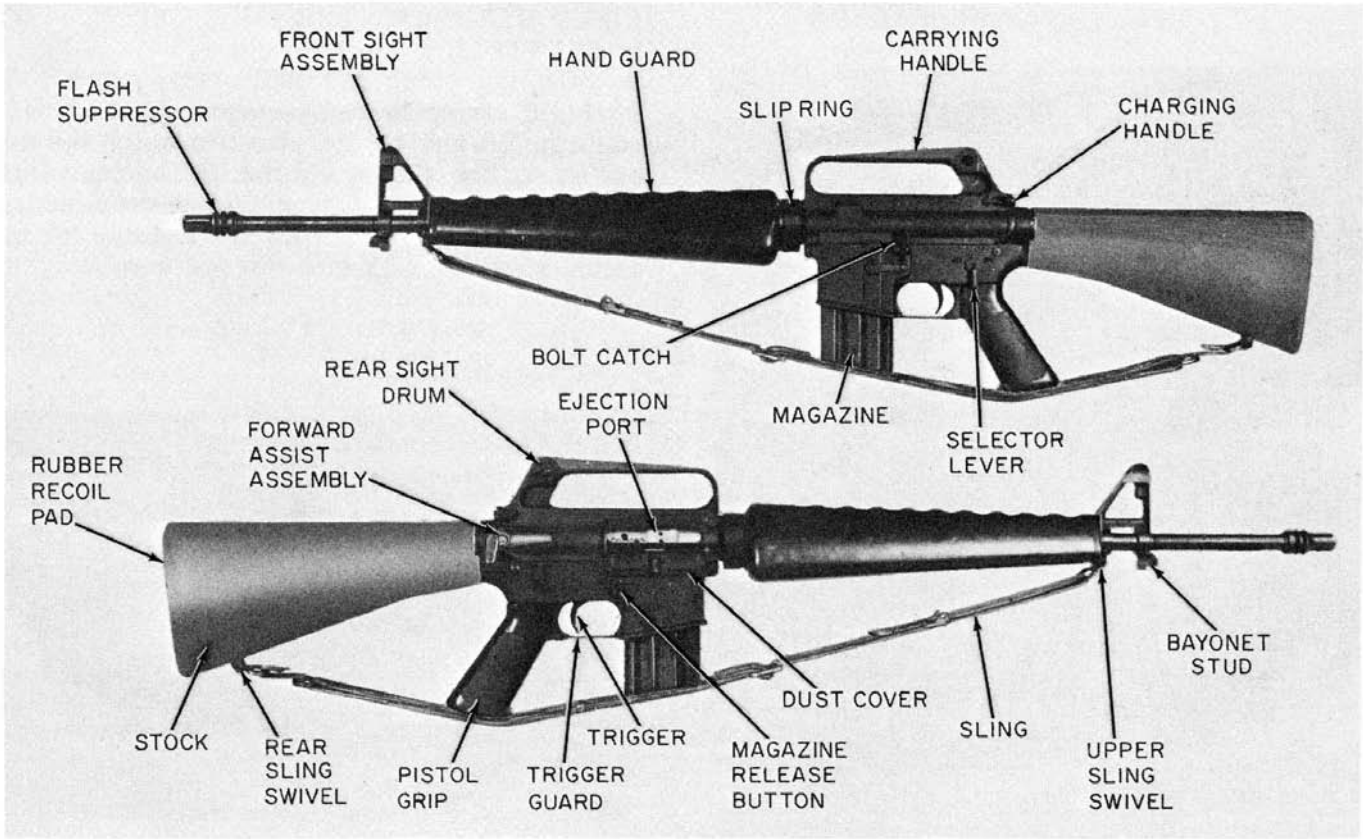
2. Remove the magazine as shown in figure 11-22. Grasp it with the right hand (fingers

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29.316

Figure 11-19.—7.62-mm rifle M14 and controls, left front view.



29.344

Figure 11-20.— Rifle, 5.56-mm, XM16E1, left and right side views.

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29.346
Figure 11-21. — Selector lever pointing to SAFE.

curled around the front of the magazine, thumb placed on magazine catch button), apply pressure on the magazine catch button with the thumb, and pull the magazine straight out of the weapon.

3. Lock the bolt open as shown in figure 11-23 and 11-24. Grasp the charging handle with thumb and forefinger of right hand, depress the charging handle latch with right thumb, and pull to the rear (fig. 11- 23). When the bolt is fully rearward, press the bottom of the bolt catch with the thumb or forefinger of the left hand (fig. 11-24). Allow the bolt to move slowly forward until it engages the bolt catch, and return the charging handle to its forward position.

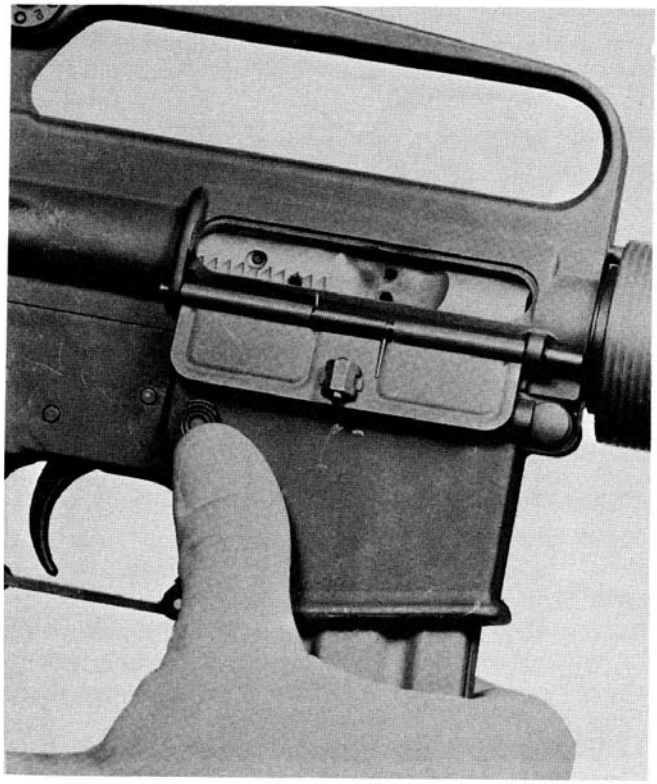
4. Inspect the receiver and chamber of the weapon by looking through the ejection port to ensure that these spaces contain no ammunition.

5. Check the selector lever to ensure that it points toward SAFE, and then allow the bolt to go forward by depressing the upper portion of the bolt catch.

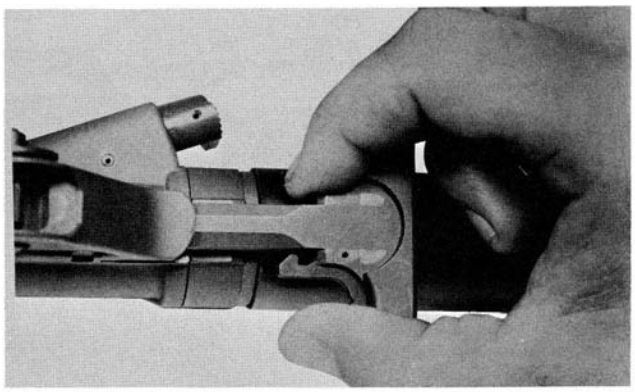
CAUTION: The selector must be in the SAFE position to prevent damage to the automatic sear.

FIELD STRIPPING THE M16E1 RIFLE

Field stripping can be accomplished without supervision and is the extent to which the weapon should be disassembled for normal maintenance. As the weapon is disassembled, the parts should be laid out on a table or other clean surface in the order of removal. from



29.347
Figure 11-22. — Removing the magazine.



29.348
Figure 11-23. — Pulling the charging handle rearward.

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29.349
Figure 11-24. — Locking the bolt open.

left to right. This makes assembly easier because the parts are assembled in the reverse order of assembly. Nomenclature should be learned as the weapon is disassembled and assembled to enable you to better understand the operation of the weapon.

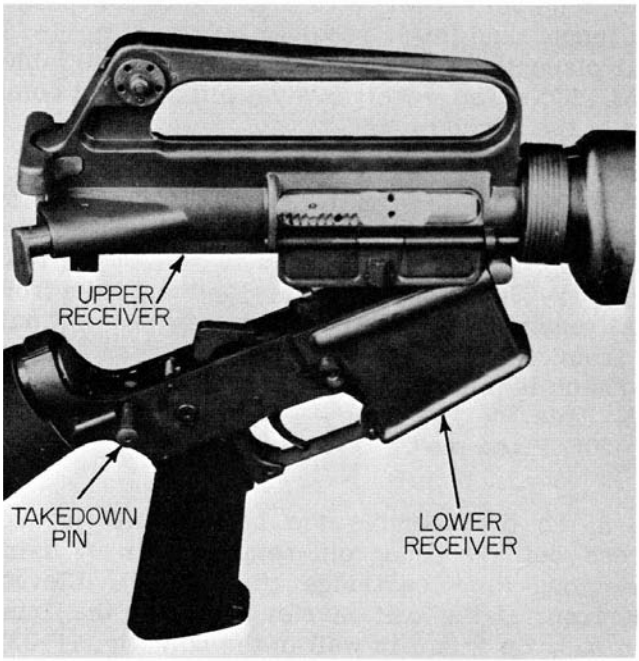
The steps in field stripping are as follows:

1. Remove the sling and place the rifle on a table or flat surface, muzzle to the left.

2. Keeping the muzzle to the left, turn the weapon on its right side. Use the nose of a cartridge to press the takedown pin (fig. 11-25) until the upper receiver swings free of the lower receiver (fig. 11-26). CAUTION: The takedown pin does not come out of the receiver.



29.350
Figure 11-25. — Pressing takedown pin to the right.



29.351
Figure 11-26. — Breaking upper receiver away from lower receiver.



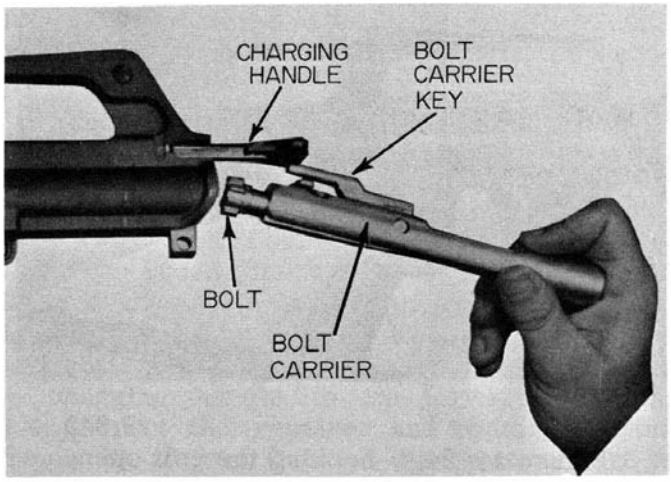
29.352
Figure 11-27. — Pressing out receiver pivot pin.

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3. Again using the nose of a cartridge, press the receiver pivot pin (fig. 11-27). Separate the upper and lower receiver groups (fig. 11-28) and place the lower receiver group on the table. CAUTION: The receiver pivot pin does not come out of the receiver.

4. Pick up the upper receiver group; keeping the muzzle to the left. Grasp the charging handle, pressing in on the latch, and pull to the rear (fig. 11-23) to withdraw the bolt carrier from the receiver. Grasp the bolt carrier and pull it from the receiver (fig. 11-29). When the bolt carrier is removed, the charging handle will fall free of its groove in the receiver (fig. 11-30). Place the receiver on table.

5. To disassemble the bolt carrier group, press out the firing pin retaining pin by using the nose of a cartridge (fig. 11-31). Elevate the front of the bolt carrier and allow the firing pin to drop from its well in the bolt (fig. 11-32). Rotate the bolt until the cam pin is clear of the bolt carrier key and remove the cam pin by rotating it 90 degrees (1/4-turn) and lifting it out of the well in the bolt and bolt carrier (fig. 11-33). After the cam is removed, the bolt can be easily removed from its recess in the bolt carrier (fig. 11- 34).

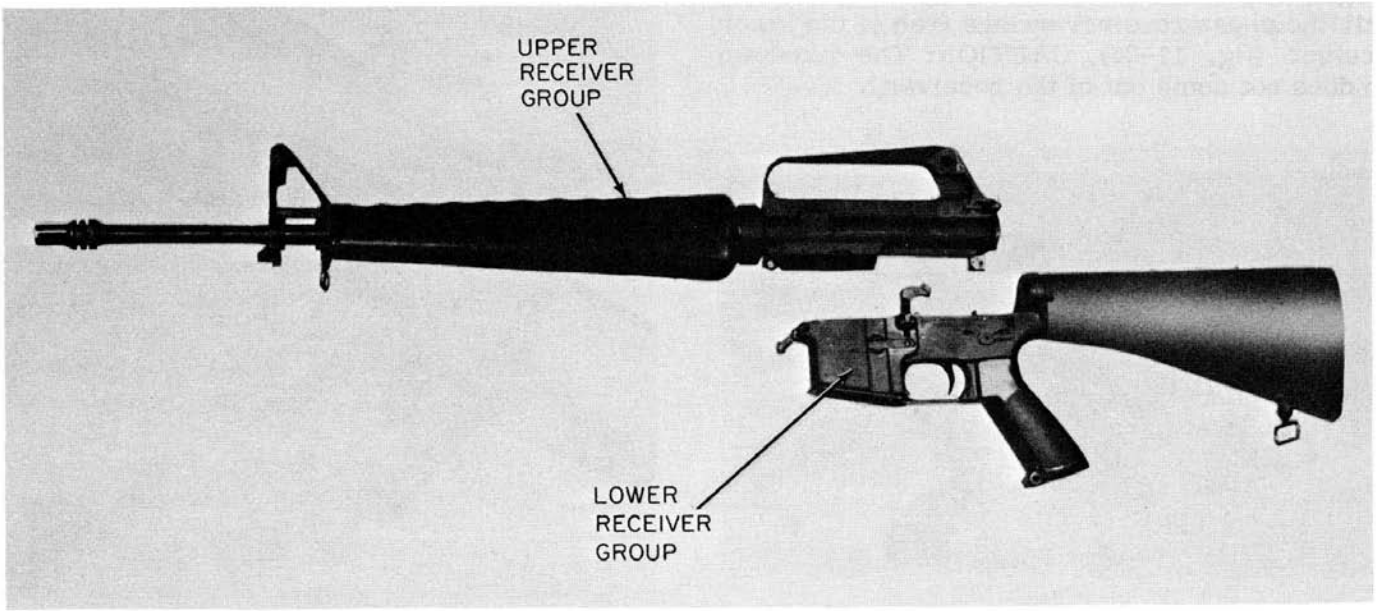


29.354

Figure 11-29.— Removing bolt carrier from receiver.

Operating the M16 Rifle

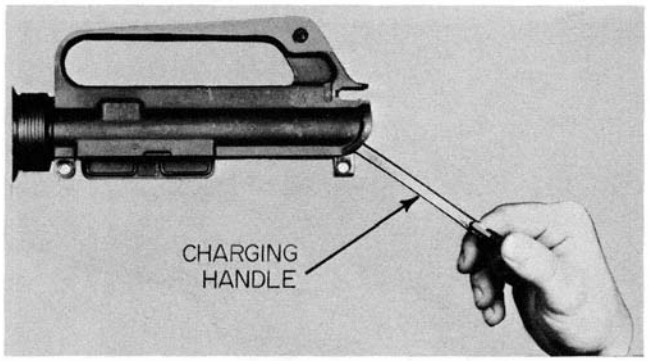
The magazine has a capacity of 20 rounds and may be loaded with any amount up to that capacity. The magazine follower has a raised portion generally resembling the outline of a cartridge. Cartridges are loaded into the magazine so that the tips of the bullets point in the



29.353

Figure 11-28.— Upper and lower receiver groups.

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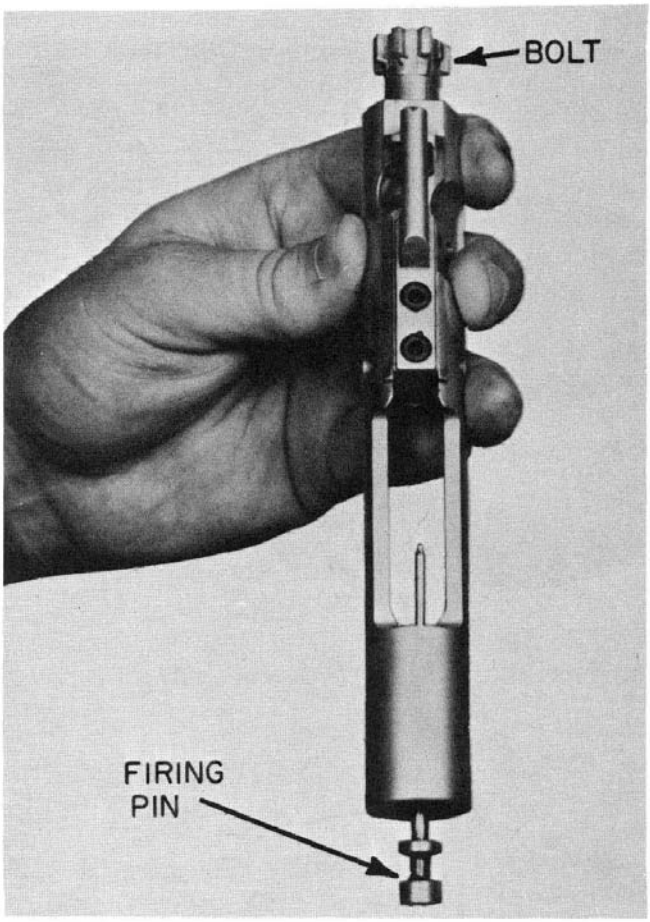


29.355
Figure 11-30. — Removing the charging handle.

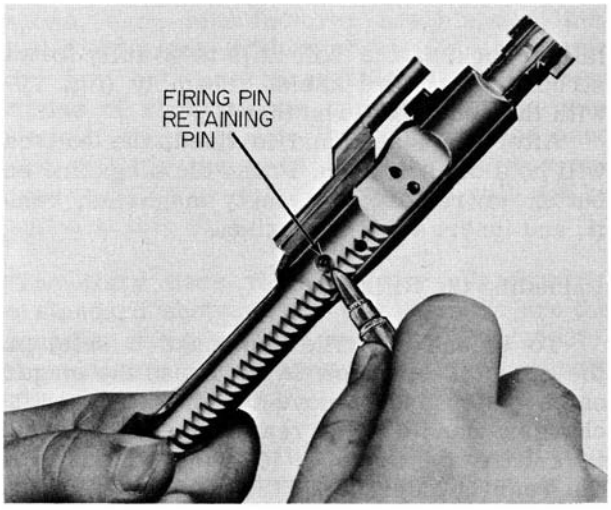
same direction as the raised portion of the follower (fig. 11-35).

Loading the Rifle

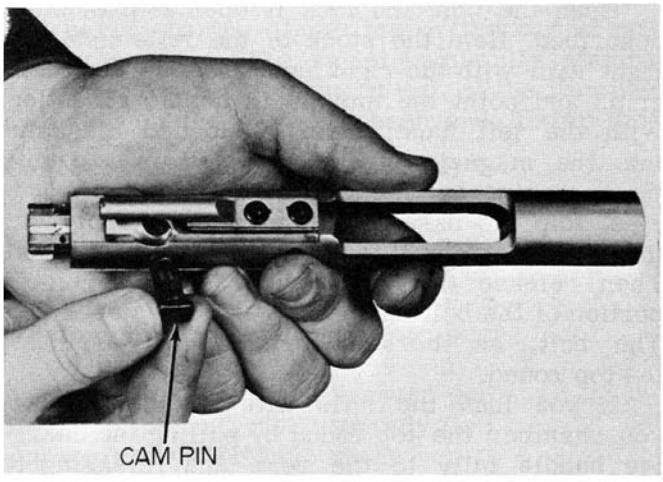
With the hammer cocked, place the selector lever on SAFE. The magazine may be inserted with the bolt either open or closed. However, you should learn to load with the bolt open since this reduces the possibility of a first-round stoppage and saves the time required to



29.357
Figure 11-32. — Removing the firing pin.

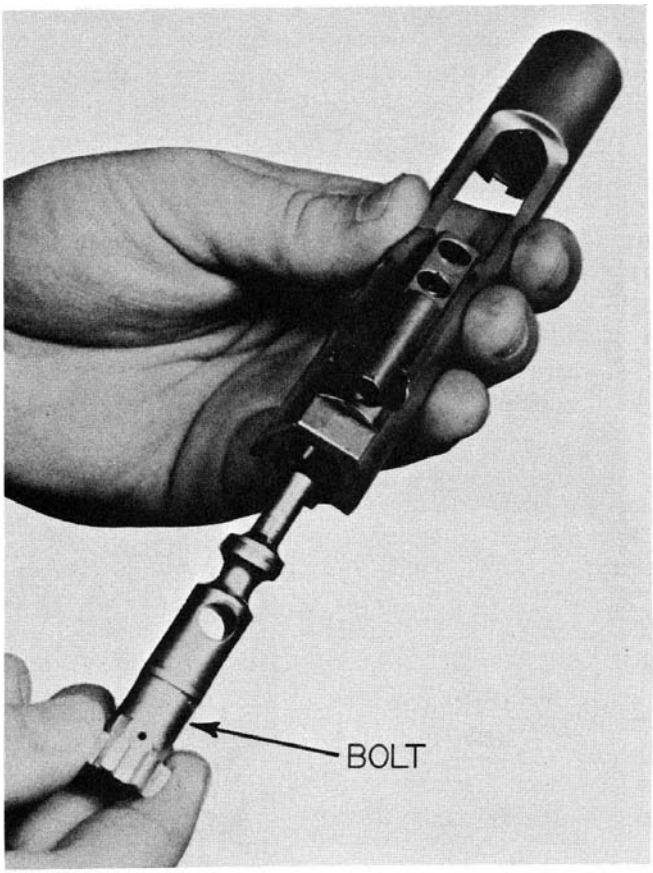


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Figure 11-31. — Pressing out firing pin retaining pin.

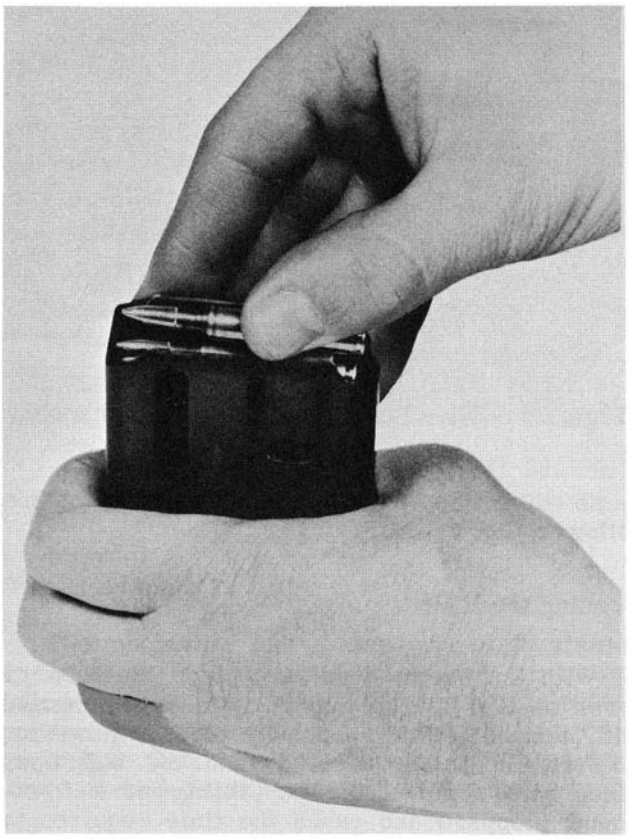


29.358
Figure 11-33. — Removing the cam pin.

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29.359
Figure 11-34. — Removing the bolt.



29.360
Figure 11-35. — Loading cartridges into magazine.

chamber the first round by pulling back the charging handle.

Open the bolt and lock it open as previously described. Hold the stock of the rifle under the right arm with the right hand grasping the pistol grip, and point the muzzle in a safe direction. With the left hand, insert a loaded magazine into the magazine feedway. Push upward until the magazine catch engages and holds the magazine. Rap the base of the magazine sharply with the heel of the hand to ensure positive retention. Then release the bolt by depressing the upper portion of the bolt catch as previously described. The bolt, as it rides forward, will chamber the top round.

If you load the rifle with the bolt closed, you chamber the top round by pulling the charging handle fully to the rear and releasing it. NOTE: Do not "ride" the charging handle forward with the right hand. If the handle is eased forward from the open position, the bolt may fail to lock. If the bolt fails to go fully forward. strike the forward assist assembly (fig. 11-20) with the heel of the righthand.

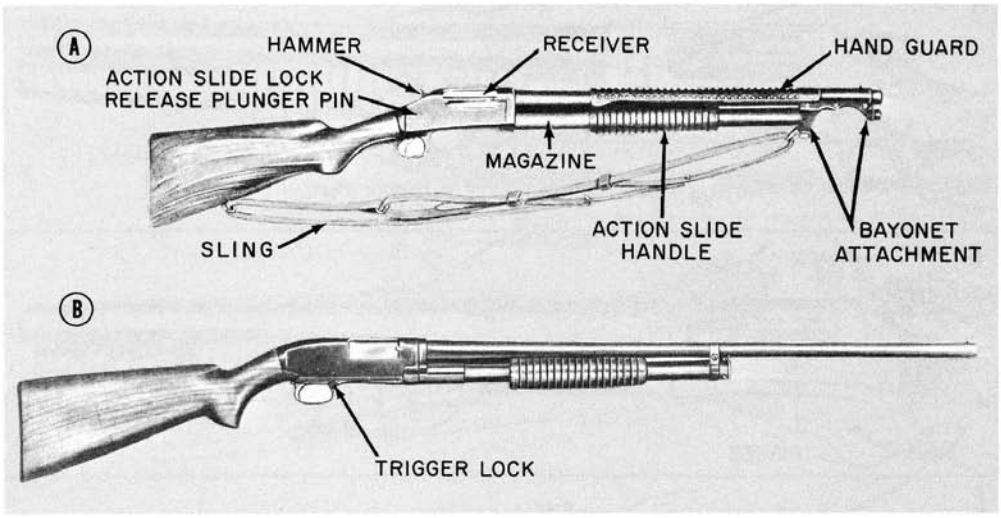
After the last round is fired, the bolt catch will hold the bolt open. Press the magazine catch button to release the empty magazine, remove it, and insert a full magazine.

Unloading the Rifle

To unload the rifle and make it safe. place the selector lever on SAFE, press the magazine catch button and remove the magazine, pull the charging handle to the rear, inspect the chamber to ensure it is clear, lock the bolt carrier to the rear by depressing the lower portion of the bolt catch, and return the charging handle forward.

The rifle is clear (and therefore safe) ONLY when no round is in the chamber, the magazine

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84.254.4:.257.1

Figure 11-36. — Shotguns: A. Winchester 12-gage M97, riot type; B. Winchester M12, sporting trap type.

is out, the bolt carrier is to the rear, and the selector lever is on the SAFE setting.

SHOTGUNS

Shotguns are not primarily designed as military weapons, but actually are intended for civilian use in sporting or police work.

Since shotguns are not standardized military weapons, each manufacturer has his own line, and the different models of weapons and their parts are not interchangeable. The different varieties of shotguns are named after the uses for which they are intended. The method used in determining the gage of a shotgun was explained earlier in this chapter so will not be repeated at this time.

The Navy uses riot guns for guard work. The standard shotguns for this purpose are the Winchester 12-gage M97 and M12 (fig. 11-36). Riot guns normally are equipped with bayonets, handguards, and slings.

In this section we will take up the functioning, construction, and maintenance inspection of the two standard issue shotguns mentioned above, that you will most likely use in the fleet. For information on other shotguns that you may come across, see Army Technical Manual TM- 9-1005-206 (series).

WINCHESTER SHOTGUN M97

Now, let's go into a little detail on the Winchester 12-gage M97. used in the Navy for guard work (fig. 11-37). This is a manually operated repeater, slide action hammer type shotgun with full-cylinder. 20-inch barrel. (Grades for skeet and trap use are available with other barrels.) It is available in either takedown or solid-frame construction. and normally comes equipped as a riot type with bayonet, handguard, and bayonet attachment. For positive identification of this shotgun. look for the maker's name, gage, model, and barrel boring at the top of the barrel near the breech end. The serial number is stamped on the lower face, forward end, of the receiver, and also on the barrel breech end, lower face.

Characteristics of the Winchester Shotgun M97 (Riot Type)

Length (in. overall) with 20-in. barrel (approx.)	39
Weight without bayonet (lb).	7.2
Maximum muzzle velocity. avg. over 40-yd range (fps)	1,070
Approximate chamber pressure (psi)	11,000
Length of barrel, riot type only (in.)	20
Approximate maximum range (#00 buckshot) (yd)	748
Patterns (percentage) of shot in a 30-in. diameter circle at 40 yds (#00 buckshot)	33-1/3

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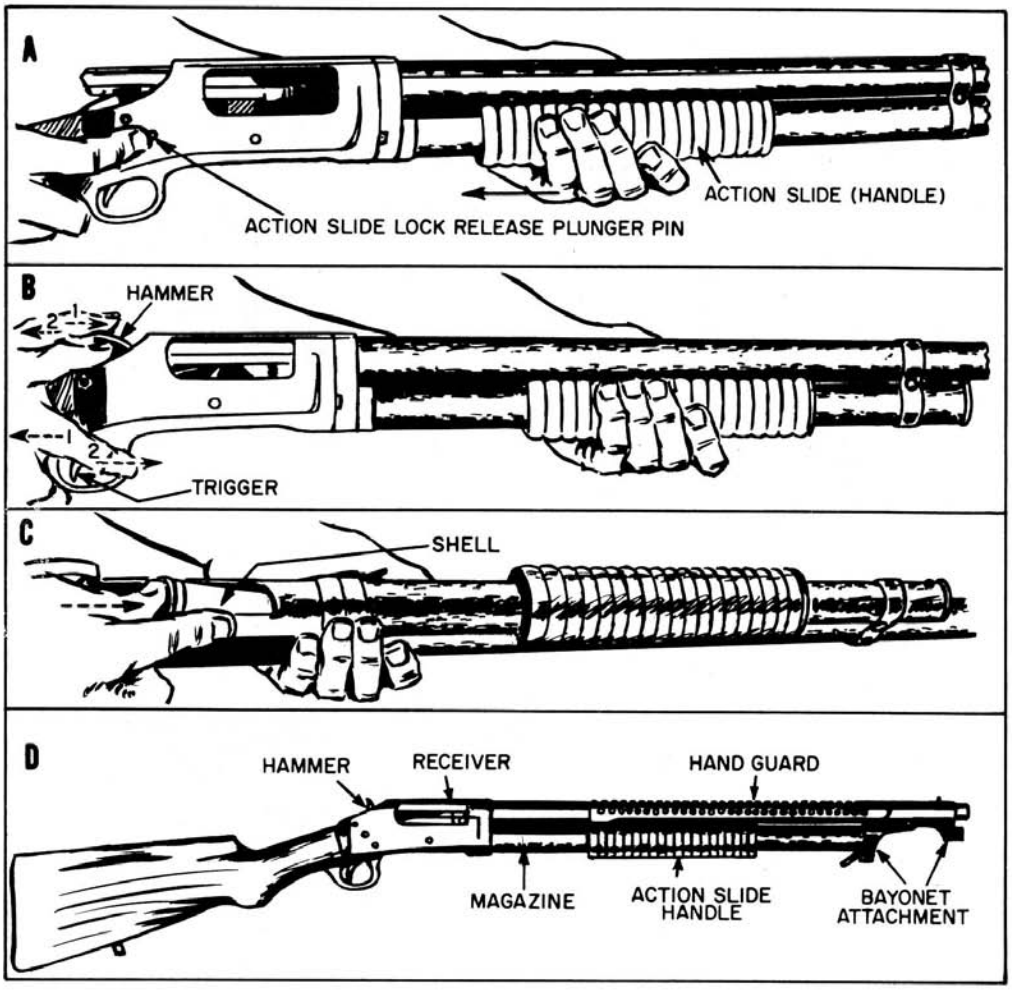


Figure 11-37.—Winchester shotgun M97, riot type. A. Depressing the action slide lock release plunger pin, and retracting action slide. B. Setting hammer at half cock. C. Loading the magazine. D. General view. 84.254

Bore	12 gage
Trigger pull (lb)	4 to 8
Shell capacity	5 in magazine, 1 in chamber

Functioning of the Winchester M97

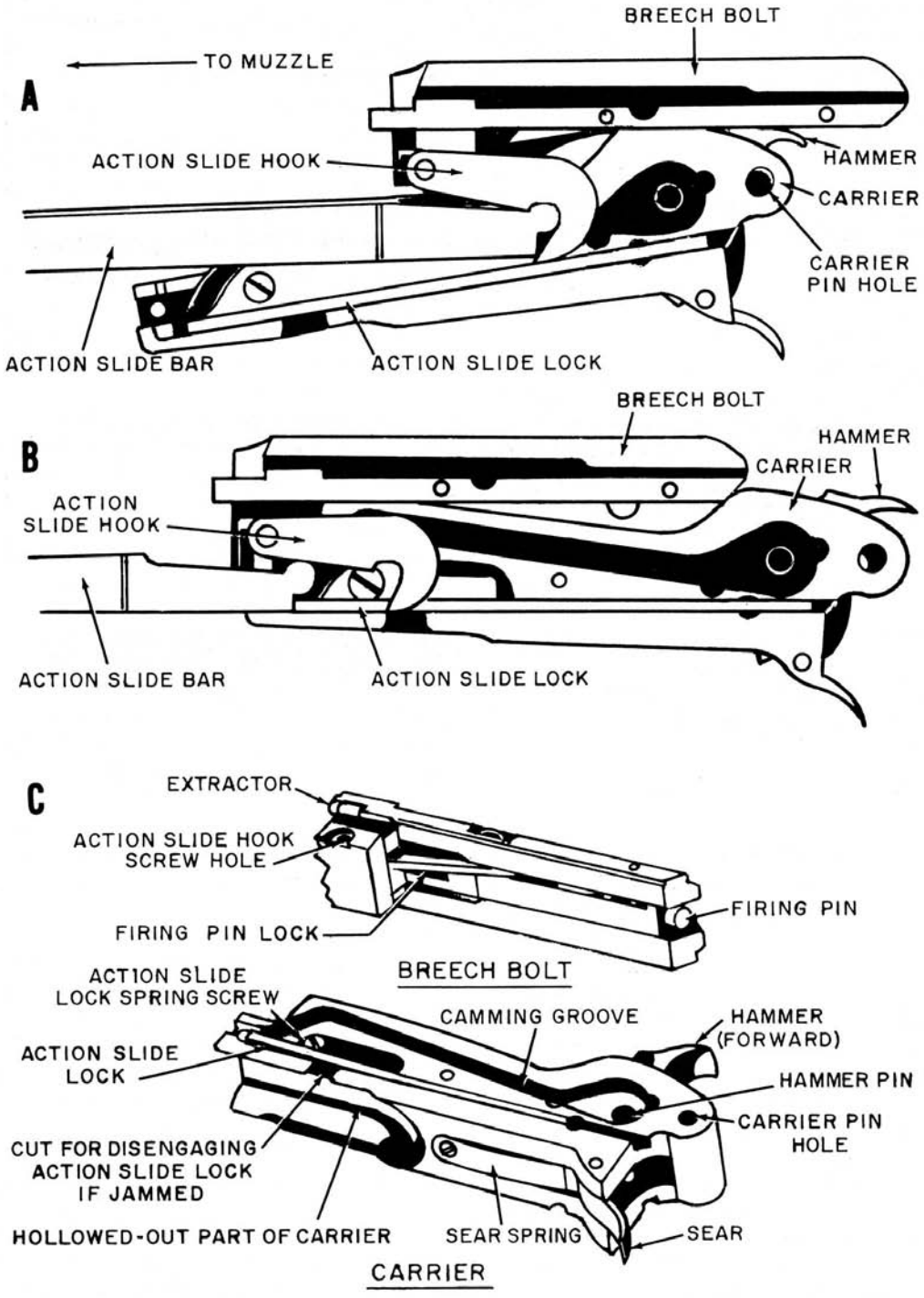
The heart of the Winchester M97's mechanism is shown in figure 11-38. The important units, which are housed in the receiver, are the breech bolt, the carrier, the action slide bar, and the action slide hook.

The carrier (fig. 11-38C) is an irregularly shaped steel piece pivoted on a carrier pin running horizontally through its after end. Its forward end swings vertically as the carrier is cammed up and down. The carrier contains the hammer, sear, and action slide lock. Note the concave (hollowed-out) part of the carrier. A similar concavity is in the top side of the carrier.

The rectangular breech bolt contains the firing pin, firing-pin lock, and extractors. The boxlike part of the bolt below the bolt's forward end contains the action slide hook screw hole.

Now look at figure 11-38 to see how the mechanism works. Part A shows the position of the mechanism with the action slide handle pulled aft. The action slide bar, which is connected to the handle, has on its extreme after end a lug that fits into the carrier's camming

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Figure 11-38. — Winchester 12-gage shotgun M97. Breech bolt, carrier, and slide bar groups. A. Position with action slide handle retracted. B. Position with action slide handle forward. C. Detail view of breech bolt and carrier.

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groove, camming the carrier downward. Movement of the action slide handle also actuates a linkage (not shown) to draw a shell from the magazine and deposit it on the upper concave surface of the carrier.

In this position, the action slide bar's after end engages the action slide hook, which is pinned to the breech bolt, thus pulling the bolt to rearward position, opening the breech, and camming the hammer back to cocked position.

Figure 11-38B shows the mechanism with the action slide handle pushed forward. As the action slide bar cams the carrier upward, it pulls the action slide hook and bolt forward, so that they strip the shell from the upper surface of the carrier and drive it into the chamber. The hammer is left in the cocked position, engaged by the sear. The action slide lock on the carrier slips upward and locks the action slide bar so that the bar and action slide handle cannot be moved back. The shotgun is now ready to fire.

When the hammer falls in firing, the action slide lock is automatically disengaged so that the slide handle can be pumped for ejecting, reloading, and recocking.

There is no trigger safety on this shotgun. To set the gun at SAFE, you move the hammer to HALF COCK, which also locks the trigger and the action slide handle. Half cock is the hammer position midway between full-cock and hammer-released positions.

Loading and Firing The Winchester M97

To load the gun chamber from the magazine, first disengage the action slide lock so that the action slide handle can be operated. If the gun has just been fired, do this by moving the action slide handle slightly forward to unlock it. (When the gun is fired as a repeater, and the gunner holds the handle, gun recoil automatically acts to unlock it.) If the hammer is at full cock, press the action slide lock release plunger pin (fig. 11-37A) and push the handle forward to unlock. If the hammer is at half cock, pull back to full cock, and proceed as above to unlock.

With the action slide handle unlocked, move it smartly back, then forward. The shotgun now can be fired.

When the hammer falls in firing, the action slide lock disengages automatically. But if the chamber is to be opened or the gun unloaded without firing, the hammer must be set at SAFE and the slide-lock release plunger (which disengages the slide lock) depressed. Then the action slide handle can be pulled back to eject the shell in the chamber (fig. 11-37 A). The procedure for setting the hammer at half cock (fig. 11-37B) is as follows:

1. Set the hammer at full-cock, either by pulling it back with your thumb or by operating the action slide handle.
2. Hold the hammer firmly with the thumb, press the trigger, and ease the hammer down slightly beyond half-cock position. Release pressure on the trigger as soon as the hammer is released from full cock.
3. Pull the hammer back until it clicks into position at half-cock.

The only safe way to carry the shotgun with chamber loaded is at half-cock. NEVER let the hammer down when there is a live shell in the chamber, except in the act of firing.

To set the hammer at full-cock again, simply pull it back with the thumb. The shotgun is then ready to fire.

To empty the chamber without firing, after the hammer has been set at half cock, pull the hammer back to full-cock, press the action slide lock release plunger pin, and retract the action slide handle.

To load the magazine (fig. 11-37C), press the shell, nose first, into the after end of the magazine against the magazine follower, until the spring loaded retainers or SHELL STOPS snap out behind it to hold it. Load another in the same way, and continue loading until all five are in. To transfer a shell from magazine to chamber, work the slide handle back and forth once.

To unload the magazine, press in the two shell-stop plungers on the magazine, and let the shells slide out. Retract the action slide handle to eject a chambered shell. Inspect receiver and chamber to be sure the gun is completely empty.

Loading and unloading the magazine should be done only with the hammer at half-cock.

To load the chamber only, with magazine empty. retract the action slide handle; place the shell directly in the chamber through the ejection opening in the receiver; close and lock the bolt by pushing the slide handle forward again; and set the hammer at half-cock.

SAFETY PRECAUTIONS WHEN LOADING. UNLOADING. AND FIRING. - In addition to the general safety precautions applicable to small arms, note the following specific precautions for this weapon.

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1. Keep the hammer at half cock (safe) when the gun is loaded unless you are about to fire.
2. Never let the hammer down on a loaded chamber except in firing.
3. When operating the action slide handle;
   a. Keep fingers outside the trigger guard.
   b. Keep the gun pointed in a safe direction.

Maintenance Inspection of
Winchester M 97 Shotguns

VISUAL INSPECTION AND ELEMENTARY REPAIRS. - The most important parts to inspect visually are the barrel and bore. Look for looseness of the barrel in the receiver, for rust, pits, leading, cracks and bulges. If it's loose, tighten it. Remove leading (dull gray streaks) and rust (dark patches) from the bore. Bulges, cracks, or serious rust and pitting mean that the barrel should be replaced. Bulges may not be easy to detect. Look for a shadowy depression or dark ring in the bore, and for a raised ring or distortion on the barrel outer surface. Also check for loose wood screws and cracks in wood parts.

The simple maintenance and repair operations that will take care of many defects revealed by visual inspection can be performed easily by most small-arms repair personnel, even by those not necessarily shotgun experts. Such operations (other than routine cleaning and lubrication) include repair of cracks in wood parts, reseating wood screws, and tightening barrels in their receivers, and they apply both to M97 and M12 Winchester shotguns.

Rust or corrosion outside the bore can, if it's light, be removed with an oily rag or a rag moistened with rifle bore cleaner. More stubborn deposits may require careful rubbing with crocus cloth or even with fine steel wool. Be careful not to scratch metal surfaces any more than necessary. To remove corrosion or leading in the bore, push a wad of fine steel wool straight through it several times. Don't scrub or turn the wad in the bore.

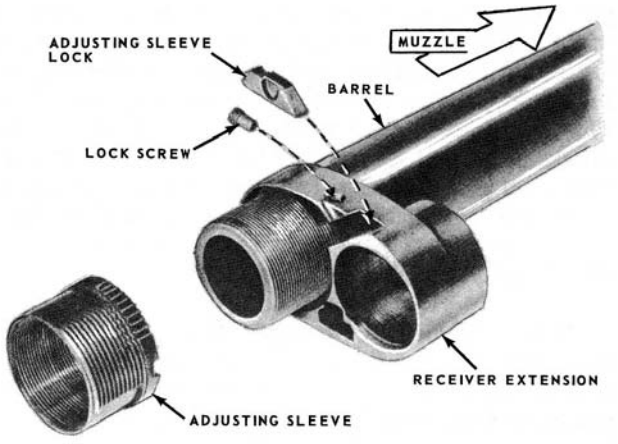
When wood screws strip out, you can reset them by boring out, plugging, reboring the stripped hole, and reseating the screw. You can often check small wood cracks by boring a small hole just ahead of the crack and plugging it with shellac or plastic wood (NOT with a wooden plug). But if the crack is extensive, replace the part.

In takedown type Winchesters, you can tighten a loose barrel and magazine where they mate with the receiver as follows:

1. Take down the gun. Remove lock screw from receiver extension. Slide back and disengage adjusting sleeve lock from adjusting sleeve (fig. 11-39).
2. Turn sleeve back one notch, engage lock with sleeve, and replace lock screw.
3. If barrel is still loose when reassembled, repeat until tight.

FUNCTIONING INSPECTION. - This is done with the gun completely assembled. Be sure it's not loaded and use dummy shells. If none are available, you can use fired shells if you bend inward the prongs at the open end so that the length of the shell is about the same as that of a live shell. NEVER use live shells for testing. Here is the testing procedure:

1. With breech bolt locked and hammer at full cock, press in the action slide lock release plunger pin. Push action slide handle forward slightly and pull smartly and fully to the rear; then push smartly and fully forward. Repeat several times to test smoothness of action. Do not slam the mechanism.
2. Let hammer down to half cock, press release plunger pin, and try to retract action slide as above. It should not be possible to do it.
3. Retract hammer slightly to clear sear, retract trigger, and ease hammer down to fired position. Repeat test as in 1 above-. The action slide should retract.



84.256
Figure 11-39. — Winchester shotgun M97. Barrel adjusted sleeve (disassembled).

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4. Retract slide as in 1. above, release plunger pin, and push slide smartly and fully forward to lock breech bolt. Then try to retract action slide. This should be impossible with hammer at full cock until action slide lock is disengaged.

5. With breech bolt locked and hammer at full cock, pull trigger to test firing mechanism. Set hammer at half cock and try to pull trigger. Since at half cock the firing mechanism is in SAFE position, pulling the trigger should NOT fire the gun.

6. With hammer at full-cock, close but do not lock breech bolt. Then try to fire. The gun should not fire until the breech bolt is locked.

7. Put two dummy or fired shells in the magazine. Work the action to test gun for feeding, loading, extraction, and ejection. The second shell should not leave the magazine until after the carrier drops as the first shell is ejected. NOTE: Fired shells may not work through the action as easily as live or dummy shells. Allow for this when testing.

8. Test for trigger pull, using the same general method as that described for carbines. Trigger pull should be between 5 and 8 pounds with the pressure to be applied about 1/4 inch from the lower end of the trigger and parallel with the barrel. When testing, the gun must be unloaded, action locked, and hammer at full cock.

The functioning inspection is extremely important. If a bolt fails to lock properly or a slide lock or similar part fails to function, the breech may blow open when the gun is fired, with a risk of serious injury to the firer. No gun is acceptable unless it passes ALL phases of functioning inspection. If repair parts, proper tools, and qualified personnel are aboard, defective weapons should be repaired. (See Army TM-9-1005-206 (Series) for information on troubleshooting and repair work.) Otherwise defective shotguns should be turned in to the issuing activity (or Naval Supply Center) for replacement.

WINCHESTER SHOTGUN M12

The Winchester shotgun M12 is a manually operated "hammerless" repeater of the slide-action type generally issued in 12-gage (but you'll sometimes find 16-gage specimens), The barrel, magazine, and action slide group are similar in design to (though not interchangeable with) those of the M97, but the receiver and operating mechanism differ, The riot type gun (the one most often issued in the Navy) is usually furnished with a 20-inch plain full-cylinder bore barre,. and may be equipped with a bayonet attachment and hand guard at the barrel's muzzle end. Figure 11-40A shows a sporting model. Identification marks are located in the same places as on the M 97.

Loading and Firing The M12 Winchester Shotgun

In general outline, the operations required for loading and firing the M12 Winchester are similar to those for the M97. Here are the main differences (concerned mostly with the concealed hammer of the "hammerless" M12, and the slightly different loading arrangements):

1. There is no hammer half-cock position. The shotgun trigger safety is a lock button in the trigger guard bow (fig. U-40B. In SAFE position (pushed to the right) it blocks trigger movement rearward. Pushing it to the left (to FIRE position) reveals a red band and unlocks the trigger. If there is a shell in the chamber, the safety should be at SAFE unless the gun is to be fired. Safety precautions when firing are similar to those for the M97. Keep fingers out of the trigger bow when operating the action slide handle, and release the trigger completely between shots.

2. As with the M97, the gunner disengages the action slide lock after each shot by moving the action slide handle slightly forward before retracting it. (When fired as a repeater. this happens automatically.) But. if the hammer is already cocked, he must first press up the rear end of the action slide lock (visible in the receiver just to the left of the trigger) to disengage it.

3. To load the magazine, press a shell, nose first, into the rear of the magazine against the magazine follower until it slips in front of, and is retained by, the carrier. Load other shells in the same way until five in all are loaded. Loading should be done with the breech bolt locked.

4. To unload magazine, press up the carrier with breech bolt locked, and allow the shells to slip out one by one.

5. To transfer a shell from magazine to chamber, slide trigger lock to SAFE, release action slide lock, and operate action slide handle. Test breech bolt for looking by trying to retract slide handle. (It should not retract.) Leave trigger lock on SAFE unless you intend to fire at once.

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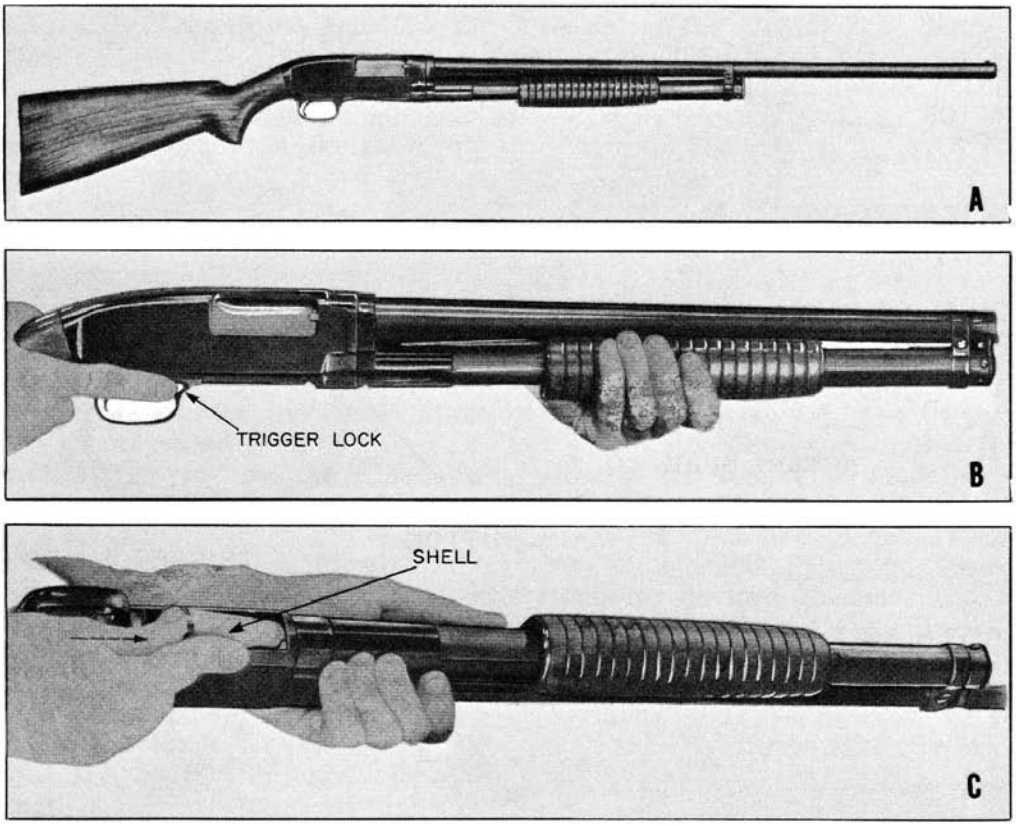


Figure 11-40. — Winchester shotgun M12. A. General view. B. Trigger (safety) lock. C. Loading the magazine. 84.257

6. To unload the gun, slide trigger lock to SAFE, and unload magazine. Disengage slide handle to extract and eject shell in chamber. Inspect magazine and chamber to be sure gun is empty.

7. Loading the chamber without loading the magazine is done exactly as with the M97, except that you set the M12 trigger safety button at SAFE.

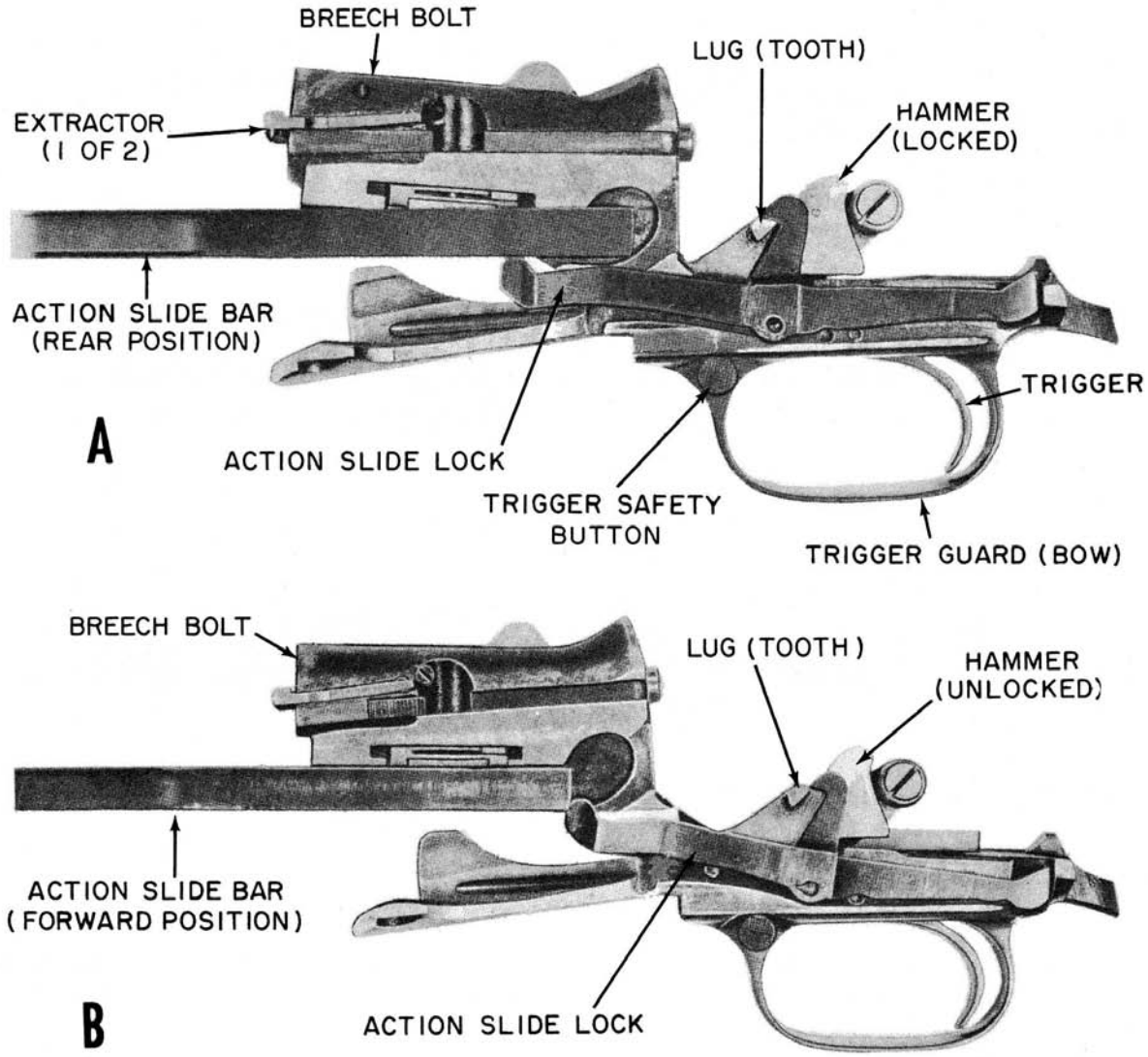
Functioning of the Winchester M12

As with the M97, the mechanism of the M12 is operated when you work the action slide handle back, then forward. A cam lug on the action slide bar after end engages a camming aperture in the left side of the breech bolt. As the slide moves aft, the breech bolt rear end is cammed down from in front of the locking shoulder in the top of the receiver and the bolt moves to the rear. As the slide moves forward, the breech bolt also moves forward and its rear end is cammed up in front of the locking shoulder.

As the breech bolt moves aft it cams back the hammer which is caught and held by a hook (fig. 11-41A) on the action slide lock. As the breech bolt reaches forward position, the action slide lock, which has been held down by the action slide bar, is released and springs up behind the action slide bar to block its rearward movement (fig. 11-41B). At the same time, the lock releases the hammer, which is then held by the sear.

The M12 Winchester, much like the M97, uses a carrier (not illustrated) to transfer shells from the magazine to the chamber, but the timing of its operation is a little different from the M97. As the breech bolt starts forward it cams the carrier up and down rapidly. The shell resting on the carrier is lifted in line with the bore and the breech bolt pushes it into the

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Figure 11-41. — Winchester shotgun M12. Breech bolt and action slide bar groups. A. Action slide bar disengaged; hammer locked. B. Action slide lock engaged; hammer unlocked.

chamber. The carrier has immediately returned to the lower position and is in readiness to receive another shell. As the breech bolt closes, the action slide bar cams the shell cut-off to release a shell from the magazine. The magazine spring pushes it onto the carrier.

The fired shell is extracted from the chamber by the extractors in the breech bolt as the bolt moves to the rear, and is knocked out of the receiver by the ejector through the ejection opening.

Maintenance Inspection Of The
M12 Winchester Shotgun

VISUAL INSPECTION AND ELEMENTARY REPAIRS. - These aspects are the same for the M12 as for the M97, discussed earlier, even the details of tightening the barrel.

FUNCTIONING INSPECTION. - As with the M97, you can use fired shells, even if somewhat deformed, for functioning tests if you turn in the open ends. But make allowances

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for these deformations when judging smoothness of action. Be sure the gun has no live ammunition in it when performing these tests. Here are the testing operations:

1. With breech bolt locked and hammer cocked, press upward on the action slide lock rear end. Push action slide handle forward slightly, pull smartly and fully to the rear, then push smartly and fully forward. Do this several times to test smoothness of action. But don't slam the mechanism.
2. Retract action slide as in 1. above, release pressure on rear of action slide lock, and push slide smartly forward to lock breech bolt, then attempt to retract the action slide. The action slide should not retract.
3. Pull the trigger to make the hammer fall. Try to retract the action slide. It should retract.
4. Retract it fully, then push forward until the breech bolt is fully forward, but not raised to the locked position. Pull the trigger to release the hammer. The hammer should not descend until the breech bolt is fully locked.
5. Place two more dummy or fired shells in the magazine and work the action to test for feeding, loading, extraction, and ejection. The second shell should not leave the magazine until the breech bolt is locking behind the first shell in the chamber.
6. With breech bolt locked and hammer cocked, push the trigger safety lock all the way to the right. Pull the trigger. The trigger should not retract nor should the hammer descend.
7. Push trigger lock all the way left so that red band shows, and pull the trigger. The trigger should retract and release the hammer.

CALIBER .45 LINE-THROWING GUN

The line-throwing gun (fig. 11-42) is the only gun firing a projectile of small arms caliber that is not intended as a weapon. The gun is also unique among those we have taken up in this chapter in that it is not of Army origin. It is used only by the Navy, and the reference publication for it is OP 546.

The gun is designed to pass a small line from Slip to ship or from a ship to a pier. A projectile, with one end of the line attached, is fired from the gun by the impulse of a blank cartridge. This small line serves as a messenger for the larger running lines of refueling rigs, high lines, breeches-buoys, etc.

The gun is single shot with a smooth bore (.45 cal.), and a short barrel of tip-down action hinged to the frame. It is ruggedly constructed, and the breech has been heavily reinforced to withstand the relatively high chamber pressures.

The shot line is made of nylon with a minimum (when new) breaking strength of 125 pounds. It is wound on a wooden spindle in such a way that, when the spindle is removed for firing, it will payout without fouling. The ammunition is a blank 45-70 cartridge loaded through the breech of the gun and the projectile through the muzzle.

The projectile (fig. 11-42) is made up of three major units: a buoyancy chamber, an illuminating unit, and the rod. The buoyancy chamber is a plastic bottle-shaped cylinder fitted onto the front of the rod. It serves to keep the projectile afloat. The illumination unit is essentially a small flashlight which is enclosed in the buoyancy chamber. It is especially useful during night operations for obvious reasons. The rod is the part of the projectile that goes in the gun's muzzle. The nylon shot line is attached to a slide on the rod. If the rod gets scratched, burred, or slightly bent, use fine emery cloth to get it back into shape. Do NOT fire any projectile that fails to enter the bore freely.

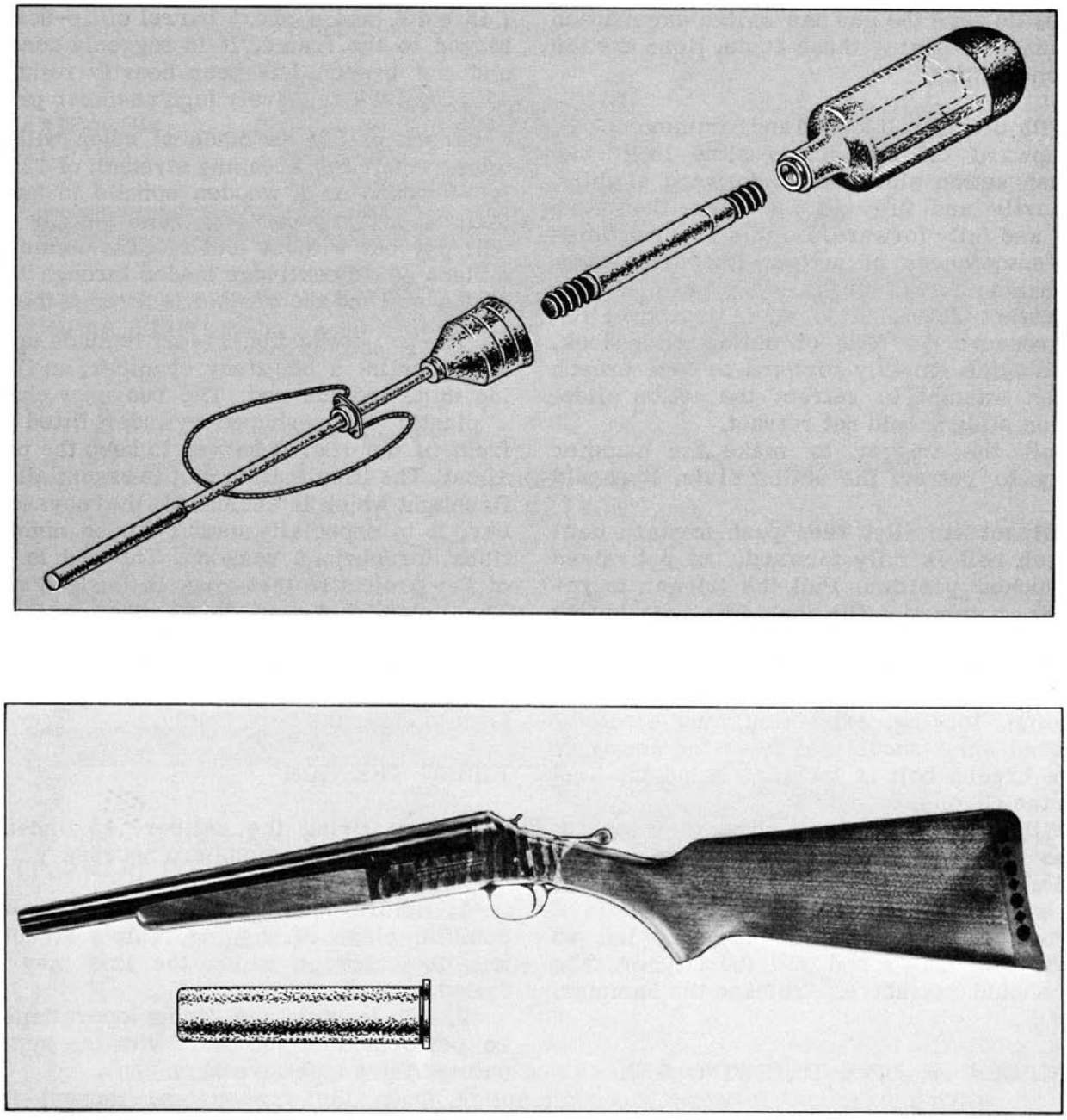
FIRING THE GUN

Before firing the caliber .45 line-throwing gun, certain precautions are necessary:

1. Before loading, select an outboard firing position clear of rigging, ship's structure, or any obstacles on which the line may become fouled.
2. All loading and firing operations are to be performed at the rail, with the gun pointed outboard in a safe direction.
3. Open the breech and inspect the bore to see that it is thoroughly clean and dry, and slip the projectile into the muzzle to see that it moves freely. The bore and the projectile must move freely its entire length of travel in the bore. Excessive friction produces dangerously high chamber pressure and reduces range.

It takes two men to safely fire the line-throwing gun unless the special canister is used. One man holds the coiled line and the other fires the gun. Assuming that the projectile has been properly prepared, follow this procedure:

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Figure 11-42. — Caliber .45 line-throwing gun and projectile.

Both men station themselves at the rail, the man holding the coiled line to leeward of the shooter. On a ship underway this precaution normally puts the man with the gun forward of the man holding the line.

If the line has not yet been attached to the projectile, do it now. Knock out the wooden spindle; pull enough line from the center of the coil and tie it to the slide on the projectile. Don't pullout any more line than is necessary for this operation.

Try the projectile in the bore of the gun, it must pass through freely. Now take the projectile out of the bore.

Standing at the rail, open the breech by pressing the unlocking lever to one side.

Insert a cartridge into the breech.

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Close the breech.

Insert the projectile rod into the bore as far as it will go.

Brace the gun firmly against the shoulder. Cock the gun by pulling back on the hammer until it reaches the full cock position.

Aim the gun. At short ranges the gun is fairly accurate. At long ranges, however, you will have to elevate your aim and use "Kentucky windage" to lead the target. The path of the projectile and line are seriously affected by wind. Also, the projectile is relatively slow moving, so target speed is a factor in aiming the gun. About the only firm guideline we can give you is that your shot should be placed well clear of personnel on the receiving ship.

Fire the gun.

When the man holding the coiled line sees that the projectile has definitely crossed the other ship, he squeezes the coil, halting any further paying out of the shot line.

Take a bight in the line and secure what is left in the coil with it. Bend your shot line to whatever running lines are going to be sent over to the receiving ship.

Your interest in the proceedings now is largely one of trying to get your shot line and projectile sent back with the rig.

Note 1: In the event of misfire, keep the gun braced against your shoulder and pointed in a safe direction. Recock and attempt to fire again. If repeated attempts to fire fail, wait one minute before opening the breech and removing the cartridge. Take a quick look at the primer to see if it has been struck by the firing pin; if so, deep six it.

The firing pin of the line-throwing gun is a short, free-floating type. It is a good idea before you shoot to elevate the gun and jiggle it to bring the firing pin out toward the hammer as far as it will go.

Note 2: When shooting the gun do NOT lay your thumb on top of the stock immediately behind the breech unlocking lever. Instead. lay it alongside the frame. The recoil of a line- throwing gun is such that, if you hold it incorrectly, the unlocking lever can pinch or even penetrate your hand. And there is the possibility that if your hand is placed so as to interfere with the unlocking lever's rearward movement, the lever may be cammed to one side, unlocking the breech. In this case, recoil may be accompanied by a rapid unintentional disassembly of the gun.

Maintenance

Authorized disassembly of the line-throwing gun is limited to the following steps:

1. Remove the foregrip by pulling it down firmly to release the spring snap which secures the grip to the barrel.
2. Remove the barrel by opening the breech and pushing back on the barrel, disengaging it from the frame.

The gun is reassembled by following these steps in reverse order.

When the gun is stored in the armory, it is kept lubricated with a light oil, as are all small arms. When it is to be fired, however, the bore must be completely cleaned and dried by running patches through it. Also, between consecutive firings a dry patch should be run through the bore to remove all powder residue from the previous shot. The line-throwing gun is known for its kick, and anything causing the projectile to bind in the bore adds dangerously to the gun's recoil.

BROWNING MACHINEGUN, CALIBER .30, M1919A4

Browning machineguns (abbreviated BMG) are standard Army weapons used by the Navy afloat, ashore, and in aircraft. The two calibers - .30 and .50 - have basically similar mechanisms.

The caliber .30 BMG is issued to combat vessels and many auxiliaries as a landing-force weapon. Its general characteristics are listed below. In this section we'll take up its functioning, operation, and general (nonroutine) inspection and maintenance. For further details, see Army FM 23-55 and TM-9-1005-212 (Series).

General Description

The caliber .30 BMG is a recoil-operated, belt-fed, water- or air-cooled automatic weapon, various models of which are designed for use in aircraft or on ground mounts. The type we shall take up is the M1919A4, illustrated in figure 11-43 on the M2 ground mount. This is an air-cooled weapon designed for use with fabric belts. It has a heavy barrel surrounded with a perforated steel jacket to improve cooling. It uses a leaf-type sight. The .30 cal. BMG weighs approximately 31 pounds (less tripod) and has an extreme usable range of 2,000 yards. The rate of fire for the weapon is 400-500 rounds per minute.

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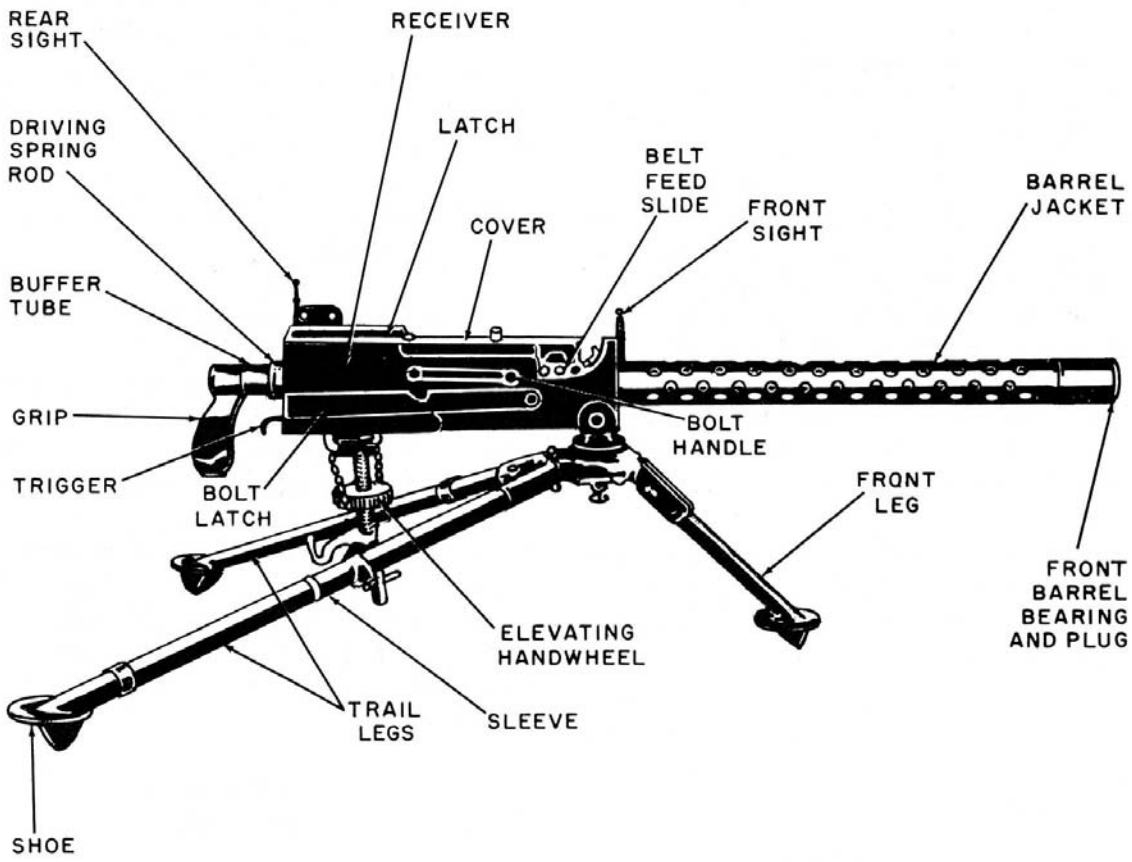


Figure 11-43.— Browning machinegun, caliber .30, M1919A4, on M2 mount.

Construction and Functioning
Of The Caliber .30 BMG
M1919A4

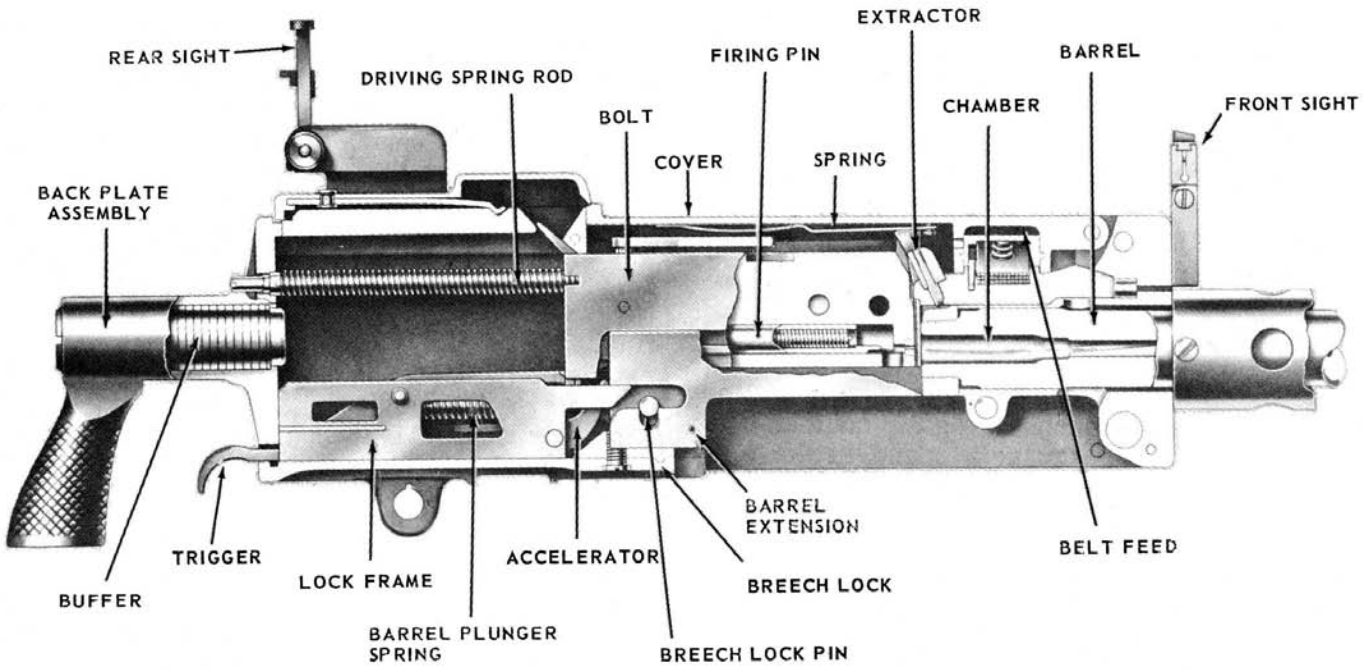
Figure 11-44 shows the BMG caliber .30 M1919A4 in cross section, with recoiling parts fully forward (in battery). The main exterior structure of the weapon is the receiver, which more or less corresponds in function to the slide of a naval gun. The major recoiling parts inside it are the barrel, barrel extension, and bolt.

The receiver is supported on pivots by the tripod mount M 2, which provides a stable mounting for the gun, is quickly collapsible for transport, and provides for elevation and train of the gun by hand as required (fig. 11-43). At the after end of the receiver is the back-plate assembly (fig. 11-44), which has a pistol grip for the gunner and a buffer to take up the shock of recoil of the bolt. Inside the after end of the receiver is the lock frame, which houses the trigger, the accelerator (which you'll learn more about very shortly), and the barrel plunger spring and plunger (on which the barrel and barrel extension slide in recoil-counterrecoil movement). The sights are on top of the receiver (fig. 11-43); there is also a cover, hinged at its forward end, in which are the parts of the belt feed mechanism - in particular, the belt feed lever - that are cammed by the groove in the top of the bolt (fig. 11-45). The fabric ammunition belt passes under the cover, through the top of the receiver, from left to right.

The barrel is secured to the front of the barrel extension, which incorporates a barrel locking spring to hold the barrel in place, and a breech locking device which locks the recoiling parts together at the beginning of the recoil movement. The bolt, shown in some detail in figure 11-45 incorporates the sear mechanism, cocking lever and associated parts, and firing pin and spring in its interior. On its face is the extractor (which incorporates also the ejector and a T-slot. In its sides are the recesses in which the breech locking mechanism functions.

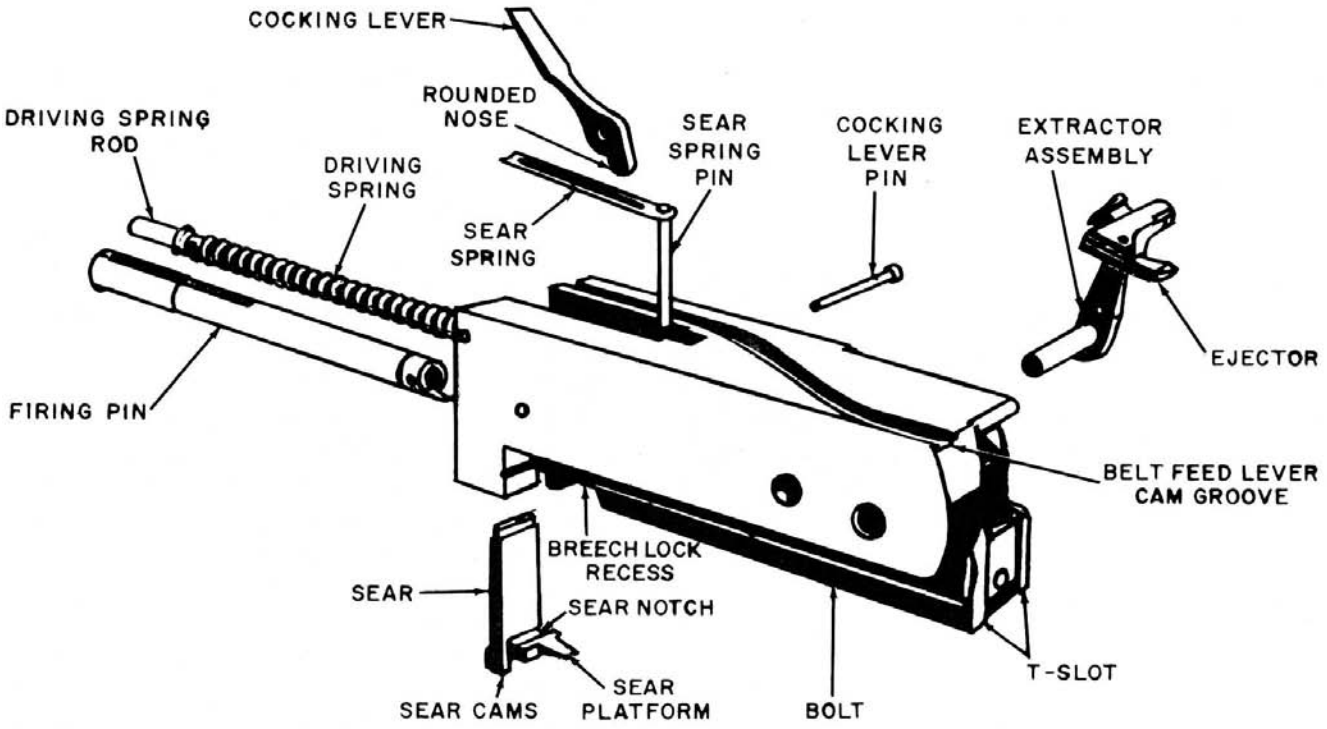
Before we go through the functioning cycle of the BMG, notice how the moving parts move:

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Figure 11-44. — Browning machinegun, caliber .30, M1919A4. Right side, sectional view.



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Figure 11-45. — Browning machinegun, caliber .30, M1919A4. Bolt assembly.

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1. The barrel and barrel extension move in recoil and counterrecoil. The total length of this movement is about 5/8 inch. For the first half of this movement in recoil these parts are locked to the bolt.

2. The bolt also moves in recoil and counterrecoil but, after unlocking from the barrel and barrel extension, it's kicked backward by the accelerator all the way against the buffer.

3. As the bolt moves aft in recoil, the extractor hauls a round out of the belt. As the bolt moves forward in counterrecoil, the extractor is cammed down, pushing the next round to be chambered down into the T-slot in line with the chamber, then up again so that with the ejector it grips the next round in the belt. The sides of the T-slot engage the cartridge base from the time the extractor forces it down into line with the chamber during counterrecoil until, after firing, it's kicked out by the ejector during the next counterrecoil.

4. The accelerator is pivoted on the lock frame. In recoil, its lower part is pushed back by the recoiling barrel extension; its upper end engages the bolt and kicks it back. In counterrecoil, the bolt turns the accelerator forward, unlocking the barrel extension so that it can counterrecoil too.

5. The cocking lever, which is pivoted in the bolt, is cammed by part of the top of the receiver so that its upper end swings forward during recoil and backward during counterrecoil. The lever's lower end pushes the firing pin aft during recoil.

6. The firing pin moves forward in the bolt to strike the cartridge primer when released by the sear, and is pushed backward in the bolt in cocking action during recoil.

We've traced what each major moving part does in the functioning cycle of the BMG. Now let's follow the cycle step by step. Remember that this cycle is practically the same in the caliber .30 BMG as its caliber .50 big brother; if you know one, you know the other. We assume the cycle starts with the gun fully loaded and cocked, and a loaded ammunition belt in the feedway.

1. FIRING. (See fig. 11-46A.) The gunner pulls the trigger. Its forward end lowers as its rear is raised, camming the sear down to release the firing pin's shoulder from the sear notch. The firing pin spring drives the pin into the cartridge primer, igniting the propelling charge.

2. FIRST STAGE OF RECOIL. The bolt, barrel. and barrel extension begin recoiling together. After 5/16-inch movement, the pins on either side of the breechlock contact the camming surfaces on the front of the lock frame, which pull the breechlock down into the barrel extension. This disengages the bolt from the barrel and barrel extension.

Figure 11-46 shows the unlocking. Figure 11-46C shows the caroming action and the action of the accelerator at the same time. In its final 5/16 inch of recoil movement, the barrel extension pushes the accelerator aft. The accelerator's tips kick the bolt back and then (as shown in figure 11-46D) it engages the T-shaped lug of the barrel extension and locks it in recoil position.

3. SECOND STAGE OF RECOIL. (See fig. 11-46E). As the bolt continues to recoil, the extractor hauls the next round out of the belt and the T-slot in the bolt face hauls the empty case out of the chamber. The extractor cam in the cover pushes the extractor down as the bolt moves to the rear. At the end of recoil, the bolt hits the buffer, which brings it to a stop. During recoil the following feeding and cocking operations also occur.

a. Feeding. (See fig. 11-47A and B.) Driven by the camming groove in the bolt, which engages its stud, the belt feed lever pushes the belt feed slide and pawl to the left (position 1). The belt-holding pawl keeps the belt from moving with them.

b. Cocking. (See fig. 11-47C.) As the bolt moves from position 1 (in battery) to position 2 (full recoil), the cocking lever is cammed as shown to retract the firing pin to a point where it can be engaged by the sear notch.

4. COUNTERRECOIL. (See fig. 11-46F.) As the bolt is driven forward by its driving spring, a spring-loaded plunger in the extractor engages cams in the receiver which push the extractor first down, then up, as shown by the arrows. In the downward movement, the extractor pushes the new round into the T-slot on the bolt, and the ejector tip knocks the empty case out of the T-slot. In the upward movement the extractor and ejector are positioned to engage the next round in the belt. As the bolt nears the end of counterrecoil, it pushes the accelerator tips forward, causing the accelerator to unlock the barrel extension, which is then driven forward by the barrel plunger spring. Next, the breechlock cam (fig. 11-46B) pushes the breechlock up to engage the breechlock recess in the bolt

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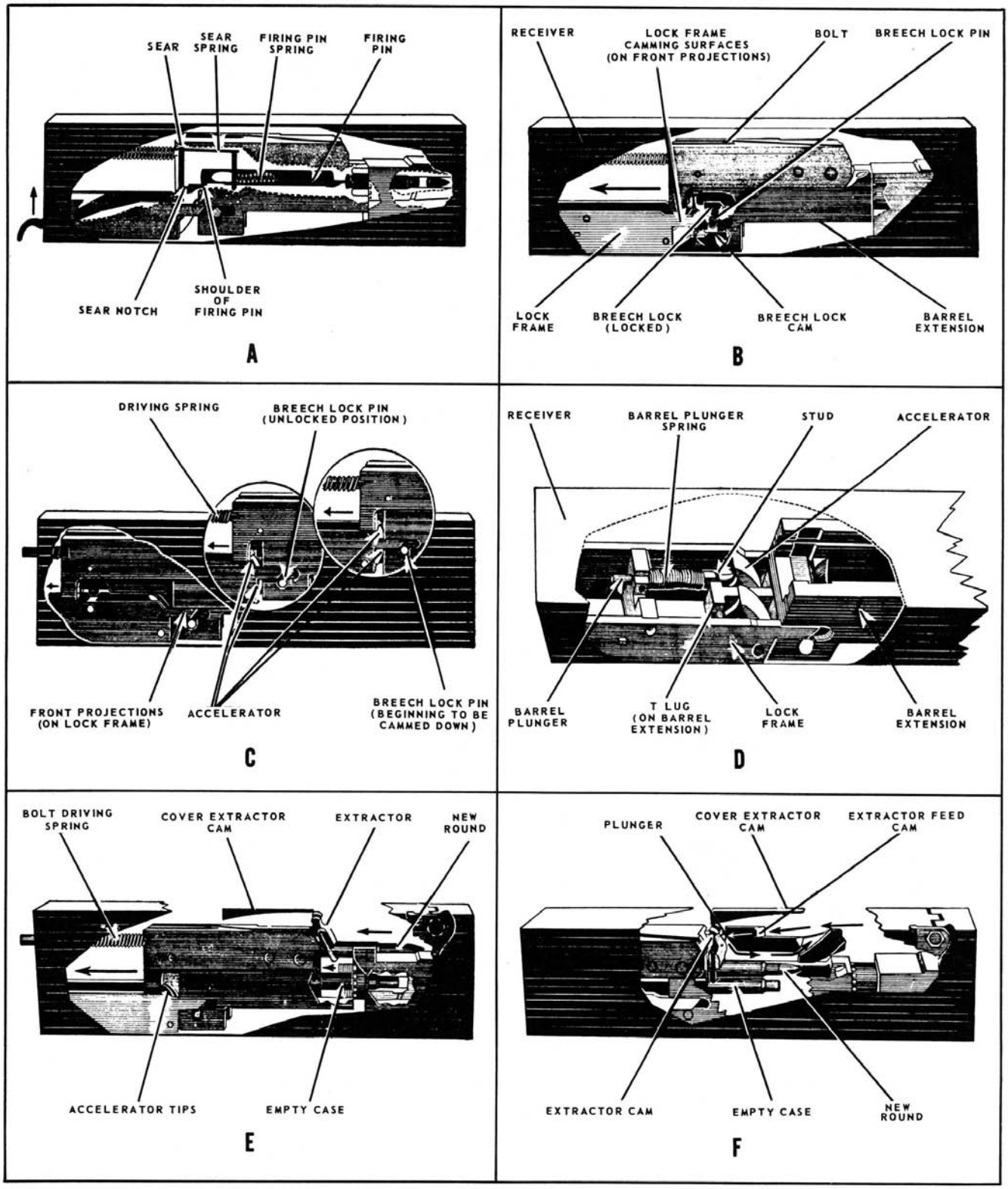
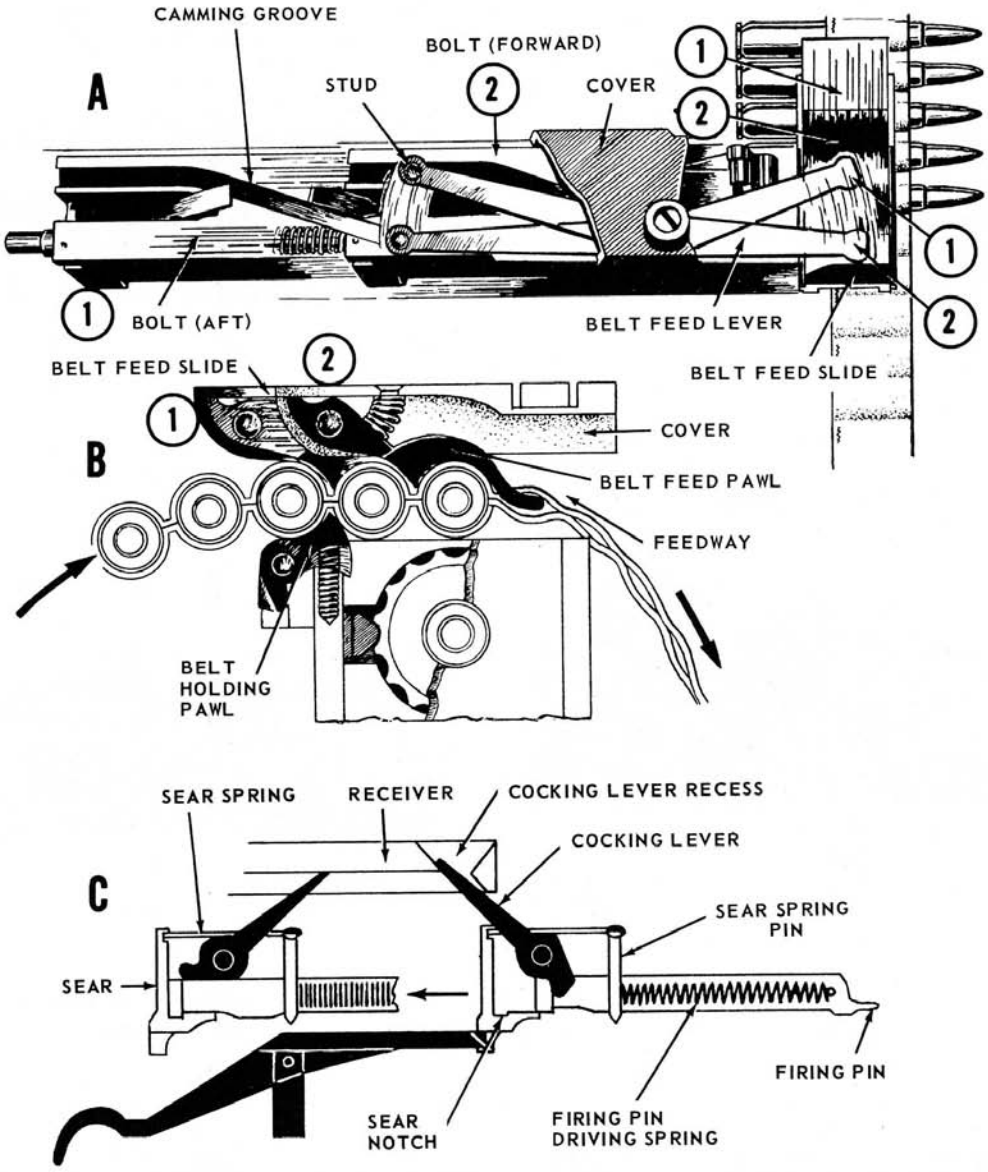


Figure 11-46. — Browning machinegun, caliber .30, M1919A4. Functioning cycle. (NOTE: Some parts are omitted for the sake of clarity.) 84.266

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Figure 11-47. — Browning machinegun, caliber .30 M1919A4. A and B Feeding action. C. Cocking action. (NOTE: Some parts are omitted for the sake of clarity.)

so that the barrel extension and bolt reach the end of counterrecoil movement locked together. The bolt rams the cartridge home. If the gunner is pulling the trigger, the sear releases the firing pin to fire the next round and repeat the cycle. If the trigger is released, the sear holds the firing pin and the cycle comes to an end with the recoiling parts in battery and the firing pin retracted.

