ASSEMBLIES

16-INCH TRIPLE MOUNTS

U.S.S. NORTH CAROLINA (BB55)
U.S.S. WASHINGTON (BB56)
U.S.S. SOUTH DAKOTA (BB57)
U.S.S. INDIANA (BB58)
U.S.S. MASSACHUSETTS (BB59)
U.S.S. ALABAMA (BB60)

Chapter I

General Description

1. The main battery of each ship of the title comprises nine 16-inch 45 caliber guns. These are emplaced in three enclosed, armored, triple mount turrets, which are located on ship center line, two forward and one aft. The arrangement provides fire concentration of nine guns on either beam, six forward and three aft with precise location of turret and trunnion axes as tabulated below.

MOUNT LOCATION DATA					
Battleships 55 & 56			Battleships 57, 58, 59 & 60		
Turret No.	Vertical axis at frame	Trunnion axis above baseline*	Turret No.	Vertical axis at frame	Trunnion axis above baseline*
1	45 + 2'	57' 7"	1	41 + 3'	58' 9"
2	62 + 2'	65' 7"	2	58 + 3'	66' 9"
3	138	57' 4"	3	123 + 2'	58' 9"
		Frame			Frame
Ccntrol tower T.B.T.		72 + 1'9"	Control tower T.B.T.		68
Director No. 1		86	Director No. 1		83 + 1'
Director No. 2		121	Director No. 2		104 - 1'
*Baseline is 31 feet, 6 inches below deep water line, BB 55, 56; 33 feet, 6 inches all others.					

2. Each triple gun mount is an assembly* of 16-inch ordnance units, mechanisms or devices of the following Ordnance designations. The number of units of each design and their respective gun and turret locations are given in the "Lists of Assemblies" for each turret, Appendix I.

Gun, Mark 6, Mod. 1

Breech Mechanism, Mark 3, Mod. 1

Firing Lock, Mark 14, Mod. 5

Gas Ejector, Mark 4 or Mark 4, Mod. 1

Yoke, Mark 4, Mod. 1

Slide, Mark 4 or Mark 5

Deck Lug, Mark 6

Elevating Gear, Mark 4 and Mods.

Training Gear, Mark 1 or Mark 1, Mod. 1

Rammer, Mark 4 and Mods.

Sight, Mark 4 and Mark 4, Mod. 1

Projectile Ring, Mark 1

Projectile Hoist, Mark 7 and Mods.

Powder Hoist, Mark 8 and Mods.

Range Finder Stand, Mark 46

Fire Control Equipment

3. The triple mounting of these units in the turret provides separate gun and slide assemblies, served independently by their respective hoist and rammer assemblies, and enclosed within flame proofed subdivision of the gun house which provides separate gun compartment for each gun. The arrangement and equipment of all turrets is virtually identical, the principal variations being in the powder hoist height of lift, the elevating and training gear drives and the slide designs.

4. The ordnance assemblies are of the types and have design and performance characteristics indicated in the outline below.

*With Assembly Number and ship installation as given in the Preface.

(a) *Gun.* - The gun is a built-up piece of six cylindrical forged steel elements comprising a shrunk and ring locked assembly of three hoops and a jacket on a tube and rifled liner. It has conventional slide cylinder, slide key, yoke locking ring and seat for screw box liner. The bore is chromium plated from the band slope to the muzzle.

(b) *Breech mechanism.* - The breech mechanism is of the rotating plug, carrier type, with segmental stepped screw thread locking device. Plugs and carriers swing downward to open and are spring counterbalanced and hydraulically buffed. The opening device is a manually actuated operating lever; the closing mechanism is pneumatic.

(c) *Firing lock.* - The firing lock is similar to the standard lock (Mk. 14, Mod. 4) heretofore used throughout the fleet with breech mechanisms of this type.

(d) *Gas ejector.* - The gas ejecting arrangements are of conventional design and automatic action served from ship's supply.

(e) *Yoke.* - The yoke is of conventional design, is attached to the gun shoulder by standard type locking ring assembly, and provides lug seats for attachment of the gun recoil and counterrecoil mechanisms.

(f) *Slide.* - The slide designs are of two types, a cast slide being common to assemblies 69 to 71, 75 to 77 and 81 to 83, inclusive, while other numbers have forged slides. Both types are otherwise similar in their attached hydraulic recoil and hydro-pneumatic recuperator mechanisms. Both provide cylindrical sleeve bearing with bronze liners for supporting the gun and for providing for its recoil reciprocation. In this bearing the gun is prevented from rotating by conventional slide cylinder key in the barrel and mating longitudinal keyway of the slide bore. The trunnion journals are pivoted in special roller bearing assemblies which are mounted in deck lug bearings of the gun girders. The latter are plate and box girder structures with inboard girder elements common to the adjacent guns.

(*g*) *Elevating gear.* - The elevating machine, separate for each gun, is a conventional square thread screw and driven nut mechanism with oscillating bearing mounting for nut and nut gear assembly. It is arranged with power input to the nut gear through an electric motor driven variable speed hydraulic transmission. Control of the latter is through a hydraulic servo unit connected to the transmission tilting plate and arranged for alternative selective control:- *Remote control** through a receiver regulator; and, *director or local control* through gun layer's handwheel gear. The gun layer is located on the electric deck and operates by follow-the-pointer orders mechanically transmitted from right or left sight pointer's stations and electrically transmitted by director.

(*h*) *Training gear.* - The turret training machine is an annular rack with twin pinion-wormwheel drives and electro-hydraulic transmission arrangements in which a single pump supplies the two hydraulic motors which are coupled to the respective worms. Control is similar to the elevating gear with variation permitting trainer's input, mechanically, from right or left sight trainer's stations, to the control valves of the servo unit.

(*i*) *Rammer.* - The ramming machines are independent units separately controlled and are conventional arrangements of electro-hydraulic drive ramming chains. The spiral chain track casings and the power units are located on the shelf plate overhang beneath the turret officer's compartment. A feature of the design is an adjustable stop control mechanism which provides automatic cut-off at limits of chain travel.

(*j*) *Projectile hoist.* - Projectile stowage is on two levels with arrangements on each for stowage fixed and stowage rotating. Loading apertures for each of the three hoists are flush with each stowage level and permit any hoist to be loaded from either level by parbuckling. The rope and capstan rigs which thus serve the hoists also enable skidding the shells from the fixed stowage to the rotating ring and thence to the hoists. The latter are

* Planned. Not installed initially.

reversible hydraulic lifts which move projectiles in stages, each stage being equal to delivery of a projectile from the hoist to the hoist cradle. Cradle and spanning tray are equipped with hydraulic power cylinder which pivots projectile and cradle to loading position aligned with the rammer and gun.

(*k*) *Powder hoist.* - Powder hoists are electro-hydraulic powered car type lifts housed within separate curved course hoistways which extend from the 2nd platform to delivery apertures at the respective rammer trays. Each car is arranged in an interlock system which automatically interlocks the hoist controls and the hoist doors and prevents simultaneous opening of upper and lower doors. Powder is manually served from the magazines through self closing scuttles in the lower foundation and the powder handling room bulkhead to the car. Thence, the loaded car delivers full service charge of six bags to the rammer tray without further handling.

(*l*) *Sight.* - The sight installation is a duplex arrangement comprising identical left and right stations, outboard respectively of the wing guns. Each such station has telescope equipped pointer's and trainer's stations and a follow-the-pointer sight setter's station, with handwheel outputs thence to the telescope mounts to provide line of sight deflection and angle values. Synchronized cross shafts interconnect the like equipment of each station and thus eliminate lag as one station takes over from the other. Gun and turret position control from these stations are by mechanically transmitted orders to the respective gun layers and the turret train operator. Turret train has alternative direct control as indicated in (h).

(*m*) *Range finder stand.* - The range finder stand is a stabilized range finder operating and supporting mechanism with hood enclosing elements, all of conventional arrangement and design and identical installation in all turrets.

(*n*) *Fire control.* - The fire control installations in each turret comprise a range finder (43 ft. base), an auxiliary computer, a system of

indicators, the sight telescopes and other units together with transmitting circuits. These are arranged to serve in alternative control systems of three types and several variations.

(1) Local fire control is the designation for turret control using turret range finder range factors and auxiliary computer values to position the guns.

(2) Primary fire control is director system of control from forward or after fire control director through plotting room computer and automatic transmission, thence to the mount indicators. Primary control may be by continuous transmission of corrected orders or by selected position alternatives.

(3) Auxiliary control is an alternative emergency director system for use when the plotting room circuits or computers are out of commission. It is director fire control by means of control tower auxiliary computer or No. 2 turret computer. Selector switches for this system of control are located in turret No. 2.

(o) *Protection.* - The preceding described ordnance units are housed within a rotating turret structure which is protected by heavy armor plate on the gun house and from the shelf plate to the 2nd deck is enclosed within a cylindrical barbette of proportionately thick plate. Belt armor, deck plating and heavy circular foundation plates constitute protection for the space below. Thus enclosed the entire space is water, gas and weather sealed with special provision for adequate ventilation of all subdivisions and for maintenance of air pressure level throughout. Semiautomatic sprinkling facilities are provided for gun compartments, hoist trunks and projectile stowage. All water, compressed air, power supply services and communication leads are brought in conventionally through a central column trunk and column pivot casting.

5. Descriptions and maintenance instructions for each ordnance assembly described in the above outline are contained in the chapters following.

Chapter II

GUN ASSEMBLY

GUN MARK 6, MOD. 1
BREECH MECHANISM MARK 3, MOD. 1
FIRING LOCK MARK 14, MOD. 5
GAS EJECTOR MARK 4, AND MARK 4, MOD. 1
YOKE MARK 4, MOD. 1

General Description

1. The three gun assemblies of each turret comprise virtually identical arrangements of gun, breech mechanism, firing lock, gas ejector and yoke of the designs indicated in the title. Each such gun is mounted in a separate slide and is located in a turret subdivision that provides separate gun compartment isolated from the adjacent guns, the booth and the sight stations. It is a bag type gun and carrier type breech mechanism assemblage, with conventional screw box liner, gas check seat, plug and mushroom closure of the breech. Yoke and gas ejector designs are conventional. In general arrangement the assembly is similar to the heavier gun assemblies of the U.S.S. WEST VIRGINIA class, but ballistics and details are substantially different.

2. Right, left and center gun assemblies vary only as to positions of parts; guns mounted in cast steel slides (Mk. 4) vary from guns mounted in forged steel slides (Mk. 5) by the design of the gas ejector system. These variations are described in the text below.

GUN

3. Gun Mark 6*, Mod. 1 (dr. no. 204093) is a 16-inch 45 caliber built-up assembly of six cylindrical elements. Designated in the usual manner (letters from bore out and numbers from breech forward) these are: the liner, tube "A", jacket "B1", hoop "B2", hoop "C1", and hoop "C2". The profile of this gun is a straight slide cylinder from the breech 304 inches toward the muzzle and thence a stepped and tapered chase to a straight muzzle cylinder. The bore has uniform twist rifling of 96 grooves. It is chromium plated, 0.0005 inch, from the band slope to the muzzle. Other features and data are according to the tabulation following.

* All guns of this mark in service are of the modified design in which the breech mechanism hinge lug has been moved from the yoke to the bottom of the gun shoulder.

TABLE OF DIMENSIONS - WEIGHTS - BALLISTICS	
GUN	**AMMUNITION**
Max. dia. 46.0 ins.	16-in. A.P. Projectile (Type A)
Total length 736.0 ins.	Dr. no. 199144
Total weight (breech solid) 192,310 lbs.	Weight 2240 lbs.
Center of gravity (from breech, breech solid) 253.12 ins.	Length 4.0 Cals.
Powder chamber:	Ogival Radii:
Diameter 18.35 ins.	Projectile, 24.0 ins., 13.7 ins.
Choke Dia. 17.50 ins.	Windshield 144.0 ins.
Length 91.435 ins.	16-in. A.P. Projectile (Type C)
Volume 23,194 cu. ins.	Dr. no. 204205
Rifling:	Weight 2700 lbs.
Length 616.86 ins.	Length 4.5 Cals.
Length of Cr.plate 625.0 ins.	Ogival Radii:
No. of grooves 96	Projectile, 24.0 ins., 19.0 ins.
Depth 0.15 ins.	Windshield 144 ins.
Twist - right hand, one turn in 25 calibers.	Service powder charge:
Travel of projectiles	No. of bags 6
A or C 624.073 ins.	Weight of charge 542 lbs.
	Ballistics:
	(Service Velocity)
	O.P. 757 2300 f.s., I.V.
	O.D. 3456* 2225 f.s., I.V.
	(Target Velocity)
	O.P. 758 1800 f.s., I.V.
	O.D. 3455* 1725 f.s., I.V.
* Calibration of range scales of fire control equipment is based on these computed range tables of average velocities.	

4. *Screw box liner.* - The screw box liner, an adapter threaded into the breech of the gun, provides a stepped thread arrangement to accommodate the plug (drs. no. 216317 and 216318). Made of nickel steel, the liner has buttress type male thread, right hand, one-half inch pitch. It screws into the breech of the gun to butt against a shoulder and is locked exactly in position by the lower rotating cam and safety arc which is fitted into a matching recess in the liner and gun. Provision is made inside the liner to lock the breech with 24° rotation of the plug after engagement of the plug threads. The internal surface of the screw box liner is divided into 15 sectors of 24 degrees. Divided into three groups of five 24° sectors each, the radius of each sector in the group decreases clockwise with the largest radius blank and the successive four steps threaded with 0.90 inch pitch, right hand, buttress type threads. The blank sector is undercut to provide for the 6°-12'-46" of

rotation and translation which the rotating cams provide to change the carrier closing motion to plug, breech locking, rotation. These blank sectors are also cut on radii about the hinge to clear the plug as it rotates about the hinge in retracting.

The shoulder just rear of the external thread of the screw box liner butts against the gun and leaves an annular space between the gun and the next shoulder as an air duct for the gas ejector system. A seal groove between this duct and the breech face prevents the escape of air; this seal is serviced with O.S. 1162 using stock material tool 8-Z-954. Holes drilled from this duct through the screw box liner at an angle and fitted with nozzles cause air of the gas ejector to meet in the center of the gun and on the injector principle, force a blast of air through the gun.

The face of the screw box liner is drilled to provide for mounting the Mark 2 boresight holder.

BREECH MECHANISM

5. The 16-inch breech mechanism Mark 3, Mod. 1 is of the stepped thread, rotating and swinging plug type described in detail in the paragraphs that follow. The design is the same for all three guns, the only variation being right and left assemblies of the holding down latch foot lever and the closing valve mechanism. The right hand assembly is installed on the right and center guns and the left hand assembly is on the left gun. There is a similarity between this breech mechanism and 16-inch breech mechanisms of the U.S.S. WEST VIRGINIA class, however, many details and subassemblies are new, notably, the new positive action type salvo latch, rotating cams, closing valve mechanism, and hinge lug attachment.

6. The principal components of each breech assembly are:-

(*a*) Plug.
(*b*) Mushroom and gas check.
(*c*) Carrier.
(*d*) Hinge lugs and roller bearings.
(*e*) Carrier holding down latch.
(*f*) Breech opening buffer.
(*g*) Counterbalance and closing cylinder.
(*h*) Reducing valve.
(*i*) Rotating cams.
(*j*) Operating lever and connecting rod.
(*k*) Salvo latch.
(*l*) Firing mechanism.

7. *Plug.* - Mounted on the carrier with the mushroom and gas check pad on the forward face, the plug, (dr. no. 53771), is machined to fit the screw box liner and close the breech of the gun by 29° of rotation. Divided into three 120° sectors of five 24° sectors each, the outer surface of each 120° sector has four stepped thread sectors and a blank sector decreasing consecutively in radius clockwise. The threads of the threaded sectors are 0.90 inch pitch, right hand, buttress type threads. The blank sector undercuts the clockwise adjacent threaded sector to provide the 6°-12'-46" necessary to change plug translation to rotation. These blank cuts clear the screw box liner on radii about the center of the hinge. Inside the plug, forward to rear, is a bearing surface for the carrier journal, a relieved section, and a section threaded with 0.90 inch pitch square threads. The bearing section of the inside of the plug is lubricated from an oil hole in the upper blank sector. The internal square thread is lubricated from an oil hole on the plug face. The rear face of the plug is drilled to receive the plug rotating ball pin, the plug handle, and has raised slots to provide for the rotating cam rollers.

8. *Mushroom and gas check pad.* - These two elements, shown on drawing number 53965, are assembled on the plug and carrier. The gas check pad, a fabric covered pad of tallow and asbestos, fits the forward face of the plug between the plug and the head of the mushroom and is protected by steel rings. The mushroom, a mushroom-shaped forging of nickel steel, covers the inner face of the plug and extends through the plug and carrier spindle. The mushroom is keyed to the carrier and held against the gas check pad and plug face by a split lock nut compressed spring. The stem of the mushroom, just rear of the nut, has a bayonet joint for attaching the firing lock receiver and is made to receive the primer seat bushing. A hole extends from the primer seat through the stem of the mushroom to ignite the powder in firing the gun. The gas check pad is a distensible gasket in operation; due to the difference in the area of the mushroom face and the area of the gas check pad, the pressure of the pad exceeds the gas pressure and prevents the escape of gas on firing.

9. *Carrier.* - Attached at the bottom of the gun shoulder, 9.35 inches forward of the breech face and 31.50 inches below the center of the gun and plug is the carrier hinge about which the plug and carrier rotate in opening and closing the breech. The carrier (dr. no. 53858) is a steel casting comprising a spindle, hinge, and supporting element with provision for the spring rod brackets, operating bar, firing mechanism, mushroom, safety arc, and a wrench hole for access to the lower rotating cam roller. The spindle extends into the plug, its forward

part fitted with a bronze bushing and rear part providing a 0.90 inch pitch square thread to fit the plug. This thread supplies true axial translation to the plug as it unscrews from the liner, before the carrier begins to rotate.

10. *Hinge lugs and roller bearings.* - Serving to hinge the carrier the hinge lugs fasten to the gun below the breech with the hinge center forward of the breech face of the gun. Shown on drawings 54982 and 233198 the hinge lug is a cast steel piece providing two hinge projections, a latch lever lug and two closing valve lugs. The lug is shaped to fit the gun shoulder contour. It is centered by a cover plate retained dowel and bolted to the gun with special nickel steel bolts. The hinge lugs are provided with an eccentric bushing adjustable in rotation to change the position of the hinge center on a 0.10 inch radius about the true center of the hinge. The roller bearings and cage fit inside the eccentric bushing between the bushing and the hinge pin and are retained by the hinge pin, nut and carrier. The hinge pin fits the carrier and rotates with the carrier in the hinge lug bearing.

11. *Carrier holding down latch.* - A device for holding the carrier in the breech open position (dr. no. 233710), the holding down latch is a stiff leg or toggle between the latch lug on the hinge lug and a lug on the carrier. A crank, which extends through the spring rod brackets and carrier, acts as a pivot pin for one lever of the stiff leg and is keyed to the lever so that the crank pulls the stiff leg past center allowing it to collapse. A hinge spring straightens the stiff leg latch, bringing it past center to its locked position, upon opening the breech, to secure the breech in open position. The latch operating crank is foot operated from the loading platform.

12. *Breech opening buffer.* - Located below the breech in the way of a raised pad on the carrier the breech opening buffer functions to buff the last 14° of carrier rotation. The buffer is of the piston and cylinder type with three groove type throttling ports in the cylinder wall and an expansion chamber to allow for the volume displaced by the piston rod. The piston rod extends through a Garlock type packing and a conventionally arranged spiral spring. It operates with recoil cylinder liquid (O.D. 1914) as the fluid medium. The cylinder is filled with the piston in the released position by removing the plug, piece 56474-6, and filling to level of opening (gun at zero degree elevation). When the plug is replaced it provides the expansion space needed.

13. *Counterbalance and closing cylinder.* - The counterbalance and closing cylinder, shown on drawings number 233708

and 233709, is a dual arrangement for balancing the resultant weight of the breech assembly in opening and for swinging the carrier in closing the breech. The closing cylinder bracket, mounted on the yoke, provides bearings for the journals of oscillating bearings. These bearings provide for the oscillation of the assembly in opening and closing the breech, provide spring seats and caps for the closing cylinders. Each air cylinder screws into its oscillating bearing and with the piston and spring rod extends through the spring to the spring rod brackets attached to the carrier. The spring bears on the oscillating bearing on one end and on a frictionless ball bearing washer within the spring adjusting nut at the other end. This spring is adjusted on both cylinders so that their combined action will prevent the breech down swing from being stopped with damaging shock and yet allow securing of the breech in open position by the latch. The mechanism is packed at assembly liberally with O.S. 1165 and is disassembled and repacked annually.

14. The air for closing the breech is received from the gas ejector system supply at pressure of 200 pounds per square inch. Air is passed through a reducing valve (Mason or Foster), reduced to a pressure that will satisfactorily close the breech, and ported through a rotary type closing control valve to the closing cylinders. The closing valve is controlled by a crank located on the hinge lug which is foot operated simultaneous with the latch foot lever. This closing valve is opened by the foot lever and closed by a part of the valve operating lever in the way of and moved by the carrier as the breech closes.