The feeding and cocking operations during counterrecoil are as follows:

a. Feeding. (See fig. 11-47A and B.) As the bolt moves forward, the belt feed lever is cammed to push the belt feed slide and pawl to the right (position 2). The pawl moves the belt to the right and positions the next round where the extractor can engage it when the

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bolt has returned to battery. If, because of malfunction, the extractor fails to engage and load the cartridge case, the mechanism will go through the motions in the next cycle- but the belt feed pawl will ride on top of the round that should have been loaded, without moving the belt. Thus this arrangement prevents double loading and consequent jamming.

b. Cocking. (See fig. 11-47C.) In counterrecoil the cocking lever starts in position 2 and winds up in position 1, leaving the firing pin engaged by the sear, ready for the next cycle.

The functioning cycle continues as long as the trigger is pulled and the ammunition belt continues to supply fresh cartridges.

Operation Of The Caliber .30 BMG M1919A4

The basic operations for this weapon are half loading, loading, unloading, and clearing.

To HALF LOAD the BMG M1919A4 with cover either open or closed- insert the belt into the left side of the feedway, and pull it through until the first round is positioned to the right of the belt-holding pawl. Close the cover, if open. Pull the bolt by its handle fully to the rear, and release. This cocks the firing pin and shifts the first round to the centerline of the gun so that the extractor grips it as the bolt slides into battery.

But the round is not yet chambered, and the gun cannot be fired. The cartridge does not go into the chamber until the bolt has been operated a SECOND time, for FULL LOAD. The caliber .30 M1919A4 BMG is unlike all other small-arms weapons we have studied so far in that after the ammunition-carrying device (in this case the belt) is loaded into the weapon- the bolt must be worked manually through TWO operating cycles before it can be fired.

The HALF-LOAD position therefore can be considered as a safe-but-loaded condition for the caliber .30 BMG. Actually, the weapon has no real safety of the type we have found so far on small-arms weapons and machine guns; it is ALWAYS ready to fire when a round is chambered. It is important to remember this when you're operating the gun; it must always be CLEARED if it is not to be fired.

For FULL LOAD, then, you pull the bolt handle back twice after inserting the ammunition belt. The gun can then be fired by pulling the trigger.

To UNLOAD, raise the cover, lift out the belt. pull the bolt to the rear and hold it, and look or feel to make sure there is no ammunition in the gun. Then lower the extractor, release the bolt, position the belt feed lever stud over its groove in the bolt, and lower the cover. Finally, pull the trigger to uncock the firing mechanism.

To CLEAR GUN, raise the cover, remove the belt, pull the bolt to the rear and secure it in its rearward position by engaging the extractor cam plunger in the rear of the extractor feed cam, and inspect gun to see that no ammunition is in the chamber.

Maintenance Inspection and Headspace Adjustment

Complete inspection of the M1919A4 BMG requires, because of the complexity of the weapon, fairly detailed instructions which we haven't space to go into here. Unless your job requires that you become a BMG specialist, don't go any further than field-stripping the weapon and making the other inspections and adjustments covered in this section. For further information on inspection, adjustment, and repair of the weapon, see ARMY FM 23-55 and TM-9-1005-212 (Series).

VISUAL INSPECTION. - Before going into detailed inspection, look the weapon over for damage and for missing parts. See that all rivets, screws, and so forth are in place and secure in the receiver group. Further details to look for are:

1. Check general alignment of sights.
2. Check the back plate to see that it fits snugly in the side plate grooves, and check the condition of the grooves.
3. Lift the cover and retract the bolt handle. See if the firing pin protrudes properly (there is a gage for this but in this preliminary inspection you needn't use it) and if the T-slot is smooth and free of brass and other residues. Look also to see if the recoil plate in the face of the bolt is free of corrosion and carbon.

Functional Inspection

1. Check headspace. No gage is used for this purpose. Retract the bolt about 1 inch, then ease it forward slowly. The moving parts should not bind and they should yield a solid metallic sound when they go into full battery.

The headspace adjustment is correct when. as the bolt closes: .

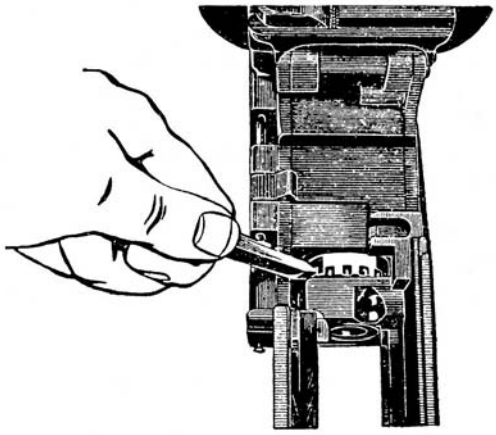
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a. the breechlock rides smoothly up the breechlock cam into its fully locked position, in positive contact with the forward wall of the breechlock recess.

b. the forward end of the bolt is positioned against the rear of the barrel.

2. Pull the bolt back, but do not release. Allow the bolt to move slowly forward, and see if it binds at any point. If it moves freely, repeat with a dummy cartridge. If it binds, determine the exact points at which it binds.

3. Check trigger pull. It should be between 7 and 12 pounds. 4. Check the barrel and barrel extension to be sure they do not bind at any point. 5. Operate the bolt with cover open and closed, and check feeding action. The feed mechanism should move freely in its full travel in both directions.



84.268

Figure 11-48. — Browning machinegun, caliber .30 M1919A4. Adjusting headspace.

HEADSPACE ADJUSTMENT. - The BMG 1919A4 headspace adjustment (distance between the face of the bolt and the rear of the barrel) is made WITHOUT using a gage. Here is the procedure (fig. 11-48):

1. Pull the bolt to the rear approximately 3/4 inch, and disengage the barrel locking spring.

2. Using the proper combination tool, or the nose of a cartridge, in the barrel notches, screw the barrel into the barrel extension until the recoiling parts will not go into battery under pressure of the driving spring when the bolt handle is released.

3. Unscrew the barrel from the barrel extension one notch at a time (checking after each notch) until the barrel and barrel extension will just go fully forward into battery without being forced. (See item No. 1 under FUNCTIONAL INSPECTION above.)

4. Unscrew the barrel one additional notch, and engage the barrel locking spring.

5. After the correct headspace has been determined, mark the notch in the barrel in which the barrel locking spring is engaged. This will simplify making the heads pace adjustment if the gun is disassembled and reassembled in the future. The adjustment is important. Tight (insufficient) headspace will cause poor timing of locking and unlocking and consequent damage to the barrel extension, bolt, or breechlock. Excessive headspace leaves too much play between bolt and barrel, and may result in ruptured cartridge cases and possible injury to the gunner.

BROWNING MACHINE GUN, CALIBER .50, M2

The caliber .50 BMG now used by the Navy and the Army is the M2, which may be equipped with either of two different kinds of barrel - air cooled (for aircraft use), or heavy barrel (HB). Although it is not used as widely in the Navy as it once was. you may still come across the HB . type on certain landing craft. (Caliber .50 MG's are still important as aircraft armament, but you're not likely to have to deal with such installations. And we 'shall not take up here the air-cooled caliber .50 BMG.)

The mechanisms of the weapon and the principles of operation are very much like those of the caliber .30 BMG that we studied earlier in this chapter. Rather than repeat the same material, we'll concentrate on the differences. without going into elaborate detail. If you need further details, see the Army's FM 23-65 and TM-9-1005-213 (Series).

The main characteristics of the caliber .50 BMG M2 are as follows:

Weight of gun with barrel (lb) 84
Length overall (in.) 65-1/8
Length of barrel only (in.) 45
Rifling
  Uniform R.H. twist. . . . . 1 turn in 15 in.
  Lands and grooves .00 0. 8 ea
Rate of fire (cyclic, rd/min). . . . . 500 to 600
Muzzle velocity (approximate, fps) 2,900
Range (approximate, yd) 7,400

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Construction Of The
BMG Caliber .50 HB. M2

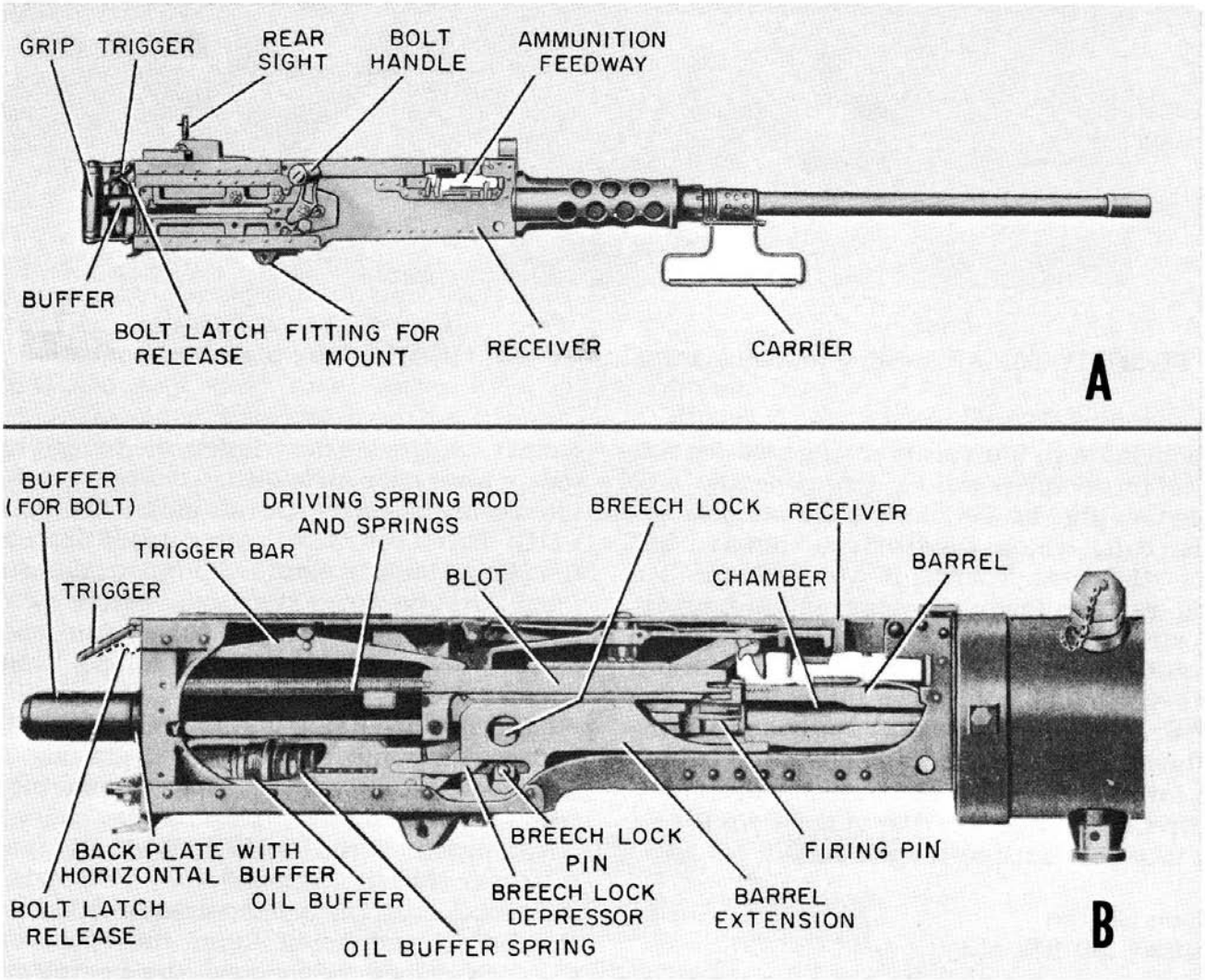
Figure 11-49 shows the caliber .50 BMG exterior and cutaway views. The cutaway view shows (dotted lines) the bolt latch release. but omits the bolt latch mechanism in the receiver. The construction in general is much like that of the caliber .30 BMG. The breechlock camming arrangements are different. as are the trigger linkage. location of the bolt handle, and other details. but the functioning is much the same. However, the ammunition feed mechanism can be arranged to feed from either side.

Note the two buffers. The upper one takes the recoil shock of the bolt. and the lower (oil) buffer takes the recoil shock of the barrel and barrel extension. There is no look frame in the caliber .50 BMG.

Operating The BMG
Caliber .50 HB, M2

You load the belt, half load, load, clear, and unload the BMG caliber .50 much as you do the caliber .30. But there are some differences in the firing controls and how you use them, as can be seen in figure 11-50.

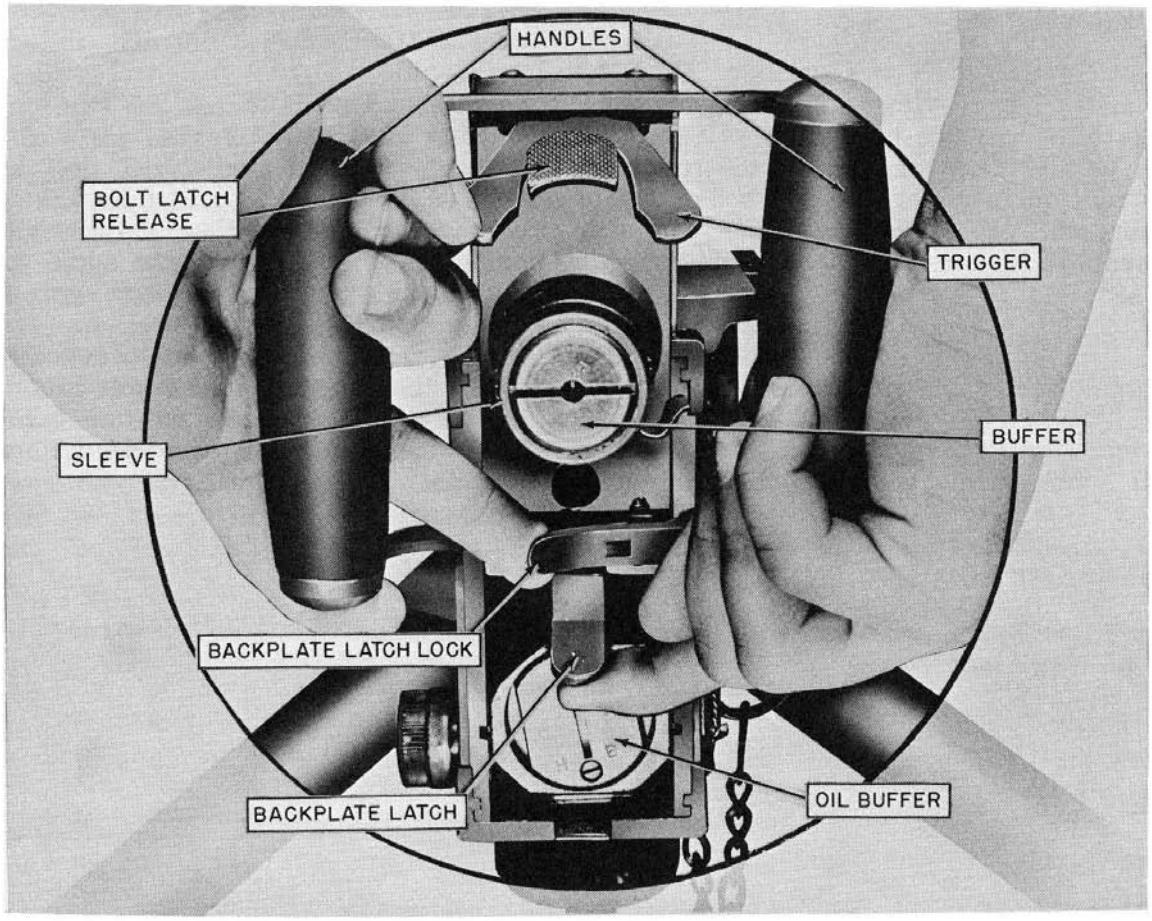
To fire the loaded and cocked gun, you depress the trigger. If the bolt latch is released, the gun will continue to fire automatically so long as the ammunition holds out and the trigger is down.



84.112

Figure 11-49. — Browning machinegun, caliber .50 HB, M2. A. Exterior. B. Cutaway view.

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84.113

Figure 11-50. — Browning machinegun, caliber .50 HB, M2. Back plate and controls.

The bolt latch in the receiver engages the bolt when it is in recoil position. Pressing the bolt latch release (fig. 11-50) causes the latch to release the bolt, which then drives forward and chambers the next round. If you release the bolt latch release lever and depress the trigger, the gun will fire once, and stop with the bolt in recoil position again. For the gun to fire in full automatic you must hold down the bolt latch release lever. It can be locked down by depressing it, then twisting the knurled sleeve on the buffer, until the lever stays down when released.

NOTE: Caliber .50 BMG's other than HB do not have this bolt latch arrangement.

Functioning Of The BMG Caliber .50 HB, M2

You can follow most of the functioning cycle in figure 11-49B. Assume the chamber is loaded, the gun cocked, and the bolt latch released. The gunner depresses the trigger, the firing pin strikes the primer, the propelling charge goes off, and the recoiling parts (same as in the caliber .30 BMG) start rearward. After 1-1/8 inch of travel the breechlock is cammed down to release the bolt from the barrel extension, which strikes the accelerator, is brought to a stop by the oil buffer, and is locked in recoil position by the accelerator.

(NOTE: In HB guns there is no oil in the buffer and some of the buffer parts are omitted. Air-cooled caliber .50 BMG's use oil buffers with oil in them.)

Meanwhile, the bolt, kicked all the way to the rear by the accelerator, rebounds against the upper buffer, and counterrecoils, unlocking the barrel extension from the receiver. When the breechlock reengages, the barrel extension locks to the bolt and both move forward together into battery. The cycle repeats when the firing pin sets off the next cartridge.

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The ammunition feeding, extraction, and ejection operations are much the same as in the caliber .30 BMG, though some of the mechanisms are somewhat different.

Ammunition Feed Arrangements Of The BMG Caliber .50 HB, M2

The main difference in the ammunition feed mechanism of the caliber .50 BMG from that of the caliber .30 is that the caliber .50 can be set up for feeding from either direction. Figure 11-51 shows both setups. Note that the caliber .50 BMG's bolt has in its top surface two camming grooves rather than one. In the place where they cross is a switch, something like a railroad switch, which must be set to select the proper camming groove for the direction of feed to be used. The other details of the mechanism setup for feeding in either direction are clearly shown in the figure.

INSPECTION AND GAGING OF BMG CALIBER .50 HB, M2

INSPECTION. Check the general appearance of the weapon. Pull the bolt to the rear. release. and check for smooth operation. Check the cover latch; be sure the spring has enough tension to keep the cover securely latched. Raise the cover and check the functioning of the cover detent pawl. Move the belt feed lever from side to side, and make sure the belt feed mechanism moves in its full travel in both directions. When you inspect the bolt, check the extractor and ejector, and look for corrosion. Check the back plate latch and lock.

After gaging, test the action of the gun mechanism by feeding several dummy cartridges assembled into a belt (with new belt links) through the gun, operating the gun mechanism by hand.

GAGING. In the caliber .50 Browning machinegun, as in the caliber .30, headspace is measured from the face of the bolt to the base of the chambered cartridge. Bad headspace adjustment in the BMG caliber .50 causes the same symptoms and malfunctions as in the caliber .30. But the procedure for gaging and adjustment of headspace is different in the bigger gun. chiefly in the use of a HEADSPACE AND TIMING GAGE (Army No. A196228). Headspace must be checked before firing, and adjusted, if necessary. Here is the procedure:

1. Retract fully, then release the recoiling parts. This cocks the firing pin.
2. Retract the bolt slightly (not more than 1/16 in.) to relieve the thrust of the driving spring between the bolt and the after end of the barrel. The forward face of the breech lock and the bolt should be in close contact, as in firing.
3. Pull up the extractor. Insert the gage in the T-slot between the face of the bolt and the after end of the barrel (fig. 11-52). If headspace is too tight, the gage won't go in. If headspace is correct or too great, the gage will slip in easily.
4. If the gage doesn't go in on the first try, unscrew the barrel ONE notch, and try the gage again. Repeat, if necessary, until it does go in. The adjustment is then correct.
5. If the gage doesn't go in the first time, screw the barrel IN one notch, and try again. If the gage no longer goes in, restore the first position of the barrel; this is the proper adjustment. If the gage still slips in, screw the barrel in another notch, and repeat. The proper adjustment is the one in which the barrel is screwed in as far as it can be without making the headspace too tight.

THE MACHINEGUN, 7.62-MM. M60

The 7.62-mm machinegun M60 is shown in figure 11-53. Major groups and assemblies are shown and indexed in figure 11-54.

Figure 11-53 shows the gun mounted on a bi-pod. It may also be mounted on tripod mount M122 (fig. 11-55). The method of installing the gun on the tripod mount is shown in figure 11-56.

Loading And Firing

Ammunition for the M60 machinegun is fired from a metallic, split-link belt containing 100 rounds. At one end of the link belt there is a double link. It is this end, the one with the double link, that is started into the gun.

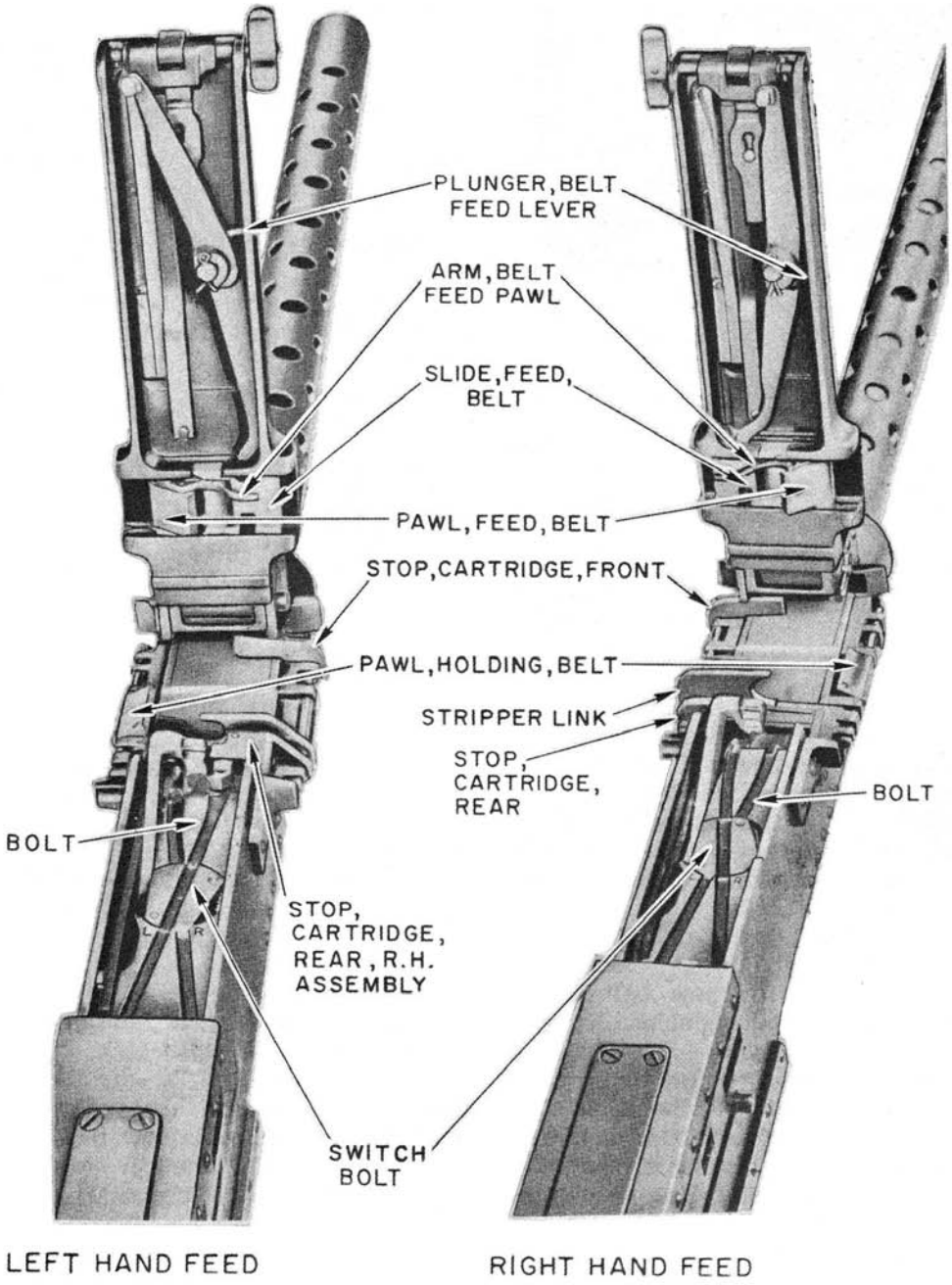
Figure 11-57 shows the steps in loading and firing the M60 machinegun.

CASUALTIES

Runaway Gun

A broken or worn sear may cause the casualty "runaway gun," a situation in which the

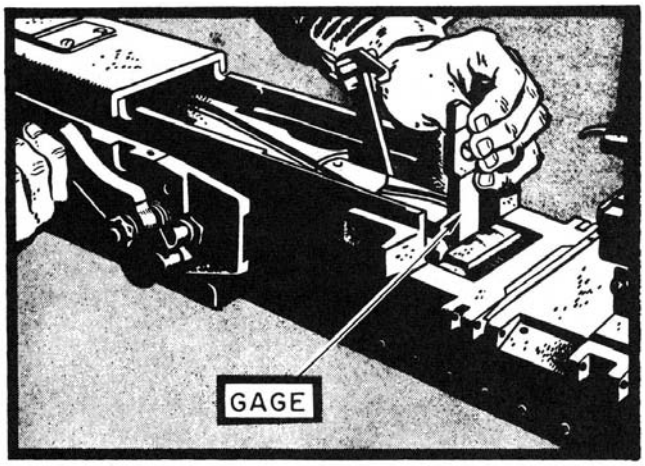
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84.114

Figure 11-51. — Browning machinegun, caliber .50 HB, M2. Feeding mechanism parts set up for left-hand and right-hand feeding.

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84.115
Figure 11-52. — Browning machinegun, caliber .50 HB, M2. Headspace gaging.

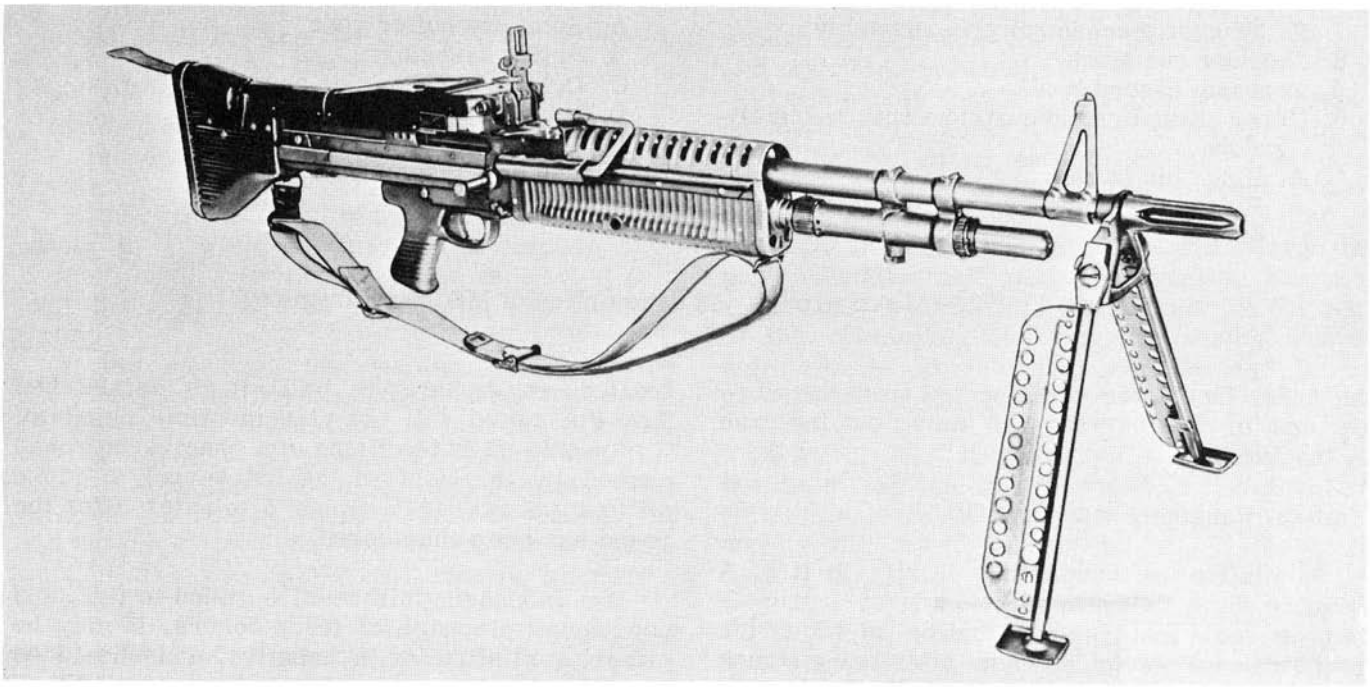
gun continues to fire after the trigger is released. When this casualty occurs, you hold the fire on the target until feeding stops or the ammunition is expended. You then notify maintenance personnel at once.

Ruptured Cartridge Case

A cartridge case may rupture so that the forward portion remains in the chamber and only the rear portion is extracted. When a rupture of this type occurs, a new round will be fed into the chamber, and the following may occur:

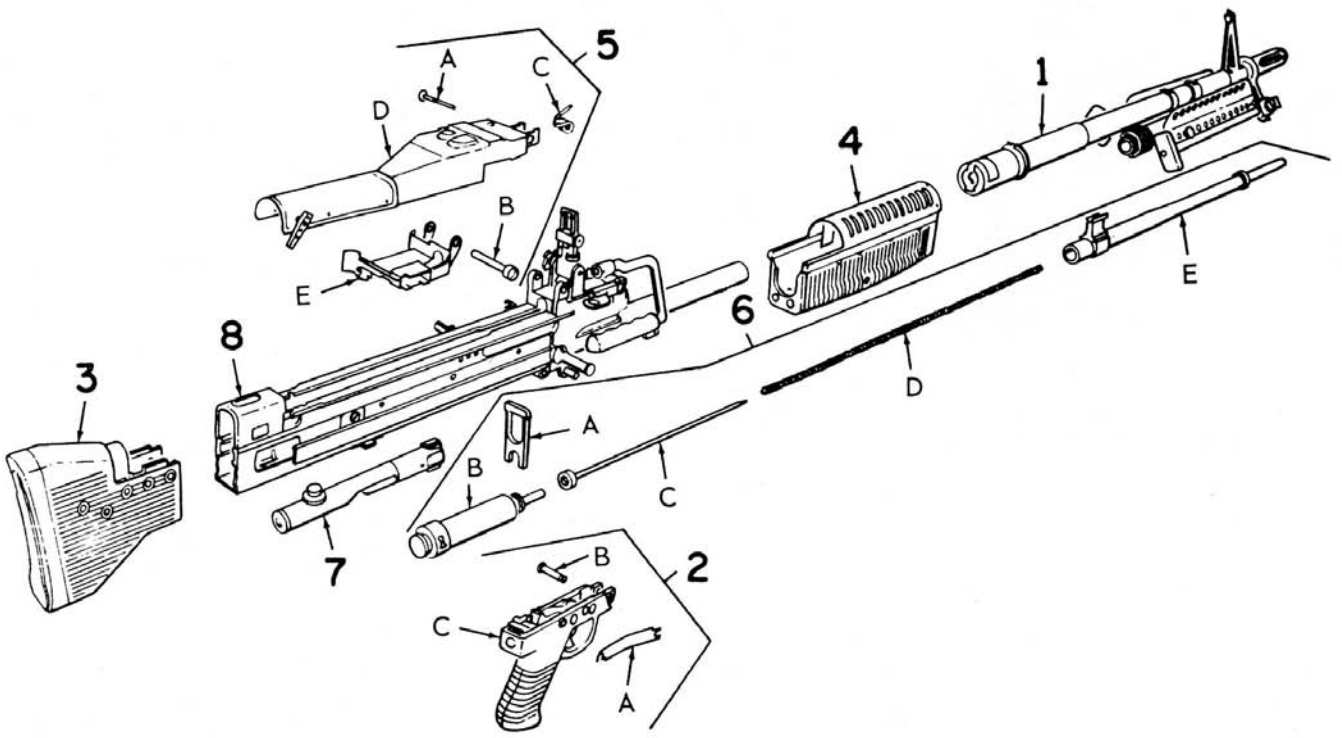
1. Incomplete chambering, because the live round cannot be seated fully. It may be compressed enough to cause detonation, with possible damage to the gun, injury to personnel, or both.
2. A round driven into the ruptured case without detonation. You remove this round by the following steps: (a) Retract bolt and move safety to S position. (b) Insert cleaning rod in muzzle end of barrel, set against nose of cartridge, and tap rod gently to eject cartridge from chamber.

To remove a ruptured cartridge case from the breech, you use the ruptured cartridge case extractor shown in figure 11-58. You insert the ruptured cartridge case extractor through



45.578
Figure 11-53. — 7.62-mm machinegun M60.

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1. Barrel assembly with bipod assembly
2. Trigger mechanism grip group
   - A. Leaf spring
   - B. Retaining pin
   - C. Trigger mechanism grip assembly
3. Shoulder gun stock
4. Forearm assembly
5. Cover assembly and cartridge tray assembly groups
   - A. Hinge pin latch
   - B. Hinge cover pin
   - C. Spring
   - D. Cover assembly
   - E. Cartridge tray assembly
6. Buffer assembly and operating rod assembly groups
   - A. Retaining buffer yoke
   - B. Buffer assembly
   - C. Driving spring guide assembly
   - D. Spring
   - E. Operating rod assembly
7. Breech bolt assembly
8. Receiver group

29.373

Figure 11-54. — Major groups and assemblies of M60 machineguns.

the case, insert the cleaning rod from the muzzle end of the barrel, and drive out the case by tapping the rod lightly.

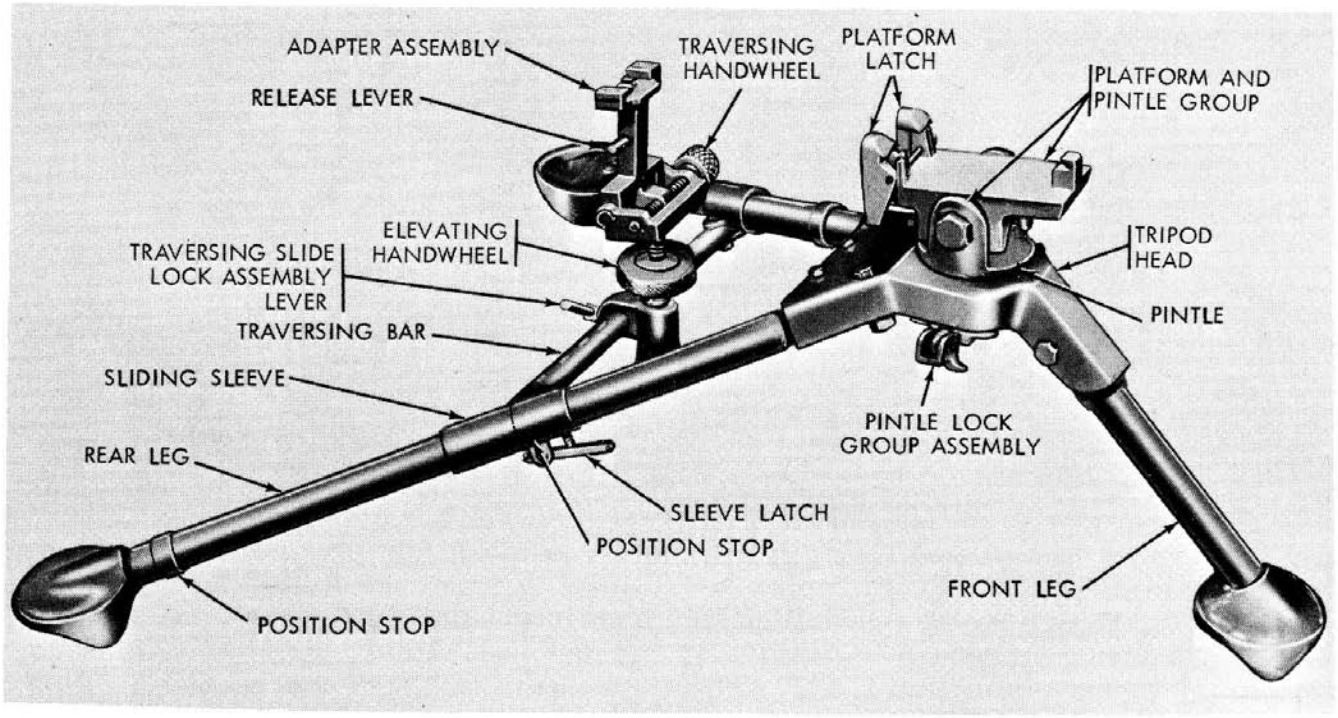
Misfire, Hangfire, and Cook-Off

A misfire is a complete failure to fire. A hangfire is a delay in functioning of a propelling charge - that is, a situation in which the primer in the cartridge case, after being struck by the firing pin, does not detonate the propelling charge immediately, but does detonate it after an interval. NOTE: A misfire must be treated as a hangfire until it is established that the round will not at some time detonate.

A cook-off is the firing of a chambered round caused by the heat of the hot barrel. A cook-off may occur as long as 5 minutes after the round has been chambered.

If a stoppage (failure of a round to fire, and consequent stoppage of feed) occurs, it may be either a misfire or a hangfire, and should be treated as a hangfire. Wait 5 seconds, and then pull the cocking handle all the way back, ensuring that it stays back.

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Figure 11-55. — Machinegun tripod mount M122.

If this procedure ejects the chambered round, relay the gun on the target and attempt to fire. If the weapon does not fire, it must be cleared by qualified personnel and the ammunition inspected to determine the cause of the stoppage.

If pulling back the cocking handle fails to eject the chambered round, move the safety to S (safe) position, remove ammunition and links, and inspect the receiver, chamber, and extractor.

If there is a round in the chamber, move the safety to F (fire) position and attempt to fire. If the round fires and the case is ejected reload the gun, relay on the target, and continue firing.

If the round in the chamber does not fire and the gun is hot enough to cause a cook-off (if 200 rounds were fired within the previous two minutes, it may be hot enough), wait five minutes with the bolt in forward position. Then remove the round, reload, relay on the target, and attempt to fire. Disregard the 5-minute wait if the gun is not hot enough to cause a cook-off.

Double Feed

"Double feed" is a situation in which a live round is fed into a chambered spent case or chambered live round.

When the gun fails to extract a spent case, the bolt automatically recoils, picks up the next (live) round, and feeds it into the chambered case. The force may compress the live round enough to detonate it, with damage to the gun and injury to personnel.

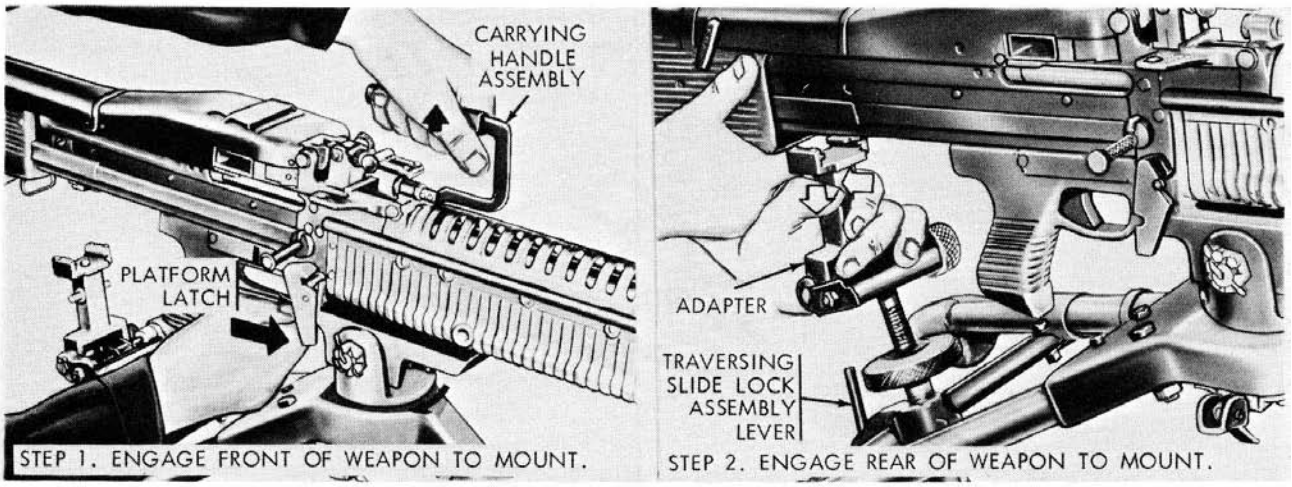
Double feed into a live round will not occur automatically because, when a round fails to fire, the bolt does not recoil, but remains in forward, closed position. The correct procedure here is to proceed as described for a hang- fire. If, instead of doing this, you charge the gun manually and pull the trigger, the next round will be fed into the primer in the base of the chambered live round, causing one or both rounds to detonate, with damage to the gun and injury to personnel.

WARNING: If there is belted ammunition on the feed tray and a live round in the chamber, NEVER retract the bolt and allow it to go forward.

FIELD STRIPPING

The steps in field stripping the M60 machinegun are shown in figures 11-59 through 11-65. White arrows shown on illustrations indicate disassembly, black arrows indicate assembly.

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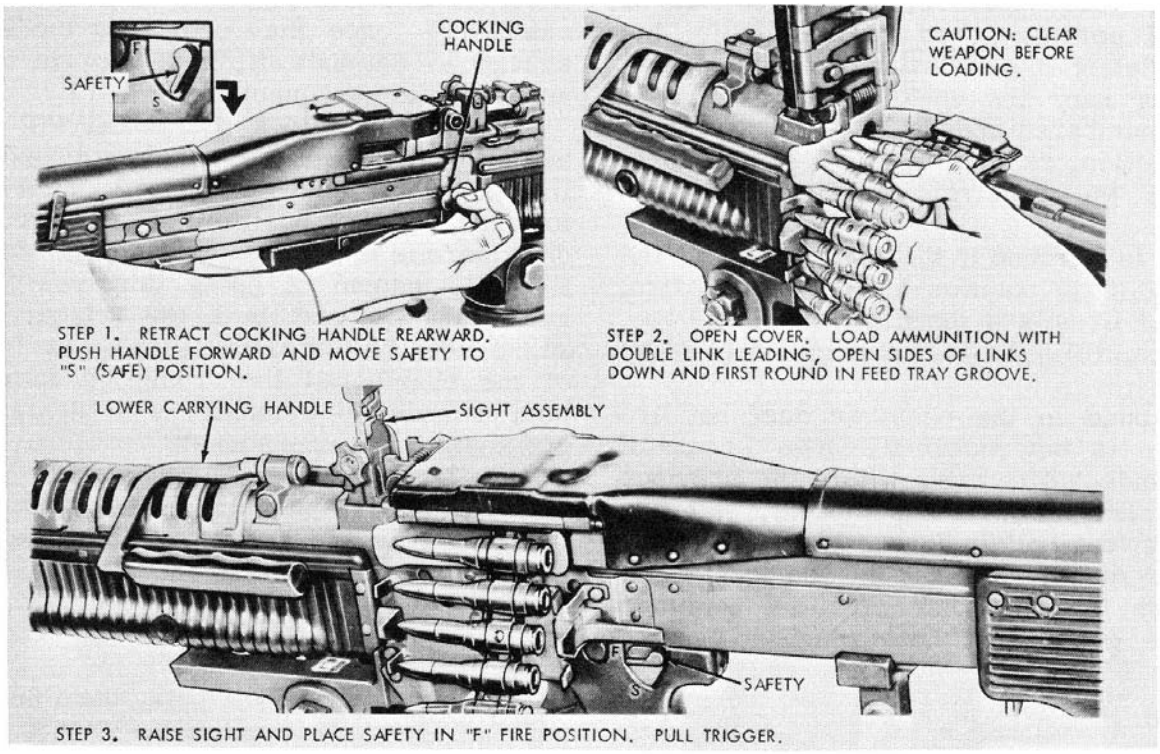


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Figure 11-56. — Installing M60 machinegun on tripod mount.

SUBMACHINEGUNS

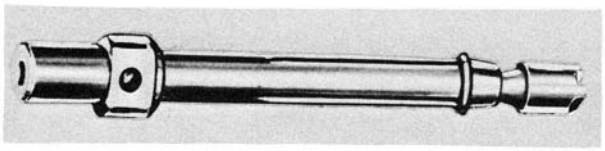
These weapons were designed to provide a large volume of fire against personnel at short range. Development work since 1942 has consisted largely of simplifying the mechanism, reducing the maintenance requirements, and perfecting a new type of construction that is cheaper



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Figure 11-57. — Steps in loading and firing the M60 machinegun.

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Figure 11-58. — Ruptured cartridge case extractor.

to manufacture. All of this was done, of course, without any adverse effect on the weapon's reliability.

Because of the low power of the pistol type cartridge used, complicated operating mechanisms are not required. All submachineguns now are of the simple blowback (inertia) type.

The submachineguns we will examine here are the .45 caliber Ml (fig. 11-66A) and M3A1 (fig. 11-66B), Designed as shoulder weapons, they can also be fired from the hip, if properly braced against it. The Ml (tommygun) has a maximum effective range of 150 yards, can be fired either in single or automatic fire, and has a rate of fire of 700 to 800 rounds per minute. The M3A1 has a slightly longer maximum effective range (200 yards), and is fired in automatic only, with a rate of fire about half that of the M1.

Operating The M1
Submachinegun

LOADING. - To load the Ml submachinegun, first retract the bolt handle (fig. 11-67) to cock the weapon. Turn the safety (fig. 11-66) to SAFE. Push the loaded magazine up into the groove of the trigger frame until the magazine catch snaps into position.

The weapon can be fired either in semiautomatic or in automatic.

SINGLE FIRE (SEMIAUTOMATIC). - Turn the rocker pivot aft to SINGLE and the safety to FIRE. Squeeze the trigger to fire each round, and release the trigger quickly.

FULL AUTOMATIC FIRE. - Turn the rocker pivot forward to FULL AUTO and the safety to FIRE, Squeeze the trigger to fire a burst. The gun will continue to fire automatically as long as the trigger is held and there is ammunition in the magazine.

UNLOADING. - When the magazine has been emptied, the bolt is automatically held in open position. To close the bolt on an empty chamber, rotate the magazine catch counterclockwise to remove the magazine, then grasp the bolt handle in retracted position, and squeeze the trigger. Let the bolt go slowly forward on the empty chamber.

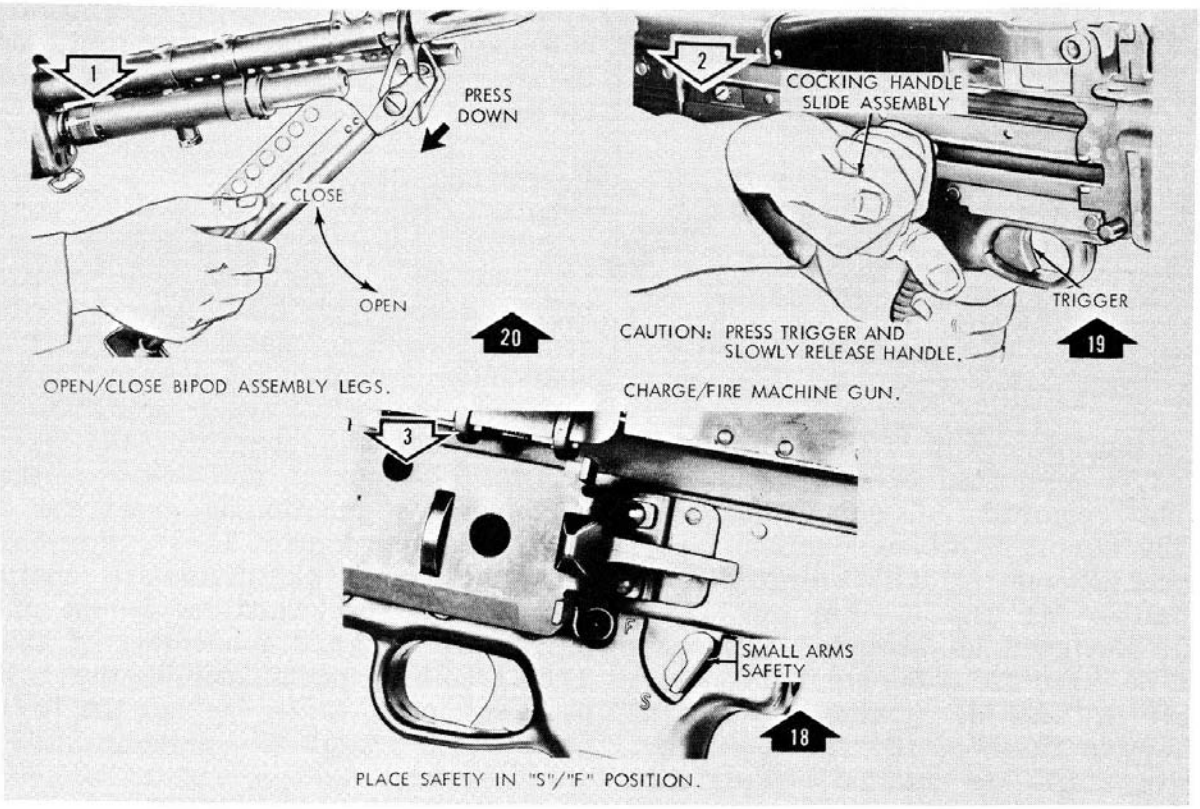
Functioning Of M1
Submachineguns

Like the 20-mm AA gun, which is also blowback-operated, the M1 and M3 submachine-guns fire from an open bolt - that is, the trigger mechanism releases the bolt which, as it moves forward, strips a round from the magazine, rams it into the chamber, and fires it. You can follow most of the details of the M1 submachinegun's functioning from the disassembled view of figure 11-67. For the sake of convenience, we can divide its functioning into two phases - backward movement of recoiling parts, and forward movement of those parts. The recoiling parts include the bolt and the parts attached to it, but not the barrel or any parts of the trigger mechanism.

BACKWARD MOVEMENT. - As the cartridge fires, the pressure of the powder gases forces the bolt to the rear against the recoil spring. The extractor holds the empty case against the face of the bolt. After the bolt has traveled to the' rear about 2 inches, the ejector throws the case through the ejector opening. The bolt still has about 1-3/4 inch to go aft before the back of the bolt contacts the buffer. During rearward movement, the bolt compresses the recoil spring and the buffer absorbs the remaining shock. On the bolt underside are two sear notches. If the bolt strikes the buffer, the rear sear notch will pass over the sear and the sear will engage the front notch. If the bolt fails to strike the buffer, the sear will engage the rear notch.

FORWARD MOVEMENT. - When the trigger is squeezed, the sear released the bolt, which is forced forward by the recoil spring. After moving about 1 inch, the front of the bolt contacts the topmost cartridge in the magazine and pushes it forward and along the bullet ramp in the receiver into the chamber. When the cartridge is seated in the chamber, the extractor engages the rim of the cartridge. Just before the bolt reaches its forwardmost position, the lowest point of the hammer on the underside of the bolt strikes the receiver, much as in the 20-mm AA gun, causing the hammer to pivot

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Figure 11-59. — Field stripping the M60 machinegun.

around the hammer pin and strike the head of the firing pin with its upper end. This fires the cartridge.

Disassembly

Usually, disassembly of the Ml submachinegun need go no further than the steps outlined here.

First, place the rocker pivot on FULL AUTOMATIC and the safety on FIRE. Depress the frame latch and slide the frame group from the barrel and receiver group.

Press inward on the buffer pilot and lift out the buffer. Let the buffer pilot out slowly. Remove the buffer pilot and recoil spring.

Next, with the receiver upside down, slide the bolt aft and tip the rear end up until the bolt handle rests in the semicircular cut on the right hand side of the receiver. Press the bottom of the hammer rearward to disengage the bolt handle, and remove the handle.

Remove the bolt by sliding it rearward and lifting it out of the receiver.

Drifting the hammer pin out of. the bolt will release the hammer, the firing pin, and the firing pin spring. To reassemble the weapon, proceed in the reverse order of disassembly.

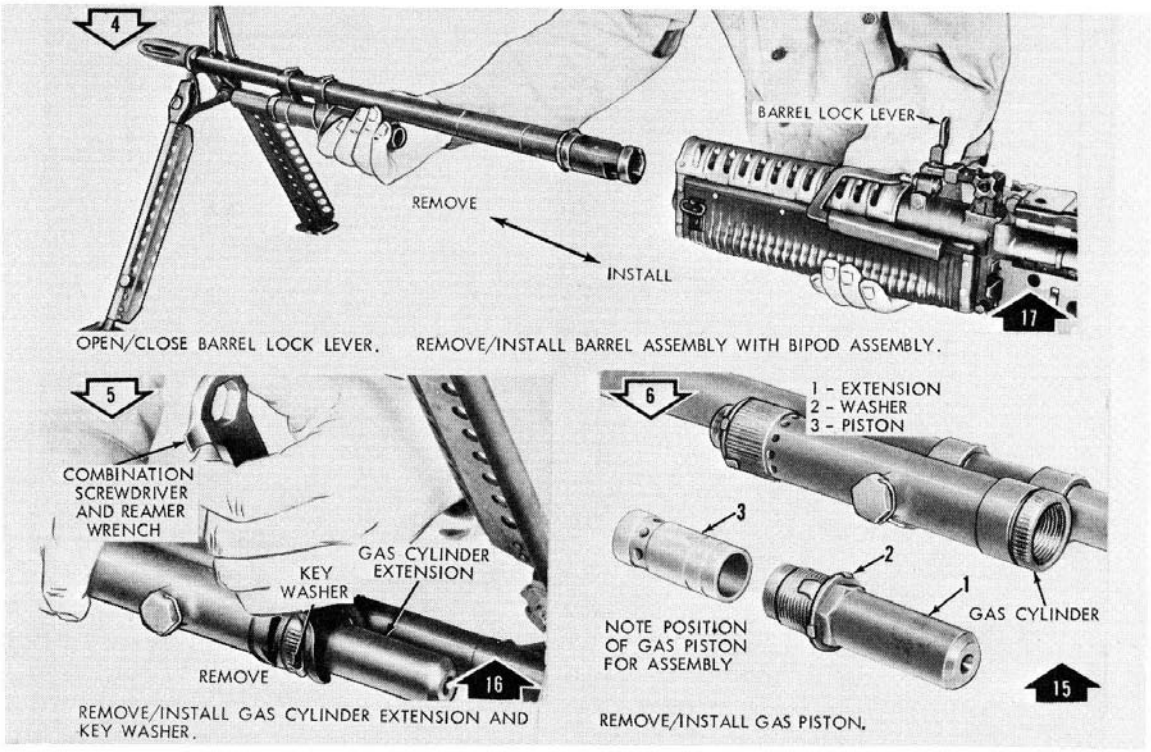
SUBMACHINEGUN
CALIBER .45 M3A1

Though crude in appearance, the M3A1 (fig. 11-66B) is compact, rugged, low in cost, and simple to manufacture. The weapon is entirely metal, with a telescoping stock made of a single piece of steel rod. The stock serves double duty as it also is a cleaning rod. The weapon has no provision for semiautomatic fire, but the very low cycling rate permits a gunner to fire single shots after a little practice.

An unusual feature of this gun is the hinged cover over the ejection port. This cover must be open to fire since it acts as the safety. When the cover is down, it locks the bolt in either its open or closed position.

The M3A1 cannot be cocked unless the cover is open because cocking is done by placing a

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Figure 11-60. — Field stripping the M60 machinegun — Continued.

finger in the cocking hole and drawing the bolt aft until it is caught by the sear.

Operation

The weapon is loaded by drawing the bolt back to the cocked position, closing the cover to lock the bolt, and then inserting the magazine. To fire, lift the cover to unlock the bolt, and squeeze the trigger.

When the trigger is pulled, the sear is moved downward. This releases the bolt which is driven forward by the two compressed driving springs. As the bolt goes forward it picks up a round from the magazine and pushes it into the chamber. When the round is fully seated, its base sticks out slightly from the chamber. As the bolt continues forward, the round is completely enclosed by the round recess of the bolt and the chamber, and the fixed firing pin strikes the primer.

When the round is fired, the chamber pressure will reach its maximum almost immediately but because of the inertia of the heavy bolt and the resistance of the driving springs, extraction will not be completed until the pressure has declined. The bolt moves to the rear, bringing the empty cartridge with it. As the empty cartridge strikes the ejector it is thrown through the open port in the top of the receiver.

The bolt continues to the rear, compressing the driving springs. "Then, if the sear is still held depressed, the bolt moves forward again to repeat the cycle. If the trigger has been released, the sear will engage the bolt and hold it in a cocked position.

CAUTION: Because of its simplicity, the M3A1 lacks several safety features of the other small arms. The weapon is safe only when the magazine is out and the bolt is forward. Do not load the weapon until ready to use it, and don't unlock it until it is raised to be fired.

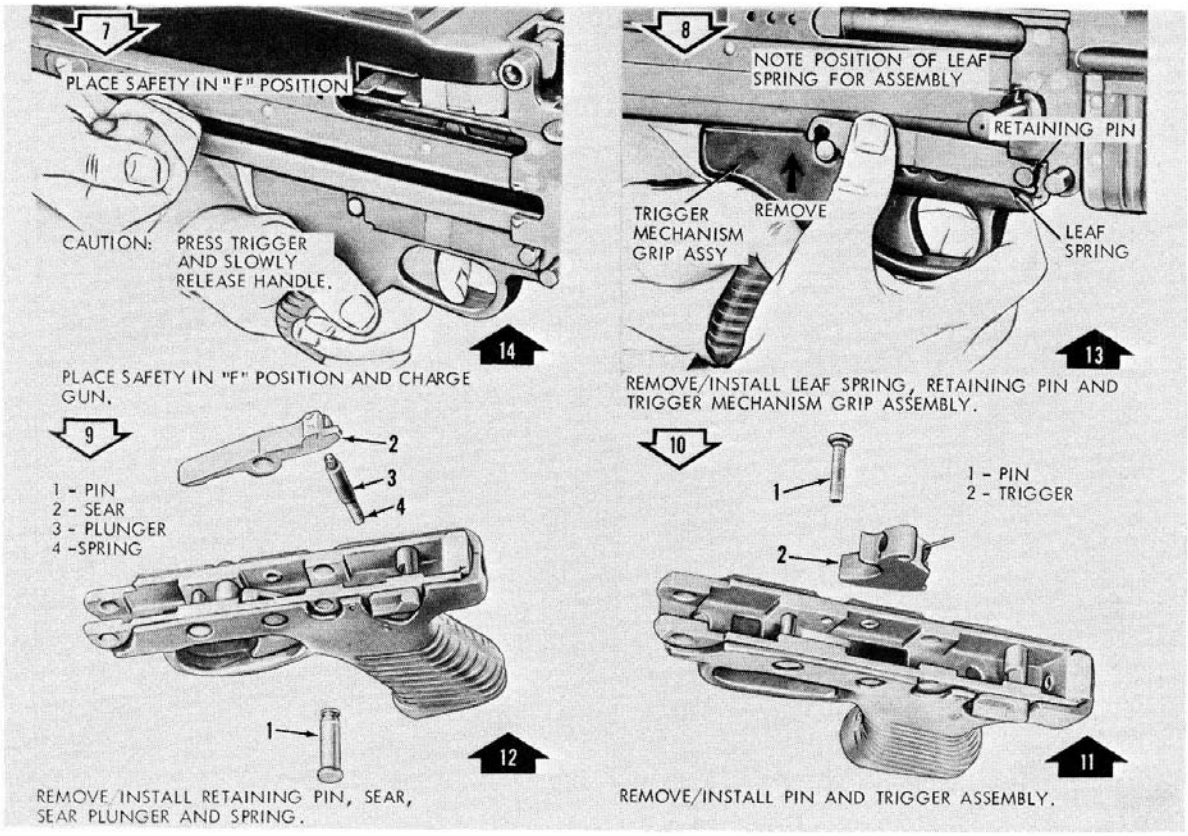
Disassembly

To disassemble the M3A1, first press the magazine catch (fig. 11-68), and slide out the magazine. Then squeeze the trigger and allow the bolt to go forward on an empty chamber.

Press in on the stock catch and remove the stock by pulling it directly to the rear.

To remove the trigger guard, place one side of the shoulder rest of the stock against the

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Figure 11-61. — Field stripping the M60 machinegun — Continued.

housing assembly and pry out the rear end of the trigger guard. Unhook the trigger guard by rotating it toward the front of the weapon.

To remove the housing assembly, pull down on its after end slightly and pull it to the rear. Now the magazine catch and spring can be removed.

Remove the barrel by lifting the ratchet, and unscrewing the barrel collar counterclockwise from the front.

The bolt can now be taken out through the front of the receiver. Press out the sear pin and withdraw the trigger pin from the assembly. Take the trigger assembly out the opening in front of the sear. No further disassembly is permitted.

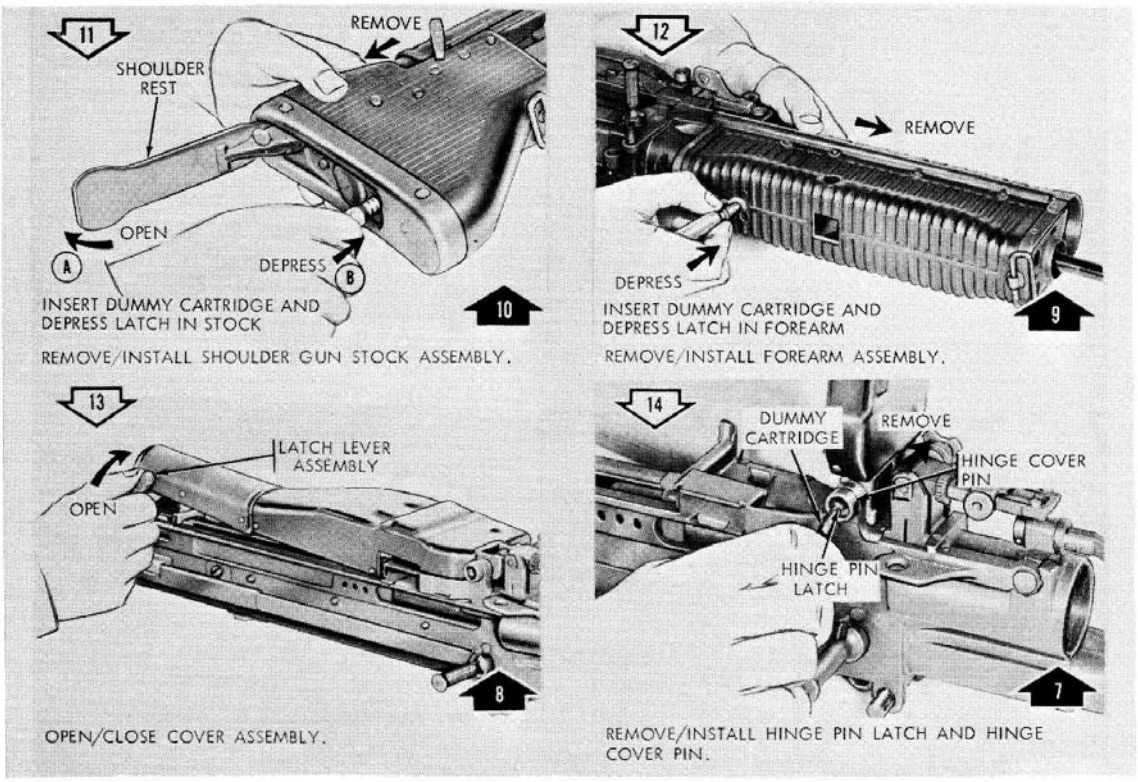
Assembly

To assemble the weapon, start by placing the trigger assembly in the receiver. Insert the trigger pin far enough to hold the assembly in place. Manipulate the sear into position by pressing the trigger while pushing upward on the sear. Insert the sear pin, then press both ends of the trigger pin home. Place the bolt group in the receiver with the retaining plate to the rear, and the grooved side of the bolt down. Replace the barrel, screwing the collar down (but not too tight). Replace the magazine catch. With the receiver upside down, insert the ejector, and fit the forward end of the housing into its slot in the magazine guide. Drop the rear end of the housing, making sure it is properly seated. Put the forward end of the trigger guard into its slot in the housing. Press the rear end of the trigger guard until it snaps into its slot in the pistol grip.

BROWNING AUTOMATIC RIFLE M1918A2

The automatic rifle differs from the other rifles we have taken up in this chapter in that it is not fired as often from the hand or shoulder as it is from a bypod. In combat ashore, in fact, it is employed as a light machinegun more than as a rifle.

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Figure 11-62. — Field stripping the M60 machinegun — Continued.

The Browning automatic rifle has one standard model the M1918A2 (fig. 11-69.) It is a caliber .30, gas-operated, magazine-fed, air-cooled weapon, capable of automatic fire only, though you can fire it single shot if you have a quick expert trigger finger. The rate of fire can be varied between fast (550 rounds per minute) and slow (350 rounds per minute) by a selector. Its box-type magazine contains 20 rounds of the same type ammunition as that used in the M1 rifle.

Since the BAR is a gas-operated weapon, its operating cycle bears a certain resemblance to that of the M1 semiautomatic rifle. However, the two weapons have quite different designs and the BAR requires separate study. The remaining portion of this chapter on small arms will cover the BAR main assemblies, how they function, and the overall operation and maintenance of the rifle.

General Characteristics of the BAR

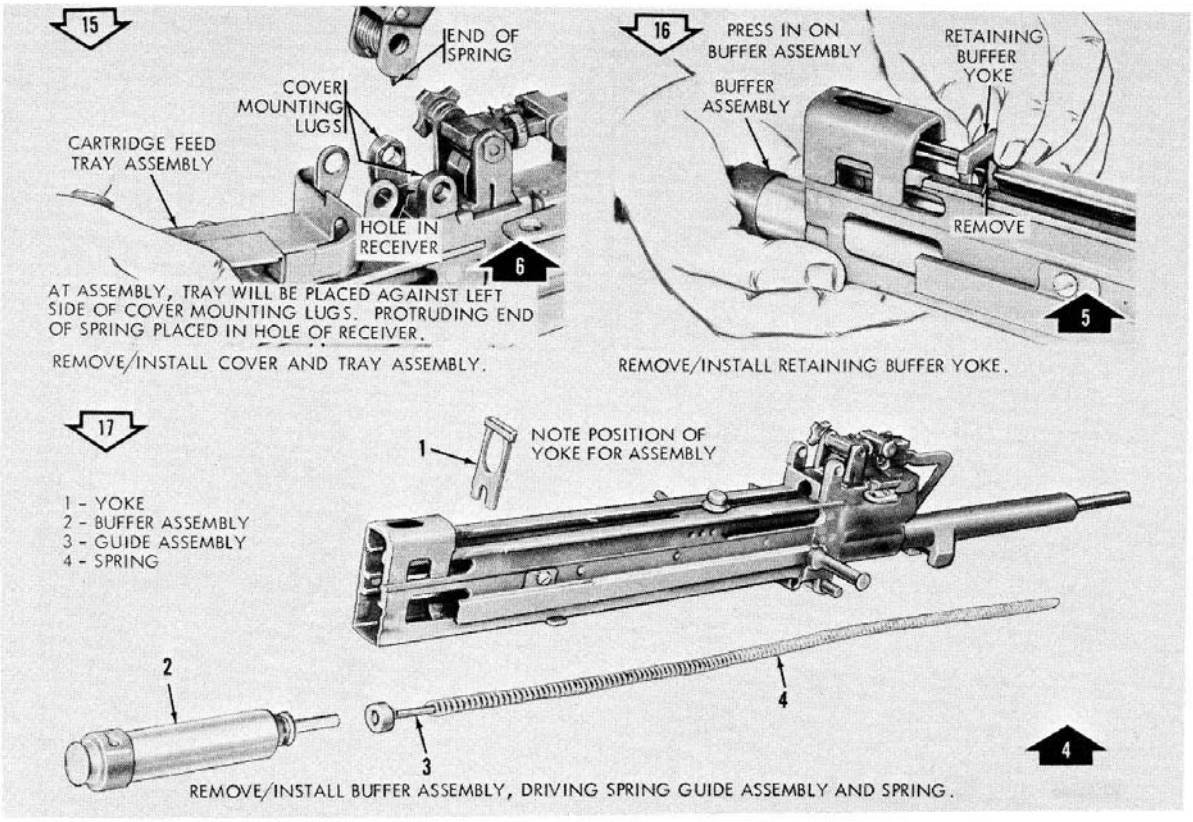
Length (in.)	47.8
Weight, without bipod and magazine (lb)	16.5
Length of barrel (in.)	24.07
Maximum range (yd)	3,000
Maximum effective range (yd)	500
Rifling	1 turn (RH) in 10 in.
Trigger pull (lb)	6 to 10
Rate of fire (rd/min)	
Normal cyclic rate	550
Slow cyclic rate	350

How to Load and Fire the BAR

LOADING THE BAR MAGAZINE. - Hold the magazine in the left hand, top up. Insert the cartridges singly in the top of the magazine, with the cartridges pointing toward the short side of the magazine. With the thumb of your right hand press each cartridge downward until it is held firmly by the lips at the top of the magazine. The magazine holds 20 rounds.

LOADING THE MAGAZINE INTO THE BAR. - Press the magazine release and withdraw the empty magazine. Hold a loaded magazine with its base in the palm of your right hand; cartridges point to the front. Insert the magazine between the magazine guides in front of the

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Figure 11-63. — Field stripping the M60 machinegun — Continued.

trigger guard to push it home. Tap the bottom of the magazine to ensure that it is seated. The magazine can be inserted with the operating parts either aft or forward. It is ordinarily inserted after the rifle has been cocked.

SETTING THE CHANGE LEVER. - Set the lever to "F" for slow fire or to "A" for normal. To set it at SAFE ("S"), depress the change lever stop and push the change lever into position (fig. 11-72).

FIRING THE BAR. - To fire, squeeze the trigger. To fire single shots, set the change at "F" and quickly squeeze and release the trigger for each shot.

Main Assemblies and Functioning of the BAR

The principal groups of the BAR are the operating group, trigger group, and the buffer and rate-reducing group. Other groups are the forearm, bipod, rear sight, and receiver groups.

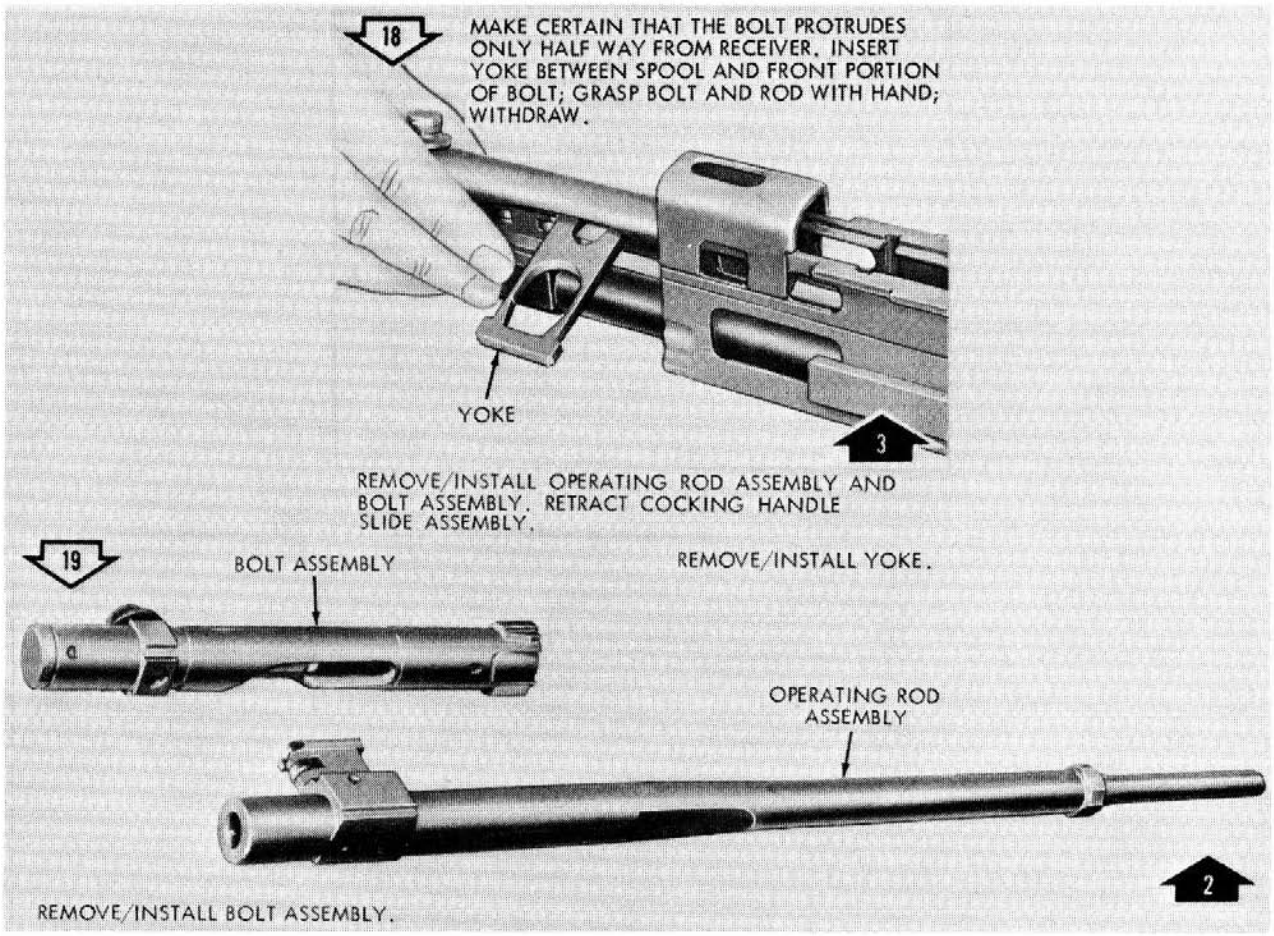
The functioning of the BAR is divided into two phases - rearward movement and forward movement of the operating group, which together, make up one cycle. The cycle begins with ignition of the next cartridge. We'll first take up this cycle, and then the rate-reducing and trigger groups.

REARWARD MOVEMENT. - (See fig. 11-70.) The operations that occur in rearward movement are gas action, slide movement to the rear, unlocking, firing pin withdraws, extraction, ejection, and termination of movement. Let us examine each of these in turn.

1. Gas action. (See fig. 11-70A, inset at right.) When a cartridge is ignited the expanding powder gas drives the bullet through the barrel. As the bullet passes a port in the barrel six inches from the muzzle, part of the high-pressure gas passes into the gas cylinder where it acts on the gas piston while the bullet travels the last six inches of the barrel.

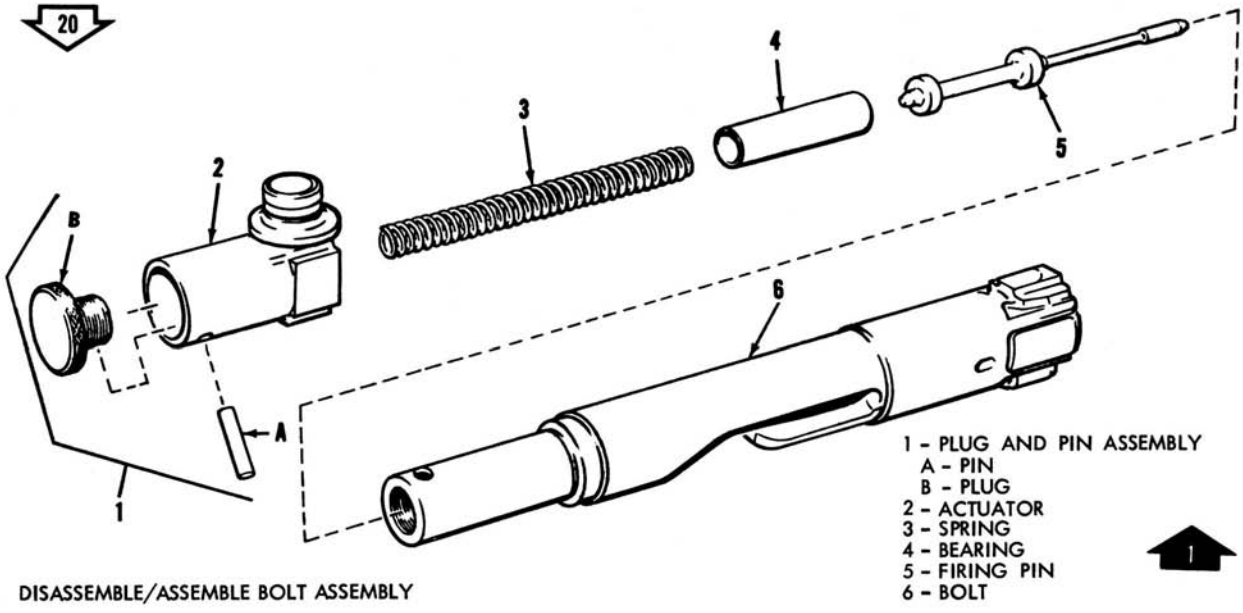
The effect is a sudden blow on the piston which drives it to the rear. carrying the slide

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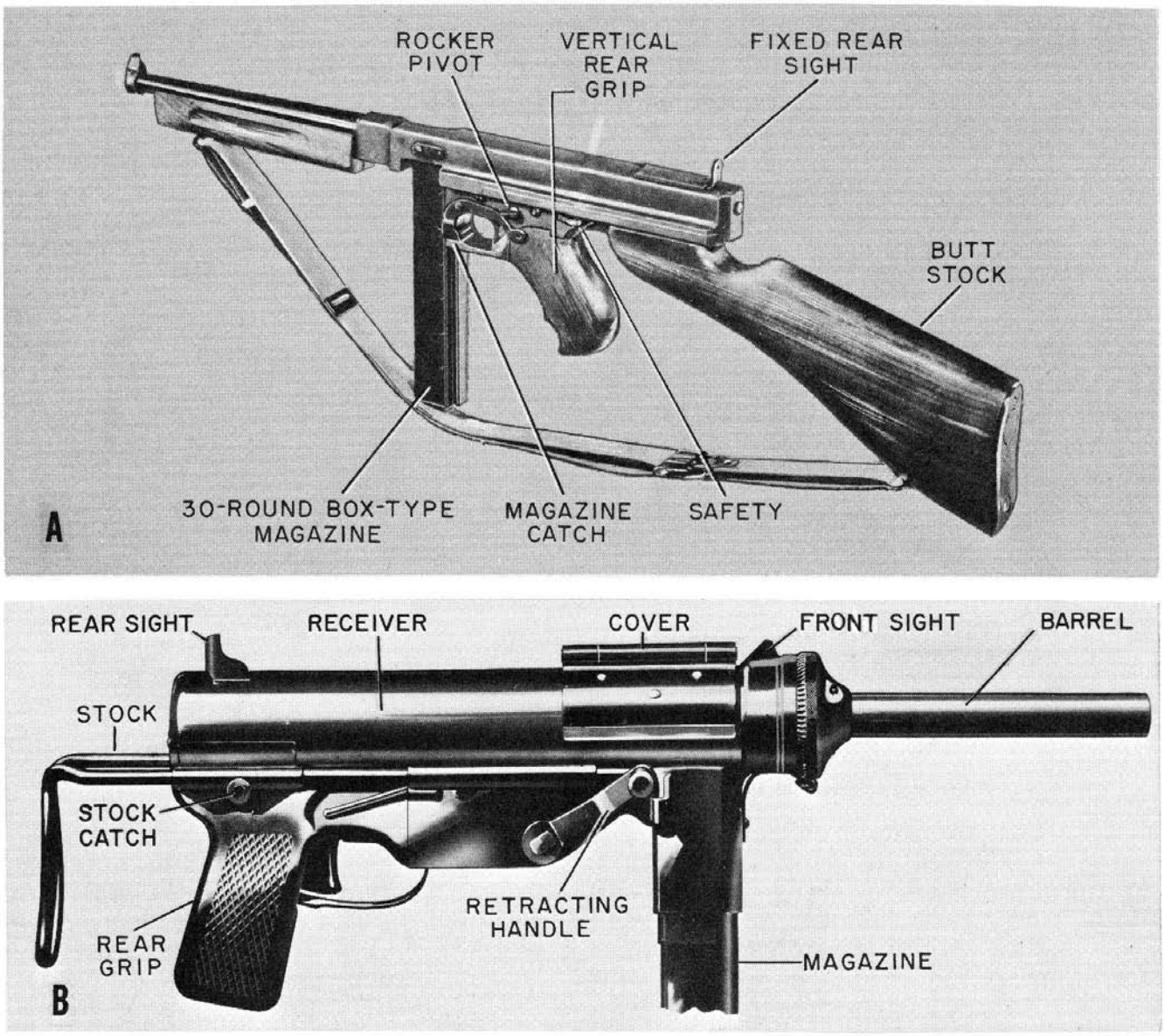
Figure 11-64. — Field stripping the M60 machinegun — Continued.



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Figure 11-65. — Field stripping the M60 machinegun — Continued.

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Figure 11-66. — Caliber .45 submachineguns.

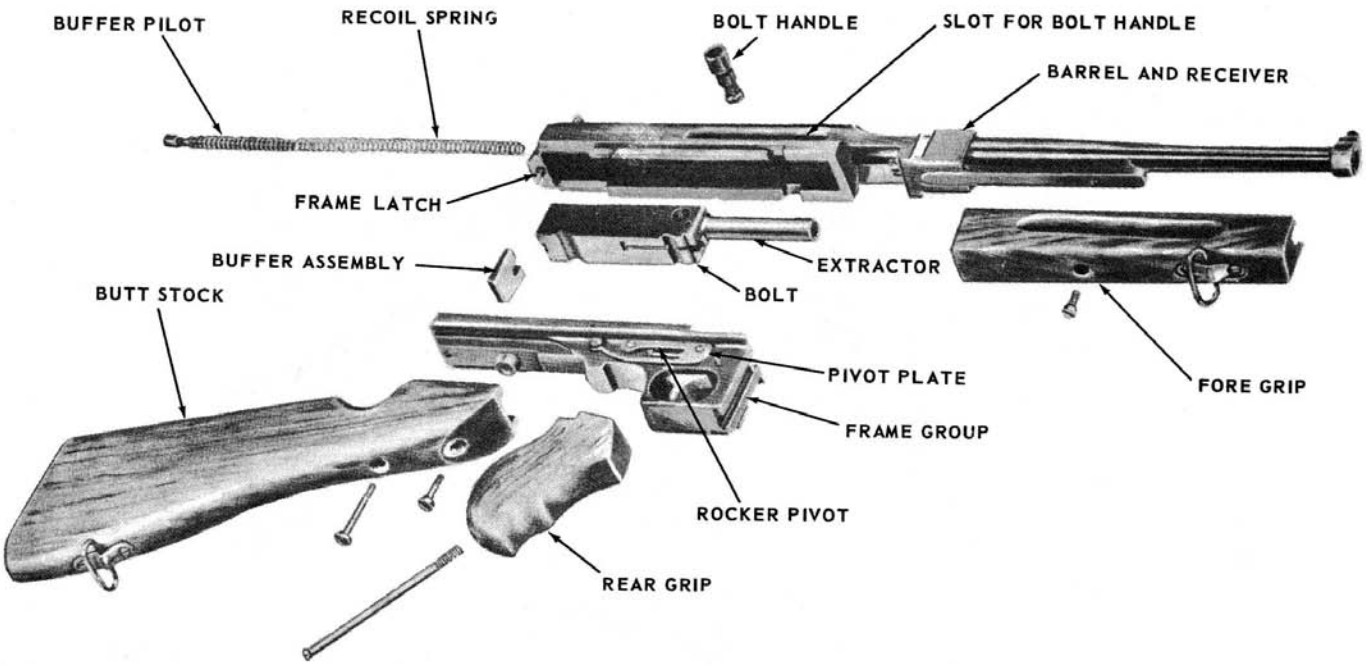
with it. When the piston head passes out of the gas cylinder, the gas expands around it and exhausts through portholes in the gas cylinder tube.

2. Movement of slide. (See fig. 11-70A.) As the slide moves to the rear. it compresses the recoil spring. (This stores energy for the forward action.) Before the slide begins to move aft, the hammer pin is about 0.19 inch forward of the bolt link pin. As it moves this. 0.19 inch aft, it moves the hammer from the firing pin but does not unlock the bolt.

3. Unlocking. (See fig. 11-70A and left inset.) Unlocking begins as the hammer pin passes under the bolt link pin. The bolt link revolves forward about the hammer pin, drawing the bolt lock down and to the rear. The lock and bolt accelerate until the slide has traveled about 1.2 inch when the bolt lock is completely down, out of the locking recess. It is now supported in front on the bolt supports.

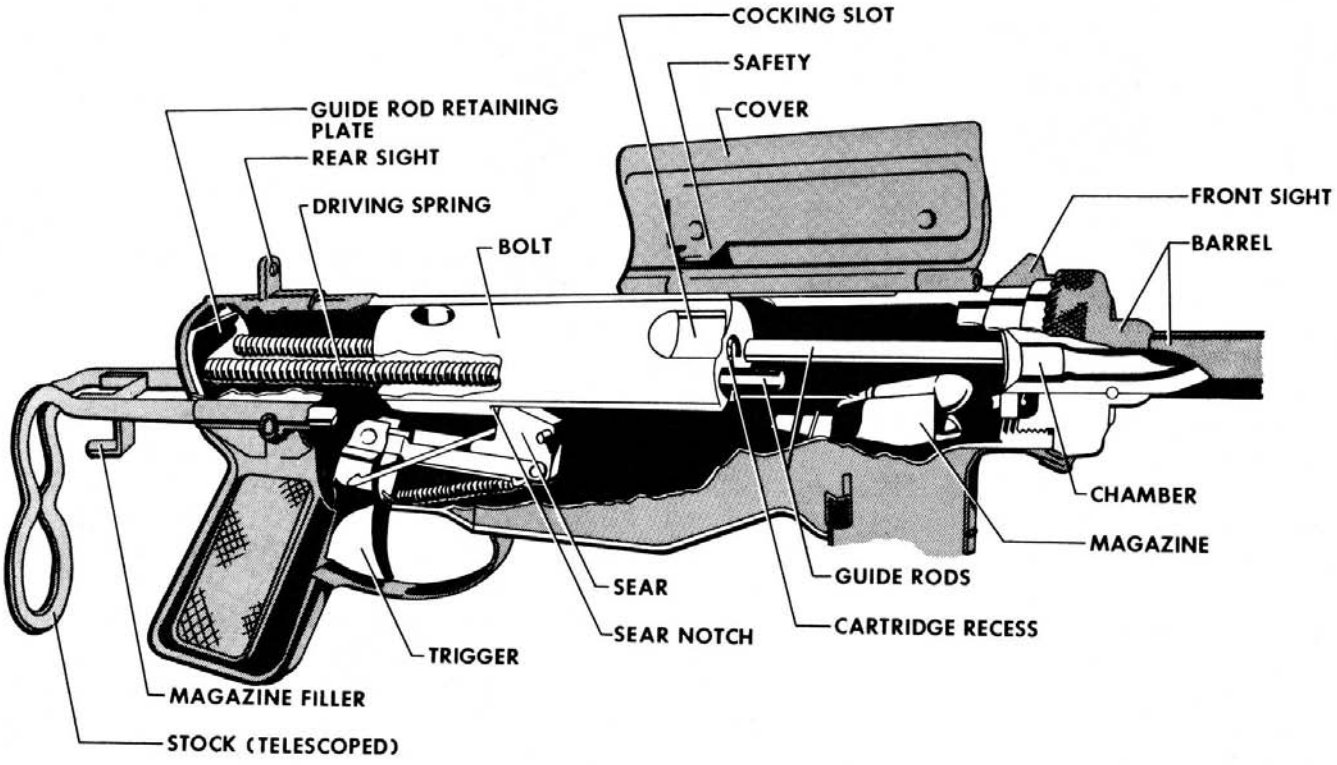
The bolt mechanism begins moving slowly at first and does not reach the speed of the slide until the slide has traveled about 1.2 inch aft. This avoids the shock of a sudden start at the instant the gas strikes the piston, and allows the bullet to clear the muzzle, preventing blowback.

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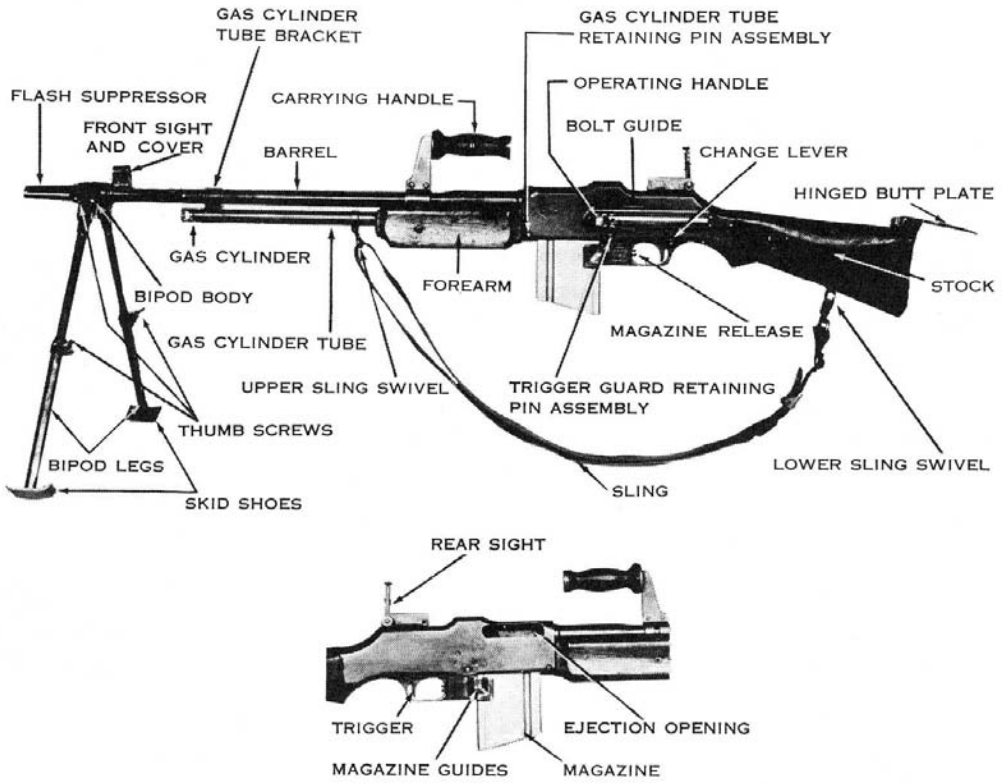
Figure 11-67. — Submachinegun M1, disassembled.



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Figure 11-68. — Cutaway view of submachinegun.

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Figure 11-69. — Browning automatic rifle M1918A2. General view.

4. Withdrawal of firing pin. (See fig. 11-70A and left inset.) As the bolt lock revolves down from locked position. a cam surface in the bottom contacts the firing pin lug, retracting the firing pin from the face of the bolt.

5. Extraction. (See fig. 11-70A. inset. and fig. 11-70B.) The bolt begins to retract when the circular cam surface on the descending bolt lock's underside cams the rear shoulder of the bolt supports. This action loosens the cartridge case. The bolt has traveled aft about 5/32 inch when the firing pin is withdrawn, and about 11/32 inch when the bolt lock is completely down. From this point the bolt is drawn to the rear by the bolt lock and bolt link, along with the slide, and carries with it the empty cartridge case which is held firmly on the bolt face by the extractor.

6. Ejection. (See fig. 11-70B.) When the slide is about 1/4 inch from the end of its rearward travel, the base of the case strikes the ejector, which kicks the case through the ejection opening in the receiver and out.

7. End or rearward movement. This phase ends when the rear end of the slide strikes the buffer head and sear release (not illustrated). The recoil spring then pushes the slide forward 1/10 inch. The sear nose (if not depressed) engages the sear notch on the slide and the piece is cocked for the next burst or shot.

FORWARD MOVEMENT. - (See fig. 11-71.) Now the BAR begins the second phase of its functioning - forward movement. The steps in this movement are action of the recoil spring, feeding, locking, and ignition.

1. Action of recoil spring. (See fig. 11-71.) When the gunner squeezes the trigger, the connector depresses the sear nose to release the slide which is driven forward by the recoil spring, carrying with it the bolt assembly. After about 1/4 inch of travel, the feed rib front end contacts the top cartridge, which is forced up by the magazine spring.

2. Feeding. This action carries the cartridge forward and the bullet ramp on the breech deflects it upward toward the chamber. The base of the cartridge slides across the face of the bolt and under the extractor.

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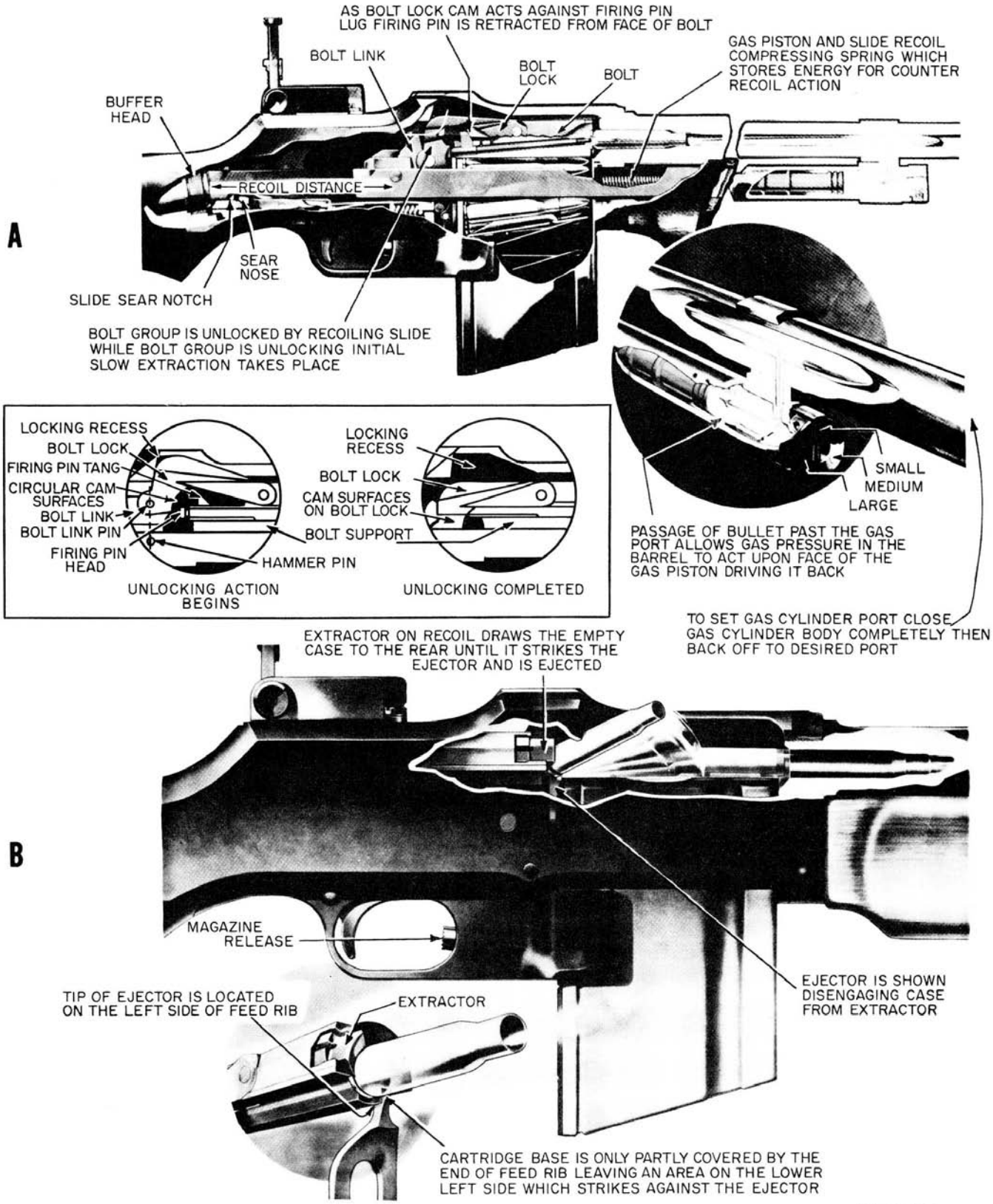


Figure 11-70. — Browning automatic rifle M1918A2. Functioning during rearward movement.

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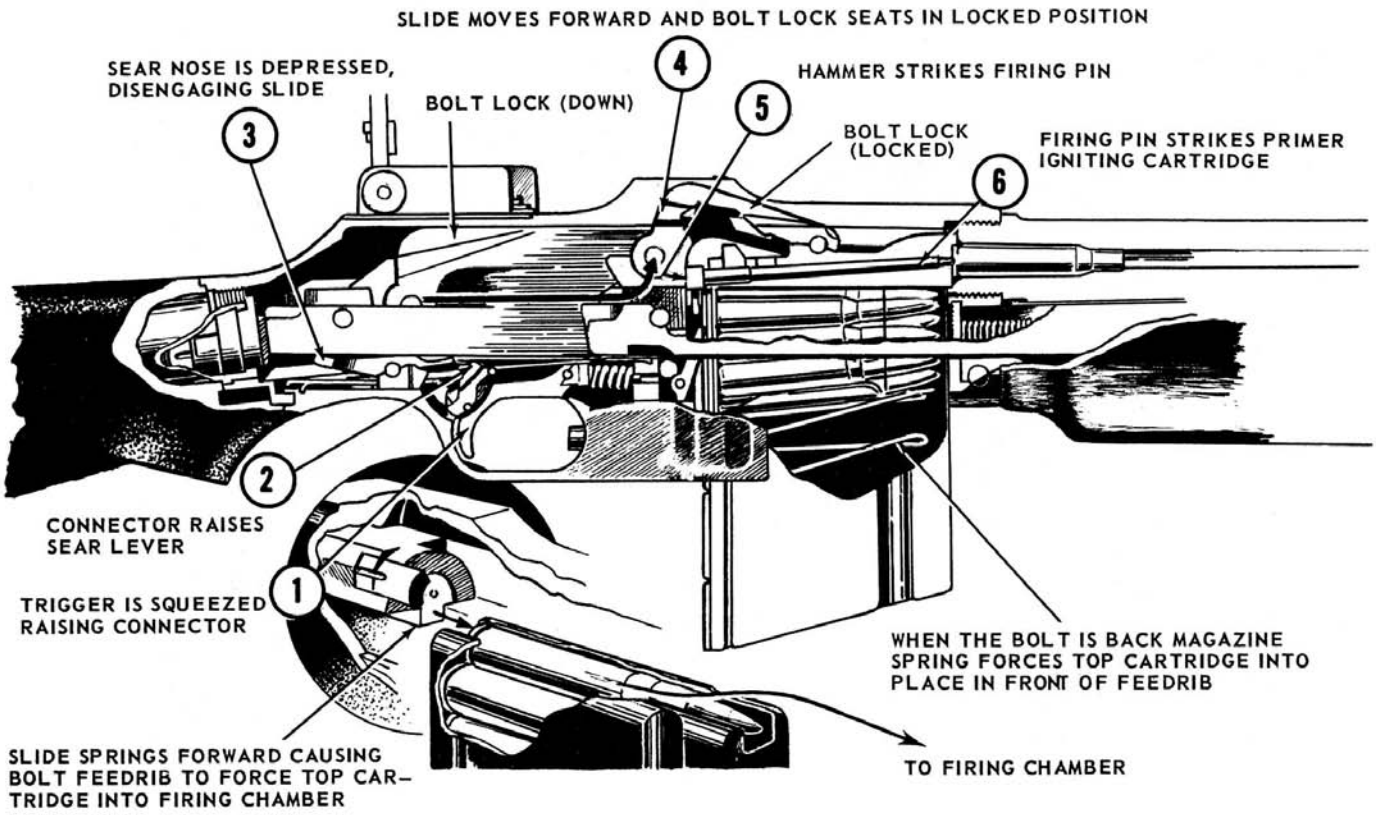


Figure 11-71. — Browning automatic rifle M1918A2. Functioning during forward movement.

3. Locking. As the slide approaches its forwardmost position, the rear end of the bolt is cammed upward about the bolt lock pin into the locking recess, and a rounded surface on the bolt lock slips over the locking shoulder in the receiver. This lock lever action forces the bolt home to its final position. The two locking surfaces on the bolt lock and receiver register as the hammer pin passes under the bolt link pin (reverse of unlocking action previously described). The slide and hammer move forward about 1/10 inch farther to complete the action.

4. Ignition. If the sear is down (see below), the hammer strikes the firing pin head, igniting the cartridge.

FUNCTIONING OF THE TRIGGER GROUP. - The trigger group is set for SAFE when the change lever is on S. For a fast or normal cyclic rate the lever is moved to A and for a slow cyclic rate the lever is moved to F. Figure 11-72 shows in detail how the trigger group and change lever work.

When the trigger group is set for normal cyclic rate, the lever on A. the sear nose stays down as long as the trigger is held back, and the rifle continues firing at a cyclic rate of about 550 rounds per minute until the magazine is emptied or the trigger is released.

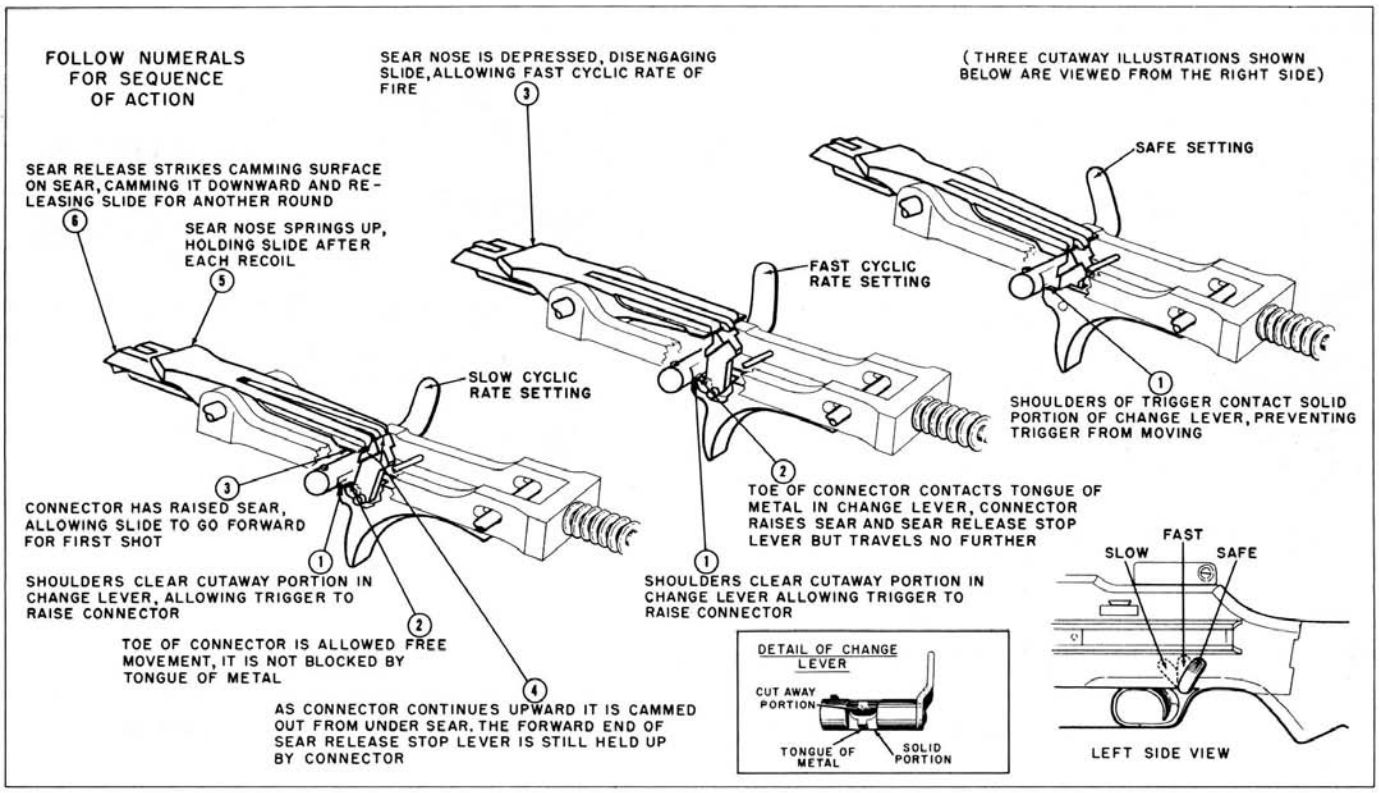
When the trigger group is set on F, the sear nose is only momentarily depressed when the trigger is held back. At the end of every cycle, the sear nose reengages the slide sear notch, and remains engaged until the sear release in the buffer cams the sear down. This reduces the cyclic rate to 350 rounds per minute, or single shots may be fired for each press and quick release of the trigger.

When the trigger group is set at SAFE, the sear cannot be released from the sear notch by pressing the trigger.

Maintenance and Inspection of the BAR

As with the other small arms taken up in this chapter. your main concern with regard to

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Figure 11-72. — Browning automatic rifle M1918A2. Change lever and trigger group functioning.

maintenance of the BAR (other than routine cleaning and care) is careful periodic gaging, inspection (both visual and functional), and gas port adjustment. For details on other adjustments and repair, and information on tools and gages required see the Army's Maintenance Manual, TM 9-1211.

PRELIMINARIES TO INSPECTION. -

1. Before inspection, hold each rifle with the muzzle pointed at the floor, clear it, and inspect the chamber for a live round. Be certain that there are no obstructions in the bore of the chamber. Do not touch the trigger until the rifle has been cleared.

2. Before inspection, properly clean the rifle to remove grease, dirt, or foreign matter which might interfere with proper functioning or obscure the condition of the parts. Use a serviceable magazine and dummy cartridges in functioning inspection. Test fire only if it can be done safely where such fire is authorized.

VISUAL INSPECTION. - Look at the exterior of the rifle for general appearance, rust, corrosion, and presence of all parts. Then check the details below:

1. Check the following for looseness: butt stock on receiver, butt plate on butt stock and hinge, swivel bracket on gas cylinder tube, near sight base on receiver, leaf group on base, front sight base on barrel, blade in base, and flash hider on barrel.

2. Check bipod for proper fit on flash hider, and outer butt plate for proper locking action. If necessary, assemble friction washer assembly with spring to front.

3. See if the butt swivel is free on the bracket.

4. Inspect the bore and chamber for pits, corrosion, and mechanical damage.

FUNCTIONAL INSPECTION.-

1. Hand operate to check for functioning and smoothness of operation.

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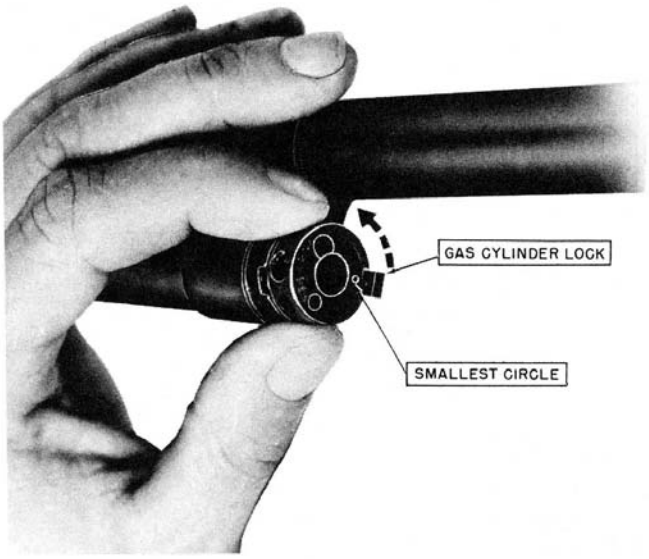
2. Check fit. of magazine in receiver, and function of magazine catch and catch release with magazine.

3. Using magazine and dummy cartridges, test the loading function of bolt, and the function of the extractor and the ejector. If neck of ejected case is dented, it indicates that ejection is weak (casing striking side of receiver). This may be caused by bent cartridge neck, worn ejector head, or ejector scraping on bolt.

4. Inspect locking action of bolt lock and bolt.

5. Fire several rounds of service ammunition and examine primers of fired casings. If primer shows indications of being set back in firing pin hole of bolt, due to an enlarged firing pin hole or recessive wear of bolt face, it will be necessary to replace the bolt.

6. Check trigger pull. It should be between 6 and 10 pounds.



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Figure 11-73. — Browning automatic rifle M1918A2. Gas cylinder adjustment.

GAS CYLINDER PORT ADJUSTMENT. - The gas cylinder adjustment should be made only if the rifle needs it - for example, if failure to recoil or to eject properly is caused by insufficient gas. Only the gas cylinder parts are to be adjusted using this procedure (fig. 11-73):

1. First, unlock the gas cylinder assembly by forcing out the lock, screw the assembly all the way in until it is finger tight, and back off the assembly one complete turn.

2. Turn the cylinder so that the smallest circle passes through the shortest arc to a position under the barrel. Lock the cylinder in place.

3. If the weapon still recoils or ejects poorly when fired, rotate the gas cylinder one turn in or out to improve alignment. If such adjustments do not help, turn the cylinder to the next largest circle.

Insufficient gas indicates a clogged or poorly aligned gas port - evidenced by slamming in operation, overheating, and excessive firing rate. In rare cases poor gas adjustment may permit the gun to fire uncontrolledly. So its important to check this adjustment.

HEADSPACE GAGING. - Every BAR should be headspaced before it is issued to personnel for firing, and after firing exercises. Minimum headspace should be 1.940 inch; maximum should be 1.950 inch. Use gages Z021-7319944 (1.940 in.) and Z021-7314454 (1.950 in.).

SAFETY PRECAUTIONS

Small-arms safety precautions, like all safety precautions, largely are a matter of common sense. Every gun should be considered loaded until proven otherwise by examination; never trust your memory or anyone else's memory in this respect. TO THINK a gun is unloaded can be fatal. Be positive.

NEVER point a firearm at anyone or anything you do not intend to shoot, or in any direction where accidental discharge might do harm. When checking operation or releasing spring tension, point the weapon upwards or

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in some safe direction before pressing the trigger. Never place the finger inside the trigger guard unless ready to fire.

Do not work on a weapon you do not thoroughly understand. Ask a senior ordnanceman or other qualified personnel to instruct you if possible; otherwise refer to the proper technical publication. Never use force in disassembling and assembling small arms. They are all so constructed that undue force is unnecessary if parts are properly assembled or removed.

Safety features should be frequently tested for proper functioning. For obvious reasons, an inoperative safety device is more dangerous than no safety device at all.

In weapons with detachable magazines, always remove the magazine as the first step in unloading or clearing a stoppage. It should be noted that, in ALL magazine-fed weapons, the shape, position, and condition of the magazine lips are extremely critical and, if dented, will interfere with proper feeding of the cartridge into the chamber. The majority of stoppages in magazine-fed weapons is due to faulty magazines and consequently care must be taken when handling them not to cause damage.

Before loading ammunition into the weapon, check for dirt, oil, grease, malformation, loose bullets, or other defects.

Check the bore prior to firing to be sure it is free of foreign matter or obstructions. If, during firing, there is any indication of misfire or weak charge, make sure a bullet is not lodged in the bore. An obstructed bore will cause a serious accident when the next round is fired.

To minimize danger from hangfire, wait 10 seconds after a misfire, then clear the weapon quickly. If the weapon cannot be cleared quickly and the barrel is hot, DANGER OF COOKOFF EXISTS. Leave the round in the chamber, point the weapon in a safe direction, and allow it to cool before removing the misfired round.

SPECIAL PRECAUTIONS FOR PISTOLS AND REVOLVERS

Automatic pistols in the hands of inexperienced or careless persons are largely responsible for the saying "It's always the unloaded gun that kills." It is a fact that many accidental deaths and injuries are due to a mistaken belief that removing the magazine of a pistol (or other magazine-fed weapon) is all that is necessary to unload it. Nothing could be further from the truth. To completely unload a pistol or other magazine-fed weapon and render it safe to handle. it is necessary to not only remove or empty the magazine, but also to MAKE ABSOLUTELY CERTAIN THE CHAMBER IS EMPTY. The only way this can be done when handling the caliber .45 pistol is to pull back the slide and inspect the chamber either visually or by feel if it is dark. This should be done AFTER the magazine is removed, and with the muzzle pointed upward. Of course, if the chamber is loaded, the round will be extracted and ejected when the slide is operated. "I didn't know it was loaded" is never an excuse for the accidental discharge of a weapon - especially for the ordnanceman.

When handling revolvers, a simple visual inspection is sufficient to determine if any chambers in the cylinder are loaded.

Keep hammer fully down when pistol or revolver is not loaded.

When the pistol is cocked, keep the safety lock in the ON position until ready to fire.

Let's review briefly some of the safety precautions that apply to the handling of ALL small arms:

1. Never point a weapon at anyone unless you intend to kill him.
2. Unless the weapon is to be used immediately, never carry it with a round in the chamber.
3. Unless you are about to fire it, the safety of every small-arms weapon must always be ON.
4. Consider a gun loaded until you yourself have opened the chamber and verified that it is empty. It isn't enough to wail, afterward. "I didn't know it was loaded." The "empty" weapon is the dangerous one.
5. Before firing any weapon, be sure that there are no obstructions in the bore.
6. Before firing any weapon. be sure the ammunition you are using is the right ammunition. For example, the caliber .30 carbine cannot use standard rifle ammunition. Nor should you try to use Very signals with shotguns, even though they look much like shotgun shells.
7. Before firing, be sure there is no grease or oil on the ammunition or in the bore or chamber. Although lead bullets may be lightly waxed or greased, there must NEVER be any lubricant on the cartridge case. (This does not apply to aviation ammunition.) Lubricant on the case or chamber is particularly bad because, upon firing, the case slips backward, causing a dangerously heavy thrust against the bolt.

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8. Keep ammunition dry and cool. Keep it out of the direct rays of the sun. Keep ammunition clean, but do NOT polish it or use abrasives on it. Do not attempt to use dented cartridges, cartridges with loose bullets, or cartridges eaten away by corrosion. Be particularly careful with tracer ammunition which can ignite spontaneously if damp.

9. Misfires and hangfires can occur with small-arms ammunition as well as with other types. On some weapons like the automatic pistol, the line-throwing gun, the Springfield rifle, the hammer-type shotgun, and a few others, you can recock and attempt to fire again without opening the breech. If, after a couple of tries, this proves unsuccessful or, if the weapon cannot be recocked without opening the bolt, wait at least 10 seconds, then open the bolt and eject the defective round.

Defective small-arms ammunition should be disposed of in accordance with current regulations. It is prohibited to force out a bullet by firing another bullet.

A misfire with blank cartridges may leave unburned powder deposited in the bore; always check the bore after any misfire and clean if necessary.

10. Guard against BLOWBACK. In this connection, blowback refers to leakage of high-pressure gases to the rear around the closed bolt. It can be caused either by excessive wear of the bolt or chamber, by obstructions that foul the bore, or by both. Blowback can be avoided by gaging and checking your weapons regularly and replacing worn parts as indicated, and by checking (see No. 5 above) to be sure that there are no obstructions in the bore.

THE LANDING PARTY

As a Gunner's Mate, you must know how to issue, assemble, and demonstrate the use of landing party (infantry) equipment. To help you learn this, the Navy has issued a publication called the Landing Party Manual, OPNAV P34-03. It covers nearly all aspects of the naval landing party. It is interesting reading, and is recommended for all Gunner's Mates.

In scope, this chapter falls somewhere between the simple requirements of the Third Class GM and the complete coverage of the Landing Party Manual. Here we will discuss the following:

The EQUIPMENT - what it is, how to make it up, and how to wear it.

LANDING PARTY ASSIGNMENTS - what you might expect to be doing if you are assigned to a landing party.

LIVING ASHORE - some factors to be considered when your living spaces and galley are miles away. Let's start the chapter by finding out what a landing party is.

THE SHIP'S LANDING PARTY

To most sailors, the term landing party might bring to mind one of two things. First, a peaceful, if dull, march down main street in a parade or, second, mortal hand-to-hand combat with enemy troops ashore. While both situations are true functions of the landing party, they represent the extremes. The landing party may also be called away to help after a national disaster, to quell riots and other serious disorders, and to perform police functions such as the imposition of martial law.

ORGANIZATION OF THE LANDING PARTY

The size of a landing party varies, depending on the type of ship that lands it. A destroyer is required to maintain a 13-man rifle squad. A cruiser will furnish a rifle company of about 200 men. The common denominator of all landing parties, regardless of size, is the rifle squad, and our discussion here is based on this squad.

Figure 11-74A shows an organization chart of a rifle squad. It is made up of the squad leader and three fire teams. Each of the fire teams consists of 3 riflemen and the individual fire team leader; thus there is a total number of 13 men in the squad. As a Gunner's Mate you will be the logical man to lead either a fire team or the entire squad.

Figure 11-74B shows the result of combining the landing parties of three destroyers. This is the rifle platoon. Notice that, with the exception of the six people at the platoon headquarters, the major unit of the platoon is the rifle squad.

You will find that the larger size landing parties employ some machine guns as well as rifles. A machine gun can deliver a heavy concentration of fire, but its crew is capable of

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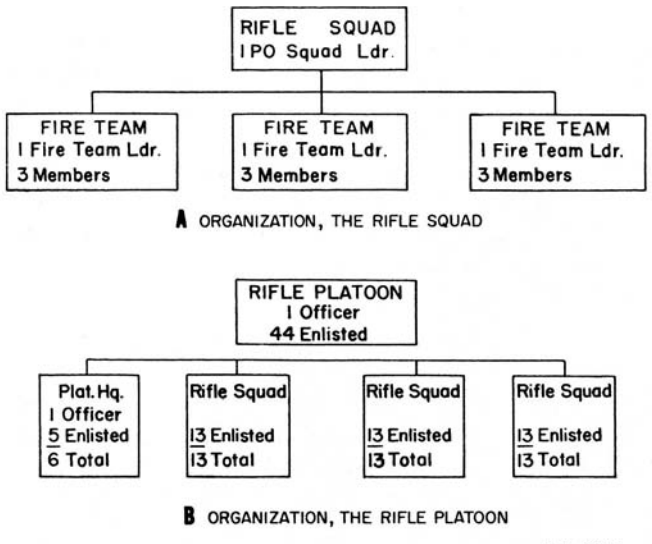


Figure 11-74. — Organization chart of a ship's landing party.

little independent action. Machine guns are used only as supporting weapons.

LANDING PARTY EQUIPMENT

The type and amount of equipment carried ashore by the men of the landing party depends upon the nature of the operation. We can skip operations such as the parade mentioned earlier, where your only equipment will be a smart looking dress uniform. The equipment we will discuss is that taken ashore and used in emergency field operations.

Figure 11-75 shows what is known as the basic individual combat equipment. This is the minimum equipment, other than weapons, to be carried by each member of the squad. A man's position in the squad - fire team leader, rifleman, etc. - will determine what supplementary equipment he will be issued. For example, the supplementary equipment carried by a rifle squad leader is shown in figure 11-76.

A complete list of basic and supplementary infantry equipment can be found in the Landing Party Manual. The manual also lists all members of a landing party, and shows the equipment each will be issued.

How to Assemble and Carry Equipment

A pack, Marine Corps M1941, is carried by each member of the landing party. It is made up of a haversack, a knapsack, belt and suspenders, blanket roll, bayonet, and scabbard.

The haversack (fig. 11-77 A) is carried when you expect to enter a combat zone. In it you carry your personal articles:

Poncho	Towel
Eating Utensils	Toilet articles
1 pair of socks	Extra pair of shoe laces
1 set of underwear	1 day's rations

The knapsack (fig. 11-77B) is used to carry extra clothing when you do not have your seabag with you or it is not easily accessible. The following articles are usually carried in the knapsack.

Pair of shoes	2 shirts
Pair of trousers	2 pairs of socks
2 sets of underwear	

The belt and suspenders are shown in figure 11-77C. As you would imagine, the belt can become pretty heavy when it is loaded down with ammunition, canteens, and sometimes the bayonet and knapsack. This makes the suspenders a necessary part of this arrangement.

The blanket roll (fig. 11-77D) can be made up as either a short or long roll. The short roll is as wide as the length of an extended tent pole. The long blanket roll is the width of the blanket. To assemble either, lay the gear out as in the illustration, roll it up from the bottom, and secure with the straps.

Pack Assemblies

Several types of packs can be made from the Marine Corps pack M1941. They fall into two categories - the marching packs and transport packs.

The light marching pack (fig. 11-78A) is made up of the haversack, supported by its own suspender straps. To assemble it, you need only to bring the free ends of the haversack suspender straps through the pack strap loops and back up to the "M" buckle. The pack can be adjusted to fit at the "M" buckle.

The marching pack (fig. 11-78B) requires the use of the belt and belt suspenders. In figure

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Figure 11-75. — Basic individual combat equipment.

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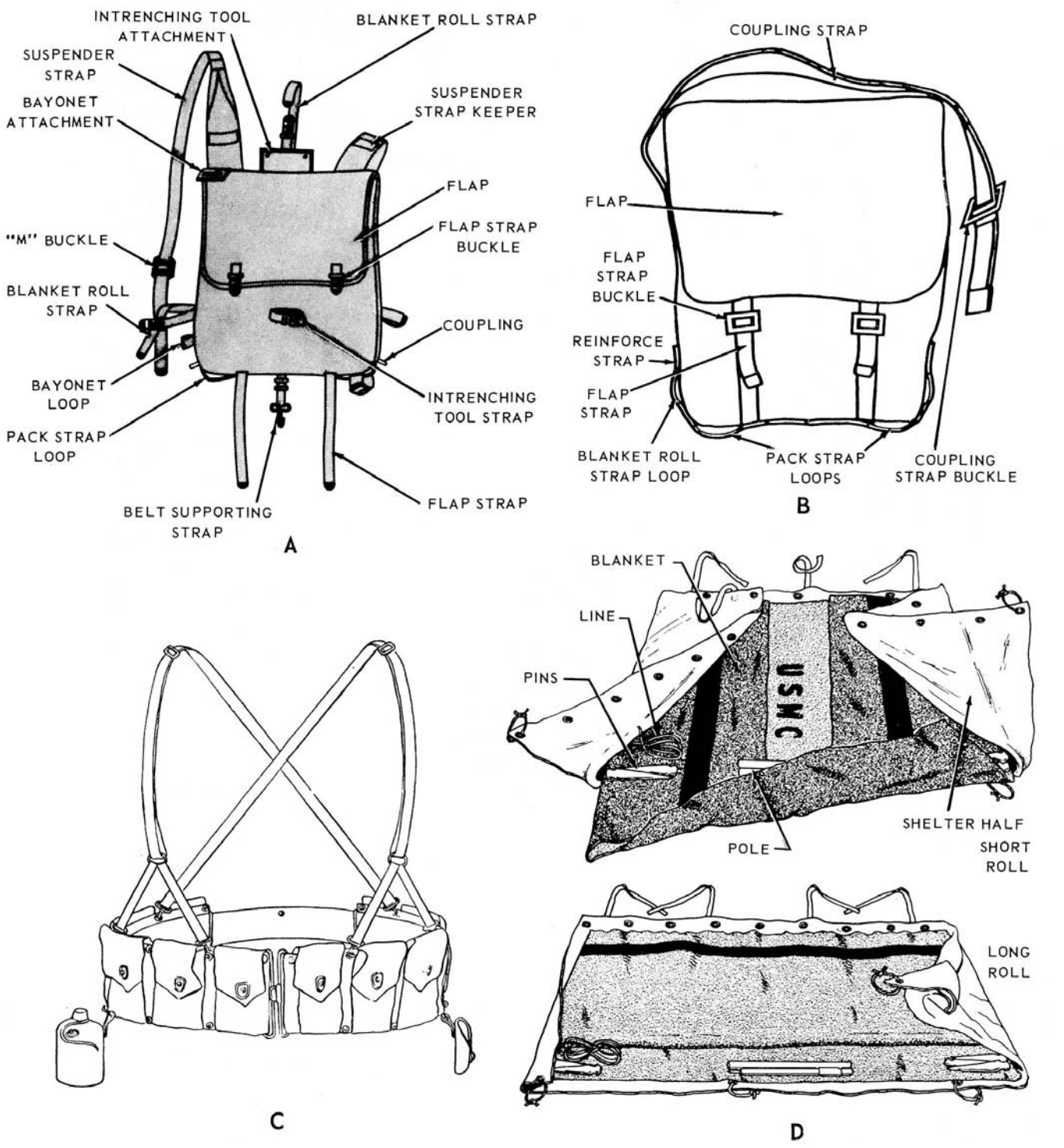
Figure 11-76. — Supplementary equipment of a rifle squad leader.

11-79 you can see how it is assembled. The haversack suspender straps are passed down through the belt suspender rings, then double back on themselves. They are brought back up and passed through the keepers on the broad part of the suspenders. The belt suspender pack straps go back under the haversack through the pack strap loops, and then cross in the back of the haversack. (Note that the belt suspenders do NOT pass over the shoulders. They pass under the haversack and help support it.) The belt suspenders then snap into the haversack "M" buckles.

When the short blanket roll is bent around the haversack and secured to it with the blanket roll straps, the assembly is called the field marching pack (fig. 11-78C).

The transport pack (fig. 11-78D) consists of all the items mentioned so far, plus the knapsack. It is used for field exercises when

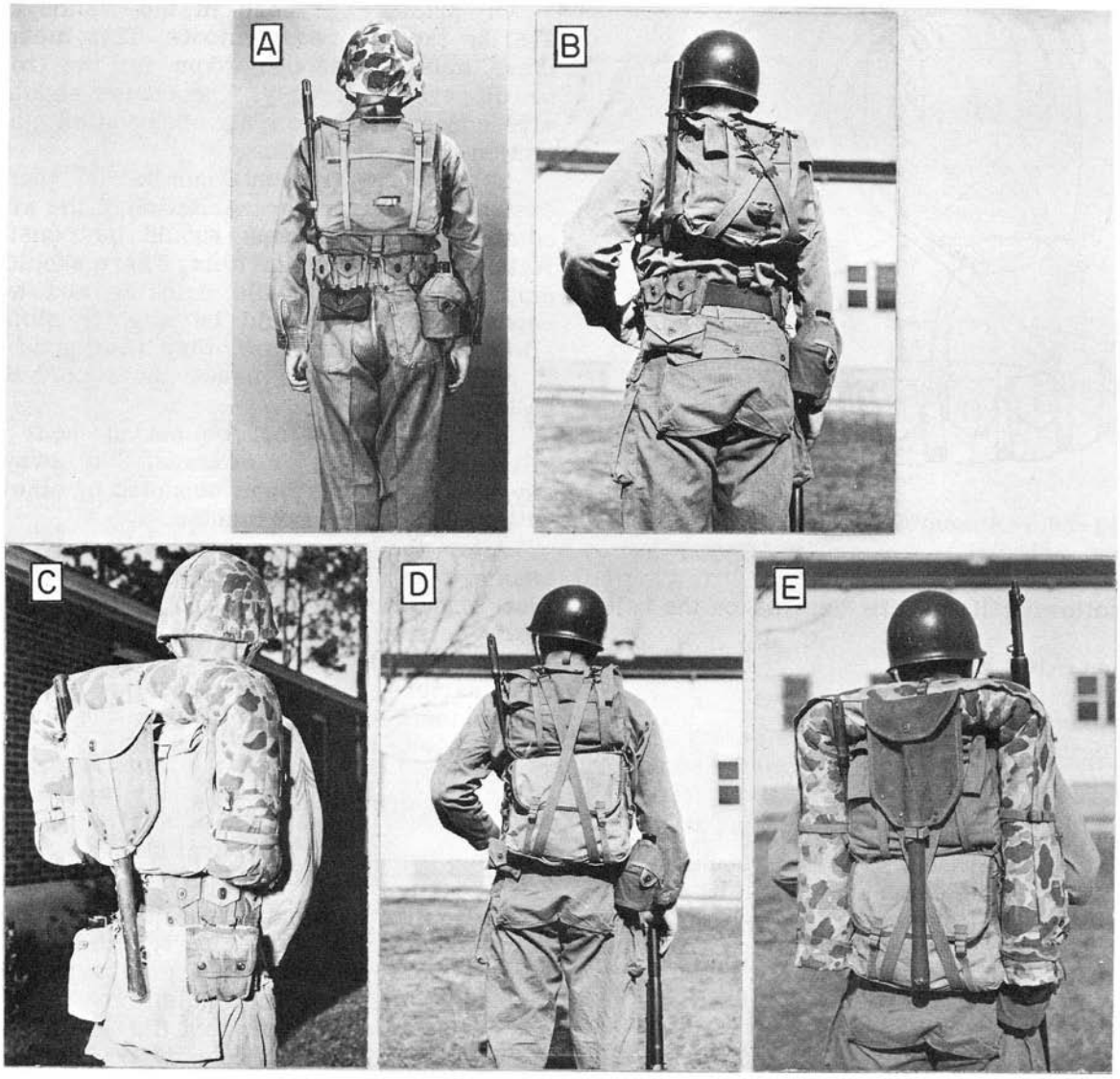
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Figure 11-77. — The Marine Corps pack-A. Haversack, B. Knapsack. C. Belt and suspenders. D. Blanket roll.

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Figure 11-78. — Pack assemblies-A. Light marching pack. B. Marching pack. C. Field marching pack. D. Transport pack. E. Field transport pack.

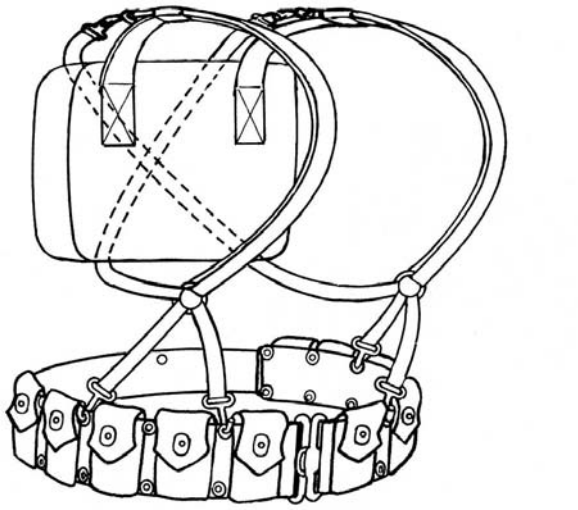
slow movement due to the extra weight is no problem. It is made up similarly to the marching pack. The knapsack coupling strap is passed through the two haversack couplings, drawn up snugly, and buckled. Then the belt suspender pack straps pass under the knapsack (through loops) and cross in the back as before. They are then snapped to the haversack "M" buckle.

When the long blanket roll is added to a transport pack, the assembly is called the field transport pack (fig. 11-78E).

Other Individual Items of Equipment

The helmet, with its liner, is always worn in combat. On special occasions (police and guard duties, or parades and ceremonies), the liner alone may be worn if prescribed by the officer in charge of the landing party. This helmet is exactly like the one used aboard ship, and the same regulations apply to wearing it.

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Figure 11-79.—Assembling the marching pack.

The following items are carried on the belt:

Bayonet - left hip
Canteen - left buttock
Pistol - right hip
Wire cutters - right front
BAR spares - front of right hip

The entrenching tool is carried by an attachment on the haversack. If no entrenching tool is issued, the machete and sheath can be carried in its place. If field glasses, gun mask, or map case are carried, they can be slung from the shoulder.

SHELTER

Depending upon the tactical situation, the landing party may be sheltered in bivouac, camps, or billets. Troops are in bivouac when provided with shelter tents or other hastily improvised shelter. Troops are in camp when sheltered by tentage other than shelter tents, or by huts or other temporary structures especially constructed for military purposes. Billets are private or public buildings not especially designed for military purposes.

Billets (and most likely camps) will be chosen and prepared in advance of the landing party arrival. The choice is made by the landing party officer. For this reason we discuss some factors of choosing a site and living in bivouac.

Choice of Site

Of primary concern in the choice of site are the tactical requirements. This means that there must be enough room for the troops to be dispersed properly. The choice should provide concealment from air observation, and protection from air attack.

If these requirements can be met, then other desirable features for sanitation of the area and comfort of the troops should be considered. Water is an important item. There should be an ample supply to handle drinking and washing needs. The site should be slightly sloping to allow water to drain off. Stay near good roads; if nothing else. this eases the supply to your galley.

Bivouac should not be set up near native villages, marshes, or swamps. Stay away from any site which has been occupied by other units within the preceding 2 months.

After the site is selected, it may be necessary to establish outposts, guards, and patrols. (See chapter 8 of the Landing Party Manual.) Work details are then assigned to arrange for waste disposal, and to set up the galley, the headquarters, etc. It is preferred that these assignments be made prior to the arrival on site to prevent delay and confusion.

All men not assigned to other details should be put to work pitching tents.

Pitching the Tent

Normally, each individual in the landing party carries half of a shelter tent. with the required number of pins and poles (one guy line. five tent pins. and one tent pole). Two men carry and occupy one complete tent (fig. 11-80).

When properly instructed, two men should be able to erect a shelter tent (also called a "pup" tent) in five minutes. Here is the basic method:

Pairs of men pitch tents together. Each man spreads his shelter half. The shelter halves are then buttoned together. One man slips the pole into the eyelets in the front of the tent and holds the pole upright.

The other man pins down the front corners of the tent in line with the pole, then pins down the front corners of the tent, and drives the guy pin two-and-a-half pin lengths in front of the front triangle. He places the loop of the guy over this pin, runs the other end of the line through the loops of the shelter halves, and ties it. making sure that the pole is vertical when

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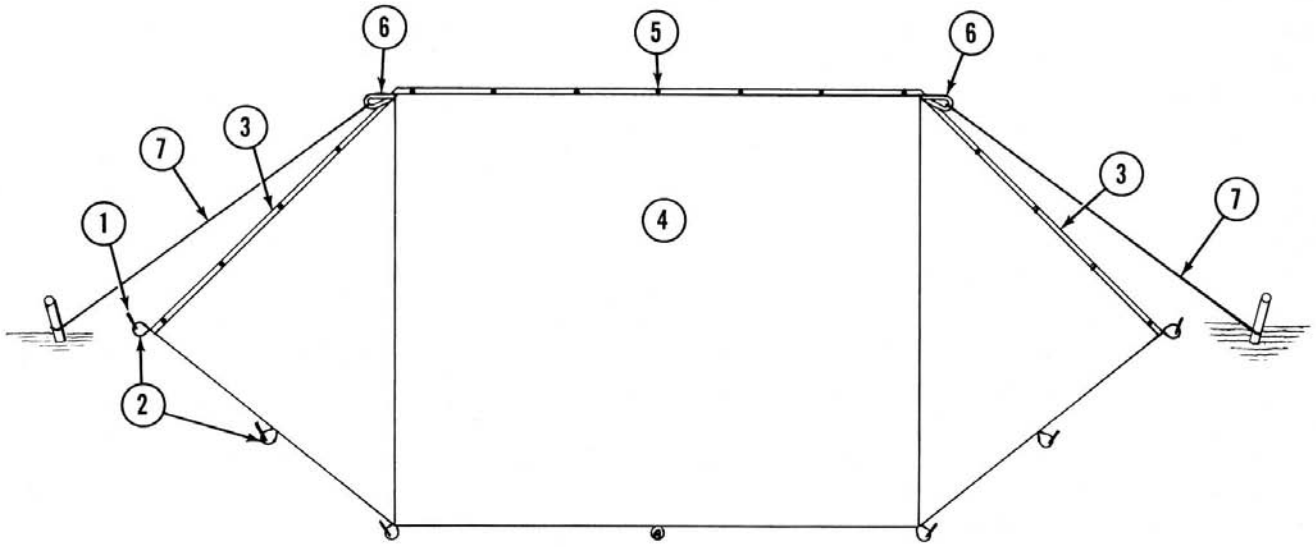


Figure 11-80.—Erecting a shelter tent.

the line is taut. He then adjusts the rear tent pole through the eyelets in the rear of the tent. The first man pins down the rear corners of the tent, drives in the rear guy pin so that it is two-and-a-half tent pin lengths from the rear pin of the triangle, then adjusts the guy line. Then they pin down the sides.

The tent should be trenched immediately after it is erected. This should be done even if the bivouac is for one night.

Remember that this is only a basic method. The Landing Party Manual describes a drill method that is performed "by the numbers," but is similar to the one above.

To strike pup tents, first unbutton enough buttons so that each man can grasp a tent pole and pull it to the left or right. When the tent is flat on the ground, pull the pins, finish unbuttoning the halves, and roll the packs.

Hygiene and Sanitation

Field sanitation is a term applied to the sanitary practices and principles which must be observed to maintain the health of the group when permanent type facilities are not available. In general they are the same common sense rules which apply to shipboard living. In the field. however. they take on added importance. Improvisation is a necessity and, if it conforms to the correct principles, it should be encouraged. Basically, sanitation is concerned with food and water, and with waste disposal.

Food should be obtained through your supply system. Emphasis must be placed on the proper preparation and handling of foods and the sanitizing of mess gear. A model field dishwashing unit can be set up by using a line of four GI cans. The first can in line is for garbage and waste; the second is a pre-wash can and has the soap in it; the third contains the hot water for quick and adequate washing of the mess gear; and the final can contains actively boiling water for rinsing.

All water in the field should be regarded as unsafe for drinking until a medical officer or his representative has approved it. If it ever becomes necessary to use water from an unapproved source, it must be chemically treated or boiled. Boiling in this case means boiling for 20 minutes, not just heating it up.

Water can be chemically treated by using the Lyster bag and kit, or by water purification tablets. Both are issued with instructions for their use. Chemically treated water may not taste so good but it is safe.

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Waste disposal is important. Proper disposal is necessary to eliminate places where rodents and insects can live and breed. Human waste especially must be disposed of correctly since a careless unit may so contaminate a site that it will be unfit for further use for months.

Kitchen waste and human waste are deposited in trenches which are dug according to the instructions in chapter 7 of the Landing Party Manual.

Personal hygiene deals with the efforts you must put forth to keep in good physical, mental, and moral health, and to protect yourself from disease. Obeying the following rules of field sanitation is a matter of hygiene.

1. In the case of a suspected illness or disease, see the corpsman. It has been said, "A person who treats himself has a fool for a patient." By postponing proper treatment, you may not only harm yourself but be a source of danger to your shipmates.
2. Eat your meals slowly. Don't eat to excess, and never have a big meal before a long march or other strenuous exercise.
3. Drink plenty of water, but not all at one time. Drink only from your own cup or canteen.
4. The entire body should be bathed at least three times a week. Feet should be washed daily and dusted with powder. Care of feet is a primary factor in marching ability.
5. While it is comparatively easy to destroy vermin with DDT, every effort must be made to keep them from getting a start amongst your group. Body lice (which actually live in the clothing rather than on the body) can transmit serious diseases. The best way to prevent lice is to keep a clean body, and to change frequently to clean clothes.

The information in this section of the chapter is, of course, just as important aboard ship as shore, and you have been drilled in these matters many times. Aboard ship, compliance with sanitation and personal hygiene rules is well supervised, with immediate penalties for the wrongdoer. Ashore, however, it becomes a matter of self-discipline. There is no compartment cleaner, scullery men, master-at-arms, etc. Ashore, the duties of these individuals are wrapped up in one man - you.

STOWING, ISSUING, AND MAINTAINING LANDING PARTY EQUIPMENT

Most ships have a landing force locker or at least a space designated especially for the stowage of landing party equipment. You will be responsible for the security of this equipment. Much of the equipment, and all weapons, are highly pilfer able items. The rule is to keep the space locked, and impose strict accountability for the key.

All small arms are considered equipage, and a signature of subcustody is required before they are issued from their normal place of stowage. Signatures of custody may also be required (at the weapons officer's discretion) before issuing other items of landing party equipment such as knives, canteens, and ponchos. It is important to get the signature of the man receiving the equipment, any type of signed custody record can be used. The important thing is to keep the equipment locked up and, when it is issued, get a signature.

While some pieces of landing party equipment (such as tents and ponchos) are water resistant, they should not be folded and stowed while wet. This will cause mildew to attack the fabric. When tents are erected, they should be slackened. A tent will shrink when drying out after a rain. On occasion, tents whose lines have not been slackened have split down the middle upon drying.

When the contents of a canteen have been used, empty it entirely. Even a small amount of water left in it will cause slight corrosion, and a disagreeable odor and taste.

Leather shoes and boots can be treated with saddle soap. The application should be thorough in order to clean and soften the footwear, and to replace some of the oil in the leather.

Mess gear should be clean and dry before you pack it away. After the final rinse in boiling water, dry these items by shaking them in the air. Do not use a cloth to dry them. Upon being issued a weapon, the receiving individual becomes responsible for its proper care and use. This requires training, which is the job of the Gunner's Mate. Instructions for the operation, maintenance, and repair of infantry weapons were covered earlier in this chapter.

When operating with a landing party, there is a good possibility that the hand grenade will be used. The following section briefly discusses types of hand grenades and steps required for their safe and proper use.

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HAND GRENADES

A hand grenade is a small bomb with the user's arm providing the motive power to get it to the target. Hand grenades may be filled with explosives, explosives and chemicals, or (for practice purposes) may be empty or contain inert filler. Hand grenades come in many sizes, shapes, and types and are designed to fulfill a wide variety of purposes. They can be used for providing material and personnel casualties; for screening, signaling, and illuminating; for demolition and harassing; and for incendiary action.

TYPES AND CHARACTERISTICS

The general types of hand grenades issued by ordnance are: (1) training, (2) practice, (3) fragmentation, (4) offensive, and (5) chemical. Each type is designed to do a special job. For a summary of the characteristics and capabilities of each hand grenade refer to Army Field Manual FM 23-30.

Certain characteristics, common to all hand grenades, are:

1. The range of a hand grenade is relatively short. The range depends on the ability of the individual and the weight and shape of the grenade. A well trained sailor should be able to throw the fragmentation hand grenade an average of about 44 yards. He may average only about 27 yards with the heavier white phosphorous smoke grenade.

2. The effective casualty radius of a hand grenade is relatively small when compared to that of other weapons. Effective casualty radius is defined as the radius of a circular area around the point of detonation within which at least 50 percent of the exposed personnel will become casualties. The effective casualty radius varies with the type of hand grenade used, so the casualties can and do occur at distances greater than this radius.

3. Delay type fuzes are used in all standard hand grenades. Detonation of the grenade is not on impact, but after the delay element in the fuze has burned. The fuze assembly (fig. 11- 81) consists of a fuze body, safety lever, safety pin, striker spring, a primer, a delay element, and detonator or igniter. For further information about the operation of the fuze assembly, refer to FM 23-30. All casualty-producing grenades (fragmentation, offensive, and while phosphorous) have a 4- to 5-second delay. Because of this short delay, personnel must stay alert when arming and throwing hand grenades.

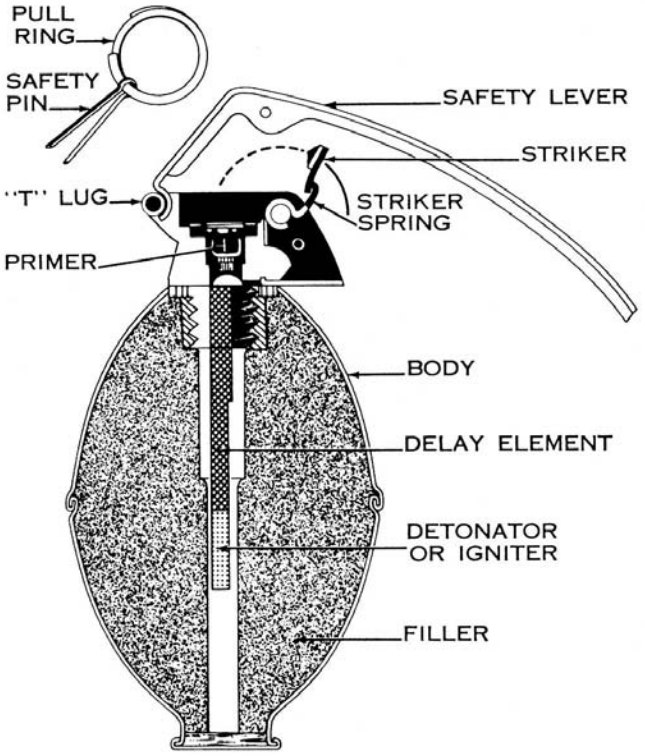


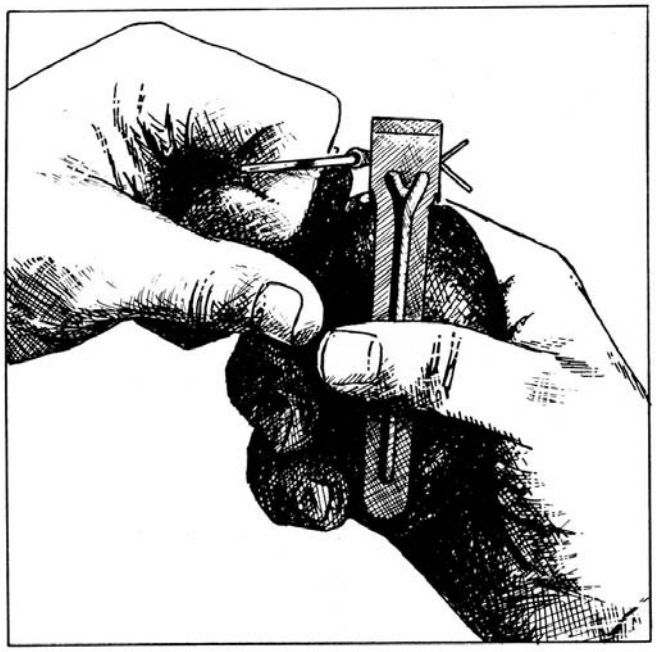
Figure 11-81.—Functioning of the fuze.

PROCEDURES FOR THROWING

For greater accuracy and range, the grenade should be thrown like a baseball, using the throwing motion most natural to the individual. It is important to grip the grenade properly. Figure 11-82 shows the proper position of the grenade prior to pulling the safety pin. First cradle the grenade in the fingers of the throwing hand. Hold the safety lever down firmly under the thumb, between the tip and first finger joint. In this way, the grenade fits snugly into the curved palm of your hand, giving you a firm, comfortable grip, but don't relax your thumb pressure on the safety lever until you throw the grenade.

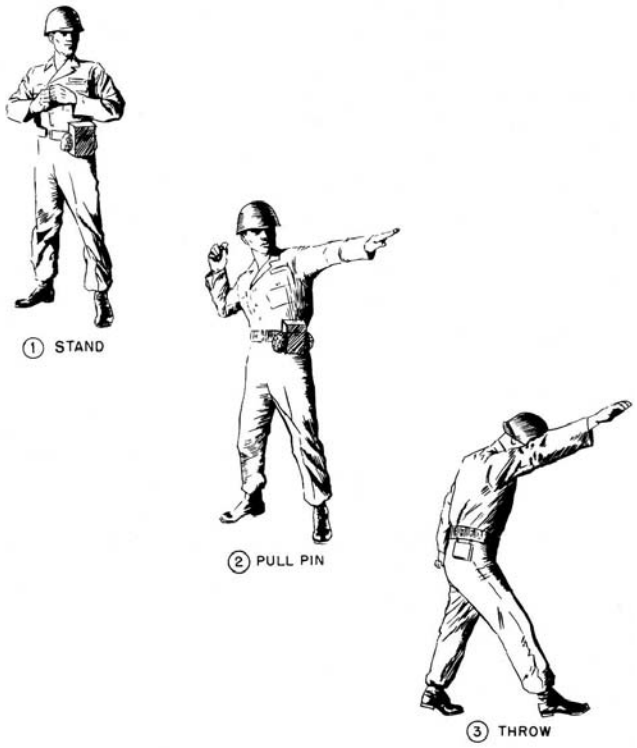
The first steps in grenade throwing are to develop good throwing habits, and several throwing positions. Four throwing positions are recommended: (1) standing, (2) kneeling, (3) prone, and (4) crouch.

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Figure 11-82. — Proper way to grip the hand grenade.



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Figure 11-83. — To throw from the standing position.

The procedures for throwing from the standing position are as follows:

1. Stand half-facing the target, with your weight balanced equally on both feet. Hold grenade chest high, using the correct grip (view 1 fig. 11-83).
2. Pull pin with a twisting, pulling motion. Cock your throwing arm to the rear (view 2).
3. Throw the grenade with a free and natural motion. As it leaves your hand, follow through by stepping forward with your rear foot (view 3). Observe the point for probable strike, then duck your head to avoid fragments or other effects.
4. Recover, then resume the original standing position.

Field Manual 23-30 explains the proper steps to be taken when using any of the other positions.

SAFETY

The following safety precautions must be observed when handling or using hand grenades:

1. Do not take any grenade apart unless ordered to do so by competent authority.
2. Do not tamper with grenades and do not recover or tamper with live grenades that fail to explode (duds). These duds are recovered and destroyed only by qualified personnel.
3. Do not pull the safety pin until you are ready to throw the grenade. If the safety pin will not pullout easily with a pulling-twisting motion, straighten its ends. In the majority of cases, this will not be necessary. Maintain a firm grip on the safety lever when removing the safety pin.
4. After you pull the safety pin, throw the grenade. Do not attempt to replace the pin in order to return it to a safe condition.
5. When throwing a fragmentation grenade without protective cover, drop immediately to a prone position, face down, with your helmet toward the grenade. Keep your arms and legs flat against the ground. Other men in the area who are exposed must be warned to drop to a similar position. Steel helmets must be worn at all times when using grenades.

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6. Although little danger is involved in using practice hand grenades, they require some degree of care in handling and throwing. You can throw the practice grenade a safe distance but, for the purpose of training and to preclude injury from an improperly loaded grenade, take cover. Wear the steel helmet, and keep all other personnel at a safe distance. Practice grenades that fail to function (duds) are not recovered for at least 10 minutes, and then only by trained personnel.

7. Grenades are issued in the "with fuze and without fuze" condition. They are not necessarily shipped in separate containers. The detonator of a fuze is very sensitive to heat, shock or friction. Army Field Manual FM 23-30 explains the safety precautions and steps taken when fuzing hand grenades.

DEMOLITION

If you are assigned to the Seabees, your job as a GM will have a lot to do with handling of explosives and demolition materials. Demolition equipment also is issued to ships for use in eliminating hazards to navigation, and the Gunner's Mates aboard are responsible for handling it.

A subject like this is not, of course, to be covered in a single section of one chapter. The use of explosives and associated blasting equipment for construction projects or large- scale demolition involves highly developed skills. These skills are developed through intensive training and a great deal of experience. It was pointed out at the beginning of this chapter that the information on demolition contained in this chapter is to familiarize the GM with the explosives and equipment used in demolition work. It is NOT intended as a self-teaching text to train GMs to become experts in demolition.

The discussion in this section will give you some idea of the tools used, and the names and uses of some of the more important explosives and other materials involved in this work. We will not try to cover the specific practical application of demolition explosives. For a much more detailed discussion, which includes other demolition equipment and techniques, you should read OP 2212, Vol. 1, Demolition Materials.

DEMOLITION CHARGES

The demolition explosive usually issued to ships is most often TNT, in cast or pressed form, but it may be Tetrytol. The explosives come in half-pound and 1-pound blocks (fig. 11-84). TNT is also the main component of the 55-pound demolition charge.

The half-pound and 1-pound blocks are issued in cardboard boxes, and can be used either by themselves or as boosters to set off larger charges. Both sizes are made with cap wells (or activator wells) into which you can insert blasting caps (which we will presently explain).

The Mk 2 demolition charges (fig. 11-85) now issued to ships have rectangular rust- resisting steel cases a little over 9 inches square and a little over 14 inches high. Mods 2 and 3 (earlier mods are obsolete) are similar except that the Mod 2 has handling lugs. The 1-pound TNT block that is used as a booster to detonate the charge fits into a cavity in the main cast charge; the blasting cap that sets off the 1-pound block is screwed into the block's activator well. Figure 11-85 shows the charge as set up for blasting. The blasting cap is not inserted until just before the charge is set off.

BLASTING CAPS

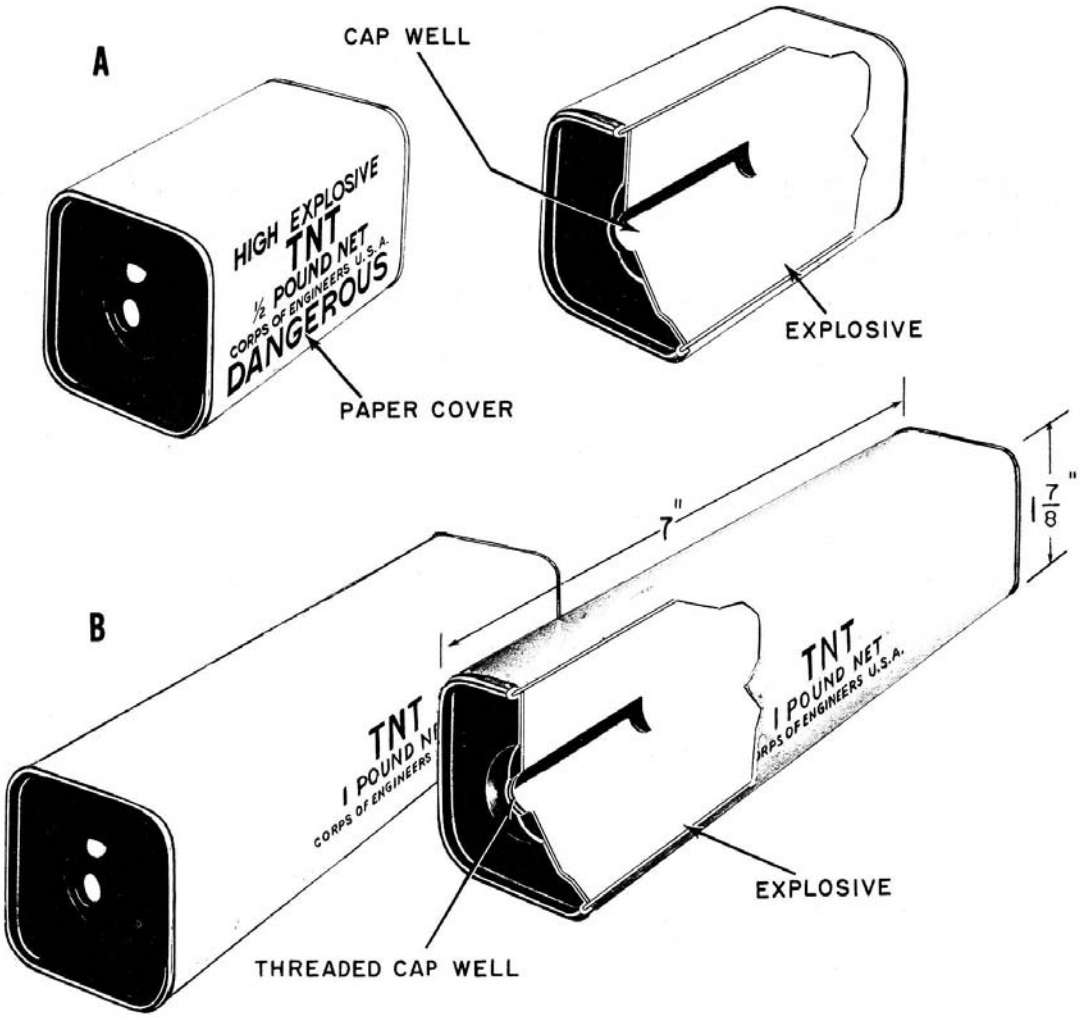
Blasting caps are used for initiating high explosives. They are designed to be inserted in cap wells of demolition charges, and are also the detonating element in certain land mine firing devices. Special military blasting caps are designed to detonate the less sensitive explosives like TNT, military dynamite, and tetrytol. Blasting caps are extremely sensitive and may explode unless handled carefully. They must be protected from shock and extreme heat and not tampered with. Blasting caps must never be stored with other explosives. Two types, electric and nonelectric, are used in military operations.

Nonelectric Blasting Cap

The Cap, Blasting Special, Nonelectric (fig. 11-86) is capable of detonating all standard types of demolition material that has been properly primed with the blasting cap for nonelectric firing.

The nonelectric blasting cap is contained in a clear-lacquered copper or aluminum tube. Three small explosive charges; the ignition

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Figure 11-84. — TNT blocks-A. 1/2-pound block. B. 1-pound block.

charge, priming charge, and base charge are assembled in layers in the partially filled tube. A portion of the tube remains empty so the blasting cap can be fitted over and crimped to a time blasting fuse or the snout of a coupling base.

A flame from either a time blasting fuse, detonating cord, or special firing device will ignite the ignition (flash) charge. This ignites the priming charge which, in turn, detonates the base charge.

This blasting cap, along with time blasting fuse, is used for firing demolition charges nonelectrically. This method, while not the preferred one (electrical firing is safer), is used under many conditions because of the light weight of the material and speed of placement and use.

NOTE: Fuse. A fuse is a slow-burning powder-filled cord that carries flame to an explosive or combustible mass after burning for a predetermined time. Fuze (Not to be confused with Fuse). The term fuze is a general one applying to any device that causes detonation, expulsion, or ignition upon the fulfillment of certain conditions. such as completion of a time delay, certain disturbances, impact, or inertia. The term is usually used in connection with bombs, pyrotechnics, or rocket heads. In demolition work, the term fuze is sometimes used interchangeably with the term firing device.

For all the details on the use of nonelectric blasting caps and their methods of ignition.

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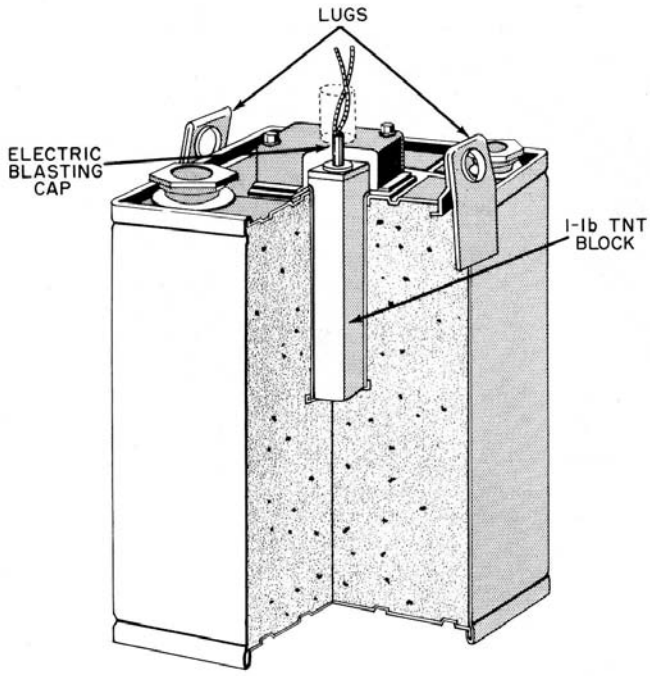


Figure 11-85. — Demolition Charge Mk 2 Mod 2 (prepared for electrical firing).

it is recommended that you read FM 5-25. Explosives and Demolitions and OP 2212; Vol. 1. Demolition Materials. Figure 11-87 illustrates the method used in setting up a cap and fuse for nonelectric firing of a demolition charge.

The burning rate of time fuse will vary by the way it is handled and the conditions under which it is burned. So testing of the burning rate is essential before setting up a charge for demolition with a nonelectric blasting cap. The burning rate of fuses issued by the NavOrdSysCom varies between 30 and 45 seconds per foot.

Refer to figure 11-87 while we briefly go through the procedure of setting up a charge.

STEP 1. Cut off and discard a 6 to 12 inch portion of the exposed end of the blasting time fuse. A test must be made of the burning rate by burning a 6-foot sample length of time fuse. The 6-foot sample length should be tested from the same coil that will be utilized for the shot. The sample length should be initiated by an M60 Time Blasting Fuze Igniter if available.

STEP 2. Cut off the desired length of time fuse and push it through the hole in the unthreaded end of the priming adapter.

STEP 3. Remove one nonelectric blasting cap from its box. Check inside the cap to ensure it is clear of obstructions. Check the end of

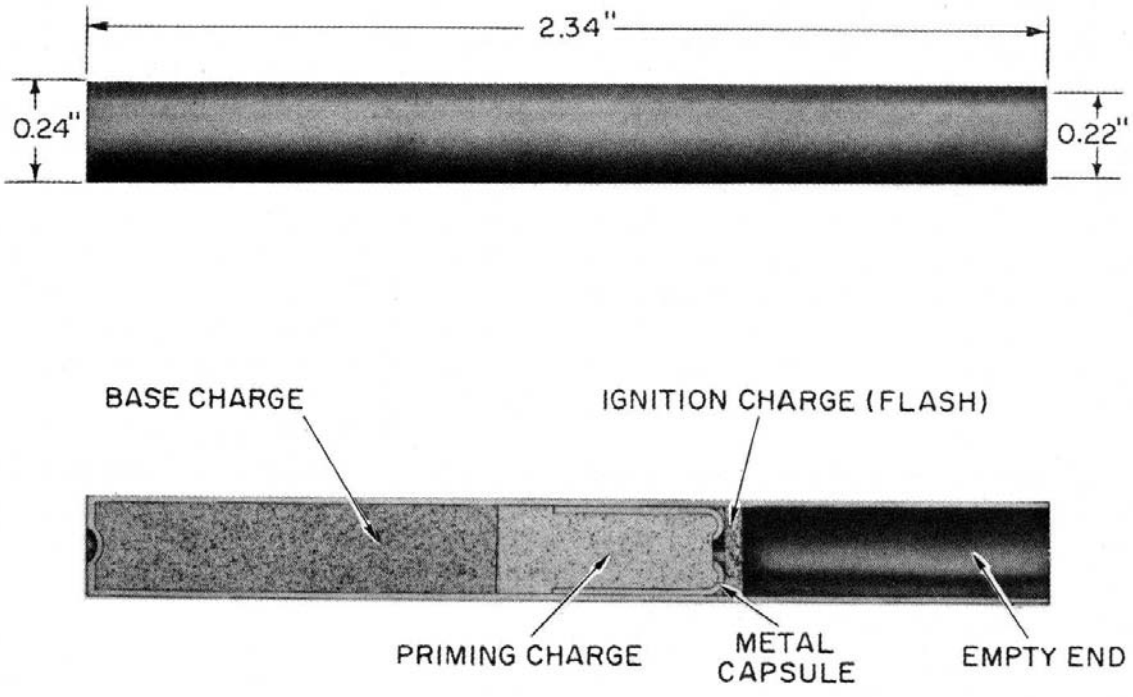
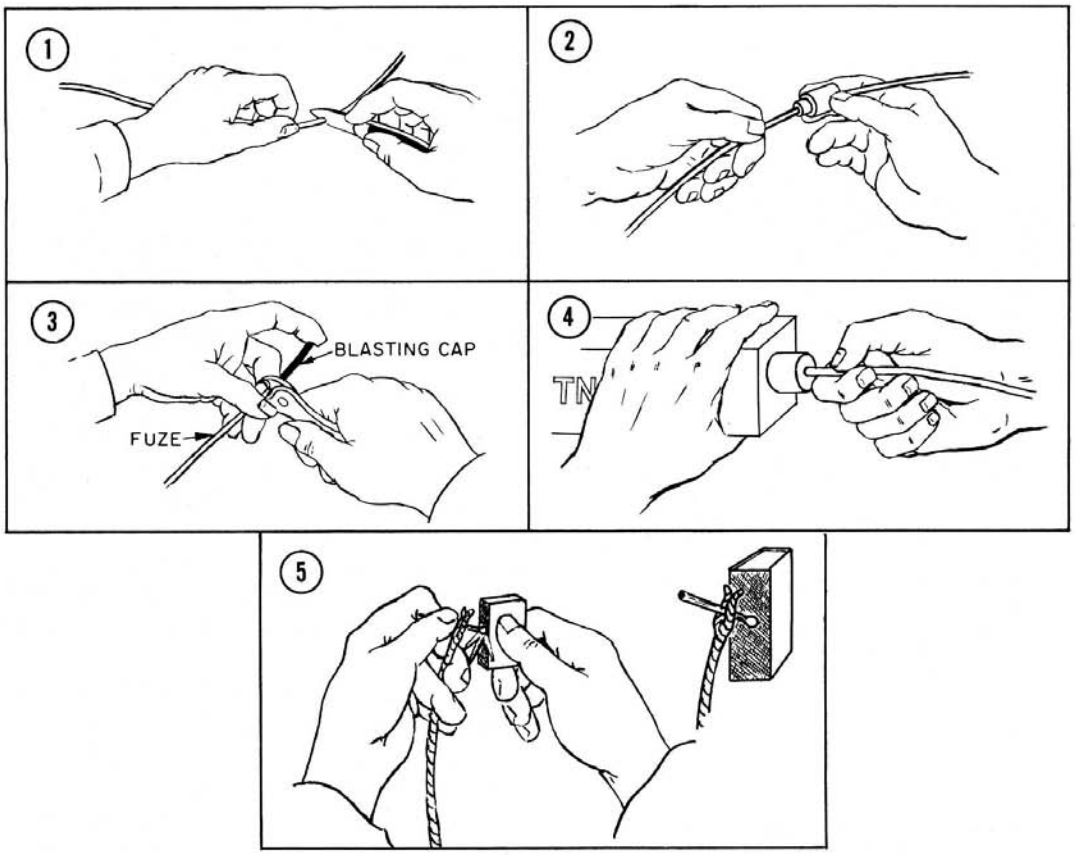


Figure 11-86. — Cap, Blasting, Special, Nonelectric.

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Figure 11-87. — Using cap and fuze for nonelectric firing of demolition charge (TNT block).

the time fuse to ensure a square cut. Insert the time fuse into the cap (DO NOT TWIST OR TAP). Crimp the cap onto the time fuse 1/8 inch from the open end of cap. Use only the crimping tool to crimp caps. (DO NOT CRIMP NEAR FACE).

STEP 4. Insert the cap into the activator well of the demolition charge. Screw the adapter into the charge to hold the blasting cap in place. If screw adapters are not available, some means should be taken to prevent the cap from coming loose from the charge, such as wrapping a string tightly around the block a few times and tieing it securely over the well as shown in fig. 11-88.

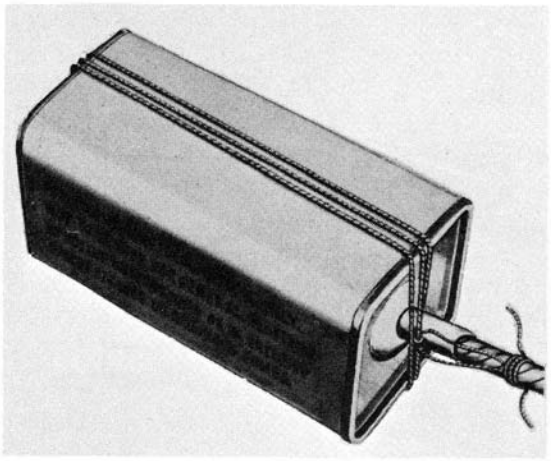
STEP 5. The blasting time fuse may be lighted two ways. The first, which should always be used if available, is the M60 Time Blasting Fuze Igniter. Since it is the safest and surest method. If the M60 fuze igniter is used, it should be installed on the time fuse, prior to the installation of the blasting cap. The second way is by a wooden match. Slit the time fuse longitudinally and insert a match in the slit so that the head of the match protrudes slightly from the side of the time fuse. Hold the match and match box as shown in illustration No. 5 of figure 11-87 and draw the abrasive side of the match box against the match head. Do not attempt to light the match unless you are prepared to do it successfully the first time. After you have struck the match, depart vicinity and take cover - even though the attempt appears to be unsuccessful. Walk calmly but smartly to a safe area - NEVER RUN. If a long distance is necessary to reach the safe area, then additional length should be allowed on the blasting time fuse. STEP

6. If a misfire is encountered, wait 30 minutes plus time for the blasting time fuse to burn.

Electric Blasting Caps

Figure 11-89 shows Cap. Blasting. Special. Electric Type. Nos. 1-10 Delay. The cap comes in 10 delay types, with each delay type differing in length as well as delay time. The delay

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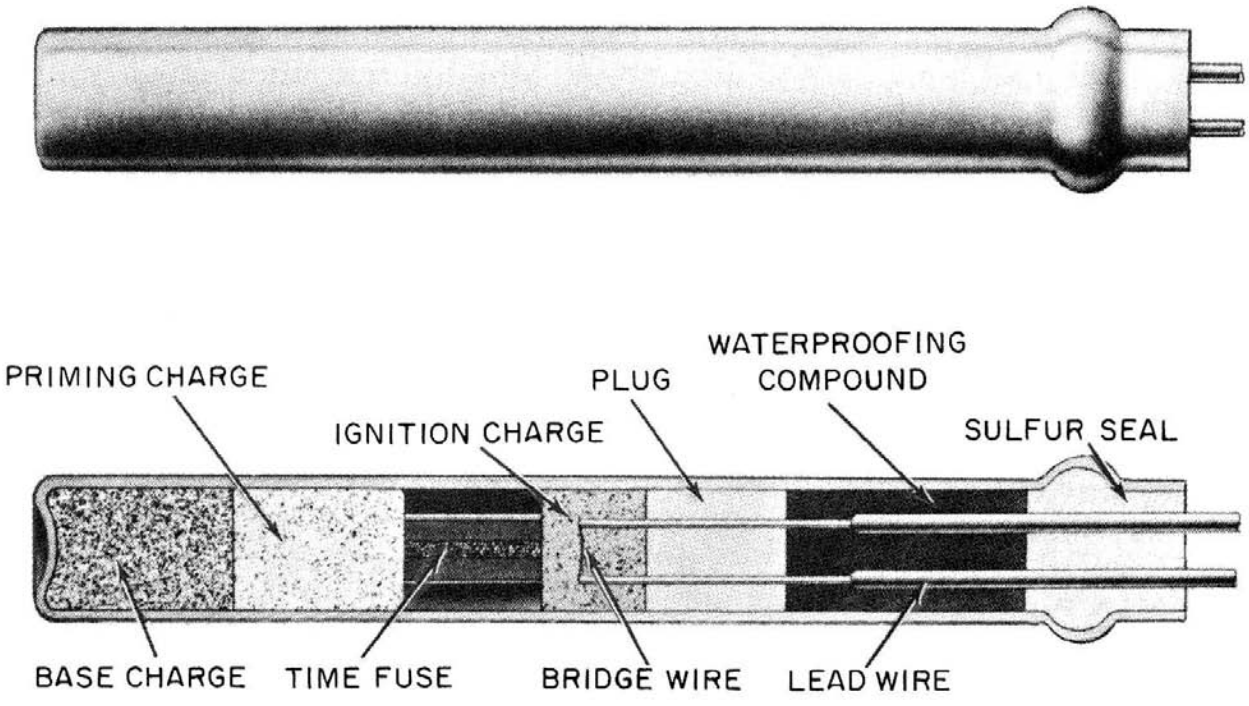


53.163(83B)
Figure 11-88.—Half-Pound Block of TNT Primed Nonelectrically.

time and consequently the length of a particular cap is dependent on the amount of delay charge contained in the delay element.

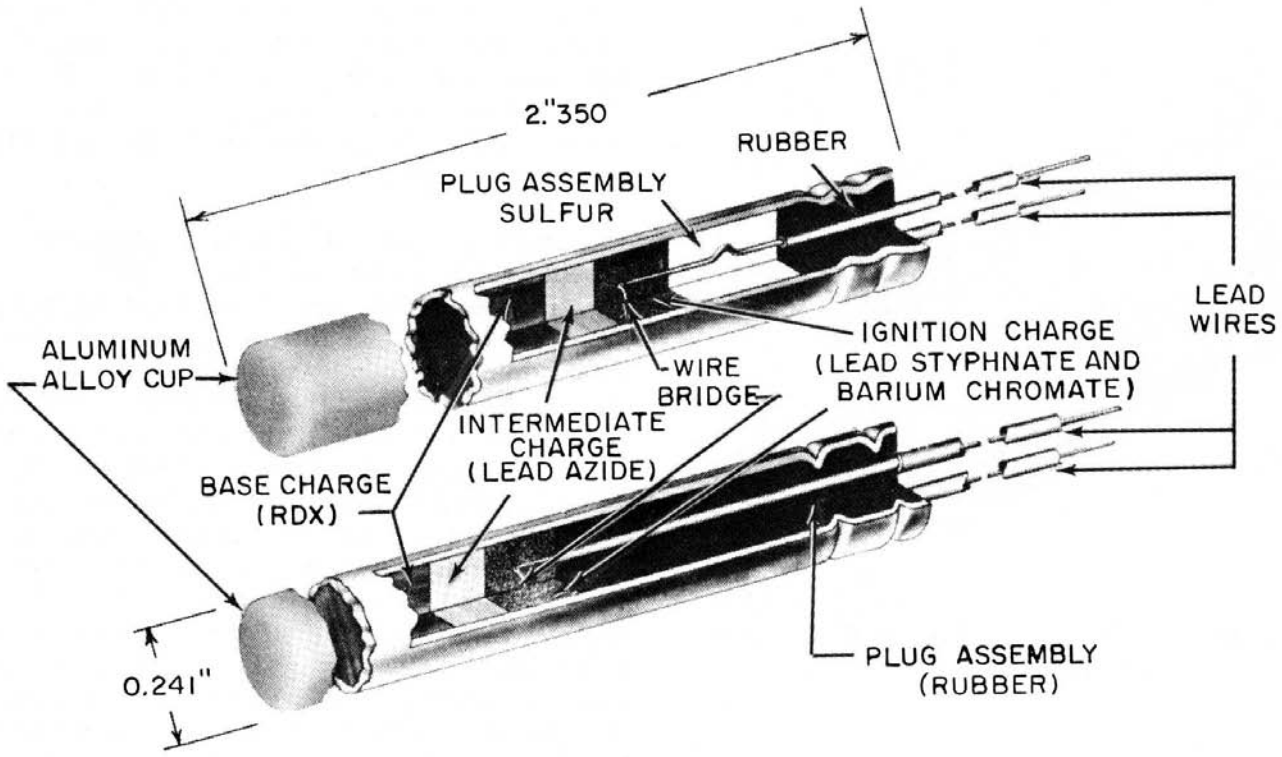
It can be seen in the figure that the construction of an electric blasting cap is simplicity in itself. An electric current heats a wire bridge, setting off the heat-sensitive priming charge which. in turn. sets off the PETN base charge. This detonates the TNT block into which the cap has been inserted; if the block is the booster to a larger main charge, the train of explosions comes to an end with the detonation of the main charge.

Another type of electric blasting cap is shown in figure 11-90. This is the Cap, Blasting, Electric. M6 and is used as the previously mentioned caps, to initiate high explosives. The cap consists of an aluminum alloy cup containing a base charge of RDX, intermediate charge of lead azide and an ignition charge of lead styphnate and barium chromate. The lead wires are 12 feet long and extend through a rubber plug assembly or a cast sulphur and rubber assembly into the ignition charge where they are connected to a wire bridge. The electrical characteristics of the M6 are so closely controlled that caps of this model, of different manufacturers, may be mixed in a firing circuit without causing misfires. A short-circuiting tab or shunt, as in other electric blasting caps, fastens the leads together to prevent accidental electric firing of the cap. These must NOT be removed until just before the cap is wired into the firing circuit.



53.157(83B)B
Figure 11-89.— Cap, Blasting, Special, Electric Type, Nos. 1-10 Delay.

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53.157.2(53C)

Figure 11-90. — Cap, Blasting, Electric, M6.

The electric blasting cap fits into the activator well of the demolition charge. But it doesn't fit tightly and can easily slip out. To hold the cap in the charge you use a primer adapter, a small plastic cylinder that screws into the threaded end of the TNT block and holds the cap in place. Figure 11-91A shows the adapter assembled in the block, with part of the adapter cut away to show how it holds the cap in place. Figure 11-91B illustrates the two steps in assembling the adapter and cap before they go into the charge. These steps are described in the next section of this chapter.

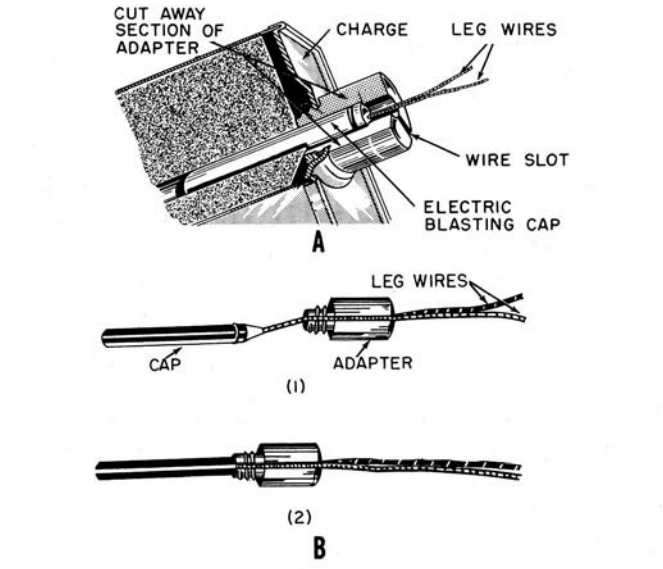
The other equipment used for electrical firing of demolition charges include a blasting machine for supplying current to the blasting cap (fig. 11-92), wire or cable of required length (the cable may be on a special reel like the one shown in figure 11-93 for connecting the machine to the charge, insulating tape for protecting the splices which connect the cable to the caps, and a blasting galvanometer for testing the circuit before you fire the charge.

BASIC PROCEDURES FOR SETTING UP AN ELECTRICAL CIRCUIT AND BLASTING

As a second class Gunner's Mate, you must be able to demonstrate your ability to work with the demolition equipment on your own ship. In general, this will most likely mean that you will have to show that you can work with the equipment we have discussed so far in this section. Of course, nothing you read here or elsewhere will make you a genuine expert with demolitions. You need real training and experience with the gear for that. But, so that you can see how all the equipment we have described is used together, let's take up, step by step, the procedure for preparing and setting off a demolition setup, using demolition charges Mk 2 Mods 2 or 3 and electric blasting caps.