15. *Reducing valve.* - The Mason type valve is generally used with the breech closing mechanism. It functions to control the pressure to the closing cylinders. Reduced or throttled air pressure acting on a spring controlled diaphragm controls a pilot valve which in turn controls the spring loaded, piston operated, throttling valve to control pressure to the closing cylinder. The stem of the pilot or auxiliary valve is spring held against the diaphragm and moves with the diaphragm as the diaphragm is moved against its adjustable spring by closing cylinder pressure. The diaphragm spring is adjusted to control closing cylinder pressure for satisfactory operation of the breech mechanism by a square head adjusting screw extending through the top of the valve. The main valve operating piston is operated by inlet chamber pressure ported to it by the pilot or auxiliary valve and acts against the stem of the spring loaded main valve to open the valve and throttle air to the closing cylinder. The operating piston is restrained against chatter by an integral dashpot arrangement. A lifting bolt (50266-18) is provided for pulling the dashpot

piston out of the cylinder. This valve assembly and the Foster valve are both 3/4 inch reducing valves with union connections to the air line and are secured to the breech face of the yoke by pipe clips.

16. *The Foster valve* is alternately used as a reducing valve for the closing cylinder and functions to control the pressure the same as the Mason valve. The arrangement of the Foster valve is shown on drawing number 179766. It consists of a valve controlled by a spring loaded diaphragm between closing cylinder pressure and atmospheric pressure. The main valve is a faced plunger, spring held against a funnel shaped piece extended through the valve port and connected to the diaphragm. The main valve operating piece which extends through the diaphragm is held against the main valve by spring pressure and moved away from the main valve by ported closing cylinder pressure to allow the main valve to close. The pressure to which the main valve holds the closing cylinder air pressure is determined by the spring pressure back of the diaphragm and is adjustable by means of a spring pressure adjusting screw on top of the valve.

17. *Rotating cams.*- The upper and lower rotating cams work in synchronism with the cam rollers on the plug to transform plug and carrier rotation about the carrier hinge to plug rotation about the carrier spindle. This change of motion is produced by the experimentally determined curved cam surfaces of the rotating cams which produce plug rotation (when closing) from carrier motion in the final 5°-38'-41" of carrier travel and first 6°-12'-46" rotation of plug. These movements impart the rotation necessary for complete engagement of the stepped threads. The upper cam is secured to the screw box liner by two bolts and further held by the salvo latch bracket which fits into an undercut in the side of the cam flange. The lower cam is fitted into a recess cut in the gun and screw box liner and is secured with four bolts. An integral part of the lower cam is the control arc, made on a radius about the hinge center, which projects through the carrier with the breech closed. After the plug has been completely rotated when opening the breech this arc functions to retain the plug in its rotated position until the cam roller strikes the cam surface in closing. The upper and lower brackets for the cam rollers fit into the raised slots in the rear face of the plug and are further secured to the plug by a bolt. The cam rollers are pin mounted on these brackets. The cam and cam roller sets are synchronized for each breech upon manufacture and because of the exacting position requirements are not provided with adjustment.

18. *Operating lever and connecting rod.* - The operating lever is a cast steel lever pivoted on the side of the

carrier with a connecting rod extending from a pivot on the lever (2.75 inches from the fulcrum) to a plug pin in the breech plug rear face. The motion of the lever about its fulcrum causes the connecting rod to reciprocate and thus rotate the plug through 29°. A beveled, spring-plunger catch is contained in the handle end of the lever to catch the salvo latch when the breech is closed. The connecting rod, pin connected to the operating lever, is of forged steel and has a split socket bronze bearing fitted on the ball of the plug pin. The wedge retracting lever catch fastens to the operating lever to connect the lever to the firing mechanism. In opening, the operating lever is stopped at the end of its swing by a rawhide bumper. In closing, the swing of the operating lever is stopped by the operating lever buffer in the salvo latch bracket.

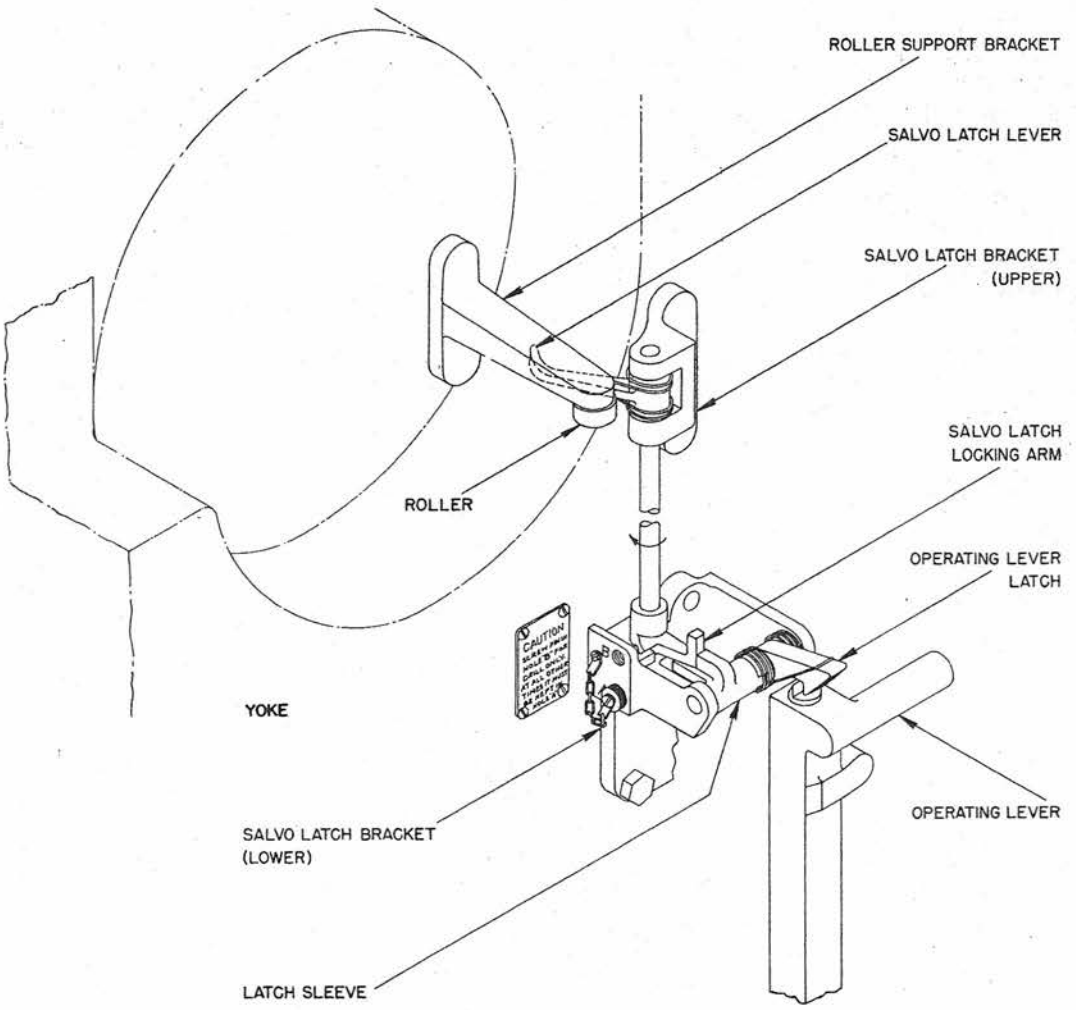

Fig. 1 - Salvo Latch

19. *Salvo latch.* - The salvo latch is an automatic latching device of positive action type that functions to prevent lifting of the operating lever latch, when the breech is closed, and which operates to release the lever latch after the gun recoils. Figure 1 shows the assembled arrangement. This includes a lower salvo latch bracket on the gun and an upward extending shaft with a lever cam that is positioned in the way of a cam roller mounted on the slide.

The lower salvo latch bracket is bolted to the screw box liner and fits into an undercut in the upper rotating cam. Integral with the salvo latch bracket is the cylinder and expansion chamber of the operating lever buffer. This buffer is of the plunger type using recoil cylinder fluid O.D. 1914 as the liquid medium, throttling it through four different length milled grooves in the plunger. The buffer is filled to the level of the filling plug and thereafter upon replacing the plug contains air sufficient for operation.

The latch lever cam is positioned in the path of a cam roller attached to a bracket on the counterrecoil cylinder. When the gun recoils the cam roller moves the salvo latch lever, rotates a shaft from the upper bracket to the lower bracket and moves the salvo latch locking arm. The displacement of the salvo latch locking arm allows the salvo latch catch to rise and prevent the salvo latch locking arm from returning. The salvo latch locking arm, attached to the salvo latch lever shaft, is positioned in the way of a lug on the latch sleeve and since the latch sleeve is connected to the operating lever latch, the latch cannot then be lifted. However, when the latch locking arm is held in its displaced position by the latch catch, the operating lever latch can be raised to release the operating lever. The raising of the operating lever latch compresses the spring of the latch catch allowing the latch locking arm to be repositioned over the latch catch and also be in the way of the lug on the operating lever latch sleeve to lock the lever latch.

20. To defeat this combination requires a deliberate act for the operating lever cannot be released until the gun has recoiled except by first moving the latch locking arm aside. The operating lever latch then remains unlocked until it is lifted to release and unlatch the operating lever when it depresses the latch catch to reset the mechanism. Provision is made, however, to secure the latch locking arm in its unlocked position for drill purposes by screwing the latch locking pin into hole "B". Extreme care must be exercised to ascertain that the latch locking screw is secured in hole "A" and not "B" when the gun is fired as this lock is to prevent the danger of opening the breech in case of misfires or hang fires which might go unnoticed when a number of guns are fired in salvo.

21. *Firing mechanism.* - The firing mechanism is an assembly for positioning the firing lock and synchronizing its position to the position of the operating lever. Connected to the operating lever by the retracting lever latch, the wedge retracting lever is adjacent to the operating lever. A crank shaft from the wedge retracting lever extends through the operating lever shaft to the crank operated crosshead. The crosshead, sliding vertically in a slot in the carrier, has a part extending into the crosshead slot in the lock operating bar. This mechanism changes wedge retracting lever rotation to crosshead vertical translation which in turn acts through the lock operating bar slot to cause lock operating bar translation at 21° from vertical. This motion of the lock operating bar, as the wedge retracting lever rotates with the operating lever in opening the breech, retracts the wedge of the firing lock and the used primer is ejected. In case of misfire the wedge can be retracted without opening the breech by unlatching the wedge retracting lever and rotating it independent of the breech operating lever. A spring latch in the end of the operating bar facilitates the removal of the firing lock which can be unlatched and removed by fully retracting the wedge to clear the safety arc and rotating the firing lock 90° on its bayonet type joint on the mushroom stem. The assembled arrangement of the mechanism is shown on drawing number 59295.

FIRING LOCK

22. Firing Lock Mark 14, Mod. 5, used with this assembly provides both percussion and electric firing. As operated by the firing mechanism the firing lock is in a position to fire the gun only when the breech is completely closed. This firing lock is shown on drawing number 118488 and is described in Ordnance Pamphlet 239.

GAS EJECTOR

23. The gas ejector is designed to expel gases from the muzzle of the gun and prevent gas from entering the turret when the breech is open. A part of the high pressure air and gas ejecting system, shown on Philadelphia Navy Yard drawing number BB556-4902 BZG, the section under ordnance cognizance is shown on drawing number 216388. Torpedo charging pressure is brought into the turret through the central column to supply air for the counterrecoil system, the gas ejector and auxiliary gas ejector. Being reduced in pressure, gas ejector air passes into seven relay tanks located on the upper and lower shell handling flats and from thence through swivel joints past the slide trunnions to the slide. The ejector air supply passes through an expansion joint from the slide to the yoke and breech of the gun.

24. Extending from a 1-1/2 inch Globe valve adjacent to the shelf plate and transverse gun girder below the slide trunnion, the gas ejector includes all the elements required to deliver air to the screw box liner of the breech. Three swivel joints provide for the changing position of the slide. To allow for motion of the yoke with respect to the slide on recoil the air is carried from the slide to the yoke by an expansion joint. This is a sliding connection that consists of a sleeve arrangement with a stuffing box mounted on the slide and yoke. (Packing for this stuffing box is 1/4 inch, Navy specification 33P7.) Gas ejector valve Mark 7, poppet type, controls the gas ejector air. Turned on automatically by a cam on the plug when the breech is opened the valve is closed manually when the gas has been expelled.

25. A hole from the face of the screw box liner to the gas ejector chamber between the screw box liner and the gun, admits air from the gas ejector valve. This annular gas ejector space is sealed by a plastic metallic packing between the screw box liner and the gun. Three holes extend through the screw box liner from the gas ejector space and are fitted with nozzles to cause the jets of air to meet in the center of the bore of the gun.

26. This arrangement causes a blast of air at 200 pounds per square inch pressure to be released into the gun directed toward the muzzle. The gases of firing are thus expelled simultaneous with the opening of the breech. In case of emergency an auxiliary gas ejector provides a hose with a quick opening valve and nozzle which can be directed into the gun. This auxiliary gas ejector is stowed overhead adjacent to the breech of the gun.

27. The two gas ejector designs differ only as to piping arrangements. Gas Ejector Mark 4 applies to gun assemblies installed in cast steel slides; the modification applies to gun assemblies installed in forged steel slides.

YOKE

28. The gun yoke is a large cast steel counterbalancing unit mounted on the gun shoulder and providing lug seats for attachment of the recoil piston rod at the bottom and the two recuperator yoke rods at the top. Yoke Mark 4, Mod. 1 (dr. no. 233703) is installed on right, center and left gun assemblies. The yoke is secured to the gun by a key and locking ring on the gun. A shoulder on the yoke butts against the rear face of the yoke locking ring recessed in and secured to the gun. The yoke locking ring which slides on over the muzzle

of the gun, threads into the yoke, bearing against the ring on the gun and forcing it against the shoulder on the yoke thus securing the yoke to the gun. When in place the yoke locking ring is secured by a lock plate bolted in one of twelve positions provided.

29. The shape of the yoke provides for elements of the gun slide and breech. Two pockets in the center of the top of the yoke accommodate balancing lead. Just below the balancing pockets are two holes to fasten the yoke to the counter recoil cylinder yoke rods and at either side are spaces to clear the counter recoil cylinders. Forward at the top of the yoke is a slot to receive the yoke locking device. Two holes located forward and below the gun on the yoke are for stop pins* to stop the yoke on return to battery. The large lug on the bottom of the yoke is used to secure the gun assembly to the recoil cylinder piston rod. To provide for fastening the hinge lug of the breech mechanism to the gun, the lower section of the yoke is cut away toward the breech. Inside the yoke a keyway is provided for the gun locking key and the forward end of the bore is machined to form the locking ring shoulder and screw thread. A recess provides for the locking ring locking plate. A slot on the side of the yoke is for the gas ejector piping.

Operation of the Gun Assembly

30. The sequence of gun operations incident to loading and firing are as follows: Having prepared the salvo latch for firing operation by securing the latch locking screw in hole "A" the latch locking arm is manually thrust aside for initial opening of the breech. The operating lever latch is then disengaged and the operating lever pulled rearward and downward rotating the plug and swinging the breech open. Counterbalanced by springs the plug swings downward and is stopped by the breech opening buffer and is secured in the open position by the carrier holding down latch.

31. Opening rotation of the plug trips open the gas ejector valve. The gas ejector operates to expel the gases continuously until the valve is cut off by the plugman. The plugman observes the condition of the gun bore, using the auxiliary gas ejector if necessary, and cuts off the gas ejector when ready for loading.

32. With the plug latched open the primer is inserted by the primerman whose platform is located below and left of the plug (right and center guns), and below and right of the

* Gun assemblies mounted in cast steel slides omit these pins; the pins are seated in the rear face of the slide.

plug (left gun). The gun being loaded the holding down latch lever is foot operated to release the latch and the foot lever of the closing valve is moved to open the valve. The plug swings up, follows the rotating cams, rotates until the operating lever is almost to the latch. The operating lever is then latched by hand to prevent any possibility of it rebounding, thus allowing the unfired primer to be partly ejected and sheared off on reclosing.

33. The operating lever latch is locked by the latch locking arm until recoil of the gun moves the latch locking arm aside releasing the latch for reopening the breech in the new cycle of operation. Distinction is made between initial manual positioning of the latch locking arm and automatic positioning by the salvo latch cam and roller to release the operating lever latch upon gun recoil.

34. It is possible to eject the primer without opening the breech by unlatching the wedge retracting lever from the operating bar and pulling it down. The primer can then be extracted and replaced.

35. *Non-firing operation.* - When the breech is to be opened without firing the gun, two methods can be used. The latch locking arm can be manually thrust aside to unlock the operating lever latch each time the breech is opened or the latch locking arm can be secured in the unlocked position by placing the latch locking pin in hole "B". Every precaution should be exercised to ascertain that the latch locking pin is removed from hole "B" and placed in hole "A" upon securing the breech.

MAINTENANCE INSTRUCTIONS

36. The gun assemblies are to be operated, adjusted and serviced in accord with the regulations prescribed in the "Ordnance Manual" and the instructions that follow.

37. *Lubrication.* - Lubricate the gun assemblies according to the schedules and with the lubricants prescribed on the lubrication charts.

38. *Adjustments.* - Maintain adjustments of adjustable elements of the gun assemblies as prescribed in paragraphs 46-49.

39. *Gun bore.* - Chromium plated gun bores must be serviced after firing as follows:

(*a*) Wash the bore with a hot solution of soda (one pound laundry soda to four quarts of fresh water), using a bare sponge and towel wrapped sponge.

(*b*) Rinse with fresh water.

(*c*) Dry with clean towel.

(*d*) Pass the bore gage observing constrictions; lap with powdered pumice and mineral oil; confine lapping to constricted areas. *Do not use emery cloth or wire brush.*

(*e*) Repeat operations (b) and (c).

(*f*) Oil with light mineral oil, symbol 2110, using towel wrapped bristle sponge.

40. *Breech mechanism, servicing.* - The gun breech, the screw box liner and all breech mechanism finished surfaces are unpainted parts that are to be maintained bright, free from corrosion, pitting and gummy lubricant and dirt. All such surfaces should be lightly coated with clean, fresh mineral oil when not in use. Before operating the assembly in drill or firing, wipe off surplus oil with clean cloths retaining only a minimum oil film. Before firing slush the gas check pad with a thin coat of tallow and white lead (one part lead, two parts tallow, by weight) and inspect for proper seating. Between rounds fired wipe the mushroom with a sponge or cloth dampened with fresh water.

41. *Buffers, servicing.* - The breech opening buffer and the operating lever buffer must be serviced to maintain liquid at the levels of the respective filling plugs at all times. Use recoil cylinder liquid, O.D. 1914, only. Always check the liquid levels in these buffers before firing and before conducting gun drill. When making such check verify full normal return action of the plungers; inspect the plunger packings for leakage.

42. *Counterbalance springs and closing cylinders, servicing.* - The spring and closing cylinder system must be disassembled, cleaned and repacked with fresh lubricant annually. Use the lubricating compound specified by O.S. 1165.

Caution: Never open the breech with springs disconnected.

43. *Reduction valve, servicing.* - When operating properly the reducing valve can be adjusted to completely cut off the air. If operating improperly the valve should be tested and, if necessary, replaced or repaired. *New Mason valves* and Mason valves in service are disassembled (refer to par. 53)

and lubricated with oil, Navy symbol 1042, before being placed in service and semi-annually thereafter. *The Foster valve* has a rubber diaphragm which should be protected from oil.

44. *Firing lock, maintenance.*- The firing lock is to be overhauled (by competent personnel only), cleaned with alcohol or gasoline, and inspected for damage before gun firing. After firing the lock should again be overhauled and given a coat of preservative grease to prevent rust.

The condition of the primer seat is to be tested with a primer and cleaned or replaced, if necessary, before firing.

45. *Gas ejector system, maintenance.* - The gas ejector is to be thoroughly inspected before firing. The joints should be tested for leaks with soap and water or light oil. The gland on the stuffing box of the expansion joint should be adjusted tight enough to prevent leaking but not tight enough to lock the joint. If the gas ejector poppet valve leaks it must be disassembled, reseated, and the stem ground to permit proper operation. Holes through the screw box liner are to be kept clear. The air pressure should be maintained at 250 P.S.I. in the relay tanks, for normal operation. Upon evidence of an air leak between the screw box liner and the gun, the packing should be tested in accordance with stock material 8-Z-954.

Adjustments

46. The breech mechanism must be maintained in accurate adjustment at all times. Improper adjustment can result in serious damage to the mechanism and danger to the personnel.

47. *Reducing valve, adjustment.* - Both the Mason and Foster valves are adjusted by means of a square head adjusting screw at the top of the valve. This screw is turned in or out by means of a socket wrench to adjust the pressure to the closing cylinders. The pressure is adjusted to cause the breech to close, swinging the operating lever to within easy hand closing distance from the salvo latch. The air cylinders will easily slam the operating lever into latched position with less than 40 P.S.I. pressure with the breech properly assembled, however, there being a remote possibility of operating lever rebound with the danger of shearing the primer on reclosing, the system pressure must be adjusted so that the lever must be manually latched.

48. *Counterbalance springs, adjustment.* - The springs are adjusted to balance the assembly so that when the breech is opened normally it will swing down and latch without a

jarring stop or rebound. The adjustment is made by removing the set screws from the adjusting nuts and threading the nuts to adjust the springs until the above condition is achieved. The set screws are then replaced to set into the groove in the thread of each spring rod.

49. *Eccentric bushings.* - With the plug and screw box liner first having been coated with a mixture of two parts tallow and one of white lead to prevent seizing or galling, the plug is repeatedly closed and the eccentrics turned until the greatest ease of closing is attained. The breech is fitted at the Naval Gun Factory to cause the breech to close and latch on 40 P.S.I. air pressure or less. After the breech hinge eccentric bushings are adjusted the air pressure should be reduced to provide closing as prescribed in paragraph 47.

Assembly and Disassembly

50. *General.* - Assembly and disassembly of gun yokes and guns are yard jobs performed with equipment and by personnel familiar with the procedure. Firing locks are attached and are dismantled as indicated in O.P. 239. Assembly and disassembly of the gas ejector systems are apparent from the general arrangement drawings and details. The breech mechanisms are assembled and reassembled as outlined in paragraphs 51 to 55.

51. Because of the weight of the various parts of the breech mechanism a set routine of assembly and disassembly is prescribed. To facilitate handling, a table of weights is listed below.

Screw Box Liner- - - - - - - - - -	1192	pounds
Hinge Lug - - - - - - - - - - - -	250	"
Carrier - - - - - - - - - - - - -	571	"
Plug - - - - - - - - - - - - - - -	1403	"
Counterbalance and closing cylinder assembly - - - - - - -	248	"
Mushroom - - - - - - - - - - - -	223	"

52. The elements of the breech mechanism are assembled and disassembled in the following routines: (details being apparent from study of the drawings).

(a) Assembly.

(1) Hinge lug.
(2) Carrier and hinge pin.
(3) Plug, cam rollers, and cams.
(4) Operating lever and rod.
(5) Close with block and tackle and lock.

(6) Counterbalance and closing cylinder assemblies.
(7) Mushroom, firing lock, and other details.

(*b*) *Disassembly* is almost the reverse of the assembly operation with special care being taken to be sure the breech is not opened with the counterbalancing springs disconnected except with properly rigged tackle. The routine is as follows:

(1) Firing lock.
(2) Mushroom.
(3) Close breech and remove springs.
(4) Rig block and falls. Secure carrier. Open and remove plug.
(5) Hinge pin and carrier.
(6) Hinge lug.
(7) Other details.

53. *Disassembly of the Mason valve* is made according to the instructions that follow, referring to drawing number 50266. Back off adjusting screw (50266-1) until all tension is removed from the spring. Place the valve in a vise, clamping to the hexhead of dashpot cylinder (50266-13). The spring case (50266-4) is then unscrewed from the body of the valve and the diaphragm spring (50266-3), diaphragm (50266-16) and diaphragm button are removed. Unscrew the auxiliary valve seat (50266-15) using a socket wrench (tap lightly with a hammer to loosen if necessary). The auxiliary valve is then disassembled using a screw driver to turn the auxiliary valve (50266-6) and holding the nut (50266-17) by wedging it with a screw driver. Using the threaded lifting bolt (50266-18) screwed into the top of the main valve, the main valve (50266-11) and spring (50266-14) are removed. Place the valve in a vise with *soft* jaws against the threaded ends from which the couplings have been removed. Unscrew the dashpot cylinder (50266-13) and pull out piston (50266-12). The piston is then removed from the dashpot, using lifting bolt (50266-18) if necessary.

54. *Assembly of the Mason valve* is in the following sequence. Referring to drawing number 50266, insert dashpot piston (50266-12) into dashpot cylinder (50266-13). Place piston (50266-12) into valve body and tighten dashpot. Assemble main valve (50266-11) and spring (50266-14). Place the auxiliary valve (50266-6) in the seat (50266-15). Insert spring (50266-7) and secure nut (50266-17). Screw auxiliary valve assembly into valve body. Assemble spring button (50266-2), spring (50266-3), diaphragm button (50266-5) and diaphragm

(50266-16) in the spring case (50266-4) screw onto valve body over auxiliary valve.

55. *The assembly and disassembly of the Foster valve* is apparent from drawing number 179766. The personnel is cautioned, however, to relieve tension on the adjusting spring and remove diaphragm before removing the main valve assembly.

Chapter III

16-INCH DECK LUG, MARK 6

Description

1. Each gun assembly (ch. II) and its separate gun slide (ch. IV) is mounted in the turret structural gun girder weldment through horizontally positioned slide trunnions. These are large journals (18.5 ins. dia.), integral with the slide casting (or forging) and measuring 79.5 inches transverse width from end face to end face across the trunnions. Each of these journals rests in a bearing block in the gun girder with a large specially designed roller bearing assemblage providing friction-less rotative movement for slide and gun. The pair of bearings and their retainer and cover plate elements comprise the ordnance unit designated 16-inch Deck Lug, Mark 6.

2. Deck lugs are identically arranged with respect to the three gun emplacements of each turret and all turrets are alike. In each turret the triple installation, comprising the six bearing elements, is located at the front of the turret in a transverse row seated at the top of the gun girders. These gun girder bearing seats are very precisely machined so that the common axis for all six bearings is parallel to the turret roller path, being 183.0 inches above the plane of the axes of the rollers and 128.0 inches forward of the mount transverse centerline. Deck lugs as thus positioned in line are rigidly secured, separately, beneath heavy caps which bolt to the gun girder bearing blocks and confine the bearings against vertical displacement. They are secured against horizontal displacement by the rigidity of the gun girder weldment and by bearing retainers which provide non-adjustable spacing of the two bearings of each deck lug. This retainer design, as described in paragraph 6, ties the two bearings together through the integral structure of the slide and its trunnions. (The deck lugs have no transverse tie rod unit such as the arrangements commonly employed in earlier turret structural designs.)

3. Turret sub-division bulkheads which isolate the sight stations and the spaces above the two box gun girders from the gun compartments, provide access arrangements for the respective deck lug bearings. Four of the six bearings - the two outboard bearings and one in each box gun girder - are covered by close-fitting flame-proof plates. These plates are arranged with portable sections to permit service access.

Trunnion Bearings

4. Each trunnion bearing assembly consists of a large radial roller bearing, a flat-plate thrust bearing, a bearing retainer, an outer bearing seat, a cover plate and bolts for securing the seat, the retainer and the cover plate. These parts are arranged as shown on drawing number 216341 with the radial bearing secured by the retainer to the trunnion and with the outer bearing seat and the cover plate secured to the gun girder bearing block and cap. The thrust plate is located between the bearing block and the slide and below the trunnion.

5. *Radial bearing.* - Each trunnion radial bearing consists of 24 cylindrical steel rollers equally spaced in a two-piece bronze cage which has riveted assemblage; an inner ring and an outer ring. The assembly is 30.0 inches in diameter (outer ring), 5.8 inches in width (across the inner ring) and positions the roller centers in a circular path of 25.0 inches diameter. The rollers are special roller bearing steel, chromium plated, solid, true cylinders, 3.5 inches by diameter of 2.5 inches. They are housed in separate, equally spaced pockets of the cage. Roller paths are conventional rings of special steel, accurately ground to provide concentric cylindrical races. The inner ring seating area is a three degree tapered bore which provides wedged seat on a complementary collar of the retainer.

6. *Bearing retainer.* - The bearing retainer is a circular plate with cylindrical collar which fits over the slide trunnion. The inner ring seat (a wedge cone of three degree slope) provides a shoulder against which the ring is wedged. Twelve equally spaced bolts, locked when seated, secure the piece to the end face of the trunnion. Four threaded holes for jack screws provide for disassembly of the bearing from the retainer. The assembled bearings and retainers when fully seated on the trunnions space the two deck lug radial bearings 68.5 inches, center to center.

7. *Outer bearing seat.* - The outer bearing seat is a flanged ring, 31.5 inches diameter, secured by eight equally spaced bolts to the bearing block and cap. It confines and centers the outer ring of the bearing. The inward face of the seat is provided with an annular groove for a lubricant seal which is compressed against the side face of the slide. This seal is a wool felt strip of square section, secured in the groove with shellac. The outer flange of the seat is arranged with twelve equally spaced tapped holes (for cover plate bolts), six jack screw holes (for disassembly of the seat from the bearing block), and in the lower half, six small tapped holes (for selective positions for four lubricating fittings for the thrust bearing, par. 9).

8. *Cover plate.* - The cover plate is a large recessed disc with bolt flange machined to seal against the outer bearing seat. It completely encloses the trunnion and bearing to provide a lubricant retaining cover with filling and drain plugs for servicing the bearing (refer par. 11). Two annular rings, within the cover and integral with the plate, are accurately machined to provide 360° contact, respectively, with the bearing outer ring and the roller cage. Thus the plate when assembled functions to secure the outer race and the cage and to prevent thrust displacement of the bearing.

9. *Thrust plate.* - The thrust plate is a 120° bronze bearing sector secured by four bolts on the inside of the gun girder bearing block. It is centered beneath the trunnion to provide a lubricated thrust surface opposed to the side face of the slide. A system of radial grease grooves distributes lubricant from four grease fittings which are located as indicated in paragraph 7. This bearing surface has installed alignment parallel to the side face of the slide with total thrust clearance, between the slide and the two plates, of 0.002 inch. The design of the thrust bearings and of the bearing block includes provision for maintaining this thrust clearance, i.e., gun girder spread with resultant excess slide thrust movement can be corrected by installing over size thrust plates. Over size plates have been installed in certain gun emplacements. The installation can be made without disturbing the radial bearing assemblies; bearing block seats for the thrust plates are milled to permit under sized plates to be dropped and new plates to be raised and secured, performing the operations in the limited space beneath the slide (see clearance cut indicated on dr. no. 216341).

MAINTENANCE INSTRUCTIONS

10. The deck lug assemblies are to be serviced and maintained in adjustment in accord with the regulations prescribed in the Ordnance Manual and the instructions that follow.

11. *Lubrication.* - The deck lugs are to be lubricated according to the schedules and with the lubricants prescribed on the lubrication chart. Lubrication of the radial bearings is primarily for preservation. The voids of the bearing and cover plate should be maintained full of the grease specified and therefore they must be inspected at frequent intervals. Loss of lubricant from these bearings can be gauged by regular inspection and cleaning of the bearing block surfaces (below the thrust plates), observing any excessive quantity of grease that has dripped from the bearings, - seepage exceeding normal grease loss from the thrust bearings indicates radial bearing loss of lubricant and must be replaced without delay.

12. *Deck lug adjustment* .- All elements of the deck lug are designed for fixed, non-adjustable arrangement. Correction of excessive slide thrust clearance (normal, 0.002 in.) is only to be made by installation of over size thrust plates (see par. 9).

Chapter IV

16-INCH SLIDE, MARK 4 AND MARK 5

General Description

1. Turret triple gun mount arrangements provide three independent gun slides. These have conventional trunnion support in gun girder deck lug bearings which are separate for each slide, the three slides being thus pivoted for independent elevating movement. Two similar designs are installed in the eighteen mount assemblies of the class; 16-inch triple mount assemblies numbers 69, 70, 71, 75, 76, 77, 81, 82 and 83 being equipped with slides Mark 4, whereas triple mount assemblies 66, 67, 68, 72, 73, 74, 78, 79 and 80 are equipped with the Mark 5 design. These designs differ principally in that the main element of the Mark 4 slide is of cast steel with integral lugs for plunger yoke rails, recoil cylinder seat and shield plates, whereas the Mark 5 main element is a steel forging with attached parts in lieu of the integral lugs. They also differ as to arrangement of depression stop buffers and yoke stop pins.

2. The designs (see drs. no. 215656, 215657 for Mark 4, and drs. no. 231074, 231075 for Mark 5) are of the same general arrangement, have identical recuperator and recoil mechanisms and are virtually the same as to all other details. The descriptions which follow are typical of both designs except as indicated.

3. Each slide in addition to the large casting or forging includes a hydraulic recoil system a hydro-pneumatic recuperator system, rear end brackets, loader's platform, a cylindrical gun cover, upper and lower shield plate, a yoke locking device and a slide securing mechanism. Completely assembled these units form an assembly over 31 feet long, 78.5 inches across the trunnions, 100.25 inches high (excluding depression stop buffers) and weigh from 40 to 42 tons each. (Weights vary between any two assemblies, the Mark 4 slides being somewhat heavier than the Mark 5 type.)

4. The gun slide bore of the casting or forging is fitted with four bronze liners at the front, two at the rear, each 10 inches wide and all bored after assembly to finished diameter of 46.03 inches. (The slide cylinder of the gun is 46.0 inches diameter.) Each liner is provided with oil grooves which are supplied from grease fittings accessible on the bottom of the slide. At the top the liners and the slide are milled throughout the length of the bore, 4 inches wide, to provide keyway for the gun slide cylinder key.

5. The slide bore is extended forward through the gun port by a steel plate cylinder subassembly, designated the gun cover (see dr. no. 216398). This unit is a weldment of one-half inch plate, 47.5 inches diameter and 69.5 inches long. It has bolted flange mounting (with gasket) at the front face of the slide. At its forward end is a wiping ring assembly providing oil and weather seal on the gun barrel. A leather buckler clamped on the outer surface of the wiping ring (packing ring) and mounted on the front face of the shield completely encloses the gun cover.

6. Within the turret the slide arrangement has twin counterrecoil cylinders and plungers with plunger yoke and yoke rods on top, a single recoil cylinder seated on the bottom and on either side at the rear, right and left rear end brackets. The latter are arranged to assemble either the elevating screw pin or the slide securing device and a cantilever platform bracket which extends rearward to span the gun pocket. Right and center guns are arranged with the platform bracket and securing device assembled to the right rear end bracket, the elevating pin mounted in the left rear end bracket; for the left gun the arrangement is reversed.

7. At the rear of the slide, on top and centered between the counterrecoil cylinders, the yoke locking device is secured in a seat which is aligned with a notched lug on top of the yoke. This device consists of a necked eye bolt, a nut pin and bracket. When stowed it is secured against displacement by running the nut against a shoulder of the bracket. In its locked position, the eye bolt (designated safety link) with nut behind the notched lug secures the gun in battery. The necked section of the link is of sufficient strength to retain the gun from sliding out at any angle with recuperator empty, but will fail without other casualty if the gun is fired before stowing the device. In the Mark 5 slide the bracket is combined with the depression stop buffer housing. (The Mark 4 design has two buffers mounted on top of the rear caps that secure the counterrecoil cylinders.)

Recoil Mechanism

8. The gun is mounted in the slide in such arrangement that when fired it recoils 48 inches rearward and returns to battery position. This cycle occurs through functioning of the recoil and recuperator mechanisms. The energy of recoil being absorbed in part by each unit with the accumulated energy of the recuperator returning the piece and the recoil system buffing the return movement.

9. The recoil mechanism is a hydraulic throttling device which has assembled arrangement as shown on drawing number

215632, Mark 4, drawing number 231086, Mark 5. It comprises a recoil cylinder, cylinder head, piston and piston rod, piston ring, three throttling rods, piston rod packing, gland and two piston rod nuts. Assembled together these parts are attached by caps beneath the slide with piston rod secured in the yoke. The rod is aligned parallel to the gun axis and forty-one inches below it. Two expansion tanks placed symmetrically adjacent to the cylinder head are joined by pipe manifold which is connected to a lead in the top of the head and forms a closed system for expansion of liquid against trapped air. A filling and drain valve at the rear bottom of the recoil cylinder provides for liquid filling and draining. The cylinder is a nickel steel piece of 26 inches bore diameter by 60.25 inches long overall. The head which closes its forward end is also of nickel steel 33 inches diameter by 20.25 inches from flange seat to front of buffer cylinder. It is seated to the cylinder with copper gasket, dowel pin and twenty 1.75 inches special nickel steel bolts. Two threaded holes diametrically opposite in the flange provide for disassembly jackscrews.

10. The buffing cylinder of the head is a bore of 9.75 inches diameter, 16.50 inches depth, fitted at its open end with bronze bushing which has bore of 9.5 inches. The forward wall in addition to the expansion lead is provided with drilled lead and tapped seat (normally plugged) for attachment of pressure gauge.

11. Three throttling rods, spaced 120 degrees and parallel to each other and the cylinder axis, are secured at the rear in threaded seats in the cylinder base and are supported at the front in the cylinder head. They have variable diameter to vary the rate of flow of liquid through the piston ports.

12. The piston, piston rod and buffer are of steel, machined from one piece. The piston is fitted with a bronze ring on its outer periphery which is turned to a diameter of 25.990 inches and which thus has radial clearance of 0.005 inch in the cylinder. The rod passes through a stuffing box* at the rear to connection with the gun yoke. The buffer, 16.5 inches long, 9.495 inches diameter, has four longitudinal grooves of varying depth which function in the last 16.0 inches of counter movement to throttle liquid from the cylinder head bore.

13. The expansion tank pipe manifold is fitted with two cap plugs located beneath the slide in front of and slightly above the top of the cylinder (gun at zero degree). With one plug removed for venting when filling the cylinder at the drain and filling valve (see filling routine, par. 38) and with the gun at zero degree elevation the recoil system will hold approximately 100 gallons of recoil cylinder liquid.**

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* Packed with waterproof hydraulic flax graphite coated coil packing, O.S. 687.

** O.D. 1914, latest revision.

Counterrecoil System

14. The counterrecoil mechanism (refer drs. no. 215645, Mark 4; 231089, Mark 5) is a hydro-pneumatic type of initial high air pressure with differential hydraulic pressure functioning to distend the packing that retains the air. It comprises a paired arrangement of cylinders and plungers, a single differential cylinder unit, a plunger yoke, yoke rods, gauges, valves and other parts including a large removable cover. The entire assembly is located on top of the slide with the two cylinders parallel, spaced 36 inches between axes and in a plane parallel to and 30 inches above the gun center line. The differential cylinder is centered between the counterrecoil cylinders.

15. Each counterrecoil cylinder is a monel metal forging, machined all over, 117.25 inches long with exterior diameter of 15 inches. The cylindrical interior surface has diameter of 12 inches. Short pipes connect the air chambers of both cylinders with the air side of the differential cylinder. Hydraulic leads connect the wet side of the differential cylinder with the plunger packing seats at the forward ends of the two cylinders.

16. The plungers are monel metal forgings. Each is a hollow cylinder, open at the rear, closed at the front, 73 inches long by 9 inches outside diameter. Its outer surface is a highly finished cylinder which functions with the hydraulically distended packing to prevent loss of air pressure. Supported at the front in the plunger yoke each plunger is free to slide through the packing with gun reciprocation.

17. The plunger packing (each cylinder) is an assembly 13.75 inches long confined between a shoulder at the rear and a gland at the forward end of the packing seat. It is a symmetrical arrangement of ring-shaped elements comprising the gland, a rear liner, two bearings, two packing seats, twelve chevron type preformed composition* packing rings and one plunger packing follower. The last is centered at the hydraulic lead connecting to the differential cylinder and is drilled and otherwise shaped to permit application of pressure uniformly to each of the two banks of six chevron rings.

18. The differential cylinder unit (drs. no. 215646, Mark 4, 231090, Mark 5) is bolted to the top of the slide and has connections to the two counterrecoil cylinders as indicated above. It includes a free floating piston with rod extending rearward (to atmosphere) through a cylinder head stuffing box. Piston and stuffing box are fitted with preformed

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* O.S. 749.

cylinders is housed beneath a plunger cover. The forward ends of each plunger seated in the yoke is constrained by recuperator pressure and locking pin. The cover, fitted with a large portable section, consists of pieces of formed plate and flanged frames in a riveted, spot welded assembly which is bolted to the slide.

Rear End Brackets

21. The two brackets located as described in paragraph 6 are similar right and left steel castings. They are bolted to machined seats on the slide. They provide mounting attachment for assembling the loader's platform bracket and are machined to assemble the elevating screw pin and the slide securing device. On the bottom face of each is located an elevating stop which is positioned in the way of an elevating stop buffer (seated in the respective gun girders). The symmetrical arrangement and design of these rear end brackets (as assembled) adapt any slide to right or left or center position of any triple gun assembly; elevating screw pin assembly being possible in either right or left bracket.

22. *Slide securing device.* - The mechanism assembled in the rear end bracket for stowing the slide is a handwheel operated screw and pin device. It functions at zero degree gun position to seat a four inch diameter tapered steel pin in an aligned tapered socket located in the gun girder. It thus serves to relieve the elevating screw and nut gear from dead load stresses. The device includes latch provision to prevent pin movement when the pin is run-out or retracted. A second socket is provided in the gun girder to align with the pin when the gun is at twenty degrees elevation. This socket provides for securing the slide whenever the portable air charging pipe is installed for purpose of replenishing the recuperator air charge and for performing the tests prescribed in paragraph 39. Steps and hand grips in the gun girder give access to the securing device from the pan floor when the gun is in either position.

Slide Operation

23. With recoil mechanism filled and with the recuperator charged, the action of the slide when the gun is fired is as follows:

As the gun recoils the recoil piston and the two plungers are drawn to the rear. Liquid in back of the recoil piston flows through the throttling ports in the piston (at variable rate) and simultaneously the plungers further compress the initial high air pressure in the recuperator to a maximum of approximately 2400 pounds per square inch. The combined

chevron packing rings* which are spring and hydro-pressure distended. A liquid filling port, equipped with needle valve and plugged liquid filling pipe permits charging the rod side (between piston and cylinder head) with differential cylinder liquid**. Thus the piston has plunger cylinder air pressure on its forward face by reason of the connecting lead indicated in paragraph 15, and hydrostatic pressure on its rear side. Since the effective piston area of the wet side is less by reason of the rod passing out to atmosphere the resulting pressure on the plunger packing is greater than cylinder air pressure. This differential pressure is an amount inversely proportionate to the difference in effective piston areas. Thus since liquid pressure is always greater, air cannot escape and if leakage occurs in the mechanism it must be liquid. Such leakage is shown by the position of the differential piston and an attached indicator rod (visible at the breech). A pressure gauge located on top of the differential cylinder is arranged with lead connecting to the liquid side of the cylinder and at all times indicates the pressure on the plunger packing (approx. 114.5% air pressure). This gauge has a special safety installation which provides against loss of liquid in the event of gauge rupture. The mounting consists of a plate with screw thread gauge seat bolted over a cavity in the forging. A leather diaphragm under the plate separates the packing lead below from the gauge lead in the plate. For proper functioning of this arrangement it is necessary that the space above the diaphragm shall be completely filled with liquid before the recuperator is charged.