1. Determine where the charges are to be placed. This, of course, depends on what is being demolished and the purpose of demolition. If you're sinking a floating hulk that's a menace to navigation, place the charges so that the hulk will go down promptly in water deep enough so

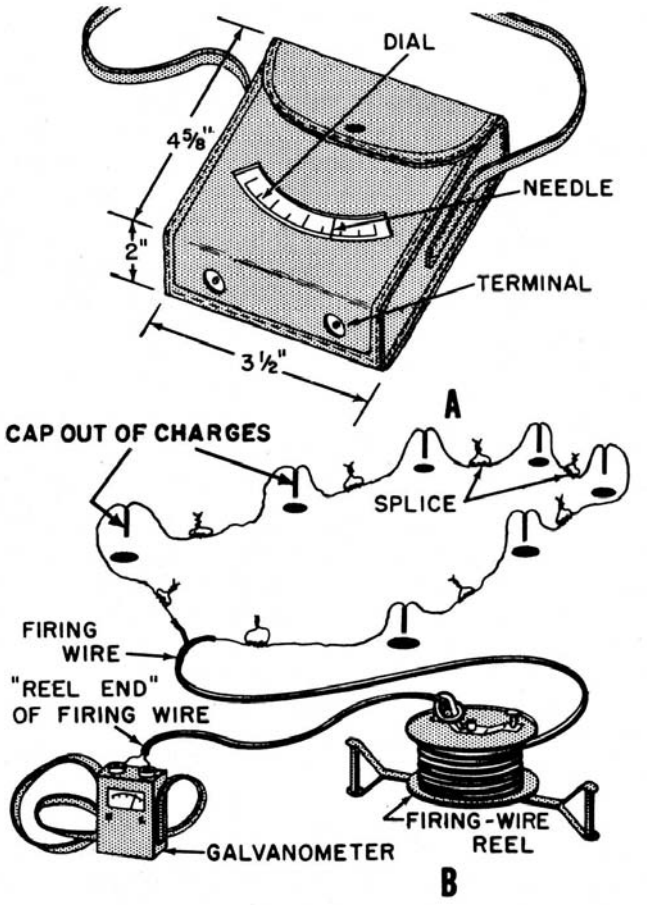
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53.158

Figure 11-91. — The priming adapter-A. Priming adapter and electric blasting cap assembled into charge. B. How to assemble the priming adapter and cap before assembly into charge.

that it will be out of the way. Make sure that all WT (water tight) doors are open. If you're scuttling your own ship (this sad possibility is fortunately not frequent, but it might be necessary in the event of imminent capture by the



84.3

Figure 11-93. — A. Blasting galvanometer. B. Testing the firing circuit.

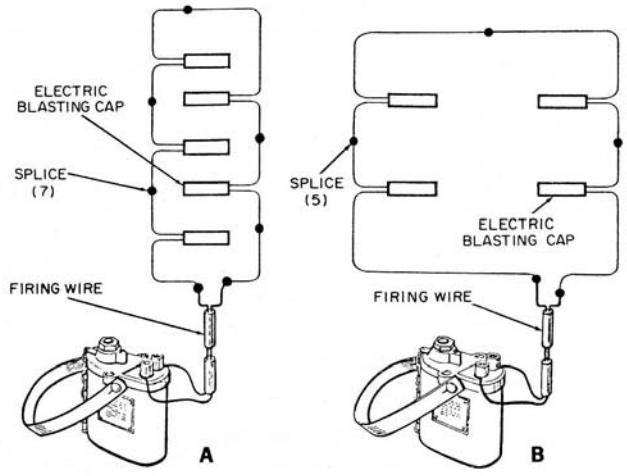


Figure 11-92. — A. Leapfrog Series Circuit. B. Common Series Circuit. 83.206

enemy), you must, in addition, make it as difficult as possible for anybody ever to use the ship again. Or you may be wiring up small charges to be used in destroying secret or confidential equipment against the possibility of capture. You'll be guided by orders from competent authority, but you must know something about demolition techniques.

2. Usually you will set off several charges at once. To do this, you place the charges and make up a circuit which includes the blasting machine and all the charges in series. First you wire in all the caps, then connect them to the cable, and then test the circuit. Here are these steps in more detail:

a. Make sure your caps are all of the same manufacturer. Except for the M6 which was described earlier, caps of different make should

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NEVER be used together in one circuit. Be sure not to use more caps than your blasting machine is designed to handle; it's better to use fewer. When you take caps out of their box, don't try to pry them loose with a sharp instrument; use your fingers, and slide them out carefully. Examine the caps before wiring them up; reject any that show signs of moisture or corrosion.

b. Grasp the wire above the cap and straighten the coils from the wire leads, being careful not to put tension between cap and wire leads. Place caps behind a suitable barrier or in a heavy gauge bucket. Test each cap individually as far away from the bucket or barrier as the leads will allow with the galvanometer. After test of cap, shunt the cap by twisting the two wire legs together. Do this until you have tested the number of blasting caps you will use.

c. You make electrical tests for demolition setups with only one instrument- the blasting galvanometer. (See fig. 11-93A.) You must NEVER use any other instrument. The blasting galvanometer is in a box, usually protected by a leather case, with a dial face on which you can see the galvanometer needle. It contains its own small batter as a source of current. At the base of the box are two terminals - flat metal discs. You test by touching the wires you are testing to the terminals. If current flows (and the currents indicated by the galvanometer are very tiny ones that will not set off a blasting cap), the needle deflects.

d. First you test both cable conductors BEFORE they are connected to anything. (Make sure their ends are not twisted together.) You should get NO steady indication on the galvanometer. (But it's O.K. for the needle to flick, then return to zero.) If you DO get a steady galvanometer needle deflection, there is a current leak or short circuit in the cable (caused by defective insulation or conductors touching each other). If the trouble cannot be rectified, use other cable that will test O.K.

e. Next, you wire the cable to the caps (but do NOT connect the blasting machine). Test the complete circuit by touching the cable terminals at the "reel end" (where the blasting machine will be connected) to the galvanometer. (See fig. 11-93B). This time you should get a definite steady needle deflection. If you don't, go over your circuit and repair it where it's broken. Test each splice and cap individually, if necessary. Or you may use the procedure described in the next section of this chapter for locating breaks in the circuit.

f. After testing the circuit, the next step is to set each blasting cap in its charge. Open the top of the charge shipping box. (The charge need not be removed from the shipping box to be used. however.) Break the paper seal protecting the activator well in the booster but don't use the blasting cap as a tool. Make sure there is no dirt in the well. Then slip the leg wires of the cap through the priming adapter's wire slot with the threaded end of the adapter pointing toward the cap (fig. 11-91).

If the leg wires don't slide readily through the slot, don't try to force them by pulling on the cap. Grasp the wires about 6 inches from the blasting cap and slide the adapter slot along the wires away from the cap. Tilt the adapter as you do this. to make the entry of the wires easier.

Now insert the cap gently all the way into the activator well; hold the adapter away from cap until it's all the way in. Then work the adapter down the wires until it reaches the well, and screw it in gently but firmly as far as it will go. Last, tie the wires so that the cable doesn't strain them at the cap. The Mk2 Mods 2 and 3 charges have cable anchors under the bolts in the booster covers that can be used to secure the cable.

If you haven't tested the circuit, do it now. If time permits, it may be a good idea to do it again even if you tested it before assembling the caps into their charges.

3. The last step is to connect the blasting machine. Make sure everything else is in readiness, and that all personnel have cleared the danger area. Connect the cable to the blasting machine. Most blasting machines have removable handles; don't put the handle on until after the machine is connected, and just before you blast. To operate the machine, twist the handle smartly through its full range.

4. If the blast does not occur, remove the handle of the machine (and put it into your pocket to make sure nobody operates the machine inadvertently) and DISCONNECT the machine. Then, after 30 minutes and only then. is it safe to investigate the trouble further.

PROCEDURE FOR LOCATING BREAKS IN THE FIRING CIRCUIT

Here is a way (illustrated in fig. 11-94) in which a break in the firing circuit may be located if the circuit test from the reel end indicates an open circuit, or if you have a misfire.

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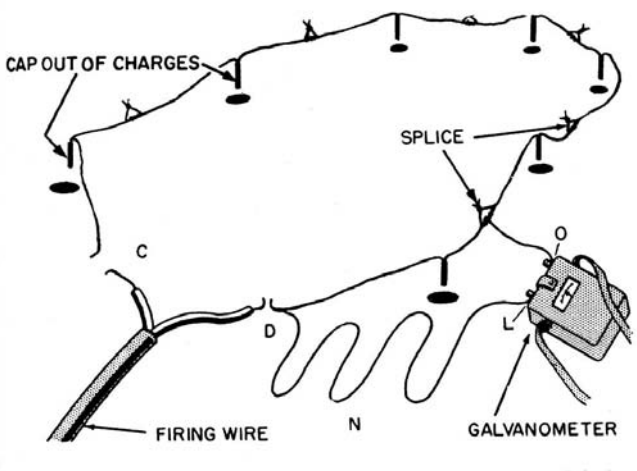


Figure 11-94. — Locating breaks in the firing circuit.

1. First disconnect the blasting machine. Make sure the two wires at the reel end of the firing cable are separated and not touching any conductor.

2. Connect the two spliced wires at the far end of the firing cable (C and D in fig. 11-94) with the blasting galvanometer. (Don't break the splices; just touch them to the galvanometer's terminals.) If the instrument now shows a complete circuit, these connections (C and D) or the cable are faulty.

3. If the galvanometer still shows an open circuit, connect splice D to one terminal (L) of galvanometer, using a wire (N) long enough to reach all connections in the circuit. Move around the circuit with the galvanometer, touching the other terminal (O) to all splices in succession. At the first point where the instrument shows an open circuit, you know that there is a break between that point and the previous one.

If the break is accessible, splice the broken wire. If you can't handle it as a misfire; use additional priming, or set up another charge close by. After this repair, continue the test to locate additional breaks. When all are repaired, test the circuit again from the reel end.

SAFETY

Here is a brief summary of precautions to ensure both reliability and safety, which you should bear in mind when blasting with electric caps:

1. Use only Army Engineer Special blasting caps of the types described previously for military demolitions. Other caps are weaker and may cause misfires.

2. Use only one brand of cap in anyone circuit.

3. Before using a blasting cap, inspect it for moisture. If you see any sign of dampness, use another cap. Never use a sharp instrument to pry a cap out of its box, and never take a cap out of its box unless you intend to use it.

4. All the firing in an electric blasting circuit must be the responsibility of one person only, and that man must know his job. He should keep the blasting machine, or its operating handle, on his person while the circuit is being wired to avoid accidental firing.

5. Before firing or testing, be sure the safety shunts are removed from all caps, but don't remove the shunts until you are actually wiring the caps into the circuit. If shunts are missing, keep the cap wires twisted together.

6. Never fail to use the blasting galvanometer to test your complete circuit before the blasting machine is connected. Don't depend on visual inspection only. Use no other device to test the circuit. Dry-cell powered ohmmeters, for instance, may set off the blasting caps.

7. Never yank the leg wires of an electric cap, or subject them to any steady pull. This is important to remember when you're installing the priming-adapter. Secure the leg wires and firing cable with strong twine or other fastenings so that pulls on the cable will not be transmitted through the splice or to the cap.

8. Don't connect the cable to the blasting machine until you're ready to fire and the danger area is clear. Unless you are actually testing the circuit or you are actually making ready to blast, it's a good idea to keep the free ends of the cable twisted together.

9. Avoid setting up an electric blasting circuit when there is a thunderstorm brewing. In general, protect electric blasting caps, whether in circuit or not, from any stray electric currents.

10. When you use the blasting machine, twist the handle sharply to be sure you get enough output to fire. If the machine has a thong, wrap it about your wrist to prevent the machine from slipping when you twist. Immediately after the blast, disconnect the machine and twist the cable

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conductors together. If your circuit misfires, try once more. If it misfires again, disconnect the blasting machine, put the handle in your pocket. and twist the cable conductors together before you try to investigate the cause of misfire.

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CHAPTER 12

GENERAL MAINTENANCE

INTRODUCTION

The purpose of this chapter is to give you maintenance information, and explain techniques and procedures applicable to guided missile launching equipment in general. Maintenance information for your equipment can be found in its OP, usually Volume 2 of a series.

The effectiveness and reliability of your equipment depend largely upon the care and attention you give it. A malfunctioning launcher power drive puts an entire missile weapon system out of operation. One open lead in a launcher-to-round connector destroys the effectiveness of a missile weapon system. Heavily grounded synchro transmission circuits introduce erroneous information into the receiving units of any weapon system. Improperly lubricated loading equipment may freeze up. If you can't load missiles, you can't launch them. And if you can't get them into the air, you might as well stay tied up to the dock. But there is no point in belaboring the obvious. You can probably think of many instances of improper maintenance that would put a weapon system out of commission or reduce its effectiveness. We include the above points only to illustrate how important your maintenance activities, as a GMM, are to the fighting effectiveness of your ship. Too many of us feel that the small maintenance tasks we are called on to do, like setting up loose screws on terminal boards, are unimportant. Admittedly, this is a long and boring process. But it must be done. Otherwise the vibration of the ship will loosen the screws a little more each day until finally they fall out. What happens then? Electrical leads are detached, and you may spend hours tracing the trouble. And in the meantime your ship may be defenseless.

DEFINITION OF MAINTENANCE

The work you do on equipment falls into two broad categories: (1) actions you take to reduce or eliminate failures and to prolong the useful life of your equipment, and (2) actions you take when a part or component has failed and the equipment is out of service. Therefore, we can think of the whole business of general maintenance as consisting of PREVENTIVE maintenance and CORRECTIVE maintenance. Figure 12-1 shows these two aspects of maintenance and the phases of each type.

In maintenance work of any type you must use knowledge and skills of two fundamental kinds. First, you must have SPECIFIC information which applies only to the particular equipment you are working on. Second, you must have and use certain GENERAL skills and knowledge which apply to many kinds of equipment.

The specific information required consists of special maintenance procedures and processes. These are detailed step-by-step directions which have been approved by NAVORD SYSCOM, type commanders, or other authorized sources. You can find specific maintenance information in the equipment OP or in type commander checkoff lists, and the Maintenance Requirement Cards (MRC) for the equipment.

General maintenance skills and procedures are based on knowledge which is not contained in equipment OPs but must be learned on the job and from Rate Training Manuals such as this one. And it is this kind of information that forms the basic content of this chapter.

PREVENTIVE MAINTENANCE DEFINED

What is preventive maintenance? Let's use a familiar experience to illustrate the meaning of the term. You have probably owned a car or have taken part in keeping one in good shape. Undoubtedly you found out that there is more to having a car than simply driving it. You have to put air in the tires. Oil and water must be checked periodically. The car has to be washed and waxed to prevent the paint from peeling off.

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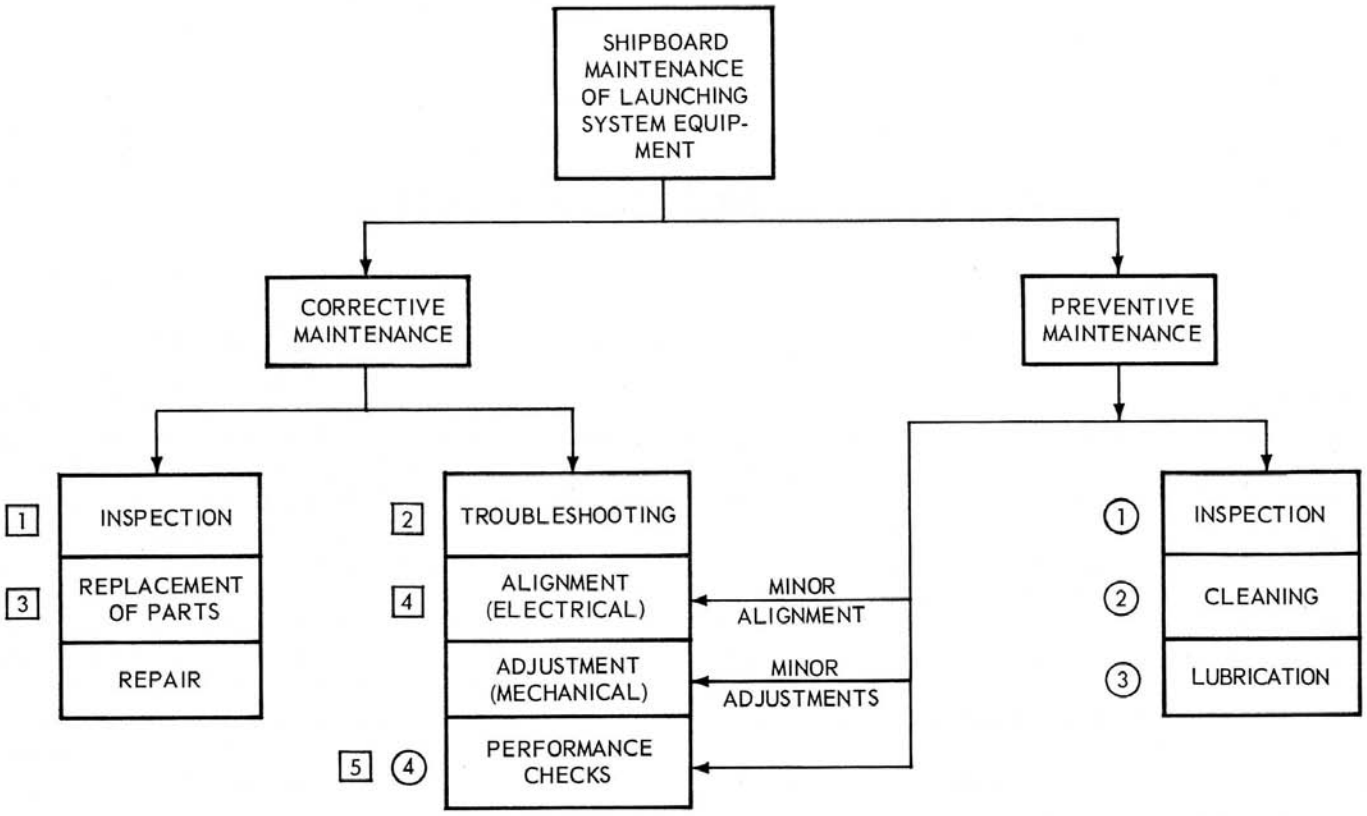


Figure 12-1. — Phases of maintenance.

Periodically, the brakes must be adjusted, the spark plugs cleaned, and the motor tuned up. If you faithfully follow the manufacturer's suggested maintenance program, the chances are your car will not be laid up in the garage for long repair periods.

The procedures for maintaining launching system equipment are not exactly those you follow in taking care of a car, but the purpose is identical, and that is to stop trouble before it starts.

Preventive maintenance, then, consists of the care, upkeep, and minor repairs and adjustments performed by the GMM to ensure the best operation of his equipment and to reduce the chance of sudden equipment failure. It involves four major types of activity, as shown in figure 12-1:

1. Periodic inspection.
2. Periodic lubrication.
3. Periodic cleaning.
4. Periodic performance checks.

In certain of the following sections of this chapter we will discuss each of these aspects of preventive maintenance. But before we do, let's consider the second maintenance category - corrective maintenance.

CORRECTIVE MAINTENANCE DEFINED

When preventive maintenance or the poor performance of equipment reveals that a casualty or malfunction exists in a system or equipment, some form of corrective maintenance is required. Corrective maintenance includes those activities needed to restore equipment to its designed capabilities or efficiency. This includes the repair of battle damage or damage caused by wear or accident.

Corrective maintenance generally is performed in five phases: (1) inspection, (2) troubleshooting, (3) repair of replacement of parts, (4) alignment and adjustment, and (5) performance checks. Occasionally there is an overlap of some of the

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activities of preventive and corrective maintenance; therefore; it is difficult to find a sharp dividing line to separate the two.

MAINTENANCE LEVELS

Maintenance work on ordnance equipment is done on three distinct levels. First, there is maintenance work done on board ship. The work done here is called Organizational Maintenance. It is done on a day-to-day basis and includes the preventive and corrective maintenance performed by ship's force.

But the ship's force hasn't the facilities nor always the skills to perform certain less frequent but necessary maintenance operations. Examples of this type of operation are star-gauging guns, systems alignment, and special maintenance problems. Work of this kind is done aboard tenders and repair ships by highly skilled personnel. This second level of maintenance is called Intermediate Maintenance.

Finally, there are some jobs, such as the major overhaul of hydraulic systems, lifting of launchers to inspect and repair roller paths, and overhaul of main sprinkling control valves, that are customarily done in naval shipyards. Such work may be done by yard workers, by the ship's force, or by both. Maintenance work done in yards rather than afloat is termed Depot Maintenance.

ORDNANCE DRAWINGS

When we talk about NAVORDSYSCOM drawings or naval ordnance equipment in general, certain terms that need defining always appear. Some of these terms are: part, subassembly, assembly, and major assembly.

A PART can mean an item that is made up of a single piece of material such as a casting, or a machined or stamped piece of metal. Tachometers, synchros, valves, lubrication fittings, and other units that are not usually disassembled during maintenance fit into this category. If two or more single pieces are welded, brazed, or soldered together, you can call these items parts.

A SUBASSEMBLY refers to a combination of two or more mechanically connected parts which can be disassembled without destroying their designed use. A solenoid valve is an example of a subassembly. If you remove the solenoid, it can still function as a solenoid, and the valve can be operated by hand.

An ASSEMBLY consists of mechanically connected subassemblies and/or parts. As a combination, and assembly is capable of performing a specific function. Despite the rigorous definitions laid down here, you must keep in mind that the distinction between an assembly and a subassembly is not always exact.

A MAJOR ASSEMBLY refers to an assembly which has been assigned a Mk and Mod number. A launcher guide arm is a good example.

A SUBSYSTEM is a major functional part of a system that can operate alone. An example is a missile launcher. It can train, elevate, and launch missiles even if the feeder is out of service. Of course an inoperative feeder means that you will have to find some other way of putting missiles on the launcher. You might use a chain fall, for instance. It's been done before. But the point is that once you do load a missile on the launcher you can aim and launch the weapon independently of the rest of the system.

A SYSTEM is a major functional part of a complete weapon system. A guided missile launching system and a fire control system are good examples.

Manufacturers of ordnance equipment make drawings of their equipment. Copies of these drawings, reproduced by blueprinting, the ozalid process, or in some other way, are supplied to every ship or shore installation that has the equipment or for some other reason requires copies or prints of the drawings. Many drawings are reproduced in OPs and other technical manuals. Many of the drawings you'll see are made by the NAVORDSYSCOM; others are made by the contractors who manufacture the equipment for NAVORDSYSCOM. In any case, ordnance drawings are all set up similarly.

TYPES OF DRAWINGS

Drawings differ, depending on their purpose. The main types of drawings, as classified according to purpose by NAVORDSYSCOM, are:

1. GENERAL ARRANGEMENT DRAWINGS. This kind of drawing shows the completely assembled equipment. It indicates general appearance and relationships of important component assemblies, and identifies the drawings that describe the components of the equipment. The purpose of this type of drawing is to provide for equipment familiarization. Important dimensions of equipment are shown, and major assemblies are identified. Figure 12-2 is an example of a general arrangement drawing.

2. INSTALLATION DRAWINGS. These show such features as mounting pads and brackets, shock mounts, points of entrance for cabling and

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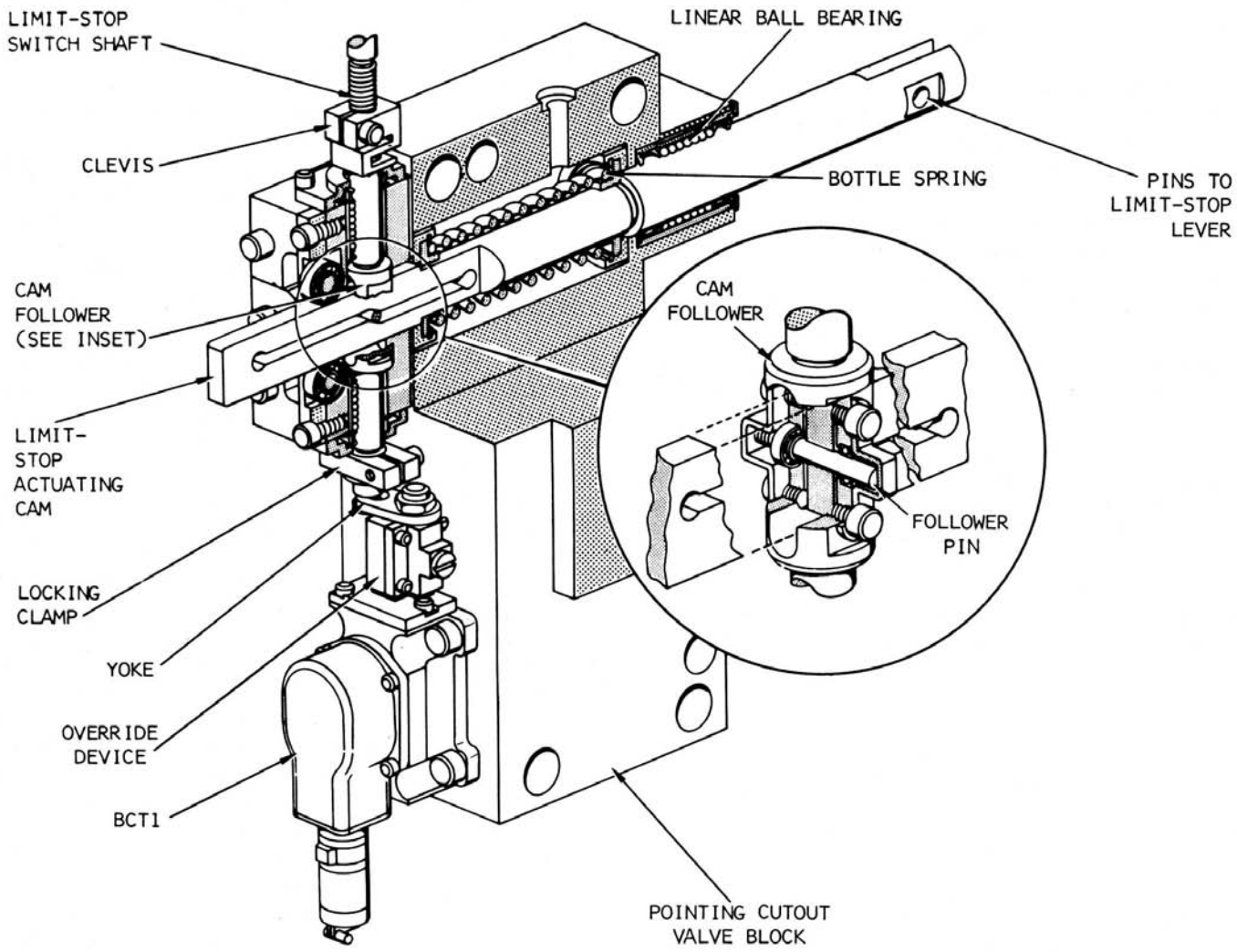


Figure 12-2.—General arrangement drawing.

mating mechanical parts, type of cable required, dimensions of mounting hardware needed, and directions for orienting the equipment and securing it to place on bulkhead or deck. One variety of this type of drawing, called an outline drawing, shows overall dimensions and clearances required for operating and servicing equipment. These drawings may also give such vital statistics on the equipment as weigh, ventilation required, the degree to which the equipment enclosure is protected against spray and dust, and so on.

3. ASSEMBLY AND SUBASSEMBLY DRAWINGS. These show the constructional details of the assemblies of which the complete equipment is made up. In general. you can think of an assembly (or subassembly) as any group of two or more parts assembled to make up a unit. As we said before, the words assembly and subassembly are sometimes used pretty loosely, but the idea is plain enough. In any case, an assembly drawing is intended to enable a properly equipped shop to make up the finished assembly from the prescribed parts and assemble them. Along with the bill of materials (usually a part of the drawing). it shows what materials and parts, how many of each, and what sizes and types go to make up the complete assembly. It also shows dimensions, and makes reference to other drawings.

4. DETAIL DRAWINGS. When you disassemble any piece of equipment far enough, you eventually get down to individual pieces that cannot be disassembled any further. These are represented by

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DETAIL DRAWINGS, which give all the information that a properly equipped shop will need to make the pieces exactly as needed.

5. WIRING DRAWINGS. The main purpose of a wiring drawing, usually called a wiring diagram. is to show you how to wire apiece of equipment or system. There are several kinds of wiring diagrams:

An EXTERNAL wiring diagram shows how to connect an item of equipment to the ship's wiring system or to other pieces of equipment. It shows terminal boards, binding posts, jacks, and other connection points and devices, and identifies them by letters and numbers. Lines denote the electrical conductors to be installed. The drawing shows the size and type of wire to be used; the kind of insulation, shielding, duct work, and armoring specified, as applicable; lengths of cable needed; where ground connections are to be made; where joints must be soldered, welded, or clipped; and so forth. And it specifies the kind of current (d-c or a-c), frequency, and voltage carried by each conductor.

An INTERNAL wiring diagram does the same for wiring inside the equipment. It also identifies and shows where fuses are, the size and type to be used, and their circuits. It locates, and identifies with standard symbols, all lamps, motors, synchros, resistors, capacitors, transformers, chokes, switches, relays, and other electrical components in the equipment, and gives their electrical values. It identifies all the terminals and connection points. This is one of the most useful kinds of drawings for electrical maintenance and troubleshooting.

An ELEMENTARY wiring diagram is about halfway between the diagrams we have just discussed and the SCHEMATIC, to be taken up shortly. It shows terminal and connection points, component locations and valves, and so on, but it also is so arranged that it's much easier to follow and understand the circuit than with the usual wiring diagram. The elementary wiring diagram, like the pure schematic, has little respect for the actual sizes and shapes of parts or equipment, or for their physical location or orientation. The traceability of the circuit is a much more important consideration.

ISOMETRIC wiring diagrams show the routing of cables in a large installation.

6. SCHEMATIC DRAWINGS. About the only general statement you can make about schematics is that their primary purpose is to help the user understand the functioning of the equipment. Electrical schematics are most common, but you also see hydraulic, mechanical, and pneumatic schematics of systems. You will find schematics of all the types mentioned in OPs, and they are very helpful in learning how a system works.

One type of schematic that you'll find helpful in understanding and tracing the functioning of moving parts - especially rotating mechanical components-is the MECHANICAL SCHEMATIC or GEARING DIAGRAM. When they appear as NAVORDSYSCOM drawings, diagrams have such information as pitch and number of gear teeth on a gear, functions of cams, connections between electrical and mechanical devices (such as switch contacts operated by cams), and a great deal more. You can get exact information on equipment mechanisms from a gearing diagram something that other types of schematics often give in only an approximate way, if at all.

7. LUBRICATION DRAWINGS. A lubrication drawing, called a lubrication chart, for launching systems and other ordnance equipment, is often a general arrangement drawing, or a group of them showing several views, in which lubrication fittings and other points are called out by labels. Symbols representing the types of lubrication to be used are displayed on the chart. The OP on every equipment normally has the required lubrication charts in the appendix, or in the section on maintenance.

8. SKETCHES. NAVORDSYSCOM recognizes two kinds of sketches - LINE SKETCHES and INDEX LISTS.

LINE SKETCHES are made up and treated much as regular engineering drawings are. The main difference between them and engineering drawings is that sketches apply to experimental or preliminary ordnance work. You will come across them if you are assigned to a precommissioning crew or some activity that is doing ordnance development work.

The term INDEX LIST is a general name that includes a number of different types of lists of drawings. One type, the LIST of DRAWINGS or LD, is discussed in further detail below. Others are:

Index to List of Drawings. This is the same as the Master List of Drawings, discussed below.

Index to Assemblies. This is a tabulation of all the assemblies of some type of ordnance gear-for example, all the different assemblies that make up a launcher are included in this type of list.

9. LISTS OF DRAWINGS (LDs). A List of Drawings, as mentioned above, is considered by

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NAVORDSYSCOM to be a variety of a sketch. In itself. this detail of classification isn't especially important in your job. but it is worth remembering that an LD is a key to the drawing system used by the NAVORDSYSCOM. Beginning at the top of the system. a MASTER LIST of DRAWINGS, or Master LD, is prepared for each major system (such as a launching system). This list includes all components of the equipment concerned. Each component is itemized by assemblies, subassemblies, and details on a separate LD. Thus, you will have a component LD for the launcher, feeder, and so forth.

The identifying number for each component LD is given, together with the general arrangement drawing number, on the master list of drawings for the system. Each component LD also shows the special tools required to service that component. By reference to the list of drawings and the drawings for the mark and mod of a given assembly and subassembly, it is possible to work down to an individual part and to identify the correct nomenclature, drawing, piece number, design dimensions, tolerances, and all other necessary maintenance information.

HOW YOU USE DRAWINGS

When we refer to a "drawing" or "engineering drawing" without qualification, we usually refer to an assembly, subassembly, or detail drawing. Such drawings, as we have seen, explain how to manufacture some part or assembly. And they are also a valuable guide for you in overhauling and repairing the equipment. These drawings are valuable not only because they show how the parts fit (though this is very important itself). but also because they describe and enumerate the fastening hardware you need to put the assembly together (including exactly the proper bolts, nuts, patent fasteners, pins, and so on). And they also show the minor but essential parts that the assembly must have so that it will continue to function as the designer intended it to. A watertight enclosure will leak if it hasn't exactly the gasket named in the drawing; screws will loosen if they haven't been assembled with the proper lock washers specified in the drawing; and nuts will work free if they haven't been secured with the cotter pins listed in the drawing.

The other types of drawings are equally valuable. General arrangement drawings are good references for the exact nomenclature of major units and as guides to drawings on component assemblies. Installation and outline drawings contain just the information on clearances and dimensions that ship's personnel require when a new piece of equipment is to be installed, and they show how to arrange the piping and wiring to be connected to it. External wiring diagrams show just how to hook equipment into the ship's wiring; after installation, they help in troubleshooting for faulty circuits and malfunctioning components, and in electrical alignment of synchros and other data transmission devices. Internal wiring diagrams are equally useful for making circuit checks in case of trouble in the equipment. Elementary wiring diagrams are helpful in training personnel, and can be used in circuit checking too. And LDs are helpful for guidance in tracking down through the maze of drawings the particular piece of information you may be looking for.

Every ship carries copies of drawings on its equipment, in the form of blueprints and photoprints. These copies are assembled into sets, each set covering one item. Photoprints usually are bound in books. Aboard ship, both blueprints and photoprints are called "ordnance drawings."

These drawings will be available to you. You'll find them either in a special file in you shop, or in the custody of your department head. Also, many of the drawings that you will need as maintenance aids are in the OPs. In fact, all graphic and printed maintenance material will soon be incorporated in the technical manuals. Then you won't have to assemble the printed material you'll need on the job. Make use of the drawings; they'll help you to become familiar with the ordnance you will overhaul. (Remember, when you handle them. to treat confidential drawings as you would any other confidential publication.)

Down in the lower right-hand corner of each drawing you'll find a number. That's the "drawing number." On each detail that's pictured in the drawing, you'll find another smaller number. These are the "piece numbers." These numbers identify both the hardware and the drawing. Sometimes you'll find a letter after the piece number; that shows how many times that piece has been changed or modified since the original design.

Every part of every ordnance device (unless it's very small) has its drawing and piece number stamped on it. The first number is the drawing number; the second is the piece number. For

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example, you'll find numbers like 120460-2. Read that: drawing number 120460, piece number 2.

Look for these numbers, and use them. Refer to them when you report on a particular piece, or when you order new parts.

References on Drawings

We're not going to go on to discuss in full detail how to read other kinds of schematics of assembly and detail drawings. For elementary information on the theoretical background of drafting, on how to read drawings of all types (including other kinds of schematics), how to make them, what you can find out from the title box, standard sizes of drawings, and the like, see the basic course, Blueprint Reading and Sketching, NavPers 10077-C. If you are interested in the techniques of drafting, you may want to look up the Rate Training Manual for Engineering Aid. But with mastery of the basic course, Blueprint Reading and Sketching, NavPers 10077-C, and the material presented in this chapter, you are adequately armed to deal with ordnance drawings so far as your job as a GMM is concerned.

PLANNED MAINTENANCE

In recent years ordnance equipment has become so complex that serious maintenance problems have developed. You can understand why complexity of equipment leads to maintenance problems if you will consider for a moment what makes up a launching system. It consists, as you learned in chapter 6, of three or four major sub-systems. Each subsystem, such as a launcher, contains many components, assemblies, subassemblies, and parts. To illustrate, some launching systems contain over 1500 relays. Every item we have just listed requires some sort of maintenance. When you think of the hundreds of mechanisms and thousands of parts in launching system that need to be kept in operating condition. you can see that the scope of the maintenance task is tremendous. And since there are so many parts in a system, the chances of a malfunction increase considerably.

All the parts, assemblies, and subsystems in a missile launching system are interrelated; they work together as a whole. In some instances if a single part breaks down the entire system becomes inoperative.

Compared to other ordnance installations, launching systems are large and require many men to keep them in good operating condition. But there is a limit to the number of skilled technicians the Navy can find and assign to a launching system. And we probably don't have to tell you that GMMs are scarce. But enough men are assigned to do the overall maintenance job if it is planned, scheduled, and carried out efficiently.

To meet the challenge of the maintenance problem caused by equipment complexity and limitations on the number of personnel that can be assigned to a launching system, the Navy has set up a new maintenance program. The program is called the Planned Maintenance Sub-System (PMS). The complete system includes material and manpower management and is called the Standard Navy Maintenance and Material Management System (3-M System).

While the 3-M System is a new one, it is not the first attempt to standardize maintenance so it will be uniformly good and also simplified.

HISTORY OF MAINTENANCE PLANS

Let's briefly discuss the maintenance systems in their evolutionary order. The first such system was call POMSEE and dealt only with electronic equipment. The word POMSEE stands for "Performance, Operation, and Maintenance Standards for Electronic Equipments." The radar is an integral part of some weapons control systems and it is difficult to separate the radar's operation from that of its associated equipment.

The Satterwhite system was developed aboard ship by Chief Fire Control Technician Charles E. Satterwhite. This was a complete maintenance system for the Gun Fire Control System Mk 56. The maintenance system had a consolidated list of all the maintenance jobs arranged in a systematic schedule. Each job was described on a Job Description Card (JDC). The job was broken' down into simple, easy to follow steps; the tools, materials, test equipment, and references needed to do the job were listed. Illustrations were provided when there was a need to locate or to clarify a point in the job description. Little has been left to chance. The Satterwhite system was not confined to fire control equipment, for which it was originated, but job description cards were made for ordnance equipment, including missile launching systems.

The PRISM system, "Programmed Integrated System Maintenance," was a logical evolution of the Satterwhite System and incorporated many of its features. But some fire control systems, particularly the missile systems, are an integral part of a weapon system, and its maintenance requirements are closely integrated with the

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entire system. The cards to be used with the PRISM system were called Maintenance Requirement Cards (MRC).

The Integrated Maintenance Plan (IMP) was devised to provide a maintenance program for an entire weapon system instead of the individual equipment within the system. IMP contains a complete schedule of all the maintenance events for the system. The schedule is arranged to ensure efficient use of the men involved and a comprehensive testing and servicing of the equipment. Since IMP includes the whole weapon system, close coordination between ratings associated with the system is necessary. The next obvious step is to expand the maintenance system to include the entire ship.

The Daily System Operability Tests (DSOT), and other test procedures (to be performed at less than daily frequencies), comprise the testing portion of IMP. The testing portion is tied or keyed to associated system troubleshooting aids. These aids consists of Logic Trees, for isolating faulty equipment of the system, and Pyramids, for isolating faults within an equipment of the system. Logic trees and pyramids will be covered under troubleshooting in the next chapter.

The cards used with the IMP system are also called Maintenance Requirement Cards (MRC). If you were to compare a JDC and MRCs for the same equipment or type of equipment, you could readily see the similarity in the information supplied for the job at hand. An earlier printing of this text has reproductions of sample cards. An MRC may be just one card, but more often than not, there are several pages attached to each other by a spiral fastening. The cards are plastic coated to resist stain and damage.

NAVY MAINTENANCE AND MATERIAL MANAGEMENT SYSTEM

The Navy Maintenance and Material Management (3-M) System has been implemented in the Navy as an answer to the ever present problem of maintaining a high degree of material readiness. Although the 3-M system is designed to improve the degree of readiness, its effectiveness and reliability are dependent upon you the individual. The accuracy with which you perform your work, along with the neat and complete recording of required data on the prescribed forms, is one of the keys to the degree of readiness of your ship and therefore is a reflection on your success as a petty officer.

The 3-M system is a uniform plan of maintenance with an internal central management aboard ship to coordinate a shipwide maintenance system and an external central management to coordinate the Navy-wide maintenance system and maintenance data collection. The 3-M system was developed by the office of the CNO to coordinate the work of NAVSUP, NAVORD, NAVAIR, and NAVSHIP with respect to equipment maintenance.

The 3- M system is not envisioned as a cure for all equipment problems and attendant maintenance resource demands, nor does it eliminate the urgent need for good leadership and supervision based on experience and reasoned judgment. The system will, however, produce a logical and efficient approach to the solution of maintenance problems, and a large reservoir of knowledge about maintenance. Proper application of these system products will result in improved equipment performance with less maintenance effort and will lead to meaningful improvements in equipment design and logistic support.

The two basic elements of the 3-M system are the Planned Maintenance Subsystem (PMS) and Maintenance Data Collection Subsystem (MDCS). The Planned Maintenance Subsystem provides a uniform system of planned preventive maintenance. The Maintenance Data Collection Subsystem provides a means of collecting necessary maintenance and supply data, in a form suitable for rapid machine processing. A man-hour accounting system is used aboard repair ships and tenders in conjunction with the Maintenance Data Collection Subsystem.

Preventive maintenance should not be confused with corrective maintenance. Preventive maintenance is a scheduled check on select parts of a piece of equipment. Corrective maintenance is the repair of equipment.

As a third or second class gunner's mate, you will be concerned with both the Planned Maintenance Subsystem (PMS) and certain portions of the Maintenance Data Collection Subsystem (MDCS).

The organization and administration of the 3-M system are covered in Military Requirements for P.O. 3&2. NavPers 10056-C. Study this material thoroughly, for the 3-M system will eventually be used exclusively throughout the Navy.

The Planned Maintenance Subsystem (PMS) supersedes all other maintenance, systems such as POMSEE, Satterwhite, and IMP. Perhaps, we should have used the word "absorb" rather

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than "supersede" because most of the management tools and maintenance techniques of the former systems have been incorporated into the PMS. Thus it will not be difficult for you to become accustomed to working with the PMS.

Each piece of equipment was studied to determine the amount of servicing required to sustain its operational performance and the tests required to check its performance. The study was made on the piece of equipment as an individual item and as it functions as part of a complete system, the maintenance oriented data was processed and integrated into the PMS. The PMS contains the minimum amount of plannable maintenance necessary to keep the equipment and the system in a state of operational readiness. Each command, however, retains the prerogative to increase the maintenance to meet local conditions.

The Daily System Operability Test (DSOT) is a daily test designed to check the overall readiness and effectiveness of the entire weapon system. The DSOT will reveal almost any kind of trouble that may arise, especially in the interchange of information between systems and equipments in the weapon system. Although the entire test requires only about thirty minutes, the men of the associated ratings in each subsystem monitor the test, standing ready to find and correct the cause of any failure. This test and the tests for each piece of equipment are run on a prescribed schedule. The maintenance requirements of the system and the equipment are broken down into simple tasks that are described on Maintenance Requirement Cards (MRC), in an easy to understand step-by-step procedure. The MRC and maintenance scheduling are covered in Military Requirements for P.O. 3&2. NavPers 10056-C. and therefore will not be discussed here.

The P02 assists in the preparation of the weekly schedule of preventive maintenance.

Some of the MRCs on missile equipment are classified. The classified MRCs are stored separately and have a different color than the unclassified MRCs (classified MRCs normally are pink). The classified maintenance tasks are scheduled on the same schedule as the unclassified tasks.

General safety precautions are not listed on MRCs; only specific precautions that are related to the maintenance task are listed. Keep this fact uppermost in your thoughts while on the job. We will discuss general safety precautions pertinent to missile equipment in the next chapter of this course, and at the end of this chapter.

Moreover, only unique operating situating dealing with the task are contained on the MRC. it is assumed that you are familiar with the normal operation of the system or equipment. Thus a basic requirement is to know the operation of your equipment.

SHIPBOARD MAINTENANCE DATA COLLECTION SYSTEM

The primary purpose of the Maintenance Data Collection Subsystem (MDCS) is to ensure that the basic maintenance data is recorded once, and only once, and that the system provides the information to all who need it. Data in the MDCS flows in three distinct but related cycles: (1) local cycle; (2) local-central cycle; (3) central-external cycle.

The local cycle - the basic source of data is the maintenanceman aboard ship who provides information to the local central. After key-punching the source data onto standard Electric Accounting Machine (EAM) cards, the punched cards are forwarded daily or at other specified time intervals to the central data processing activity, where they are recorded on computer tapes for computer processing. Navy-wide data, as applicable and appropriate, is then sent back to the reporting units. This completes the cycle - the technician now has maintenance data with which he can improve his operations; he can also compare his actions and equipment with those of the rest of the fleet.

The central-external cycle, in addition to supplying "feedback" data to the reporting units also supplies the data to the appropriate command. At the command, the maintenance data is evaluated to determine if either the equipment or the maintenance procedures can be improved.

The shipboard maintenance reports and records required by MDCS are all listed in OPNAV 43P2, and covered in your military requirements course. The MDCS provides a uniform means to record maintenance actions aboard ship. This in itself has simplified your paperwork connected with maintenance, but at the same time the data contained and retained in the data system has become more complete. The latest revision to OPNAV 43P2 has reduced the number of reportable items considerably, this will further reduce the paperwork required in reporting maintenance actions in MDCS. Many of the various reports and records used prior to the implementation of the 3-M system, were replaced or eliminated by the use of MDCS. The shipboard portion of the MDCS provides a guide for the administration of maintenance data, but local conditions as

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determined by the fleet or type commander may require the use of some of the former records and reports.

LUBRICATION

If you grew up in a city, perhaps the only connection you had with lubrication was taking the family car to the garage or the gas station for greasing and oil change. But if you grew up on a farm or had a car that you had to keep in running condition yourself, you are well aware of the need for regular lubrication of all moving metal parts. If your car ever burned out a bearing, you've had a lesson that you are likely to remember. And since you have been in the Navy you've heard a great deal about the importance of lubrication. We won't let you forget it.

LUBRICANTS: QUALITIES OF

Lubricants are of two general classes-oils and greases. Oils are fluids; greases are semisolids at ordinary temperatures. Both have several qualities that determine their suitability for a particular lubrication job. One of the most important is VISCOSITY.

Viscosity is the measure of the internal friction, or resistance to flow of a liquid or a semisolid. It varies with the temperature as well as with the nature of the substance. Petroleum jelly (Vaseline) can hardly be said to flow at room temperature, but it can be melted to a rather thin liquid. On the other hand, many kinds of oil flow readily at ordinary temperatures. but become much thicker when they're cold.

Viscosity is expressed in terms of S.S.U. units. (S.S.U. means "Seconds, Saybolt Universal" and represents the number of seconds it takes a given quantity of the lubricant at a specified temperature to pass through the Saybolt Universal Viscosimeter or Viscometer.) The higher the S.S.U. number of a lubricant at a given temperature, the more viscous the liquid. The Navy uses the S.S.U. measurement, rather than the S.A.E. (Society of Automotive Engineers) Grades, to designate lubricants.

The VISCOSITY INDEX (V.I.) is an indication of the variation of viscosity of the lubricant with variation in temperature. The higher the index, the less the viscosity varies with the temperature; thus, a high index is a desirable quality. You want a lubricant that won't solidify and gum up in cold weather, nor liquefy and leak away in hot weather.

Viscosity index can be improved up to a point by putting chemical ADDITIVES into the oil. (Additives are put in by the manufacturer. Don't try to brew up your own special oil by adding anything to it.)

The FLASH POINT of a lubricant is the temperature at which it gives off flammable vapors. The FIRE POINT (always higher than the flash point) is the temperature at which it will take fire if ignited. The POUR POINT (of an oil) is the lowest temperature at which it will pour or flow.

OILINESS is the characteristic of an oil which prevents scuffing and wear. You might think this depended on viscosity, but a complicated relationship of many factors is involved. Certain substances have been found which increase the oiliness of a lubricant.

CHEMICAL STABILITY concerns a lubricant's ability to "take it." Certain oils and greases tend to deteriorate under influence of high temperatures, exposure to air or water, or introduction of impurities. A lubricant with good chemical stability will resist such deterioration. You can often detect deterioration by change in color, formation of varnish or gum deposits, formation of sludge, change in viscosity (of oil) or consistency (of grease), hardening (of grease), or by other telltale signs. Change in viscosity can be more accurately measured by viscometer but serious change is easy for the expert to detect.

These signs of deterioration means that the lubricating and corrosion-preventing qualities of the substances are impaired. You'll find it useful to know the signs of deterioration in oils and greases well enough to recognize them when they appear.

Lubricants, preservatives and hydraulic fluids all protect metal against corrosion, at least to a certain extent. Corrosion prevention is, of course, the main function of a preservative. The corrosion-resisting qualities of lubricants and hydraulic fluids can be improved by adding chemicals called INHIBITORS. In general, inhibitors are added to the substance by the manufacturer before delivery to the Navy.

Other qualities or properties of lubricants are: dropping point, penetration, neutralization number, work factor, viscosity change, aniline point. Chemists in lubrication work need to understand the meaning of the terms; we list them only to impress you with the fact that just any oil will NOT do.

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FUNCTIONS OF LUBRICANTS

Now that we have discussed some of the qualities of lubricants. you can see how they apply to the jobs that lubricants have to do. Lubricants are used for three purposes-to reduce friction, to prevent wear, and as a protective cover against corrosion.

As a protective cover against corrosion, the use is obvious. As a preventive against wear, the use is equally obvious when you consider the matter of friction. Lubricants form a layer or film between the metal surfaces, which actually keeps the metals from touching. The moving parts literally "ride" on the lubricant. In the instance of two metal surfaces sliding across each other where space cannot be provided for ball bearings, the lubricants themselves serve as "liquid bearings." In all mechanical devices, lubrication is necessary to counteract friction as much as possible. Only the presence of a thin film of lubricant to separate metal surfaces keeps modern machinery going. If the film disappears, you have hotboxes, burned-out and frozen bearings, scored cylinder walls, leaky packings, and a host of other troubles - the least of them being excessive wear. All of these troubles are the result of direct metal-to-metal contact without adequate lubricant. Lubricants do not move naval guns and equipment but they keep them movable.

Specifications

Because proper lubrication is an absolute necessity, selection of high quality lubricants having the right viscosity and other properties for each job is of vital importance. When you drive your car into the local filling station and tell the attendant, "One quart of No. 30 oil, 75-cent grade." you are specifying the kind of oil you want.

When the Navy buys oil (or almost anything else), it too must specify what it wants. The Navy cannot be as offhand about its purchases as the average motorist is. To make sure that the supplier knows exactly what is wanted, the Navy prepares detailed descriptions of the things it wants to purchase. These detailed descriptions are called specifications, or specs.

Every agency of the Federal Government does its purchasing, as far as possible, by using specifications. Each agency issues specifications. Each specification is a printed or mimeographed booklet or leaflet describing a particular product or item supplied. The specifications are identified by names, numbers, and letters. Lubricants, preservatives, hydraulic fluid (and many other items) are often known by these spec numbers and symbols. An example of an item you have used is MIL-F-17111, Fluid, Power Transmission. All specifications issued by the various armed services are being coordinated and reissued as Military Specifications.

Oils

Many oils employed by the Navy in ordnance equipment are identified by four-digit symbols headed by the letters MS (Military Symbols). These were formerly called NS (Navy Symbol). You should be able to read and translate these symbols.

The following classes of Military Symbol oils are approved for use in naval ordnance.

Class 1- Aircraft-engine oils (high V.I.)
Class 2 - Forced-feed oils (low V.I.)
Class 3 - Forced-feed oils (medium and high V.I.)
Class 5 - Mineral cylinder oils

Viscosity for oils of classes 1, 3, and 5 is determined at a temperature of 2100 Fahrenheit, and for class 2 at 1300 Fahrenheit. These classes are straight mineral oils without chemical additives.

Now, assume the Military Symbol (MS) on a certain oil is 3050. What does this tell you about this oil? The first digit - 3 - tells you that the oil is class 3, a forced-feed oil of medium or high viscosity index. The last three digits - 050 - indicate the viscosity as 50 at a temperature of 210° F. That's how you read Military Symbols for oils.

Other oils used in naval ordnance gear are identified by other symbols. Thus, all Navy Department specifications for lubricants begin with 51. The stock number is different for each size of container of the material. Some lubricants and hydraulic oils are procured for use in ordnance equipment only; these are identified either by (Ord) following a Military specification (MS) number, or by the letters as (instead of MS) in front of the number. Lubricants intended for Army equipment are identified by Army specifications beginning with the number 2 (example, 2-82C). As all specifications are brought under Mil specs, the old designations will be replaced by MIL numbers.

On lubrication charts, note that the number of the lubricant to be used at each place is not repeated, but a "target" symbol is used instead.

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This avoids confusion with the number used to identify the part to be lubricated, which may be used several times in the chart. The meaning of the target symbols is explained in the notes on the chart, as well as in OD 3000.

Greases

Lubricating greases are a mixture of soaps commonly, calcium soap or sodium soap - and lubricating oil. The oil may be a mineral oil (petroleum base), or a synthetic oil.

The purpose of the soap is to make the oil "stay put" at the point of application. The soap traps the oil within its mass, but the actual lubrication is done largely by the oil in the grease. You might think of it as an oil-soaked sponge. The heat of friction "squeezes" the sponge, melting the grease and releasing the oil to perform the lubrication.

Greases can be classified according to the kind of soap used in making them. Each kind of soap has specific properties.

CALCIUM (LIME) SOAP GREASE will not absorb moisture or emulsify (separate into its original ingredients). Consequently, it is specified for general lubricating purposes where bearings are exposed. However, calcium soap grease has a low melting point, and is not suitable for hot-running bearings.

SODIUM-SOAP GREASE emulsifies in the presence of moisture but has a higher melting point. It should be protected from moisture. It is used for ball and roller bearings.

Other kinds of soap bases used in greases are aluminum soap, and lithium soap, with others added to the list as found by experimentation and test at laboratories.

GRAPHITE GREASE, as the name implies, contains graphite. The graphite acts as a mild abrasive to smooth roughened wearing surfaces, as a filler to smooth over any pits in the surfaces, and as a friction reducer. However, because of its abrasive action, graphite grease should not be used in bearings that are in first-class condition except under high temperatures at which ordinary greases would be destroyed. Technically, since graphite grease contains no soap, it is classed as a lubricant oil, but it looks and is applied like other grease. Molybdenum Disulphide, Spec. MILM-7866, can be used instead of the graphite grease.

GEAR LUBRICANTS are a mixture of high viscosity oils and just enough sodium soap to cause "jellying." Gear lubricants are suitable for high gear-tooth pressure and moderate speeds where the design of the case is such that ordinary oil cannot be retained.

As with oils, the viscosity of greases varies with temperature. If temperature changes make it necessary to change oil, check your lubrication chart to find out whether you have to change the grease too.

LUBRICATING TOOLS

Some lubricants are applied by smearing them on the surfaces to be lubricated, but you'll most often use a tool (grease gun, oiler, or grease pump) especially designed to put lubricant into the equipment through a lubrication fitting.

Grease Guns

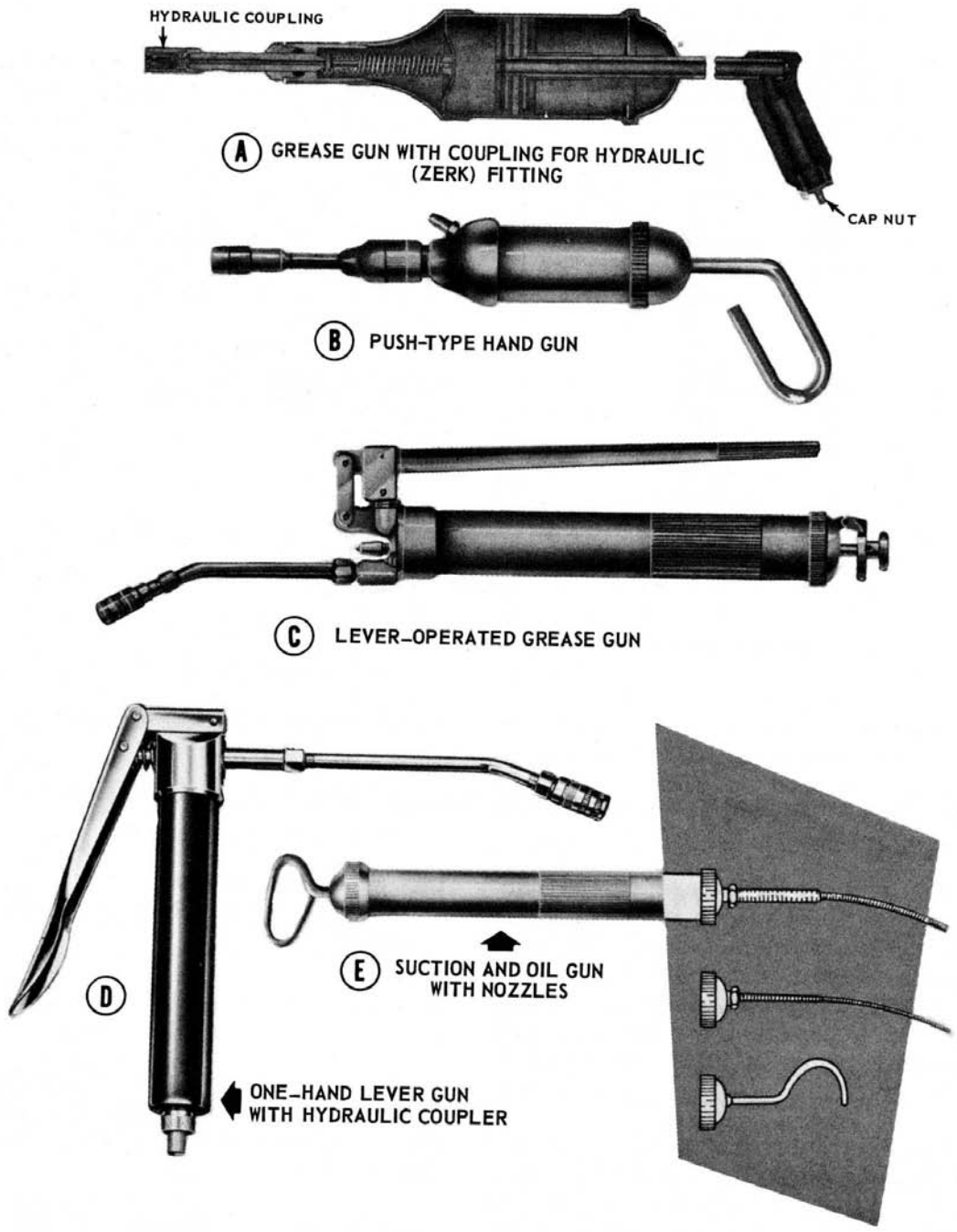
Grease is applied by a grease gun or pump through a nozzle that is designed to match the fitting.

Although ordnance plants and repair shops have electrically or pneumatically powered equipment, you probably will have to depend on your own right arm for power to operate lubricating equipment. In this section we shall therefore take up only the hand-powered lubricating equipment you are likely to use.

Hand-operated grease guns are of two types, depending on how they are loaded. To load one style, you remove a cap that comes off with the handle and stem (fig. 12-3), and fill the body with grease, using a paddle or spatula. As you might expect, this method of loading can be messy, and it also exposes the lubricant to dirt and moisture. A faster and cleaner kind of gun (fig. 12-3A is loaded by removing the cap nut from the end of the hollow handle and forcing grease in through the handle with a hand gun loader (fig. 12-4A), or a bucket-type lubricant pump (fig. 12-4B).

The hand gun loader is a 25-pound container equipped with a hand-operated pump and a fitting that mates with the opening in the handle of the grease gun. The bucket-type lubricant pump makes use of a loader adapter and loader valve when it is used for loading a grease gun. One pound of lubricant is delivered with every seven full strokes of the pump. The loader will deliver lubricant only when the grease gun is placed on the loader valve. You can see how much less messy the loader is than the paddle, and how it protects the lubricant against contamination. Besides, you don't have to run back to the storeroom to refill your gun.

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Figure 12-3. — Hand-operated grease guns.

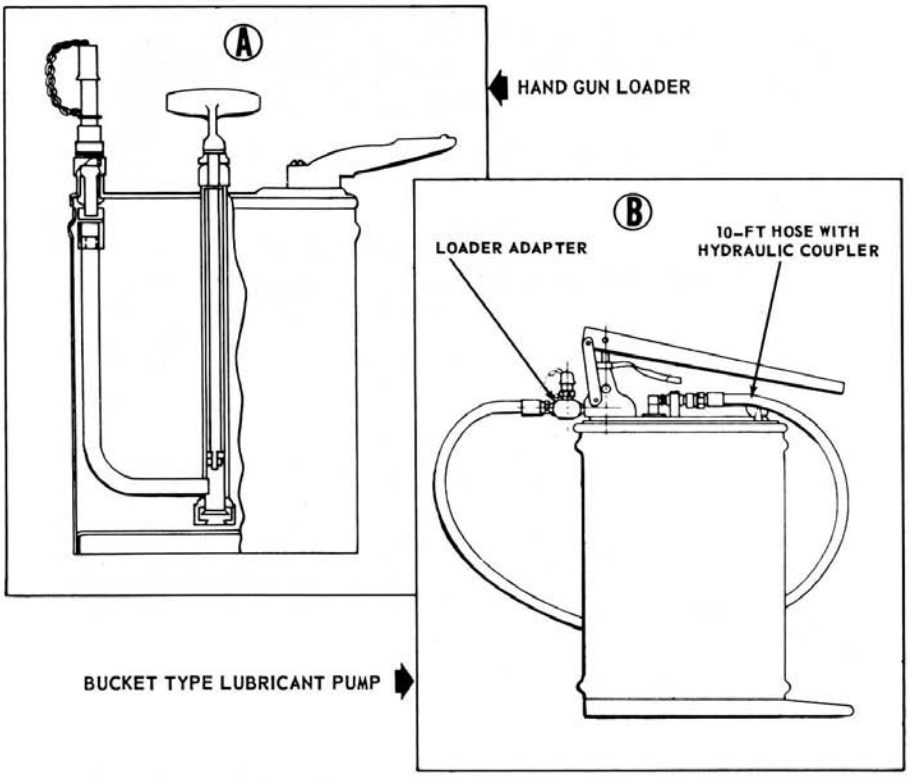
Different nozzles can be attached to the grease guns for different types of fittings. The lubricant pump also has various couplers and adapters that attach to the hose, so that the pump can be used on different fittings.

Grease guns can be used for oil if the point to be lubricated has the proper fitting, or an oil gun (fig. 12-3E) may be used.

A lever type grease gun (fig. 12-3C and D) is being introduced; it gives more positive lubrication than the Zerk grease gun.

When you need to apply large quantities of grease - as, for example, in a launcher roller path - a grease gun is too small. The bucket type hand-operated lubricant pump (fig. 12-4B)

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Figure 12-4. — Hand-operated grease pumps: A. Hand gun loader; B. Bucket-type lubricant pump.

holds the same amount of grease as the hand gun loader, and is fitted with a pump operated with a lever. It has a 10-foot hose with a hydraulic T-handle adapter and a 90° adapter for working in cramped spaces. With this pump you can build up a lubricant pressure of 3500 psi, and deliver a pound of lubricant every 20 full strokes.

The hand-operated lubricant pump can handle any type of lubricant generally required on naval ordnance equipment except greases of calcium soap type, and MS9150-240-3155, type A, grade 4, MIL-T-3123.

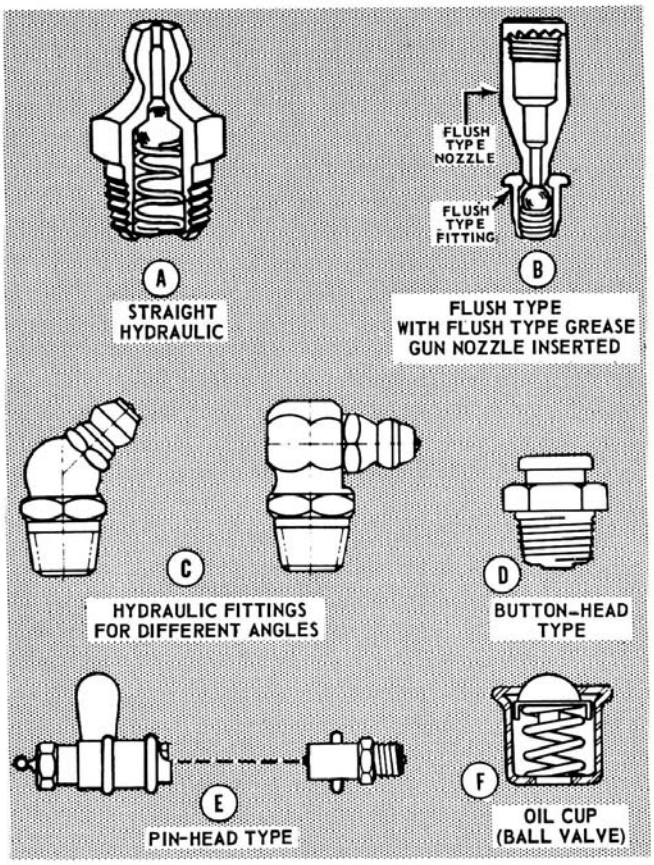
If you can arrange it, use several grease guns - one for each type of lubricant you will need. Then you can save time by taking care of all the fittings requiring a specific type of lubricant before going on to apply the next type. For example, if you're working on a ready service ring, take care of all the fittings on that equipment that require MIL-G-16908 before working on those that take MIL-L-18486A. If you must use one gun for more than one lubricant, be sure the gun is as empty as you can make it before adding a different lubricant. Mixing lubricants is not good practice.

Fittings

Grease fittings are of several types - hydraulic (unofficially called the Zerk fitting, after its inventor), button-head, pintype, and flush (fig. 12-5).

The hydraulic fitting protrudes from the surface into which it is screwed, and has a spec ally shaped rounded end that the mating nozzle can grip. A spring-loaded ball acts as a check valve. The nozzle will not slip off the fitting during lubrication, but can be easily disengaged by a quick forward-backward movement. Push-type (Zerk) hydraulic fittings are being replaced by commercial button-head and pin-type fittings, which provide more positive connection with the grease gun. Figure 12-5 part A, shows a cross-section view of a straight hydraulic fitting, and part C shows hydraulic fittings made for different

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Figure 12-5. — Lubrication fittings.

angles. They are made to fit most any angle, and with different threads and body lengths.

The oil cut with ball valve (fig. 12-5F) is the most popular type for oil fittings. When using a gun equipped with nozzle for hydraulic type fittings (fig. 12-5A, C), just place the nozzle on the fitting and push forward on the handle. This slips the nozzle onto the fitting and at the same time builds up hydraulic pressure in the gun, forcing the grease out of the nozzle. Then relax the pressure. A spring forces the handle back, ready for the next stroke. Three strokes are usually enough. Only one hand is needed to work this type gun. The grip action of the nozzle coupler holds the nozzle firmly to the fitting until pulled free. The Zerk grease gun can be used with the button-head fitting by adding an adapter.

The flush fitting (fig. 12-5B) is flush with (or below) the surface into which it is set, so that it will not foul moving parts. It is used also where there is not sufficient clearance to ,install protruding fittings. The flush fitting also has a ball type check valve. When using a gun equipped for flush type fittings, you must exert a steady pressure against the grease-gun nozzle to keep it in contact with the flush fitting while pumping lubricant, since the nozzle has no grip on the fitting. Otherwise, the method of use is much the same as with hydraulic fittings.

As with other routine jobs, it helps to have a standard operating procedure that you can habitually follow. Here's one that will be helpful:

1. First, consult the lubrication chart and locate the fitting.
2. Clean the fitting carefully with a lintless cloth.
3. Apply the correct amount of the specified lubricant. (Be careful of the amount you apply too much will cause excessive heat in the bearing and strain the grease retainers, while too little is on a par with too late.)
4. Wipe all excess grease from around the fitting.
5. Check off the fitting on your chart. A fitting must NOT be missed just because it is battered or "frozen" fitting probably means that the oil holes throughout the bearing are clogged. This means tearing down the bearing and cleaning all parts carefully. Grease that fitting even if it requires an hour of extra work. Plastic protective caps are often provided for fittings. These caps keep out contaminants and also aid in keeping the grease in the fitting.

LUBRICATION CHARTS

Frequent reference has been made to LUBRICATION CHARTS. They are published in the OPs for ordnance equipment and are necessary to do your maintenance job properly. Copies of some charts may be obtained for use as checkoff lists. A sample chart is reproduced in figure 12-6. On it you can see the use of "target" (Nos. 1, 2) symbols, and schedules for lubrication. Large equipments have several charts with numerous places indicated for oiling or greasing. It would be easy to forget some places or to use the wrong lubricant if you didn't have the chart to guide you and to check off as you work.

Check with your chief to be sure you have the latest revision of the lubrication charts. There may not be any change for years, but the discovery of a better lubricant results in changes in many charts. Or renumbering of items in the supply system may change the designation.

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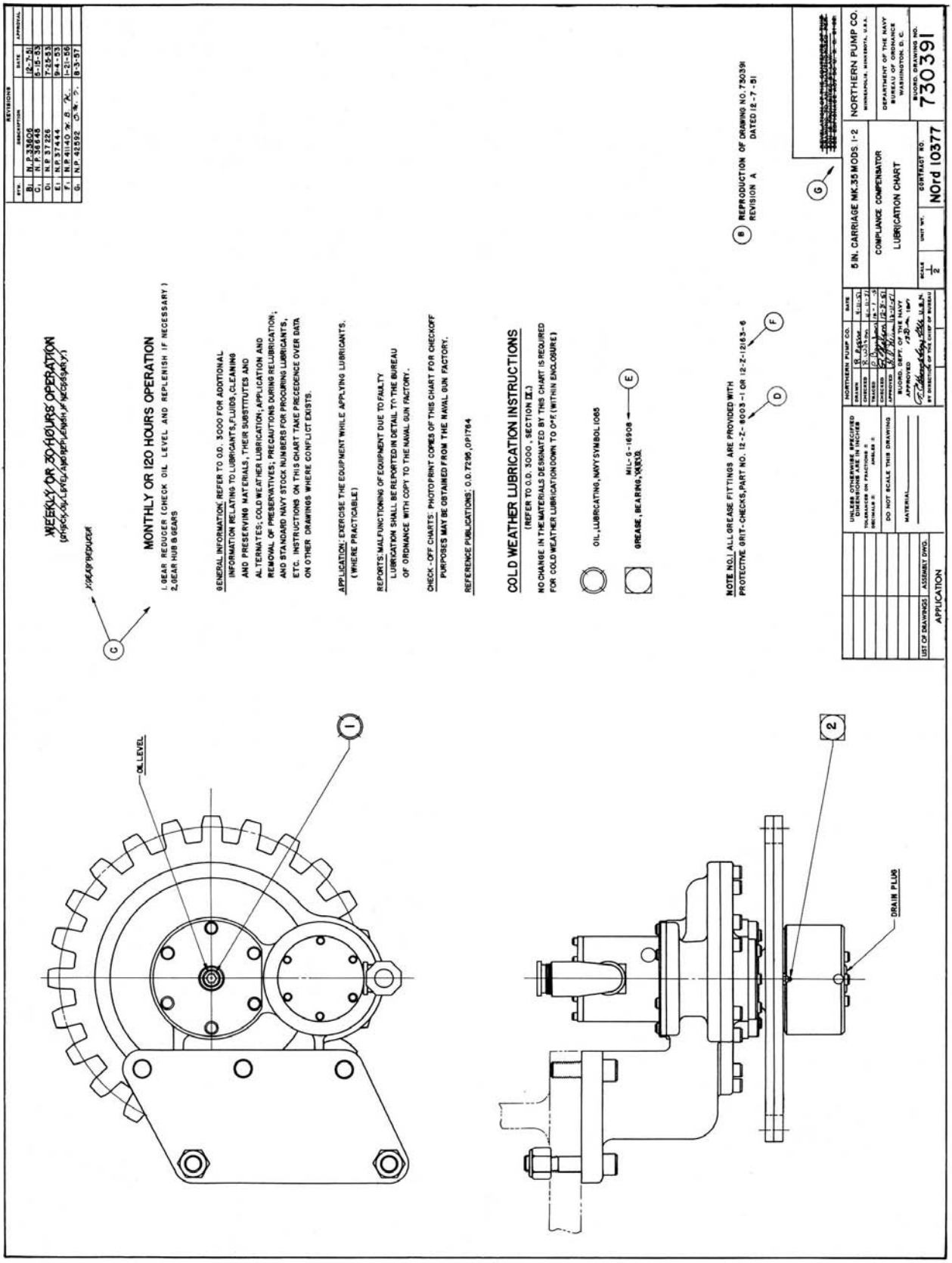


Figure 12-6.—Lubrication chart, showing points of lubrication, types of lubricant, frequency of lubrication, and other instructions.

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The change may have been issued as a pen-and-ink change which is written into each affected chart by personnel in charge of the OPs and charts on your ship, or it may be a reprinted chart with the new changes. Be sure you have the latest.

Lubrication charts also show the kind of hydraulic fluid to be used and the fill level.

LUBRICATION CHART SYMBOLS. - On lubrication charts, lubricants and hydraulic fluids are identified by symbols, each symbol signifying a specific oil or grease. Examples are shown in figure 12-6. The symbols are identified in OD 3000, or any OP lubrication chart. They may be changed from time to time. If your OPs and ODs are up to date, they will give you the CURRENT meaning of each symbol.

ALTERNATES AND SUBSTITUTES. - If the lubricant prescribed in the OP or MRC for a piece of equipment is not available, you may find it necessary to use either an alternate or a substitute lubricant.

A SUBSTITUTE lubricant is one that will fill the need for a limited time, but does not have all the essential properties of the prescribed lubricant. As soon as the prescribed lubricant becomes available, all of the substitute must be removed from the equipment, which must then be completely relubricated with the prescribed material.

An ALTERNATE lubricant is one whose characteristics closely resemble those of the prescribed lubricant, so that its removal is not necessary when the prescribed material is available.

Alternates and substitutes for prescribed lubricants (as well as for cleaning materials, hydraulic oils, and preservatives) are listed in OD 3000.

If none of the listed lubricants is available and you must choose a substitute, keep in mind that the substitute should be as near as possible to the specified lubricant in lubricating and rustpreventive qualities, viscosity, and ability to withstand the temperature ranges of the equipment.

In brief, when the prescribed stuff is not to be had, use an alternate if you can, a substitute if you must.

HYDRAULICS

The fluid used in hydraulic systems is often spoken of as hydraulic oil, and many of them have an oil (petroleum) base. The term' 'hydraulic fluid" is more inclusive as it includes all liquids used in hydraulic systems. Three types of hydraulic fluids are water base, petroleum base, and synthetic base liquids. Various combinations of ingredients have been tried in each of these types. The Navy has tried quite a few of them and uses different ones in different situations. No "best" hydraulic fluid has been found. Use the one that is prescribed for the unit you are serving, and observe the precautions that go with it. For example, MIL-H-19457 (cellulube) is a fire-resistant hydraulic fluid used in the magazine hydraulic assemblies of GMLS Mk 12. However, it is highly corrosive to fibrous materials and to some paints, so you have to be careful not to spill any of it on such materials (as clothing, etc.).

A fuller discussion of the types of hydraulic fluids and their properties may be found in Fluid Power, NavPers 16193-B, and in OD3000, Lubrication of Ordnance Equipment. Since a great deal of your maintenance work will involve the hydraulic components (of which there are many) in the missile system, it is well to know something about the medium involved. The same course also tells how to test the hydraulic fluid for contaminants, deterioration, and decomposition. Probably the most frequent cause of trouble in a hydraulic system is the presence of contaminants in the fluid. How does dirt get into a closed system'? Some can get in when the system is being filled with the hydraulic fluid, or when some is being added. Bits of metal from joints in the piping or tubing get broken off by the moving stream of fluid. Chemicals in the fluid can precipitate particles of materials in the fluid when the temperature or the pressure is too high, forming sludge. These and other causes of contamination are discussed in Fluid Power, NavPers 16193-B. Before you begin working on the hydraulic component, pull the MRC from the file and study it. The general rules and cautions for draining, flushing, and refilling hydraulic systems are given in Fluid Power, but the specific directions for your equipment are on the MRCs on your ship, and the OPs for the system.

CLEANING, PAINTING, AND PRESERVING

Besides the technical maintenance details on your gear, you will be responsible for cleaning, painting, and similar housekeeping work that every member of the crew is expected to do in maintaining the space he works and lives

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in. It is the duty of the Division Officer to supervise the maintenance, preservation, and cleanliness of all spaces and equipment assigned to the division, but the activation of the tasks is usually undertaken by the division leading petty officer, and that may be a PO 3 or PO2. That means you have to know how to do the work and be able to teach others. Military Requirements for Petty Officer 3 & 2. NavPers 10056-C. gives you pointers on how to handle the assignments for supervising such work.

As a Gunner's Mate M. most of your cleaning and preserving work will be done on metal surfaces, principally steel. The preservatives must protect the metal against rust and corrosion; the cleaning materials must clean the surface before the preservative is applied.

Rust is caused by the slow burning (oxidation) of iron. When iron or steel rusts, it combines slowly with the oxygen in the air.

Technically, corrosion is not exactly the same as rust, since its meaning includes metal being eaten away by acid, or by the action of salt water, or other substances. Rust and corrosion are dangerous and destructive saboteurs that attack unguarded metal at the slightest opportunity.

The way to protect metal from rust and corrosion is to protect it from the air. Paint is a good protective, but many metal surfaces, such as moving parts, cannot be painted.

The lubricants used on moving parts serve as rust preventives to some extent, but often this protection is not enough. These are temporary preservatives for protecting metal from water and weather. Light oils and greases are applied to exposed gun parts and mounts as temporary protection against corrosion. Bright steel work, such as exposed cam and linkage surfaces should have such protection. SLUSHING OILS, available in several grades, are provided for this purpose. All old oil and dirt should be cleaned from the part and the surface thoroughly dried before new oil is applied.

AUTHORIZED CLEANING AND PRESERVING MATERIALS

Some lubricants (for example. preservative lubricating oil for use in small arms and light machine guns) have preservative additives (rust inhibitors) and can serve for short-term preservation, but NO preservative is intended for use as a lubricant.

When lubrication is not desired. there are special preservatives (permanent type) which may be brushed or sprayed on the surface to be protected, or in which the small parts of a mechanism may be dipped. After treatment, the preserved mechanism can be stored for a long period. (The length of time depends on the characteristics of the preservative, the kind of storage, etc.)

A rust preventive that can be used either to protect exterior surfaces or (as when pumped through a hydraulic system) for preserving interior surfaces, tubes, etc., is the THINFILM POLAR TYPE compound, which is available in several grades. HARD-FILM compound, also in several grades, is for metal exterior surfaces only.

Rust preventives are NOT lubricants, and should not be used instead of lubricants. Before treating metal surfaces with rust preventives, BE SURE TO REMOVE ALL TRACES OF RUST AND CORROSION, AND ALL OF THE OLD LUBRICANT.

BE SURE TO REMOVE ALL OF THE RUST PREVENTIVE before adding lubricant to ordnance equipment that has been stored with rust-preventive compound coating. OP 1208 (third revision) Instructions for Inactivation, Maintenance, and Activation of Ordnance in Vessels in Inactive Status, gives step-by step instructions for removing preservatives from launchers and other ordnance equipment. Chapter 5 of OD 3000, Lubrication of Ordnance Equipment (fourth revision) deals with cleaners and preservatives. It contains a chart of all cleaning and preserving materials authorized for use on ordnance materials. This chart gives the specification number, characteristics, applications, federal stock number, container size, and substitutes, while the text elaborates on the use of each item. Some of the materials will be described very briefly in the following pages.

DRY-CLEANING SOLVENT (Varsol or Stoddard Solvent) is useful for cleaning away old grease, oil and rust preventives. However, its hard on rubber (use soap and water on that). Because of its irritating, flammable fumes, it should be used only where there is plenty of ventilation and where there are fire extinguishers handy. Diesel fuel or kerosene can also be used for the same purposes as dry-cleaning solvent. The correct solvent MUST be used since some solvents leave a residue or cause corrosion. Therefore, ALWAYS check the OP for the equipment.

Spraying or splashing of the solvent must be avoided during cleaning. If the solvent were to fall upon a bearing surface, it would cut or

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render the lubricant less effective, causing excessive wear. After the solvent has been used, the parts must always be wiped dry with a clean lint-free cloth.

REMOVING RUST

When using abrasives to remove rust, be careful to select the proper type (see OD 3000) and use it sparingly.

NEVER use abrasives without permission from the proper authority. Only experienced personnel may use abrasives or wire-brushing. Carelessly used abrasives can do more damage than rust. A few strokes of even a fine abrasive would destroy the accuracy of many closefitting parts which are machined to close tolerances, and would lead to costly replacements. Always be extremely careful to keep grit from getting into bearings or between sliding surfaces.

After the rust has been removed, the parts must be thoroughly cleaned and dried. Avoid leaving your own fingerprints on the metal. Cleaned surfaces should not be touched by bare hands before the rust preventive is finally applied. When the surface is clean and dry, you are ready to start applying paint or preservative.

PAINTING POINTERS

Painting is one of your important maintenance jobs. Instructions for using the chipping hammer in preparing metal surfaces for painting are given in Basic Handtools, NavPers 10085-A.

Except for special applications like camouflage, the primary purpose of painting in the Navy is preservation rather than decoration. You don't paint just for the sake of appearances, nor as a substitute for cleaning. But when you do paint, you do a thorough and neat job. Thorough means that you cover every square inch of the surface to be painted, and neat means that you keep paint off places where it doesn't belong. You have learned before now that it is much better and easier to keep the paint off the places where it shouldn't be than to clean it off afterward. Always keep paint off gaskets, bright work, grease fittings, rubber parts and rubber covered wires, electrical leads and contacts not protected by armor or conduits, instruction or data plates, and working parts of surfaces that are normally supposed to be protected by a coat of lubricant.

The first thing to do when you are given a painting job is to remove the old paint, which you have been taught to do properly.

The paint stripping solution recommended in OD 3000 is 8 ounces of sodium hydroxide (0-S-598, Type 1) in 1 gallon of near-boiling water. Rinse with clean, hot water after paint is removed.

Before applying paint, be sure the surface is clean and dry. Paint will not adhere to damp or oily surfaces, or to surfaces covered with dirt, rust, or solvent. Galvanized surfaces must be wiped with ammonia, vinegar, or a special priming solution called "wash primer" before the paint will adhere. Brush the solution on, allow it to dry, and then wipe it off. Never use an abrasive on galvanized surfaces.

O-S-598 may not be used on aluminum, zinc, tin, terne, or lead.

Soap and water are one answer to the problem of removing all dirt and traces of old oil or grease from metal surfaces to be treated with rust preventives, paint, or other preservative. Wash away all soap; then see that the surfaces are DRY, and finally, apply rust preventives (or paint) without delay. It's sometimes hard to get at pockets or cavities in which water collects; be sure they are not neglected.

The standard finish for United States naval ship super-structures is a gray paint whose exact color and composition are prescribed by NAVSHIPS. You will use that paint for the exterior of launchers and the missile house.

A prescribed gray-blue paint is used for exterior steel decks. Interior bulkheads and overheads are painted with a white paint prescribed by NAVSHIPS, and interior steel decks are usually finished with gray deck paint, though white is prescribed for decks in ammunition spaces. These are the general rules for painting; you'll get details on painting jobs from your chief.

Safety Lines

A special kind of painting job that you, as a Gunner's Mate, are responsible for is that of painting safety lines to mark off safe working areas. Circular safety lines are painted on the deck around a launcher to indicate the areas you should stay out of when the launcher is being trained. "Blast area" lines are painted on the decks around missile launchers to show how far away you must get to be safe from the hot rocket blasts. Similar safety lines are necessary to show safe working areas around overhead handling equipment and other machines that may be dangerous to men who fail to keep away from working parts.

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CLEANING ELECTRICAL COMPONENTS

Ever since you were handed a paint brush aboard ship, you have been warned not to paint electrical equipment. If you were headless, you had to painstakingly clean it off, and you surely have learned your lesson on that score. However, dust and dirt on electrical equipment still require removal regularly. When cleaning electrical and electronic equipment, always use an approved cleaning agent.

Alcohol should never be used for cleaning electrical equipment. Not only is it afire hazard, but it also damages many kinds of insulation.

Cleaning Electrical Contacts and Switches

SWITCH MAINTENANCE. - While the switch itself is relatively simple to check- it sometimes offers difficulty in maintenance because it is inaccessible. After a visual inspection of the connections and the switch, a continuity test will indicate any malfunctions. When the switch mechanism is found to be defective, it normally is not repairable and therefore should be replaced.

When enclosed switches are used, failure to seal properly around cable openings causes the most difficulty. Atmospheric changes permit "breathing" of moist air into enclosures with improperly sealed cable openings, and the moisture in the air may condense within the switch enclosure. The condensation can short across the switch terminals and can corrode the switch actuators in a manner that may make them inoperative. This difficulty can be corrected by careful sealing of openings or by using hermetically-sealed switches. Hermetically-sealed switches will also prevent dust and dirt from reaching the contacts and thereby causing high resistance and open circuits.

Some switches are damaged during installation, particularly those with plastic housings. Proper care in installing or replacing plastic enclosed switches will eliminate this.

Some switches depend upon pressure for their operation. These switches have adjustments so that they will operate at the correct time or pressure. In many cases if the adjustments are not accurate-damage can result.

RELAY MAINTENANCE. - The relay is one of the most dependable electromechanical devices in use but, like any other mechanical or electrical device. relays occasionally wear out or become inoperative for one reason or another. Should relay inspection show that a relay has exceeded its safe life, the relay should be removed immediately and replaced with another of the same type. Care should be exercised in obtaining the same type replacement because relays are rated in both voltage and amperage.

As guides for spotting potential relay trouble during preventive maintenance, the following are suggested. Check for charred or burned insulation on the relay. Check for darkened or charred terminal leads coming from the relay. Both of these indicate overheating. If there is even a slight indication that the relay has overheated, it should be replaced with a new relay of the same type. An occasional cause of relay trouble is not the fault of the relay at all, but is due to overheating caused by the power terminal connectors not being tight enough. This should always be checked on preventive maintenance.

It is not recommended that covers be removed from semi sealed relays in the field. Removal of a cover in the field, although it might give useful information to a trained eye, may result in entry of dust or other foreign material which may cause contact discontinuity. What is even more serious, removal of the cover may result in loss of or damage to the cover gasket. One of the prime advantages of hermetically-sealed relays is that they cannot be taken apart.

Relays can be ruined by the use of sandpaper or emery cloth for cleaning the contacts. A BURNISHING TOOL should be used for this purpose. Two types of burnishing tools are stocked at naval supply activities, and either type can be obtained through regular supply channels. The appearance and use of one kind of burnishing tool are shown in figure 12-7 A. The surfaces of the tool that are used to clean the relay contacts should not be touched by the fingers prior to use; and. after use, the burnisher should be cleaned with alcohol.

When relays contain bent contacts, no attempt should be made to straighten them with long nose pliers. Such as attempt often causes further damage with the result that the entire relay must be replaced. Bent contacts can be straightened effectively by using a CONTACT BENDER. The bender can be made locally from 0.125-diameter rod stock according to the dimensions shown in figure 12-7B.

Be sure the power is off and remains off while you are working on an electrical contact or switch, or relay.

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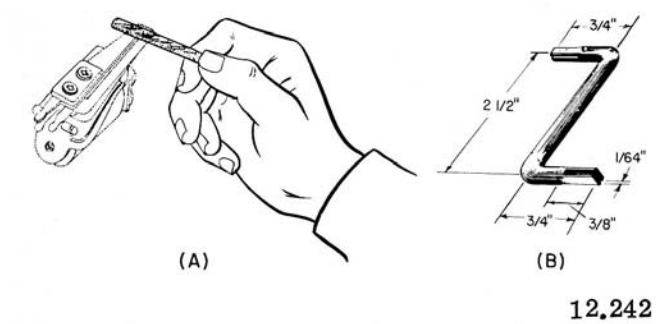


Figure 12-7.—Relay special tools: A. Burnishing tool; B. Point bender.

Cleaning Rotating Machinery

Rotating machinery should be inspected and cleaned at prescribed intervals (periodic checks) and whenever repairs to the machinery have been made. For such cleaning and inspection, the following procedure is suggested.

1. Unfasten and remove end cover.
2. Remove dust and dirt from machine and end covers, using clean, dry compressed air or a soft brush.
3. Loosen, gently remove, and inspect brushes, being extremely careful not to nick or mar edges of brush. Note the location and position from which each is removed so that it can later be replaced in exactly the same position.
4. Check commutators or slip rings for excessive wear, pitting, dirt, thrown solder, or other defects. A highly polished commutator or slipring is desirable, but a dark-colored one should not be mistaken for a burned one. If the surface is dirty, clean with a lint-free cloth moistened in a cleaning solution (Specification P-D-680) and wipe dry. Avoid fingermarking the commutator or slipring surface.
5. Secure all brushes in their holders, making certain they are replaced in exactly the position from which they were removed.
6. Replace and secure end covers.

Sliprings

Sliprings are solid metal rings mounted on the rotor of alternating current machines to transfer the power to or from external circuits through brushes or wipers. Slip rings are also used on synchros, director connections, and stable element connections. Slip rings are usually made of silver, copper, bronze, or other nonferrous metals, although iron and steel have been used.

While they vary in size and type, the maintenance of sliprings is essentially the same for all types. They should be inspected periodically for wear, grooving, and cleanliness. Normally, the surface of the rings should be bright and smooth.

Wiper contacts are used with devices that do not require high current and consequently require only light pressure when making contact. Excessive pressure will result in excessive wiper wear, because the wiper contact is usually of a softer material than the rings. Any contacts showing considerable wear should be replaced.

If sliprings are inspected and found rough, scratched, or grooved, corrective action must be taken. They can be smoothed with a fine crocus cloth or sandpaper. However, care should be exercised not to cause high and low spots which will interfere with high speed operation. Further repairs, such as cutting with a lathe, should be performed at overhaul activities (Navy yards and tenders). Also, in cleaning with a solvent, be careful not to allow the solvent to enter the bearings since the solvent will cut oil or grease. This, of course, will cause the lubricant to flow out of the bearing.

Commutators

Commutators have been called the "soft spot" of d-c machinery because they require considerable maintenance. Unlike the slipring, the commutator is a series of copper segments separated by an insulator. When the brushes make contact with a pair of segments, and armature coil is connected into the circuit. Thus, when the motor or generator is moving, the brushes and commutator switch coils in and out in the proper sequence. Basic Electricity, NavPers 10086-B. shows commutator construction.

The normal appearance of the commutator is a shiny, smoothly worn, chocolate brown color. A blackened or pitted commutator is caused by poor brush and segment contact, open or shorted coils, overloads, etc. If the brushes are causing the blackened appearance, they should be replaced and then the commutator should be cleaned. Cleaning is accomplished by the use of fine sandpaper and the recommended solvent. The sandpaper should be held against the commutator by a piece of wood that is grooved to fit the commutator. NEVER USE EMERY CLOTH. Emery is an electrical conductor which will cause a short circuit.

If the fault is other than brush and segment contact, that is, a short or open coil, the

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machine should be replaced and sent to overhaul. Another fairly common defect is HIGH MICA. As the copper of the commutator wears down, the mica, which is the insulation separating the segments, does not. Consequently, it may be higher than the segments. The high mica gives a bounce to the brush every time it passes underneath; this results in arcing because the brush is constantly breaking contact. High mica can be spotted by rubbing your fingernail over the surface of the commutator. There should be a small depression between each segment. If there is high mica, this depression disappears. Undercutting is the remedy for high mica, and this operation is normally reserved for the overhaul activities.

PROTECTION AGAINST MOISTURE

Aside from mechanical injury, the biggest source of electrical trouble on board ship is moisture. And salt water moisture is the worst kind because it is a conductor of electricity. Thus, when a cable or box becomes saturated with salt water, two things happen: First, a current path to the ship's hull is formed which is a ground; and second, especially where dissimilar metals are involved, electrolysis and corrosion occur, and the connections or wire fittings are slowly eaten away.

The battle against moisture is never-ending. Moisture creeps into the smallest openings. Watertight covers must be kept watertight. When you remove a cover, check the condition of the gasket, the knife edge, and the securing bolts or dogs. Where possible, when checking an electrical circuit, use a connection box in a protected space. When moisture is discovered in an instrument or connection box, dry it out with a hot-air blower or an electric lamp.

A reasonable degree of protection against the accumulation of moisture is obtained by a daily energizing and workout of the equipment.

Variations in temperature cause air to be breathed through any opening or vent in the equipment. As the temperature rises, the air inside a piece of equipment expands and is partly expelled. When the temperature falls, the air inside the equipment contracts and outside air is admitted. As the air cools, condensation or sweating takes place. Electrical heaters are installed in some instruments to eliminate this source of moisture. The heater keeps the interior of the instrument at a temperature higher than that of the surrounding air. In many instruments, the circuit to the heater bypasses the power switch, and voltage may be present even though the power switch is off. Remember this when working around the heater circuit. Some equipments use an air drier, or desiccator unit, to moisture proof the mechanisms within the unit. The unit is sealed by dust covers and is airtight except for the connection to the air drier. The air drier consists of a unit that contains silica gel crystals. The silica gel crystals absorb moisture from the air within the unit.

SALT AND FUNGUS. - Salt and fungus found in your equipment should be removed immediately. A salt, when moisture is present, will corrode metals and is a conductor of electricity. Fungus growth causes decay, rapid deterioration of insulating materials, and shorts or grounds in electrical circuits. Under some circumstances you can use fresh water to remove them. After cleaning the equipment, however, make sure the water is completely evaporated. An approved cleaning solvent, inhibited methyl chloroform (O-T-620), can be used to clean away salt or fungus. But inhibited methyl chloroform will attack electrical insulating materials and bare ferrous surfaces if it is not completely evaporated or otherwise removed at the completion of the cleaning operation. Contact time with this solvent should be limited because it is toxic. Care in the use of this solvent should be exercised since concentrations of the vapor can be fatal. Adequate ventilation is necessary when it is used.

MAINTENANCE SKILLS AND PROCESSES

SOLDERING

A discussion of soldering is found in Basic Electricity, NavPers 10086-B and in Basic Handtools, NavPers 10085-A. Here we will review the highlights of that discussion and then consider some aspects peculiar to your work.

Soldering is the uniting of two or more metals by means of fusible alloy. There are two general classes of solder, hard and soft. The differences between the two are in composition, melting temperature, and strength. Soft solder, and alloy of tin and lead, is used in electronic wiring. In most naval electronic equipment, a solder of 60 parts tin and 40 parts lead is preferred because it flows at a lower temperature and solidifies faster than standard tin-lead solders. Use only rosin flux in soldering electrical connections.

Besides the soldering iron (copper) discussed in the basic text, soldering guns are also used by

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the GMM. Several sizes and types are illustrated in Basic Electricity. The induction type is illustrated and its use described in Basic Handtools. The soldering gun consists of a stepdown transformer with the primary connected to 115-volt a-c, and a soldering copper forming a loop across the secondary. The heat is generated by the secondary current and concentrated at the tip. This concentration of heat is due to the shape of the soldering end. It is a relatively safe device since it heats in a matter of seconds. Upon release of the trigger, the tip will cool in a correspondingly short period of time. However, do not lay it down on flammable material, but rest it on the metal holder provided.

You should exercise caution in any soldering operation. One common misuse of the soldering iron is the improper removal of excess solder from the iron. Avoid striking the iron on a solid object to remove the excess solder. This may damage the heater element. A practice occasionally used in the field is the whipping or swinging of the iron. This practice can prove to be very dangerous to nearby workers. Excess solder should be removed with a damp cloth. During the soldering operations and while the soldering iron is not actually in use, keep it in its holder to avoid a fire hazard. Contact with a hot iron or molten solder can cause serious and painful burns.

Let us consider for a moment the end product properly and improperly made soldered joints. You can see them in figure 12-8.

A good, well-bonded connection is clean shiny, smooth, and round. See figure 12-8A and 12-8B. It shows the approximate outline of the wire and terminals. The wire and terminals are completely covered, and the solder adheres firmly. The insulation is close to but not in the hole or slot; it is approximately 1/16-inch from the terminal. It is not charred, burned, nicked, or covered with rosin. A film of rosin may remain on the joint and need not be removed unless fungus proofing is anticipated.

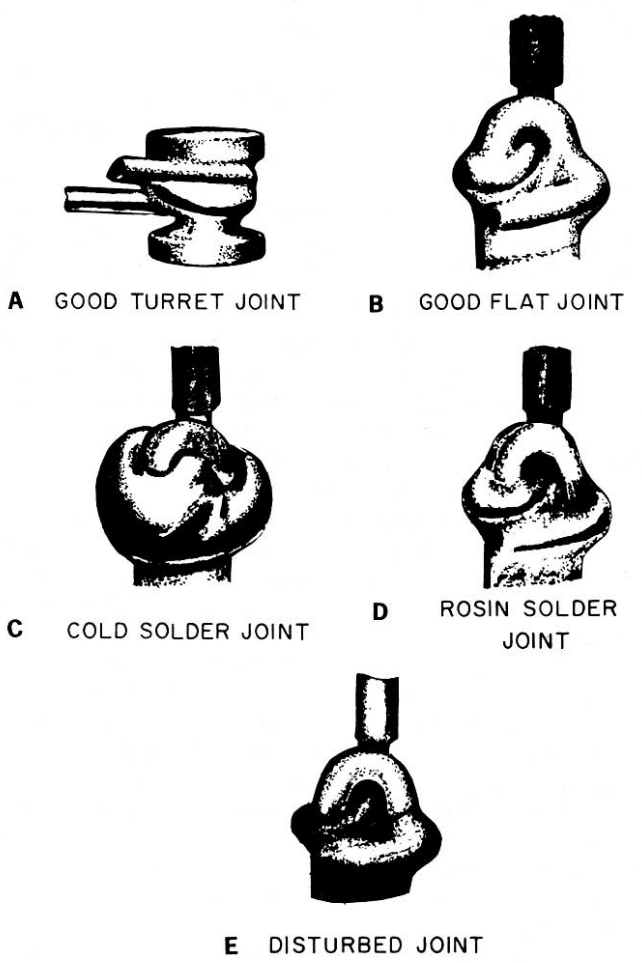


Figure 12-8. — Types of properly and improperly made soldered joints.

Defective Soldered Joints

Proper preparation of the soldering iron (cleaning, tinning) described in Basic Handtoo1s, will prevent many defects. Soldered joints may be defective for a variety of reasons, such as the following.

A COLD solder joint (fig. 12-8C) has a dull appearance and a crystallized texture. Because of the poor union between the wire and terminal, the joint will in time develop high resistance as the metals oxidize. This type of joint is caused by insufficient heat during soldering, and may be the result of too Iowa wattage soldering iron, by a copper bit that is too small, or poor contact between iron and joint. A cold solder joint may be repaired by reheating; however, it may be necessary to take the joint apart and resolder it if dirt or oxide covers the wire.

A ROSIN joint (fig. 12-8D) is so named because the wire is held by rosin rather than solder. The flux is spread over the terminal, and instead of the solder bonding with the terminal, the solder settles on top of the rosin. The joint may have all the appearances of a good joint, but a little pressure will cause movement or an ohmmeter will indicate an open. A rosin joint

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occurs when using a "cold" iron or one that is too small. In most cases, merely applying a hot iron will clear up a rosin joint.

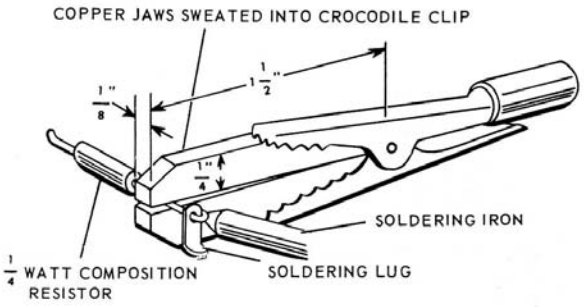
A DISTURBED solder joint (fig. 12-8E) has an irregular on crystallized appearance and the solder may be chipped off with a fingernail or a pointed tool. It is caused by the wire being moved before the solder has fully set. Since it may loosen later in service. it should be repaired in the same manner as the cold solder joint. This type of joint is often the source of noise in the equipment.

An INSUFFICIENT solder joint can introduce high resistance in the circuit and, as current flows, undesirable heat. It may loosen and cause an open or intermittent operation, depending upon the amount of oxide present. This heat, or a visual inspection may reveal this condition, but it may be necessary to use an ohmmeter to detect this type of solder joint. To repair it, it should be taken apart; and after cleaning off the oxide, the joint should be resoldered correctly.

A NO-SOLDER joint may cause noise due to oxide or vibration; the circuit may open entirely. A visual inspection and an ohmmeter will indicate this condition. The joint should be taken apart, cleaned, and then resoldered correctly. There are many other soldering defects, such as excessive solder, loose solder, and insulation too close or too far from the joint. Invariably these defects can be traced to the technician making the connection.

Occasionally some special techniques are required in soldering. In equipment using miniaturized components, the physical dimensions of resistors have greatly decreased and application of a soldering iron close to the body of these small carbon composition resistors causes a PERMANENT change in resistance. Overheating of these resistors and other components during soldering can be avoided only by restricting heat conduction along the terminating leads.

The most acceptable means of preventing this overheating is by use of a thermal shunt. (fig. 12-9). This shunt should be placed as close to the resistor and as far from the joint as possible. Be certain that the clamp does not contact both the resistor and the joint. If you don't have a clamp type shunt, and don't have time to make one, you can use a small pair of needle-nose pliers. If you wrap a rubber band tightly around the handles, the pliers will grip the resistor lead so that you won't have to hold them in place while you solder.



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Figure 12-9.—Thermal clamp type shunt used while soldering resistors or other small components.

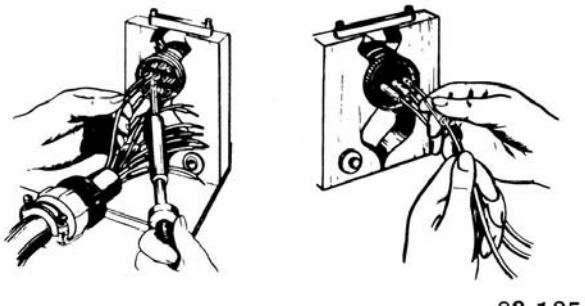
Procedure for Soldering Wires to Connector Terminals

One of the most difficult and exacting jobs is soldering wires to connector terminals. The terminals are all jammed together in a small space, leaving little room to work in. Figure 12-10 shows a typical connector and part of the soldering procedure used to connect wires to the connector terminals.

When you solder wires to a connector in a panel or in a jig, you should start at the side away from the iron. When the connector is free and you can hold it in your hand, you can solder with a stationary iron. Position the iron so that the tip is facing you. The solder by holding the terminal and wire against the tip. When you use this method, start at the center of the connector. You can then rotate the connector as your work continues.

Don't forget to tin the wires and terminals before you start to solder. Another preliminary step that is often forgotten is to put sleeving over the wires. And after you finish soldering and the joints have cooled, slip the sleeving over the cooled joints. The sleeving should fit snugly over each soldered terminal and wire. This helps support the wire and the soldered joint. In Basic Handtools, NavPers 10085-A, the section on miscellaneous skills describes soldering of electrical connections with a soldering iron and also by "sweating" the joint. The method of stripping insulated wire with a pocket knife and with side-cutting pliers is described and illustrated in the same text.

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Figure 12-10. — Soldering leads to a connection.

Mechanical Connections for Soldering

No connection should depend upon the strength of solder alone for security, because solder is relatively soft. All electrical connections should be made mechanically strong before they are soldered. If you crimp or wrap the wire tightly around the terminal before you begin to solder, you will have a secure base upon which to solder. When properly done, crimping or wrapping prevents disturbing the joint while you are soldering and while the solder is cooling.

To make a good mechanical connection you don't have to wrap the wire around the terminal two or three times. Just wrap the stripped end of the wire around the terminal 1 1/2 turns. These are enough turns to make the connection mechanically strong. If you put on more turns, they add nothing to the strength of the connection and simply make it more difficult to remove them from the terminal. Be careful to bring the end of the insulation as close to the terminal as possible without allowing insulation to interfere with the soldering operation. The wire should be wrapped around the terminal so that the tension on the wire will be transmitted to the terminal and not to the solder.

Sometimes you may have to crimp a wire wrap to make a good mechanical connection. Use a pair of pliers to squeeze the wire wrap against the terminal.

After you finish making the connection, and before you begin soldering, cut off the ends of the leads. Leave about 1/16 inch of lead from the connection. This will leave enough wire to get a grip on when you need to remove the wire.

Types of Terminals

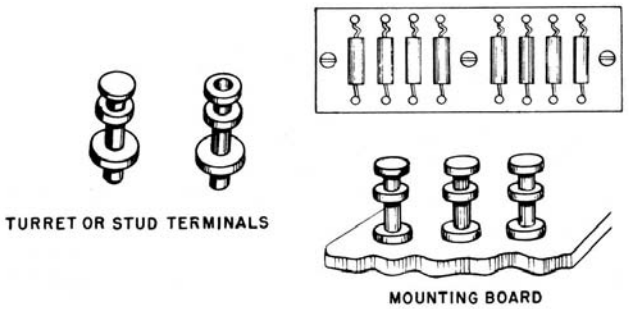
There are four basic types of terminals:

1. Turret or stud terminal.
2. Flat terminal.
3. Hook or eyelet terminal.
4. Split terminal.

The TURRET or STUD terminal is used primarily on component mounting boards; see figure 12-11. To make the wrap, lead the wire directly to one side of the terminal. Wrap the lead 1 1/2 turns around the terminal, and crimp if necessary. On the turret terminal. it is best to wrap the component (resistor, capacitor. and so forth) lead on the upper portion of the terminal, and the connecting wires or wire on the lower part. (See figure 12-12). For easy maintenance, it is best to wrap the wire over the terminal post from the bottom up and to be consistent in either clockwise or counterclockwise wrapping. Clockwise wrapping is preferred because there is a natural tendency for people to attempt unwinding the wire in a counterclockwise direction.

The FLAT. PERFORATED terminal (fig. 12-13) is used on most tube sockets, potentiometers, wafer switches, and micro-switches. To make the wrap, insert the wire through the hole and wrap the wire 1 1/2 turns around the body of the terminal.

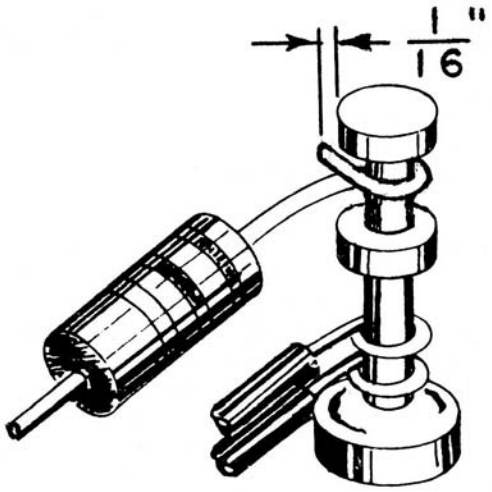
If you use heavy wire, or space does not permit you to wrap properly, you can make a good mechanical connection by crimping. Just feed the wire through the hole, bend the wire



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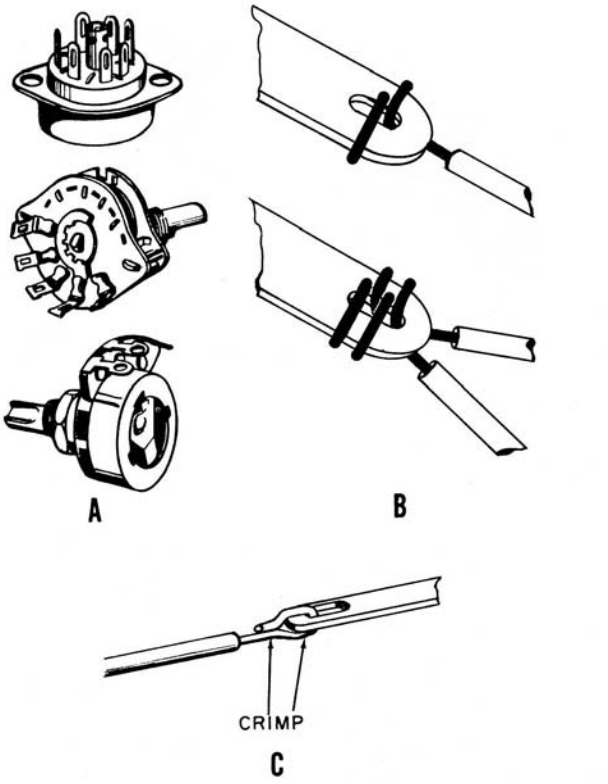
Figure 12-11.—Turret or stud terminals and application.

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Figure 12-12.—Correct wrap on stud terminal.



83.128:.129

Figure 12-13.—Flat perforated terminals: A. Applications; B. Correct wraps; C. Crimping a flat terminal lug.

around the lug 180°, and crimp firmly. Look at figure 12-13C.

The HOOK or EYELET terminal is used on most relays. (See figure 12-14). To make a good mechanical connection on this type terminal, you can feed the wire through the loop and wrap one full turn on the shank.

The SPLIT terminal (fig. 12-15) is used on transformers and heavy components. Lay the wire in the slot and wrap 1 1/2 turns around the body.

Basic Electricity. NavPers 10086-B. classifies terminal lugs as soldered and solderless, and describes and illustrates them according to that classification. The solderless terminal lugs are further classified according to the method of mounting with different splicer sleeves.

CRIMPING

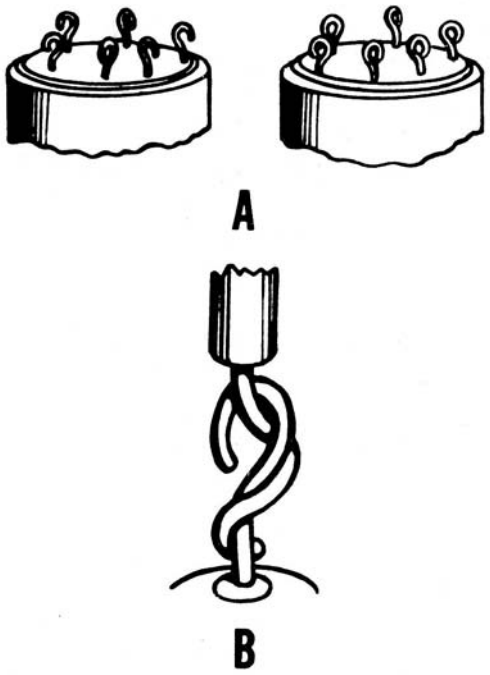
In naval electronic equipment almost all of the permanent connections are made by soldering. In the electrical systems which are incorporated in launching systems however, the permanent connections may be made by crimp-on terminals. This use of crimping is relatively new and avoids some of the limitations of soldered terminals. The quality of soldered connections depends mostly upon the operator's skill. Such factors as temperature, flux, cleanliness, oxides, and insulation damage due to heat, all affect the quality of soldered connections.

The crimp-on or solderless terminals require relatively little operator skill. Another advantage is that the only tool necessary is the crimping tool. The connections are made more rapidly; they are cleaner and more uniform. Due to the pressures exerted and the materials used, the crimped connection or splice, properly made, has an electrical resistance that is less than that of an equivalent length of wire.

The basic types of terminals are shown in figure 12-16. (A) shows the straight type, (B) the right angle type, (C) the flag type, (D) the splice type, and (E) the disconnect splice type. There are also variations of these types, such as the use of a slot instead of a terminal hole, three-and four-way splice type connectors, etc.

Various size terminal or stud holes will be found for each of the different wire sizes. A further refinement of the solderless terminals is the insulated terminal; the barrel of the terminal (fig. 12-16) is enclosed in an insulating

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Figure 12-14. — A. Hook and eyelet terminals; B. Correct wrap.

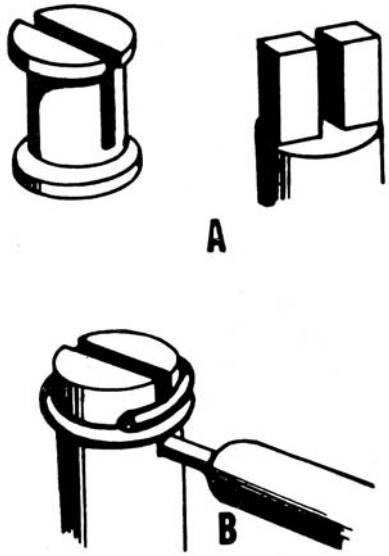


Figure 12-15. — A. Split terminals; B. Correct wrap. 83.131

material. The insulation is compressed along with the terminal barrel when crimping, but is not damaged in the process.

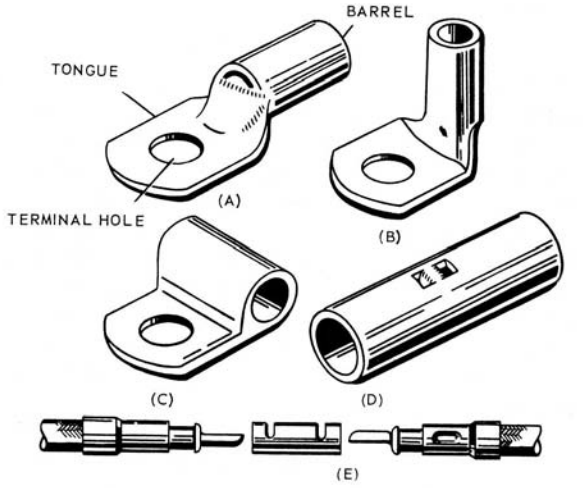
This eliminates the necessity of taping or tying an insulating sleeve over the joint.

There are two types of crimping tools used with copper terminals. For wire sizes AWG (American Wire Gage) 10 or smaller, a small pliers type of crimper is used. For the larger wire sizes, a large and powerful pincer type crimper is used. The small pliers type crimper has several sizes of notches for the different size terminals. The large pincer type is adjusted to an index mark for the different size terminals. Care should be exercised to select the correct crimping tool for the particular terminal. Do not tin stranded wires. (The solder forms a line of stress concentration on each strand, which may result in vibration failure.) Always use insulation-grip terminals for wire sizes No. 10 AWG and smaller, regardless of application, to protect conductors from mechanical vibration and fatigue.

The procedure for crimping a cooper terminal to a cooper wire is as follows:

1. Strip the cable insulation carefully to avoid cut or nicked strands. Remove the proper length of insulation.

2. See that the stripped cable end extends into the terminal barrel for the full length of the barrel.



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Figure 12-16. — Basic types of solderless terminals: A. Straight type; B. Right angle type; C. Flag type; D. Splice type; E. Disconnect splice type.

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3. Center the terminal barrel in the crimping tool so that pressure on the strands, from the crimped strands to the unsecured strands, will be gradual, thus preventing stress concentrations.

4. Now crimp the terminal, making sure that the crimper is fully closed to ensure proper crimping.

5. Inspect the joint with a probe through the inspection hole. The end of the conductor must come to the edge of the inspection hole.

Take care with this procedure because improper procedures will eventually cause terminal failure. Be particularly careful of undercrimping, overcrimping, the use of the wrong crimping tool, improper cleaning methods, and cutting or nicking the conductors. A loose contact will allow an oxide film to form between the wire and terminal; this will result in increased resistance.

If the correct tools are used, and the proper procedures followed, the connections will be more effective electrically, as well as mechanically, than soldered connections. A visual inspection is very important for it will reveal oxidation, deterioration, overheating, and broken conductors. In some cases it may be necessary to check these connections with an ohmmeter; the proper resistance, for all practical purposes, is zero. Any defective terminal should be removed and a new terminal crimped on.

TYING AND LACING

While making repairs or fabricating a new cable, it may be necessary for you to tie or lace the cable. The accepted method for lacing cable harnesses is shown in figure 12-17A. The use of the continuous lacing method is restricted to panels and junction boxes. The purpose of lacing is to keep all cables neatly secured in groups and to avoid possible damage from chafing against equipment or interference with equipment operation. When continuous lacing is used, it shall not include cables of more than one harness group.

Continuous lacing is restricted in its use because, if the cord is broken, the lacing has a tendency to unravel. In place of continuous lacing, typing (or short-section lacing) is used. The method of tying is shown in figure 12-17B. In the first method, tie a clove hitch about the wires. Then tie a half hitch over the clove in such a manner as to produce a square knot.

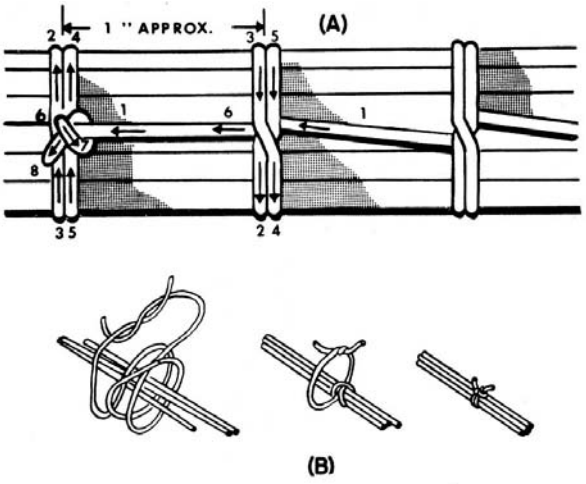


Figure 12-17.—Lacing and tying of electric wires: A. Harness; B. Method of tying.

On color conductors, the lacing twine should be the same color as the insulation of the conductor. When repairs have to be made on wiring that is laced, the lacing may have to be removed to make the repairs, and a new harness made after the repairs are made. Before lacing, lay the conductors out straight and parallel to each other; do not twist them together.

SHIELDING AND BONDING

Shielding

Shielding is the enclosing of cables or electrical units in metal to prevent high frequency interference. Shielding causes the high frequency voltage to be induced in the shield rather than in the units or cables. Shielding is used where a unit is to be protected from radio frequency noise. It is also used to keep cables or units from emitting radio frequency noise. Thus, shielding is used to keep outside noise out and inside noise in.

Where shielding of cables is used. it is very important that it be well grounded at one end of the cable. (Radiating circuits such as pulse cables and transmission lines use coaxial cables. The outer flexible conductor of "coax" often serves as the shield, but occasionally an additional braid is used for shielding.) Regardless of the system used, the conductor forming the shield is grounded.

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Disturbances caused by spark discharges are the most difficult to control. A spark discharge not only radiates but also causes voltage variations in the circuit. Shielding is effective for the radiations but not for line variations. These variations in the line can be smoothed out by the use of filters. The function of such filters is to block or bypass voltages and currents of frequencies which would cause interference.

Bonding

Bonding straps are used to tie together, electrically, any parts of an equipment or system which are insulated from the ship's structure. Bonds are used, for example, to connect the various panels of launching systems to the ship's structure. Some of the reasons for bonding are:

1. To minimize interference to electronic equipment by equalizing the static charges that accumulate.
2. To provide a proper "ground" for electronic equipment.
3. To provide a low resistance return path for single-wire electrical systems.
4. To aid in the effectiveness of shielding.

A bond is usually made of a flexible metal strap provided with a crimped-on terminal at each end. It is usually made of tinned copper wire.

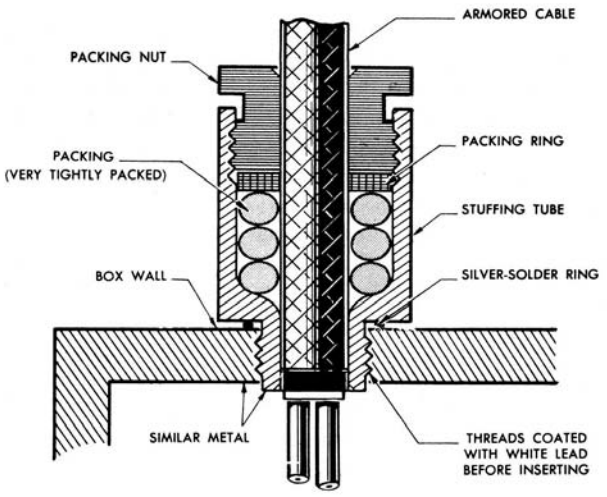
The bond must be intact and make a good electrical connection at all times. In replacing a bond, be careful to make a good metal contact. If, in preparing the surface for the bonding connection, you have to clean the surface with sandpaper, be sure not to damage the original finish on the metal. Place bonds in such a position that they will not interfere with the operation of the unit and will not be damaged or broken loose because of the motion or vibration of the unit.

CABLE SPLICING

Cable splices should not be used except as an EMERGENCY measure.

If an emergency condition exists, solder may or may not be used, as the condition warrants, but in any case the splice should give a good electrical and mechanical joint without solder. The splice should be taped to give insulation equivalent to the rest of the cable. A permanent repair must be made as soon as it is possible.

Ordinarily there is not enough slack wire for making splices. However, if there is enough slack, the two splices used by GMM s are the "western union splice" and the "flexible wire splice." These and other splices and joints are covered in Basic Electricity. NavPers 10086-B; chapter 7, for types of tape used over splices, and methods of applying.



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Figure 12-18. — Cross section of watertight stuffing tube with cable inserted through it.

WATERTIGHT BOXES AND FITTINGS

Aside from mechanical injury, the biggest source of electrical trouble on board ship is moisture. And salt water moisture is the worst kind because it is a conductor of electricity. Thus, when a cable or box becomes saturated with salt water, two things happen: First, a current path to the ship's hull is formed, which is a ground; and second, especially where dissimilar metals are involved, electrolysis and corrosion occur, and the connections or wire fittings are slowly eaten away. Therefore, practically all of the electrical wiring aboard ship is run in waterproof, fire-resistant, armored cables which terminate in watertight boxes.

The cables are run into boxes through stuffing tubes, also called terminal tubes. When renewing cable, these tubes must be repacked with a standard packing corresponding to the size of tube, and the packing ring and nut must be tightly secured. Figure 12-18 shows a cross-sectional diagram of a stuffing tube properly assembled with an armored cable in place. Stuffing tubes similar to the one shown are used to ensure

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watertight integrity where cables pass through decks and bulkheads. Where cables pass through the deck, pipe risers are used in order to prevent mechanical injury to the cable. The stuffing tube is then inserted at the top of the pipe.

Terminal and junction boxes used for most fire control work are rated according to the number of terminals they contain, for example, 10-wire box, or 50-wire box. All wires are lugged at the ends to ensure solid connections at the terminal strips or blocks within each box. The lugs are, or should be, stamped with circuit designation numbers to assist the maintenance men in tracing out circuits. You'll find the cable leads laced together with cord and neatly arranged in each box to make for compactness and ruggedness. Always rearrange the box in this manner after pulling out leads for inspection, making tests, or relugging.

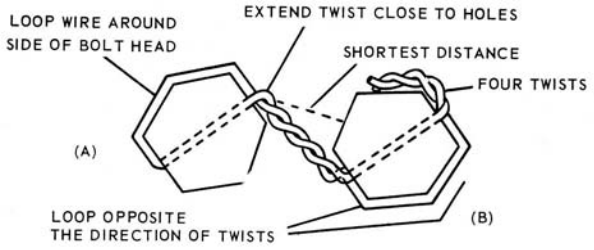
SAFETY WIRING

Screws, bolts, electrical and mechanical connectors, and other devices are safety wired as an additional security against the effects of vibration. Figure 12-19 shows the basic principles of safety wiring. The wire is threaded through the bolthead in such a direction that if a bolt tends to loosen, the wire will become tighter.

The wire used in safety wiring usually is made of annealed brass or annealed stainless steel. The size is not critical, depending mainly on the size of bolt being secured. The bolt used has a hole drilled through the head.

Refer to figure 12-19. The general procedure for safety wiring is to follows:

1. Thread the wire through the first bolt so that the wire exits on the side nearest the second bolt (point A).
2. Loop the wire around the side of the bolthead. The loop should be opposite the direction followed by the twisted wire so as not to interfere with it. Never kink the wire as it will be weakened at this point.
3. Twist the wire by hand; hold the wires so that an angle of about 90 degrees is formed between them. Do not use pliers as this tends to develop kinks and nicks, and to make the twist too small and tight.
4. Thread one end through the second bolthead, and the other end around the side of the bolthead that is opposite to the direction of the twisted wire.
5. Pull both ends tight, and give a minimum of four twists on the far side of the second bolt.



12.245

Figure 12-19.—Safety wire.

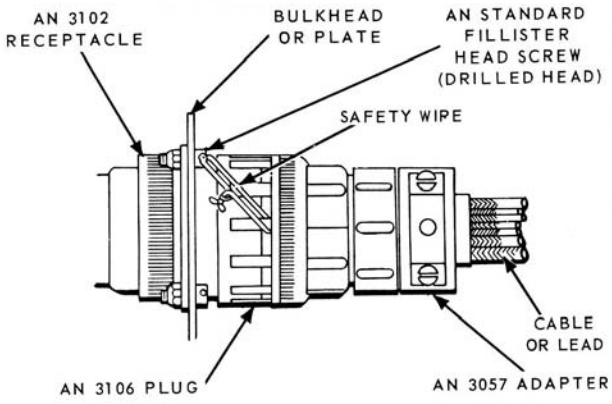
6. Cut off the wire and bend it along the side of the bolthead.

Under conditions of severe vibration, the coupling nut of the AN connector may vibrate loose; and with sufficient vibration, the connector will come apart. When this occurs the circuit carried by the cable will open. The proper protective measure to prevent this occurrence is a safety wiring attachment as shown in figure 12-20. Remember, any time a safety wire is NOT replaced a failure may result.

The safety wire should be as short as practicable and must be installed in such a manner that the pull on the wire is in the direction which tightens the nut on the plug.

MOUNTING BALL BEARINGS

If one is available, you should always use an arbor press for mounting ball bearings on a



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Figure 12-20.—Safety wiring for plug connectors.

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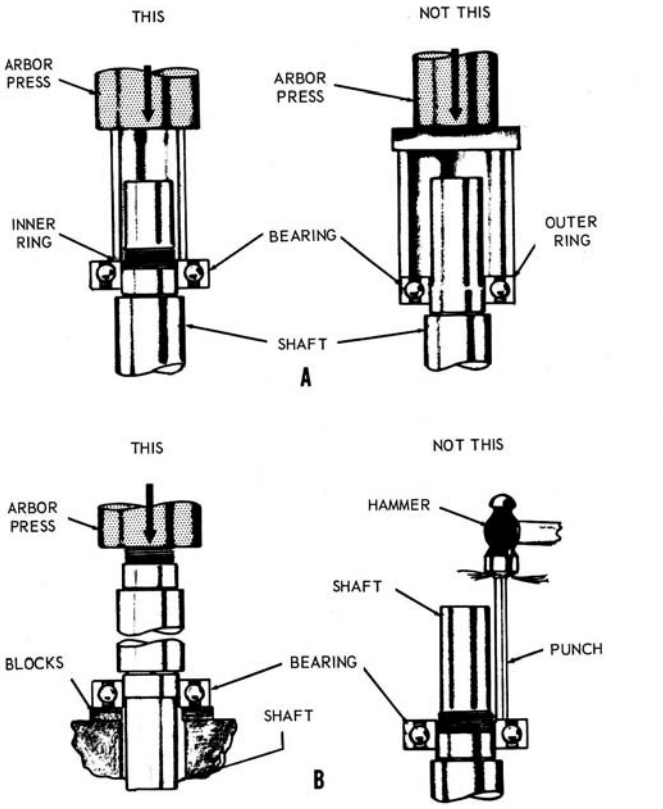


Figure 12-21.—Mounting ball bearings, correct and incorrect methods: A. With an arbor press; B. Without an arbor press.

shaft. Figure 12-21 shows the right and wrong ways to use this tool. A word of caution - never put the full force of the press on the OUTER RING of the bearing. This will apply a heavy load on the balls and races before they are seated and may seriously damaged the bearing. You should always apply force on the inner ring.

Before you put the full force of the arbor press on the bearing, make sure it is started straight and not misaligned. If you force a cocked bearing. it will twist the inner race and may crack it. Also, because the inner race is extremely hard. it is likely to burr or score the shaft seat.

Never use a hammer and punch to drive a bearing to its seat. If you do, the bearing will be cocked from side-to-side and may score the shaft or damage the bearing. And what is worse, the damage may not show up until after the bearing is in service. You end up with a job to do over. Use the proper tool; it will save you trouble and time in the long run.

The bearing mounting method we've just described is fine if the shaft is free of the equipment. Then you can put it in an arbor press. But how can you put a ball bearing on a shaft that is in an equipment? Just get a piece of round copper pipe whose internal diameter is larger than the shaft. The diameter of the pipe should also be about the same diameter as the inner ball bearing ring. Start the bearing on the shaft. Get the bearing on straight. Slip the piece of stock over the free end of the shaft and bottom the pipe on the inner ring of the bearing. Center a block of wood on the other end of the pipe. Now gently tap the wood near its center. This helps to distribute the force of successive hammer blows evenly on the inner bearing ring.

Removal of Ball Bearings

You can also use an arbor press to remove ball bearings from a shaft. The correct removal methods are illustrated in figure 12-22.

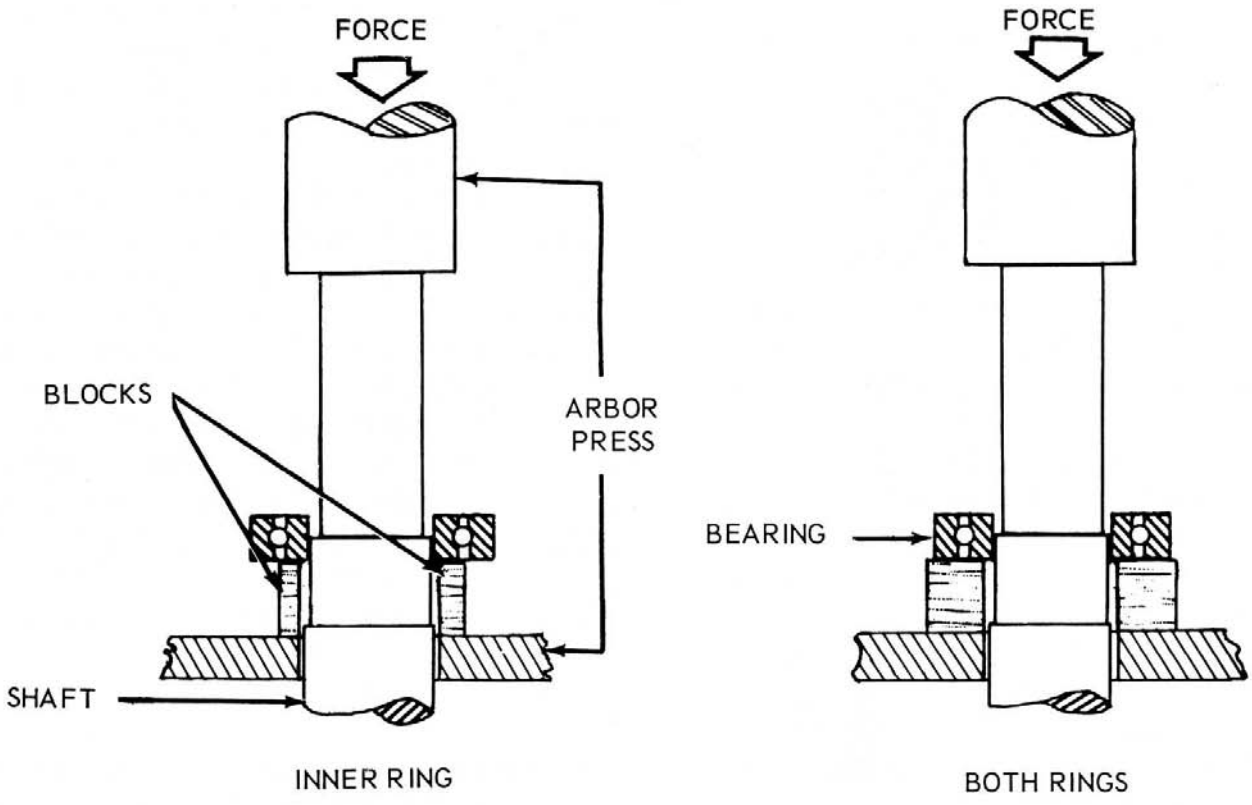
You can use pullers to remove bearings. This tool is shown in figure 12-23, and you can see there the technique of using the puller. Where gears and other removable parts won't let you get at the bearing directly, the puller jaws can be placed behind the part. Then the part and bearing may be removed as a unit as shown in part B of figure 12-23.

REMOVAL AND REPLACEMENT CONSIDERATIONS

Planning is the most important step in the removal and replacement of equipment units. Planning covers such items as getting the correct tools, removing hazards to personnel and equipment, and finding a working space, if you have no shop. Study the equipment OP. Find the section that has the disassembly and assembly instructions in it. Read the procedures and rehearse in your mind what you plan to do. Go by the book. If these things are not considered, time may be lost, or equipment damaged.

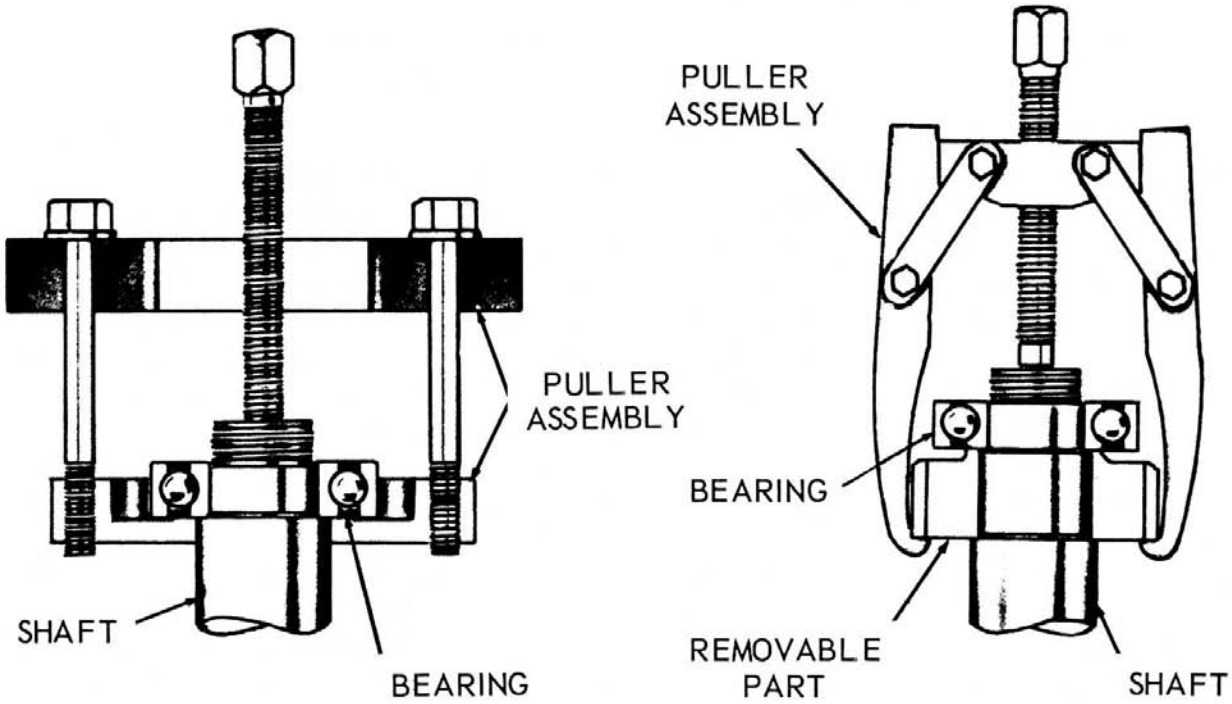
As we said before, when you remove a unit from an equipment for maintenance, periodic check, or lubrication, planning is the first step. Clear the route the unit will take to the working space. This includes removing all obstacles such as doors and hatches, if the unit is large. Clear and clean the working area.

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Figure 12-22.—Removal of ball bearings with an arbor press.



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Figure 12-23.—Removing ball bearings with a puller assembly.

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Before you remove the unit, disconnect all cables. Be sure you tag and identify each lead. You'll need this information when you reinstall the unit. Since only cables with electrical connectors have to be unplugged, there is, of course, no tagging problem here. But you must note the alignment of mechanical connections. If the connections have zero positions, they should be disconnected when the unit is on zero. Mark with a scribe the mating gears or any other part that will give you a zero reference. If you install a unit the same way you removed it, this will save you a lot of time in the realignment process.

Common and special tools should be obtained and laid out. If the unit is heavy, get a chain fall. Get a Boatswain's Mate to help you, if you haven't had much experience with rigging. Explain to your strikers the entire removal or replacement procedure. Tell each man what his specific job is and what you want him to do. You will issue all instructions. Time them so that the procedure will go smoothly and effectively. Work cautiously. This eliminates the possibility of injury to your men and damage to the equipment. Observe all safety precautions.

When the unit is in the shop, or at the working space, you should follow certain precautions before you disassemble the unit. Clean the outside of it. When you remove the covers inspect the gaskets. If you find them damaged, get new ones.

In conclusion, plan every job before you start it. If you've never done it before, assemble and study every maintenance aid about the job that you can think of. Get the OP and MRC and study them. Look over the appropriate ordnance drawing. Talk over the job at hand with someone with more experience.

Before you discard any part, be sure to check supplies and confirm that there is a part to replace. You might have to make a temporary repair of the old part. The MRC states whether the part is to be repaired or replaced, and by whom. The Supply Department should have all the necessary parts, but check to be sure before you deep six anything.

Reinstallation

Reinstallation of major units is usually just the reverse of the removal procedure. You should take special pains to see that gear meshes, and coupling and linkage connections, are made properly.

The meshing of gears is extremely important. An incorrect gear mesh causes excessive wear and binding. This shortens the life of the equipment. The gear faces must face squarely. If the mesh is square but too tight, there will be no lost motion. This may sound like an ideal situation. But it is not. No lost motion results in excessive gear wear.

Before you connect couplings, check their shafts for alignment. If the shafts are at an angle to each other, they may bind. When you connect linkages, the connecting pin or bolt must be checked to ensure that when the linkage is moved it will not catch or bend.

Be careful when you plug electrical connectors into their receptacles. You might bend or break the connecting pins. Make all connections tight.

Brushes

Brushes are found in numerous sizes and shapes and are made of various materials and compounds. Many brushes used in electrical equipment are made of a composition of graphite and other forms of carbon. In all probability, the majority of the maintenance you will perform on rotating machinery will be concerned with brushes. Brushes should be checked for wear, chipping, oil soaking, sticking in the brush holders, spring tension, length, and area of contact with the commutator. If for any reason a brush is removed and is to be replaced, it should be marked or tagged so it may be replaced in the same brush holder in the same position it occupied before removal. Never attempt to change the location of the brushes.

Brushes that show excessive or improper wear, chipping, or are oil soaked, should be replaced. Care should be exercised in obtaining the correct replacement. It is important that the brushes be changed before they are completely worn away, in order to prevent damage to the equipment in which they are used.

In order that the technician can tell when replacement is necessary, a brush marking system has been developed. Brushes are marked by a readily noticeable groove in their edges to indicate allowable wear. This groove extends from the top of the brush down to a point 75% of the brush wearing depth. (The top is the end opposite the wearing face.) Thus, if the brush is worn down to the groove, it must be replaced. If no groove is present, consult the equipment OP for acceptable minimum brush lengths.

In the replacement of brushes, you will find that some new brushes are ready to use. That is. the brush face is slightly concave so that it

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fits tightly on the commutator. However, because other new brushes are NOT ready for use, they must be sanded in. This sanding, or seating, can be accomplished by wrapping fine sandpaper around the commutator. The paper is placed sand side up with a lap following the direction of normal rotation of the device, and is held in place by a rubber band. Do NOT use glue or tape. The brushes are placed in their holder under spring tension, and the armature is rotated slowly by hand in the direction of normal rotation. In so doing, the contact surfaces of the brushes are sanded until their curved surfaces match the curvature of the commutator. The carbon dust from the brushes must be removed from the device by using dry compressed air, followed by cleaning with solvent.

TORQUE WRENCHES

There are times when, for engineering reasons, a definite pressure must be applied to threaded fasteners (nuts and bolts, as they are commonly called). This pressure can properly be applied by a torque wrench. Proper torque aids the locking of all types of thread locking fasteners. After tightening, nuts and bolts are held by the static friction of the nut and bolt head against the surface of the items being held together and the friction on the threads of the nut and bolt against each other. This friction is caused by the clamping force created by a slight stretching of the bolt when the nut is tightened. The metal being slightly elastic will pull back towards its original dimensions creating large clamping forces. Excessive tightening will cause the metal to pass its limit of elasticity and cause a permanent stretch.

The principle of torque is based on the fundamental law of the lever, that is, force times distance equals a moment, or torque, about a point. Torque is often called a torsional or twisting moment. It is a moment which tends to twist a body about an axis of rotation. If a common end wrench is used to tighten a bolt for example, a force times a distance, a torque is applied to overcome the resistance of the bolt to turning.

Figure 12-24 shows three torque wrenches, the deflecting beam, dial indicating, and the micrometer setting type. The deflecting beam which operates on the deflecting beam principle is probably the simplest and most common type evolved from the three principles listed in the preceding paragraph. The primary component is the beam or measuring element. It is alloy steel and may be round, double round, straight flat, or tapered flat. To one end of the beam is attached a head piece containing the drive square (tang) and fixed pointer mounting. A yoke is attached to the other end. Mounted on the yoke is the torque scale handle and, when provided, the signaling mechanism. As a force is applied to the handle, the beam deflects with the scale. The pointer remains fixed, hence a torque is indicated on the scale.

The torsion bar or rigid case type wrench, also shown in fig. 12-24, has its actuating element enclosed in a rigid frame with a removable access cover. The deflecting beam, used in some rigid case wrenches, is similar to that explained above.

The third torque wrench shown is the micrometer setting type. To use the micrometer setting type, unlock the grip and adjust the handle to the desired setting on the micrometer type scale, then relock the grip. Install the required socket or adapter to the square drive of the handle. Place the wrench assembly on the nut or bolt and pull in a clockwise direction with a smooth, steady motion.

There are several different types of torque wrenches, but all of them have two basic parts - something that will deflect with the load and something to show how much the sensing element has deflected.

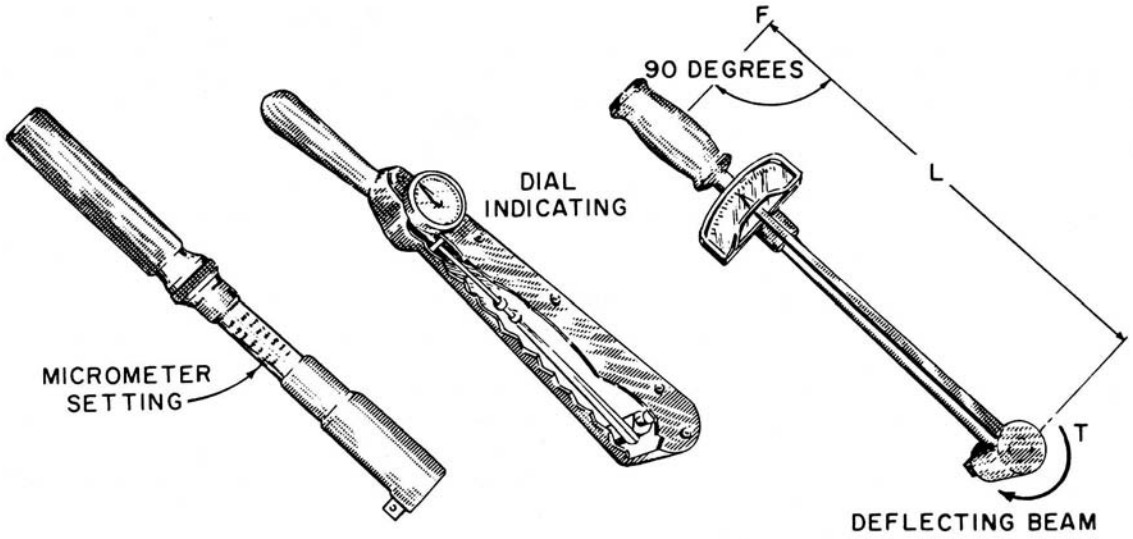
The torque wrench should be calibrated frequently. One that hasn't been recently calibrated and isn't normally stored in its protective case is a dangerous tool. You can't expect to get a meaningful reading from a precision instrument which has been abused. The flat and round beam types will normally give true readings as long as their pointers indicate zero and the drive heads are tight. Because this type can be kept in calibration, they are recommended for shipboard use.

Other type wrenches that indicate by means of dial indicator or by releasing or signaling when a preset load is reached are more sensitive to shock and dirt, hence should be calibrated whenever possible. A minimum of 30 days between calibration is recommended. Never check one torque wrench against another.

An important point to remember is: "Always use the proper size wrench;" one with the desired torque near the 3/4 mark of full scale.

When torquing, the critical maneuver is the application of force to the wrench handle. It must be applied slowly and evenly until the desired torque value is indicated on the wrench scale. When installing a unit which is circular

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Figure 12-24. — Torque wrenches.

or has more than one side, the bolts should be cross torqued. It may be necessary to cross torque two or three times before an even torque is reached, but be sure the maximum torque is not exceeded.

Nuts and bolts should be tightened to the torque reading required by the installation drawings. The formula often used is that torque in foot-pounds is 0.2 times the bolt diameter times the desired bolt load. A load of about 60 percent of the yield stress of the bolt material is used for most naval applications. However, bolt load varies depending upon whether the bolt or stud is used to support the load itself or to hold together two load supporting members. Installation drawings will indicate the torque value specified by the designer.

If the bolts are loaded in tension, the torque must be great enough to maintain tightness when the assembly is unloaded and not so large that the bolts yield under load. With this type of loading, all bolts must be equally torqued to share the load.

NOTE: Always inspect for clean lightly oiled threads and clean surfaces before torquing. Discard all hardware with burred threads. For more detailed information on the use and care of torque wrenches refer to NAVSHIPS Technical Manual, Chapter 9090.

SPECIAL TOOLS

Special tools are used only for one purpose and only on one type of equipment. They are supplied by NAVORD, and instructions for their proper use are provided in publications applicable to the specific type of equipment.

NONSPARKING TOOLS

Nonsparking or nonferrous tools are special tools made from a nonferrous metal, (metal containing no iron). These tools are used by Gunner's Mates in area where a spark may create a conflagration, such as on or around explosives. Nonsparking tools generally are made of copper alloy (bronze), however they may be made from other nonferrous materials. The material from which these tools are made is relatively soft so care must be exercised when using them to prevent breakage or distortion of the tool. Nonsparking tools should be stowed in separate tool boxes and should not be used as common tools.

SAFETY PRECAUTIONS

The only really safe practice around machinery is to be sure all the power is off before you begin doing your maintenance work. Routine lubrication jobs are not done in the heat of

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battle, so there is no excuse for having any of the machinery running.

If you must use power to rotate or move some of the equipment, be sure no one is in the way of the moving parts, and observe all safety precautions. That means a safety watch must be maintained.

Never wear loose or torn clothing or neckerchiefs that can get entangled in machinery. Gloves, long sleeves, rings, and bracelets should not be worn while working on machinery.

Wipe up any spilled oil or grease at once. Be careful to keep lubricants away from electrical contacts, from electric wires, and from all rubber parts. All petroleum products have a bad effect on rubber. Overpacking of bearings can cause runoff of lubricants which might then contact electrical parts or rubber parts.

Obey NO SMOKING rules.

When it is necessary to use kerosene or dry-cleaning solvent to remove caked or gummy lubricants before applying fresh lubricant, observe fire precautions and ventilation requirements. Remember also that these solvents are skin irritants.

When you've finished, recharge the lubricating guns, clean up, and stow the gear. Check your chart once more to be sure you haven It slipped up anywhere.

Some new type lubricants for use at low temperatures contain substances harmful to the skin. Observe the caution on the containers.

In spite of repeated precautions and warnings about the danger of fumes, fatal and near-fatal accidents continue to occur. Whenever work is undertaken in a small compartment with any toxic solvent, such as those used in paints, trichlorethane, or dry-cleaning solvent, adequate precautions must be taken before the work is begun. Even though the outcome is not fatal. exposure to toxic fumes can do permanent damage to the kidneys, brain, or nervous system.

Precautions should include:

(1) Sufficient mechanical ventilation to reduce the concentration of toxic fumes to a safe level. When possible, ventilation should include an exhaust for fumes as well as an intake for fresh air.

(2) When a safe level of ventilation is doubtful, workers in the compartment should wear an air line respirator provided with a pure air supply.

(3) Men working in a compartment where fumes may be above a safe toxic level should always work in pairs, so that one man remains outside the compartment as a safety watch at all times. The man outside should have a respirator so he won't be overcome if he has to go into the compartment to bring out an overcome man.

(4) Under no circumstance is 1.1.1-trichlorethane (methyl chloroform) to be used in a closed compartment.

As a petty officer, you must see that the regulations are observed by the men in your charge.

Basic Military Requirements, NavPers 10054C, contains several pages of safety rules in the chapter on seamanship. Basic Electricity, NavPers 10086-B, devotes a whole chapter to electrical safety. Appendix III of Basic Handtools, NavPers 10085-A, consists of electrical safety rules, and all the OPs for the equipment have a summary, in the front of the book of the safety rules scattered through the volume. The illustrated chart of instructions for mouth-to-mouth resuscitation should be posted in one or more places in the working spaces. The danger from electricity is present in all parts of the ship.

Special safety rules applicable to a particular component or to a particular maintenance process are given on the MRC for that part or process.

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CHAPTER 13

COMMON TEST EQUIPMENT AND LOGICAL TROUBLESHOOTING

In preceding chapters we have presented the basic operating principles of missile launching systems, and explained how they fit into the shipboard missile weapons system. But an understanding of the theory of operation is only part of the knowledge you need for successful maintenance of launching system equipment. You must be able to use test equipment and to troubleshoot. In this chapter we will cover test equipment used to measure electrical quantities, and the basic techniques for troubleshooting electronic circuitry.

The device that you will use most frequently in your maintenance tasks is the meter. For this reason, we shall first review meters before we discuss other test equipment and troubleshooting techniques. You will find a more complete coverage of meters in chapter 15 of Basic Electricity, NavPers 10086-B.

REVIEW OF METER OPERATION

We want to emphasize that a thorough understanding of the construction, operation, and limitations of electrical measuring instruments, coupled with the theory of circuit operation, is essential in serving and maintaining electrical equipment. Remember that the best and most expensive measuring instrument is of NO use to the man who does not know what he is measuring or what the readings indicate.

The three types of meters that you will most often use are ammeter, ohmmeter, and voltmeter. It is well to pay special attention to each application in this review.

AMMETER

The ammeter is used to measure current. The GMM uses the ammeter to acquire further information while performing an operational check on a malfunctioning launching system to further localize the malfunction to a specific unit. The ammeter must always be placed in series with the circuit to be measured. The ammeter consists of a basic meter movement and a combination of shunt resistors in parallel with it.

The ammeters used in missile systems test equipment and component test sets usually are panel-mounted instruments. In these applications they can be used to detect the current drain of the major electrical circuits and thus provide a valuable first step in finding trouble. When ammeters are not included as parts of the equipment, current measurements can be made only after the circuit wiring has been opened and the meter inserted in series with a suspected part.

A multiposition switch or a series of pin jacks allows the use of various shunt resistors to give different current ranges. When using an ammeter, always have the meter on the highest range before connecting it into a circuit.

OHMMETER

The ohmmeter is widely used by GMM's in making resistance measurements and continuity checks. You will find wide use for this instrument in checking cables and locating malfunctioning components in electrical circuits. The ohmmeter consists of a basic meter movement connected as an ammeter, a voltage source, and one or more resistors used to adjust the current through the meter movement. The meter must be adjusted for "zero resistance" prior to making resistance measurements. MAKE SURE YOU DON'T USE AN OHMMETER ON AN ENERGIZED CIRCUIT. If you do, the meter will make smoke and burn out.

The theory and construction of the series type and the shunt type ohmmeters are discussed in Basic Electricity, NavPers 10086-B, which also describes a more specialized type of instrument, the megohmmeter, or meggar. The use of resistance checks for locating defective parts in electronic circuits is somewhat similar to the process of voltage checking. As with the voltmeter, the observed values are compared with the normal

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values given in the equipment manual to identify the malfunctioning part. This method, like voltage checking, is most effective after the trouble has been isolated to a single stage.

VOLTMETER

The voltmeter uses the basic meter movement with a high resistance in series. The value of this series resistance is determined by the current necessary for full-scale deflection of the meter, and the voltage being measured. Because the current is directly proportional to the voltage applied, the scale can be calibrated directly in volts for a fixed series resistance.

The sensitivity of voltmeters is given in ohms per volt, and may be determined by dividing the resistance of the meter, plus the series resistance, by the full-scale reading in volts. This is the same as saying that the sensitivity is equal to the reciprocal of the current (in amperes). Thus, the sensitivity of a 100-microampere movement is the reciprocal of 0.0001 ampere, or 10,000 ohms per volt. The sensitivity of the meter depends on the strength of the permanent magnet field and the weight of the moving coil.

The sensitivity of a voltmeter is an indication of how accurately it measures voltages in a circuit. In many cases, a sensitivity of 1,000 ohms per volt is satisfactory; however, if the circuit in which the voltage is being measured has high resistance, a greater sensitivity is required for accuracy. The higher the sensitivity rating, the higher the resistance in the meter branch of the circuit, and the less serious the effect of shunting the circuit. If a meter of low ohms per volt is used to measure the voltage in a high resistance circuit, the effect of the meter shunting load being measured will result in an inaccurate reading. Thus, the higher the sensitivity, the more accurate the reading.

Like the ammeter and ohmmeter, the voltmeter normally utilizes several resistors with a switching arrangement to permit multirange operation. Be sure to set the selector switch for maximum voltage range before connecting the meter to an energized circuit.

MULTIMETERS

During troubleshooting, you, as a technician are often required to measure voltage, current, and resistance. To eliminate the necessity of obtaining three or more meters, you will use a multimeter. The multimeter combines a voltmeter, ammeter, and ohmmeter in one unit. It includes all the necessary switches, jacks, and additional devices. By proper arrangement of parts, the multimeter can be built into a small, compact unit utilizing one meter movement; capable of being switched to different ranges.

A typical multimeter circuit is shown in figure 13-1. A three-range milliammeter, a three-range voltmeter with a sensitivity of 2,000 ohms per volt, and a two-range ohmmeter are combined in this circuit. A 0-500 microampere meter movement with a resistance of 100 ohms is the basic meter movement for the multimeter.

The AN/PSM-4 is a multimeter commonly used in the Navy. There are three controls on the face (fig. 13-2) of the instrument. The 10 position rotary switch in the lower left corner is used as a function selector. (Five of these positions set up ohmmeter connections within the instrument. For these resistance positions, the function selector also acts as a range selector.) The 8-position switch in the lower righthand corner selects ranges of voltage and current. The ZERO-OHMS control is continuously variable and is used to adjust the meter circuit sensitivity to compensate for battery aging in the ohmmeter circuits. It is used to set the pointer at full scale (indicating zero ohms) when the function selector is set at any resistance range and the test probes are shorted together.

Prior to using the meter for measuring volts, amps, or ohms, be sure that the meter movement is on zero. Observe the meter face, making sure that the indicating pointer is pointing to the left hand side of the meter, and the pointer is on zero for volts, and infinity for ohms. If the pointer is not on zero, make correction by the turn screw head located at the base of the meter face.

VACUUM TUBE VOLTMETER

The ordinary voltmeter is practically useless for measuring voltages in high-impedance circuits. The electronic voltmeter is a highly sensitive instrument for accurately measuring a-c voltages from 250 microvolts to 500 volts, within a wide frequency range. The meter consists essentially of a multistage amplifier terminated by two crystal diodes, connected in a bridge circuit, and a meter movement to indicate rectified current. One such meter is designed with shaped pole pieces so that the indications

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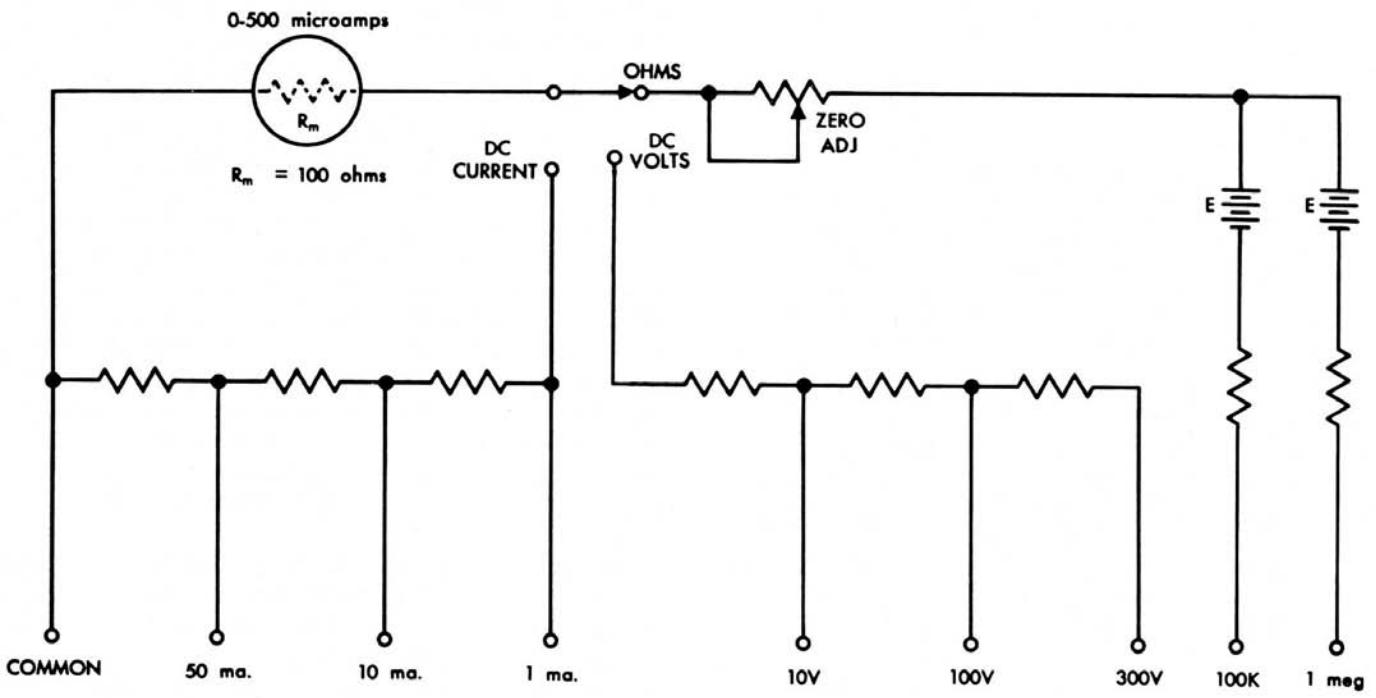


Figure 13-1.—A typical multimeter circuit.

are proportional to the logarithm of the rectified current which is accurately proportional to the input voltage over the working range of the instrument. A unique feature of the electronic voltmeter is that it gives meter readings that are substantially independent of variations in line voltage and internal circuit components. See Basic Electronics, NavPers 10087-B, for a more detailed description of this meter. The outward appearance of one model is similar to a multimeter (fig. 13-2). Since the meter uses vacuum tubes, it requires a power which is built into the meter to provide voltage for meter operation; the meter is plugged into a 117-volt a-c power outlet. Allow a few minutes for the vacuum tubes to heat to operating temperature before proceeding with the measurement. The meter is zeroed by turning the zero adjustment knob to zero before making any measurements. The meter may be used to measure a-c volts, d-c volts, or resistance.

Use of Meters

The following are guides for the proper use of meters.

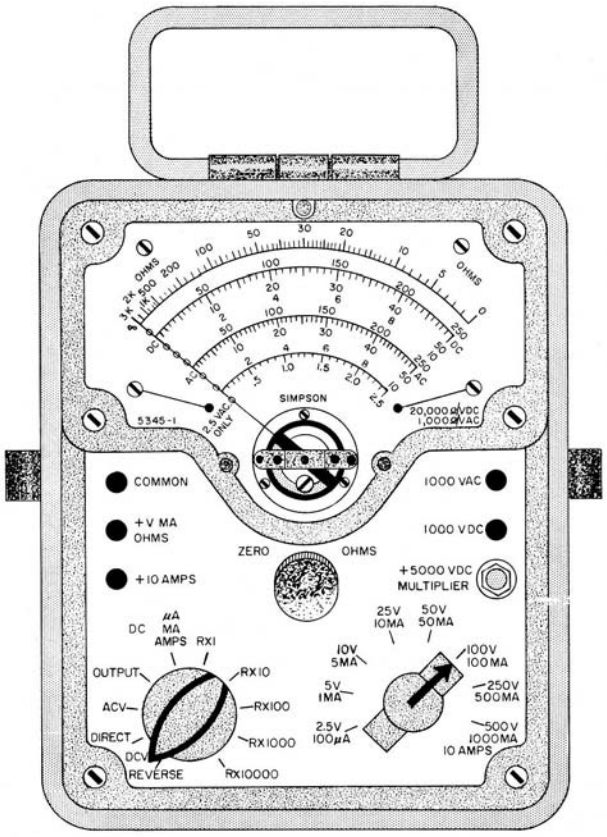
1. An ammeter is always connected in series - NEVER in parallel.
2. A voltmeter is connected in parallel.
3. An ohmmeter is NEVER connected to an energized live circuit.
4. Polarity must be observed in the use of a d-c ammeter or a d-c voltmeter.
5. Meters should be viewed directly from the front. When viewed from an angle off to the side, an incorrect reading will result because of optical parallax.
6. Always choose an instrument suitable for the measurement desired.
7. Select the highest range FIRST, take a reading, and then switch to the proper range.
8. In using any meter, choose a scale which will result in an indication near midscale.
9. Do not expect to obtain a meter accuracy greater than the guaranteed limits.
10. Remember, a low internal resistance voltmeter) (low sensitivity) may result in incorrect readings.

Meters are delicate, costly, and difficult to repair or replace. Be careful not to drop them or bump them against other objects. They are used often and must be accurate or they are useless.

TECHNIQUES FOR METER USE

The techniques suggested here are not the only ones that you can use. You will find, as you

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Figure 13-2. — Multimeter AN/PSM-4.

develop your technical skill, there are other variations and techniques in use. As an example, consider the techniques for measuring current in a circuit. This can be done by placing an ammeter in series. It can also be accomplished by measuring the voltage across a resistor of known value. Then, using Ohm's law, you can calculate the current. This makes it unnecessary to open the circuit before you connect the meter.

CONTINUITY TEST

Open circuits are those in which the flow of current is interrupted by a broken wire, defective switch, or anything else that prevents current flow.

The test used to check for opens (to see if the circuit is complete or continuous) is called CONTINUITY TESTING.

An ohmmeter (which contains its own batteries) is excellent for a continuity test. In an emergency a continuity test can be made using two sound-powered telephone handsets. Normally, continuity tests are performed in circuits where the resistance is low. An open is indicated in these circuits by a high or infinite resistance reading.

The diagram in figure 13-3 shows a continuity test of a cable connecting two launching system units. Notice that both connectors are disconnected and the ohmmeter is in series with the conductor under test. The power should be off. Checking conductors. A. B. and C. the current from the ohmmeter will flow through plug No. 2, through the conductor, and plug No. 1. From this plug it will pass through the jumper to the chassis which is "grounded" to the ship's structure. The metal structure will serve as the return path to the chassis of unit 2, completing the circuit to the ohmmeter. The ohmmeter will indicate a low resistance.

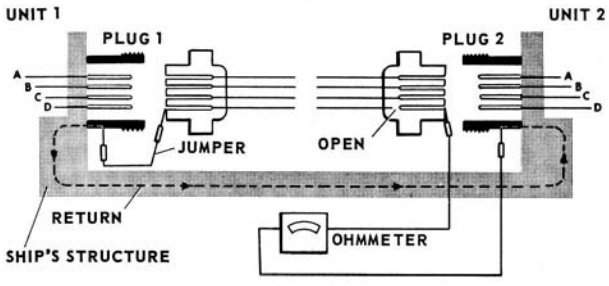
Checking conductor D in figure 13-3 will reveal an open circuit. The ohmmeter will indicate maximum resistance because current cannot flow. With an open circuit, the ohmmeter needle is all the way to the left on a series type ohmmeter, which reads from right to left.

When the ship's structure cannot be used as the return path, one of the other conductors may be used. For example (referring to figure 13-3). to check D. a jumper is connected from pin D to pin A of plug 1 and the ohmmeter leads are connected to pins D and A of plug 2. This technique will also reveal the open in the circuit.

TEST FOR GROUNDS

Most of the electrical circuits on shipboard should be ungrounded and they should be kept free of accidental grounds. Power circuits are insulated from ground.

Grounded circuits are caused by some conducting part of the circuit making contact either



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Figure 13-3. — Continuity test.

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directly or indirectly with the metallic structure of the ship. Grounds may have many causes. The two most common are the fraying of insulation from a wire allowing the bare wire to come in contact with the metal ground, and moisture soaked insulation.

Grounds usually are indicated by blown fuses or tripped circuit breakers. Blown fuses or tripped circuit breakers, however, may also result from a short other than ground. A high resistance ground may also occur where not enough current can flow to rupture the fuse or open the circuit breaker.

In testing for grounds, the ohmmeter may be used. By measuring the resistance to ground of any point in a circuit, you can determine if the point is grounded. Take another look at figure 133. If you remove the jumper, you can test for ground on each conductor of the cable. This is accomplished by connecting one meter lead to ground and the other to each of the pins of one of the plugs. A low resistance will indicate that a pin is grounded. Both plugs must be removed from their units; if only one plug is removed, a false indication is possible since a conductor may be grounded within the unit.

Grounding is required as a safety measure on certain installed and semiportable electrical equipment and on portable electrical equipment such as handtools. Grounded type plugs and receptacles are required for portable tools. The approved method of installing and testing grounded type plugs, cords, tools, and receptacles is given in Basic Handtools, NAVPERS 10085-A, in the Appendix Ill, which quotes the rules directly from NAVSHIPS 0901-000-0020 (formerly NavShips 250,000, Vol. II), Technical Manual. Articles 60-21 to 60-40, quoted in part in Basic Handtools. are required study for all hands. The NAVSHIPS volume also includes instructions for artificial respiration, additional safety precautions, instructions and regulations for use of extension cords, and use of personal electrical equipment, such as electric shavers, etc. Ground detector voltmeters are permanently installed on many Navy ships for measuring the insulation resistance to ground from d-c circuits and equipment.

TEST FOR SHORTS

A short circuit, other than a grounded one. is one in which two conductors accidentally touch each other, directly or through another conducting element. Two conductors with frayed insulation may touch and cause a short. Too much solder on the pin of a connector may short it to the adjacent pin. In a short circuit, enough current may flow to blow a fuse or open a circuit breaker. However, it is entirely possible to have a short between two cables carrying signals; such a short may not be indicated by a blown fuse.

Other indications of a short may be smoke, sparks, flame, and the odor of charring insulation. The charred insulation locates the point where the short occurred; however, many circuits are so enclosed they cannot be seen.

As when checking for a ground, the device used for checking for a short is the ohmmeter. If you measure the resistance between two conductors, a short between them will be indicated by a low resistance reading. In figure 13-3, by removing the jumper and disconnecting both plugs, a short test may be made. This is performed by measuring the resistance between the two suspected conductors.

Shorts are not reserved for cables; they occur in many components, such as transformers, motor windings, capacitors, etc. To check a component for a possible short, measure its resistance. Compare your reading with the resistance given on schematics or in the equipment OP.

VOLTAGE TEST

The voltage test must be made with the power applied; therefore, the prescribed safety precautions MUST be followed to prevent injury to personnel and damage to equipment. You will find in your maintenance work that the voltage test is of utmost importance. It is used not only in isolating casualties to major components but also in the maintenance of subassemblies, units, and circuits. Before checking a circuit voltage, check the voltage of the power source to be sure that it is normal.

Obviously, the voltmeter is used for voltage tests. In using the voltmeter, make certain that the meter used is designated for the type of current (a-c or d-c) to be tested, and that it has a scale of adequate range. Since defective parts in a circuit may cause higher than normal voltages at the point of test, the highest voltmeter range available should be used at first. Once a reading has been obtained, determine if a lower scale can be used without damaging the meter movement. If so, use the lower scale, so as to obtain a more accurate reading.

Another consideration in the circuit voltage test is the resistance and current in the circuit. A low resistance in a high current circuit would

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result in considerable voltage drop, whereas the same resistance in a low current circuit might have a negligible effect. Abnormal resistance in part of a circuit can be checked with either an ohmmeter or a voltmeter. Where practical, an ohmmeter should be used, and the test carried out with the circuit "dead."

The majority of the electronic circuits encountered in your equipment will be low current circuits, and most voltage readings will be direct current. Also, many of the schematics indicate the voltages at many test points. Thus, if a certain stage is suspected, and you want to check the voltage, a voltmeter placed from the test point to ground should read the voltages as given on the schematic.

Many OPs also contain voltage charts in which all the voltage measurements are tabulated. You will find more information on these charts later in this chapter. These charts usually indicate the sensitivity of the meter used to obtain the voltage readings for the chart. To obtain comparable results, the technician must use a voltmeter of the specified sensitivity. Make certain that the voltmeter is not loading the circuit while taking a measurement. 1f the meter resistance is not considerably higher than the circuit resistance, the reading will be marked lower than the true circuit voltage. (To calculate the meter resistance, multiply the rated ohms per volt sensitivity value of the meter by the scale in use. For example, a 1,000 ohms-per-volt meter set to the 300-volt scale will have a resistance of 300,000 ohms.)

RESISTANCE TEST

Before checking the resistance of a circuit or of a part, make certain that the power has been turned off and that capacitors in the associated circuit are discharged. To check continuity, always use the lower ohmmeter range. If a high range is used, the meter may indicate zero even though appreciable resistance is present in the circuit. Conversely, to check a high resistance, use the highest scale, since the low range scale may indicate infinity though the resistance is less than a megohm.

In making resistance tests, take into account that other circuits that contain resistances and capacitance may be in parallel with the circuit to be measured. In this case an erroneous conclusion may be drawn from the reading obtained. Remember, a capacitor will block the d-c flow from the ohmmeter. To obtain an accurate reading if other parts are connected across the suspected circuit, one end of the circuit to be measured should be disconnected from the equipment. For example, many of the resistors in major components and subassemblies are connected across transformer windings. To obtain a valid resistance measurement, the resistor to be measured must be isolated from the shunt resistances.

Resistance tests are also used for checking a part for grounds. In these tests, the parts should be disconnected from the rest of the circuit 80 that no normal circuit ground will exist. It is not necessary to dismount the part to be checked. The ohmmeter, which is set for a high resistance range, is then connected between ground and each electrically separate circuit of the part under test. Any resistance reading less than infinity indicates at least a partial ground. Capacitors suspected of being short circuited can also be checked by a resistance measurement. To check a capacitor suspected of being open, temporarily shunt a known perfect capacitor across it, and recheck the performance of the circuit.

ACCURATE MEASUREMENT OF RESISTANCE, CAPACITANCE, AND INDUCTANCE

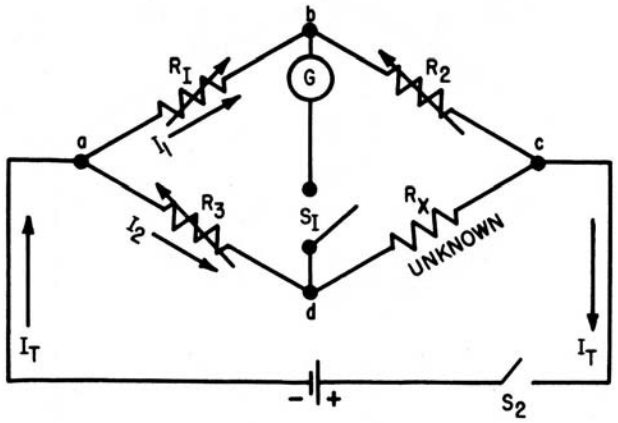
An instrument employing a bridge circuit should be used in the measurement of resistance, capacitance, and inductance where a high degree of accuracy is desired. Bridge circuits are used in both a-c and d-c measuring instruments. Both types will be discussed in this section.

USE OF D-C BRIDGES

A circuit that is widely used for precision measurements of resistance is the Wheatstone bridge. This bridge is covered in detail in Basic Electricity, NavPers 10086B. We shall discuss only its use in determining the value of an unknown resistor. The circuit diagram of a Wheatstone bridge is shown in figure 13-4.

In figure 13-4, R_l, R_2, and R_3 are precision variable resistors and R_X is the resistor whose value is unknown. The galvanometer G is inserted across terminals b and d to indicate the condition of balance. When the bridge is properly balanced, there is no difference of potential between terminals b and d. Thus, the galvanometer deflection, when the switches S_1 and S_2 are closed, will be zero. In reading the diagram, remember that R is resistance measured in ohms, I is current measured in amperes, E is voltage measured in volts.

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Figure 13-4. — D-c Wheatstone bridge circuit.

The operation of the bridge is explained in a few logical steps. When the switch S_2 is closed, current will flow from the negative terminal of the battery to point a. Here the current will divide as in any parallel circuit, a part of it passing through R_1 and R_2 and the remainder passing through R_S and R_X. The two currents, labeled I_1 and I_2, unite at point c and return to the positive terminal of the battery. The value of I_2 depends on the sum of resistances R_1 and R_2 , while the value of I_2 depends on the sum of resistances R_3 and R_X. R_1, R_2 and R_3 are adjusted so there will be no deflection of the galvanometer needle when both switches are closed. Thus, there is no difference of potential between points b and d.

This means that the voltage drop across R_1 (E_1.) is the same as the voltage drop across R_3 (E_3). By similar reasoning, the voltage drops across R_2 and R_X, that is E_2 and E_X, are also equal. Expressed algebraically,

$$E_1 = E_3$$

or $$I_1 R_1 = I_2 R_3$$

and $$E_2 = E_X$$

or $$I_1 R_1 = I_2 R_X$$

Dividing the voltage drop across R_1 and R_3 by the respective voltage drop across R_2 and R_X,

$$\frac{I_1 R_1}{I_1 R_2} = \frac{I_2 R_3}{I_2 R_X}$$

Simplifying

$$\frac{R_1}{R_2} = \frac{R_3}{R_X}$$

$$R_X = \frac{R_2 R_3}{R_1}$$

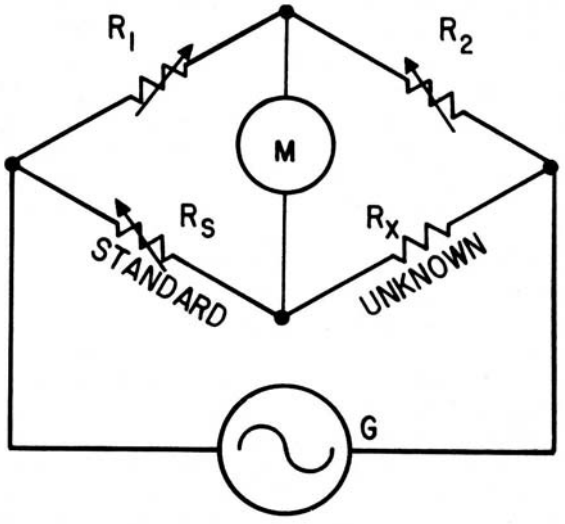
The resistance values of R_1, R_2, and R_3 are readily determined from the markings on the standard resistors, or from the calibrated dials if a dial type bridge is used. Then, after the bridge has been properly balanced, the unknown resistance may be determined by using the formula.

USE OF A-C BRIDGES

A wide variety of a-c bridge circuits may be used for the precision measurements of resistance, capacitance, and inductance. A typical bridge used by the Navy is the ZM-11/U. It is a very flexible test instrument capable of determining values of resistance, capacitance, and inductance over a wide range. A technician using a bridge such as this will need a knowledge of its operation.

A-c Resistance Bridge

The Wheatstone bridge discussed previously under d-c bridge circuits is also applicable to a-c circuits, as shown in figure 13-5.



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Figure 13-5. — A-c resistance bridge circuit.

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As shown in the figure, an a-c signal generator is used as the source of voltage. Current from the generator G passes through resistors R_1 and R_2, which are known as the ratio arms, and through R_S and R_X. R_S is an adjustable standard resistance and R_X is the unknown resistance. When the voltage-drops across R_1 and R_S are equal, the voltage-drops across R_2 and R_X are also equal, and no difference of potential exists across the meter. As discussed in the section on d-c bridges, when no voltage appears across the indicating device, the following ratio is true:

$$\frac{R_1}{R_2} = \frac{R_S}{R_X}$$

and

$$R_X = \frac{R_2}{R_1} R_S$$

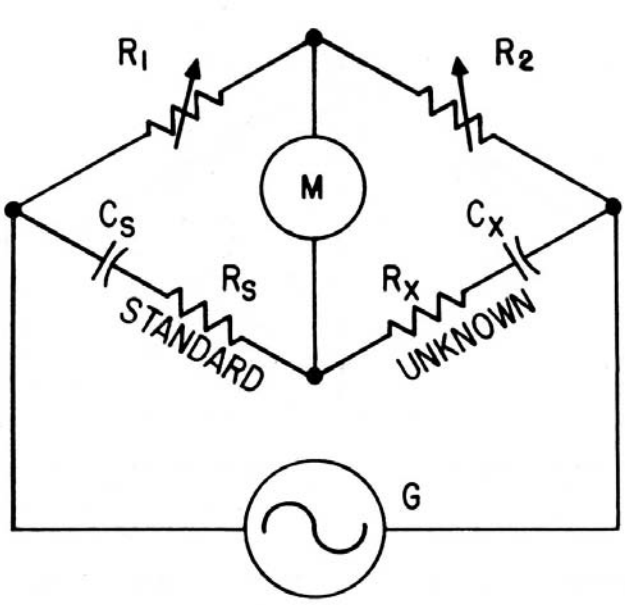
It is necessary to select the proper resistance values of R_1, R_2, and R_S so that the meter will remain centered when power is applied. With these values of resistance known, the value of the unknown resistance may be found.

A-c Capacitance Bridge

Capacitance is the property of an electric circuit that resists or opposes any change of voltage in the circuit. If the voltage increases, capacitance tries to hold it down; if the voltage decreases, capacitance tries to maintain the previous voltage. Capacitance in a circuit resists change in the circuit. It also enables energy to be stored in an electrical circuit. The device that is used for storage is a capacitor, sometimes called a condenser.

With this brief review, we shall proceed with the use of a capacitance bridge.

The value of an unknown capacitance C_X may be determined by the capacitance bridge contained in the ZM-11/U. It is shown in simplified form in figure 13-6. The ratio arms, R_1 and R_2, are accurately calibrated resistors. C_S is a standard capacitor whose capacitance is known, R_S is the equivalent series resistance of the standard capacitor, and R_X is the equivalent series resistance of the unknown capacitor. (The letter "C" denotes capacitance in farads. The farad is much too big



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Figure 13-6. — A-c capacitance bridge.

for practical electrical circuits, so the microfarad is the unit normally used.)

With the a-c signal applied to the bridge, R_1 and R_2 are varied until a zero reading is seen on the meter. Zero deflection indicates that the bridge is balance. (Note: In actual practice the variables are adjusted for a minimum reading, since the phase difference between the two legs will not allow a zero reading.) Since current varies inversely with resistance and directly with capacitance, and inverse proportion exists between the four arms of the bridge.

Thus,

$$\frac{R_1}{R_2} = \frac{C_X}{C_S}$$

or

$$C_X = \frac{R_1}{R_2} C_S$$

Since Rl and R2 are expressed in the same units, $\frac{R1}{R2}$ becomes a simple multiplication factor .This equation will give a numerical value for C_X and the answer will be in the same units as C. (farad, microfarad, etc.).

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Similarly, the following direct proportion exists between the four arms of the bridge:

$$\frac{R_1}{R_2} = \frac{R_S}{R_X}$$

or

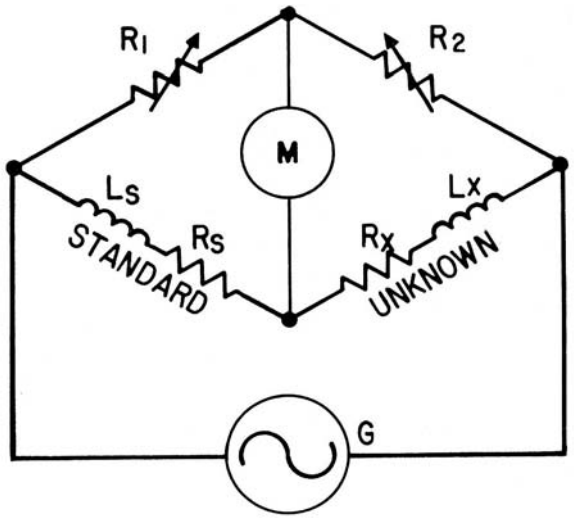
$$R_X = \frac{R_2}{R_1} R_S$$

Thus the unknown resistance and capacitance, R_X and C_X, can be estimated in terms of the known resistance R_1, R_2, and R_s and the known capacitance C_S.