19. Each counterrecoil cylinder is provided with a gauge mounted on the rear end of the cylinder with an adjacent name plate designating it as "Air Gauge-K". The lead connecting this gauge with the cylinder air chamber is arranged with a valve (designated, "Air Valve-Z"). The valve is normally closed, is covered by a cap plug and is only operated to obtain gauge reading or when charging or replenishing air pressure. Normal air pressure required in the system is 1600 pounds per square inch. This is stamped on an instruction plate attached adjacent on the rear face of the yoke. For additional data as to the gauges, valves and indicator, refer to the liquid and air charging instructions of paragraph 38.

20. The connection between the above described counterrecoil mechanism and the gun is an arrangement of two yoke rods, a plunger yoke, a gun yoke and securing nuts. The plunger yoke is mounted on ways on top of the slide and together with the plungers and the forward ends of the counterrecoil

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* O.S. 749.

** For specification and filling instructions, see paragraphs 26 and 38.

retarding force checks recoil in 48 inches movement (about 1/3 second of time) and the gun is drawn back toward battery position by the energy stored in the recuperator (maintained against leakage by reason of the hydraulic packing). After thirty-two inches of countermovement the buffer starts to displace liquid from the bore of the cylinder head. This displacement occurs through four grooves of variable depth and through the very fine clearance between the buffer and the entrance bushing. It retards the countermovement and brings the oscillating assembly to a gentle stop as the gun reaches battery position. The return flow of liquid through the piston ports during the counteraction, imposes some brake effect but the major retardation is performed by the buffer in the last 16 inches of movement.

MAINTENANCE INSTRUCTIONS

24. The importance of proper care and of regular thorough inspection of the slide assemblage cannot be overstressed. Indifferent servicing of slide bearing surfaces and mechanisms and of the parts of other units attached will result in improper functioning and serious damage. Observe the general regulations as to slide maintenance contained in the Ordnance Manual, chapter VI, and the specific directions below.

25. Never charge the recoil system with other liquid than that prescribed by Ordnance Data 1914, latest revision. When filling, strain through a fine mesh screen (120 wire to inch or finer). Whenever the system is drained follow the instructions as to care, preservation and test as directed by O.D. 1914. Always keep the liquid at the level of the cap plug (expansion line) with gun at zero degree elevation.

26. Never charge the differential cylinder with any liquid other than ice machine oil, Navy Symbol 2075. Replenish when necessary to maintain indicator "S" flush with the rear face of the indicator rear end bracket.

27. Never let the recuperator air pressure fall below the minimum indicated on the instruction plate (refer to par. 38).

28. Maintain the drain valve, the cylinder head plug, cap plugs, air and liquid valves, safety gauge, air gauge and plugs, tight. Close and cap air valve "Z" except when performing the tests of paragraph 39.

29. Never wipe the plungers with dirty, greasy or harsh rags. These highly finished cylindrical surfaces must be free

from scars and scratches. They do not require lubricant or a rust protecting film of oil.

30. For protection of the mount and personnel it is imperative that the slide securing pin is seated in the socket and the yoke locking device is in "gun locked" position whenever the mount is not being operated.

31. Do not deface, alter or paint over name and instruction plates.

32. Special tools, spanner wrenches, open end wrenches, liquid pumps and portable pipes are provided for servicing slide elements. These and no others are to be used when working on the unit.

33. When servicing the recuperator follow the routines for replenishing liquid and for charging air as prescribed by drawing number 215247 and paragraph 38.

34. Lubricate the slide according to the frequency and with the lubricants specified by the lubricating chart.

35. *Routine preparation of the slide for firing.*

(*a*) Lubricate all bearing surfaces.

(*b*) Read and record the recuperator air pressure, both air gauges. Readings should be identical on each. Recharge if at the minimum prescribed.

(*c*) Measure and record projection of indicator "S". Replenish liquid to place the rod flush with the rear end bracket.

(*d*) Disconnect and stow the slide securing pin.

(*e*) Verify the adequacy of recoil cylinder liquid. Replenish if necessary until liquid appears at the cap plug of the expansion line (gun at zero degree elevation).

(*f*) Disconnect and stow the yoke locking device.

(*g*) Check the adequacy of liquid in the elevating and depression stop buffers.

(*h*) Make certain that the plunger cover is securely latched.

36. *Instructions for stowing the slide after firing.*

(*a*) Connect and run tight the yoke locking device.

(*b*) Read and record the recuperator air pressure.

(*c*) Measure and record the differential indicator rod position. If loss of oil occurred during firing, ascertain the cause, correct and recharge.

(*d*) Make external inspection of the recoil system for evidence of loss of liquid.

(*e*) Perform alkalinity tests prescribed by O.D. 1914.

(*f*) Remove the plunger cover and examine the plungers, yoke shoes and rails for galling.

(*g*) Inspect the differential cylinder leads, the gauge and the gauge safety plate for leakage.

(*h*) Bring the gun to zero degree position and seat the slide securing pin.

37 *Servicing the recoil system.*

(*a*) Filling routine:-

(1) Prepare adequate quantity of recoil liquid.

(2) See that the yoke locking device is connected.

(3) Connect the standard funnel and filling hose to the filling and drain valve.

(4) Remove one cap plug from the expansion line manifold.

(5) Open the filling and drain valve.

(6) Support the funnel above the level of the cap plug aperture and run liquid in until it appears at the aperture; pour last portion slowly to allow the buffer to fill.

(7) Close filling and drain valve; remove hose and replace cap.

(8) Replace the cap plug.

(b) Draining routine:-

(1) Connect the yoke locking device and secure the slide at zero degree elevation.

(2) Connect the filling hose to the drain valve.

(3) Provide adequate buckets on the pan floor to catch liquid.

(4) Remove one cap plug from the expansion line manifold.

(5) Open the drain valve and run liquid in buckets.

(c) Piston rod packing replacement:-

(1) Perform the draining routine.

(2) Bleed recuperator air pressure.

(3) Uncouple the yoke locking device.

(4) Jack out of battery (approx. 10 ins).

(5) Back off the cylinder nut.

(6) Slide the gland out.

(7) Remove the split rings of worn packing.

(8) Carefully clean packing seat.

(9) Install new packing (O.S. 687).

(10) Replace gland and cylinder nut.

(11) Jack gun into battery and connect the yoke locking device.

(12) Perform the filling routine, (a).

(13) Retract the securing pin.

(14) Take the gun down to twenty degrees elevation, connect the portable pipe and recharge the recuperator.

38. *Servicing the recuperator.* - Detailed routines for charging recuperator air pressure and replenishing differential liquid are given on drawing number 215647. Other instructions are included on instruction plates attached to the yoke except as follows:

(a) *To replace plunger packing.* - The routine below is prescribed when the chevron packing rings are to be replaced. In this operation the rear liner and its bearing must not be withdrawn. If the rear liner is to be removed (for replacement of the bearing or for other reason) the counterrecoil cylinder must be disassembled intact from the slide and the plunger must be withdrawn before disassembling the packing. The operations which follow should be performed preferably with the gun at zero degree elevation. If they are performed at twenty degree position (for more convenient access) extreme care must be exercised to prevent the plunger slipping into the cylinder.

(1) Secure the yoke locking device.

(2) Seat the slide securing pin in socket.

(3) Remove the plunger cover.

(4) Secure C-clamps to the rails immediately rearward of the plunger yoke.

(5) Remove air valve cap "Z" and plug "X".

(6) Open "Z" and exhaust the recuperator pressure.

Note: It is not necessary to drain the liquid from the differential cylinder. The position of the packing lead is such that only the liquid in the packing will be lost.

(7) Remove locking pin (202214-2) from yoke, one plunger only.

(8) Remove the twelve stud nuts and lock washers from the gland and slide the gland forward.

(9) Place wood block and pad beneath plunger in front of cylinder.

(10) Break plunger from yoke and withdraw sufficient to remove the gland.

(11) Slide the plunger rearward sufficient to assemble connecting rod, 236064-4, rail fixture, 236064-2, with eye nut, 236064-7, on the forward end of the connecting rod and with stop rod, 236064-6, and nut seated in the rail fixture. Attach sheave to the yoke (use eye bolt in the plunger yoke seat). Move pendant through sheave and attach to the eye nut. Snub pendant at the projectile hoist cradle.

(12) Slide plunger into the cylinder until the stop rod bears on face.

(13) Remove packing elements to position on the connecting rod.

(14) Draw plunger forward until eye nut is at sheave.

(15) Install wood block bearing under forward end of plunger.

(16) Remove eye nut and rail fixture.

(17) Remove packing from connecting rod and replace with new chevrons and gland.

(18) Reassemble rail fixture and eye nut and remove wood block.

(19) Install packing in cylinder and secure the gland. Do not move plunger.

(20) Remove rail fixture, connecting rod, sheave and pendant. Support plunger forward end until it is again seated and secured in the yoke.

(21) Recharge the recuperator and replenish the differential cylinder liquid according to the routines of drawing number 215647.

(22) Remove the C-clamps and replace the plunger cover.

Routine Tests of the Slide

39. The slide assembly and particularly the elements of the recuperator require periodic tests and exercise to maintain the unit in good operating condition. The tests described below are in compliance with the regulations of the Ordnance Manual, chapter VI, modifying those instructions to apply to the design of the assembly.

(*a*) *DAILY.*

(1) See that the yoke locking device is connected with the nut drawn tight. The device is to be so connected at all times except when the gun is to be fired and when performing the tests prescribed below.

(2) Read and record in the turret battery log the recuperator pressures as indicated by right and left air pressure gauges "K", differential cylinder liquid pressure gauge "P", and liquid volume as shown by indicator "S". Recharge air and liquid if minimums are indicated. If readings compared with previous log entries indicate continual loss ascertain the source and correct. Temperature changes will cause small variations in pressure.

(*b*) *MONTHLY.*

(1) Check the level of recoil system liquid with gun at zero degree. Replenish if necessary until liquid flows from the cap plug (expansion line manifold).

(2) Elevate the gun to twenty degrees, lubricate the gun slide liners, seat the slide securing pin, and perform the following operating test.

(a) Assemble the portable air charging pipes as shown on drawing number 235345.

(b) Uncouple and stow the yoke locking device.

(c) Bleed air until gun slides out of battery.

(d) Open supply valve until gun returns to battery.

(e) Repeat operations (c) and (d) twice and give final charge in accord with instructions of drawing number 215647.

(3) Return the gun to five degrees elevation and connect the yoke locking device. Perform the following differential piston exercise.

(a) Bleed the liquid until the differential piston moves out six inches.

(b) Replenish liquid as prescribed by drawing number 215647.

(c) Repeat operations (a) and (b) twice.

(4) With the liquid pump connected as in subparagraph 3 (including oil pressure gauge) bleed the recuperator air charge to zero and pump liquid until the piston has moved to its fully charged position with gauge pressure of 1000 pounds per square inch. Observe that the plunger packings hold this pressure. Recharge the air pressure to service pressure and bleed liquid until indicator "S" is flush with the rear face of the rear end bracket. Restore the recuperator and mount to stowed position.

(c) *ANNUALLY.* (While at home yard, assisted by yard force.)

(1) Test and calibrate all air pressure gauges "K" and all liquid pressure gauges "P" by comparison with standard gauges.

(2) Open counterrecoil and differential cylinders. Examine condition of packing rings, packing seats, gland, bearings, liner and follower. Clean out the cylinders, inspect and note amount of sediment. If large amount of sediment is found, forward sample to Bureau of Ordnance. When reassembling renew such parts as necessary. Do not use any chevron rings* or safety gauge diaphragms, except those provided by the Naval Gun Factory.

(3) Report details of the inspection by letter to the Bureau of Ordnance.

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* Refer O.S. 749.

Chapter V

16-INCH ELEVATING GEAR, MARK 4 AND MARK 4, MODS. 1 AND 2

General Description

1. The elevating gear installations of each turret of the U.S.S. NORTH CAROLINA and WASHINGTON are three independent assemblies. These are similar designs, identically powered and controlled, and differing only as to position and arrangement of subassemblies. They are designated 16-inch elevating gear, Mark 4, for the right gun, Mark 4, Mod. 1, for the center gun, and Mark 4, Mod. 2, for the left gun.

2. The principal units of each are an electric motor with reduction gear, a hydraulic transmission, response gear, screw and nut oscillating bearing elevating machine, control gear and servo control mechanism. These are shown in their mechanical arrangements for all assemblies on the schematic diagram of drawing number 230774.

3. The assemblies are principally located below the respective guns forward and below the gun pockets in the pan floor and electric deck spaces. The arrangements on those two levels are shown on the plan view sections of the turret at the pan floor and the electric deck, drawings number 230772 and 230773, respectively.

4. The assemblies provide gun elevating limits of movement and speed of laying as follows:

Maximum elevation- - - - - - - - - - - - - - -45°
Maximum depression* - - - - - - - - - - - - - 2°
Maximum speed (average)- -12° of arc per sec.
Loading angle - - - - - - - - - - - 5° elevation

Electric Motor

5. The electric motor and speed reducing unit for each gun is in the electric deck space with rotor and output shafts horizontally positioned and with drive shaft connection extending forward to the A-end of the hydraulic transmission. The wing units are similarly located with relation to their respective guns. (See drs. no. 230778 and 231603.) The center unit is offset from beneath its gun and is located between the parallel divisional bulkheads which are beneath the right hand gun girder box. (See dr. no. 230779.)

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* Zero degree, Turret No. 2, peacetime; two degrees battle; see paragraph 30.

6. Each motor assembly comprises three elements; motor, speed reducer and auxiliary pumps. The pumps are flange mounted on the speed reducer and the latter is flange mounted to the drive end of the motor case. The unit is a compact assembly of commercial manufacture (Reliance Electric Co., Northern Pump Co.) and has design characteristics as tabulated below. Its controller is an across-the-line starter of magnetic type arranged with overload, short-circuit and undervoltage protection. It is similar to the controller described in chapter VII and is located in the projectile flat machinery space with its push-button control station at the gun layer's station; see wiring diagram drawing number 230450.

Data - Electric Motor Assembly

Motor:-
- Type - 60 cycle, 440 volt, 3 phase
- Horsepower - 60
- Speed - Constant
- R.P.M., full load - - - - - - - - - - - - - - - - - 1750
- Rotation (looking at pinion) - - - - - - - -Clockwise
- Weight (including reduction gear)- - - - -1688 lbs.
- Lubrication - - - - - - - - - - - - - - -Grease cups
- Manufacturer's type designation - - - - - AA-B-505-Y
- General arrangement drawing - - - - - - - - - 268377

Speed reducer:-
- Type - enclosed spur gear train
- R.P.M., output shaft, ratio 3.342 to 1 - - - - - 500
- R.P.M., auxiliary pump drive, ratio 2.085 to 1 -835
- Rotation, pump and output shafts - Counterclockwise
- Lubrication - - - - - - - - - - - - - - - - - - - Oil bath
- General arrangement drawing - - - - - - - - - 268473

Pump:-
- Type - double; rotary gear
- Pressure, supercharge pump - - - - - - - 50 lb.sq.in.
- Pressure, servo pump - - - - - - - - -400 lb.sq.in.
- Capacity, supercharge pump - - - - - - - - 9.0 G.P.M.
- Capacity, servo pump - - - - - - - - - -13.5 G.P.M.
- General arrangement drawing- - - - - - - - - - 268463

7. The connecting shaft between the speed reducer output shaft and the A-end shaft is arranged at both ends with special couplings. These are commercial units which provide floating compensation for slight misalignment. Each is an assembly of splined hubs, which seat on the respective shaft ends, and flanged sleeves which enclose the hubs. The sleeves have annular involute gears enmeshed with gear teeth on the hubs. When installed with flanges bolted each coupling is partially filled with oil to provide lubrication for the enmeshed gearing.

Hydraulic Transmission

8. The drive transmitting arrangement installed between the preceding described power plant and the elevating nut gear of the oscillating bearing (par. 15), is a hydraulic, variable displacement machine of commercial manufacture (Northern Pump Co.). It comprises a variable displacement pump (designated the A-end) and a fixed displacement hydraulic motor (the B-end), mechanically separate but having interconnecting hydraulic pressure leads. Basically these components of the transmission as shown on drawings number 268461 (A-end) and 268462 (B-end) are the elements which convert input shaft rotation of constant speed and direction to reversible, variable speed output shaft rotation. They are thus identical to many installations of like function and the same or similar manufacture used throughout the fleet.

9. The transmission provides drive speed range and performs under pressures and loads as tabulated in the data below.

Transmission Data

Speed of A-end input	500 R.P.M.
Speed of B-end output	0 to 500 R.P.M.
Torque load:-	
Normal, rated	2000 lb.ft.
Maximum, rated	2200 lb.ft.
Pressures:-	
Relief valve setting	1450 P.S.I.
Replenishing pump pressure	50 P.S.I.
Servo pump pressure	400 P.S.I.
Constant horsepower control setting;-	
Maximum	108 H.P.
Temperatures:-	
Normal oil operating range	-120° to 175°F.
Max. permitted oil temperature	185°F.

10. *A-end.* - The A-end is an assembly of a multi-cylinder rotating pump within a case. The pump comprises a cylinder barrel, having nine parallel axially disposed cylinders, pistons and connecting rods, a socket ring, with connecting rod bearings, and a socket ring bearing assembly which is mounted in a part designated the tilting box. The mounting of these parts on the main shaft (driven by the electric motor) is such that the cylinder barrel is spring compressed against a valve plate and is keyed to the shaft while the socket ring has trunnion pivot in the main shaft. Thus the socket ring is free to turn in its tilting box bearings and may be adjustably positioned as to angular value with respect to the

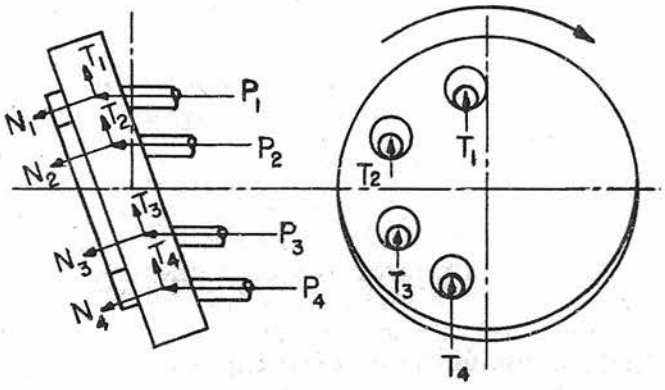
shaft axis. Such angular movement is imparted to the tilting box through the control arrangements. Tilt of the socket ring from a plane normal to the shaft axis gives piston reciprocation and consequent suction and pump displacement of liquid through the cylinder head ports and through radially aligned, semiannular parts of the valve plate. The latter ports (two) are the pressure and suction ports with leads connecting to the similar ports of the B-end valve plate.

11. *B-end.* - The hydraulic motor or B-end is a mechanism similar to the A-end but lacks an angularly adjustable bearing for the socket ring assembly. Instead it has a stationary thrust roller track inclined at 70 degrees to its shaft axis.

12. The preceding described A-end and B-end units and their connecting leads are filled with hydraulic oil. Of this total volume only that oil which is between the A and B pistons is "active" in the transmission of power. All other fluid is reserve, completely fills the voids within the cases and by means of a circulating pipe system which extends to an expansion tank, has reservoir expansion capacity and thus functions to dissipate heat. The manner in which the active oil functions to transmit power is explained in the next paragraph.

13. *Theory of power transmission.* - Whenever the electric motor is in operation the A-end main shaft and its attached pump assembly rotates at constant speed. That rotation is always counterclockwise (looking at the valve plate end), and moves the nine ports of the cylinder barrel counterclockwise around the face of the valve plate and over the two semiannular ports. Those ports have positions which on a clock face extend counterclockwise from 3 to 9 o'clock forming the upper port, which is separated by "lands" from a lower port that extends from 9 to 3 o'clock, counterclockwise. The tilting box axis (centered in pivots in the case) is parallel to the vertical (12 o'clock to 6 o'clock) line of the valve plate. Thus the socket ring bearing may be positioned to be near either land (3 o'clock or 9 o'clock). Such tilting box movement is the criterion as to direction flow of high pressure (i.e., which valve plate port will receive the pumping strokes). If the tilt is toward 3 o'clock each piston as it rotates past that land is at the top of its cylinder and as it continues toward 12 and 9 positions (counterclockwise) it sucks oil from the low side of the active system. At the 9 position it crosses the other land and starts to pump through the lower port. Pumping continues until that piston again reaches the first land. If, the tilting box is moved until its socket bearing is parallel to the valve plate, reciprocation of the pistons ceases and the unit is at neutral. If it is moved to tilt toward 9 o'clock, pumping occurs through the upper port and the B-shaft rotation is reversed.

B-shaft rotation is caused by the tangential components as illustrated in the vector diagram below. There the piston thrusts P1, P2, P3, P4, are transmitted through their connecting rods to the socket ring. Each such thrust resolves into an "N" and a "T" component, the former perpendicular to the thrust plane of the socket ring bearing and the latter tangential to it. From the relation of the latter to the B-shaft it will be seen that each exerts a turning movement about the shaft.



14. On the output end of the B-end is a flange mounted bracket (upper response drive) which encloses the splined coupling of the B-shaft to the drive shaft of the oscillating bearing pinion. The bracket is also flange mounted to the adjacent face of the bearing block (oscillating bearing). This close coupled enclosed arrangement (as shown on dr. no. 216429) is a quill drive coupling which permits slight play and thus compensates for misalignments.