Inductance Bridge

Inductance is the property of any electric circuit that opposes any change in current through that circuit. It is symbolized by the letter "L", and the unit for measuring is the henry, h. Actually it is the expansion and contraction of the magnetic field as current varies which causes the effect known as inductance. Thus, inductance, the effect of counterelectromotive force, opposes any change in current flow, whether it is an increase or decrease, slowing down the rate of change.

The value of an unknown inductance Lx may be determined by means of the simple bridge circuit shown in figure 13-7. The ratio arms R_1 and R_2 are accurately calibrated resistors. L_S is a standard inductor whose inductance is known; R_S is its resistance. R_X represents the resistance of the unknown inductor.



12.254

Figure 13-7. — A-c inductance bridge.

Refer to figure 13-7. The a-c signal is applied to the bridge while the two variable resistors Rl and R2 are adjusted for a minimum or zero deflection of the meter, indicating a condition of balance. When the bridge is balanced,

$$\frac{R_1}{R_2} = \frac{L_S}{L_X}$$

or

$$L_X = \frac{R_2}{R_1} L_S$$

and

$$\frac{R_1}{R_2} = \frac{R_S}{R_X}$$

or

$$R_X = \frac{R_2}{R_1} R_S$$

Thus, the unknown resistance and inductance can be estimated in terms of the known resistances R_1, R_2, and R_3 and the known inductance L_S.

Checking Electrolytic Capacitors

The ohmmeter method of checking electrolytic capacitors is a method used by many technicians if precision test equipment is not available or close at hand.

Basically, capacitors consist of two plates which can be charged, separated by an insulating material called the dielectric. There are many kinds of capacitors, of different sizes, shapes, and materials, used in electrical and electronic circuits. Electrolytic capacitors are used where the values of capacitance are greater than 1 mfd, ranging from 1 to more than 1,000 mfd. Unlike other types of capacitors, the electrolytic capacitor is polarized and, unless properly connected, will act as a short circuit. A special type is made which compensates for changing polarity and which may be used on a-c.

One of the main functions of electrolytic capacitors is to change (filter) pulsating d-c to pure d-c in rectifier power supply circuits. Large electrolytic capacitors normally have both voltage ratings and capacitance stamped on the

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side. Capacitors must always be discharged before measuring. To discharge the capacitor, connect a jumper to each lead of the capacitor.

A resistance measurement is made on the discharged electrolytic capacitor, using the high resistance range of the ohmmeter. When the ohmmeter leads are first applied across the capacitor, the meter pointer rises quickly and then drops back to indicate a high resistance. The test leads are then reversed and reapplied. The meter pointer should rise again-even higher than before - and again drop to a high value of resistance. The deflections of the meter are caused when the capacitor is charged by the battery of the ohmmeter. When the leads are reversed. the voltage in the capacitor adds to the applied voltage, resulting in a greater deflection than at first. If the capacitor is open-circuited, no deflection will be noted.

If the capacitor is short circuited, the ohmmeter indicates zero ohms. The resistance values registered in the normal electrolytic capacitor result from the fact that there is leakage present between the electrodes. Because the electrolytic capacitor is a polarized device, the resistance will be greater in one direction than the other.

Should a capacitor indicate a short circuit, one end of it must be disconnected from the circuit and another resistance reading made to determine if the capacitor is actually at fault.

Unless your ohmmeter has a very high resistance scale, you will not see a deflection of the meter when checking small capacitors. Even a scale of R x 10,000 is not sufficient for very small ones; the smaller the capacity, the less leakage across the plates, therefore more resistance.

USE OF THE MEGGER

A thorough discussion of the operating principles of the megger is found in Basic Electricity. NavPers 10086-B. Briefly, a megger is an instrument for measuring very high resistance (insulation resistance). It consists of a hand-driven d-c generator and a suitable indicating meter, together with the necessary resistors. The name MEGGER is derived from the fact that it measures resistance of many megohms. Its full name is megohmmeter. The need for such an instrument exists because ohmmeters will not accurately measure these high resistances. The low voltage in an ohmmeter is not sufficient to move enough current through high resistances. The generator within the megger will supply enough voltage to cause a measurable amount of current to flow; the meter indications will be in megohms.

There are various resistance ratings of meggers, with full scale values as low as 5 megohms, and as high as 10,000 megohms. Figure 13-8 shows the scale of a 100-megohm. 500-volt megger. Notice that the upper limit is INFINITY, and that the scale is crowded at the upper end. The first scale marking below infinity represents the highest value for which the instrument can be accurately used. Thus, if the pointer goes to infinity while making a test, it means only that the resistance is higher than the range of the set.

There are also various voltage ratings of meggers (100, 500, 750, 1000, 3500, etc.) The most common type is the one with the 500-volt rating. This voltage rating refers to the maximum output voltage of the megger. The output voltage is dependent upon the speed of turning of the crank and armature. When the megger's armature rotation reaches a predetermined speed. a slip clutch will maintain the armature at a constant speed. The voltage rating is important, for the application of TOO high a voltage to even a good component will cause a breakdown. In other words, do not use a 500-volt megger to test a capacitor rated at 100 volts.

Meggers are used to test the insulation resistance of conductors in which shorting or breaking down under high voltage is suspected. In some situations, meggers are used to prevent unnecessary breakdowns by maintaining a record (Resistance Test Record, NAVSHIPS 531-1 (1063) of insulation resistance of power and high voltage cables, motor and generator windings. and transmission lines. These records will reflect fluctuations in resistance and aid in determining when the components should be replaced to prevent a breakdown. In all cases, when making measurements, it is important to record the exact amount of other equipment included in the circuit in order to make significant comparisons with past or future measurements. NAVSHIPS Technical Manual, chapter 9600 (formerly 0901-0000020, chapter 60), illustrates the record card and discusses the various factors that effect insulation measurements, and how to make allowances for these factors in interpreting the results of the measurements. The duration of the test application, the presence of residual charges, the length of cable being tested, and the attachment of other components are some of the things that influence the test. Possible causes of low insulation resistance are faulty connections. and

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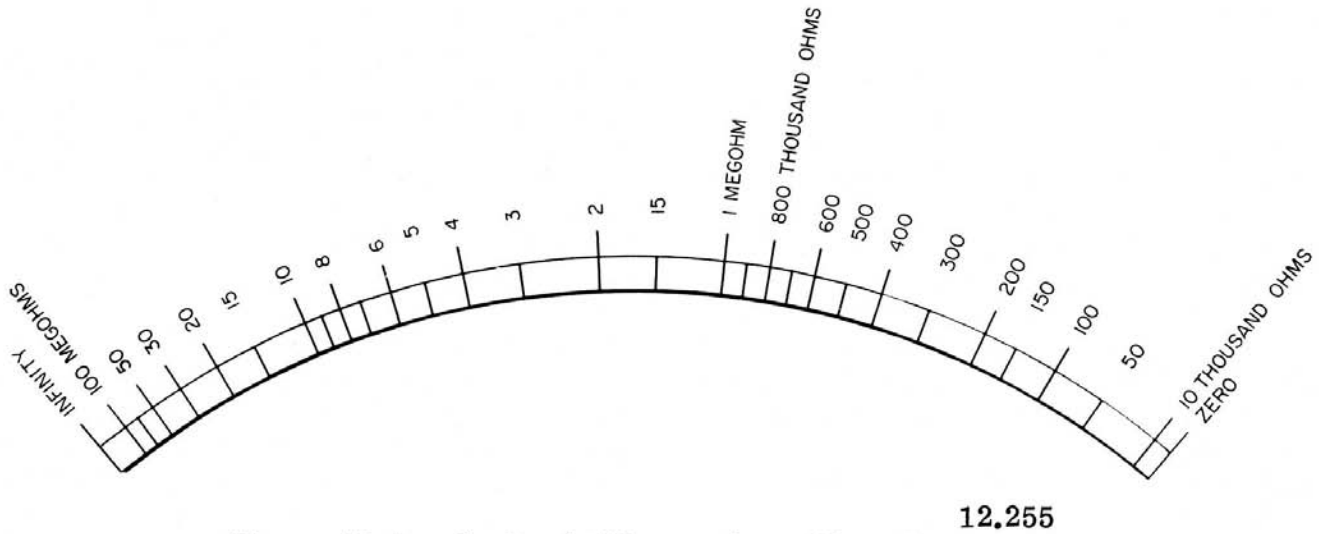


Figure 13-8.—Scale of 100-megohm, 500-volt megger.

accumulations of dirt or foreign material. Moisture is damaging to all insulation, varying with the type of insulation, and this will effect the megger test. A comparison of the results of successive test would reveal such progressive deterioration.

Although the instruction in NAVSHIPS Technical Manual were written for ship's electricians, the conditions that affect insulation resistance on ship's power and lighting equipment have the same effect on missile launching systems, and will influence the megger readings in the same way. In the course of general maintenance and upkeep of a missile launching system, it is always possible that insulation resistance tests must be made. Therefore, GMMs should become familiar with the megger and how to use it.

Precautions When Making Megger Tests.

Precautions to be followed in the use of the megger are listed below:

1. When making a megger test, the equipment must NOT be live. It must be disconnected entirely from its source of Supply before it is tested.
2. Observe all rules for safety in preparing equipment for test and in testing, especially when testing installed high voltage apparatus.
3. Use well-insulated test leads, especially when using high range meggers. After the leads are connected to the instrument and before connecting them to the component to be tested, operate the megger and make sure there is no leak between the leads. The reading should be infinity. To make certain the leads are not disconnected or broken, touch the test ends of the leads together while turning the crank slowly. The reading should be approximately zero.
4. When using high range meggers, take proper precautions against electric shock, especially while the component is under test. There is sufficient amount of capacitance in most electrical equipment to "store up" enough energy from the megger generator to give a very disagreeable and even dangerous shock. Owing to a high protective resistance in the megger, its open circuit voltage is not as dangerous, but care should be exercised.
5. Equipment having considerable capacitance should be discharged before and after making megger tests in order to avoid the danger of receiving a shock. This can be accomplished by grounding or short circuiting the terminals of the equipment under test.
6. Make sure that the connections on removable test leads on portable meters are secure. One report has been received of a test lead that came adrift, touched a rocket motor, and fired it.
7. Never implicitly trust insulation when considering personal safety. Insulation may look perfect yet not prevent a shock. Sufficient leakage current may be present to cause a fatal shock. Be sure power and control circuits are deenergized before beginning work on any part. Tag switches open so no one will close them while you are testing. NAVSHIPS Form 3960 (3-63) may be used for tagging switches open. You just need to write in your name and rate before attaching the tag. You remove the tag (no one else may do it)

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when you have completed your work on the circuit and are ready to reenergize it.

TUBE TESTING

Although each electron tube purchased by the Navy has been thoroughly tested electrically and mechanically, it is possible, nevertheless, for tubes to be damaged in shipment, storage, or handling. Therefore, a tube should be tested before it is used the first time.

Electron tubes do not last indefinitely. Coated cathodes lose their power to emit electrons because the coating flakes off. Likewise, impregnated emitters of filament type tubes become depleted with age. There are other factors that cause electron tubes to function improperly-for example, defective seals permit air to leak into the tube and "poison" the emitting surface, and vibration or excessive voltage may cause internal shorts or opens. Whenever electronic equipment operates subnormally, one of the first maintenance procedures is to check the tubes with a tube tester. This often results in finding weak tubes and replacing them prior to failure;. As a GMM you are responsible for operating tube testers.

The practice of wholesale removal and test of electron tubes on a periodic basis is not to be done. This routine type of tube testing has been specified in some maintenance manuals but revised editions will delete this requirement. The revised procedure will call for tube testing only if the equipment containing the tube is not performing properly. Isolate the cause, identify the tube that appears to be at fault, and remove and test that one. If test shows the tube to be good, return it to its socket, and continue your search for the cause of the trouble. Do not interchange tubes if it can be avoided. If the test shows the tube to be at fault, put in a new tube of the same kind, testing it first. Sometimes a new tube will not work in a particular socket, and several new ones may have to be tried.

TYPES OF TESTERS

Two types of tube testers are in general use. One, the EMISSION-TYPE tester, indicates the relative value of a tube in terms of its ability to emit electrons from the cathode. The second and more accurate type is the MUTUAL-CONDUCTANCE (or transconductance) tube tester. This tube tester not only gives an indication of the electron emission, but also indicates the ability of the grid voltages to control the plate current.

The end of the useful life of a tube usually is preceded by a reduction in electron emissivity that is, the cathode no longer supplies the number of electrons necessary for proper operation of the tube. In the emission tester, the proper voltages are applied to each electrode in the tube, and a meter indicates the plate current. If the tube has an open element or is at the end of its useful life, the emission tester gives an indication of this defect in the lower, or reject, portion of the meter scale.

A tube may have normal emission and still not operate properly because tube efficiency depends on the ability of the grid voltage to control the plate current. The emission-type tester indicates only the plate current, and not the ability of the grid to control the plate current. The transconductance type tube tester, however, indicates how the tube operates, not merely the condition of the emitting surface.

The terms "mutual conductance" and "transconductance" are used interchangeably in many texts. The Navy Department prefers transconductance but many commercial tube testers are marked "mutual conductance."

When the prefix "dynamic" is used, as in "dynamic transconductance," it means that the characteristics of the tube in operation are being tested. The difference between the dynamic and static characteristics lies in the effect produced by the load impedance on the operation of the tube. Most tube testers, other than the emission type, test the dynamic characteristics by placing the tube in a working circuit.

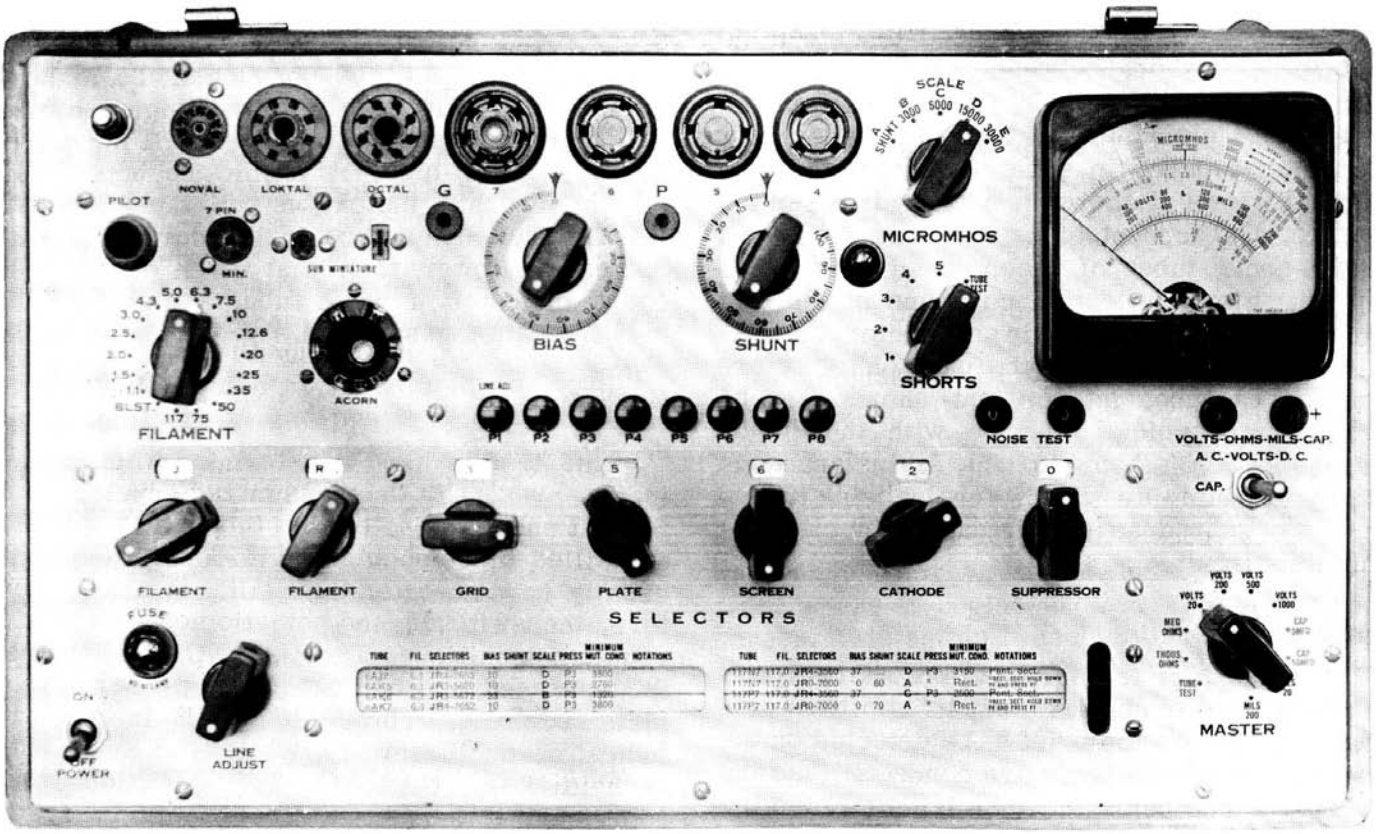
TYPICAL TUBE TESTER

The tube tester shown in figure 13-9 is a typical portable tube tester of the dynamic mutual-transconductance type designed to test electron tubes of the standard type and many of the miniature and subminiature types. A multimeter section, using the same indicator, is also incorporated in the equipment to permit measurements of a-c and d-c volts, d-c mils, and resistance and capacitance in a number of ranges.

This combination tube tester and multimeter is also called a vacuum tube analyzer. The equipment is capable of checking accurately all receiving tubes of filament or cathode type, and of 4-, 5-,6-, 7-prong, octal, loktal, naval, 7 pin miniature, subminiature, and acorn types.

The tube tester has a roller chart (shown through "windows," lower part of fig. 13-9) indicating the tubes that may be tested. Listed opposite the tube designations is a series of

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Figure 13-9. — Typical tube tester or vacuum tube analyzer.

numbers and letters which indicate the position of each switch and potentiometer of the SELECTORS and also the correct pushbutton to push. These switch positions connect the tube into a circuit that is comparable to the operating circuit of the tube. When the potentiometers are adjusted to the values indicated on the chart, the correct operating voltages are applied to the tube so that it can be checked under operating conditions. As newer tubes than those listed on the roller chart are used in equipments, other charts are published, giving the new switch positions and potentiometer settings. When conditions warrant, new roller charts incorporating the latest tubes are prepared.

TESTS MADE WITH TUBE TESTER

Let us now consider each of the individual tests performed by the instrument, one at a time. These tests are: (1) line voltage test, (2) short circuit test, (3) noise test, (4) rectifier test, (5) mutual-conductance test, (6) gas test, and (7) tests performed by means of the multimeter section.

Line Voltage Test

It is necessary to maintain rated voltage across the primary of the power transformer if the meter of the tube tester is to register correctly. Therefore, a variable resistor is connected in series with the power input leads so that the voltage applied to the primary may be adjusted to the correct value. A special switch (the line-adjustment switch, lower left in fig. 13-9) connects the meter to the line, so that you can see when the line adjustment control is correctly set.

The line voltage should be adjusted after the filament switch is in the correct position and the tube is in the test socket. Some tubes draw a high filament current, and would load down the operating voltage of the equipment if the line were adjusted first. The tube tester is designed to accurately test tubes under certain operating conditions, but the operating voltages must be accurate to accomplish this purpose. Correct line voltage adjustments will result in the required operating voltages.

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Short Circuit Test

The short circuit test is used to determine if there is a short between any two elements within the tube. The SHORTS switch connects the various elements of the tube under test to a voltage source in series with a neon lamp so that it glows if there is a short between the elements. On account of cross connections and taps in some tubes of recent design, the neon lamp will glow on certain positions of the test switch although the tube is in satisfactory operating condition. Study the tube data chart before discarding a tube. Intermittent shorts may be detected by tapping the tube with the finger while the switch is being turned. An instantaneous flash of the lamp as the switch is being turned should be ignored as this is caused by charging within the circuit.

Noise Test

The noise test is similar to the short circuit test and is used to check for any intermittent disturbances that are too brief to be detected on the neon lamp. Two test leads are connected into the jacks above and below the neon lamp (across the neon lamp) and the other ends of the leads are connected to the antenna and ground of a radio receiver. The SHORTS switch is then turned; through the various positions as the tube under test is tapped gently. Any intermittent disturbances between the electrodes cause a momentary oscillation that is reproduced by the loudspeaker! as noise.

Rectifier Test

Rectifier tubes and diode detector tubes can be tested only for emission; therefore, the rectifier test is quite simple. The diode or rectifier tubes are tested by first setting all the switches and potentiometers to the positions indicated on the roller chart. The tube is placed in the proper socket and the line voltage is adjusted after the tube has been allowed time to warm up. Then the designated diode or rectifier button is pushed. The meter will indicate above the rectifier mark for a good tube. If the reading is below the mark, the tube is weak or gassy. If there are two or more plates in the tube, each is tested separately.

Mutual-Conductance or Quality Test

Mutual-conductance tests are performed on amplifier tubes by positioning the SELECTOR switches and potentiometers as indicated by the roller chart. After placing the tube in the proper socket, and adjusting the line voltage, a short circuit test should be conducted. To make the mutual-conductance test, the designated pushbutton is depressed. The meter will indicate the quality of the tube. It should be noted that to obtain accurate indications on the meter, the RANGE switch must be in the correct position. A reading lower than that given on the roller chart indicates a weak tube. A higher reading may indicate a gassy tube.

Gas Test

This test is used to determine whether there is gas present in the vacuumized envelope of the tube. It should be noted that this is NOT a test for gas-filled tubes such as thyratrons. The gas test usually is made after the quality test and, therefore, the switches and potentiometers are in the required positions. The GAS NO. 1 (P1) button is depressed which connects the proper grid and plate voltages. This will result in a certain indication on the meter. While GAS NO. 1 button is held down, GAS NO. 2 (P2) button is also depressed. If the tube is gassy, the meter reading will increase. If the increase is more than two divisions on the scale, the tube is not acceptable because of excessive gas.

Multimeter Measurements

The multimeter portion of the instrument is entirely separate from the tube tester although the same meters are sometimes used. The following measurements may be made: alternating current and direct current voltages up to 100 volts; resistance ranges (usually three ranges); d-c ranges, 0 to 20 and 0 to 200 milliamperes; capacitance, up to a maximum of 20 microfarads.

TUBE TESTER LIMITATIONS

In general, tube testers do not completely indicate tube performance because they present a fixed impedance to the tube grid and plate which mayor may not be that of the equipment in which the tube is to operate. Also, the tester takes no account of the interelectrode capacity of the tube. Specifications allow a wide deviation of interelectrode capacity which makes an accurate prediction of tube performance with a tube tester difficult. The range of operating frequency affects performance also.

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It is impracticable to design a complete testing instrument that will evaluate the performance of any tube in any circuit in which it is being used. A tube may test low on the tester and yet work perfectly well in the circuit or. on the other hand, it may check good in the tester and not function in the equipment. As a rule, therefore, only dead, shorted, or extremely weak tubes should be discarded purely on the basis of a tube tester check.

Further, it is NOT advisable to replace a large number of tubes, especially in high frequency circuits, without checking their effect on the circuit, one tube at a time. In any complicated circuit, it is bad practice to arbitrarily replace a large number of tubes. It is better to replace them either tube by tube or in small groups. Be sure to replace each tube with an identical replacement.

Another aid to checking new tubes is the "eyeball" check. Many new electron tubes with visible defects find their way into equipment. A quick visual inspection of all new tubes will save time by eliminating those with obvious defects. Some of the things to watch for are crushed spacers, loose internal plate structure, bent or missing pins, broken tips, and cracked glass envelopes.

CATHODE-RAY OSCILLOSCOPE

The cathode-ray oscilloscope is one of the most useful and versatile of test instruments. It is essentially a device for displaying graphs of rapidly changing voltages or currents, but is also capable of giving information concerning frequency values, phase differences, and voltage amplitude. It is used to trace signals through electronic circuits, to localize source of distortion, and to isolate troubles to particular stages.

The terms cathode-ray oscilloscope and cathode-ray oscillograph are sometimes used interchangeably but this is, strictly speaking, not correct. The oscillograph contains a means for producing records or tracings of the traces that flash across the screen of the cathode-ray tube. Because of the speed, pen and ink tracings such as those produced by an electrocardiograph are not possible; photographic records of the screen image are made. The tracings can be studied and compared to determine what the transient traces on the oscilloscope showed. Not all oscilloscopes have the recording device.

The oscilloscope is an instrument consisting of a cathode-ray tube and associated circuits for use in viewing wave shapes of voltages or currents. The cathode-ray tube, which is discussed in detail in Basic Electronics, NavPers 10087-B, consists of three parts- an electron gun for supplying a stream of electrons in the form of a beam, deflection plates for changing the direction of the electron beam a small amount, and a screen covered with a material which gives off light when struck by the stream of electrons directed at it by the gun.

As shown in figure 13-10 the associated circuits include a time-base (sweep) generator whose output is amplified by the horizontal amplifier. This output is applied to the horizontal deflection plates (in the cathode-ray tube), causing the electron beam to move from the left to the right side of the screen at a uniform rate. Then the beam returns almost instantly to the left side, where it begins another sweep across the screen. This action is accomplished by generating a voltage that arises at a uniform rate to a certain value and then quickly drops to its starting value. A wave shape such as this is called a sawtooth wave.

A sawtooth voltage wave is applied to the horizontal deflection plates, where it causes the electron stream to change direction. Since negative voltages repel and positive voltages attract electrons, the gradual rise in voltages causes the left plate to become increasingly negative and the right plate increasingly positive and thereby causes the spot to move across the screen. The quick drop of the voltage to its starting value returns the spot from right to left in a very short time. This is called the flyback time.

The sawtooth voltage is normally generated by the time-base generator, and applied to the horizontal deflection amplifier. But if you want to use an external signal for horizontal deflection, you apply it to the horizontal input terminals. The waveform fed to the horizontal deflection amplifier is increased in amplitude to that needed for a trace of the desired length, and applied to the horizontal deflection plates.

Signals applied to the vertical input terminals are amplified by the vertical deflection amplifier and applied to the vertical deflection plates.

By studying figure 13-11 you can see how a sine wave is reproduced on the screen when a sawtooth voltage is applied to the horizontal plates and a sine wave voltage is applied to the vertical plates. The sawtooth, which represents time, is divided into segments numbered t_0 to t_4. The input

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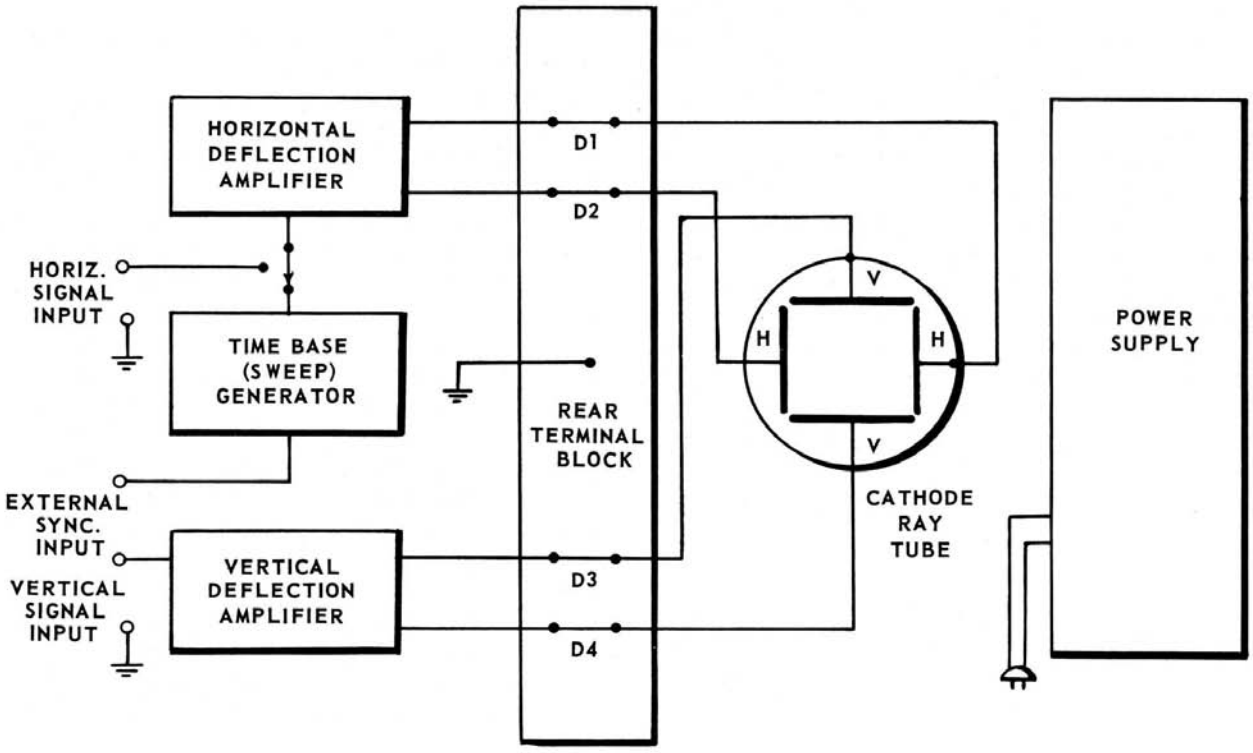
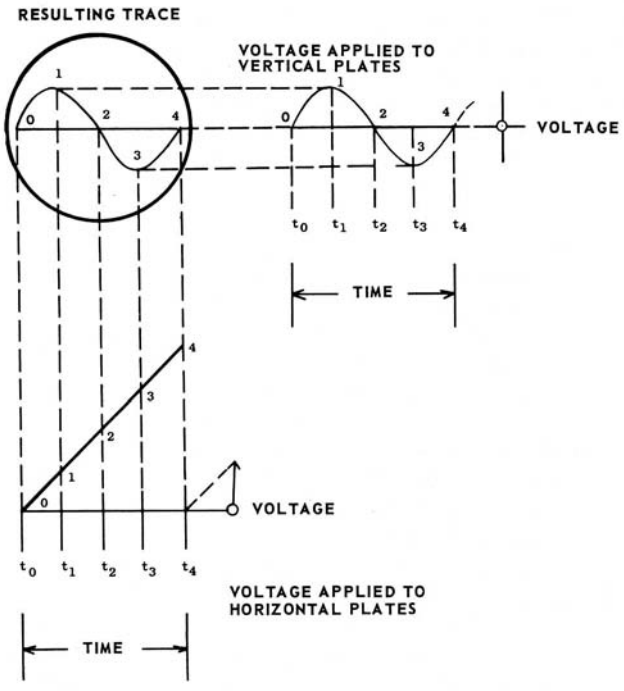


Figure 13-10. — Block diagram of a cathode-ray oscilloscope. 12.257



12.258

Figure 13-11. — Development of sine wave on face of oscilloscope.

sine wave also has the same divisions to show the instantaneous voltage amplitude at these points. The resultant is a single cycle of sine wave on the screen.

Your ability to operate an oscilloscope properly will not only help you perform your duties but will provide a means of visually illustrating the operation of various electrical circuits to be studied as you advance in rate. It is not a simple instrument but a sophisticated device that can give you much information about the circuit you are testing if you know how to interpret what it shows you on the screen. You need the manufacturer's instructions for the model you have aboard.

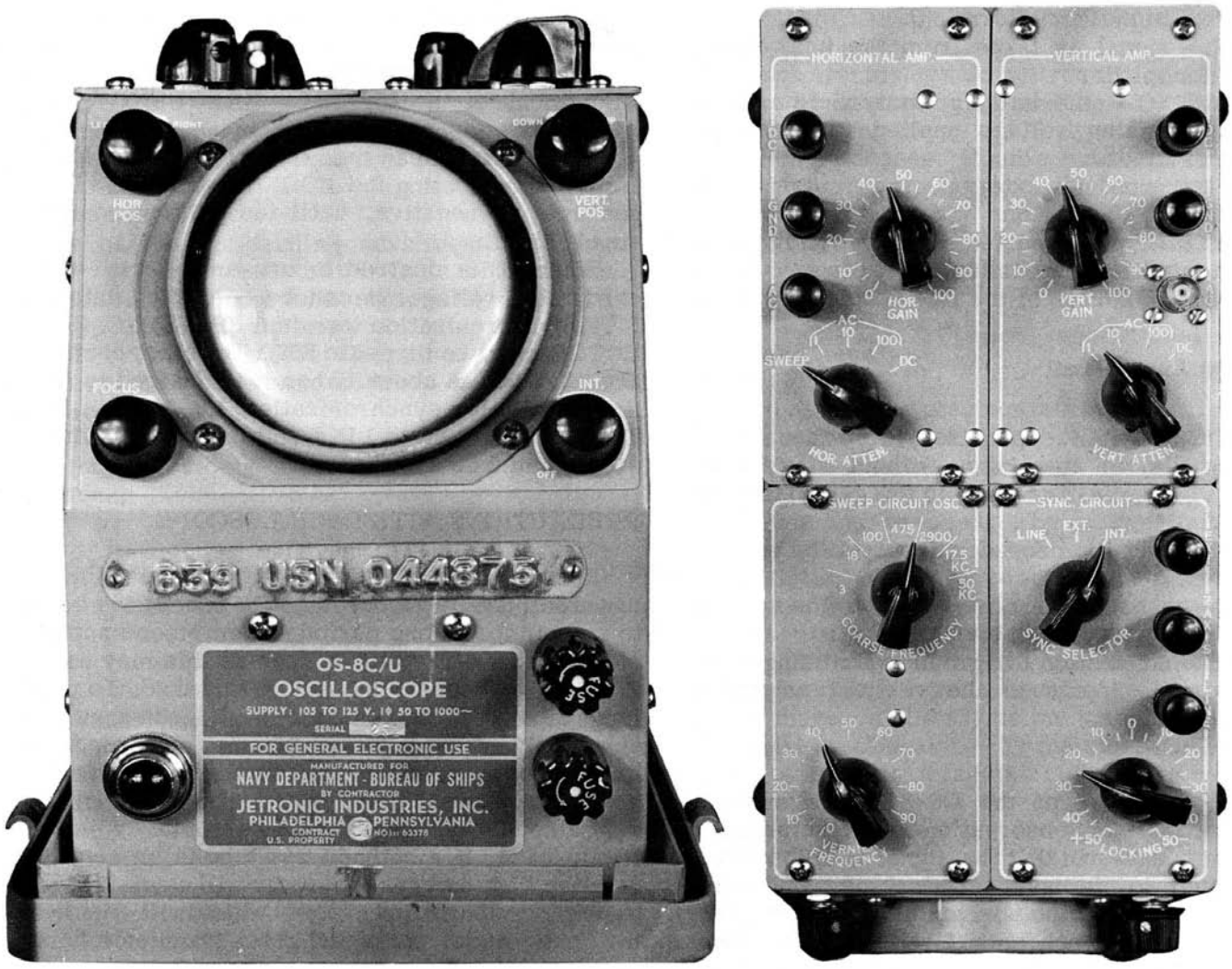
OSCILLOSCOPE CONTROLS AND THEIR FUNCTIONS

A typical cathode-ray oscilloscope is shown in figure 13-12. A description of the operating controls and their functions is as follows:

Front Panel Controls

INT-OFF - operates the power off-on switch and controls the intensity or brightness of the image on the screen.

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1.86.1

Figure 13-12. — General-purpose Oscilloscope OS-8C/U.

FOCUS - adjusts the focus or sharpness of the trace on the cathode-ray tube. HOR. POS. and VERT. POS (Left-right. down-up) - used to adjust the position of the trace on the screen, either horizontally or vertically.

Horizontal Amp. Panel

HOR. ATTEN. - selects the source of signal. a-c with attenuation sweep, or d-c. The signal is then fed to the horizontal amplifier.

HOR. GAIN - controls the gain of the horizontal amplifier.

DC - connection for d-c input to the horizontal amplifier.

AC - connection for a-c input to the horizontal amplifier.

GND - connection for ground when using either a-c or d-c inputs to the horizontal amplifier.

Sweep Circuit Osc. Panel

COARSE FREQUENCY - provides a coarse adjustment of the sweep frequency.

VERNIER FREQUENCY - provides a fine or vernier adjustment of the sweep frequency.

Sync. Circuit Panel

SYNC. SELECTOR - provides for the selection of the synchronizing voltage source as follows:

LINE - signal is taken from input to power supply.

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EXT. - signal is supplied by an external source connected to the EXT. terminal.

INT. - signal is taken from the input to the vertical amplifier.

LOCKING - selects the polarity and amplitude of synchronizing voltage applied to the sweep circuit oscillator.

EXT. - input for external synchronizing voltage.

Z AXIS - connection for external voltage to be used in intensity modulation of the electron beam.

LINE - a source of the line supply frequency.

Vertical Amp. Panel

VERT. ATTEN. - provides for attenuation of a-c signals or d-c input without attenuation.

VERT. GAIN - controls the gain of the vertical amplifier.

DC - connection for d-c input to the vertical amplifier.

AC - connection for a-c input to the vertical amplifier.

GND - connection for ground when using either a-c or d-c inputs to the vertical amplifier.

OPERATION

The operation of the OS-8C/U cathode-ray oscilloscope for observation of waveforms is relatively easy, in that the signal to be observed is applied to the a-c terminal of the vertical amplifier and that the horizontal sweep frequency need only be synchronized with it. The steps for operating the OS-8C/U are listed below:

1. The signal to be observed is connected to the a-c input terminal of the vertical amplifier, and the ground connection of the input signal is connected to the GND terminal.
2. The INT-OFF control is turned clockwise to switch the power on. After the oscilloscope has warmed up, adjust the brightness or intensity of the trace to a comfortable level.
3. Set the COARSE FREQUENCY control to the lowest frequency.
4. Set the SYNC SELECTOR switch to the INT. position.
5. Set the VERT. GAIN and the VERT. ATTEN. controls for suitable deflection.
6. Set the HOR. GAIN control for desired pattern width.
7. Slowly rotate the VERNIER FREQUENCY control until the desired pattern appears and is steady.
8. If the number of cycles is too great, the COARSE FREQUENCY control is adjusted a step higher until the desired number of cycles appear and are steady. This may require readjustment of the VERNIER FREQUENCY control.
9. The trace can then be locked in synchronization by adjusting the LOCKING control, either positive or negative, until the pattern appears steady and fixed.

When it is desired to use an external synchronizing voltage, it can be connected into the EXT. synchronization terminal. The SYNC. SELECTOR must be turned to EXT. The other controls are adjusted as above. When it is desired to use line voltage for synchronization, the SYNC. SELECTOR is turned to LINE and the other controls are adjusted as above.

PRECAUTIONS WITH OSCILLOSCOPE

The principal precaution to be observed in the use of cathode-ray tubes is not to permit the beam to remain for a long period of time on one portion of the cathode-ray tube screen as this may cause the tube to become burned or streaked. To prolong tube life, the intensity and focus controls should always be adjusted for minimum readable brilliance to produce the smallest practicable spot or narrowest line.

Cathode-ray tubes should be handled with extreme care. If a cathode-ray tube is broken, the relative high external pressure will cause the tube to implode (burst inwardly), which will result in the inner metal parts and glass fragments being expelled violently outward. In addition to the danger from the flying fragments, the inner coatings of some tubes are poisonous if absorbed into the blood stream. Cuts from such coated glass can cause serious, even fatal, illness. Therefore, do not break defective tubes when preparing to dispose of them. Place the removed tube in the empty box of the replacement tube, and don't leave it around on work benches, etc. Safety glasses and gloves should be worn while handling CRT tubes.

The case of the oscilloscope offers some protection to the tube, but do not handle it roughly. When stowed, it should be secured so it will not shift about.

SERVICING TRANSISTOR CIRCUITS

After you have worked with vacuum tube equipment, you will find that maintaining and

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troubleshooting transistorized equipment presents no new problems. Most transistorized equipments use printed circuits, on which components are neatly arranged without stacking. This makes the transistors, resistors, capacitors, and other components easy to get at for troubleshooting. However, you must be careful to prevent damage to the printed wiring while you are investigating with test probes.

One of the outstanding advantages of transistors is their reliability. Over 90% of the failures in electron tube equipment are tube failures. Transistors, however, have long life. This factor, among others, decreases the amount of maintenance necessary to keep transistorized equipment operating.

Transistor Servicing Techniques

The techniques used in servicing transistorized equipment are similar to those used in servicing electron tube circuits. Basically, these techniques are:

1. Power supply check
2. Visual inspection
3. Transistor check
4. Voltage check
5. Resistance check
6. Signal tracing
7. Component substitution

Power Supply Check

The first step you should take in troubleshooting is to check the power supply to see if its output voltages are present, and are set at their correct value. Improper supply voltages can cause odd effects. You can prevent many headaches if you first check the power supply. Transistor circuits require relatively low amounts of power compared to electron tube circuits and, for this reason, small batteries like the carbon-zinc types and the newer mercury types are used. When transistor circuits are operated from an a-c source, the transistor power supply uses components smaller than those needed for electron-tube power supplies.

Visual Inspection

Visual inspection is a good servicing technique. Occasionally you can find a loose wire or faulty connection before extensive voltage checks are made. Faulty components such as burned resistors seldom occur since the power supply voltage usually is very low compared to a vacuum tube power supply.

Although transistors do not require a vacuum, they must be hermetically sealed, according to U.S. Joint Army-Navy (JAN) specifications in glass or metal cases. Plastic cannot be relied upon to remain moistureproof. Water vapor will quickly contaminate any unprotected transistor junction, and greatly increase the saturation current. Visually inspect transistors for broken seals.

Transistor Check

Transistors, like electron tubes, can be checked by substitution. Transistors, however, have a characteristic known as leakage current which may affect the results obtained when the substitution method is used. The leakage current can affect the gain or amplification factor of the transistor. It is more critical in certain applications than in others. Thus, it is possible that a particular transistor will operate satisfactorily in one circuit and not in another. It also has been found the amount of leakage current will increase slightly as the transistor ages.

Transistor Checker. - Transistors can be checked by using a Transistor Tester. The following tests will reveal the condition of a transistor.

1. Tests to determine if its elements (emitter, base, collector) are short circuited.
2. A test to determine the current gain. The technical expression for this procedure is "measuring the beta parameter of a transistor."

Basic Electronics, NP 10087-B points out that current gain is assigned the symbol BETA (β).

One type of transistor tester used by technicians is the TS-1100/U. It can measure current gain while the transistor under test is either in or out of the circuit. But the transistor must be removed from the circuit when you are checking for a short-circuited condition.

Voltage Checks

Voltage measurements provide a means of checking circuit conditions in transistor circuits as they do in tube circuits. The voltages in transistor circuits are much lower than in tube circuits. For example, the bias voltage between the base and emitter is in the order of 0.05 to 0.2 volts. Therefore, a sensitive VTVM is usually required. When you make voltage

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checks, make sure polarity is observed to avoid error in measurements. In an electron tube circuit, if you find a positive voltage on a grid, a leaky coupling capacitor is indicated. But in a transistor circuit the base-to-emitter voltage may be positive or negative, depending on the type of transistor. For example, the PNP type normally operates with the base negative with respect to the emitter, whereas the opposite is true of NPN transistors.

(If you need to refresh your memory on the construction and theory of transistors, refer to Basic Electronics, NavPers 10087-B.)

Check the schematic of the circuit under test for the proper polarity as well as magnitude of voltage.

Current Check

There may be times when you will want to make a current check in a circuit. In circuits that are wired in the conventional manner, you can easily unsolder a lead or remove a connection, and then place an ammeter in the circuit. With printed wiring this is not always possible. But you can calculate the current by using Ohm's law. For example, if the collector is to be measured, measure the voltage drop across the collector resistor (load) and measure the resistor with an ohmmeter. By using Ohm's law, you can calculate the collector current.

Resistance Checks

Resistance measurements generally are not made in transistor circuits, except to check for open windings in transformers and coils. Resistors and transistors have little tendency to burn up or change value, because of the low voltage power supplies used in transistor circuits. It is important to remember that, before you attempt to measure the resistance of any transistor circuit component, you must REMOVE THE TRANSISTOR OR COMPONENT. Since the ohmmeter has a battery, the wrong voltage polarity may be applied to a critical stage and cause permanent damage to the transistor. Another word of caution. Always disconnect the supply voltage before you remove a transistor from its socket. This prevents current surges that might damage the transistor.

Signal Tracing and Component Substitution

You can trace a signal through a transistor circuit just as you do in a vacuum tube circuit. When you find a faulty component, replace it with a duplicate. Charts are supplied with the equipment, showing what transistors may be used.

Precautions

Although transistors are rugged, you must observe certain precautions. The leads are the most fragile part. Whether they are long and flexible or short and rigid, they should be treated carefully. When transistors with long flexible leads are soldered or resoldered, make sure you don't overheat the transistor. Use the heatsink technique. Heat from the soldering iron must be dissipated so it is not carried into the transistor via the leads. If the transistor is being wired into a circuit, each lead must be gripped between the iron and the transistor by a heat shunt (fig. 12-9) to reduce the heat transmission.

The metal jaws act to form a low resistance heat path which conducts the heat away from the part. The soldering iron should be a small pencil type of low wattage (35-40 watts). When inserting (soldering) the transistor leads into a circuit, be careful of voltage polarity. Incorrect polarity can easily and permanently damage a transistor.

Transistors with short rigid leads usually are plugged into sockets. In some cases, however, these transistors are plugged directly into the printed board, and then dip soldered.

Transistors require low operating voltages. Small changes in these voltages can greatly upset the biasing of transistors. In some circuits, small bias changes can result in destruction of the transistor. Therefore, make sure you don't short out any circuit component. This action could disturb all the voltage relationships in the equipment, and thus destroy a number of transistors.

Except for the special precautions and servicing techniques mentioned here, servicing transistor equipment should present no greater problem than servicing the electron tube counterparts.

TROUBLESHOOTING

The materials used in launching system equipment are considered to be the best obtainable. The equipment has been carefully inspected and adjusted at the factory to reduce maintenance to a minimum. However, a certain amount of checking and servicing by you will always be necessary if your equipment is to be kept in efficient and dependable condition. A large part of your daily

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activities will be spent in preventing equipment failure by detecting defective operation and component deterioration in the early stages. This is accomplished by properly carrying out the prescribed preventive maintenance routine. Inefficient performance of preventive maintenance programs will accelerate the deterioration of your ship's armament, and will increase the time that you spend troubleshooting. Nevertheless, components do break down even under ideal conditions, and you will have to troubleshoot to find and correct the casualty or malfunction caused by faulty components.

"Troubleshooting" is a term used to mean locating the cause of casualties to equipment. Another term often used is "casualty analysis." The name is not important but the task is. An inoperative power component can disable a whole system. It is vital to the operation of the missile system to locate the faulty component and replace or repair it.

The most important part of troubleshooting is the logical approach. Without this approach, troubleshooting becomes a hit-or-miss affair that consumes much time and energy.

In this section we will describe the troubleshooting procedure which is followed by most experienced technicians in locating all except the most self-evident faults. It consists in starting with large areas (circuits or parts of a circuit) suggested by the symptoms and eliminating those areas where the fault is NOT located. When the general area containing the fault is identified, progressively smaller segments are eliminated until only the small segment containing the fault is left. When this stage is reached, the fault usually reveals itself; if not. it can be located by individually testing a small number of parts and connections. Logical troubleshooting by a process of elimination can by applied to all types of ordnance equipment. In this section we will confine the discussion solely to electronic troubleshooting techniques. However, the basic concept of the troubleshooting philosophy described here applies equally well to mechanical, electrical, and hydraulic equipment.

TROUBLESHOOTING PROCEDURE

The following procedure is general enough to be useful when troubleshooting most electronic equipments. Figure 13-13 shows in block form the seven steps required to analyze the equipment, find the defective component, and make the appropriate repairs.

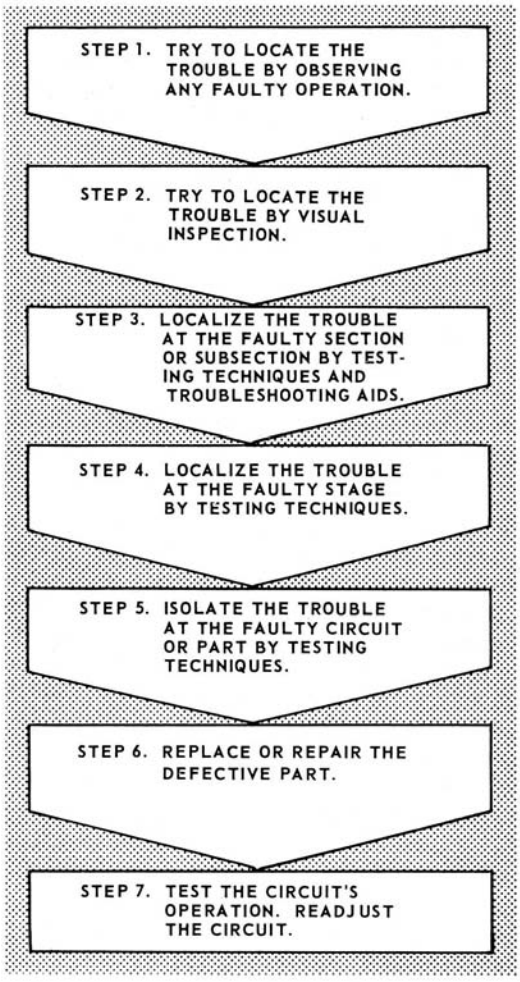


Figure 13-13. — Logical troubleshooting steps.

First, of course, you must recognize that some part is not functioning as it should. That means you must know how it should function so that you can recognize symptoms of malfunctioning.

STEP 1. Investigate the symptoms. Try to locate the trouble by observing the equipment's operation. This may mean applying an input signal, some physical movement of the equipment's parts, or other means of activating operation. Check the operator's impressions of what happened at the time of failure. You should check all meters, lamp displays, or other monitoring devices. Too for any telltale evidence that will reveal the major unit in which the trouble exists. If you know the equipment well.

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you can generally tell in what functional circuit the fault exists by observing the operation of the equipment and meter or lamp indications. This first step is the beginning of the process of casualty analysis using effect-to-cause reasoning. You see the effect (symptoms); now you must analyze the evidence to find the cause of trouble.

STEP 2. An internal visual check is the logical second step in finding a defective component. Look for loose connections, burned parts, controls which are not working properly, resistors which are discolored, tubes without glowing filaments, or any other abnormal indications. Many casualties do not result in symptoms which can be detected directly by our senses, so it is necessary to resort to other means of detecting failures. The next steps require the use of test equipment.

STEPS 3, 4, and 5. Troubleshooting steps 3, 4, and 5 consist of localizing the trouble to the faulty part. If the trouble has not resolved itself from a logical solution of the data available in steps 1 and 2, you must then utilize the troubleshooting aids listed below. They are discussed in more detail later in this section. In conjunction with the troubleshooting aids and logical reasoning, tracing a signal from its source through a circuit is the best technique for isolating the trouble to a section, stage, or part. The use of test equipment is required. It is used to measure or indicate the presence of a signal at the various check points. The signal can be traced from the source until it is lost at some checkpoint, or you can start at the output of the circuit and work backward until you find the defective stage. To find the defective part is a matter of checking a small number of elements. Look for the simplest defects first.

STEP 6. This entails the replacement or repair of the defective part. You know that ALL replacements or repairs should duplicate the defective part. In an emergency two resistors or two capacitors properly connected may be used to duplicate the value of the defective part. However, such substitutes are always temporary. The permanent replacement should be made as soon as the correct parts are available. Remember, permanent replacements are always exact duplicates.

STEP 7. Test the circuit and equipment operation. Readjust the circuit if necessary. After you make either temporary or permanent repairs, always test the equipment. Use the operational tests given in the applicable OP or log or Planned Maintenance System cards, if available. They contain information telling you what adjustments are required and how to make them.

SYSTEM TROUBLESHOOTING AIDS

Basically, the purpose of corrective maintenance is to restore the system's operation to acceptable standards. To restore the system to its operational standard, the operation and standards must be known. If the missile loader, for example, is expected to load a missile every 37 seconds but it takes 2 minutes per missile, it is not operating up to standard and you must find where the fault lies. The OPs for the system contain detailed information on the operation of the system as well as the functions of the units of the system. The Planned Maintenance System tells you what tests and maintenance are to be performed.

One-Function Schematic Diagrams

These drawings show the internal and interconnecting circuitry between all parts of the weapon system. Each depicts in a single diagram all circuits involved in one particular function, (quantity or signal) of a system. This eliminates the need for using many separate diagrams for each of the equipments involved in the particular function. Circuit information is displayed by functional flow from left to right. The unit in which the signal originates is on the left of the drawing; the unit that ultimately receives the signal is to the right. All major equipments, terminal boards, patch panels, dials, plugs, and other electrical components are labeled.

These one-function diagrams are not only an aid in troubleshooting but they provide a key to the understanding of the entire weapon system. The OPs containing one-function diagrams are unclassified, and therefore are readily available to missile system personnel. Figure 13-14 shows an example of a simplified one-function diagram.

Data Functional Diagrams

These diagrams show data transmission and functional circuits relevant to weapon system loops or modes of operations. Primary data flow is depicted as heavy lines. Each diagram emphasizes all alternate and test inputs and all points

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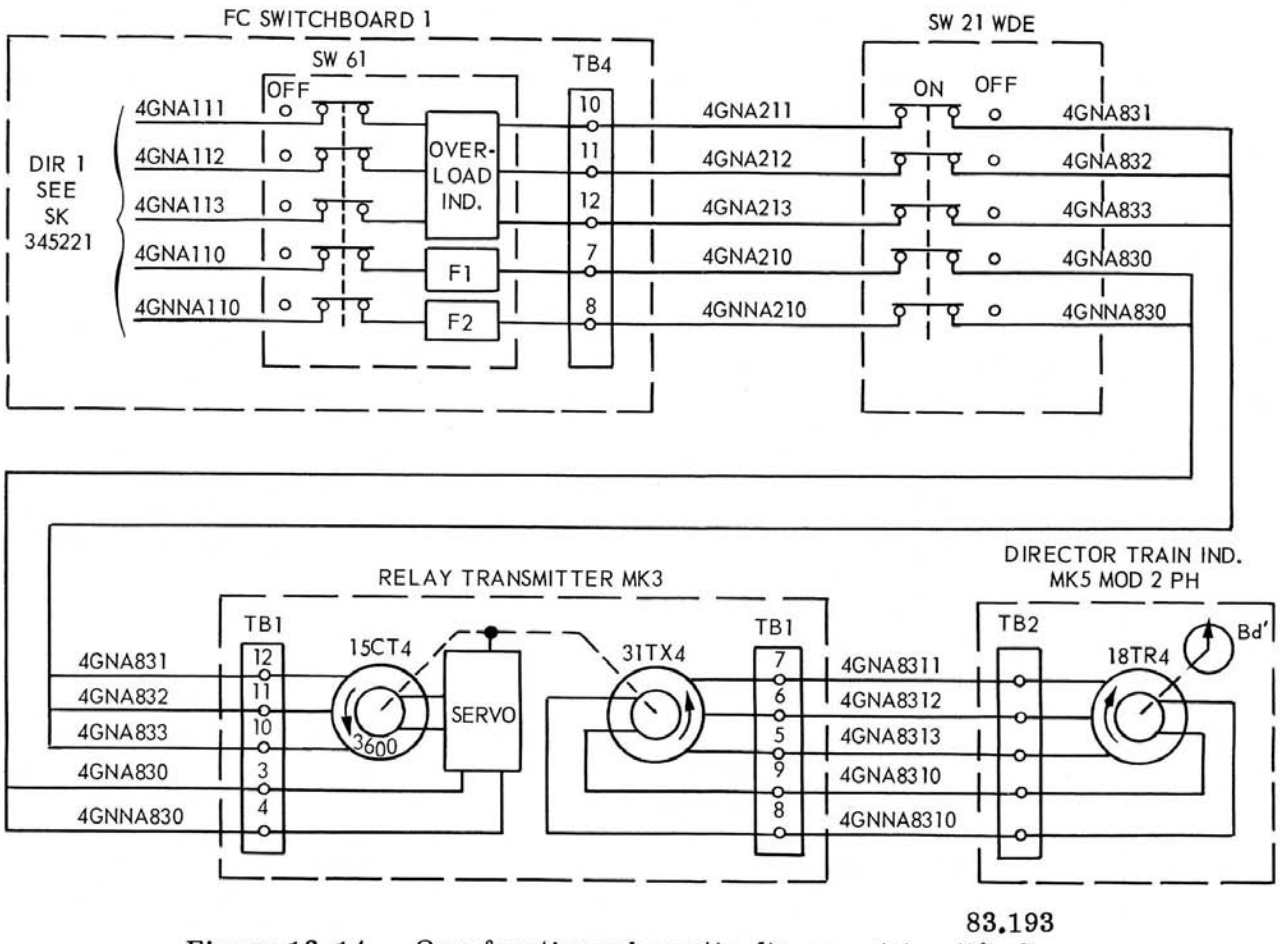


Figure 13-14. — One-function schematic diagram (simplified).

of data readout such as servodials, test points, and 'scope indications for a particular loop or mode. By tracing the primary data flow lines you can quickly determine which components are significant to fault isolation and functional understanding. Each missile weapon system has its own set of data functional diagrams. For example, OP 3472, volume 8, contains the data functional diagrams for DDG 2-24 Class Tartar Guided Missile Weapon System.

Control Functional Diagrams

These diagrams are provided only for the more complex control circuits. The diagrams show the time-related, ON-OFF stages of lamps, relays, switches, and other control devices for the various control circuits, with primary data flow depicted as heavy lines. Use of these diagrams will enable you to quickly determine the desired ON-OFF stage of the various control or control related devices. A comparison with the actual circuit indications will isolate a fault to specific functional areas or to components in the control circuit.

Fault Directories

In the PMS (Planned Maintenance System), tests are keyed to the troubleshooting procedures. The fault directories are the primary means of determining the appropriate troubleshooting aids for an indication of a fault observed in the system tests. Each fault directory lists the various phases of the associated test in corresponding sequence, with the probable faults which may occur during each phase of the test. References to the most appropriate troubleshooting documents associated with each test indication are provided by the directory. In most cases, the referenced documents are functional diagrams and fault logic diagrams.

The Indicator Directory is the primary means of determining the appropriate troubleshooting

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documents for an indication of a fault observed on a specific indicator during random operation of the system. This directory provides an alphabetical listing of all indicators shown in the functional diagrams. The listing references the most appropriate diagrams associated with each indicator.

Fault Logic Diagrams

These diagrams will enable you to rapidly isolate faults encountered in system tests. Each diagram (fig. 13-15) begins with a statement describing the fault. The first block in the diagram contains a question about the fault that may be answered either "yes" or "no". If the answer is yes, you proceed to the next block via the solid line; if the answer is no, you would follow the broken line leaving the box, which tells you what to check. The second block (via the solid line) contains a yes or no question similar to the one in the first block. You again determine the proper answer to the question and proceed to the next block according to the answer obtained. This process is repeated until you are referred to a block containing a statement describing the action required to correct the fault. Figure 13-15 is a simple example of a fault logic diagram; others are more extensive.

Indications that occur normally during the system tests and which can be helpful in fault analysis are presented in the diagrams as questions. Blocks that contain fault correction procedures reference functional diagrams, further troubleshooting procedures, or the fault-troubleshooting documentation reference table associated with each fault logic diagram.

EQUIPMENT TROUBLESHOOTING AIDS

When the defective or improperly adjusted component has been found, equipment or unit troubleshooting aids come into use to help you restore the component to its proper functioning state. These aids include: (1) servicing block diagrams, (2) schematic diagrams, (3) voltage distribution diagrams, (4) voltage and resistance charts, and (5) equipment troubleshooting pyramids. A brief description of each of these follows. The troubleshooting charts have long been the basis of maintenance work. You will find them in numerous publications about your equipment, or posted on or near your equipment.

Troubleshooting Charts

Troubleshooting charts give a systematic procedure for locating malfunctions in an equipment. The chart lists easily observed or measured symptoms of improper equipment functioning, the probable cause, and the corrective action to be taken by the technician.

In most cases, troubles cannot be pinpointed to a particular circuit element (tube, resistor, capacitor, etc.) by means of the chart. However, the fault can be localized to a particular circuit and the faulty element then localized by checking tubes, taking waveforms, and measuring voltage and resistance. Before using the charts, observe all external indications of trouble. Check for blown fuses, open interlocks and switches, and the proper setting of operating controls. You may recognize this time-tested aid under other names.

Block Diagrams

This troubleshooting aid should enable the technician to see, in a general way, the course of each circuit. From it you can perceive the relationship between circuits and components. Also, you can determine the general location of the test points for checking the condition of the equipment. The servicing block diagram should aid you in localizing the trouble to a small segment. It thus stands, in usage, in an intermediate position between the trouble chart and the schematic diagrams.

Schematic Diagrams

A schematic diagram shows how the parts of a circuit are connected for the operation of the equipment. It does not tell how the parts look or how they are constructed. Each component is illustrated by a symbol. A set of schematics enables the technician to trace the passage of energy throughout the entire equipment, and to test the operating condition of each part and connection.

Voltage Distribution Diagrams

These diagrams trace the distribution of the supply voltages throughout the equipment. The diagrams show all the relays, contacts, switches, and access points for that particular voltage distribution.

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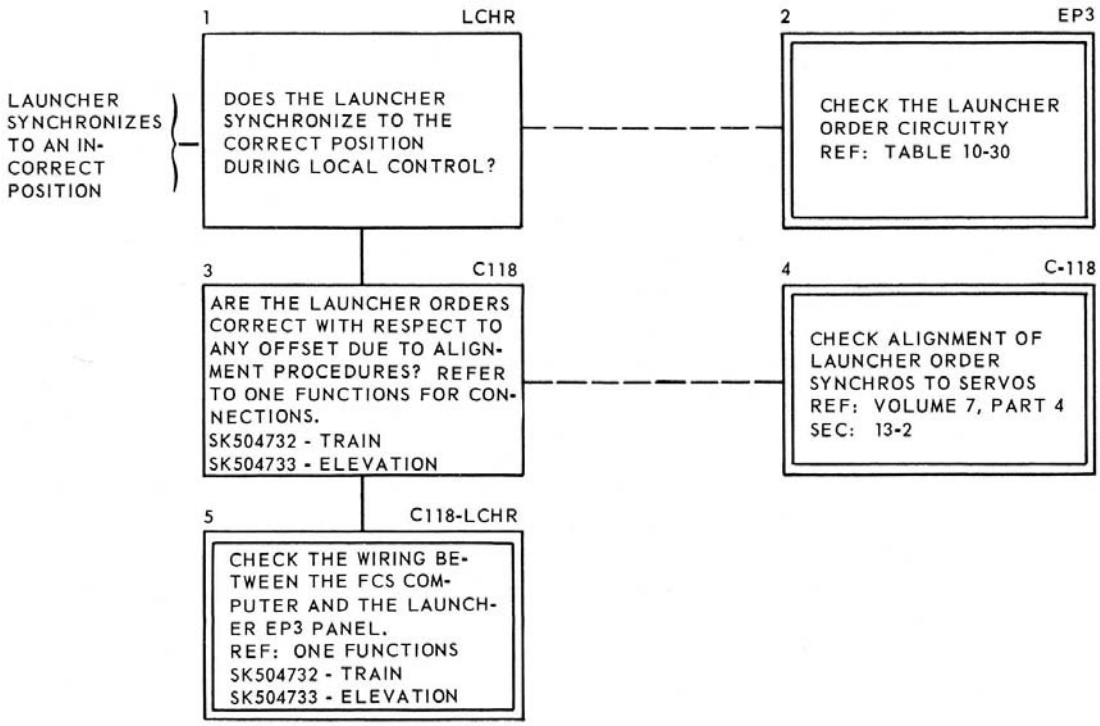


Figure 13-15. — Fault logic diagram — launcher synchronization in error.

Voltage and Resistance Charts

These charts show the normal voltage and resistance values at the pins of connectors and tube and transistor sockets. Voltage and resistance charts are used to pinpoint the faulty element after it has been isolated through the use of troubleshooting charts and servicing diagrams. After isolating the source of trouble to a stage or area of a circuit, determine which chart you should use. Generally, there is one for each chassis in the equipment. Using servicing diagrams for reference, check voltage in the circuit, starting with the input stage and continuing until the output is reached. Repeat this procedure for resistance measurements. When an abnormal indication is observed, discontinue the procedure and check the component or components involved to pinpoint the trouble. However, keep in mind that various controls will effect voltage and resistance readings; if a faulty reading is obtained, these controls should be checked for their proper setting.

Equipment Troubleshooting Pyramids

These pyramids, contained in the OPs associated with the weapon system, deal with the interdependency of the subassemblies essential to each function and, for a given local test setup, list the values and allowable tolerances of that function. Subsequent checks of the various inputs that affect the function are contained in blocks which radiate downward from the statement of the function. The blocks contain recommended corrective action if the check of the input is at fault. Each leg of the pyramid is terminated by an input and reference to other pyramids or related documents, or by a source assembly such as an oscillator. Thus, the equipment troubleshooting pyramids will enable you to quickly localize faults and to perform the necessary corrective action by referencing the associated material.

Troubleshooting Printed Circuits

Locating components and circuit tracing in a printed circuit is generally easier than with wired circuits. The mass of wiring, terminal strips and obscured testpoints are virtually eliminated. The components in a printed circuit are grouped in an orderly manner, and tracing the circuit is somewhat like following a breadboard model.

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Chapters 4 and 5 in Blueprint Reading and Sketching, NavPers 10077-C, illustrate electrical and electronic diagrams, and give instructions for reading them.

PRECAUTIONS AND TECHNIQUES IN MAKING ELECTRICAL MEASUREMENTS

Some safety rules were given in the discussion of the use of each test instrument. Some additional precautions are given here for each type of measurement.

VOLTAGE MEASUREMENT

Most troubles can be found by taking voltage measurements. These measurements can be made easily since they are always made between two points in a circuit and the operation of the circuit need not be interrupted. Unless otherwise indicated in the voltage chart, voltages usually are measured between the indicated points and a common return.

Always use a meter that has the same ohms-per-volt sensitivity as the one used originally to develop the voltage chart. The type of reference meter used will be stated on the chart, but your meter does not have to be an exact duplicate. It must have the same sensitivity rating, otherwise erroneous readings will result due to differences in circuit loading. Always begin voltage measurements by setting the voltmeter on the highest range, so that the voltmeter will not be overloaded. Then, if necessary to obtain increased accuracy, set the voltmeter to a lower range. Always use the range that gives maximum voltage reading.

In checking cathode voltage, remember that a reading can be obtained when the cathode resistor is actually open, the resistance of the meter acting as a cathode resistor.

Certain precautions must be followed when measuring voltages above a few hundred volts since high voltages are dangerous and can be fatal. When it is necessary to measure high voltages, observe the following rules.

1. Connect the common (ground) lead to the voltmeter.
2. Place one hand in your pocket.
3. If the voltage is more than 300 volts, shut off the power, connect the hot test lead, step away from the voltmeter, turn on the power, and note the reading on the voltmeter. Do not touch any part of the voltmeter, particularly when it is necessary to measure the voltage between two points both of which are above ground.

It is essential that the voltmeter resistance be at least 10 times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a lower voltage than the actual voltage present when the voltmeter is not in the circuit.

When a voltmeter is loading a circuit, the effect can be noted by comparing the voltage reading on two successive ranges. If the voltage readings on the two ranges do not agree, voltmeter loading is excessive. The reading (not the deflection) on the highest range will be greater than on the lowest range. If the voltmeter is loading the circuit heavily, the deflection of the pointer will remain nearly the same when the voltmeter is shifted from one range to another.

To minimize voltmeter loading in high resistance circuits, use the highest voltmeter range. Although only a small deflection will be obtained (possibly only 5 divisions on a 100 division scale), the accuracy of the voltage measurement will be increased. The decreased loading of the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.

MEASUREMENT OF CURRENT

Current measurements other than those indicated by the panel meters ordinarily are not required in troubleshooting. Under special circumstances, where the voltage and resistance measurements alone are not sufficient to localize the trouble, a current measurement can be made by opening the circuit and connecting an ammeter in series. This procedure is not recommended except in very difficult cases.

CAUTION: A meter has least protection against damage when it is used to measure current. Always set the current range to the highest value. Then, if necessary, decrease the range to give a more accurate reading. Avoid working close to full-scale reading because this increases the danger of overload.

In most cases, the current to be measured flows through a resistance which is either known or can be measured with an ohmmeter. The current flowing in the circuit can be determined by dividing the voltage drop across the resistor by its resistance value. The drop across the cathode resistor is a convenient method of determining the cathode current.

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When the meter is inserted in a circuit to measure current, it should always be inserted away from the r-f end of the resistor. For example, when measuring plate current, do not insert the meter next to the plate of the tube, but insert it next to the end of the resistor which connects to the power supply. This precaution is necessary to keep the meter from affecting the r-f voltages.

MEASUREMENT OF RESISTANCE

Before making resistance measurements, turn off the power. An ohmmeter is essentially a low range voltmeter and battery. If it is connected to a circuit to which power is being applied, the needle will be forced off scale and the voltmeter movement may be burned out.

Capacitors must always be discharged before resistance measurements are made. This is very important when checking power supplies that are disconnected from their load. The discharge of the capacitor through the meter will burn out the meter movement and, in some cases, may endanger life. In a parallel circuit, the total resistance is less than the smallest resistance in the circuit. This is important to remember when troubleshooting with the aid of a schematic diagram.

It is important to know when to use the low resistance range of an ohmmeter. When checking circuit continuity, the ohmmeter should be set on the lowest range. If a medium or high range is used, the pointer may indicate zero ohms, although the resistance may be as high as 500 ohms. When checking high resistance or measuring the leakage resistance of capacitors or cables, the highest range should be used. If a low range is used in this case, the pointer will indicate infinite ohms, although the actual resistance may be less than a megohm.

When you measure resistance and find it less than you expected, make a careful study of the schematic to be certain that there are no parallel resistances. Before replacing a resistor because its resistance measures too low, disconnect one terminal from the circuit and measure its resistance again to make sure that the low reading does not occur because some part of the circuit is in parallel with the resistor.

In some cases it will not be possible to check a resistor because it has a low resistance transformer winding connected across it. If the resistor must be checked, disconnect one terminal from the circuit before measuring its resistance.

When checking a grid resistance, a false reading may be obtained if the tube is still warm and the cathode is emitting electrons. Allow the tube to cool, or connect the ohmmeter test leads so that the negative lead is applied to the grid.

Tolerance is the normal difference to be expected between the rated value of the resistor and its actual value. Most general purpose resistors have a tolerance of 20 percent. For example, the grid resistor of a stage might have a rated value of 1 megohm. If the resistor were measured and found to have a value between 0.8 megohm and 1.2 megohms, it would be considered normal. As a rule, the ordinary resistors used in circuits are not replaced unless their values are off more than 20 percent. Some precision resistors and potentiometers are used. When a resistor is used whose value must be very close to its rated value, the tolerance is stated on the diagram and in the maintenance parts list.

Tolerance values for transformer windings are generally between 1 and 5 percent. As a rule, suspect a transformer which shows a resistance deviating by more than 5 percent from its rated value. Always allow the transformer to cool before the resistance test is made.

Resistance in Electrolytic Capacitors

The measurement of resistance in electrolytic capacitors with an ohmmeter was described earlier in this chapter. Note that the capacitor must be discharged before making measurements. Capacitors retain their charge for some time after being disconnected from the power supply.

WHAT NOT TO TEST

Certain missile components and equipment must not be tested at all on shipboard except by specially trained personnel or under special circumstances.

Launcher firing circuits shall not be tested when rockets or missiles are on the launcher.

Continuity tests of rocket initiating elements shall not be conducted aboard ship. Rocket motor igniter circuits shall not be tested aboard ship.

No mechanical operations of any kind - machining, cutting, welding, drilling, etc. - on solid propellant rocket motors shall be permitted aboard ship.

No disassembly is permitted on rocket motors without specific permission from the competent authority.

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No steel instruments or tools which may cause sparks shall be used for cleaning or scraping explosive or flammable components of missiles, except as authorized by Naval Ordnance Systems Command.

Under no circumstances shall attempts be made to disassemble or repair any fuze system aboard ship. Fuzes shall not be tested either mechanically or electrically aboard ship except as specifically authorized by NAVORD.

Igniters shall not be disassembled or tested aboard ship unless specifically authorized and strictly in accordance with instructions from NAVORD.

No electrical check shall be made of the cable connector of the S&A device unless specifically authorized by current directives.

SAFETY PRECAUTIONS

The duties of the GMM require constant vigilance in the observance of safety precautions. These safety precautions include those concerning work with electrical and electronic equipment, work involving the handling of explosive ordnance material, work in the vicinity of equipment capable of starting fires or generating toxic gases, work done on high pressure hydraulic and pneumatic systems, and work done with small power tools. In addition to being thoroughly familiar with safety precautions, the GMM must know the authorized methods for treating burns and for giving artificial respiration to persons suffering from electric shock.

Because of the many specialized devices you will use, and because of the potential hazards in your work, you should consider the formation of safe and intelligent work habits as being equal in importance to the development of technical knowledge and skills. You should always strive to exhibit the attitudes and practices which are characteristic of "safety mindedness." One of your objectives should be to become a safety specialist, trained in recognizing and correcting dangerous conditions and in avoiding unsafe actions.

This section is in no way an exhaustive treatment of safety practices. Each GMM is expected to observe all of the safety precautions set forth in local directives, in equipment maintenance manuals, and in United States Navy Ordnance Safety Precautions, OP 3347. NAVSO P-2455, Department of the Navy Safety Precautions for Shore Activities, contains many safety precautions that are also applicable aboard ship. Safety rules for electrical and electronic equipment aboard ship are collected in chapter 9670 (formerly ch. 67) in NAVSHIPS 0901-963-0000 (formerly) vol. III of BUSHIPS Technical Manual 250-000). Also every equipment OP contains a section on safety precautions. It is up to you to familiarize yourself thoroughly with all publications concerning safety. Many of the safety regulations have developed as a result of actual experience, so give them every possible consideration.

CAUSES OF ACCIDENTS

The precautions set forth in OP 3347 apply generally to operation of ordnance equipment and to the handling of explosives. However, the Navy does not expect blind adherence to them during extraordinary occasions; it is equally important that each individual use his own ability and initiative to prevent accidents during unforeseen conditions. For this reason it will be well for you to review a few of the basic causes of accidents.

There are four closely related causes of accidents: CARELESSNESS, INEXPERIENCE, OVERCONFIDENCE, and FATIGUE.

CARELESSNESS is something most human beings have to overcome. You have to cultivate good working habits-you must learn to coordinate your mental and physical actions to a point where you can concentrate on the important parts of the job at hand without having to worry about the minor mechanical functions pertaining to it.

INEXPERIENCE can be the cause of accidents regardless of how careful the individual intends to be. The best solution to this problem is NEVER GUESS- you must learn to ask questions about things you are unfamiliar with or are not completely sure about. Beginners have a tendency to be overeager, and desire to put their hands to work. Eagerness is a good trait in any person, but you must realize that men with more experience usually know best. Work into a job gradually, and be particular about thoroughness; always be conscious of correct procedures in doing things. Train your mind and hands to function correctly so as to protect yourself and others from physical injury. For example, when you work with a screwdriver, be sure that your left hand (or right hand, if you are left-handed) is clear of the screwdriver bit, otherwise a slip of the screwdriver may drive the bit completely through your hand or may gouge deep into your arm. If you practice correct methods from the start, they'll become automatic before you realize it.

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OVERCONFIDENCE can come to both young and old, experienced and inexperienced. It is usually more closely associated with inexperience. Often, however, men grow overconfident when they become thoroughly familiar with a particular job, and have a tendency toward carelessness. To put it briefly, be confident that you know a job; but beware of overconfidence, because it may invite mistakes which can cause accidents.

FATIGUE is the cause of a large percentage of accidents. You might be highly efficient when you have energy to burn, but it's another story when you get tired; your physical actions slow up and become inaccurate. Always prepare yourself for the task ahead by learning how much endurance it requires, and then get the necessary sleep, recreation, food, and exercise to keep on your toes. Remember, to be alert and to feel your best is extremely important on the job, and you can only enjoy this feeling by keeping yourself in good physical condition.

In addition to studying safety precautions contained in OP 3347, and in this chapter, you are also referred to Ordnance Safety Precautions, OP 1014. The case studies and precautions set forth in this publication not only provide interesting reading, but also may save your life! The case histories (with pictures) of accidents in the Navy show the need for some of the safety rules you may consider unnecessary.

OPERATING ORDNANCE EQUIPMENT

Let us repeat-you should acquaint yourself thoroughly with the safety regulations provided in the appropriate OP and with those regulations posted aboard ship, before operating equipment. You will be taught how to apply many of these precautions while you are learning to operate ordnance equipment. The following list of general precautions will assist you.

1. Always inspect all training and elevating areas to make certain that all persons are clear, and that the areas are free of obstructions before operating directors, turrets, guns, or missile launchers.

2. Always use warning bells where provided before training or elevating gun mounts, turrets, or launchers during routine work and practices (except during GQ).

. Before leaving directors, turrets, guns, or launchers, always train and elevate them to their securing positions: place all controls in the inoperative position, and deenergize all power supplied to them.

4. Whenever possible, have the regular operators posted at their stations before operating a director, turret, gun or launcher from a dummy director.

5. Slew directors, guns, and launchers only when it is necessary during practices. Be sure no one is in the path of the moving machinery.

6. All telephone stations should be manned when operating systems automatically or remotely.

7. Notify all operators and persons concerned before shifting a system from one mode of control to another.

8. Never operate directors, turrets, launchers, or guns in automatic without having the regular operators posted at their stations.

9. Do not hesitate to stop any person from operating ordnance equipment if he may cause a casualty to himself, the equipment, or to any other person.

SAFETY PRECAUTIONS FOR MISSILE ELECTRICAL AND ELECTRONIC WORK

Most of the safety rules for electrical work also apply to the operation, repair, and maintenance of missile electronic equipment. Furthermore, special precautions must be taken against the high voltages normally present in electronic devices, against dangerous effects of radiated energy, and against possible injury when handling electronic parts.

The standard safety measures to be taken by personnel engaged in work on electronic equipment include the following:

1. Do not work on electronic apparatus with wet hands or while wearing wet clothing or any clothing which is loose and flapping.

2. When working within 4 feet of electronic equipment, do not wear clothing with exposed zippers, metal buttons or any type of metal fastener. No flammable articles such as celluloid cap visors should be worn.

3. Personnel should remove rings, wristwatches, bracelets, and similar metal articles when working on or within 4 feet of electronic equipment having exposed current-carrying parts.

4. When working on or near electronic apparatus, personnel shall wear high-cut shoes with sewed soles or safety shoes with nonconducting soles, if these are available. The use of thin soled shoes and those with metal plates or hobnails is prohibited.

5. Danger signs and suitable guards should be provided to warn all personnel wherever live

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parts of electric circuits and equipment are exposed when the voltages involved are 50 volts or greater.

6. Insulated floor covering should be used in work areas where electronic equipment is serviced, particularly where the deck or walls are of metal.

7. Interlocks, overload relays, fuses, and other protective devices should never be altered or disconnected except during replacement; nor should any safety circuit be modified without specific authorization.

8. Metal enclosures for electrical and electronic equipment must be kept effectively grounded.

9. Adjustments, repair, and maintenance of missile radars, radio units, and test equipment must be done only by duly authorized personnel.

10. Adjustment of transmitters and other high voltage equipment should not be attempted while the motor-generator is running or while the rectifiers are energized, unless the adjustments can be made by the use of exterior controls provided for the purpose.

11. Except in emergencies, or when authorized by the proper authority, repairs should not be made on energized electronic equipment. If such work is necessary, it should be undertaken only by experienced personnel.

12. NEVER WORK ALONE near high voltage equipment.

13. Exercise caution when using tools with metal parts, metal tapes, cloth tapes with embedded metal threads, and cleaning equipment containing metal parts. None of these should be used in any area within 4 feet of electronic equipment or wiring having exposed current carrying parts.

14. When working around electronic circuits, keep your mind on your work.

15. Exercise as much care to avoid contact with low voltages as with high voltages. NEVER TAKE A SHOCK INTENTIONALLY FROM ANY SOURCE. This is a dangerous practice and is STRICTLY FORBIDDEN. If a particular circuit operates normally at 600 volts or less, and it is necessary to determine whether it is energized, use a voltmeter, voltage tester, or other suitable indicating instrument. DO NOT draw arcs with screwdrivers, etc.

16. Before you touch the terminals of apparently deenergized equipments, short them together and to ground, using a suitable insulated shorting device.

17. When nearby transmitting equipment is in operation, be on the alert to avoid shocks and burns resulting from contact with antennas, antenna leads, and other exposed parts. 18. Special precautions concerning ordnance material should be observed before energizing transmitters.

Electromagnetic radiations is a term used to describe energy radiated by radio and radar transmitting equipment. This energy is more commonly referred to as radio waves, radio frequency energy, or RF energy.

RAD HAZ is an abbreviation for radiation hazards and is generally associated with the effects of radiation on humans. HERO is an abbreviation for hazards of electromagnetic radiation to ordnance. These terms are relatively new, although their effects have been known for some time. A thorough study has been made to establish the causes and the results of damage to the human body due to exposure of the body to radiation from various sources.

The electromagnetic radiation from radar transmitters can ignite electric primers, flares, and similar sensitive ammunition components. In addition to ordnance items, the effects of radiation on combustible materials such as gasoline and other fuels is equally hazardous.

Experiments with animals have revealed that high-intensity microwave radiation has destructive effects upon living organs. It has also been found that pain cannot always be relied upon to warn an individual of a dangerous radiation field. The most vulnerable parts of the body are those not effectively cooled by the blood stream.

Damage to the body organs is believed to be entirely due to the heat generated as a result of the absorption of microwave energy by the body's tissues and not due to any mysterious property of the microwave radiation.

Exposure of humans to microwave radiation of 10 centimeter (cm) wavelength region is considered to be the most dangerous, since the maximum heating occurs a few centimeters beneath the surface of the skin. The sensory nerves at the surface of the skin will not indicate the degree of internal heat produced and, unfortunately, the retina of the eye is situated at the zone of maximum heating. NAVORD OP 3565, Technical Manual, Radio Frequency Hazards to Ordnance, Personnel, and Fuel, tells more in detail the hazards of r-f radiation and the precautions necessary.

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HANDLING OF COMPONENTS

Static electric charges carried on the human body can burn out crystal diodes which are often used in missile radar receivers. When installing a crystal, the cartridge should be held with the fingers touching one end only. The hand holding the unit should then be grounded against the missile airframe before the end of the crystal is brought into contact with the holder.

Before you touch a capacitor, either connected in a deenergized circuit or disconnected entirely, you should short circuit the terminals to be sure that the capacitor is completely discharged. A suitable insulated lead or grounding bar should be used for this purpose. (Grounded shorting prods should be attached permanently to workbenches where electronic units are regularly serviced or overhauled.)

There is no established case history of anyone having been killed by direct microwave radiated energy - yet. There is ample evidence that eye cataracts and various degrees of sterility have been caused by this radiation power. There is much evidence to further indicate the lethal capability of microwave radiation at power levels now readily available and in common usage.

Aside from shock hazard there are two common types of radiation hazards associated with the use of high frequency, high-powered microwave equipment. One is the direct RF radiation from waveguides or antennas. The other is the X-radiation that can be generated in, and escape from, certain high voltage tubes.

The swept area of tracking radars cannot be limited so personnel must keep out of the danger area and fuel and explosives must not be exposed in the danger area. The danger areas should be posted with warning signs. Never enter an area posted for microwave radiation until the transmitter is turned off and will remain off until further notice. Never look into an open waveguide or radar set connected to an energized transmitter.

Care should be taken when using tools made of magnetic materials near radar magnetrons, since the tool can be pulled by the magnet into contact with dangerous high voltage circuits.

Fuses should be removed and replaced only after the circuit has been completely deenergized. When a fuse "blows" it should be replaced only with a fuse of the same current rating. When possible, the circuit should be checked carefully before making the replacement, since the burned out fuse usually results from a circuit fault.

GENERAL SAFETY PRECAUTIONS

Although many specific safety precautions are laid down for you in the three main publications that cover safety, there are a few general precautions which you should remember. Let's start by discussing the handling of handtools and power tools.

Handling Tools and Machinery

Many accidents occur because of the improper handling of tools. In general, these accidents occur in the form of physical injury to the person operating the tools. The following list gives the more -important general precautions to follow.

1. Whenever chipping, buffing, or grinding with handtools and powered tools, always wear goggles as a protection to the eyes. Little chips from a spinning grind wheel, or a bristle from a revolving wire brush can easily put out an eye. Many of these machines are provided with a guard; be sure to use it.
2. Always ground the provided ground lead located at the plug of portable tools such as electric drills to protect yourself from shock in case a ground occurs within the tool.
3. When working with sharp handtools, always work so that the tool is moved or thrust away from the body.
4. Never wear loose clothing or a neckerchief when working with rotating tools or machinery. Such clothing may become caught in the spinning parts and drag you bodily into the machine, causing severe physical injury.
5. Never use metal handtools on energized electrical equipment or circuits because you may get shocked, or the tool may cause a short circuit, causing molten copper to be blown into your face and eyes.
6. Never use handtools around running machinery, nor perform adjustments to running machinery unless absolutely necessary.
7. Never lay handtools on top of running machinery where vibration may cause the tool to fall into exposed working parts.
8. In the event your division officer deems it necessary to work on high voltage (exceeding 50 volts to ground) electric equipment while in an energized state, wear rubber gloves and use tools with insulated handles, and stand on an insulated mat. Always work with one hand in order to prevent the possibility of a circuit through your body from arm to arm.

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9. When working with tools, always work in a physically comfortable position, and keep the weight of your body well centered.

Electrical Work

The following list is in addition to those precautions on handtools and machinery, and is applicable to all electrical work. This list will help you prevent electric shock or burns during daily work.

1. Whenever possible, operate electric switches and controls with one hand.
2. Do not block high voltage protective cutouts on doors or covers to keep the circuit energized with the cover off. It is intended that work be performed on such electrical equipment while the circuit is deenergized.
3. Always be sure that all condensers are fully discharged before commencing work on a deenergized high voltage circuit. Use an insulated shorting bar for this purpose.
4. Tag the switch OPEN (open the switch and place a tag on it stating "This circuit was ordered open for repairs and shall not be closed except by direct order of _____.") at the switchboard supplying power to the circuit on which you wish to work. When possible, remove the fuses protecting the circuit and place them in your tool box for safekeeping until the job is complete.
5. Always remove fuses with fuse pliers, and never remove fuses until after opening the switch connecting the circuit to the source of supply. Never replace a fuse with one LARGER than the circuit is designed to take.
6. Utmost precaution should be observed when inspecting behind an open-back switchboard in an energized state.
7. Never use an incandescent test lamp unless its voltage rating is greater than the highest voltage which may be tested.
8. Always test a supposedly deenergized circuit with a voltage tester before commencing work on the circuit.
9. Never work on an electric circuit or network without first thoroughly acquainting yourself with its arrangement and with its points of power feed.

Common Safety Features
in Electronic Equipment

You should be aware of the safety features that are generally included in electronic equipment. Some of the common safety features are interlock switches, bleeder resistors, current limiting resistors, insulating controls, and powerline safety devices such as fuses. Keep in mind that these features cannot always be counted on to function. Don't develop a false sense of security just because an equipment has safety features.

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CHAPTER 14

LAUNCHER CHECKS, MISSILE REPLENISHMENT AND SERVICING

INTRODUCTION

The material in the preceding chapters, pertaining to guided missile launching systems and their component parts, serves as background information for the GMM in the performance of his primary technical duties. Among the more important of classes duty which we have not covered are power drive performance tests, missile handling, and missile component replacement, which are discussed in this chapter.

Launcher performance testing and the basic principles behind this process is the subject matter of the first section of this chapter. In the second section we will cover missile replenishment in port and at sea. The last section describes the preparations required for missile operational tests and the replacement of missile components.

POWER DRIVE PERFORMANCE TESTS

The automatic control equipment discussed in this section comprises the train and elevation power drives for launchers. A power drive is a part of the basic automatic servosystem. Power drives can be automatically controlled from a remote station which consists of a director or computer.

The automatic control equipment is designed to comply with the nature and source of the signal, the weight of the load to be moved, and the type of damping required to eliminate random movements and to ensure accuracy and rapidity of response. Automatic control is used in ordnance equipment for light loads (computers and indicators) and for heavy loads (gun mounts, turrets, fire control directors, and missile launchers).

You learned in chapter 7, Fundamentals of Servomechanisms, that the output of a perfect servo (one which responds instantaneously to an input signal) is an exact duplicate of its input. If, for example, the input shaft is rotated 10°, the servo output shaft will rotate through an angle of 10°. Assuming both shafts are in agreement and that the input shaft will rotate at, say, a constant speed, the output shaft will follow this constant speed input and will stay synchronized with it. In a perfect servo the output would never fall out of step with the input, regardless of the kind of input shaft motion. But, as you know, power drive servos are not perfect, and the output position and motion do not always represent the input. So, there will always be some angular difference between the two shafts. For example, they may not be at the same angular position, or one may be rotating faster or slower than the other. But if the error between the input and output remains within certain limits under all types of input conditions, then we can say that a particular power drive servo is performing properly.

Who determines what these prescribed limits are? NAVORDSYSCOM does. When the engineers in NAVORDSYSCOM set down specification for private contractors to build a power drive servo, the engineers define the limits. For example, the specifications may say that the launcher must follow a constant velocity signal of 10° per second and stay synchronized with 5 minutes of arc. This means that the output shaft position must not go beyond ± 5 minutes of the input shaft position. Now, to make sure that the launcher manufacturer has built the power drive to meet this specification, NAVORDSYSCOM engineers will go aboard the ship on which the launcher is installed and run a series of tests. One of these tests will determine if the launcher follows a 10°/sec constant velocity signal and does not lag or lead it by more than 5 minutes. If the launcher power drive servo does not meet this particular requirement, NAVORDSYSCOM engineers will not accept the drive until it does.

So, the contractor adjusts the servo until it follows the constant velocity signal with an error of 5 minutes or less, and a permanent

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record in the form of a tape is made to prove this fact. This record (called an acceptance test) is kept aboard the ship as evidence that the power drive servo can and has met this particular performance standard. It gives you something to shoot for, and also a record for later comparison. You can run the same test later and then compare your test results with those of the acceptance test. When yours are as good or better than the acceptance test results, then the power drive servo is performing at its best.