Oscillating Bearing

15. The elevating screw and oscillating bearing assembly is a trunnion pivoted unit supported in two journals (bearing blocks) which are wedged and bolted in the turret structure above the pan floor. Aligned with the B-end (as indicated in par. 14) it places the axis of the screw in offset position 20 inches from the vertical plane of the respective gun center line. The bearing is a conventional arrangement of a large cast steel cube enclosing a radially split elevating nut. The two halves of the nut lock together for rotation but have adjustable axial motion to eliminate end play of the screw. The bottom half is driven by a concentrically mounted elevating nut gear which is meshed with the drive pinion. Adjustment of these parts is accomplished by means of threaded upper and lower adjusting nuts located respectively in the top and bottom of the bearing. The lower of these nuts

is adjustable for purpose of adjusting the mesh of the nut gear, it is not required for adjustment of the split halves of the elevating nut (to eliminate play in the screw) which is adjusted exclusively by the upper adjusting nut. The nut gear, in addition to driving the elevating nut, is meshed with and drives a pump gear. This gear is mounted in the trunnion opposite from the drive pinion and has provision for tongue coupling to the pump shaft of a small rotary oil circulating pump which is flange mounted to the bearing trunnion. The pump is a lubricating unit which automatically reverses with the change in drive rotation and thus always delivers oil to the top of the bearing. It operates to bathe the nut and screw threads, the nut bearings and the pinion and gears, intermittently, simultaneous with nut gear drive. The discharge of this pump is connected to a cylindrical oil shield, secured concentric to the screw and attached to the upper adjusting nut. Ten screws secure the shield to the nut which has twenty equally spaced tapped holes. Thus the shield and its pump lead may be maintained at approximately the same position with any varied setting of the nut. Within the shield three threaded wiper elements secured to and rotating with the elevating nut, function to remove oil from the rising screw threads whence it drains downward through the bearing to a screw cover. This cover is attached to a flange on the lower adjusting nut and functions to carry oil past a canvas bloomer which encloses the screw from the bottom of the oscillating bearing to the top of an elevating screw pocket. The pocket is a flanged steel tank assembly attached to and extending from the pan floor to the electric deck. A suction oil lead connects the reservoir space of the pocket with the pump suction. With the gun in stowed position this system is filled with lubricant to the level of a plugged hole accessible from the electric deck.

16. *Elevating screw.* - The elevating screw is a R.H. double square thread screw, 7.75 inches diameter by 149 inches long overall (130.65 inches threaded), with lead of three inches. It is secured by conventional bronze pivot pin (no wedge and wedge bearing), at its upper end, to a bracket on the slide. The attachment has offset location as indicated in paragraph 15.

Elevating Gear Control Arrangements

17. Gun elevating movement by means of the preceding described assembly is motion controlled by positioning the tilting box of the A end. Adjustment of the tilting box is accomplished through automatic control devices or a handwheel control gear mechanism. The automatic controls function only to restore the tilting box toward neutral, whereas the hand control operates between gun limits of movement to provide starting, stopping and all variations of speed control (except when the automatic arrangements "take-over").

18. The equipment which gives this performance comprise certain hydraulic and mechanical elements built-in the A-end, B-end units or connected through the control gear to those mechanisms. These are described in the text below in the sequence and under nomenclature designations as follows:

Control gear (hand gear)
Servo control
B-end response gear
Follow-up control mechanism
Limit stop
Constant horsepower mechanism
Anti-overhauling device
Neutral return device (power failure)
Neutral starting device

19. *Control gear (hand gear).* - Movement of the tilting box in every instance except power failure is performed by a hydraulic servo unit. Control circuit flow which controls movement of the servo piston is, under normal conditions, controlled through the hand control gear and a differential follow-up mechanism; under other conditions the automatic devices "take-over" control of the control circuit flow to the servo unit. Control Gear (Hand gear) is a pedestal bracket handwheel drive, bevel gear and shaft assembly. It is located with gun layer's seat on the forward electric deck adjacent to the A-end. It is arranged with its out-put shaft coupled through a friction clutch to the limit stop and thence through meshed gears to the nut of a nut and screw type differential follow-up mechanism. The differential screw has linkage connection to the valve control arrangements. This mechanical system of handwheel control from the clutch to the valve linkage is enclosed within a case assembly attached to the top of the A-end with elements arranged as shown in the sectional views of drawing number 268468.

20. *Servo control.* - On one side of the A-end with mechanical connection extending through the A-end case to the tilting box is a hydraulic cylinder and piston assembly designated the servo unit. The arrangement of this element of the control is shown on drawing number 268466.

21. *B-end response gear.* - A system of bevel gears and shafts transmits B-end shaft speed and direction of rotation from the upper response drive bracket (par. 14) to the A-end control unit. The arrangement of this subassembly is shown on drawing number 231604. It is coupled to a control input (at the A-end) which drives the differential screw of the follow-up mechanism. The response drives for the wing guns are straight shafts from the pan floor space to the electric deck, whereas the center unit comprises vertical and horizontal shafting to accommodate the offset position of the center A-end.

22. *Follow-up control mechanism.* - Thus A-end valve control displacement (to tilt the tilting box through the servo unit) is a differential quantity comprising handwheel control input and B-end response input. The latter is mechanically automatic to restore the tilting box toward neutral. It varies as B-end shaft speed and direction change and thus automatically produces a graded decelerating movement of the valve gear, servo control and the gun.

23. *Limit stop.* - The limit stop is a screw and traveling nut device of conventional design. It is arranged in the control drive as indicated in paragraph 19 and as shown on drawing number 268468. Through the follow-up and response drive arrangements the stop has positive value at all times with respect to gun position; the stops (for the traveling nut) are adjustably positioned to decelerate and stop gun movement within turret limits of gun elevation and depression (total 47°). The equivalent values* of the unit and the operating handwheels are as tabulated below.

Total turns, limit stop screw between limits - 19.08
Total turns of handwheel between stops - - - -19.08
Arc of gun movement per handwheel turn - - - -2°30'
Handwheel turns to full tilt of tilting box - 1.833

24. *Constant horsepower mechanism.* - The constant horsepower mechanism is a mechanical and hydraulic arrangement which is provided for the purpose of limiting the maximum horsepower taken from the electric motor. Under overload conditions it functions automatically to decrease the tilt of the tilting box. Thus if the combination of hydraulic pressure and stroke of the A-end is such as to cause an input horsepower to the A-end in excess of the desired limit the unit momentarily "takes-over" the control. The mechanical elements of this control include a control cam and a constant horsepower cam mounted on a shaft within the control valve case (on the A-end); a cam follower roller mounted on a pressure measuring piston and arranged to bear on the cam surface of the constant horsepower cam; and, an eccentric slot in the control cam which actuates one end of the control valve linkage, the other end of which is trunnioned to the follow-up differential screw. The pressure measuring piston has fulcrumed linkage connected to a constant horsepower valve. This arrangement operates with tilting box movement to vary the position of the pressure measuring piston and the control valve according to the predetermined values of the cams. The manner in which the unit functions together with the hydraulic arrangements is indicated in the description of the hydraulic circuit, paragraph 29.

25 *Anti-overhauling device.* - The preceding described arrangements operate identically to prevent back pressure

* Refer to paragraph 30 as to depression stops for Turret No. 2.

from causing overhauling of the transmission. Thus under conditions of unbalanced load on the elevating screw (as when the gun recoils) the anti-overhauling control "takes over" control and the tilting box is moved toward neutral.

26. *Neutral return device.* - In event that power fails or is shut off when the tilting box is on stroke, means have been provided for manually returning the tilting box to neutral. This is designated the neutral return device. It is a hand lever unit located on top of the A-end control case and mounted on a gear and cam tube shaft assembly. The gear on this shaft is meshed with a quadrant on the tilting box shaft, and the cam is positioned to operate a servo cylinder by-pass valve. Movement of the neutral return lever thirty degrees either side of neutral operates the valve and allows the servo piston to be moved freely; rotation beyond thirty degrees rotates the gear shaft and returns the tilting box.

27. *Neutral starting device.* - A switch which interlocks the motor starting circuit is located on the control valve case with plunger extending to the top surface of the constant horsepower cam. At three degrees from neutral position the plunger rides into a detent on the cam and thus moves to close the starting circuit interlock. At all other positions of the cam the switch is open and the motor cannot be started until the neutral return device has been manipulated to restore the tilting box to neutral.

Hydraulic Control Circuit

28. The hydraulic system valve elements which function with the control arrangements described above are designated by name and symbol in the tabulation below. The symbols are reference designations shown on the diagrams described in paragraph 29.

Control Circuit Valve Data

Name	Symbol	Location
Power-off valve	V1	B-end valve plate
Servo supply cut-off valve	V2	A-end control case
Control valve	V3	A-end control case
Power-off control valve	V4	Valve body on A-end
Replenishing valve	V5	B-end
Constant horsepower valve	V6	A-end control case
Shuttle valve	V7	A-end relief valve body
Directional valve	V8	A-end control case
Relief valve	V9	A-end relief valve body
Relief valve	V10	" " " "
Pilot valve	V11	" " " "
Cut-out valve	V12	" " " "
Servo piston	P1	Servo unit
Pressure measuring piston	P2	A-end control case
Clutch shifting plunger	P4	Hand control gear bracket

29. Assuming that the assembly is correctly adjusted for normal service and that the motor is in operation, the theory and performance of the controls are as follows:

Controls neutral, plate 1. - Rotation of the control gear handwheels is transmitted through the connecting shafts, gears and clutch to differential nut, D1. Differential screw, D2, is connected through the quill drive and gears to the B-end response (shaft S3) so that the output of D1 and D2 is the difference in angular displacement between the handwheels and the response. This is a linear displacement of trunnion T1 which moves links D3 and L2 and ports servo pressure through the control valve, the constant horsepower valve and either line 4 or 5 (depending on handwheel direction) to the servo piston. Resultant movement of the latter changes the tilt and stroke of the A-end and repositions shaft S1 and control cam C1. When the control cam attains a position in agreement with trunnion T1, further movement of the servo piston is prevented. Thus the A-end stroke bears fixed relationship with respect to movement of T1 from netural. At a given speed of handwheel operation T1 will remain at a given displacement from neutral and A-end stroke and B-end speed will be directly proportional to handwheel speed. If the handwheel speed is increased, linear displacement of T1 from neutral will increase with resultant increased speed of the drive and the system will become stable at the new values of stroke and speed. If the handwheels are stopped, the B-end response will cause movement of T1 toward its neutral position and the A-end stroke will decrease to zero, resulting in the B-end coming to rest.

The design of the differential screw assembly with a shoulder on the splined end and the fixed trunnion sleeve on the other limits the linear displacement of the trunnion. These stop shoulders at displacement limits bear respectively against the end faces of the differential nut assembly and when such contact occurs the handwheel drive friction clutch, F1, slips. The equivalent motion of the gun when a shoulder bears on the nut and the handwheels are stopped is less than five degrees of graded deceleration to full stop.

Constant horsepower control, figure 2. - If the combination of hydraulic pressure and stroke of the A-end is such as to cause input horsepower in excess of the desired limit, conditions will exist in the control assembly as shown in Fig. 2. The elements involved are shuttle valve V7 (in the relief valve body), directional valve V8, pressure measuring piston P2, constant horsepower valve V6 and cam C2. Normally V6 is open to permit unrestricted flow from the control valve to the servo piston. Pressure from the main system is admitted to P2 through V7 and pipe 7. The resulting displacement of P2 causes movement of

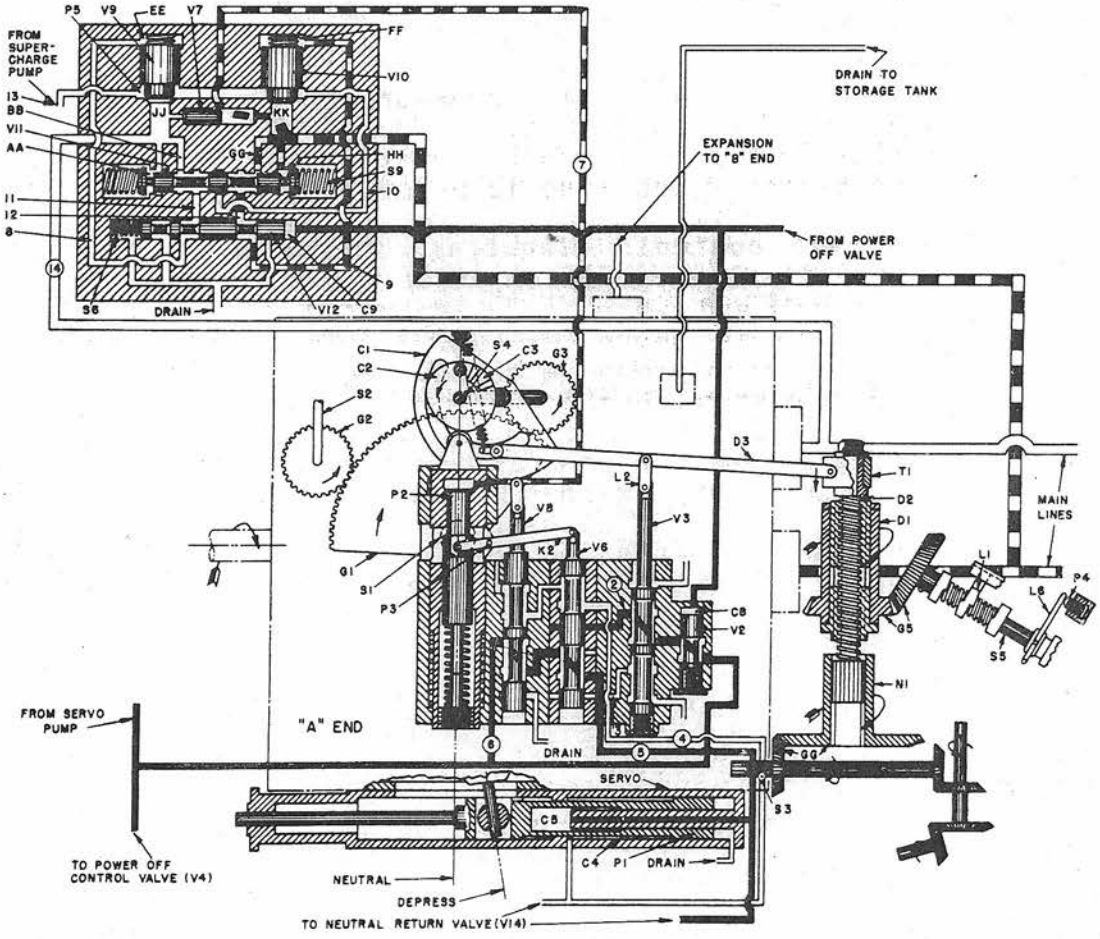


Fig. 2 - Elevating Gear Circuit Diagram (No. Pump Co.)
Constant Horsepower Control - Depression

lever K2 about pivot P3 and displaces V6. This blocks the flow of servo control pressure from V3 and opens line 6 to the opposite side of the servo piston, which is chamber C5 of the diagram (for the direction shown). Simultaneously chamber C4 is ported to the tank via V6 and V8. When motion of P1 thus reduces A-end stroke, cam C2 rotates, P2 and its outer housing move, and V6 seeks a new position toward reopening pipe 2 or 3 (depending on the direction of drive). At the required lower value of stroke a balance is thus obtained between V6 and V3 and the unit operates at the reduced stroke (with consequent lower horsepower input). When the torque demand is decreased, P2 moves back toward netural, allows V6 to open, and normal operation is resumed. If the load on the transmission is an overhauling load the functioning of the system is the same because the main line pressure is applied to P2 through the shuttle valve from the side that is high. So that the stroke is reduced no matter which line is under high pressure.

Normal control, elevating, figure 3. - The circuit flow condition under normal handwheel control and when it is operated to elevate the gun is shown in Fig. 3. The manner in which servo pressure to the right end of the servo piston (chamber C5) is controlled through valves V2, V3 and V6 is apparent from the diagram and the description as to the preceding diagrams. Main circuit relief and replenishment is illustrated by the positions of the elements of the relief valve body. Under those conditions the power-off valve (V1) of the B-end is in open position admitting servo pressure through line 15 to chamber C9 of valve V12. This holds V12 in the position shown, connecting port 9 to port 12 and port 8 to port 11. With main system high pressure entering the unit through line 14, valve V9 will be held closed by the differential area of that valve at ports EE and JJ. As pressure at port AA reaches the predetermined setting of spring S9, pilot valve V11 moves rightward closing port BB to line 11 and opening the latter to line 10. This relieves pressure in EE and causes that in chamber JJ to open V9. Pressure against the shouldered area of valve V10 allows flow of fluid to the

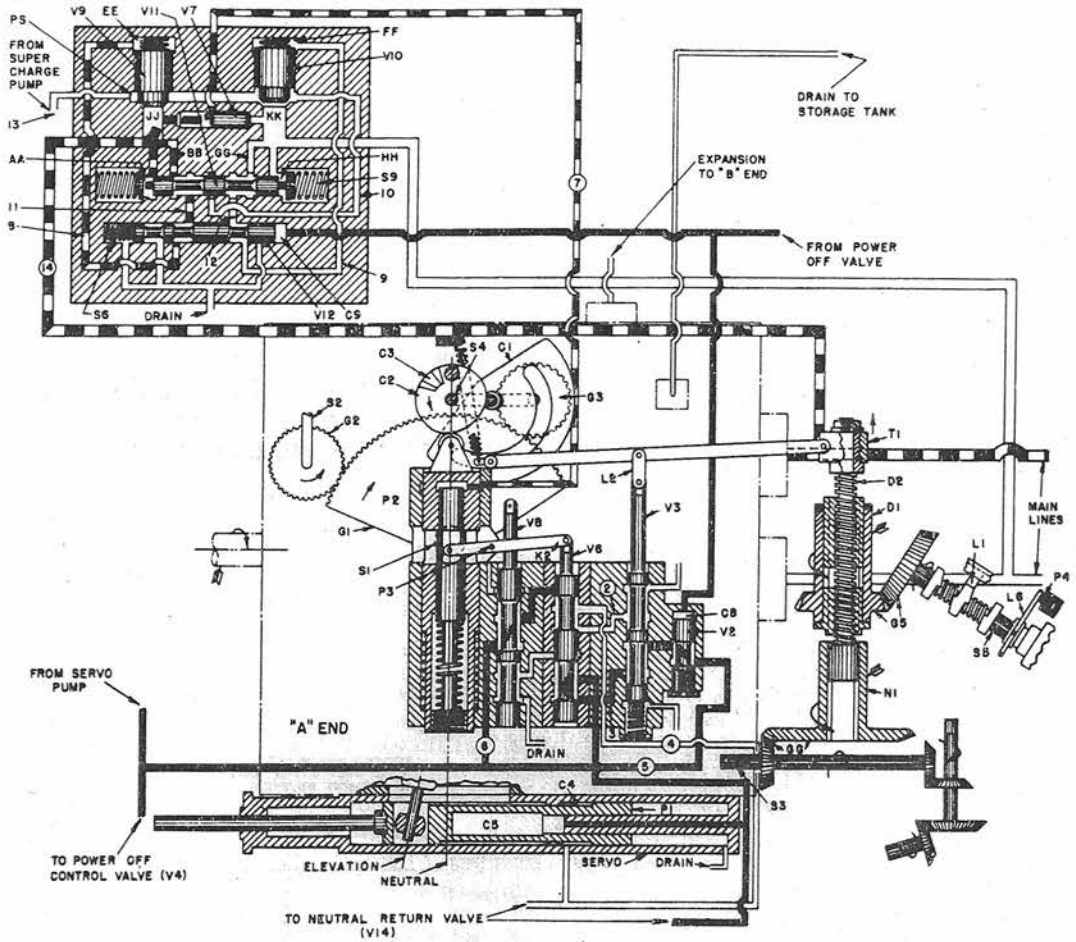


Fig. 3 - Elevating Gear Circuit Diagram (No. Pump Co.)
Normal Control - Elevation

low side of the system at port KK. When the system high pressure drops, V11 resumes its original position opening chamber EE to system pressure through BB and line 8 and thus causing V9 to close.

Under the conditions of Figure 4 the relief valves operate as a by-pass.

Power-off, Figure 4 - When the electric power unit is started the solenoid of the power-off control valve, V4, is energized. This directs the flow of oil into chamber C7 of the power-off valve, V1, forcing that valve to its open

position. In event of power failure V4 is de-energized and takes the position shown in Fig. 4. Thus chamber C7 is open to drain and V1 closes. This allows spring S6 to push V12 to the position shown opening EE and FF to drain and permitting pressure in either JJ or KK to open both relief valves and to by-pass freely.

The power-off valve opens and closes the main system ports to the B-end valve plate. When those ports are closed the oil locked in the B-end prevents any movement of the B-shaft. In order to maintain this condition against B-end oil loss two make-up check valves, V5, which are connected to the expansion tank supply, replenish the B-end.

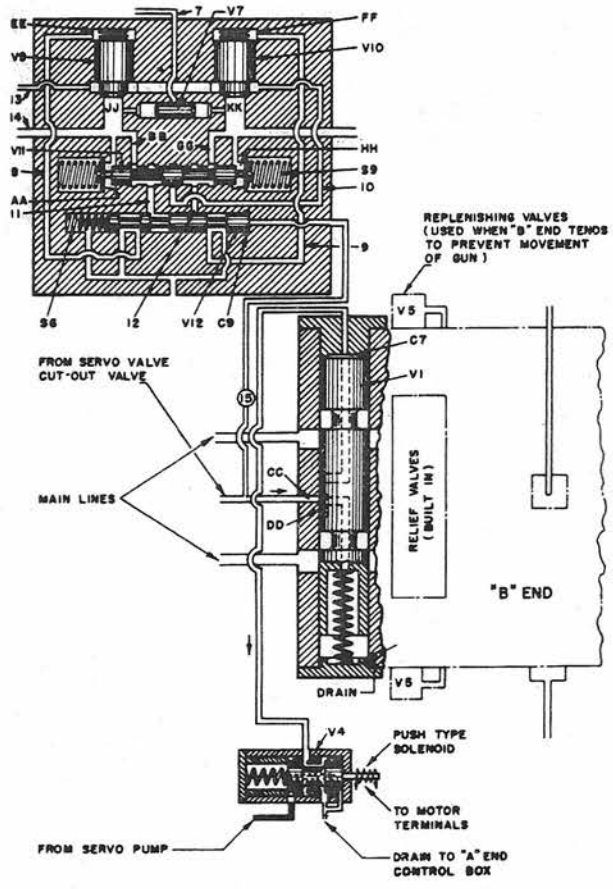


Fig. 4 - Elevating Gear Circuit Diagram (No. Pump Co.)
Power-Off Valve Closed

The power-off valve also serves the function of immobilizing the A-end control and servo units (but not the neutral return device) whenever the power is off. This is accomplished through the arrangements of the servo supply cut-off valve, V2. That valve is held open by servo pressure from port CC through line 15, and it closes to block servo pressure to the control when the power-off valve closes. Thus, during a starting operation, the A-end cannot be set on stroke by the servo unit until the main system and the servo system leads into the B-end are unrestricted.

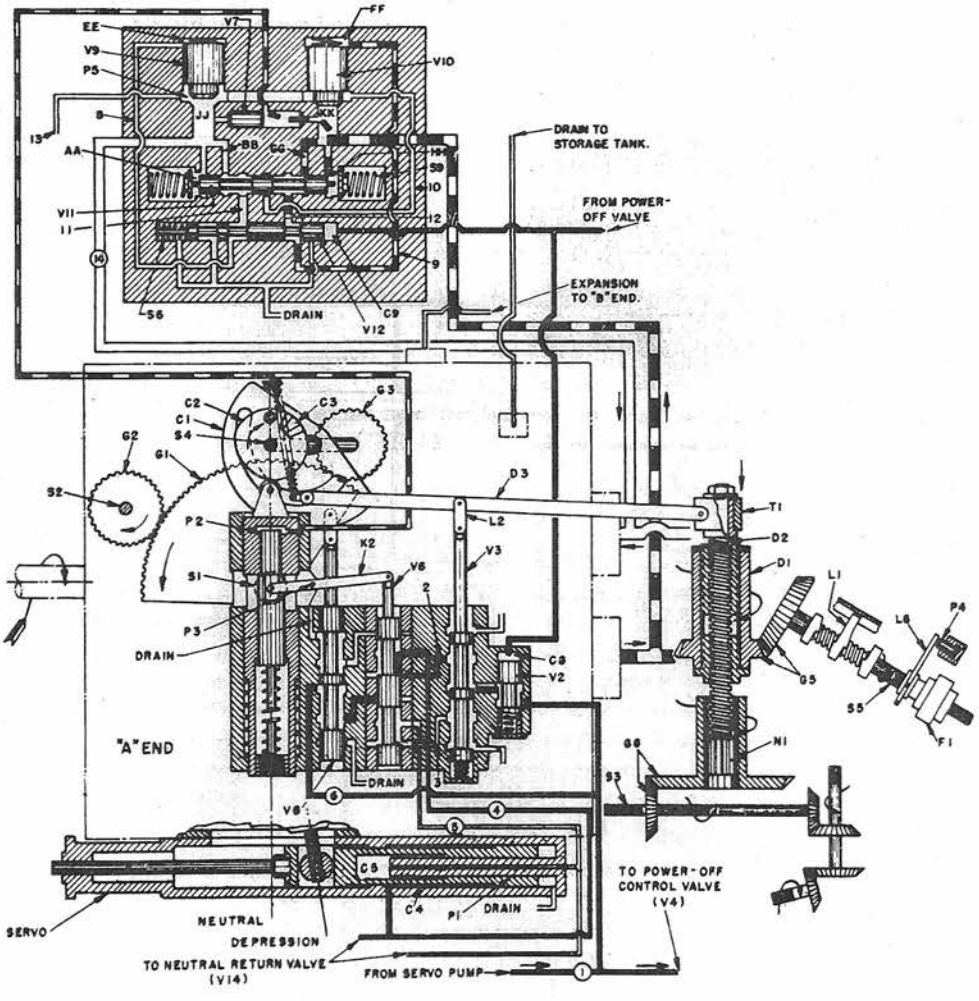


Fig. 5 - Elevating Gear Circuit Diagram (No. Pump Co.)
Normal Control - Depressing

Limit stop control, plate 2. - The device described in paragraph 23 functions at depression limit (and similarly for elevation limit) to positively stop the handwheel input and to return the tilting box to neutral through the decelerating counter movement of the response as shown in plate 2. Any rotation of the handwheels in such direction as to normally cause rotation of the limit screw beyond the set limit will cause slipping of the friction clutch. The system is free at all times to resume normal control in the reverse direction.

Normal control, depressing, figure 5, - The circuit flow conditions of figure 5 are the reverse direction of those illustrated by figure 3.

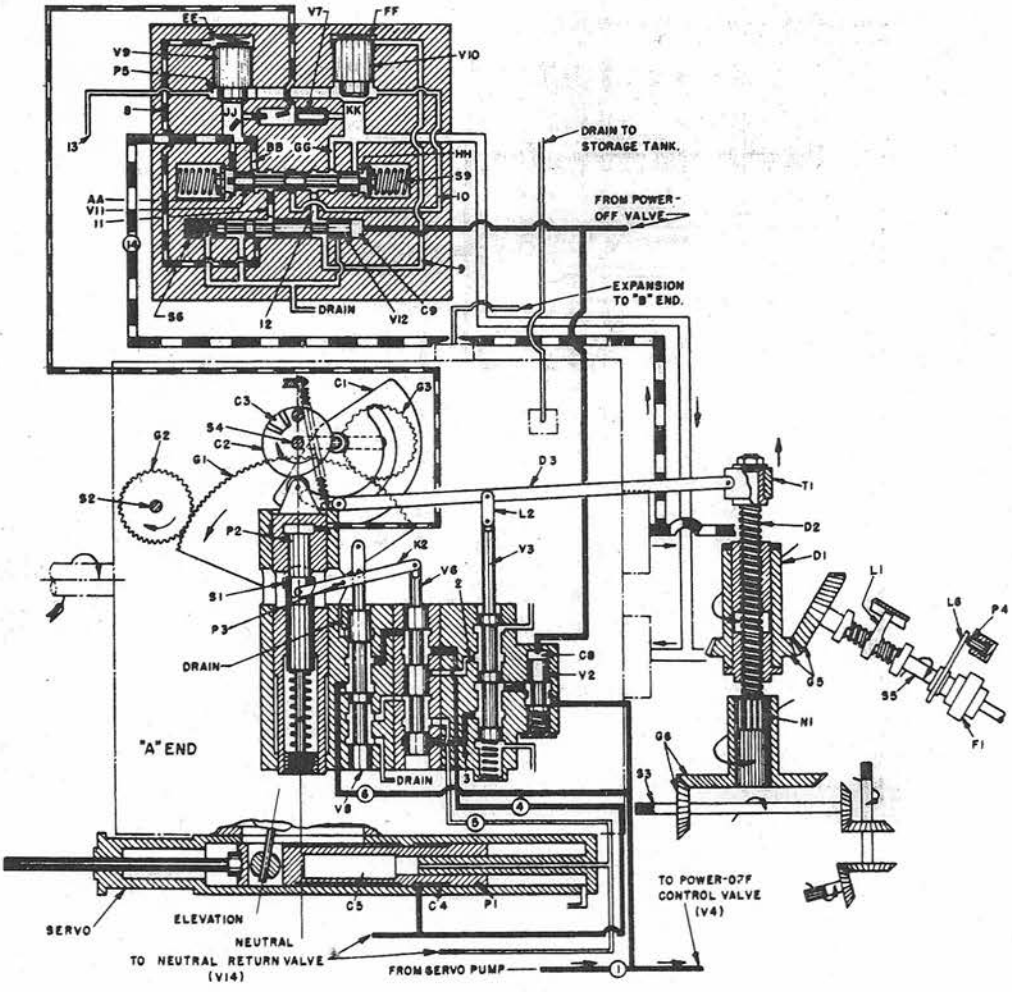


Fig. 6 - Elevating Gear Circuit Diagram (No. Pump Co.)
Constant Horsepower Control - Elevating

Figure 6. - The circuit flow conditions of figure 6 are for the reverse directions of constant horsepower control as compared to the conditions illustrated by figure 2.

Elevating Stops

30. In addition to the mechanically automatic limit stop control described above, each elevating gear includes positive stops which buff elevating movement at limits of gun depression and elevation. These are hydraulic* buffers arranged in the way of stops as shown on drawings number 217204, 230775, 233700 and 233701. The arrangements differ for mounts equipped with cast steel slides (Mark 4) as against those equipped with forged slides (Mark 5). The stops also differ in Turret No. 2 as against the arrangements in Turret No. 1 and 3. These differences and the stop arrangements are as follows: The elevating stop buffers (all mounts) comprise a pair of buffers mounted on the respective gun girders with plungers positioned in the way of stop bolts on the rear end brackets; the depression stops for cast steel slides are a pair of buffers mounted on the rear caps of the recuperator cylinders with plungers positioned in the way of pads on the turret roof; the depression stop for forged slides is a single buffer mounted between the recuperator cylinders; and the depression stop arrangements for Turret No. 2, are removable pads under the turret roof which function to stop gun movement at zero degree depression. Thus the elevating gears of Turret No. 2 are limited to total movement of 45 degrees when the pads are in place and therefore their limit stop controls (par. 23) must be adjusted accordingly.

Danger Zone Cutout Mechanism

31. In each turret an installation of three pairs of cam operated switches function to open the gun firing circuits and to close signal light circuits whenever the respective gun is laid on own ship's structure. A pair of switches comprises an elevating movement switch and a train movement switch, connected in series (operation of both required before the firing circuit for that gun is opened and the signal light circuit is closed). The arcs of fire controlled by these danger zone cutout mechanisms (and design details), are shown, for the different turret arrangements, for BB 55, 56, on drawings 233706, 238870 and 238871. The arrangements of other ships are similar. All switches are interlock switch designs of two circuit, plunger type, with firing circuit normally bridged and signal circuit normally open. Each elevating movement switch is located on the right deck lug of its gun with plunger roller positioned in the way of an actuating cam mounted on the lower slide shield plate. The three adjustable cams

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* See paragraph 34.

of each turret have identical setting. They actuate and hold switch plungers throughout gun movement in the arc from 0° to 2° depression, turret 2 and 3, and 2° elevation to 2° depression, turret 1.

The three train movement switches, one for each gun, are mounted on the holding down clip and their actuating cams are attached to the lower roller path. These cams and switches have functional arrangement for the training movement identical to the above described elevating movement devices. See chapter VI and VIII for additional data.

The signal light circuit operates a multiple arrangement of red dial signal lights. These include single dial lights at each gun layer station and three-dial signal light indicators at each pointer's and trainer's stations, at the train operator's station and at the turret officer's station.

MAINTENANCE AND OPERATING INSTRUCTIONS

32. The elevating machines are to be operated and maintained, including periodic exercise, adjustment and lubrication, in accord with the regulations of the Ordnance Manual, the instructions which follow, and the directions contained in the chapter entitled "Hydraulic Equipment".

33. *Operating precautions.* - Perform the following when preparing the gear for operation:

(*a*) Before starting the electric motor -

(1) Release and completely withdraw the slide securing pin.

(2) Perform the "Before operating" lubrication.

(3) Check and replenish the oil in the expansion tank.

(4) Verify that the filters are clear.

(5) Bring the transmission to neutral.

(*b*) Start the motor and run until the A-end valve plate temperature is 110° F.

(1) Verify that the solenoid valve has been energized.

(2) Operate the handwheels slowly.

(3) Verify that the elevating screw lubricating system is pumping oil.

(4) Operate to both limits of gun movement verifying that the limit stop control and all buffers function correctly.

34. *Buffer fluid.* - The elevation and depression stop buffers are designed for and should be filled with Hydraulic oil, O.S. 1113. These buffers should be checked for replenishment once per month at which time they should be inspected as to: -

(*a*) Full normal spring return of plungers.

(*b*) Condition of plunger packing.

(*c*) Tightness of body or bracket securing bolts.

(*d*) Alignment of plungers and stops.

35. *Hydraulic oil.* - The oil to be used in the transmission hydraulic system is that designated in Ordnance Specification No. 1113. When initially filling a system and when replenishing, the oil is to be poured through a fine mesh wire strainer of at least 120 wires to the inch; do not use cheese cloth or other rags. New assemblies should be drained after fifteen hours operation (or less), and should then be thoroughly flushed clean and refilled with fresh oil or carefully salvaged oil. Perform test inspection and analysis of oil sample from each system monthly. If there is evidence of sludge, water or acidity, drain, flush and refill with fresh oil.

36. *Instructions for filling the hydraulic system.* - When filling an empty system, it is preferable to run the oil in with the supercharge pump according to the following instructions.

(*a*) The coupling between the speed reducer and the A-end shaft should be disconnected so that the speed reducer and supercharge pump may be run independent of the A-end.

(*b*) The valve in the 1/2 inch control box drain should be kept closed until the limit stops have been set as prescribed in paragraph 44.

(*c*) To fill the A-end and B-end housings, remove the filler cover (268564-6) and pour oil into the expansion and storage tank until the oil

level remains constant at the high level petcock. With the 1/4 inch pipe plugs in the sides of the B-end valve plate loosened, the electric motor should be started and stopped, allowing the motor to run for a few seconds at a time. The oil level should be continuously checked at the low level petcock and as the oil is pumped by the supercharge pump into the main piping, oil should be added to the tank to maintain the high oil level. This procedure should be continued until oil free of air flows out of the 1/4 inch pipe plugs in the side of the B-end valve plate. Reconnect the coupling between the motor reducer and the A-end and the unit is ready to run.

Note: After the limit stops have been set, the control box drain valve should be opened. When this valve is opened, it will allow oil to flow from the expansion tank into the control box, necessitating the replenishing of the oil supply in the expansion tank.

37. *Maintenance care.* - When pipe fittings, flanges or other units of the hydraulic system are disconnected and open, maintain covers to exclude fouling. Do not remove such protection until immediately prior to reassembly. Observe the instructions of chapter XV as to cleaning pipe, assembling fittings, etc.

38. *Transmission tests and inspections.* - New transmissions or overhauled transmissions must be serviced as follows:-

(*a*) After the first week operation, tighten all bearing and foundation bolts, shaft couplings, pipe connections, etc. Check oil level.

(*b*) After the first month service, remove, filter and replace oil in the reduction gear, gear boxes and lubricating oil reservoirs. Replenish make-up oil. This operation is essential to remove any foreign matter or abrasive material resulting from initial run-in of the overhauled unit. Lubricate the assembly.

(*c*) Check and clean the oil filters at regular intervals.

39. *Lubrication.* - All parts of the elevating gear must be lubricated with the lubricants and according to the frequency prescribed by the lubrication chart.

The elevating screw lubricant must be carried to the level of the test plug hole in the tank when the mount is at rest and the gun is at zero degree elevation. The oil should be replaced quarterly with fresh oil carefully filtered through a fine mesh wire screen. Oil level must be checked before operating. The system pump can air-lock. Oil flow must therefore be checked at the screened filling plug - always immediately after starting to operate. Prime the pump and if necessary open the pump to vent and to permit priming flow to descend to the pump.

40. *Operating trouble diagnosis.* - The causes of various possible operating troubles which may occur in the electric hydraulic system are given in the subparagraphs below. An understanding of these causes and effects will facilitate installing, adjusting and servicing the mechanisms. The "trouble shooting" is in a continuity which avoids extensive disassembly until the more simple causes have been eliminated as the source of trouble.

(*a*) Motor does not start: -

Check position of tilting box. Check controller, circuit breaker and fuses.

(*b*) Drive inoperative due to control pressure failure: -

Check the servo pressure as it enters the control box to see that the proper pressure and volume of oil is being maintained at the control. A clogged filter is often the source of trouble when the servo pressure and volume is reduced.

Check the response shafting from the B-end to see that it is connected properly and there is a minimum of backlash in the connecting gearing and shafting. Any lost motion or backlash in the gearing or shafting will seriously affect the operations of the control. Sluggishness in response to operator's handwheels and failure of the B-end to stand in a set position, caused by movement of the A-end tilting box, are symptoms of lost motion.

Check the operator's handwheels and shafting connections to the A-end input shaft for lost motion.

Check the expansion connection from the A-end control box to the expansion tank. This should be shut off and the control box cover should be removed. (The pump may be run with the control cover removed.) After the cover has been removed, the piping in the control box should be examined for breakage or leaks. Examine all linkages and gears for lost motion. If the differential screw 268529-94, dr. no. 268468) has any lost motion it may be taken up by loosening the first locknut, (265800-45) and tightening the second locknut on the adjusting nut (268529-93) until all of the lost motion in the control screw has disappeared. Care should be taken that the parts are not fitted too tight, causing a binding action which is sometimes as detrimental to the functioning of the control as lost motion. If the source of trouble has not been found after following the procedure as outlined above, the next step is to disassemble the control valve body (dr. no. 268470) and inspect it thoroughly.

Trouble shooting on the power-off brake valve should start at the power-off solenoid and control valve (dr. No. 268347) and then proceed to the power-off valve in the B-end valve plate.

Check the power-off valve (268501-22) for sticking. A by-passing action might be traced to the relief valve in the B-end valve plate. If this valve is disassembled, care should be taken to reset the spring setting in its original position. The valve should relieve at approximately 1500 pounds per square inch.

(c) Drive inoperative due to main system pressure failure: -

Trouble shooting on the main hydraulic system should start by ascertaining if the unit loses its make-up or supercharge pressure.

Check the supercharge pump and filter to see that they are functioning properly.

Check the plungers (268554-16, dr. no. 268465) in the main relief valve for sticking. If the trouble is not found at this point it is most likely internal in the A or B-ends. In order to check which of the units is the source of the trouble, the slippage or expansion connections should be isolated.

The inter-expansion connections between the two units should be disconnected and the expansion from each unit run directly back to tanks. If the slippage from the B-end does not seem to be abnormal the trouble will be found in the A-end. This procedure of elimination is advisable because the servo valve and servo and supercharge relief valves discharge directly into the A-end case and make difficult discernment as to whether or not an abnormal condition exists in the A-end. The pump or motor which is causing the trouble should be disassembled and examined to find the source of the trouble.

If a condition is encountered where the pump builds up to a certain pressure and instead of increasing, pressure suddenly drops accompanied with increase in hydraulic noise, it is a sign that the main system is relieving itself. This condition may be caused by lifting of the relief valve, by a scored valve plate or by the cylinder barrel in one of the units lifting off of the valve plate. When the relief valve is relieving it is usually discernible by sound.

If the relief valve is not the source of trouble, the expansion and slippage connections on each unit should be isolated and the source of the trouble determined by watching the slippage of the units. If the valve plate on any one of the units is scored, that unit will have an excessive amount of slip. Excessive slip is sometimes caused by a scored piston. If the cylinder barrel in either of the units is lifting off, a sudden surge of oil will appear in the slip line of the unit causing the trouble. If these conditions

exist in either of these units, the offending unit should be disassembled and examined to determine the cause.

41. *To check the servo and supercharge pressures.* - The supercharge pressure should be set between 50 to 70 pounds per square inch and the servo pressure between 350 and 450 pounds per square inch. If these pressures are not within these ranges, they may be adjusted on the supercharge and servo relief valve (268480). To adjust the supercharge pressure, remove the valve cap (268569-8), which is the one nearest the mounting plate, loosen the locknut (268570-15) and screw in on the adjusting screw (268569-13) to increase the pressure or out to decrease the pressure. The servo pressure may be adjusted in a like manner with the adjustment farthest from the mounting plate.

To check the supercharge pressure or the pressure in either of the main pipes, the gauges may be connected to the 1/4 inch pipe taps in the sides of the B-end valve plate. The servo pressure should be checked in the line between the filter and the servo flange connection on the A-end control box.

Adjustments

42. *Elevating screw.* - The elevating screw pin and pin bearing is not adjustable to remove play.

43. *Elevating nut.* - Slack between the elevating nut and screw threads is removed by resetting the upper adjusting nut of the oscillating bearing assembly. To make such adjustment it is necessary to remove the ten bolts of the oil shield and the adjusting nut key before positioning the nut with large spanner. Adjustment of the lower nut (made similarly) for purpose of taking up lost motion in the mesh of the nut gear, is a yard job requiring major disassembly.

44. *Adjustment of limit stops,* (Dr. No. 268468). - The coupling between the A-end response shaft (268533-46) and the B-end response shafting should be disconnected and the traveling nut set in position by turning the handwheels. The response to regulator and the response to indicator should be disconnected until the limit stops have been set. The traveling nut should be set within three threads of the limit stop nearest the handwheels, when the limit stop has been adjusted to its maximum position in the direction of the handwheels. To adjust the limit stop, unlock lockwasher (268435-75) and screw the limit stop lock cap (268435-82) away from the limit stop (268435-8). When the limit stop lock cap has disengaged the limit stop, the limit stop may be moved to any desired position on the screw.