How can we tell whether a power drive is in top working order? By looking at it? NO. That is not the correct answer. However, it is an answer of sorts because many technicians (GMMs, GMGs, and FTs) use this "eyeball" technique for checking power drive performance. You can tell if a power drive is working at its worst, however, by watching the action of the load. For example, if the launcher overtravels three or four times when synchronizing to a fixed order signal, the most casual observer will notice that something is wrong with the drive. Or, if the launcher hunts as the director tracks a target, you know immediately something is wrong. But how can you tell from looking at the launcher if the source of trouble is in the tracking radar, director, computer, or in the power drive itself? The only way you can isolate the source of trouble is to disconnect the launcher from the computer (and the rest of the weapon control system) and run a test on the launcher drive itself. A dummy director is used to run the test. The dummy director provides an alternate source of signals, thus bypassing the FC system.

From what we've just said, you can see that it is impossible to tell if a power drive servo is working at top efficiency just by watching it operate. We must have some means of measuring its performance and then comparing this with a set of standards.

Dummy directors and error recorders are the test instruments used for dynamic (motion) testing of train and elevation power drives. Dummy directors are sources of electrical signals that are fed into the power drives under test. Figure 14-1 shows schematically how these two test units are hooked up. The error recorder makes a record of the test on a pair of paper tapes. One tape indicates the difference (error) between the signal from the dummy director and the power drive response. The other tape records the velocity of the power drive.

To test a launcher in remote control, electrical signals which represent constant velocity I simple harmonic motion, or a fixed position, are transmitted from the dummy director to the power drive servo under test. The error recorder receives a signal corresponding to launcher response, velocity, or position, depending on the type of test. As the launcher moves in answer to the changing test order signal, the error recorder makes a permanent record of the instantaneous difference between launcher order and the power drive output. The magnitudes of the errors are determined by measuring from a reference line the displacement of the curve produced by the error recorder.

The curves obtained from a dynamic accuracy test should be compared with the curves taken when the equipment was accepted by NAVORDSYSCOM. These records are kept on the ship, to be used for comparison. If the curves from the performance tests show rough response action, or a velocity or position lag in excess of that specified for the particular launcher, the power drive should be checked for malfunctioning parts. Also, the controls should be adjusted to bring the dynamic accuracy tests within allowable limits of error.

These tests are performed quarterly, during shipyard overhaul, and whenever the- launching system seems not to be operating properly. The dummy director and the error recorder are normally used together and are kept aboard repair ships and in Navy shipyards. The Mk 1 Mod 6 dummy director and magnetic oscillograph originally were issued as standard test equipment to all missile ships.

Error recording by means of magnetic oscillograph (direct writing on graph paper) can be performed by using either a stylus which writes with ink or an electric stylus which writes on special magnetic paper. In conjunction with a magnetic oscillograph, a limiter-demodulator unit must be used to calibrate, attenuate, balance, limit, and filter the error signal before it is fed to the recorder.

The instruments necessary for error recording on a missile launching system are connected into the test panel without changing the normal wiring between the fire control system and the missile launching system. Switches on the test panel are marked so the operator can see which ones to use. Receptacles on the test panel receive the cables from the test instruments.

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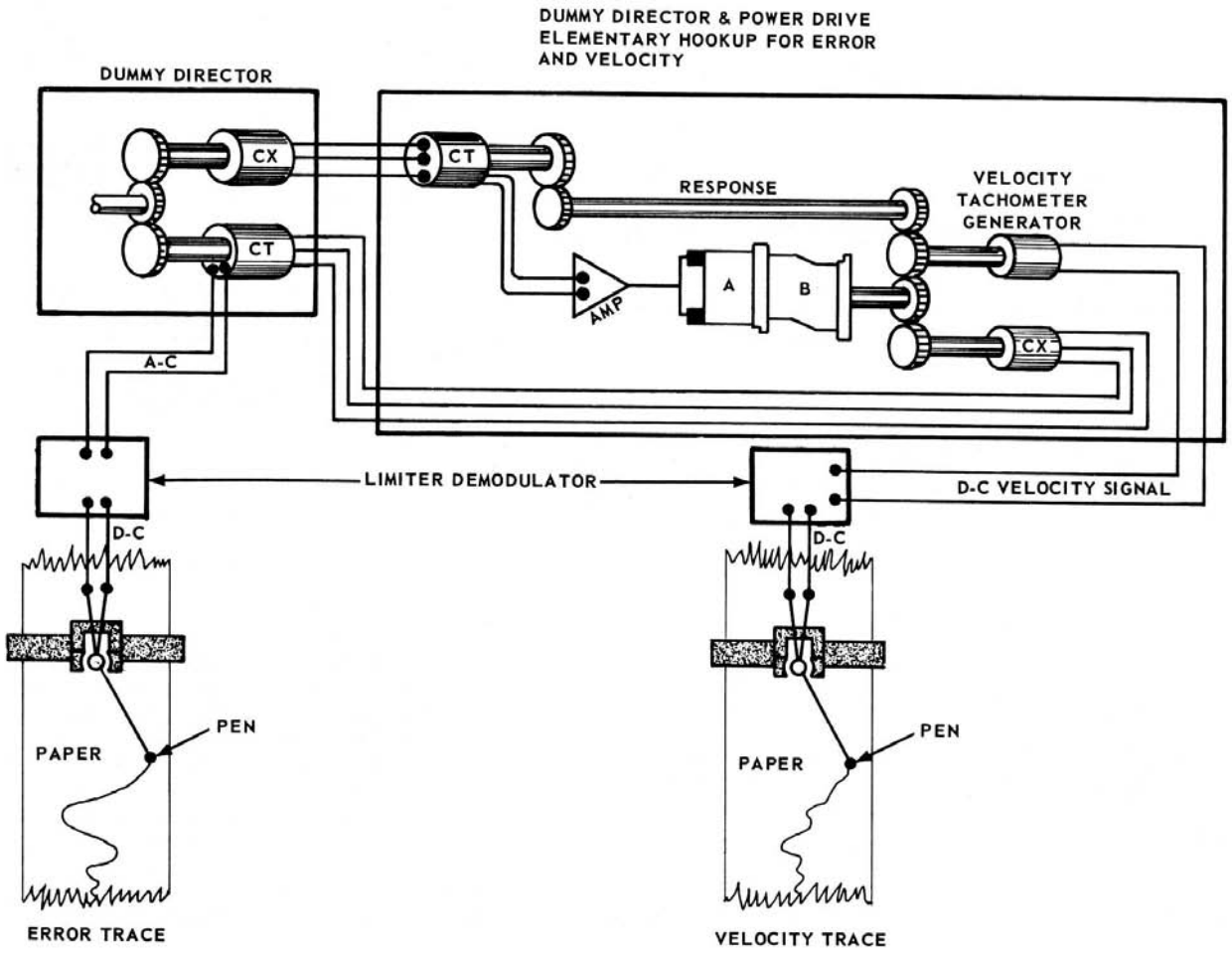


Figure 14-1.—Simplified schematic of power drive performance test hookup.

TYPES OF TEST SIGNALS

The order signals that are supplied to power drives can be classified as being of three distinct types:

1. Simple harmonic motion (SHM) orders.
2. Constant velocity (CV) orders.
3. Fixed displacement (FD) orders.

Simple Harmonic Motion (SHM)

Figure 14-2 shows a ship making a simple harmonic motion, or roll. In the diagram you can see that ship's roll swings the launcher line of fire away from the aiming point. Pitch will cause this, too. To compensate for rolling and pitching motion of this ship, correcting signals are generated in the fire control computer. These are added to the launcher lead angles to make up launcher orders. The effect of these roll and pitch compensating signals is to keep the launcher line of fire fixed in space as the ship's deck moves beneath the line of fire. (Review ch. 2 on this.)

A dummy director can be considered a motion simulator which can reproduce electrical order signals that represent motions such as roll and pitch. And these dummy signals can be controlled. You can pick the size of the signals (magnitude), how long they take to complete a cycle (period), and also their starting point (reference). To see what the terms in parenthesis mean, look at figures 14-3A and 14-3B. The illustrations show the motion of a launcher in response to a SHM signal. The dummy director is putting out a roll signal that is fed to the train power drive servo. We have picked out 45° launcher bearing as a reference from which to move the launcher. We could have chosen any bearing. We have also set up the dummy

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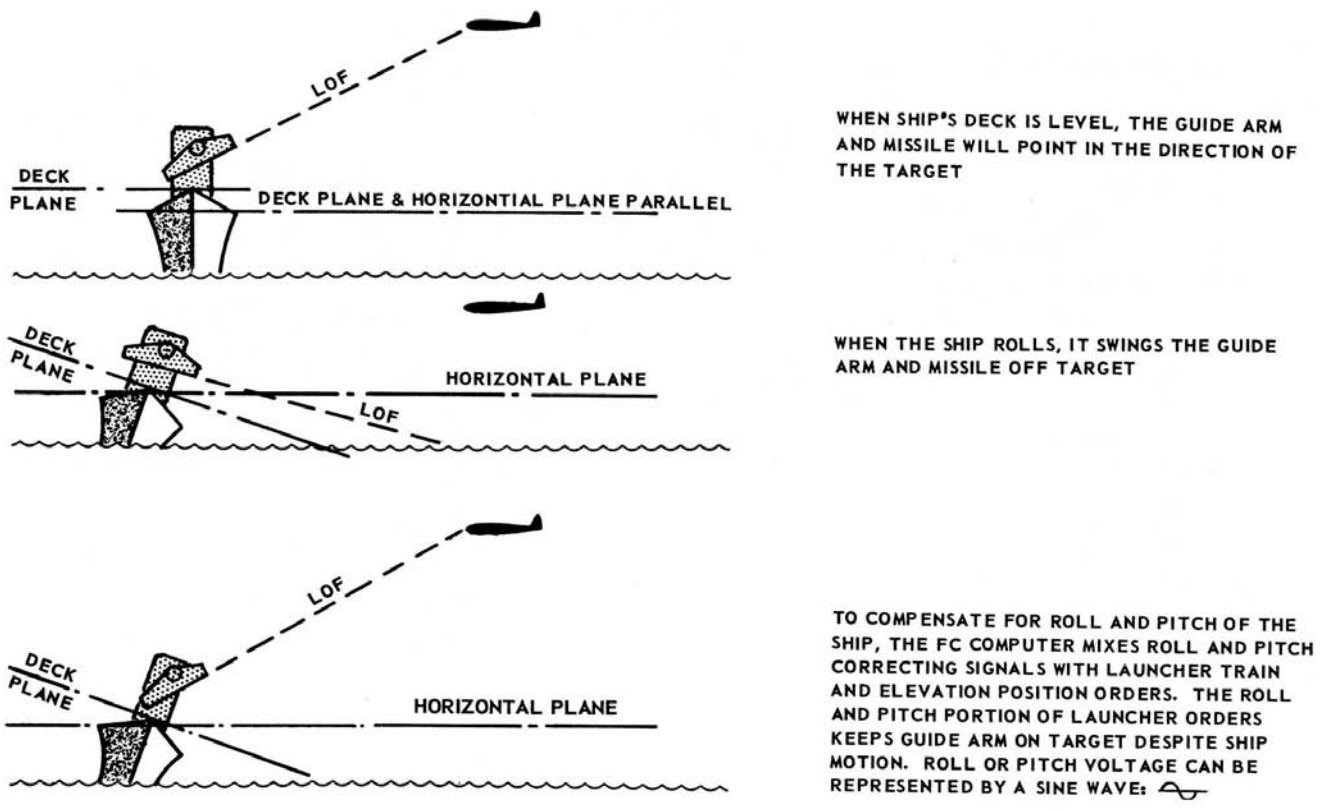


Figure 14-2. — Effects of ship's roll and pitch on launcher line of fire, and corrected line of fire.

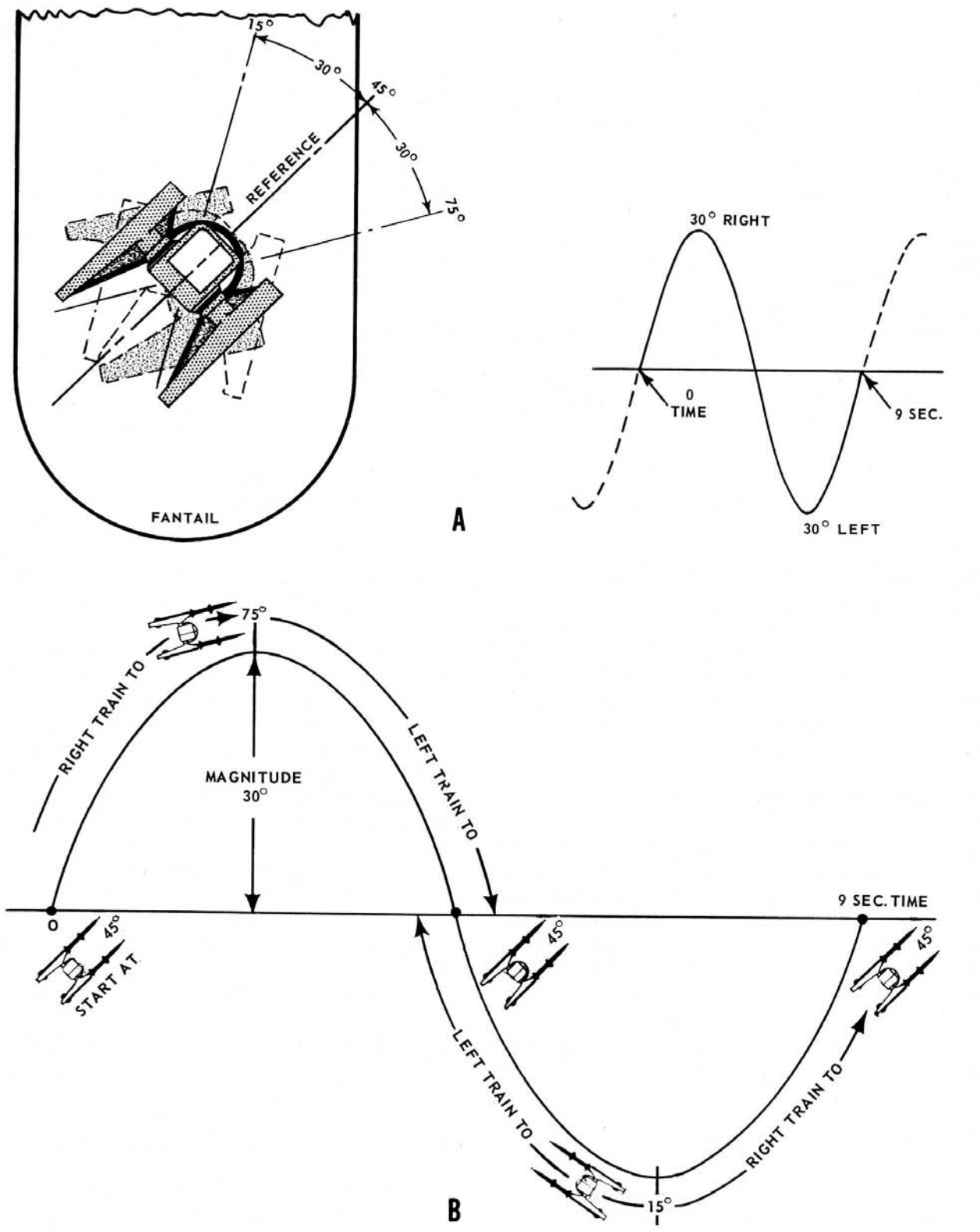
director to put out a 30°, 9-second SHM signal. This means that the signal will drive the launcher {once it is synchronized at 45° from this point to 75°, then back to 45°, then to 15°, and back to 45 degrees. It will keep up this oscillatory motion. until we deenergize the setup. Notice that the signal and the motion of the launcher describe a sine wave. You will remember that the period of a sine wave is the time it takes to complete one cycle. The same idea holds for our signal and the motion of the launcher. It takes 9 seconds for the signal and launcher to go to the right from 45° and then back to the left through the reference point to 30° on the other side of 45°, and back to the reference point. This is a fairly slow roll, and it simulates the kind of roll a ship may experience in ground swells. But you can select a variety of SHM signals. Dummy directors have controls by which you can change the amplitude and period of the output signals.

SHM signals are used to check how accurately a power drive servo follows this type of input signal. The error trace on the error recorder indicates how well the servo performs under these conditions. If the servo under test performs perfectly, a straight line shows up on the error trace. A straight line indicates that there is no error between the input signal (SHM) and the servo output (response). In practice you will never get a perfectly straight line, but the trace should be close to one.

Constant Velocity Signal (CV)

A CV signal approximates a launcher order (train or elevation) which is produced when the FC tracking radar is following a target. Figure 14-4 shows train constant velocity motion pictorially. If the tracking line of sight rotates at a train angular velocity of 10°/sec to stay on the target, the launcher must rotate at this same angular rate to maintain its line of fire on target. And over a period of, say, 5 seconds, both the director and launcher will have moved 50 degrees from a given point so long as the tracking velocity remains at 5 degrees per second.

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Figure 14-3. — Simple harmonic motion (SHM): A. Motion of launcher in response to SHM signal describes a sine wave; B. The magnitude, period, and reference of SHM signal.

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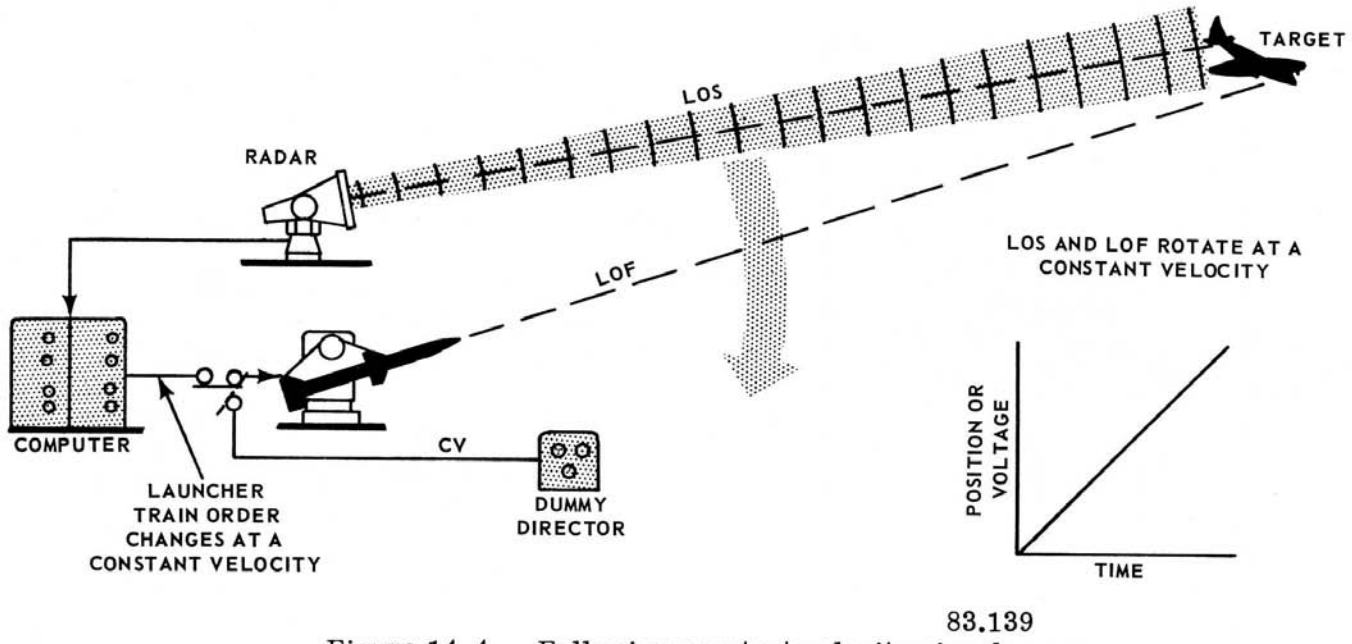


Figure 14-4. — Following constant velocity signals.

The dummy director in figure 14-4 is shown putting out constant velocity signals to simulate director tracking motion which is reflected in the launcher orders. When the launcher is switched to dummy director control, the entire fire control system and the transmission lines between that system and the launcher are isolated from the launcher.

Fixed Displacement Signal

The dummy director is also used as a source of fixed signals (fig. 14-5). These signals simulate the kinds of signals that are present at the train and elevation power drive inputs when, for example, the launcher is switched from REMOTE to STOW, LOAD, DUDJET, or LOCAL. A fixed displacement order usually involves a large change. The fixed position input results in a large instantaneous error which must be reduced by movement of the launcher to the ordered position.

DUMMY DIRECTOR COMPONENTS

Figure 14-6 shows the basic parts of a dummy director. The main servo drive controls two synchro transmitters which are the sources of 1- and 36-speed train or elevation order signals. The main servo also drives a 36-speed control transformer which is used as an error detector. It measures the difference between the input of a power drive servo under test and its output.

Missile launcher power drive servos, as you know, have a velocity input as well as position inputs. Therefore, the dummy director must provide a source for velocity signals. A tach generator geared to the main servo provides velocity signals.

Another servo, called the auxiliary servo, is connected to the main servo. The auxiliary servo and its associated controls generate simple harmonic signals at selected frequencies and periods.

Figure 14-7 shows the outside appearance of Dummy Director Mk 6 Mod 0 and Error Recorder Mk 12 Mod 0, with their carrying cases and plug-in cables. The dummy director has an auxiliary power conversion unit (auxiliary servo, fig. 14-6), which Some older models do not have. The error recorder is a modified, dual-channel commercial instrument.

THE PAPER TAPE ERROR RECORDER

The error recorders used with dummy directors contain two galvanometers and two motor-driven paper rolls. This arrangement of parts enables the unit to record two electrical values simultaneously; thus, it is called a two-channel recorder. The error recorder can be compared

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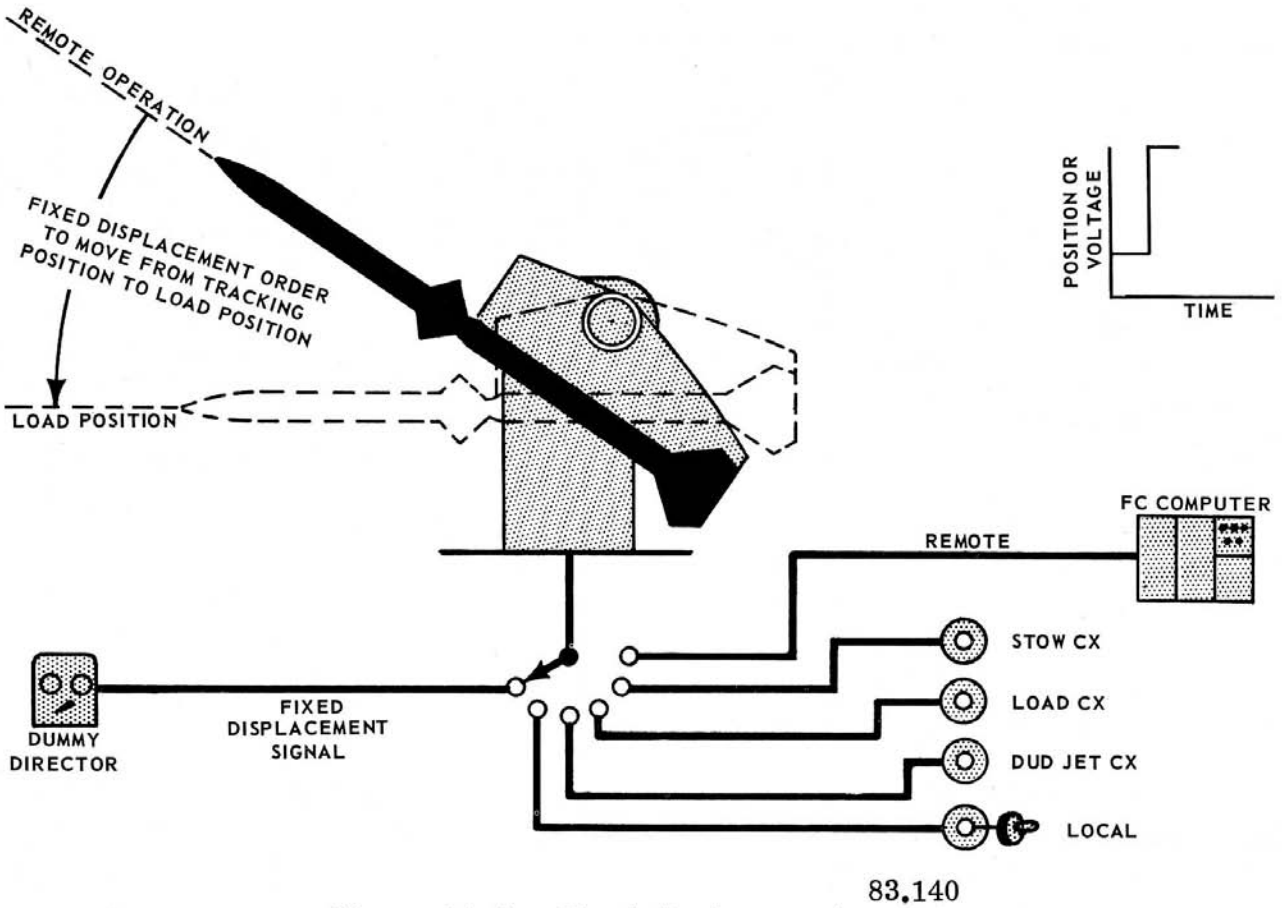


Figure 14-5. — Fixed displacement signal.

to another recording device, the oscilloscope. Look at figure 14-8. A roll of paper, feeding past a fixed point, is similar to the sweep of the scope, while the speed of the paper corresponds to the speed of the electron beam. The galvanometer (D'Arsonval) movement provides the amplitude deflection. The galvanometer is mounted so that deflection causes the pointer to move at right angles to the direction of paper travel. Writing on the paper is done by an inking pen which is attached to the galvanometer movement.

The operating principle of the galvanometer is the same at that for the galvanometer described in Basic Electricity, NAVPERS 10086-B, chapter 15. If you have forgotten how a galvanometer works, you should turn to the basic course and review this principle.

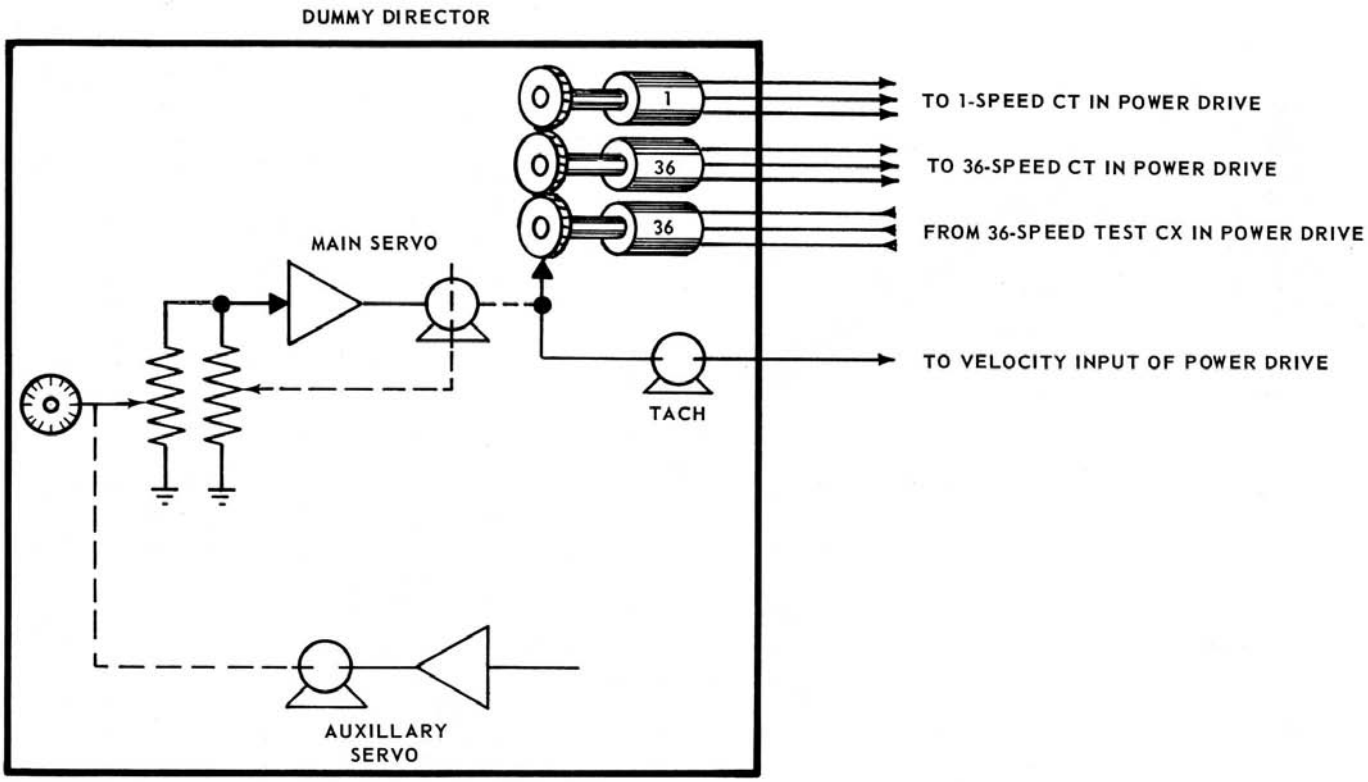
Since a galvanometer is a d-c operating device, and because the error signal is in alternating form, limiter-demodulator units are provided to change the a-c error signal to direct form. The limiter section of the unit cuts down (attenuates) the size of the input signal so that it won't drive the pen off the paper. In other words, the limiter limits the signal strength at a value which will give full deflection of the pen.

Usually, the velocity of the power drive output is measured at the same time that the error between the launcher order and launcher power drive response is measured. Since the velocity of the output is measured by a d-c tach generator, its output does not need to be demodulated, but can be fed directly to the galvanometer. But the size of the d-c velocity signal is, nevertheless, fed into the limiter section of a limiter-demodulator where the signal is attenuated.

LAUNCHER SYNCHRONIZING INDICATION SYSTEM

The launcher receiver regulator is part of the basic power drive servoloop, and includes the hydraulic pump (A-end), hydraulic motor (B-end), and the A-end and B-end response linkage. Figures 8-13 and 8-14 show the location and appearance

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Figure 14-6. — Basic parts of a typical dummy director.

of a receiver regulator. The operation of servoloops was described in chapter 7. Actually, four separate servosystems within the receiver regulator function together to position the A-end tilt plate when it receives an error signal. Each servosystem has its own feedback; therefore each can be considered a servoloop. These four servosystems are: stroke servosystem, primary servosystem, velocity servosystem, and integration system.

The stroke servosystem is used by the other servosystems to control the A-end tilt. The primary servosystem receives the remote order signal and supplies the position input to the power drive system. The velocity servosystem receives the signal, from the remote control station, which is proportionate to the velocity order input. The purpose of this signal is to increase the speed and accuracy of the launcher as it synchronizes with the dynamic signals.

The integration system signal originates in the regulator. The purpose of this signal is to improve the launcher performance when the launcher is following small dynamic signals.

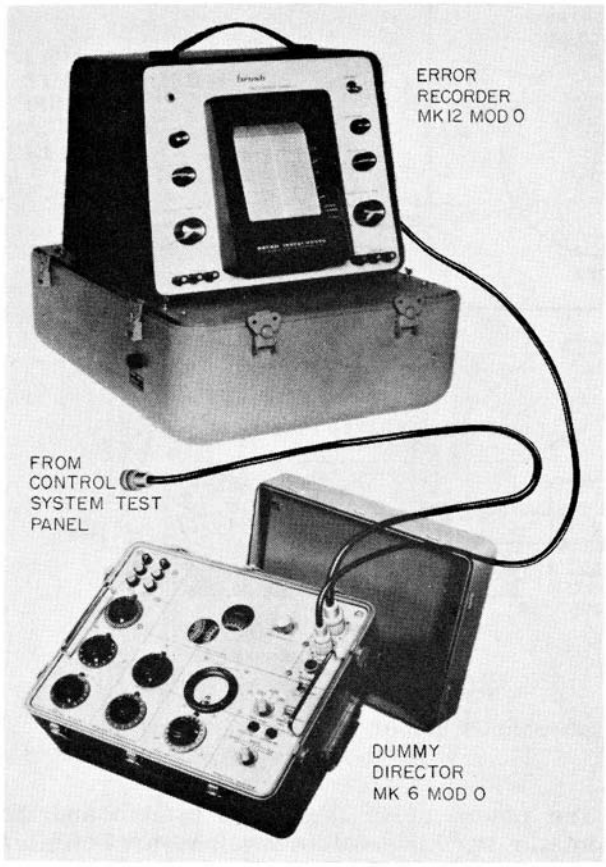
PURPOSE OF INDICATION SYSTEM

The servos mentioned above all work toward synchronization of the launcher with the signals sent from the fire control system. The men in weapons control and the launcher captain cannot see if the launcher is in the desired position, and is not pointing where a missile could be fired through part of the ship's structure. They must have some indication of the position of the launcher before the order to fire can be given. The launcher synchronizing indication system prevents the launcher from firing unless the launcher is synchronized with the director to within 60 minutes for 0.25 second and then indicates (by means of lights) to Weapons Control and to the launcher captain when the launcher is synchronized. This system also provides a method of checking synchronization during tests.

COMPONENTS OF INDICATION SYSTEM

Figure 14-9 shows the system indicating that the launcher is synchronized. It consists of valves,

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Figure 14-7.—Dummy director Mk 6 Mod 0 and Error Recorder Mk 12 Mod 0.

levers, pistons, and a switch, actuated by a rotary piston cam and transmitting motion produced by it. They are located in the receiver regulator. Indicator dials on the face of the receiver regulator show the position of the launcher, and indicating lights in Weapons Control and on the EP2 panel tell the operating personnel when the launcher is synchronized to the orders from the fire control system.

OPERATION OF THE SYNCHRONIZING INDICATION SYSTEM

As the launcher synchronizes to the remote orders, the train and elevation limit-stop system, the automatic-pointing cutout system, and the firing cutout system assure safe proper operation. When the power drives have complied with the train and elevation orders supplied by the director, the launcher-synchronized relay energizes if the train and elevation error is within the prescribed limit and the stroking pistons are receiving the train and elevation orders. When the relay closes, the launcher synchronized lights go on.

When the train and elevation power drives are synchronized to the remote orders, the launcher guide and carriage are positioned so the missile can be launched in the proper flight attitude.

Although figure 14-9 shows only a few of the valves and pistons involved and only hints at the connections to other components in the receiver regulator and the power drives, we will use it to follow through on the operation of a launcher synchronizing indication system.

The launcher synchronizing actuating lever (fig. 14-9) transmits the primary stroke motion produced by the rotary piston cam to the synchronizing indication valve, UVTD4.

UVTD4 is mechanically controlled by UVTD2 and hydraulically controls the train launcher-synchronized indication piston, UCTD23. When the error between the launcher and the order signal is less the 61', UVTD4 blocks the port from UCTD23. When the error is greater than 61' (and the launcher is therefore not synchronized), UVTD4 connects UCTD23 to tank.

The launcher synchronizing indication piston, UCTD23, actuates switch SITD26A when the launcher is synchronized. Whenever the power drive is running, servo pressure (400 psi) is ported to the small area end (top) of the piston and then is transmitted through the drilled passage and orifice to the large area (bottom) end of the piston. When the servo pressure on the large area end of the piston is blocked by UVTD4, and the launcher is within 61 minutes of synchronization for 0.25 second, the piston moves up to contact the actuating arm of SITD26A. This action closes the switch contacts of SITD26A causing the light on the EP2 panel in the Weapons Control room to indicate launcher synchronization.

NOTE: The 0.25 second delay required to extend UCTD23 and actuate SITD26A, prevents firing when the error fluctuates in and out of the 60-minute error zone.

LIMIT-STOP AND AUTOMATIC TRACKING CUTOUT SYSTEMS

The limit-stop assembly and the nonpointing zone valve block are in the receiver regulator. The limit-stop assembly is located in the lower

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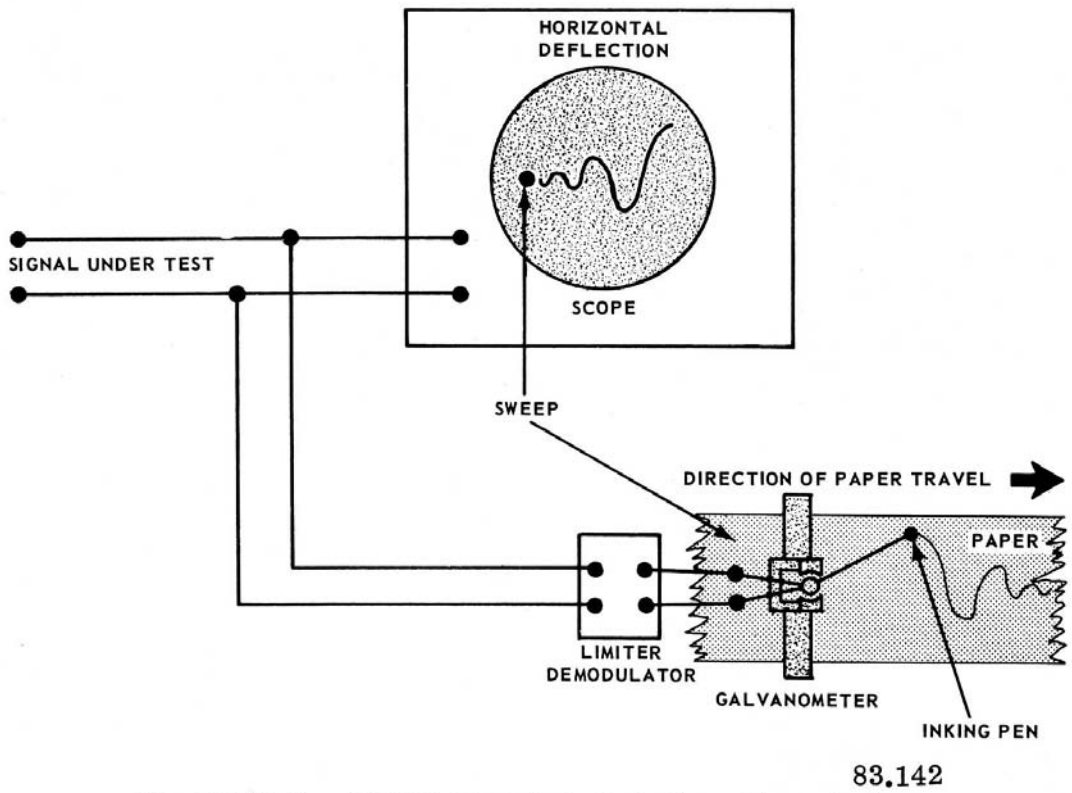


Figure 14-8. — Error recorder, one-channel paper tape.

center section of the regulator and includes the position-plus-lead (P+L) switch cams and nonpointing zone came The nonpointing zone valve block assembly is located in the lower righthand corner of the regulator. The location of components is identical in train and elevation receiver regulators. (See chapter 8, figure 8-14).

PURPOSE

The purpose of limit-stop systems and tracking and firing cutout systems is to impose limitations of the train and elevation systems when they respond to input orders. The automatic tracking cutout system tracks launcher movement and prevents the launcher from pointing into certain areas (nonpointing zones) wherein a fired weapon would be hazardous to ship structures. The firing cutout system opens the firing circuit whenever the launcher moves into areas where a fired weapon would cause damage to ship structures.

A nonpointing zone is a certain area where a missile on a launcher guide arm could be damaged by contacting the ship's structure, or could be fired from and hit the ship's structure, or could be fired from and hit the ship's superstructure.

The power drive limit-stop system and the automatic tracking cutout system are similar in certain regards since both are used to stop the launcher, if the situation warrants, and both employ the same method of bringing the A-end to neutral.

The train limit-stop system restricts the launcher movement in train; the elevation limit-stop system restricts launcher elevation and depression movements. The two limit-stop systems can function simultaneously or individually. Each receives its own actuating orders which can originate from the fixed elevating and depression stops, the automatic tracking cutout system, and the elevation limit-stop brake, for the elevation limit-stop system; and for the train limit-stop system, from the automatic tracking cutout system, and the train limit-stop brake.

The firing cutout system is an added safeguard that opens the normal and emergency firing circuits whenever the launcher enters a nonfiring area. Although the automatic tracking cutout system normally prevents the launcher from training or elevating into a nonfiring zone, the firing cutout system assures that the firing

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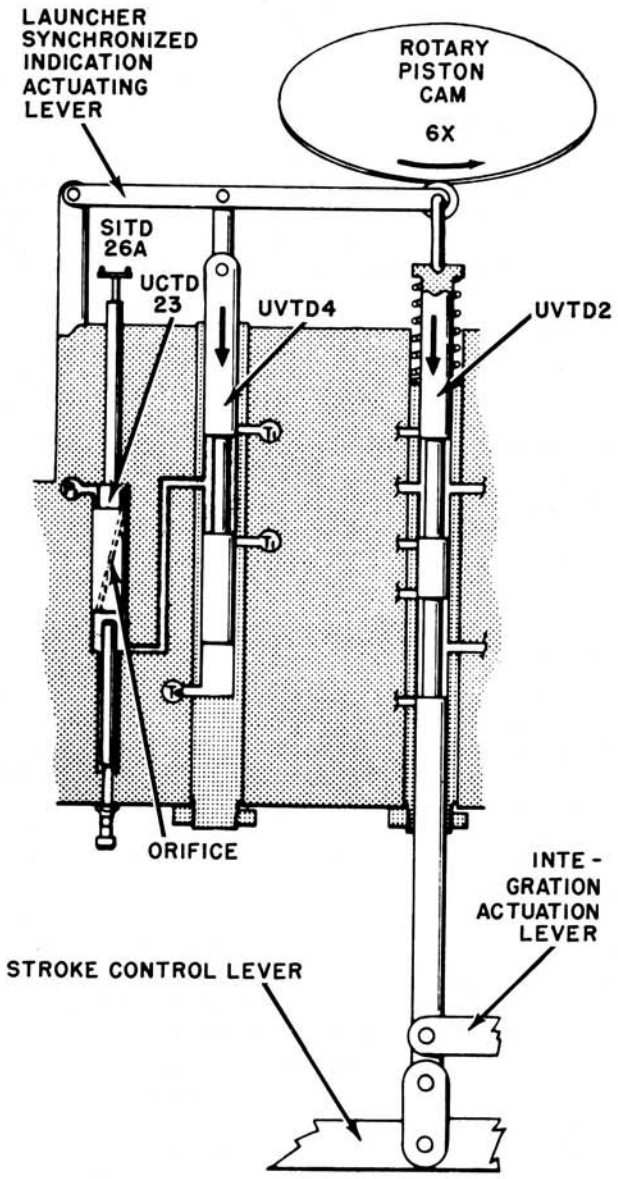


Figure 14-9.—Launcher synchronizing indication system (B-end error less than 21').

circuit is open if a malfunction should occur and the launcher would enter a restricted area. Nonfiring zones are areas which are designated as unsafe for missile firing. The nonfiring zones are enclosed by train and elevation angles that are identical to the nonpointing zone train and elevation angles.

Nonpointing zones have been called "interference" or "blind" zones. You may find these terms used in some texts.

COMPONENTS AND LOCATION

Although the train and elevation limit-stop systems are very similar in function and in components, there are Some differences.

The train limit-stop system includes the limit-stop assembly, the nonpointing zone valve block, and part of the A-end response assembly. The train limit-stop assembly consists of a differential, a limit-stop brake, a nonpointing zone cam, and four switch cams. The train nonpointing zone valve block consists of a limit-stop brake solenoid and valve, two nonpointing zone solenoids and valves, and two nonpointing zone pistons.

The elevation limit-stop assembly is similar to the train limit-stop assembly except that instead of a nonpointing zone cam, it has a gear and rack which cause the elevation power drive to elevate the launcher guide arms over the nonpointing zones, when necessary.

The elevation nonpointing zone valve block differs from the train valve block. The elevation block has three nonpointing zone pistons and three nonpointing zone solenoid-operated valves. The pistons act as the normal automatic depression stop for the elevation power drive. They actuate a gear rack instead of a plunger, as in the train valve block.

The base plate of the receiver regulator serves as the mounting base for the components.

OPERATION

Nonpointing Zones The nonpointing zone valve block is located in the lower right-hand corner of the receiver regulator.

Figure 14-10 illustrates typical nonpointing zones. Zone 3 is the highest and represents the ship's mast, bridge, and stacks. Zone 2 includes the superstructure directly behind (or in front) of the launcher. On the majority of missile launching systems with Mk 5 launchers, zone 2 represents the missile house. Zone 1 is the lower zone which comprises certain structures on the aft of the ship. If a loaded guide arm enters a nonpointing zone, the elevation automatic tracking cutout system goes into action. The elevation nonpointing zone pistons use the limit-stop rack

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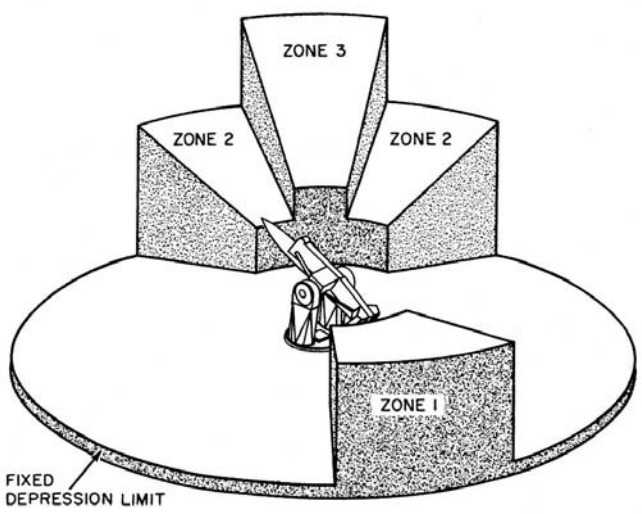


Figure 14-10. — Nonpointing zones.

to cause the launcher to elevate over the nonpointing zone, or to stop it from depressing into a nonpointing zone. As soon as the launcher trains clear of the nonpointing zone, the elevation power drive can continue to depress the launcher to the angle required for hitting the target with the missile (as determined by the fire control system).

Train Limit Stop

A train warning bell, mounted on the trunnion support housing of the launcher carriage, is used to warn personnel on the exposed deck when the launcher is being rotated. This is a safety device installed on gun mounts and turrets and on launchers. Some grisly accidents pointed out the need for such warnings.

An earlier chapter explained the operation of the electric-hydraulic system in furnishing the power to move the launcher in train (and elevation). The train limit-stop valve hydraulically controls the A-end stroke pistons during limit-stop operations. The train launcher-synchronized indication piston is controlled by the launcher-synchronized indication valve. When the launcher is synchronized, the launcher-synchronized switch is actuated and the velocity and integration signals are canceled. The switch cams (5 for train and 3 for elevation) are driven by the B-end response and are used to actuate the switches which indicate the launcher train positions. The B-end response input which is fed into the receiver regulator is led through the base plate and drives the bevel gear. The lower gear of the B-end response input shaft drives the synchro gearing, while the upper gear drives the limit-stop assembly (fig. 14-11).

The differential (fig. 14-11) constantly measures the launcher position (B-end response) and velocity (A-end tilt or lead) signals and feeds the results to the position-plus-lead (P+L) cams and to the nonpointing zone cam. Whenever a stop order is initiated by the limit-stop brake or by the nonpointing zone cam, the differential stops the launcher by positioning the crank arm. During limit-stop operation, end gear #1 (fig. 14-11) acts as the output to stop the launcher. The spider gears drive the P+L cams and the nonpointing zone came The train limit-stop system can stop the launcher by setting the limit-stop brake. However, this is done only in case of power failure. The train power drive has no fixed limit stops.

Elevation Limit Stop

The elevation power drive has fixed depression and elevation limit stops plus a limit-stop brake; that is, the launcher can never be moved 180 degrees in elevation or depression. It is possible to train the launcher full circle. The stop order for elevation is originated either by the elevation and depression fixed stops or the limit-stop brake. The limit-stop systems are also used by the automatic tracking cutout system for stopping the power drives. When the limit-stop system receives a stop order, the limit-stop cam controls the deceleration rate of the launcher as the stop order is being carried out. During limit-stop operation, the limit-stop cam transmits motion to the limit-stop lever. (See figure 14-11; the elevation limit-stop lever. as well as other components, except the limit-stop rack, are very similar to those in the train limit-stop assembly.) During limit-stop operation, the stop cam transmits stop orders from the differential to the lever (the reverse of normal operation). The differential combines the B-end response (position) with A-end response (lead) and transmits the resulting output through the limit-stop brake to the P+L shaft and to the limit-stop rack. If the brake sets or the limit-stop rack is stopped, the differential output is fed back through the stop cam to the limit-stop lever.

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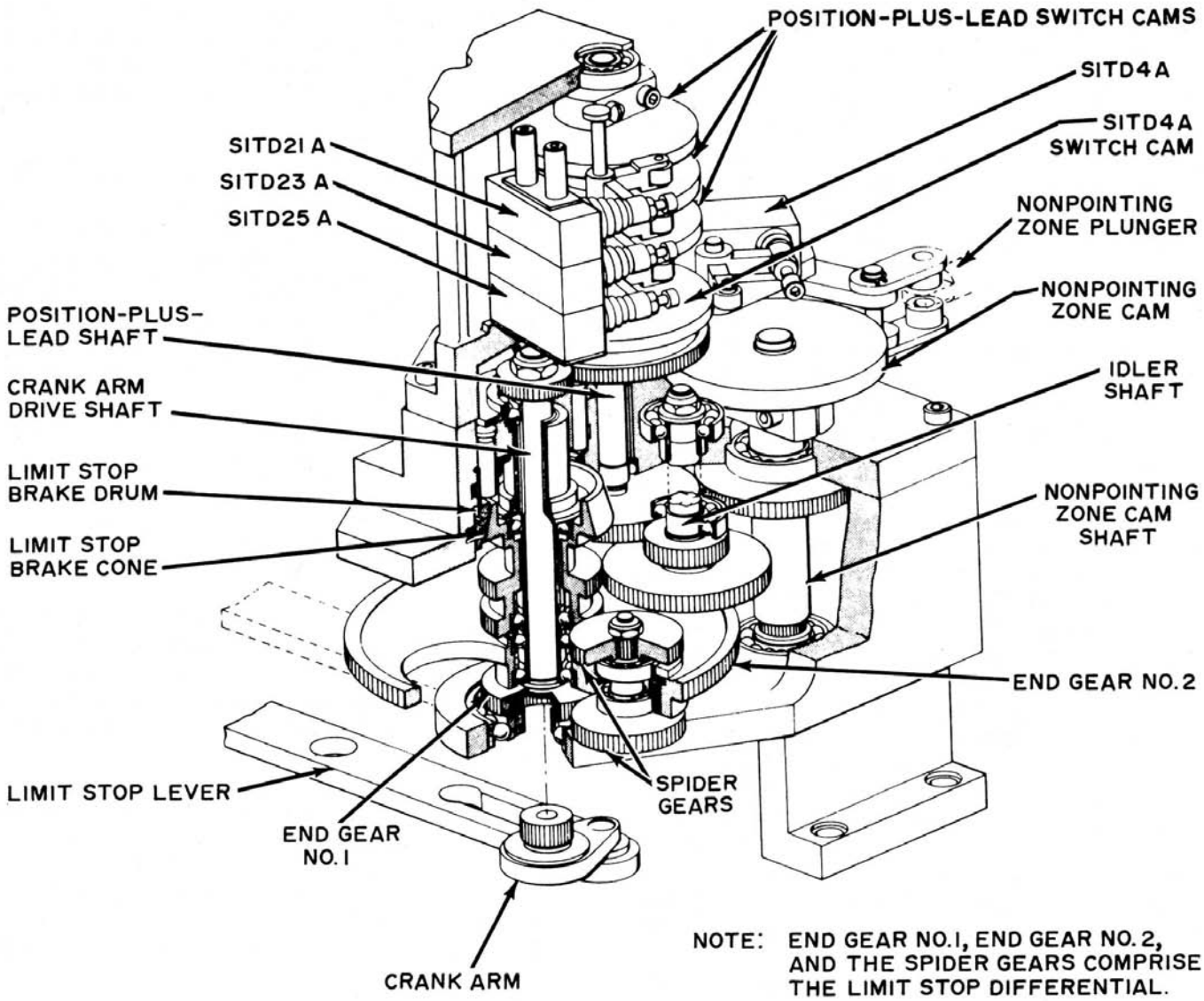


Figure 14-11. — Train limit-stop system.

Firing Cutout Systems

The firing cutout system was mentioned previously. It consists of the firing cutout switches, their associated circuitry, and a relay. The firing cutout switches are located on the train and elevation position and P+L switch stacks. They are actuated by the same switch cams as the nonpointing zone cams. A dual switch actuator, operated by a single switch cam, operates both switches (nonpointing and firing cutout) simultaneously. When the automatic tracking cutout system is set up for a particular installation and the switch cams are adjusted to the specified train and elevation angles, the nonfiring zones are established automatically. Only the depression stop nonfiring zone will have to be established and adjusted.

The firing cutout switches are wired into the launcher in the safe firing zone relay circuit. If for some reason the automatic tracking cutout system would not halt launcher movement when it is moving into a nonfiring zone, the firing cutout switch for that zone would open and thus stop the launcher.

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Automatic Tracking Cutout System

The automatic tracking cutout system actuates the train and/or elevation limit-stop system whenever a nonpointing zone is encountered and the launcher is not on a return-to-lad order. The train cutout system receives mechanical inputs from the train system but is dependent on electrical inputs to indicate the elevation position. Basically, train cutout operation and elevation cutout operation are similar in function - both use hydraulic means to actuate their limit-stop systems.

The train position response, which is supplied by the train B-end, is conveyed through the gear train in the synchro gear assembly to the train position switch cams, of which there are three, one for each zone. The switches operated by these cam are wired into the elevation nonpointing zone solenoids. (The switch cam shown in figure 14-11 appear circular, but they are curved and shaped for each installation.) Whenever position-plus-lead movement drives a stop cam lobe against the stop pin (positioned by an extended piston), P+L movement is halted and a stop order is supplied to the train limit stop system.

Since the operation of the train nonpointing zone pistons is determined by the associated solenoid-operated valves and the elevation nonpointing zone switches are wired into these solenoid circuits, piston operation is actually determined by the elevation position. Therefore, automatic tracking cutout operation in train not only depends on the mechanical P+L response to the train nonpointing zone stop cam but also on the elevation position at the time.

The elevation system cutout operation is similar to the train cutout operation. Like the train system, the elevation system receives mechanical inputs from the elevation position and P+L response and electrical indication from the train system. The elevation position response drives the elevation switch cams.

The elevation automatic tracking cutout system operates by changing the position of the launcher depression limits whenever a loaded launcher guide arm enters a nonpointing zone. Nonpointing zone pistons use the limit stop rack to prevent the launcher from depressing into a nonpointing zone or to cause the launcher to elevate over the zone. The pistons are hydraulically controlled by solenoid-operated valves. The nonpointing zone solenoids are controlled by position and P+L cams in the train receiver regulator. If the launcher approaches a nonpointing zone, the solenoid for that zone in the elevation receiver regulator deenergizes. The piston then extends and contacts the limit-stop rack and stops the elevation power drive. As soon as the launcher trains clear of the nonpointing zone, the solenoid again energizes and the elevation power drive can continue.

When the launcher guide is empty and the launcher is on a return-to-load order, relays complete a bypass circuit to the train and elevation nonpointing zone solenoids. The manner in which these relay contacts are wired into the solenoid circuits allows the position and P+L switches to be bypassed on return-to-load. This permits the launcher to pass through the nonpointing zone or zones and follow the shortest route so it can synchronize to load position with the least delay.

MISSILE REPLENISHMENT AND STRIKEDOWN

A ship at sea can be loaded with missiles, boosters, and associated components from an ammunition ship. A ship can also be replenished in port from alongside a pier or from a barge. Replenishment by helicopter has been used at times.

Replenishment at sea may be accomplished by means of anyone of four transfer methods.

1. The Burtoning method.
2. The constant tension highline method.
3. The modified housefall method.
4. The Fast Automatic Shuttle Transfer method (FAST, for short).

We will cover only the modified housefall and FAST methods because they are the methods most commonly used in the fleet. Figure 5-12 in Seaman, NavPers 10120-E, shows a regular housefall rig being used for transfer of ammunition.

MODIFIED HOUSEFALL

The modified housefall rig is shown in figure 14-12. Completely assembled missiles and boosters (less wing and fins) are removed from their containers, suspended in a transfer dolly (called a grasshopper) and transferred from the ammunition ship to the missile ship. Missiles or boosters arrive on the 01- or 02-level (depending on the type of ship) atop the deckhouse

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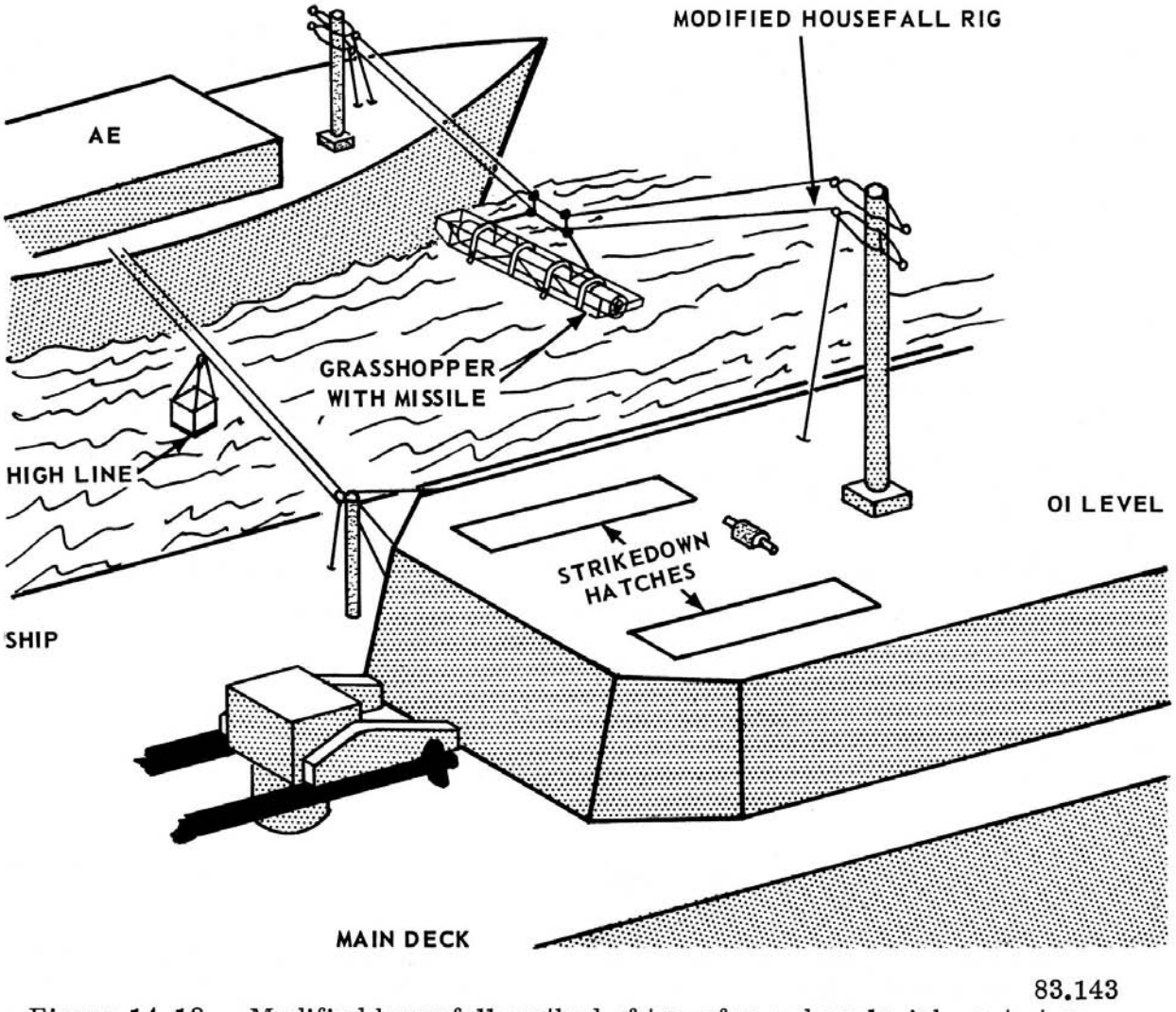


Figure 14-12. — Modified housefall method of transfer and replenishment at sea.

at a point near one of the strikedown hatches. To maintain a simultaneous port and starboard flow, missile-booster transfer is scheduled so two boosters are transferred, followed by two missiles. Scheduling of missile component transfer is arranged so that a balanced group of components will have been transferred in any given time. This is done because missiles and boosters have to be mated on the receiving ship before they can be stowed in a magazine. You have to mate a missile to a booster before you can receive the next two in the missile house. That's why they are received in the order as follows: booster, booster, missile, missile. Normally, both port and starboard strikedown hatches are used. Spare warheads and exercise heads are also transferred on the modified housefall rig.

The highline shown in figure 14-12 is used to transfer missile components such as wings fins, and spare parts (complementary items) concurrently with booster and missile transfer. The above method of missile transfer is used only if the FAST system is not installed.

FAST SYSTEM

The FAST system of missile and booster transfer uses a constant-tension highline between king posts on both the ammunition ship and the missile ship. See figure 14-13. A trolley, controlled by the inhaul lines from the ammunition ship, transfers the missile or booster, which is supported in a strongback. The trolley is engaged and held by a receiving head on top of the missile ship's king post. Next, the

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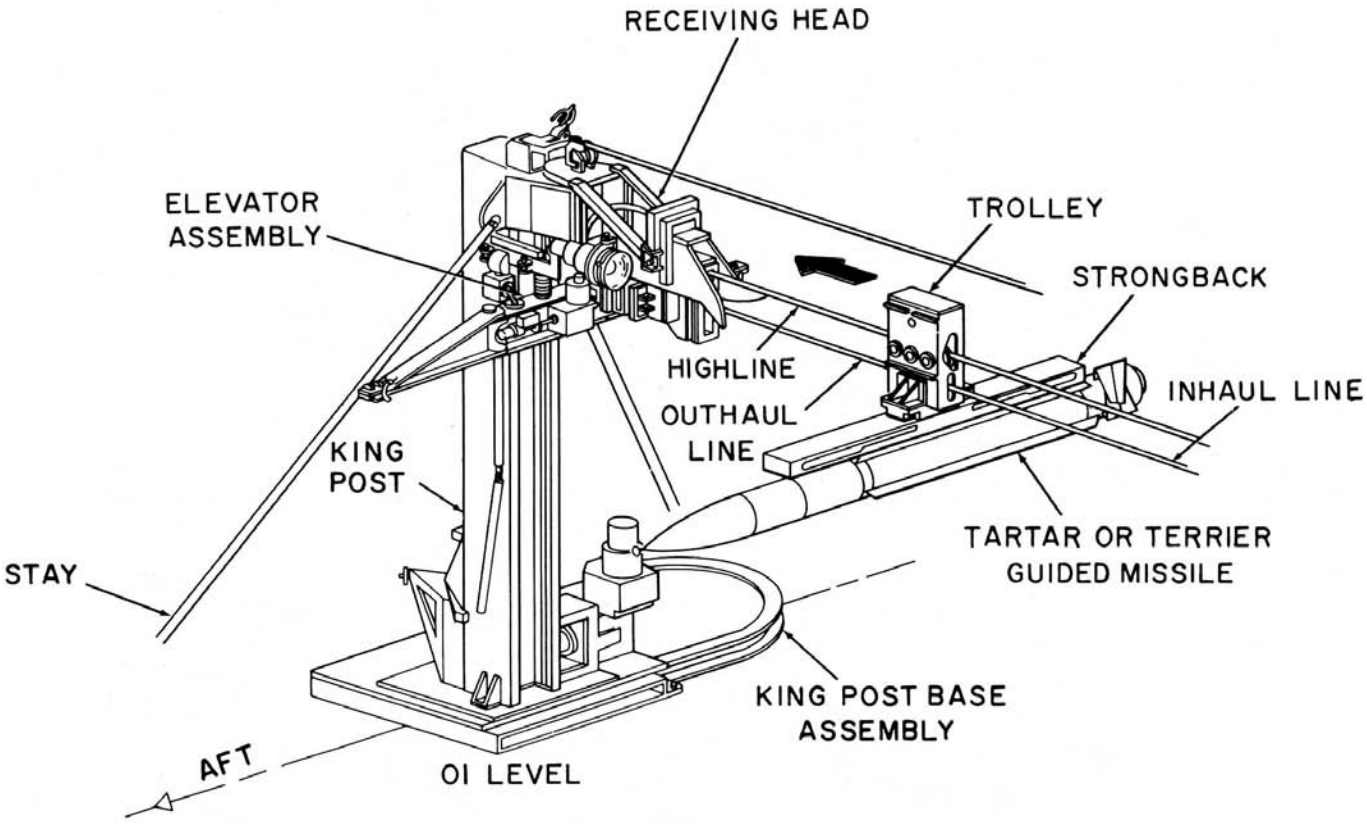


Figure 14-13. — Fast Automatic Shuttle Transfer (FAST) method for at sea transfer of missile.

elevator arms, which are under control of a console operator, close and engage the strongback. The trolley is released and returned to the ammunition ship to pick up another booster or missile. Then the FAST elevator lowers the missile or booster to the missile ship's strikedown elevator and the strongback is removed.

What we have just described applies only to Terrier Mk 9 and Mk 10 missile launching systems. The Tartar (Mks 11, 13, and 22) launching systems use the same type of FAST king post and elevator, except that the missile is lowered to a transfer cart (dolly). However, the Talos (Mks 7 and 12) missile launching systems use a different type of king post; and they use a boom to lower the missile or booster from the king post to the strikedown elevator.

STREAM METHOD

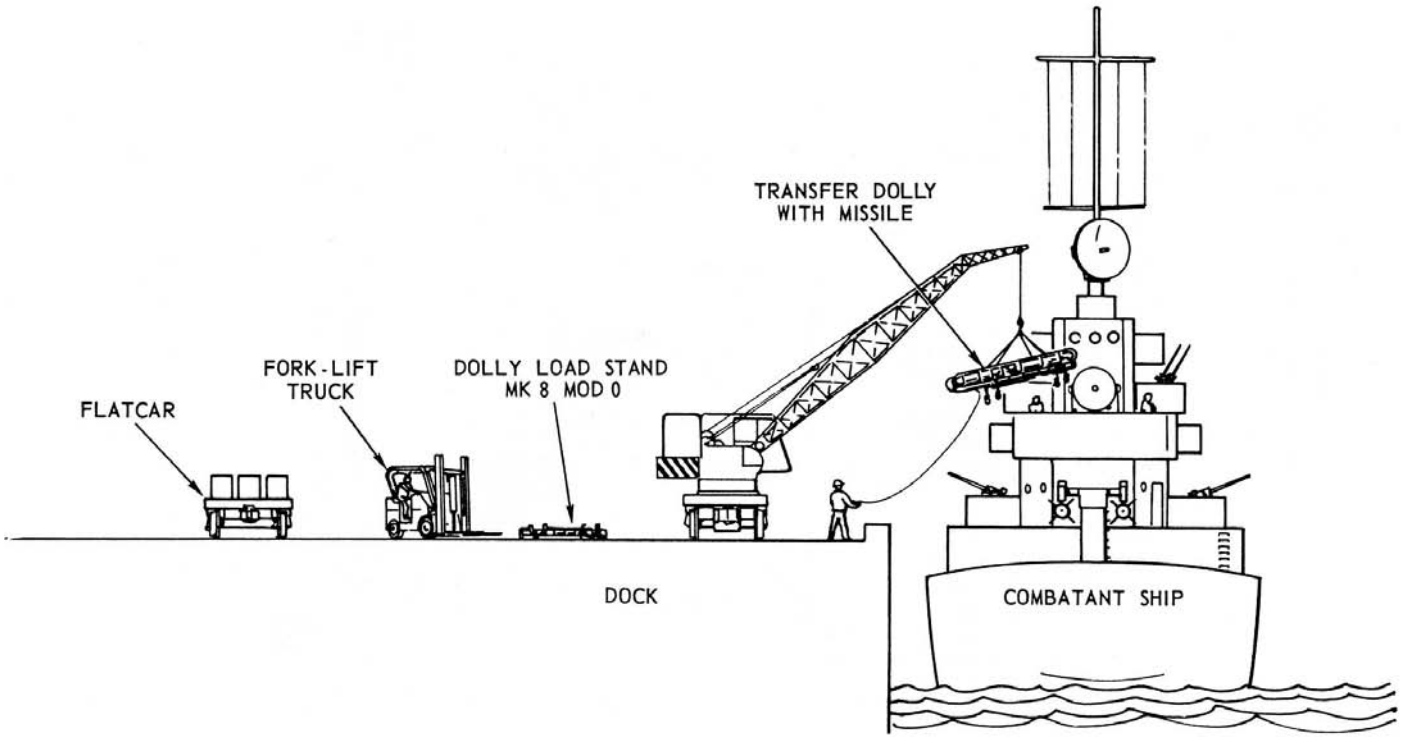
The new Standard Tensioned Replenishment Alongside Method (STREAM) actually is not a single method but a combination of transfer systems. The only common feature of this combination is the use of a ram tension highline. The system can be broadly grouped into two headings, a cargo STREAM and missile STREAM.

The STREAM method will incorporate many of the design features currently used in the FAST system. With the FAST system, a strongback is used in base missile transfer, and standard deck handling equipment is used on the receiving ship. However, after implementation of STREAM into the fleet, a transfer dolly will be used exclusively for the transfer of missiles. For more detailed information on the STREAM method refer to NWP 38.

DOCKSIDE REPLENISHMENT

When a missile firing ship (combatant vessel) is replenished from a pier or dock, a crane normally lifts the booster or missile to the strikedown area. (See fig. 14-14). Each missile and booster is decanned (removed from

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Figure 14-14. — Dockside replenishment.

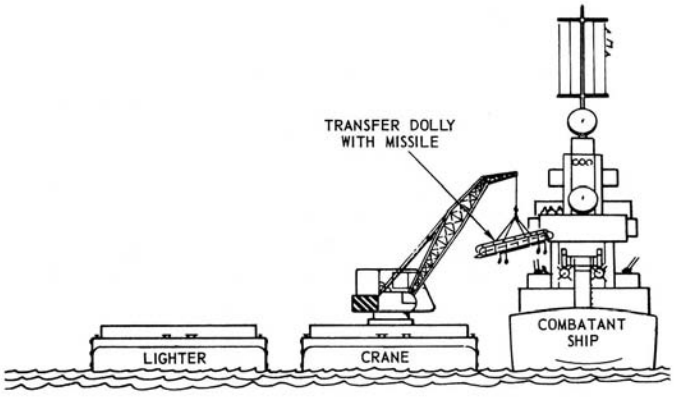
its shipping container). Then it is rotated so that its handling shoes are in the correct position for strikedown; and finally it is loaded into a transfer dolly on the pier. Incidentally, the FAST system can be used if FAST system equipment is available on the pier as well as on the ship; however, this is a very recent development.

LIGHTER REPLENISHMENT

When missiles and boosters are replenished from a lighter (fig. 14-15), a floating crane normally transfers the missile or boosters. Each booster and missile is decanned, rotated for strikedown, and loaded into a transfer dolly aboard the lighter.

SPECIAL HANDLING EQUIPMENT

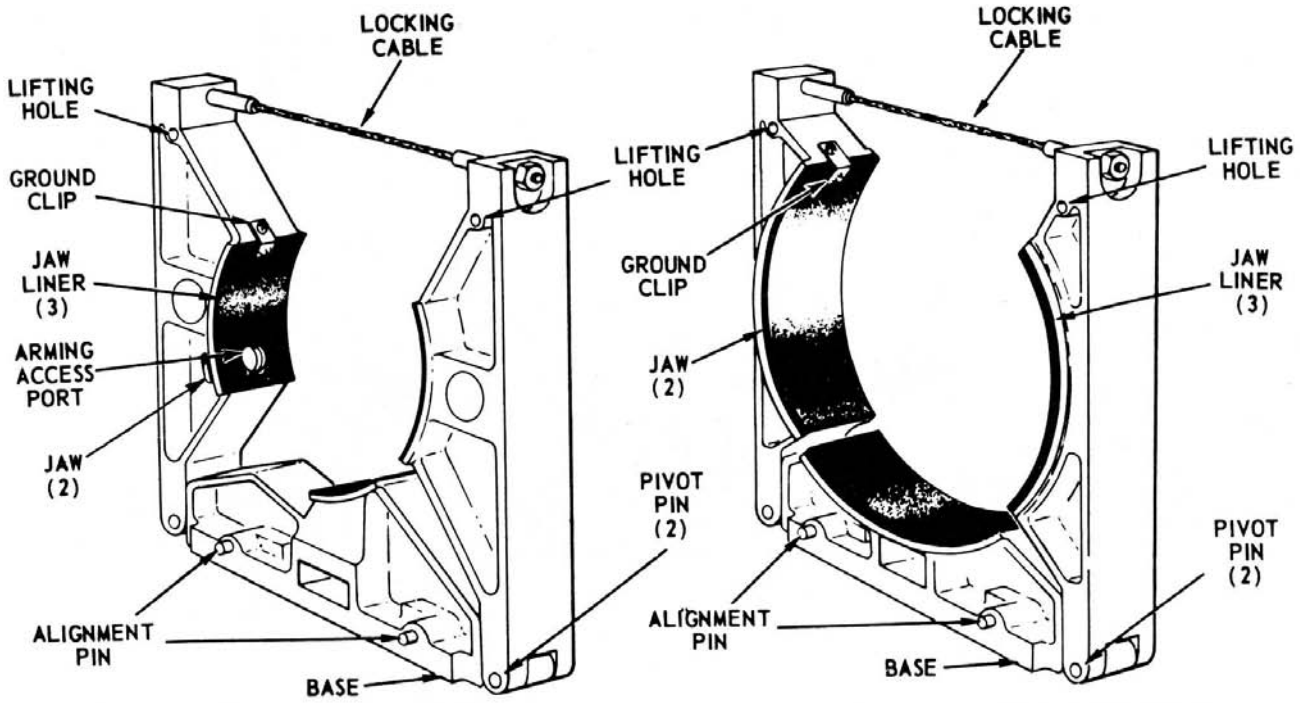
ATTACHMENTS FOR EQUIPMENT. - Handling attachments (also called transfer bands) support the missile and booster during shipment and strikedown. These bands, shown in figure 14-16, consist of a base, two pivoted jaws, and a locking cable. The base and jaws are made of aluminum, and are fitted with rubber liners to protect the skin of the missile or booster. Two pins in the base align and support the missile or booster in its container. Two holes are also located in the bottom of the base to provide alignment for pins located



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Figure 14-15. — Missile replenishment from lighter.

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Figure 14-16.—Terrier handling attachments.

on the checkout car. During strikedown, the booster handling attachments remain on the booster until it has been placed on the loader rail, and the missile handling attachments remain on the missile until it has been mated with its booster.

TRANSFER DOLLY. - A transfer dolly (grasshopper) Mk 6 supports the missile or booster during all modes of transfer except in the FAST method. The dolly also is used to place the missile in the correct position to be received by the strikedown elevator.

This transfer dolly (fig. 14-17), handles all types of Terrier missiles and boosters, as well as the Tartar missile types. Basically, the dolly consists of a tubular metal frame, two shock-mounted holding fixtures (for Terrier missiles and boosters), a Tartar rail adapter, a cable sling, and a "dead man" brake and caster wheels. The dolly is also equipped with channel guides for fork lift handling and a nose guard assembly for added protection of the missile forward section.

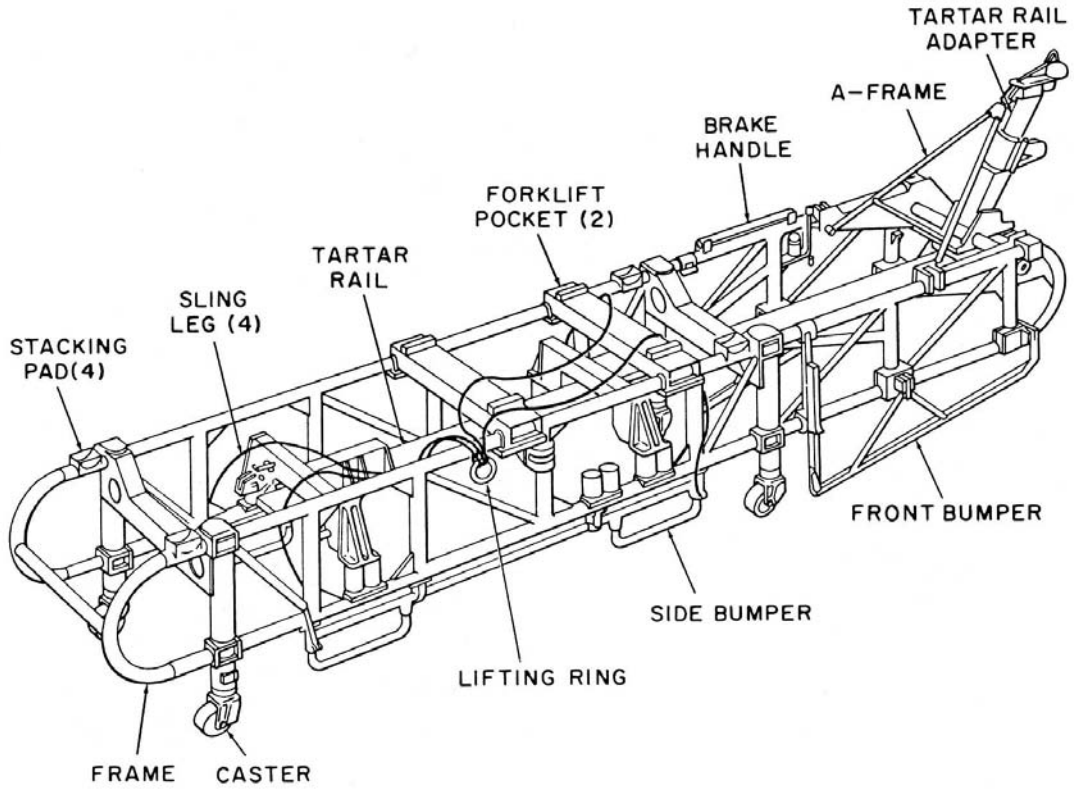
The rail adapter shown in figure 14-17 aligns the Tartar rail assembly with the launcher rail and provides a connecting surface between the Tartar rail and launcher for the missile shoes to travel on.

The adapter is coupled to and aligned with GMLS Mk 11 by means of the lower ball socket and the two lower mating guides. The upper ball socket and upper single mating guide serve the same purpose with the GMLS Mk 13. The adapter with the dolly and the GMLS is shown in figure 14-18.

The "grasshopper" is shown in use in figure 14-12, 14-14 and 14-15. Notice that it is wheeled so it can be moved easily to the strikedown elevator, or to the launcher (Tartar). Note also that it has a brake; don't forget to set it before you let go of the dolly. A sudden pitch or roll of the ship could send the dolly with its missile careening about the deck. Keep the dolly under control at all times.

OTHER TRANSFER EQUIPMENT. - The attachments shown in figure 14-16 are placed on a missile when it is to be moved by a lifting bar. Not all ships have the FAST system for at-sea transfer. Parts of missiles that are not assembled, such as wings and fins, are packed in separate containers and may be transferred

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Figure 14-17. — Tartar/Terrier transfer dolly.

to shipboard by means of slings, skip box on a highline (fig. 14-12), or with other handling equipment. Whatever equipment is used, always check it first before attaching a missile or missile component. The OP for the equipment tells you the lubrication points, the type of lubricant to use, and how frequently lubrication is needed.

Most of the missile handling equipment is designed for a particular Mk Mod, so it will fit exactly and will have the necessary strength to support the missile.

STRIKEDOWN

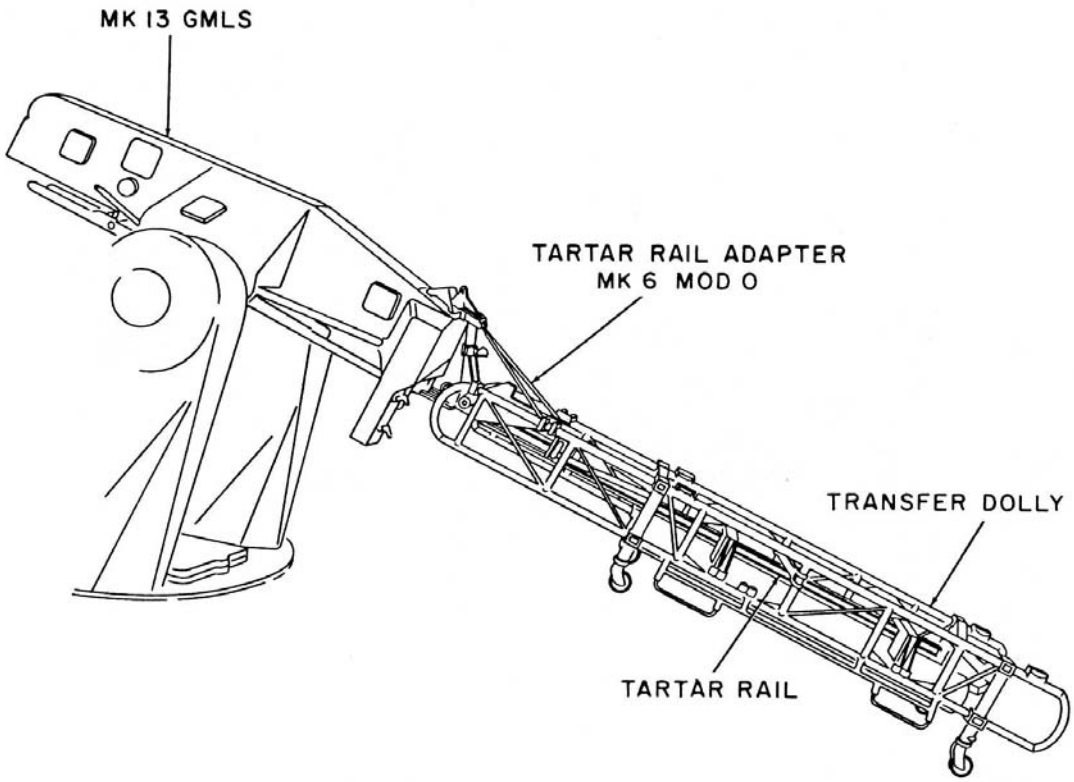
All Talos missile launching systems, and Terrier launching systems Mks 9 and 10, use a hydraulically operated strikedown elevator to lower the boosters and missiles from the 01- or 02-level into the missile house. A hydraulically operated hatch directly over the elevator must be opened before the elevator can be raised. The elevator hatch is automatically closed as soon as the elevator is clear of the hatch during lowering.

On the Mk 9 and Mk 10 Terrier GMLSs. a checkout car is used to remove the booster from the elevator and to position it on a rail preparatory for mating. The car then removes a missile from the elevator and positions it so that the booster and missile can be mated. After mating. the assembled weapon is transferred to the magazine hoist by the rail. Later on we will talk more about the checkout car and mating process.

Talos Strikedown

As you saw in figure 14-12, there is a strikedown hatch for each of the two sides of the launching system. Each side, A and B, has a complete set of strikedown equipment. For the Talos GMLS Mk 12, strikedown equipment consists of three major assemblies: (1) ready service crane, (2) mating equipment, and (3) strikedown elevator. This equipment is used for three purposes: (1) to replenish the ready service magazine, (2) to unload the magazine, and (3) to transfer the weapons to an area where internal tests on the weapons can be made. The equipment is operated from the EP6 panel and four consoles.

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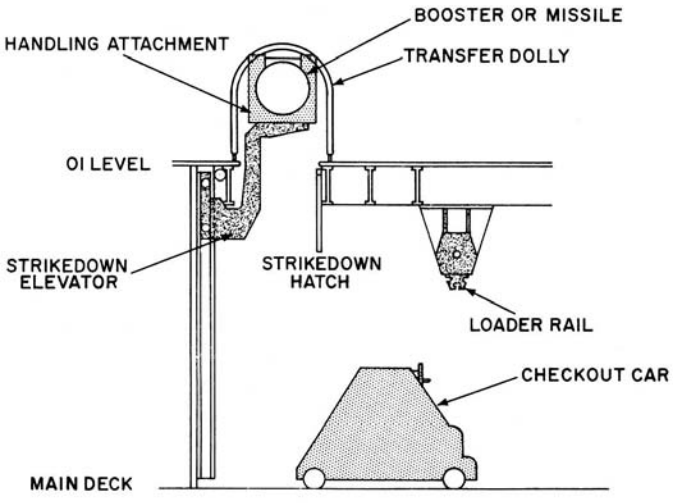


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Figure 14-18. — Tartar rail adapter alined with Mk 13 GMLS.

The missile, locked on a missile cart, is struck down first by means of the elevator, which rises beneath the hatch. Then a booster, locked on a booster cart, is struck down.

When the missile and booster are to be placed in the ready service magazine, they must be brought to the mating area and joined before being taken to the magazine. The missile and the booster, each on its cart, are moved to the mating area on a pair of rails. After mating the missile and booster, the complete round is taken to the magazine hoist by the ready service crane, which is mounted on a pair of crane rails that span the overhead between the magazine door: and the mating area. The same equipment is used to move a round from the magazine to the checkout and mating area for unmating and tests. The booster is always returned to the magazine while the tests are being made on the missile.



83.149

Figure 14-19. — Terrier strikedown operation; elevator raised to receive missile.

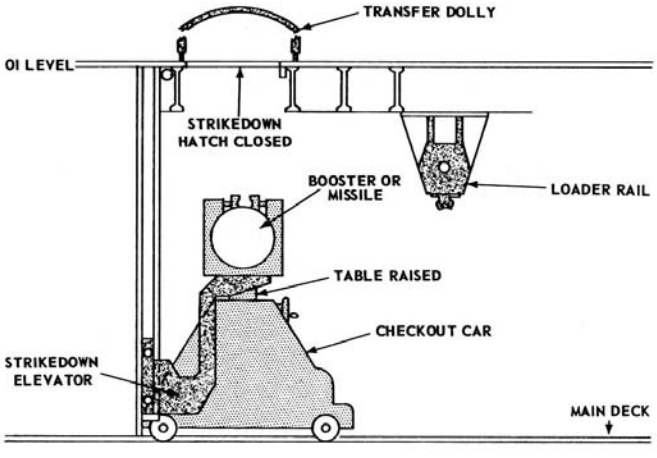
Terrier Strikedown

To get a clearer picture of the strikedown process let's look at the step-by-step movement of a Terrier booster and then a missile

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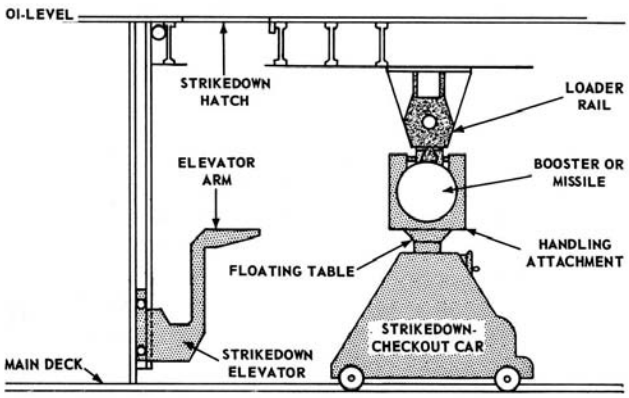
as they are struck below. Refer to figures 1419, 20 and 21 as you read the description of booster and missile flow during the strikedown procedure. Keep in mind that a booster is struck below first.

1. When a booster is in the proper position above the strikedown hatch, an operator at a control station on the 01-level and an operator at the elevator control station in the checkout area simultaneously depress their control pushbuttons. The hatch opens and the strikedown elevator raises. (See fig. 14-19.)
2. When the strikedown elevator reaches its upper position, it receives a booster from the transfer dolly or from a FAST elevator.
3. The operators push their "LOWER" pushbuttons and the elevator starts going down. As the elevator passes through the strikedown hatch, the hatch door automatically closes as shown in figure 14-20.
4. The elevator with a booster on it stops in the checkout area with the booster suspended just above the checkout table. The checkout car operators move the car into position under the booster. The car table is then raised to receive the booster from the strikedown elevator.
5. The checkout car operates by means of the car controls, bringing the booster into alignment with the loader rail. See figure 14-21.
6. The loader engages the booster shoes and the loader moves the booster clear of the strikedown area.



83.150

Figure 14-20. — Terrier strikedown operation; car table raised.



83.151

Figure 14-21. — Terrier strikedown operation; booster shoes engaged with loader rail.

7. To put a missile on the checkout car, steps 1, 2, 3, and 4 are repeated.
8. The loader returns the booster into the strikedown area.
9. The car is then positioned so that the missile is in the proper position for mating, and the missile and booster are mated.
10. The mated weapon is placed over the magazine hoist by the loader and then lowered into the magazine (ready service ring).

Tartar Strikedown

To strike down a Tartar missile, a missile is placed on the launcher guide arm and the launcher controls are then used to lower the missile into the magazine. Figure 8-16 shows the strikedown gear attached to the Tartar launcher. As the Tartar comes completely assembled, there is no mating or unmating to be done, and the missile is sent directly to the magazine where it is to be stowed. The dolly on which it is delivered to the ship is aligned with the strikedown gear. Latches on the strikedown chain spring-latch onto the missile forward shoe and the chain then can pull the missile on to the launcher guide arm, which then takes over the job or moving the missile down to the magazine. It is all done in step control, with the launcher captain at the electrical control box on deck (fig. 8-16), an operator at the EP2 panel, and men at the strikedown fixture to bring the missile to the fixture, align it, and see that the latches are attached to the missile shoe. When all the missiles have been struck down, the strikedown

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fixture is removed from the launcher and is stowed. The same fixture is used to bring missiles up from the magazine to be offloaded.

Responsibility for Missile Strikedown Equipment

The strikedown gear attached to the Tartar launcher is ordnance equipment but the rails on the deck on which you move the dolly are ship's equipment. The elevators and cranes used to move the larger missiles, the Terrier and Talos, are ship's equipment. The GMMs who use ship's equipment must exercise responsible care and give routine maintenance, but the prime responsibility for its repair and major maintenance belongs to the ship's engineering department. Always check the equipment before using it. Do not assume that it is all right. The size, weight, and dangerous characteristics of missiles and boosters make it imperative that they be moved safely.