As soon as the limit stop has been set in its approximate position, the response coupling should be reassembled and the servo valve reset approximately in its neutral position. This position is obtained by rotating the handwheels until the clutch slips and then backing-off 1.8 turns. With the unit under power control, depress the gun to the desired maximum depression and set the limit stop nearest the handwheels by engaging it with the traveling nut, following the procedure as outlined above. Next, elevate the gun to the maximum required elevation and engage the opposite limit stop with the traveling nut.

45. *Adjustment of handwheel friction clutch.* - In event the friction clutch between the handwheel input shaft and the control will not transmit the desired torque for operation of the control, the friction may be increased by tightening the three cap screws (268853-102, dr. no. 268345).

46. *Adjustment of main relief valve,* figure 7. - To adjust the main system relief valve, remove the caps (268554-7, dr. no. 268465) and adjust each side of the valve separately with the spring adjusting screws (268554-8). The proper setting of the relief valve is 1450 pounds per square inch.

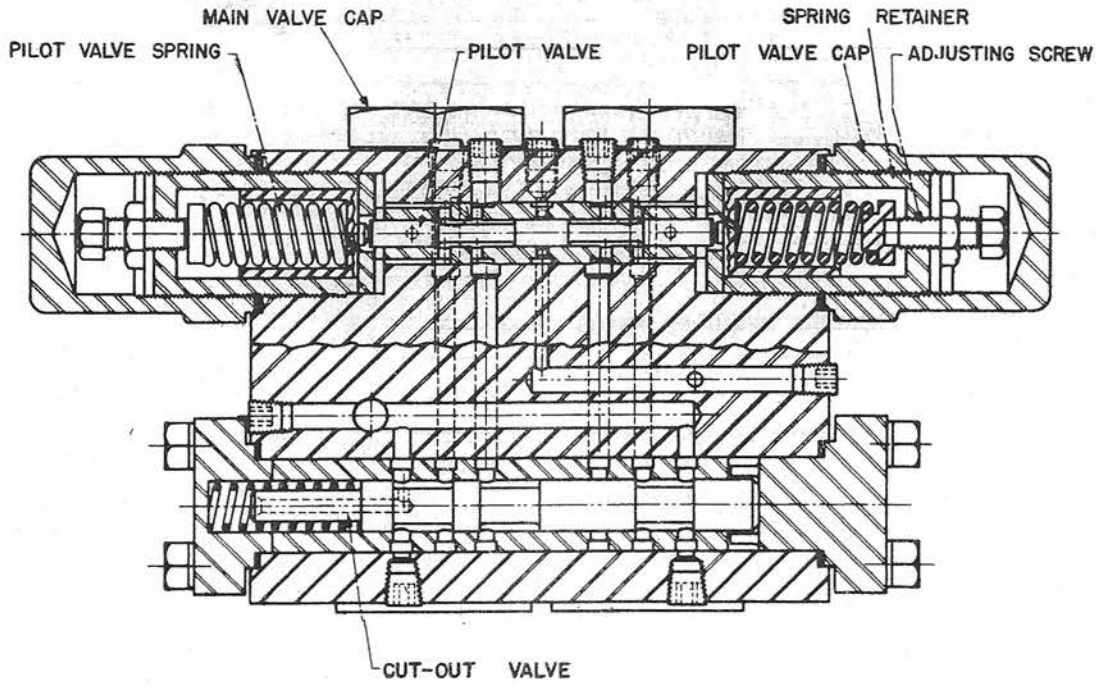

Fig. 7 - Main Relief Valve Adjustment

47. *Adjustment of constant horsepower device,* figure 8.- To adjust the constant horsepower device the cover on the control box housing must be removed. Adjustment may be made by adjusting the adjusting screw (268413-11). This increases or decreases the tension of the pressure measuring piston spring. Increasing the spring load increases the hydraulic pressure required to cause shifting of the constant horsepower valve. The factory setting of the spring as evaluated by the manufacturer is equivalent to electric motor input of approximately 108 horsepower.

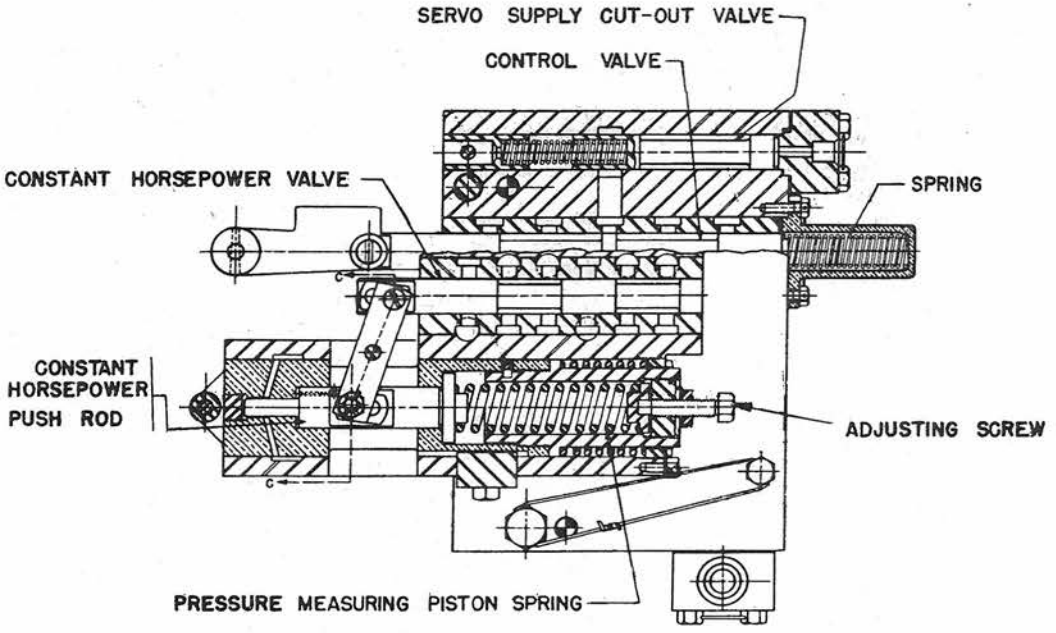

Fig. 8 - Constant Horsepower Adjustment

48. *Adjustment of relief valve in B-end valve plate,* figure 9. - Remove relief valve cap (268502-1), adjusting nut lock (268502-2) and adjust the relief valve spring (268501-5) by screwing in or out on adjusting nut (268502-4).

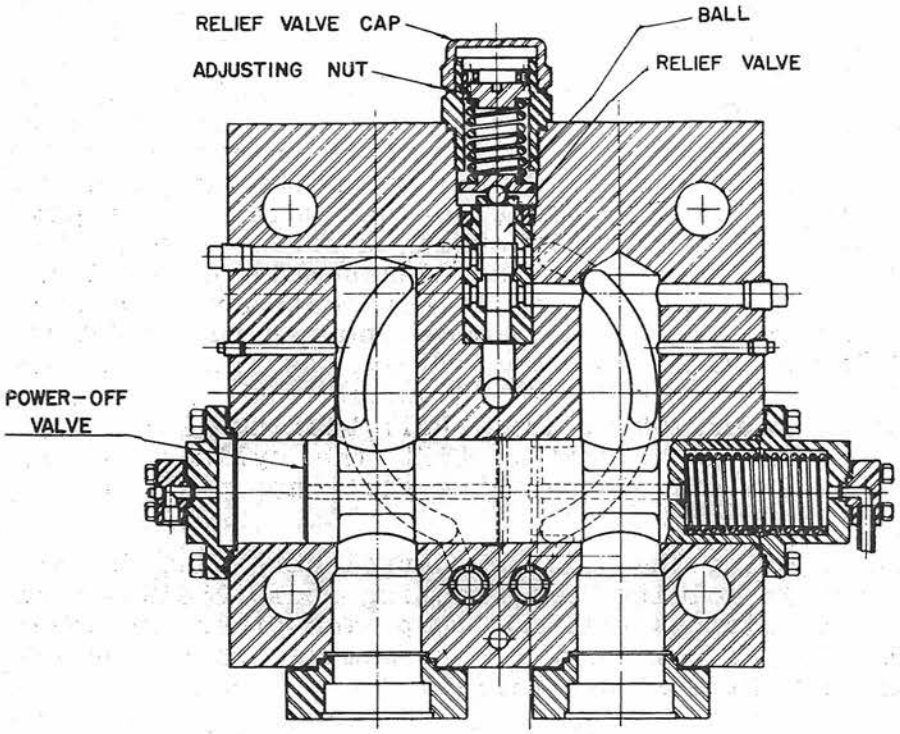

Fig. 9 - B-end Relief Valve Adjustment

DISASSEMBLY AND ASSEMBLY

49. *Disassembly of gear-motor.* - Refer to drawing number 268473. Remove the auxiliary pump from the mounting flange as indicated on the cross section. Remove the retainer cover (268543-15) being careful not to damage the oil seal (268571-21). Remove the gear case cover (268542-12). Disassembly of the remainder of the unit is apparent.

50. *Disassembly of A-end pump.* - Refer to drawing number 268461. The instructions of this paragraph give the sequence of disassembly of a complete A-end. In many cases

complete disassembly of a unit is not necessary and it is advisable to analyze the trouble and the cross-sectional assemblies carefully before starting to disassemble. Be sure that all units are completely drained before disassembly.

Remove all piping to the relief valve assembly (268465-68) and then remove the relief valve by removing the six socket head cap screws on the back side. Next remove the packing gland (268493-34) and the packing cover (268493-36). At this point it is advisable to tip the pump on end resting on supports under the front end plate (268489-46) with the drive shaft pointing down. (Do not allow the weight of the pump to rest on the control housing or servo piston housing.) It facilitates the disassembly of the A-end to tip it on end; but it is not necessary for disassembly of the unit. Remove the cap nuts (268493-32) from housing studs and lift out the studs. Remove valve plate (268487-44), locknut and lockwasher (268571-57 and 268571-49). Pull bearing (268503-55) off of the drive shaft. Lift the cylinder barrel (268482-47) off of the drive shaft and pistons.

When removing the cylinder barrel care must be exercised in holding the connecting rods (268490-3) so that the pistons will not bump each other or other parts in the pump and become damaged when they are freed by the cylinder barrel.

Remove the cylinder barrel keys (268493-52) and spring (265800-38). The inner assembly of all parts which are attached to the drive shaft, including bearing (268503-37) may now be lifted out of the housing as one assembly.

The tilting box (268492-54) cannot be removed from the housing until the control box and servo piston assembly have been removed. It is not necessary to remove the tilting box from the housing to remove the thrust bearing race (265845-66). The tilting box has three 1/2 inch 13 N.C. thread holes, tapped in the under side to be used as jackscrew holes for removing the thrust bearing.

51. *Removal and disassembly of servo piston.* - Refer drawing number 268466. Remove all external piping from the housing and remove the access cover (268547-16), machine bolt (268520-137), the two pipe plugs (268548-24) and with the servo piston centered as shown on the reference drawing, drive pin (268547-25) down and out of the stroking slide (268546-11).

Remove the nuts (268570-174) which hold the servo piston housing to the pump housing, allowing the servo piston assembly to be pulled away from the pump housing as a complete assembly. Further disassembly of the servo piston is apparent.

52. *Disassembly and assembly of control mechanism.* - Complete disassembly or assembly of the control mechanism is apparent from the following cross-sectional drawings:

Handwheel and Bracket, - - - - - - - - - 268464
Main relief valve, A-end,- - - - - - - - 268465
Control box section, - - - - - - - - - - 268468
Control box piping, - - - - - - - - - - 268469
Sectional assembly constant H.P. Valve - 268470
Section assembly friction clutch - - - 268345
Power-off control valve - - - - - - - - 268347

When assembling the control mechanism all looseness in linkages and backlash in gears must be kept at a minimum if accuracy or a minimum of lost motion is to be expected of this unit in the elevation of the guns. All valve plungers, valve sleeves, control screws, gears, etc., should be handled with utmost care in assembly or disassembly to prevent damage and consequent failure of the control to function accurately. When removing or assembling oil seals on shafts, extreme care should be exercised so that the seals will not be cracked or stretched to render them useless for sealing. Do not stretch these seals with any kind of tool in order to fit them onto the shafts; always use a sheet of thin brass or other sheet metal as a thimble to start the seal over the end of the shaft or any sharp edges that might appear on the shafts.

If the main relief valve is disassembled it must be noted that any change in the setting of springs (268409-10) will change the pressure at which the valve will operate.

When disassembling this valve the setting of the spring adjusting screw (268554-8) should be noted and reset accordingly, in assembly. After assembly it is advisable to check the valve with a hydrostatic test pump if one is available. This valve should relieve at 1450 pounds per square inch pressure.

53. *Disassembly and assembly of supercharge and servo pump.* - The sequence of operations for disassembly and assembly of this pump should be followed on drawing number 268463.

To disassemble this pump, remove the four nuts (268394-54) on one end of the pump and drive out the two top pump studs (268516-6) and the two bottom studs (268516-8). Remove the bearing plate (268517-13), liner plate (268516-9) and servo cylinder (268517-19). Turn the pump over and remove the mounting plate (268516-1), liner plate (268516-7) and supercharge cylinder (268517-14). From this same end of the pump, push the driven shaft (268516-3) down and out of the driven gear (268516-4). Next push the drive shaft (268517-11) down about one sixteenth of an inch until the key in the drive shaft just about touches the bearing plate (268517-10). Care must be exercised that the key does not hit the bearing plate and damage it. Lift the shaft up and put a shim under the gear equal to the amount that the shaft was pushed down. Repeat this until the gear (268516-12) has been removed.

When reassembling, coat the mating plates with a very thin shellac. The drive shaft should be turned slowly as the nuts (268394-54) are tightened in order to assure clearance and alignment for the gears. Do not try to run the pump unless it can be turned freely by hand.

54. *Disassembly and assembly of the B-end.* - Refer to drawing number 268462. Remove all external piping.

Remove the mounting flange (268500-35) and the oil seal (265828-42 to 46, 265828-76, 268532-40, and 265829-39). Tip the pump over, resting on the front face of piece number 268499-32 with the drive shaft pointing down. Remove the cap nuts for studs (268493-32) and remove the housing studs (268500-36). Lift off the valve plate assembly (268467-41) and the housing (268498-24). With a slight lifting tension on the drive shaft assembly, drive the drive shaft (268495-37) up and out of the bearing (268500-31). Remove the cylinder barrel (268494-53), being careful that the pistons are not damaged as they are freed by the cylinder barrel. The remainder of the disassembly is apparent.

When reassembling, make certain that all parts are free and are lubricated.

55. *Replacement limits of parts reassembled.* - The A-end pistons should be fitted .003 inch under the bore diameter in the cylinder barrel.

The B-end pistons should be fitted .003 inch under the bore diameter in the cylinder barrel.

All replacement valve plungers in the controls should be ground .001 inch under the diameter of the bore in the valve sleeves. The edges should be left sharp but without burrs.

All replacement sleeves for the valves in the control should have the hole ground and lapped with the port openings sharp but without burrs.

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Chapter VI

16-INCH TRAINING GEAR, MARK 1

General Description

1. Sixty large steel rollers support the turret for movement in train. These are mounted in a circular carriage on a roller path of 34 feet 5 inches outside diameter. The carriage is an assembly of twelve 30 degree cage sectors of five rollers each. Alternate sectors vary roller spacing in increments of five, ten or fifteen minutes. An electric hydraulic power unit with twin B-shaft outputs to two worm, worm wheel and pinion machines - all located in the rotating structure - constitutes the training gear drive. This assembly is conventionally arranged with the two driven pinions meshed with an annular rack training circle attached to the lower roller path (fixed structure).

2. The portion of this operating mechanism that comprises the power drive and its control facilities is the ordnance assembly designated, 16-inch Training Gear, Mark 1. This includes the electric motor, a reduction gear, an A-end speed gear, two B-end speed gears, two brake mechanisms, a response gear, and servo control - hand control arrangements. (The ordnance assembly does not include the driven worm-wheel bracket group.)

3. The equipment comprising this assembly is the ordnance installation as installed in each of the turrets of the USS MASSACHUSETTS and ALABAMA. (Other ships of the class are equipped with other training gear, see ch. VIII.)

4. The principal units of the assembly are located in the space above the electric deck and beneath the guns in the middle and forward half of the pan floor and electric deck compartments. The arrangement is symmetrical, with motor, reduction gear and A-end aligned on the electric deck, beneath the center gun. From the A-end valve plate large pipe manifolds (hydraulic leads) extend to the B-end units above. The two B-end drives are mounted on the pan floor and in the box gun girders (one left and one right). Their output shaft, connecting shaft, brake and driven worm are aligned longitudinally extending forward. The two worm-wheel and pinion brackets are in the forward segment at the circular bulkhead with shafts positioned vertically and extending down to the training circle. The plan arrangements at the pan floor and the electric deck are shown on drawings 230772 and 230773, respectively.

5. Total turret train movement, the position of limit stops, adjusted positions of control stops, zones of firing cut-out and other train data are as tabulated below:

Turret arc of train (clockwise; bow, zero).

Turret #1 - - - - - - - - - - - - 210° to 150°
Turret #2 - - - - - - - - - 212°30' to 147°30'
Turret #3 - - - - - - - - - - 32°30' to 327°30'

Speed of train, max.- - - - -4 deg. of arc per sec.

Zone of Firing Cut-out:

One or more guns cut-out:

Turret #1 - 2° Dep. 2° Elev. 33° Train, R & L
Turret #2 - 0° to 2° Dep. 33° Train, R & L
Turret #3 - 0° to 2° Dep. 26° Train, R & L

Electric Motor

6. The installed position of the electric motor, on the electric deck to the rear of the gun pocket, with aligned, coupled arrangement of the reduction gear and A-end, is shown on drawing 230780. The motor is a unit of commercial manufacture (Reliance Electric Co.) with design arrangement and details as shown on drawing 231539. Its specification and performance data are as tabulated below.

Motor Data

Type - Squirrel cage induction, 440 volt, 60 cycle, 3 phase, horizontal rotor, waterproof enclosure, fan cooled.
Horsepower - - - - - - - - 300 (overload rating, 540)
Speed- Constant
R.P.M., full load- - - - - - - - - - - - - - - - 1760
Amperes, full load - - - - - - - - - - - - - - - 323
Rotation, power end- - - - - - - - Counterclockwise
Lubrication- - - - - - - - - - - - - - - -Grease cups
Manufacturer's type designation- - - - AA-16B-6085
Weight, pounds - - - - - - - - - - - - - - - - - 5100

7. *Motor controller.* - The above described motor is arranged with remote push-button control by means of an auto-transformer magnetic starter. The push-button station is mounted at the train operator's station (electric deck). The controller cabinet and separate auto-transformer case are mounted together in the machinery space of the lower shell

flat. The design of these units is shown on drawing 230495. The wiring arrangement is shown on the diagrams of drawing 230496.

The controller is a waterproof enclosed panel equipped with magnetic start and run contactors, circuit breaker dashpot timer, overload, undervoltage and short-circuit protection, and door interlocked safety switch. The unit operates with the auto-transformer to start the motor at reduced voltage (50%) from "Start" push-button through a starting circuit breaker. This closes contact in the starting magnet coil circuit, the run magnet coil circuit and the run circuit breaker. Magnetic closing of the starting contactor connects the transformer to the line and supplies reduced voltage to the motor (the motor windings are connected to the transformer taps). The dashpot timer is initiated when the starting contactor closes. This timer, after a preset interval, closes and energizes the run contactor. And the latter by closing completes the circuit to supply full line voltage to the motor. The normally closed run contactor de-energizes the starting circuit magnet and contactor.

The overload protective device is an adjustable thermal type relay with magnetic reset. Its range of adjustment is from 340 to 420 amperes with normal, 355 amperes, based on 110 per cent of motor full load. The tripping delay and resetting time factors for all adjustments are given on the reference diagrams. The overload protection may be bridged for emergency operation through circuit and push-button emergency run provision. This arrangement bridges the overload relay contacts. However, the emergency run starting circuit is open (and the contactors will not close) whenever the A-end neutral switch is open. This is an interlock that prevents starting under working load (refer par. 23).

8. *Reduction gear.* - The reduction gear is a commercial unit (Falk) driven by the electric motor through a flexible coupling (Falk, #14FA). The gear provides main drive output to the A-end main shaft through a connecting shaft and two flexible couplings (see par. 9). It also provides flange mounting and drive to two auxiliary rotary type pumps. These are arranged in the hydraulic system to provide main circuit replenishment (supercharge pump) and servo control pressure (servo pump). (Refer Circuit Description, par. 25.) The unit has design characteristics as tabulated below:

Data - Reduction Gear Assembly

Speed reducer:-
Type - - - - - - -Enclosed herringbone gear train
R.P.M., output shaft, ratio 4.975 to 1 - - - 350
R.P.M., auxiliary pump drive, ratio 1.62 to 1 - 1080

Rotation, main and auxiliary shafts - - Clockwise
Lubrication - - - - - - - - - - - - - - - -Oil bath
General arrangement drawing - - - - - - - - 228471

Pump:-
Type- - - - - - - - - - - - - - Double; rotary gear
Capacity, supercharge pump- - - - - - - - 25 G.P.M.
Capacity, servo pump- - - - - - - - - - 23 G.P.M.
General arrangement drawing - - - - - - - - 268336

9. The connecting shaft couplings are commercial units (Fast's type) which provide floating compensation for slight misalignment. Each is an assembly of splined hubs, which seat on the respective shaft ends, and flanged sleeves which enclose the hubs. One sleeve of each coupling is partially filled with oil to lubricate the gearing.