MISSILE COMPONENT STOWAGE

A storeroom for the stowage of missile components and a magazine for the stowage of missile warheads are both located two decks below the checkout area. The magazine and the store room are connected to the checkout area by a trunk and hoist.

The location of the stowage spaces varies with the type of ship and the missiles carried. If you have missiles (Terrier and Talos) that have wings and fins to be assembled when preparing for firing, the wings, and fins are stowed in racks in the loading area of the launching system. Tartar missiles have their wings attached and folded, so there is no need for separate stowage, except for spare parts. A dumbwaiter type of elevator operated by an electric hoist is used to move those to or from the missile component storeroom.

Stowage Precautions

Classes of dangers can be grouped as general personnel, mechanical, electrical, and explosive. To these we might add: danger from liquid fuels, and danger from radioactive material. Below are a few specific precautions to review.

A. Missiles and components must be securely fastened in storage, stowage racks, and magazine ready service rings.

B. ALWAYS inspect handling equipment before using.

C. Missiles and components must NOT be placed in or removed from stowage racks and/or areas without using the proper handling equipment.

D. All arming devices must be in the SAFE position during stowage.

E. Arming tools must be kept in a designated place at all times, except when in actual use.

F. Ground wires must be attached to boosters and missiles in stowage, during check-out, and while being transported from one area to another.

G. Booster rocket components must be handled with care. A cracked propellant grain could result in an explosion when ignited.

H. Explosive and propellant components must be stowed in approved magazines in which the temperature range does not exceed the limits specified by NAVORDSYSCOM.

General Precautions

A. All missile operations must be in accordance with shipboard safety precautions.

B. The handling of sustainers, booster's warheads, and other propelling or explosive devices must conform with explosive handling practices aboard ship.

C. Only those personnel who are engaged in the operation in progress should be permitted in the immediate area of the missile.

D. Only approved nonsparking tools are to be used in the vicinity of explosives or propelling charges.

E. Only the correct handling equipment is to be used for lifting missiles and components thereof.

F. Electrical equipment must be shielded and grounded to prevent accidental ignition of propellants or explosives or injury to personnel.

G. Working areas must be clear of obstructions, loose cabling, hose, and unneeded equipment.

H. Electrical igniters or detonators (booster charges) shall not be exposed within 50 feet of, or stowed in any compartment with, any exposed electronic transmitting equipment, exposed antenna, or antenna lead, except where such apparatus or antenna is part of a missile test set, or is an integral part of the missile concerned.

I. Use extreme care in handling pressurized air hoses and couplings. Compressed air can exert sufficient force to severely injure personnel and/or equipment.

HANDLING BELOW DECKS

When you have only Tartar missiles, stowage does not require any handling below decks as

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the missiles are struck down to the magazine by the launcher. To offload missiles, the operation is reversed. Missile checkout is performed on the launcher guide. To replace a component in the missile, the guide arm, with the missile on it, is trained to an area where ship handling equipment is available. Again, there is no below deck handling.

Checkout Car

The checkout car is mechanically and electrically operated. The car is used for strikedown, strikeup, mating, and checkout operations.

The chassis can be moved vertically by means of the "Up-and-down" control, and can be moved forward and aft by means of the "Forward-aft" control.

The car table (fig. 14-21) can be axially adjusted by means of the "Roll" control, and can be tilted by means of the "Float" control.

Missile and Booster Carts

The missile and booster carts used to hold the missile and the booster of Talos are driven by separate chain drives. Each chain drive engages its cart when the elevator reaches the main deck with its missile or booster load, and drives it to the mating area, following the rails that lead from the elevator, through the flametight doors, to the mating area. After the missile and booster have been mated, the carts are released and returned to their positions near the elevator. There are several differences in construction of the carts; they cannot be interchanged.

Ready Service Crane

The ready service crane is used to transport the mated weapon from the mating area to an empty tray on the missile magazine hoist. When the tray receives the weapon, the hoist is at the strikedown level.

The crane is mounted on a pair of crane rails that span the overhead between the magazine door and the mating area. It is operated from a control panel on the magazine platform. The crane raises the weapon by means of its strongback, which has shoe grips that seat on the booster shoes of the missile and lock on. The strongback is raised and lowered by hydraulic actuators.

MISSILE MATING AND SERVICING

RESPONSIBILITIES OF GMM

The GMM assigned to a guided missile launching system is responsible for the handling, custody, and care of the missile used by that system. The responsibility includes the following tasks:

1. Unmating/mating.
2. Warhead and exercise head exchange.
3. Assembly and disassembly.
4. Preparation of missile for tests.
5. Missile servicing (preventive maintenance).

GMMs are not solely responsible for performing the missile system tests or for the test equipment. These responsibilities are shared by the fire control technicians. The GMMs (joins the booster and missile) all Terrier, Talos, and Standard ER missiles during strikedown and unmates these same missiles before they can be offloaded (struck up). Missiles must be mated and unmated every time they are tested (checked out) and whenever it is necessary to change warheads or install exercise heads.

The areas of responsibility for GMMs are in a changing state, tending toward more responsibility for the missile round. A review of the quals reveals a concentration on care and testing of the launching system. At the E-5 level, the GMM is responsible for positioning the missile and preparing it for testing. The deletion of the former Missile Technician rating is causing a shift in duties of the GMM with regard to the missile. As a practical matter, GMMs are already being given more responsibility for the testing of the missile round. Testing of missiles aboard ship is being reduced, however.

TESTING AND REPAIRING

As soon as practical after the missiles have been brought aboard ship, a missile system test (MST) , commonly called "missile checkout," must be performed. Thereafter, periodic checkouts will be conducted at intervals established by NAVORDSYSCOM.

For example, NAVORDSYSCOM at the time of this writing requires that BT-3 Terrier missiles be checked at 3-month intervals for the first three times and 6-month intervals subsequently. Both initial and periodic tests are conducted in areas (stations) especially provided with missile component handling equipment and test sets.

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The exact locations of missile checkout stations vary in many launching systems. However, except for the Tartar missiles which are checked out in a launcher guide arm, the checkout area is normally located in the missile house, outboard of the loaders, in or near the strikedown and mating area.

Special guided missile test sets (GMTS) have been developed for each type of missile. These test sets program the missile through a simulated flight sequence, comparing missile response to known standards. The final result of the test is a GO or NO-GO indication of missile condition. A GO indication means that the missile is flight-ready, and a NO-GO indication means that the missile has failed the test. The NO-GO (fault) lights involved indicate which component or components in the missile should be repaired or replaced. (The term "component" here means a part or group of parts (package) of a missile which, by design or construction, lends itself to a unit concept of replacement or repair.)

Missile components are not normally repaired aboard ship. When the test set indicates that a missile component is defective, a new component is installed by the GMM and the missile is retested.

To replace faulty missile components, it is normally necessary to disassemble a portion of the missile. The degree of disassembly depends on the faulty components and on the missile type. Terrier and Talos missiles are disassembled and reassembled while they are on the checkout car with the aid of special tools, handling attachments, and an overhead crane. Tartar missile defective components are removed while the missile is on the launcher guide arm with the aid of special tools, handling attachments, handling king post, and a handling hoist.

Shipboard missile servicing (preventive maintenance) consists of a series of systematic inspections, checks, and servicing operations performed at regular intervals. The frequency and type of servicing performed vary on each type of missile. For example, the Talos 6Cl missile must have its battery removed and a reconditioned replacement installed every month. The Talos also must have its fuel, hydraulic, and nitrogen systems checked bimonthly. In comparison, the Terrier BT-3A missile requires no special servicing under normal conditions. However, the hydraulic system on this missile (BT-3A) requires filling after component replacement procedures which necessitate breaking into the hydraulic system. The fluid level of the hydraulic system on the BT-3A also must be checked after each checkout.

Unless otherwise noted, the remainder of this discussion will briefly describe the shipboard procedures for Terrier BT-3A missile mating, unmating, checkout, and component replacement. To simplify this discussion, only GMLS Mk 10 handling equipment will be described.

UNMATING AND MATING

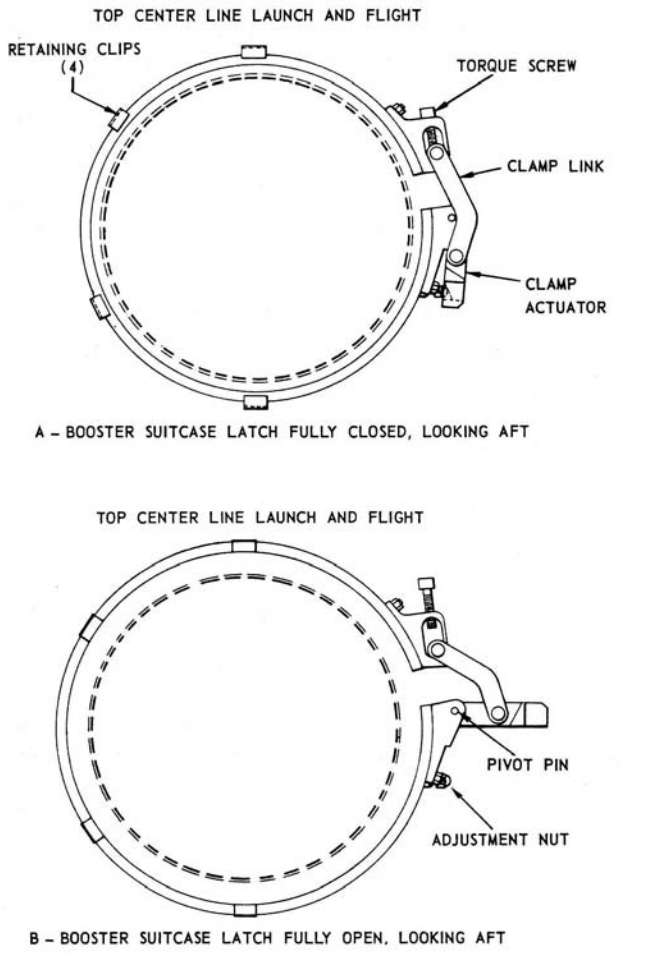
In preparation for missile checkout, missile servicing, warhead exchange, or exercise head installation, the assembled missile must be unmated. Before unmating, the following step-by-step tasks must be performed.

1. Transfer of the mated weapon from the magazine to the checkout area.
2. Moving of the checkout car inboard under the missile.
3. Moving of the car table to its aft position (towards booster).
4. Positioning of standard missile handling attachments on the car.
5. Raising of the car table to the missile.
6. Fastening of the handling attachments to the missile. Bear in mind that the handling attachments should be tightened (torqued) enough to prevent the missile from moving during mating and unmating but not to exceed a value of 660 ± 30 in.-lbs.

To separate the missile from the booster, fully loosen the booster suitcase-latch torque screw, and unlock the suitcase latch by inserting a handle in the clamp actuator to lift it upwards. (The suitcase-latch assembly is shown in figure 14-22.) With the suitcase latch fully open, the booster is separated from the missile by moving the checkout car table away from the missile.

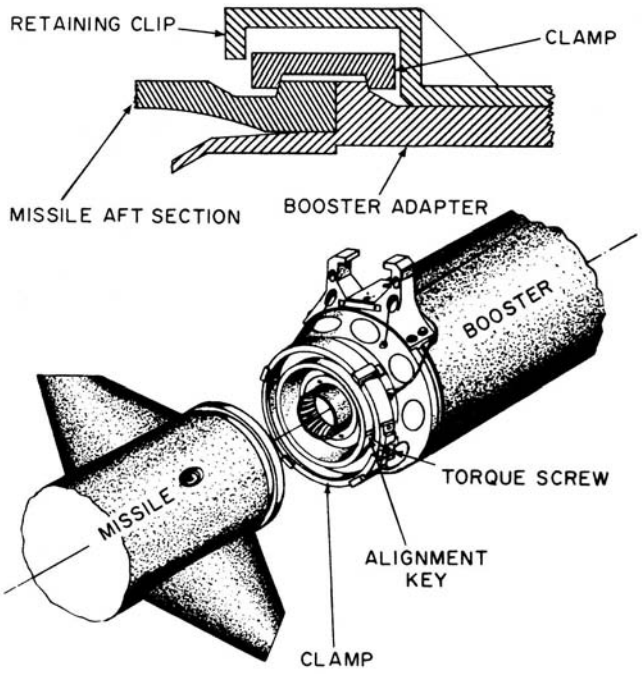
If any work is to be done on the missile, such as testing, exchange of components, or repair, the booster is returned to the ready service ring until the work on the missile is completed. Then the booster is returned to the checkout area to be remated to the missile. The movement of the missile and the booster is accomplished in Step Control by pushing the correct buttons in the correct sequence on EP4 and EP5 panels after being put in the proper mode of operation by the EP2 panel operator. Personnel must keep clear of all moving machinery, both in the assembly area and the checkout area.

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Figure 14-22. — Terrier missile-booster suitcase latch: A. Latch fully closed, looking aft; B. Latch fully open, looking aft.



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Figure 14-23. — Terrier missile-booster connection.

To remate the booster and missile, move the booster into the checkout area. Then position the checkout car so that the missile is in the approximate mating position, and proceed with the following steps.

1. Check that the torque screw is fully loosened and that the suitcase latch is open.
2. Install the missile-booster alignment insert in the missile-booster electrical contractor.
3. Carefully align the missile, by use of the checkout car controls, until the keyways of the missile are aligned with the booster alignment lugs (keys), shown in figure 14-23. Then slowly move the missile into firm engagement with the booster.
4. After checking to ensure that the adjustment nut is fully tightened, insert the clamp-actuator handle into the hole in the clamp-actuator, and lock the missile and booster together by closing the suitcase latch.
5. Check to be sure that the clamp link is making contact with the pivot pin (refer again to part A of figure 14-22) but not contacting the adjusting nut.
6. Remove the clamp-actuator handle and tighten the torque screw to 480 ± 60 in.-lbs., using a torque wrench and special hex adapter.
7. Insert a scribe, or similar tool, into the hole in the shaft under the adjusting nut. Holding the shaft stationary, loosen the adjustment nut until it makes contact with the clamp actuator. When contact is made, back off an additional 1/4 turn, and recheck the clamp link to ensure that it is still in contact with the pivot pin.

CAUTION. - Do not use the locking ring to pull the sections together, but slowly bring the two sections together. Keep the booster grounded

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and the arming mechanism in SAFE position during all handling operations. Strict observance of this safety rule is mandatory.

Inspections

Inspect threads of air or hydraulic system coupling before mating. Make certain they are free from dirt, oil, and physical defects.

After completing the mating of the missile and booster, inspect to be sure the parts are strictly aligned and the locking mechanism is secure bit not overtightened. Do not apply any oil, grease, or other compound other than authorized by the OP for the system.

Missile Servicing

Missiles received aboard ship will not require special servicing under normal conditions. They will be completely assembled and operational with exception of those that require installation of a battery before firing. When preparing a missile for an exercise flight, in addition to installation of telemetering antennas and the exercise head, flash signals and a destructor may have to be installed. See the OP for step-by-step instructions for making the installations.

PREPARATION OF MISSILE
FOR TESTING

If the missile is to be tested, the car with the unmated missile is lowered, moved outboard, and locked at the checkout station. The aft end of the missile is then connected to a blowout pipe with the use of an adapter, shown in figure 14- 24. The blowout pipe is built into the ship and exhausts overboard in the event of accidental sustainer ignition during tests.

To complete the preparation of the missile for a shipboard test, perform the following tasks.

1. Install a microwave adapter to the blowout pipe adapter.
2. Install telemetering antennas in dorsal fins #2 and #4 (used only during testing of missiles with exercise heads).
3. Remove the nose-probe shield.
4. Unfold the control surfaces.
5. Remove the forward end of dorsal fin #1 (to uncover the test receptacle).
6. Remove the access covers from the hydraulic pressure and return ports.
7. Ensure that all grounding leads are properly attached.
8. Attach the hoses and cabling to the missile.

The actual MST will be conducted by a fire control technician. After the test is completed. a good (GO indication) missile is mated and returned to the magazine. Should the missile be defective (NO-GO indication) however. it should be either mated and returned to the magazine as a dud or repaired (defective component replaced) immediately and retested. The decision of whether to return the NO-GO missile to the magazine or to repair it depends upon ship's doctrine and the tactical situation.

Missile code plugs MUST be installed onboard each ship after mating. The missiles are received with a shipping plug.

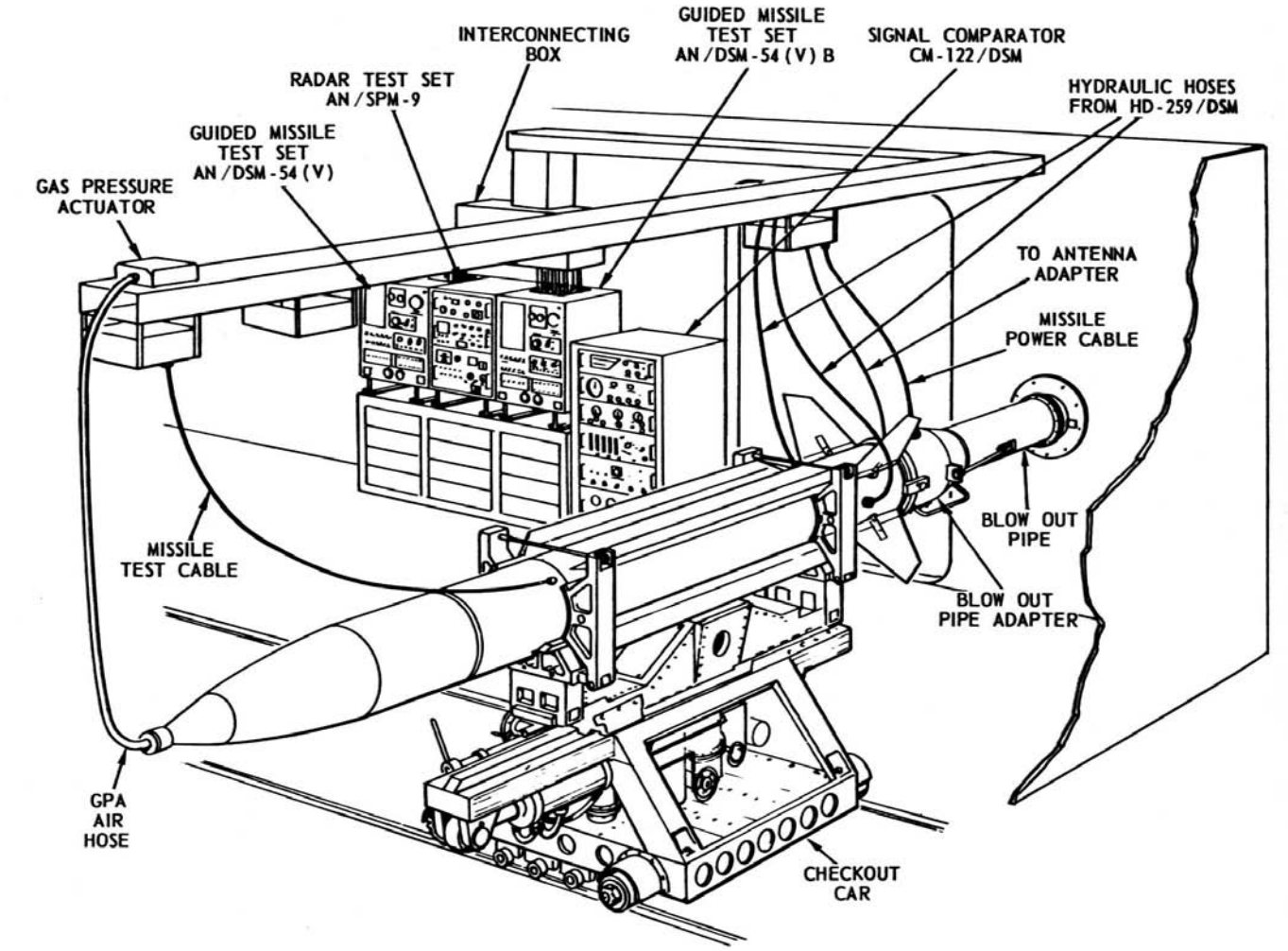
Warhead Exchange

When it becomes necessary to exchange warheads, the missile is removed from the magazine, unmated, and moved by the checkout car to the checkout area where interchange is performed with the use of the checkout area handling equipment. Before removing the warhead. it is necessary to install the warhead handling J- bar to the warhead hoists. This is accomplished by temporarily removing the J-bar and plate and engaging the J-bar slot with the hoist rollers. as shown in figure 14-25A.

To remove the warhead, use the following step-by-step procedure.

1. Remove the missile nose section (target detecting device or TDD), and the safe-and-arm (S&A) device. (The procedures for disassembly of these missile sections are described later. in this discussion.
2. Remove the J-bar adapter (refer to fig. 14-25A) from the J-bar and attach it to the warhead flange by rotating the adapter until the adapter pin is engaged - approximately 1/6 turn.
3. Position the warhead hoist so that the J-bar can be engaged with its adapter, and lock by inserting the chuck locking pin as shown in figure 14-25A.
4. Move the warhead hoist until the hoist rollers are at the indicated proper position for warhead removal and lock the J-bar to the hoist. Raise the hoist to remove any slack between the hoist, J-bar, and missile warhead.
5. Unlock the warhead from the electronic section by using a spanner to rotate the coupling (locking) ring.

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Figure 14-24. — Typical shipboard checkout area, with missile system test (MST) equipment attached to missile on checkout car.

6. Separate the warhead and electronic section 3 to 4 inches, and disconnect the electrical connector (refer to fig. 14-25B).

7. Move the hoist to position the warhead in a clear area, to permit moving the warhead from a horizontal to a vertical position.

8. Position personnel at both sides of the warhead to restrain the warhead and prevent a sharp whip when the hoist rollers pass around the curved portion of the J-bar.

9. Unlock the J-bar and carefully roll it along the hoist rollers until the warhead is in a vertical position. See part C of figure 14-25.

10. Lock the J-bar to the hoist. and move the hoist to a point above the temporary stowage cell. See figure 14- 25D. Carefully lower the warhead into the cell, and disconnect the J-bar adapter.

Assembly of replacement warhead is essentially the reverse of disassembly. Some types of warheads, however, are connected to the electronic section with a locking ring located on the warhead rather than on the electronic section. When assembling this type of warhead, the locking ring must be removed from the electronic section before reassembly. The locking ring attached to the warhead is tightened to a torque value within a given tolerance while the locking

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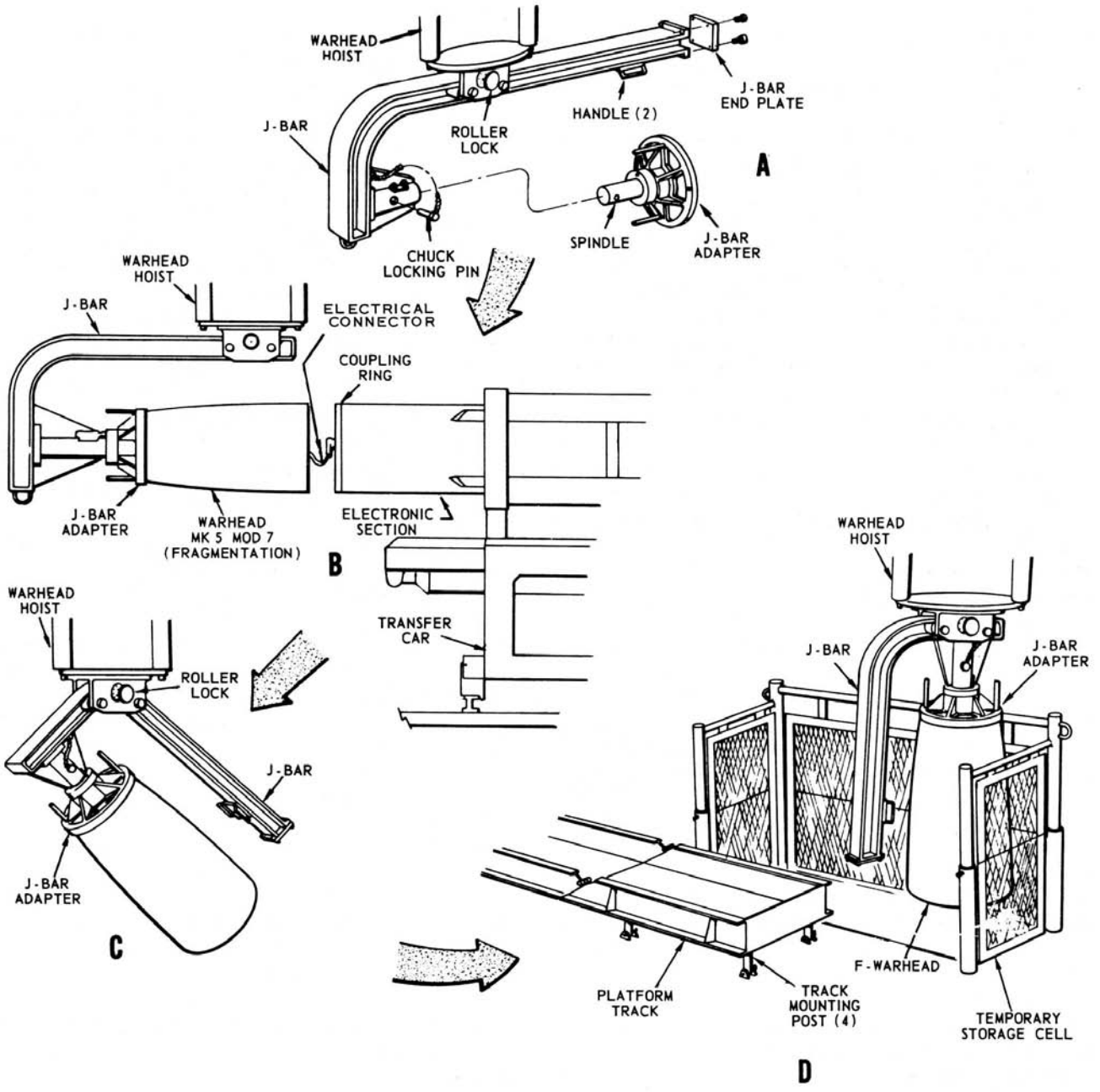


Figure 14-25. — Warhead removal, equipment and procedural steps: A. Warhead handling J-bar; B. Warhead separation from missile; C. Shifting warhead to vertical position; D. Warhead temporary storage cell. 83.155

ring attached to the electronic section is tightened to an index mark.

Exercise head installation also requires that a missile warhead be removed. Installation of the exercise head to the electronic section is accomplished in the same manner as warhead assembly, except that the electrical connections differ. The main differences between warhead exchange and exercise head installation are in connection with the preparation of the exercise head components for testing and flight. Checkout of the exercise head is to be accomplished

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by a missile system test within 30 days of the exercise firing. It should be noted that 30 days is the extreme limit. In actual practice, most commanding officers and weapons officers will require a MST within two or three days of the flight.

Before the exercise head is tested, both batteries must be charged and degassed. The batteries can be charged after they are removed from the exercise head or while they are still in the head, provided that the head can remain in the vertical position both during the charging procedure and during degassing. After battery charging, 12 hours of degassing are required before missile tests can be conducted.

Assuming that the system test of a missile assembled with an exercise head is conducted before an exercise firing, the exercise head is normally returned with the mated missile to the magazine. This means that if a destructor charge is used, it must be installed before the exercise head is secured to the electronic section. The exercise head is normally received with a dummy destructor charge installed, which must be removed before installation of a live destructor. An arming and firing device is installed with the destructor.

A flash signal (smokepot) may be used during training or evaluation flights to visually indicate fuze activation when the target is intercepted. Exercise warheads are normally received with two dummy flash signals installed. These signals are located 180° apart, near the forward end of the exercise head. Installation of the live flash signal requires only an exchange of one of the dummy signals the live signal and one electrical connection with the missile fuze section. It is necessary to remove the fuze section, however, or to install the flash signal before the fuze section is assembled to the warhead.

The flash signal can be assembled in the exercise head either before or after the exercise head is assembled to the missile electronic section. After installation of the flash signal, the exercise head must be kept grounded, and must also be handled and stored as a pyrotechnic item.

The charged and vented batteries must also be installed in the front end of the exercise head before installation of the fuze section. When the fuze section has been installed in the exercise head, a MST can be performed.

After the MST, the batteries are removed, topped off, recharged, degassed, and reinstalled in the exercise head. Because degassing requires 12 hours, the MST should be run at least 16 hours before firing.

Component Replacement

When a component of the BT-3A missile has been proved faulty, it should be replaced in accordance with the instructions in the applicable OP. The following discussion briefly describes component replacement, but is not intended to be used as instructions for missile assembly and disassembly. To attempt a detailed description of assembly and disassembly would require a book by itself.

A list of general component replacement instructions for all types of missiles follows.

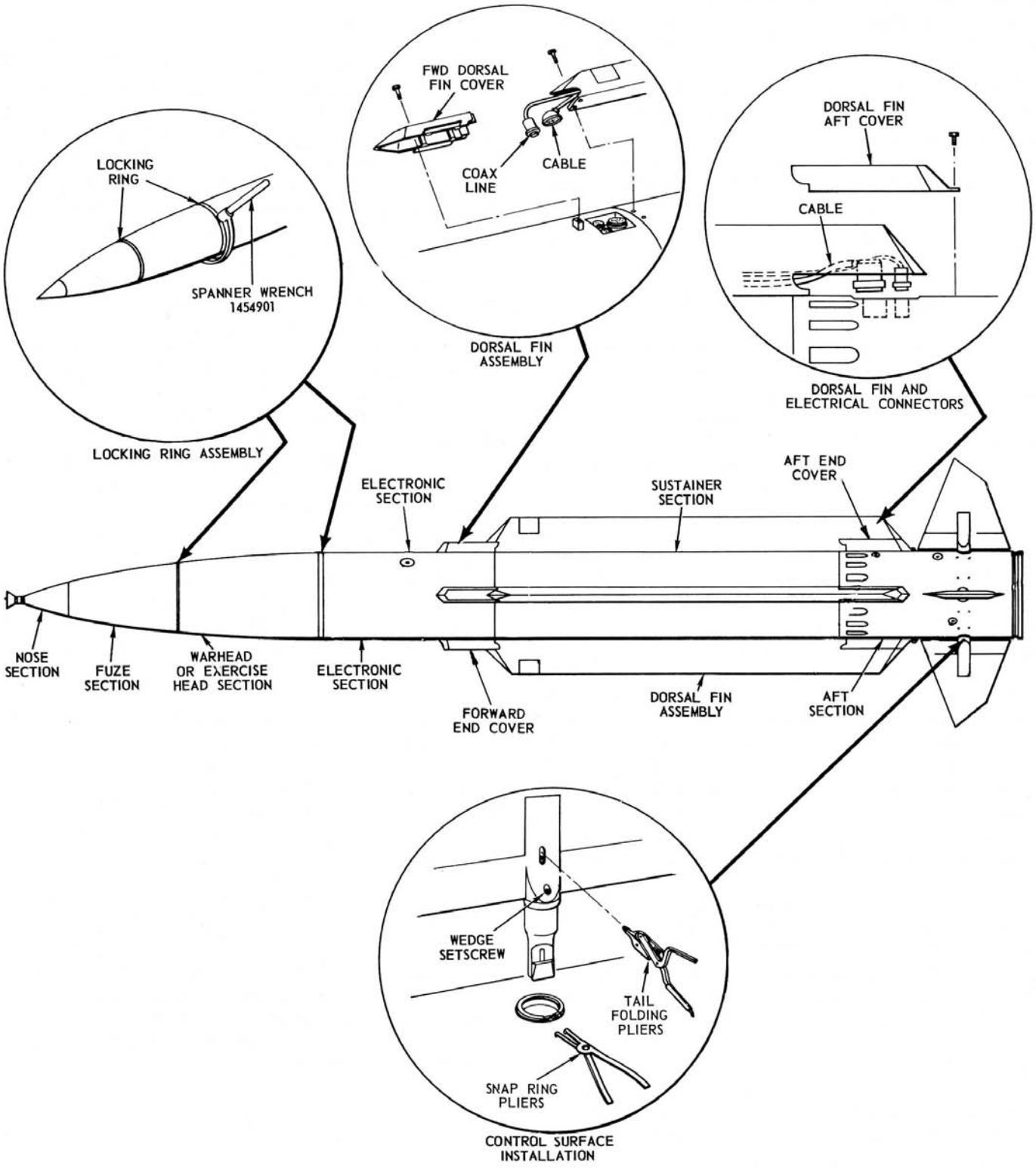
1. When provided, special tools shall always be used to assemble and disassemble a missile.
2. Only identical or authorized replacement parts shall be used to replace defective components.
3. All areas requiring sealing compound shall be recoated when components are reassembled, to preserve watertight integrity.
4. During component replacement, a visual inspection of all preformed packings (O-rings, grommets, washers, etc.) shall be conducted to determine if replacement is needed.
5. Safety lockwire removed during component replacement shall be carefully replaced with NEW safety wire.
6. Make certain that all loosened nuts, bolts, screws, and electrical and hydraulic fittings are tightened to their specified values.
7. When hydraulic components are removed, all ports should be covered for protection from foreign matter, and only clean, lintfree rags should be used to wipe and absorb hydraulic fluid leakage.

The control surfaces of BT-3A missiles are mounted in machined sockets and retained by snap rings. Removal of the control surfaces is required only when it is necessary to replace components in the missile aft section or when a defective control surface is noted.

To remove a control surface, perform the following basic steps.

1. Unfold the control surface until latched in the flight position.
2. Loosen the wedge setscrew, shown in figure 14-26, four or five turns, using the special setscrew adapter.

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Figure 14-26. — Component removal procedures on BT-3A missile.

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3. Spread the snap ring, using the special snap-ring pliers (fig. 14-26).

4. Place the control-surface removal tool between the control surface and its retainer. Lightly strike the removal tool with a mallet until the control surface is free from its socket. Lift the control surface clear of the missile.

The control surfaces are folded by inserting the tapered tips of the special tail folding pliers (fig. 14-26) into the slot in the control surface

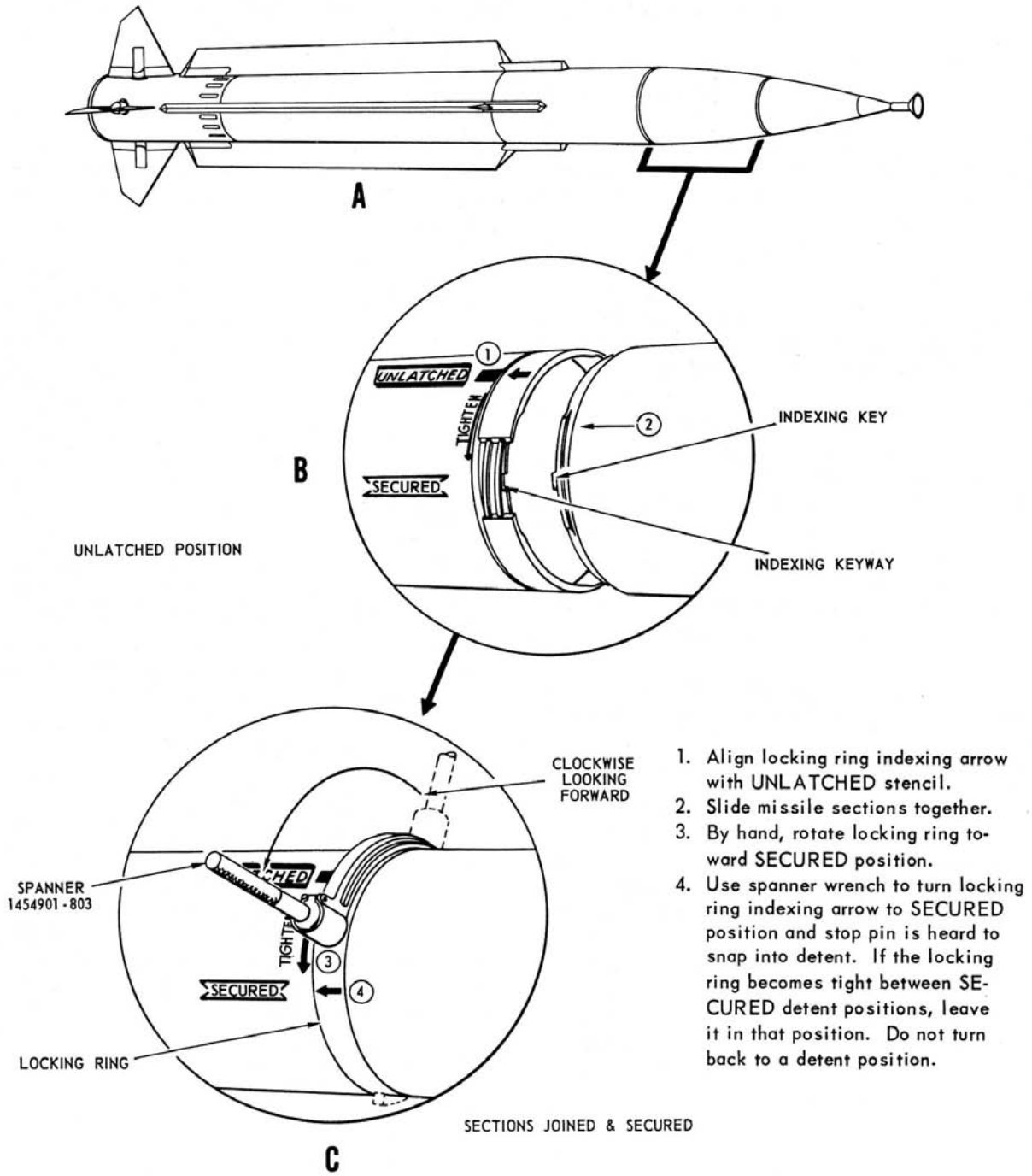


Figure 14-27. — Fuze section removal and replacement: A. Location of fuze section; B. Unlatched position; C. Sections joined and secured. 83.157

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with the longitudinal axis of the pliers perpendicular to the control surface. Using a wood or rawhide mallet, strike the pliers at the joint between the two handles. Do not pry or use lever action. When the latch pin is dislodged, compress the handles of the pliers and fold the tip of the control surface to approximately the 90 position. Remove the pliers and continue folding the surface until it latches in the folded position.

The four dorsal fins are located around the center part of the missile, as shown in figure 14-26. Each fin is assembled in three sections: forward end cover, aft end cover, and main structure. After initial installation of the dorsal fins, only the end covers need to be removed for component replacement.

To remove and install the dorsal fins, proceed in the following manner.

1. Remove the screws retaining the forward end covers, and slide the covers toward the forward end of the electronic section until they disengage.
2. Remove the screws retaining the aft end cover and slide the covers rearward until they disengage from the dorsal fins.
3. Disconnect the electrical connectors and remove the retaining bolts from each end of the dorsal fin main structure. The dorsal fin main structure can then be lifted free.
4. Replace the main structure and tighten the retaining bolts to a torque value of 90 ± 10 in.-lbs.
5. Replace the forward and aft end covers and tighten the screws to a torque value of 27.5 ± 2.5 in.-lbs.

The nose section is removed or replaced as a unit, because removal of the transducer (probe) voids the factory air-leakage test. To remove the nose section, use a special wrench adapter and socket to loosen the eight setscrews at the aft end of the nose section. Unmate the nose section from the fuze section and disconnect the electrical connections between the nose and fuze sections.

To reassemble the nose section follow in reverse the disassembly procedures, except that the setscrews should be tightened to a torque value of 13.5 ± 1.5 in.-lbs.

The fuze section is removed after the nose section, without the use of special handling equipment. With the fuze section supported by two persons and using the special spanner wrench shown in figure 14-27 turn the locking ring counterclockwise (when viewed from the rear) until the alignment arrows indicate the unlatched position. Separate the fuze and warhead sections far enough to disconnect the electrical connections between fuze and warhead. The fuze section can now be replaced or repaired.

To replace the fuze section, fasten the electrical connectors and position the indexing key on the fuze section in the indexing keyway in the warhead. Using the special spanner wrench, move the locking ring index mark to the secured position.

The circuits of the electronic section are packaged according to their functions and mounted on a T-beam in five separate plug-in packages. Each package is held to the T-beam by captive screws or bolts. The T-beam is attached to sliding rails which allow the complete electronic unit to be pulled out of the missile airframe for servicing.

The major components of the aft missile section are the auxiliary power supply (APS) and steering control unit which are combined to form the steering-power assembly. The assembly is retained within the airframe by 16 screws. When a component of this assembly is defective, it is necessary to remove the complete assembly from the airframe by sliding it rearward. The step-by-step procedures for removal of the steering-power assembly will not be described here. However, these procedures include removal of the control surfaces and dorsal fin aft end covers.

Many of your sessions will be with training missiles. You will transfer missiles from ship to magazine, and the reverse, bringing them up from the stowage to the launcher. You will conduct tests on them. In other words, you will put the launching system through its paces as if you were using a real missile. To do this you need the instructions. The instructions for Tartar Training Missile (TSAM) Mk 16 Mod 1 are contained in OP 2831. It simulates the Mk 15 Tartar missile.

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CHAPTER 15

INFORMATION: INPUT AND OUTPUT

This chapter deals with paperwork covered in the Qualifications under Administration. As a member of the weapons department you have a share in its administration. True, most of your working day is spent in keeping the launching system in working condition. However, it is your work, ability, and training, plus your equipment, that is being administered and you have some say in the administration policies.

The operational and maintenance policies on your equipment are based in part on data obtained from the records and reports that you make. Thus, administration is a tool to aid you, and is well worth the paperwork involved. The assistance you receive from administration is not always apparent; but the paperwork is yet, in the name of expediency, sometimes disregarded or slighted. When this happens, everyone loses because something is taken away from the organization.

Your big job is to keep launching system equipment in top working order. To help you do this, the Navy provides many publications and other written material pertinent to the maintenance task. In return, the Navy requires you to provide written reports on how well you are maintaining your equipment. By a roundabout way there is a constant flow of information between you and the Navy, principally between you and NAVORDSYSCOM.

Your information may leave your ship in the form of a letter or report which is processed by a machine or an individual of the Command. It is possible that information you have supplied will trigger some kind of action in the Command.

To illustrate, let's assume you have sent in five failure reports on the same relay. You may think that this recurring casualty happens only in your particular equipment, but ten other ships have also sent similar reports to the Command. An engineer in the guided missile launching system section in NAVORDSYSCOM sees a failure pattern and analyzes the relay circuit. He detects a faulty circuit design. Than he makes a design change to correct the relay failures. The engineer writes instructions on how to rewire the existing relay circuit and sends these instructions to all ships that have your launching system. These instructions are called Ordnance Alterations - OrdAlts for short. If the circuit change is not complicated or requires minor changes to equipment, you will make the circuit alterations. Thus, we have completed a correspondence loop, or in Navy jargon, we have "feedback." You have fed information to NAVORDSYSCOM and it has fed back information to you. This feedback system is very important. Any break in the loop destroys the effectiveness of the system. Don't you break it.

WEAPONS DEPARTMENT

Before going into the administrative aspects of the weapons department, let's review the department organization.

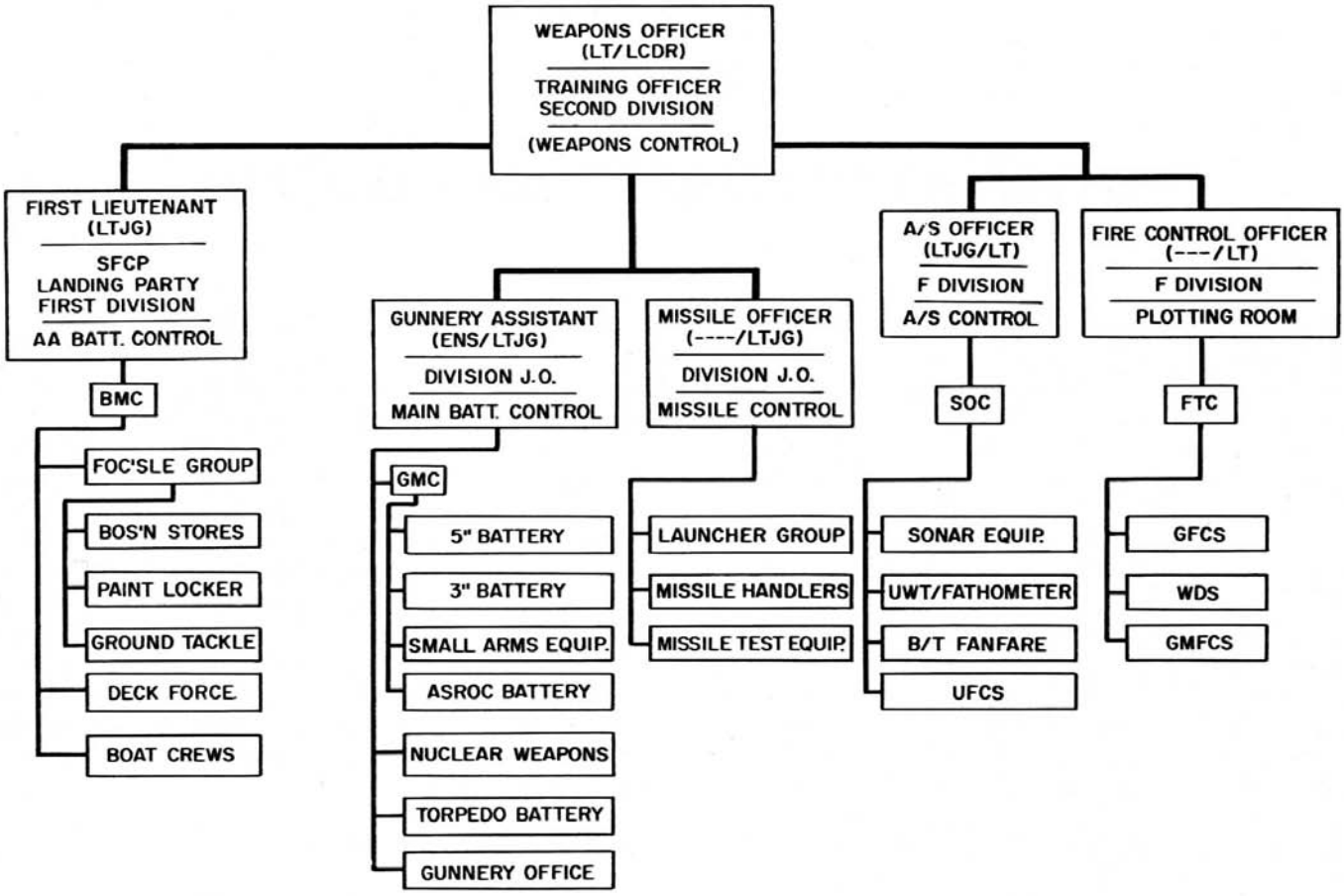
The weapons department of combat vessels whose main armament consists of guns or missile launching systems is headed by a weapons officer who, in turn, is responsible to the commanding officer.

Within the weapons department are several divisions which are designated by special letters or numbers. Each division is headed by an officer who is responsible to the weapons officer. Figure 15-1 shows a typical weapons department organization on a combat ship.

As an example of how a division operates, we will use the F division. Personnel in the F division man the gun and missile launching system fire control equipment and the plotting room. The F division personnel are further divided into units that are assigned to specific systems. Each unit operates and maintains the particular system to which it is assigned.

A relatively new concept of division designation within the weapons department has recently been implemented in the fleet. The divisions

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Figure 15-1.—Organization chart, weapons department, USS Farragut class DLG.

are WM (weapons-missiles), WG (weapons-guns) , WD (weapons-deck), and ASW (anti-submarine warfare). Within the WM division are the GMMs and FTMs who are assigned to a specific launching system. The GMMs maintain and operate a particular launching system and the FTMs maintain and operate the fire control equipment for the missile system. If more than one launching system exists within the WM designation, the division designations would be WM 1, WM 2 and so on.

Each division officer usually is assisted by a junior division officer. When making reports, most division officers do not report to the weapons officer directly, but report through an additional echelon. This usually is an assistant under the weapons officer.

Figure 15-1 is not considered to be a complete organizational chart because the weapons department may have minor changes even in ships of the same class. In the figure, certain technical personnel (such as warrant gunners) are omitted, and functional relationships are not shown. Also, the assistant weapons officer may perform dual functions.

On small ships, the weapons department organization follows the pattern of larger ships. However, since small ships have fewer officers and, relatively, a greater variety of armament, some of the billets are expanded to cover more functions.

To fully understand your weapons department, study your departmental manual. H you have any questions, do not hesitate to ask your division senior petty officer for an explanation.

Now let's see how NAVORDSYSCOM, in particular, and other commands, in general, send out information to direct the affairs of the Navy.

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THE NAVY DIRECTIVE SYSTEM

Your maintenance work is governed to a large extent by directives. The Commands and offices of the Navy Department issue directives. Fleet and force commanders and district commandants also issue directives to subordinate commands. Your own ship or station issues directives to departments and divisions within you ship's organizational structure.

For uniformity, ease of filing, and quick identification, each directive, regardless of the originator, is numbered according to a standard system. SECNAVINST 5210.11A. Department of the Navy Standard Subject Identification Codes, spells out the numbering system. But before we talk more about how directives are numbered, you should know the kinds of directives.

There are two types of directives:

1. INSTRUCTIONS, which contain information of continuing nature or require continuing action, or action which must be taken but cannot be completed in less than 6 months. An instruction can be used as a reference for a long time and is effective until the originator cancels it.

2. NOTICES, on the other hand, are directives of one-shot nature, or those which contain information or action applicable for a brief time only (usually 6 months or less. but in no case more than 1 year). A Notice has the same force and effect as an Instruction but does not have permanent reference value. It therefore contains a paragraph which indicates when it shall be cancelled. When the exact length of time a Notice is to remain in effect cannot be determined at the time it is issued, the specific date for record purposes is set far enough into the future to allow all necessary use of the notice.

You can better understand how directives are identified and numbered by considering some typical examples:

(a)	(b)	(c)
NAVORD	INST	8200.1
OPNAV	INST	1500.8
BUPERS	INST	1440.5B
BUPERS	NOTE	1223

(a) The authorized abbreviation of the originator is placed here.

(b) This part refers to the type of release (Notice or Instruction).

(c) This is the subject number which is determined by the subject matter of the directive, and is obtained from the Table of Subject Classification Numbers. You will find this table in SECNAVINST 5210.11A. The table is too long to reproduce here. But to give you some idea of what is in the instruction, here is a list of the 13 major subject groups:

1000-1999:	Military Personnel (The OPNAV Instruction, BUPERS Inst, and BUPERS Note, above, fall into this category.)
2000-2999:	Communications
3000-3999:	Operations and Readiness
4000-4999:	Logistics
5000-5999:	General Administration Management
6000-6999:	Medicine and Dentistry
7000-7999:	Financial Management
8000-8999:	Ordnance (From maintenance viewpoint, most important)
9000-9999:	Ship's Design and Ship's Material
10000-10999:	General Material
11000-11999:	Facilities and Activities Ashore
12000-12999:	Civilian Personnel
13000-13999:	Aeronautical and Astronautical Material

These major subject groups are subdivided into primary, secondary, and sometimes tertiary breakdowns. Complete information on how Ute major groups are broken down is in the SECNAVINST we have mentioned. When you get a spare moment, go to the ship's office and look over the instruction. In particular, study the information concerning the 8000-8999 major group and it's subgroups. These groups and subgroups will be of interest to you because they are guided missile weapons directives.

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To point up the importance of directives in the maintenance task, the information in NAVORD INST 8200 is about synchros, tachometer generators, and other rotating electrical components. This instruction directs you to disconnect synchros and tach-generators from the circuit during a ground test. This procedure prevents putting a high breakdown voltage across the windings of a synchro or tachometer: generator.

TECHNICAL PUBLICATIONS

ORDNANCE PAMPHLETS

The main source of technical information on operation and maintenance of ordnance is the Ordnance Pamphlet (OP for short). NAV-ORDSYSCOM publishes these technical manuals, each under its own OP number. They may be prepared by some other naval activity, by the manufacturer, by a commercial specialist in such publications, or by the Command itself. OPs dealing with ordnance equipment are organized according to the following general outline:

Introduction
Physical description
Theory and functional description
How to operate
Maintenance of equipment

In the introduction you will find a brief explanation of what the equipment is, where it is used, what it is intended to do, and the like, as well as a description of the difference among various marks and mods, if appropriate.

The section on physical description gives you a word picture of the equipment. Many illustrations of equipment are used in this section so you can easily identify the major parts.

The functional description explains in detail how such things as electrical, electronic, and hydraulic circuits in the equipment work. The operating principles of mechanical systems are also explained here.

The equipment operation section tells you what switches and other control devices to manipulate so you can put the equipment through its paces. Maintenance procedures are described in another section. Usually a whole volume is devoted to maintenance.

OPs on small equipments usually devote one chapter to each heading, though with complex systems each topic may require an entire volume. Thus there are variations but the main topic list above. or one much like it. is used by OP writers as their checklist; it shows what information you can expect to find in standard OPs on equipment, and approximately where to find it.

Some OPs (for example, OP 2213, Pyrotechnic, Screening. and Marking Devices) take up a subject matter AREA rather than a specific item of ordnance gear; such OPs do not follow the standard outline above.

OP O

OP O is the official list of OPs. It is a consolidated listing of all publications and forms which pertain to ordnance activities. OP O is divided into three parts:

Part 1. NAVORD Ordnance Publications (OPs) consists of a complete numeric listing of all OPs. It includes Special Projects. Do Not List. Cog I. Non-Cog I. Under Preparation. Cancelled and obsolete publications.

Part 2. NAVORD Ordnance Data (ODs) this part consists of a complete numerical listing of all ODs. It includes Cog I, Non-Cog I, CTDO, Non-CTDO, under preparation, Special Projects, Do Not List, Reserved Cancelled and Obsolete publications.

Part 3. Subject Index is a listing of all NAVORD OPs and ODs listed in this publication under equipment identification.

Most Ops are massive publications; some require 4 or 5 volumes. Their preparation is costly in terms of both time and money. So, when one is issued, it's likely to be a rather long time before it can be replaced by a revised edition.

But ordnance equipment is changing all the time, and the OPs on every piece of equipment must be kept up to date. This is done by issuing changes. A change is a leaflet or pamphlet that specifies in detail actual text alterations in the OP to which it applies. Changes are issued automatically to the same distribution list as the OP concerned. When received, the change should be attached inside the front cover of the OP, and the text and illustration changes called for should be entered promptly in the OP itself. There is a good chance you will make these changes. Make every effort to enter the changes as soon as received.

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Publications issued between revisions of OP O are listed in the Naval Ordnance Bulletin, a classified publication issued quarterly to give information on new developments and changes.

Interpreting OPs

As mentioned before, it requires several volumes to describe in detail all the parts of a missile launching system, its operation, and its maintenance. OP O lists them by number. title, and subject classification, and tells on what ships each system is installed. Suppose we take as an example the Terrier Launching System Mk 10 Mod 7. The chart in Appendix A of OP O tells us that this system is installed on DLGs 26 through 34 and DLG(N) 35. Turning to the listing by number and title, we see that there are four volumes of OP 3114. Earlier mods of the Mk 10 Launching system, which do not have the Asroc capability, are described in other OPs (OP 2351 being one of them) consisting of three volumes and several volumes of Illustrated Parts Breakdown (IPBs). Many of the components of the Mod 7 are identical with earlier mods. Other OPs are referenced for detailed descriptions of those components, such as OP 2350 for the launcher.

Volume 1 of OP 3114 gives the general description and operation of Guided Missile Launching System Mk 10 Mod 7, and the physical and functional description of the ready service mechanism, plus safety precautions. Volume 2 describes the special maintenance tools; volume 3 contains lubrication charts and electrical schematics; and volume 4 describes magazine components, loader components, and miscellaneous systems.

As you read the description, refer often to the illustrations accompanying the text and locate the parts named. Notice the placement of the components on your ship. Since the OP is written for the missile system installation on your class of ship, this should not be hard to do. You might take the illustration with you to help you identify components. The illustration reproduced as figure 5-13 in this manual, for example, points out the approximate location of components of the assembler. Figure 5-14 points out parts of a component. When you know where the components are and what they look like, it is easier to visualize what takes place when the equipment is operated. In fact, the OP says, "Personnel should have some familiarity with the Mk 10 Mod 7 launching system before attempting to follow figures 1-19 and 1-20." These figures in the OP show Asroc automatic operation and Terrier automatic operation.

The need for combining the study of the manual with use of the illustrations is indicated by this statement from the OP;

"It is imperative that the reader have available wiring diagrams 2206727 and 2206728 while reading the following text. The diagrams illustrate the firing circuitry and the associated relays. These diagrams are included in Volume 3 of this OP."

When you have seen the components of the launching system so that you have in mind their appearance and their location, you'll find it much easier to follow the steps in operation when you read them in the OP.

ORDNANCE DATA

Ordnance Data (ODs) are a kind of catchall. They are used for publishing advance information or instructions on ordnance equipment installation and alignment data, parallax data, and other miscellaneous information, such as tables of weights and dimensions. Formerly, ODs were used for publication of test and inspection data. Ordnance Reports are now used for this purpose. ODs are numbered consecutively by the issuing agency. ODs, like OPs, are listed in OP O.

One OD that is required reading for you, and for all other Gunner's Mates, is OD 3000, Lubrication of Ordnance Equipment. It is the one OD that your ship's library of ordnance publications must not be without. Other ODs may be useful to you, depending on the type ship you are aboard and its armament; but for that information you should consult OP O. If they are not already in your ship's library, they can be ordered.

ORDNANCE ALTERATIONS

The publications discussed so far have to do with installation, operation, maintenance of ordnance material, but not with any changes that must be made to ordnance material. At the same time, such changes must be made uniformly so that all items of a given type will continue to conform to standard specifications of performance and interchangeability.

When changes must be made to ordnance material already in the hands of the fleet, they are usually made by means of a publication

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called an ORDNANCE ALTERATION (symbol: OrdAlt). OrdAlts are numbered serially and are classified not only by security level but also by priority as either Urgent, Emergency, or Routine. They are issued only to ships and other activities which have in active service the items affected by them. OrdAlts are more than mere sources of information; they constitute a basis for requisitioning material required by the alterations involved. OrdAlts are listed in NAVORD OrdAlt 00, List of Alterations to Ordnance Equipment for All Classes of Vessels, Aircraft, and Shore Stations, which also indicates their current status; you will not find them in OP O.

Alterations which are extensive enough to modify materially the military characteristics of a ship are authorized by CNO, and are issued as NavAlts or ShipAlts by the technical bureau having cognizance over the equipment concerned. The NAVORDSYSCOM issues those NavAlts that deal with ordnance equipment, and they are listed under both OrdAlt and NavAlt numbers in NAVORD OrdAlt 00. Naval Air Systems Command (NAVAIRSYSCOM) issues instructions for ordnance used by the air arm of the Navy. This includes missiles delivered by air, such as the Sidewinder, Bullpup, and Sparrow.

REPORTS, FORMS, AND RECORDS

You probably have heard the so-called joke about the man who did a little repair job on a piece of equipment in 5 minutes but it took him 2 hours to write up his report on it. The reports are necessary; the use of forms is intended to reduce the time required for making reports as well as to improve their accuracy, and to produce uniformity that makes it possible to use machine processing of data.

REPORTS

In administering as large and complex an organization as the Navy, it is necessary to establish reporting procedures to keep the technical commands and other management activities continuously informed about the status of operations throughout a farflung network of ships and shore activities. Evaluations of new equipments, and of the methods of using them, are constantly underway. The results of these evaluations are sent to the various technical commands and the Chief of Naval Operations through the appropriate reporting channels. So you can see that the reporting procedures have a definite and valid purpose because they pave the way to improvements in equipments and operations. Not only is the Navy's operational readiness improved, but your job is made easier. Always keep in mind when you are making out a log or report, that you are contributing to these improvements.

Make sure that what you put into a report is accurate. Many occasions will arise when you will provide information that will go into, say, an ordnance inventory. In this case you will have to record name plate data from every ordnance item in your system. Such things as mark, mod, and serial numbers must be read accurately. Name plates are sometimes put in out-of-the-way places. Those that are easy to find may have a light coat of paint on them. But regardless of how difficult it may be to see the data, make certain that what you put down on paper is correct. The ordnance inventory that leaves your ship is used, among other things, to allocate spare parts.

Now then, what is a report? Broadly speaking, a report is any narrative, tabular, or graphic type of information transmitted from one office or command to another. Who requires reports? Besides NAVORDSYSCOM, the Chief of Naval Operations, fleet, force, and type commanders require reports on ordnance matters. But in this chapter we will just talk about reports that are sent to NAVORDSYSCOM and activities under its control.

Report Symbols

Like notices and instructions, reports are coded. In fact, they use the same identifying and numbering system. For example, we will use the report symbol- NAVORD 8000/. The numbers to the left of the diagonal mark indicate the subject classification number- or what the report is reporting on. In our example, it is general ordnance material. Any number to the right of the diagonal line is the sequential number of the reporting symbol in this subject matter area. The tie-in with the Navy Directives System facilitates filing and referencing of reports.

NAVORDSYSCOM Policy on Reports

NAVORDSYSCOM and its activities are required to keep reports from any source at

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a minimum, especially those from the fleet. The people in the Command are aware that your maintenance duties keep you busy. But when you must make out a report, prepare it carefully and submit it on time.

Regard all reports objectively; forms or formats are tools only. You should make every effort to provide the information available or obviously needed in your reports, rather than conform blindly to filling out forms or formats.

Recurring Reports

If you are on a ship in the operating forces, you will find recurring reports listed in OPNAVINST 5214.1C (current). This list shows the report symbol, title, form number, controlling directive, frequency of reporting, and preparing activities for each report. Reports may also be required by the Type Commander, SOPA, Operational Commander, or other Commands.

SHIP ARMAMENT INVENTORY LIST/ ORDALT REQUIREMENT

The Ship Armament Inventory List (SAIL) is produced on ORDLIS data-processing equipment. It replaces the Ordnance Inventory/ORDALT Status Reporting Program formerly used. Each ship has two copies of SAIL. Prior to a scheduled overhaul, one copy should be annotated with ORDALTs that have been completed since the last printing; this copy should be sent to NAVORDSYSCOM 7 months prior to the scheduled availability. The other copy is kept on board. Revised copies of the SAIL will be sent to each ship before overhaul. After completion of overhaul, annotate the SAIL to indicate all changes, deletions, additions, and corrections and forward a copy to NAVORDSYSCOM. Changes made at other times are reported on Ship Armament Inventory List (SAIL) Change Report, NAVORD Form 8000/2. NAVORDSYSCOM again revises the SAIL to include the changes made at overhaul. When you receive the revised SAIL, destroy the previous one.

The SAIL lists in sequence the following: all items pertaining to missile launchers, turrets, mounts, rocket launchers, projectors, torpedo tubes and depth charge release equipment; target designation systems (TDS), and weapons direction system (WDS); all items pertaining to missile test and telemetering equipment; and all items pertaining to target control systems.

The ORDALT Accomplishment Requirements (OAR) list is issued by NAVORDSYSCOM about 6 months prior to the overhaul of a ship. It shows the ORDALTs in the order of priority of accomplishment, the estimated man-hours required to accomplish, and the cost of each. The ship receives one copy, which must be given a thorough review and a report submitted within two weeks. The report must list all the ORDALTs completed after the "Prior to Overhaul" SAIL was submitted, ORDALTs that are on the OAR list but are not applicable, and a list of all the ORDALT material on board. The report goes to NAVORDSYSCOM, NAVSHIPSYSCOM, and the Ship's Parts Control Center (SPCC). They amend the OAR list, requisition supplies, and plan to accomplish as much of the additional work as is possible within the limits of the funds appropriated and the time available.

ORDALT Requirement (OAR) Lists are also published by NAVORDSYSCOM for new ships and major conversion ships. The lists are reviewed by the ship and the shipyard, and revisions submitted as in the case of ships in the active fleet.

Within 10 days after completion of overhaul, the fitting-out yard submits a report of what has been accomplished. A revised SAIL, including information from the latest OAR, is then issued by NAVORDSYSCOM and sent to the ship.

FORMS

Definition and Purpose of Forms

Forms are any printed labels and tags, placards, signs, decals, drawing formats, form letters, and any other duplicated or printed papers which require clerical fill-ins or have blank spaces for the insertion of information to complete their meaning. Forms are used for requisitioning repair parts, recording information, and reporting. Completing a form requires careful reading and checking the correct answers but it is much simpler and quicker than writing up a narrative report. Besides, it makes possible the accurate tabulation of results which are used as the basis for command decisions at all levels.

Form Numbers

The assignment of a NAVORD form number to a form shows that, before the form is issued,

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the originating activity has checked the form to make sure it does not duplicate or overlap existing forms. Sometimes the form number is the same as the reporting symbol. But this is not always true. You might even find a form with the same number as the Instruction that initiated the form. You can see that there can be confusion in identifying a form or instruction. The program is designed to eliminate and to prevent approval of unnecessary forms; to consolidate all similar forms; to standardize and simplify forms and related procedures; to ensure economical production, utilization, distribution, and stowage of forms; and to provide a central source of information about all forms.

You can find a list of forms, full information on their distribution, and instructions for requisitioning them in NAVSUP 2002. Incidentally, NAVORDSYSCOM welcomes recommendations from the fleet for the improvement of forms.

New Forms

Whenever new weapons or equipments are brought into the Navy, extra reports on all phases are needed so the performance of the new weapons or equipment can be evaluated. New report forms are introduced, tried, and revised, and some are discarded. Detailed instructions are issued to tell you how the reports are to be filled out. NAVORDINST 8821.3A gives procedures for Standardized Fleet Data Collection for Surface Missile Systems (SMS) and enclosed (with instructions) examples of NAVORD Form 8821/5, Non-Expendable SMS Equipment Status Log; NAVORD Form 8821/8, SMS Firing Report; and NAVORD Report Symbol 8821-10, Commanding Officers Narrative Report on Surface Missile Systems. These have replaced earlier forms used in reporting on missile system performance. To be of value in spotting deficiencies in the missile system, the facts recorded in the reports must be accurate. When you supply data to the person filling out the report, be sure you give correct information.

Reports used in the Maintenance Data Collection Subsystem (MDCS) are described in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C, Chapter 13. All the forms described are of importance to you. As a GMM 2 you will be required to assist in the preparation of OPNAV Form 4700-6, Weekly schedule.

The use of OPNAV Form 4790/2K is also described in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C. This is the form you have to fill out when you are unable to complete the maintenance work on a particular piece of equipment and it must be deferred until you can get parts and assistance from a repair facility. OPNAV Form 4790/2K is also used to report certain completed maintenance actions and as a work request. All details on this form must be carefully and accurately filled in. When used for deferred action, it may be several months before you can get repair assistance, and some important information could easily be forgotten in that time, so timely and accurate filling in of the form is essential.

SHIPBOARD ORDNANCE LOGS AND RECORDS

Logs

An ordnance log is a book which you record chronologically information about tests, overhauls, repairs, alterations, maintenance work, and operating performance on certain ordnance equipment.

The type commanders administrative inspection check off list determines the minimum requirements for logkeeping on your ship. It is anticipated that when the 3-M system becomes fully implemented in the Navy, the number of logs to be kept will be drastically reduced. However, because the documentation under the 3-M system does not give adequate life history of specific equipment, many rough and smooth logs are still required. Why keep an ordnance log? What is its practical value? An ordnance log serves a number of purposes. It gives the NAVORDSYSCOM a complete accounting of equipment operation. Such logs, over a period of years, help shape the policy of the Command as to the design of parts and the types of material used.

A well-kept log is handy to YOU as a casualty reference. If a casualty occurs that has happened before, the log can be consulted for the method of repair previously used. If a certain type of repair method has proved unsatisfactory, repetition of that method can be prevented by referring to the log. When a new man takes over a piece of launching system equipment or the system itself, he can refer to the equipment logs and become familiar with the equipment's peculiarities.

Alterations to equipment, and replacement of old equipment with new, have greatly increased ordnance efficiency over the years.

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These advances result from analysis of present equipment performance. This analysis must be based on accurate and complete data. Ordnance logs are an important source of this data. There are four general types of logs: smooth logs, rough logs, printed form logs, and maintenance checkoff lists. Deck logs and engineering logs were described in Seaman, NAVPERS 10120-E, with instructions given for keeping them.

Small Arms Log

The small arms log should show all pertinent information on all small arms aboard ship. It should list the weapons by serial number and type. Log entries should include any repairs, modifications, and types of casualties of each weapon, results of small arms inventories, and the location of each weapon.

Magazine Log

These logs are a record of the location and the material condition of ammunition, missiles, and pyrotechnics stored on board ship. The logs also record the condition of magazines and sprinkling systems. The GMM in charge of a magazine group maintains the log. It is a smooth log and kept in a bound ledger. The following items are usually included in the log.

1. Location and compartment number of all spaces where ammunition, missiles, or any explosive components are regularly stored.
2. Location of all maximum/minimum thermometers to be checked daily by the magazine petty officer.
3. Chronological entry of all scheduled tests, inspections, and repairs accomplished on any unit within the magazine.
4. List of equipment and components comprising the pyrotechnic allowance and the locations of each of these components.
5. Record of inspection section, usually in the back of the log.
6. Checkoff lists for inspections.

Magazine Temperature Log

As a striker or GMM, you will be expected to keep a magazine temperature log. This log shows the daily maximum and minimum temperature of missile magazines. Temperatures are also recorded daily on temperature cards posted in each magazine, warhead stowage space, and pyrotechnic locker. Space is provided on this card for recording the maximum and minimum temperatures and for the initials of the person taking the readings.

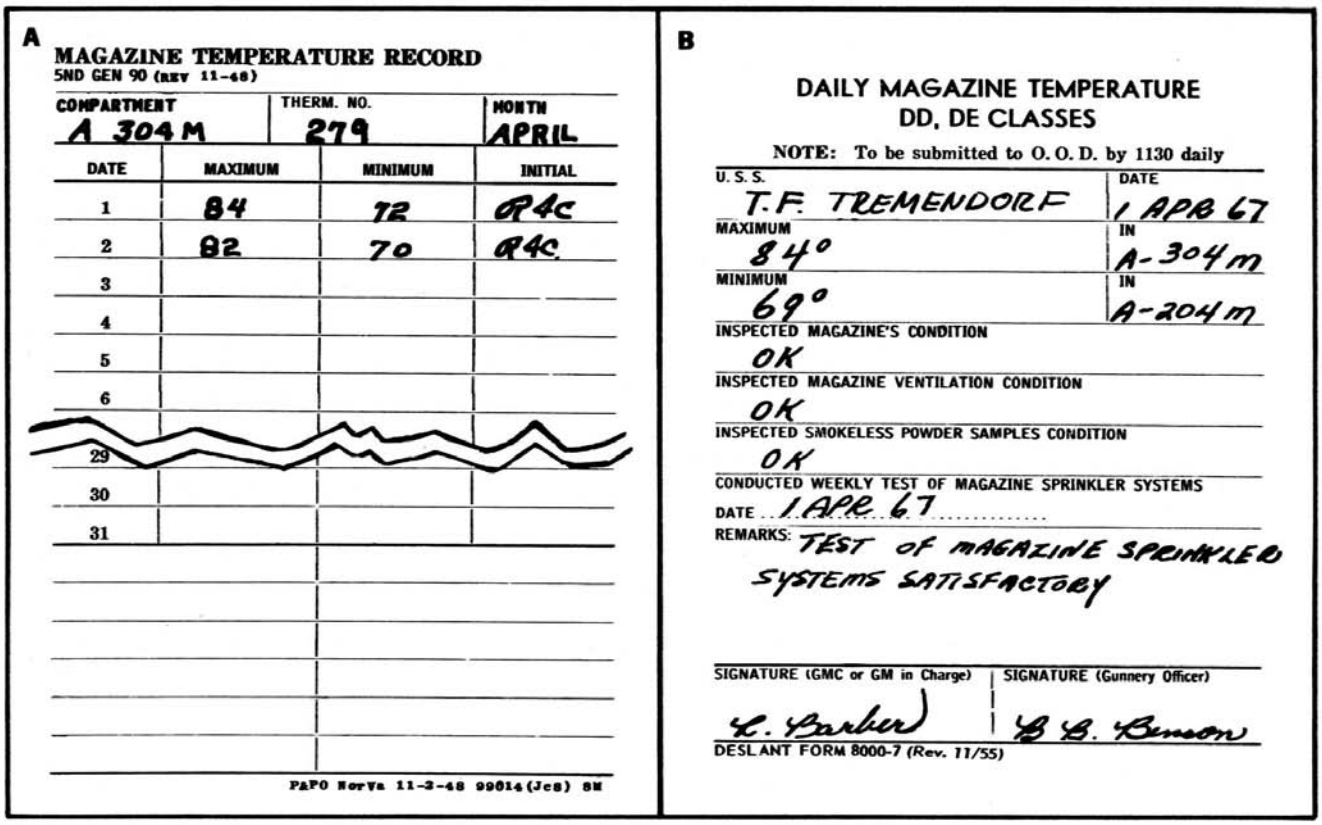
After you take the magazine temperatures, you must make out a daily temperature report. One copy goes to the commanding officer via the officer of the deck and another copy to the weapons officer. The magazine temperature log can be divided into two sections. The first section contains a chronological record of daily maximum and minimum magazine temperatures. The second section has a chronological record of monthly tests of sprinkler systems.

The maximum-minimum thermometer was illustrated in figure 10-19 and the method of reading it was described in the accompanying text. The forms used for recording the temperatures may be prepared aboard each ship, and therefore will show variations, or they may be prescribed by the Command. Figure 15-2 shows sample forms that may be used. The inspection of the magazines containing conventional ammunition components is done by the GMGs. The daily magazine temperatures are copied from the cards into a magazine log, which is the permanent record of all the magazine temperatures. Temperatures in excess of 100° F should be copied in red ink, or another color that will stand out. A separate section of the magazine log should be set aside for recording the results of the weekly sprinkling system tests. There will not be any smokeless powder samples, so you can ignore that question if it appears on the form. The temperature limit for missile propellants, however, is the same as for smokeless powder. When the temperature approaches this limit, the magazine may be cooled by turning on the ventilation. If the missile spaces are air conditioned, as they are on some new ships, you are not likely to have this problem. The temperature still has to be checked at least once a day to guard against possible breakdowns of the air conditioning system. Any time that the temperature is above 100° F, temperatures must be read and recorded every hour, and measures for cooling the area must be begun.

MISSILE LOGS

As Soon as a missile is brought on board, it must be entered and identified on the missile log. A record is kept of what happens to each

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A

MAGAZINE TEMPERATURE RECORD
5ND GEN 90 (REV 11-48)

COMPARTMENT	THERM. NO.	MONTH
A 304 M	279	APRIL

DATE	MAXIMUM	MINIMUM	INITIAL
1	84	72	R4C
2	82	70	R4C
3			
4			
5			
6			
29			
30			
31			

P&PO Norva 11-3-48 99014(Jc8) 8M

B

DAILY MAGAZINE TEMPERATURE
DD, DE CLASSES

NOTE: To be submitted to O. O. D. by 1130 daily

U. S. S. T. F. TREMENDORF
DATE 1 APR 67
MAXIMUM 84°
IN A-304 m
MINIMUM 69°
IN A-204 m
INSPECTED MAGAZINE'S CONDITION OK
INSPECTED MAGAZINE VENTILATION CONDITION OK
INSPECTED SMOKELESS POWDER SAMPLES CONDITION OK
CONDUCTED WEEKLY TEST OF MAGAZINE SPRINKLER SYSTEMS
DATE 1 APR 67
REMARKS: TEST OF MAGAZINE SPRINKLER SYSTEMS SATISFACTORY

SIGNATURE (GMC or GM in Charge) L. Barber
SIGNATURE (Gunnery Officer) B B. Benson

DESLANT FORM 8000-7 (Rev. 11/55)

Figure 15-2. — Magazine records: A. Magazine temperature record; B. Daily magazine temperature report. 5.66

missile, so that each missile has its own log. Always enter the date whenever you make an entry.

Rough Missile Logs

The missile log may be a ledger type notebook in which you write each item relating to the missile. The log should be neat, with each entry legibly written and clearly dated. The entries should be in sequence and orderly so the person who transfers them to the smooth log (usually the weapons officer) can see at once when each entry begins and ends and can read it easily.

Smooth Missile Battery Log

This log is a permanent record of important rough log items. The smooth log is not a copy of the launcher log or other equipment rough logs, but a condensation or amplification of the rough logs. The smooth log writer, usually the missile officer, takes special care to include items applicable to entry in the Ordnance History or other form used in place of it. All smooth logs are typewritten and kept in a looseleaf binder in the weapons office.

Printed Form Logs

NAVORDSYSCOM issues these for certain equipment. They are simply forms in which data are entered. They can be classed as smooth logs because they provide a legible and complete record. They also have a NAVORD Form number.

Maintenance Checkoff Lists

These are printed by either the type commander, or the ship. Essentially they form a smooth log.

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There are many other logs in which records must be kept, but the ones we have just covered concern you. For a complete list of logs and records that must be kept by the weapons department, see the appropriate ship's instruction.

MATERIAL RECORDS

Standardized material records have been established to keep track of all work done on each piece of equipment aboard ship. As a member of the weapons department, you will primarily be involved with the records concerning ordnance equipment.

Some record forms that have been in use in the past are being phased out to make way for the forms used in the 3-M system and the Maintenance Data Collection Subsystem.

Ordnance History Cards

The ordnance history cards and the shipboard 3-M system comprise the most important material records of the weapons department aboard ship. The weapons officer is responsible for maintaining these records in an up-to-date and useful manner.

The retained copies of the 3-M system schedules now are the principal sources of maintenance information on new construction. On older vessels, in addition to the retained copies of the 3-M schedules, material history is maintained on ordnance history cards. How maintenance history records are maintained depends on the type ship and how much change over from old type maintenance system to the 3-M system has been accomplished. Many of the former sources of maintenance history are replaced by the 3-M system. Various logs are also used in the weapons department for maintenance history information.

An ordnance history card contains the current history of each piece on board. Any information considered necessary in compiling a comprehensive history (major repairs, Ordalts accomplished, field changes made, etc.) is included on these cards. These history cards are retained as long as the equipment remains on board even if the vessel is placed out of service. In the event that a unit of equipment is transferred, the history card should accompany it.

A complete material history of an ordnance unit is important in determining maintenance, operational practices, safety precautions, and equipment capability. These cards can also be used as inventory records and should be grouped in a binder so that all cards for a given piece of ordnance, a gun mount for example, or located together for easy ordnance inventories. Information can be obtained for these cards from battery logs, smooth logs and a visual inspection of the equipment.

NUCLEAR WEAPONS REPORTS AND RECORDS

On ships that have nuclear weapons other than the nuclear warheads in missiles, the GMTs have the responsibility for all reports on them. The warheads contained in the assembled missiles are not the object of separate reports by you, but are shown in the report on the number and type of missiles aboard. The location, condition, and disposition of all nuclear material must be precisely accounted for to the Defense Atomic Support Agency (DASA).

Rules for peacetime operation of nuclear weapon systems issued by the Chief of Naval Operations along with official Naval Ordnance Systems Command special weapons check lists are mandatory directives which must be followed.

SPECIAL WEAPONS PUBLICATIONS

Special weapons publications which you will use are products of the Joint Atomic Weapons Publications System. The system was established by an agreement signed jointly by the Department of Defense and the Atomic Energy Commission. All Joint Atomic Weapons Publications (JAWPs) are assigned a Defense Atomic Support Agency Technical Publication (DASA TP) number. The short title for a specific JAWP consists of two parts: (1) a letter-numeral group which identifies the organization having an interest in the equipment described in the publications, (2) a letter and/or manual group that codes the publication to a specific subject. When reference to a JAWP is necessary between any of the services or agencies, the identifying designation of DASA TP is given. However, when reference to a JAWP is within a service or agency, the applicable identifying designation is used. For example, within the Navy Establishment, a JAWP is referred to as a NAVY SWOP (Special Weapons Ordnance Publication).

Publications pertaining to specific weapons system applications of a particular weapon will be identified by decimal numbers following the mark number; i.e., NAVY SWOP W25.21-X, a Mark 45 warhead used in the Terrier missile.

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Decimal numbers assigned, and presently in use or scheduled for use, are shown in NAVY SWOP 0-1.

DISTRIBUTION OF NAVY SWOPS

The Naval Ammunition Depot, McAlester, Oklahoma, maintains a NAVY SWOP Allowance list for each activity receiving NAVY SWOPs. This allowance list is kept current from the Naval Atomic Planning Support and Capabilities Report (NAPSAC), letter requests, and advanced planning information. Periodically, a copy of the allowance list is forwarded to the activity concerned for review. A copy is forwarded to the Type Commander, where appropriate, so that reference can be made to publications held by the ship. Distribution of NAVY SWOPs is made by NAD McAlester in accordance with the allowance list. NAD McAlester is the stocking and mailing point for all NAVY SWOPs except EODPs (Explosive Ordnance Disposal Publications). These are procured from the EODF (Explosive Ordnance Disposal Facility) at Indian Head, Maryland.

SPECIAL WEAPON OPERATION AND SAFETY

The operation of each type of nuclear weapon is described in the applicable NAVY SWOP. Nuclear weapons will be handled and stored in accordance with NAVY swap 50-1 and SWOPs of the 20 series. No ammunition assemblies or components shall be disassembled or modified unless authorized.

NUCLEAR WEAPON SECURITY

The Chief of Naval Operations is responsible for regulations for the security of classified matter. Basic security measures are set forth in U.S. Navy Regulations 1948, chapter 15, and OPNAVINST 5510.1 series. Specific references to classification policy, security of Restricted Data, security instructions for handling, transporting, and storing nuclear weapons components, and other security requirements are prescribed in OPNAVINST series 5510.

THE 3-M SYSTEM

During your studies of Military Requirements for Petty Officer 3 & 2, NavPers 10056-C, you learned about the Navy Maintenance and Material Management (3-M)System is now being implemented in the fleet.

The 3-M system is not covered in detail in this chapter. However, to refresh your memory on the details we will review some of the objectives of the 3-M system and its subsystems, which include the planned maintenance subsystem (PMS) and the maintenance data collection subsystem (MDCS).

The 3-M system is not designed as a cure for all equipment problems and attendant maintenance resource demands, nor does it eliminate the need for good leadership. The system is designed to: (1) reduce complex maintenance to simplified procedures that are easily identified and managed; (2) define the minimum maintenance required (preventive or corrective) and schedule and control its performance; (3) describe the methods and tools to be used; and (4) provide for the detection and prevention of impending casualties.

An effective 3-M system permits a ship to forecast and plan man-power and material needs, schedule maintenance, estimate and evaluate material readiness, and detect areas for improving training and maintenance techniques.

3-M SUBSYSTEMS

There are two subsystems of the 3-M system that are primary for shipboard personnel. The two subsystems are the Planned Maintenance and the Maintenance Data Collection Subsystems. When fully implemented and properly used, these two subsystems will:

Increase reliability. The reliability will be increased by regular planned maintenance thereby reducing the need for major corrective maintenance.

Increase Economy. Planned maintenance saves the cost of major repairs and/or equipment replacement.

Provide Better Planning. The 3-M system takes into account the many shipboard operations, upkeep, and employment schedules through advanced planning.

Simplify Records. Simplifies the recording of necessary data for shipboard maintenance management.

The MDC subsystem reduces paperwork aboard ship, superceding various reports and forms.

The Planned Maintenance Subsystem uses the Planned Maintenance System Manual, OPNAV

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43P1. This is the Departmental Master Manual which identifies all the available planned maintenance requirements for the equipments maintained by a specific department. The master manual also contains information concerning fundamentals of the PMS and is used by the department head in planning, scheduling, and supervising the required planned maintenance.

Planned Maintenance Subsystem

To set up the maintenance requirements for a weapons system and its associated equipment, data is collected from the fleet, system commands, equipment manufacturers, and other sources. The data is then analyzed to determine the necessary maintenance requirement for a given system. After the determination has been made, the necessary maintenance procedures are listed on standard Maintenance Requirement Cards (MRC) and distributed to the fleet. Eventually, every ship will receive MRCs for every piece of ordnance equipment on board ship. MR cards are covered in Military Requirements for Petty Officer 3 & 2.

Maintenance Data Collection Subsystem

The Maintenance Data Collection Subsystem provides a means of recording maintenance actions (planned or corrective) in a form suitable for machine processing; this permits evaluation of equipment performance, repair parts used, delays incurred, reasons for the delays, and man-hours required to maintain the equipment.

The Planned Maintenance Subsystem differs from the Maintenance Data Collection Subsystem in that the PMS tells when, how, and by whom the maintenance is to be performed; the MDCS informs the collection center what was done, who repaired the equipment, how long it took, and what repair parts were required to accomplish it.

To list all this information so data processing machines can use it, it must be reduced to codes. The Equipment Identification Code Manual (EIC Manual) lists the codes you will need. At first it may seem difficult to enter information by means of a code letter but, after a while, you will know many of the codes without having to look them up. However. be sure you are right because the data processing machine can't tell when you have put in a wrong code letter - you have to do it right. The information is punched onto cards which are fed to the data processing machine to collect and collate the information. Summaries of the results can point out the need for changes. One such change is the reduction in the number of tests of missiles required of GMMs.

SUPPLIES

Although the supply department is responsible for supplies, you need to know how to identify what you want to get, how to write out the request, and how to report on your use of the supplies. The publications containing the stock numbers are maintained in the supply department. Cooperation with supply personnel is essential in accomplishing your own duties.

SUPPLY DUTIES OF THE GMM

Small quantities of consumable supplies are kept in the weapons department. Included are quantities of paint, greases, oils, cleaning materials, etc., and also Some frequently used small repair parts. As the materials are used, the GMM in charge of the supplies must make replacements. He has to know how to fill out the request form that he takes to the supply department to requisition supplies. These forms are illustrated and explained in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C. The same text gives you information on sources of identification numbers for materials and spare parts. The Federal Stock Number is the most important identification number. All the FSNs are given in the Federal Supply Catalogs, but you may not have to use those to look up a number because the FSN for your equipment is usually given in several other sources. One of these is the COSAL, also described and illustrated in the above text, although no ordnance or weapons sections are shown.

COSAL AND WHAT IT MEANS

The Coordinated Shipboard Allowance list (COSAL) is the list of all operating equipment and equipage aboard a particular ship. Although the segments of the COSAL illustrated in your military requirements text are not ordnance items (except some propellants in the alphabetical listing), they show you the format of the COSAL. The ordnance segment uses the same arrangement of information. It has three parts. Part 1 lists

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the ordnance equipment and the major components, and gives the component identification numbers. Part 2 lists the repair parts allowed for the ship. The quantity of each and the Federal Stock Number is given. Anything listed in Part 2 is available aboard ship. Part 3 of the COSAL . is the final authorized on- board allowance quantity for a repair part. This is of most use to the Storekeeper. Items that are common to more than one department are totaled in this section. For example, a particular type of switch may be used in various applications on the ship. Part 3 of the COSAL will tell how many are to be on board and how many are allotted to each department. For a more detailed explanation of COSAL and how it is used, refer to Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C.

SOURCES OF ORDNANCE IDENTIFICATION

The publications most often used to identify ordnance material are:

1. The ordnance parts of the Federal Supply Catalog for identifying repair parts for requisitioning.
2. Illustrated Parts Breakdown of Ordnance Equipment (IPB). This publication is prepared by Ships Parts Control Center (SPCC). Each IPB is published for one particular type or piece of equipment, and describes and illustrates the relationship of all assemblies and parts comprising the equipment. IPB 0000 is an index of all IPBs. These were published by the former Ordnance Supply Office (OSO), now absorbed by Ship's Parts Control Center (SPCC).
3. Coordinated Shipboard Allowance List (COSAL), which was previously discussed.

One of the most important sources of identification is the information on nameplates. This may include the manufacturer's name, make or model number, size, voltage, and like information. Identification publications such as manufacturer's technical manuals may help you in identifying an item.

ORDNANCE IDENTIFICATION DATA

Ordnance identification data are important in identifying ordnance items. They should be used on all requests for material if the stock number is not available. These data include:

The MARK NUMBER, which identifies the particular model of a certain type of ordnance equipment.

A MODIFICATION NUMBER (Mod), which indicates a modification of the basic mark number. Modifications are numbered serially, beginning with zero, for each separate mark.

An IDENTIFYING NUMBER, which is the number assigned to the blueprint plan of an ordnance component or assembly. It may be a drawing number, a list of drawing numbers (LD), a sketch number, or an assembly number.

A PIECE NUMBER, which is a subdivision of the drawing number and identifies by a serial designation every item appearing on a given drawing. Sometimes the drawing and piece numbers are stamped or etched on the part itself. Piece numbers are rarely used in later type ordnance assembly drawings. It is now standard practice that each item in a drawing will have its own separate drawing number.

A revision letter is often added to identify a particular revision of a drawing or list of drawings used in the manufacture of a part.

SAFEGUARDING CLASSIFIED MATTER

The security of the United States in general, and of naval operations in particular, depends in part upon the success attained in the safeguarding of classified information. Security is not a separate burden to be imposed on personnel, but an integral part of the routine duties performed by personnel. The ideal to be sought of all personnel is that they automatically exercise proper discretion in the discharge of their duties and do not think of security of information as something separate and apart from other things. In this way, security of classified information becomes a natural element and poses no additional burden.

You will find some basic information on security in chapter 7 of Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C. In Seaman, NAVPERS 10120-E, you learned about logging classified mail, and how to handle classified correspondence. Some general pointers on security of classified information were given in Basic Military Requirements, NAVPERS 10054-C.

Publications giving any information on nuclear weapons or components have the additional classification of RESTRICTED. The material

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may be marked Confidential Restricted Data, Secret Restricted Data, or Top Secret Restricted Data. There is also Formerly Restricted Data. These also have the additional line "Atomic Energy Act of 1954" just below the classification. The old Restricted classification, not applied to nuclear information, has been discontinued.

Complete instructions on classified matters are found in OPNAVINST 5510.1C, "Department of the Navy Security Manual for Classified Information." This publication is one with which you should become familiar. Use it as the authoritative source of reference whenever a question of security arises.

The Two-Man Rule

The two-man rule is defined in OPNAV INSTRUCTION 05510.83. It is a security measure in relation to nuclear weapons and their components, including nuclear warheads. The two-man rule requires that a minimum of two authorized persons, each capable of detecting incorrect or unauthorized procedures with respect to the task being performed, and familiar with pertinent security requirements, will be present during all operations which require admittance to any portion of a nuclear weapon/delivery system which could permit its launching, arming, firing, or releasing.

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