Hydraulic Transmission

10. The drive transmitting arrangement installed between the preceding described power source and the two driven pinions of the train worm-wheel brackets, is a hydraulic, variable displacement machine of commercial manufacture (Northern Pump). It comprises a variable displacement pump (the A-end) and two fixed displacement hydraulic motors (the B-ends). The latter are mechanically independent from each other and the A-end but have manifold hydraulic pressure leads connecting them hydraulically to the A-end. These components of the transmission as shown on drawing 268332 (A-end) and 268333 (B-end) are the basic power transmitting units which convert input shaft rotation of constant speed and direction to reversible, variable speed, output shaft rotation. In general design they are larger versions of the similar units as installed in the elevating gear. However the training gear assembly attains 2 to 1 drive reduction through B-end displacement (two 13 cylinder motors) equal to twice A-end displacement (one 9 cylinder pump). For design details and theory of operation of the A-end, B-end units refer to chapter V.

11. The transmission provides drive speed range and performs under pressures as tabulated in the data below.

Transmission Data

A-end speed - - - - - - - - - - - - - - - - 350 r.p.m.
B-end speed (each gear) - - - - - - - 0 to 175 r.p.m.
Torque, B-shaft, max. (each)- - - - - 11200 lb.ft.

Pressures:-
Relief valve setting- - - - - - - - - - 1450 P.S.I.
Servo pressure- - - - - - - - - - - - - 400 P.S.I.

Replenishing pressure - - - - - - - - - - 50 P.S.I.
Constant horsepower control, max. - - - - - - 540 HP

Temperatures:-
Normal oil operating range - - - - 120° to 175°F
Max. permitted oil temp. - - - - - - - - - - 185°F

Power-off Brakes

12. Between the B-shaft outputs and the driven worms (worm-wheel bracket) each drive is provided with a mechanical brake, spring actuated to set and power actuated to release. These brakes function to stop and to hold the turret in train in event of loss of power. Each brake when applied will oppose any tendency to coast with a torque equivalent to 2500 pound feet. Each brake includes a large brake drum, two brake lined brake shoes, two main springs, brake shoe levers and a linkage connecting to the piston of a hydraulic cylinder. The assembly is supported from a separate mounting base with the drum spline coupled in the B-shaft drive. Drawing 268346 shows the arrangement of parts. Operation of the unit is described in the Hydraulic Circuit text, paragraph 25.

Training Gear Control Arrangements

13. Turret train movement by means of the preceding described assembly is motion controlled by positioning the tilting box of the A-end. Such control movement is accomplished through handwheel control gear facilities and certain automatic control arrangements. The latter function only to restore toward neutral whereas the hand control operates between turret limits of train to initiate starting motion, provide all variations of speed control, reverse and stopping. Both hand and automatic arrangements control tilting box movement by means of hydraulic servo piston and cylinder.

14. These groups of control facilities include hydraulic and mechanical elements built-in the A-end, B-end units or connected through the control gear to those mechanisms. They are described in sequence and under nomenclature designations as follows:

Control Gear (hand gear)
Servo Control
B-end Response Gear
Follow-up Control Mechanism
Limit Stop
Constant Horsepower Mechanism
Anti-overhauling Device
Neutral Return Device (power failure)
Neutral Starting Device

15. *Control gear (hand gear).* - Movement of the tilting box in every instance, except power failure, is performed by a hydraulic servo unit. Hydraulic flow which controls movement of the servo piston is normally controlled through the hand control gear and a differential follow-up mechanism; under other conditions the automatic devices "take over" control circuit flow. Control gear (hand gear) is a pedestal bracket, handwheel drive. It is located with train operator's seat on the forward electric deck adjacent to the A-end. Arranged as shown on drawing 230789, its output shaft is coupled through a friction clutch to the limit stop (par. 19) and thence to the screw of a nut and screw type differential follow-up mechanism. The differential screw has linkage connection to control valve gear built-in the top of the A-end. Drawing 268340 shows the mechanical arrangements of this subassembly, described as to control operation in paragraphs 24 and 25.

In addition to control gear operation from the train operator's station as above, the pedestal assembly includes a manually operated clutch and bevel gear drive coupled to shafting from the right and left trainers' stations (shelf plate level). This alternative control provides control gear operation and tilting box movement through the same A-end arrangements.

16. *Servo control.* - The servo piston and housing unit shown on drawing 268339 is mounted on one side of the A-end with mechanical connection through the case to the tilting box. The arrangement is an enclosed double acting piston with control circuit connections and operating cycle as described in paragraphs 24 and 25.

17. *B-end response gear.* - B-shaft speed and direction of rotation for A-end control gear response is taken from the right hand B-end. A system of bevel gears, brackets and shafts transmits the motion down through the pan floor to the A-end control. The arrangement of the subassembly is shown on drawings 230787 and 230788. It is coupled at the A-end to an input which drives the differential nut of the follow-up mechanism.

18. *Follow-up control mechanism.* - From the preceding it is apparent that A-end valve control displacement (to tilt the tilting box through the servo unit) is a differential quantity comprising handwheel control input and B-end response. These position the differential screw and differential nut (respectively) of the follow-up control mechanism shown on drawing 268340. For every differential screw adjustment by the handwheels there is automatic counter adjustment of the differential nut. The latter functions always to restore the tilting box toward neutral and varies as B-shaft speed and direction change. Thus the follow-up action produces a graded decelerating movement of the control valve mechanism, the servo piston and the turret.

19. *Limit stop.* - The limit stop is a screw and traveling nut device of conventional design. It is vertically positioned at one corner of the A-end case with control gear connection as described in paragraph 15. The unit as shown on drawing 268341 includes a housed assembly of the limit stop screw, a traveling nut, two limit stops adjustably mounted on the screw, and a friction clutch shifting mechanism. Through the follow-up and response drive arrangements the limit stop has positive value at all times with respect to turret position. It functions, by the adjusted positions of the two stops on the screw, to limit travel of the traveling nut and thus to stop rotation of the differential screw. When the latter stops revolving it is displaced in countermovement by response drive of the differential nut until the tilting box is moved to neutral. The limit stop function is thus follow-up control stopping action - a graduated stop. The limit stops for all turrets are adjusted to stop the drive at the train limits given in paragraph 5. Those arcs of train have equivalent turns of limit screw and related values of handwheel (train operator) as tabulated below.

Total turns, limit stop screw between limits (for 295° and 300° of train, respectively) - 58.98-59.98
Total turns of handwheel between stops - 147.5 - 150
Arc of train per handwheel turn- - - - - - - - - 2°
Turns of handwheel to full stroke- - - - - - - 2.72

20. *Constant horsepower mechanism.* - The constant horsepower mechanism is a mechanical and hydraulic arrangement which is provided for purpose of limiting the maximum horsepower taken from the electric motor. Under overload conditions it functions automatically to decrease the tilt of the tilting box. Thus if the combination of hydraulic pressure and stroke of the A-end is such as to cause an input horsepower in excess of the desired limit the unit momentarily "takes over" the control. The mechanical elements of this control are like those of the elevating gear units. They include a control cam and a constant horsepower cam mounted on a shaft within the control valve case (on the A-end); a cam follower roller mounted on a pressure measuring piston and arranged to bear on the cam surface of the constant horsepower cam; and, an eccentric slot in the control cam which actuates one end of the control valve linkage, the other end of which is trunnioned to the follow-up differential screw. The pressure measuring piston has fulcrumed linkage connected to a constant horsepower valve. This arrangement operates with tilting box movement to vary the position of the pressure measuring piston and the control valve according to predetermined cam values. The manner in which the device functions together with the hydraulic arrangements is indicated in the hydraulic circuit descriptions (par. 25).

21. *Anti-overhauling device.* - The preceding described constant horsepower device operates identically to prevent back pressure from causing overhauling of the transmission. Thus under conditions of unbalanced load on the training pinions (i.e., "whip", when wing gun is fired) the anti-overhauling control "takes over" and the tilting box is moved toward neutral.

22. *Neutral return device.* - In event that power fails or is shut off when the tilting box is on stroke, means have been provided for manually returning the tilting box to neutral. This is designated the neutral return device. It is a hand lever unit located on top of the A-end control case. This operates to depress a by-pass valve in the servo control circuit and to simultaneously mesh spur gears. Rotation of the lever thereafter returns the tilting box to neutral. It functions for either stroke position of the A-end pump.

23. *Neutral starting device.* - A switch which interlocks the motor starting circuit is located on the control valve case with plunger extending to the top surface of the constant horsepower cam. At three degrees from neutral position (of the tilting box) the plunger rides into a detent on the cam and thus moves to close the starting circuit interlock. At all other positions of the cam the switch is open and the motor cannot be started until the neutral return device has been manipulated to restore the tilting box to neutral.

Hydraulic Control Circuit

24. The hydraulic system valve elements which function with the control arrangements described above are designated by name and symbol in the tabulation below. The symbols are reference designations on the diagrams of plates 3, 4 and figures 10 to 14, inclusive. The performance conditions illustrated by the seven diagrams are described in paragraph 25.

Control Circuit Valve Data

Name	Symbol	Location
Control valve	V3	A-end control case
Power off control valve	V4	A-end control case (rear)
Neutral return valve	V5	A-end control case
Constant horsepower valve	V6	A-end control case
Shuttle valve	V7	A-end relief valve body
Directional valve	V8	A-end control case
Relief valve	V9	A-end relief valve body
Relief valve	V10	A-end relief valve body
Pilot valve	V11	A-end relief valve body
Servo piston	P1	Servo unit
Pressure measuring piston	P2	A-end control case
Brake release plunger	P3	Each brake unit
Clutch shifting plunger	P4	Limit stop

25. These control elements function to give train drive performance as described in the following subparagraphs:

(a) *Controls neutral,* plate 3. - Rotation of the control gear handwheels is transmitted through the connecting shafts, gears and clutch to differential screw, D2. The differential nut, D1, is connected through gearing to the B-end response (shaft S3) so that the output of the differential nut and screw is the difference in angular displacement between the handwheels and the B-shaft response. This appears as a linear displacement of trunnion T1 with resultant movement of links D3 and L2, and control valve, V3. The latter ports servo pressure through the constant horsepower valve and either line 4 or 5 (depending on handwheel direction) to the servo piston at chamber C4 or C5. Resultant movement of the piston changes the tilt and stroke of the A-end. Shaft S1 and its cams, C1 and C2, rotate in response to every movement of the tilting box (G1 on tilting box trunnion shaft drives G3). When the control cam attains a position in agreement with T1 further movement of the servo piston is prevented. Thus the A-end stroke bears fixed relationship with respect to movement of T1 from neutral. At a given speed of handwheel operation T1 will remain at a given displacement from neutral and A-end stroke and B-end speed will be directly proportional to handwheel speed. If the handwheel speed is increased, linear displacement of T1 from neutral will increase with resultant increased speed of drive. The system will become stable at the new values of stroke and speed. If the handwheels are stopped, the B-end response will cause movement of T1 toward neutral position and the A-end stroke will decrease to zero, resulting in the B-end coming to rest.

The design of the differential screw assembly with a shoulder on the splined end and the fixed trunnion sleeve on the other limits the linear displacement of the screw in each direction from neutral. When such limit of displacement occurs the friction clutch, F1, slips and B-end response operates to restore to neutral. If handwheel rotation has stopped, the restoration of the tilting box to neutral position occurs in less than two degrees movement in train.

With the control at neutral, as in this diagram, servo pressure is blocked at the control valve, the tilting box is at neutral and there is no main system flow to the B-ends. Make-up fluid from the supercharge pump is available to supply the low pressure side of the system at port P5. The arrangement of valves in the relief block provides for main system replenishment and relief through automatic action of two relief valves, V9 and V10, and a pilot valve, V11. The latter is connected to the relief valves at ports AA, BB, CC and DD. If it is assumed that line 8 is high pressure V9 will be held closed by

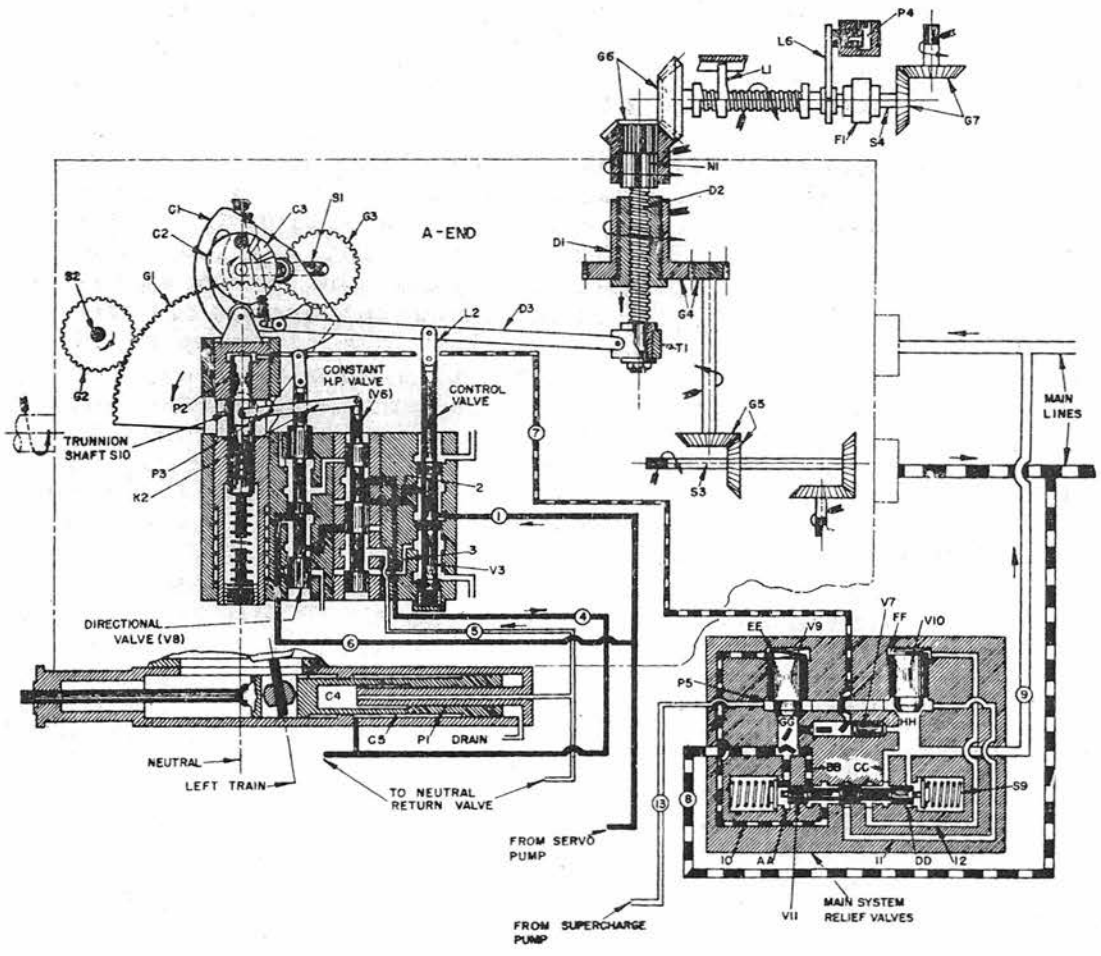

Fig. 10 - Training Gear Circuit Diagram (No. Pump Co.)
Normal Control - Left Train

the differential area of the valve at ports EE and GG. As pressure at port AA reaches the predetermined setting of spring S9, pilot V11 moves rightward, closes port BB and opens line 10 to line 11. This relieves pressure in chamber EE and enables pressure at GG to open V9. Valve V10 allows flow of fluid to the low side at port HH when pressure on the shouldered area lifts the valve. The pilot valve resumes its original position and ports pressure to EE to close V9, when the system pressure drops.

(*b*) *Normal control, left train,* figure 10. - The manner in which the controls function to produce normal train movement and the circuit flow conditions of such control are illustrated by the diagram of figure 10. Control circuit servo pressure is applied to the servo piston (chamber C5) through valves V3 and V6 as indicated in the description above, when T1 is displaced by handwheel rotation. The tilting box is moved to give A-end stroke and high pressure flow is delivered to the B-ends. V9 is closed under high pressure at EE (until such time as excess pressure displaces the pilot valve, V11). V10 is relieved and opens to permit make-up flow for main system replenishment.

(*c*) *Constant horsepower control, right train,* figure 11. - If the combination of hydraulic pressure and stroke of the A-end is such as to cause input horsepower in excess of the desired limit, conditions will exist in the control assembly as shown in figure 11. The elements involved are shuttle valve V7 (in the relief valve body), directional valve V8, pressure measuring piston P2, constant horsepower valve V6 and cam C2. Normally V6 is open to permit unrestricted flow from the control valve to the servo piston. Pressure from the main system is admitted to P2 through V7 and pipe 7. The resulting displacement of P2 causes movement of lever K2 about pivot P3 and displaces V6. This blocks the flow of servo control pressure from V3 and opens line 6 to the opposite side of the servo piston, which is chamber C5 of the diagram (for the direction shown). Simultaneously chamber C4 is ported

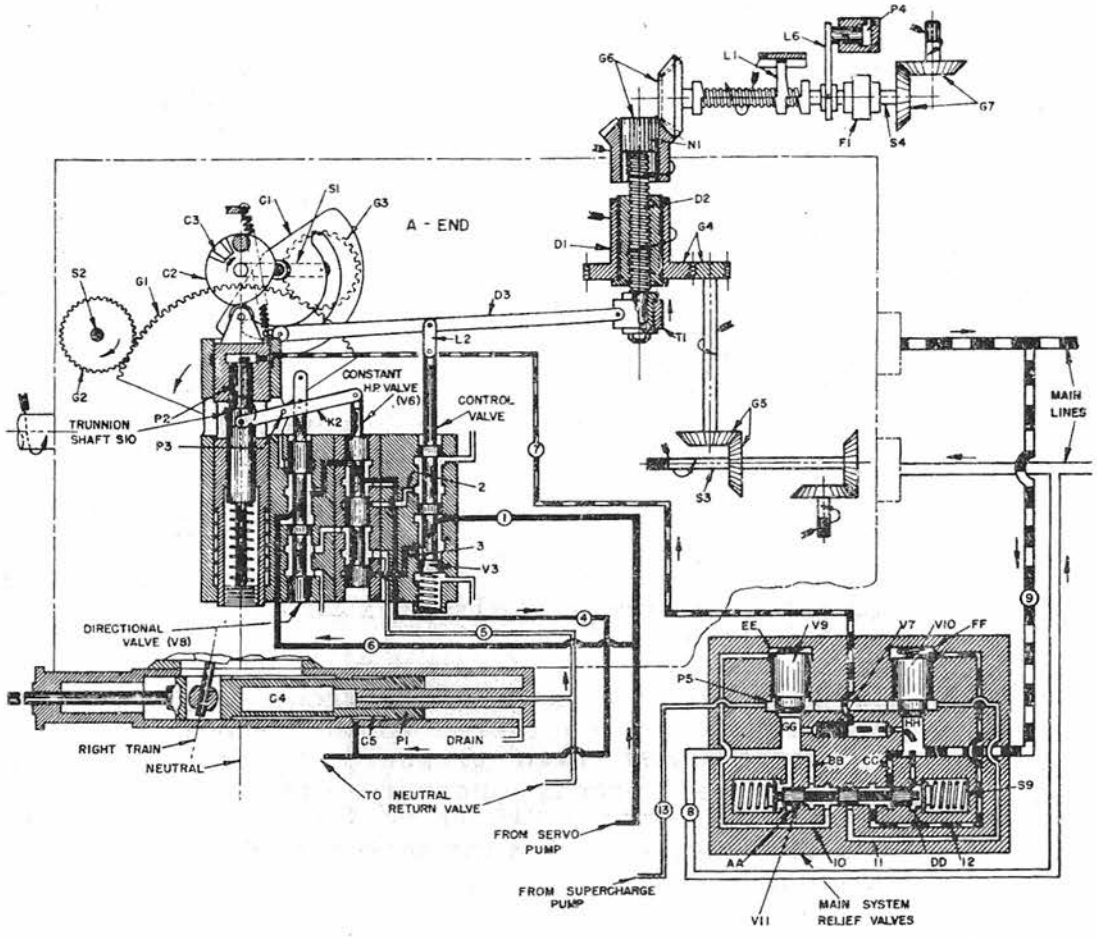

Fig. 11 - Training Gear Circuit Diagram (No. Pump Co.)
Constant Horsepower Control - Right Train

to the tank via V6 and V8. When motion of P1 thus reduces A-end stroke, cam 2 rotates, P2 and its outer housing move, and V6 seeks a new position toward reopening pipe 2 or 3 (depending on the direction of drive). At the required lower value of stroke a balance is thus obtained between V6 and V3 and the unit operates at the reduced stroke (with consequent lower horsepower input). When the torque demand is decreased, P2 moves back toward neutral, allows V6 to open, and normal operation is resumed.

If the load on the transmission is an overhauling load the functioning of the system is the same - main line pressure is applied to

P2 through the shuttle from the side that is high. The resultant servo control movement is counter to any handwheel control and always tends to restore toward neutral.

(*d*) *Power-off brake applied,* figure 12. - A power-off brake, B1, is provided on the output shaft of each B-end. In plate 3, the brakes are shown released with the holding springs compressed by servo pressure on plunger P3. When the electric motor is started, solenoid valve V4 (connected to motor terminals) is energized, the valve is moved and servo pressure is ported to release the brakes. Figure 12 shows power failure cut-off of servo pressure and porting of brake pressure cylinders to the circulating system (A-end control case).

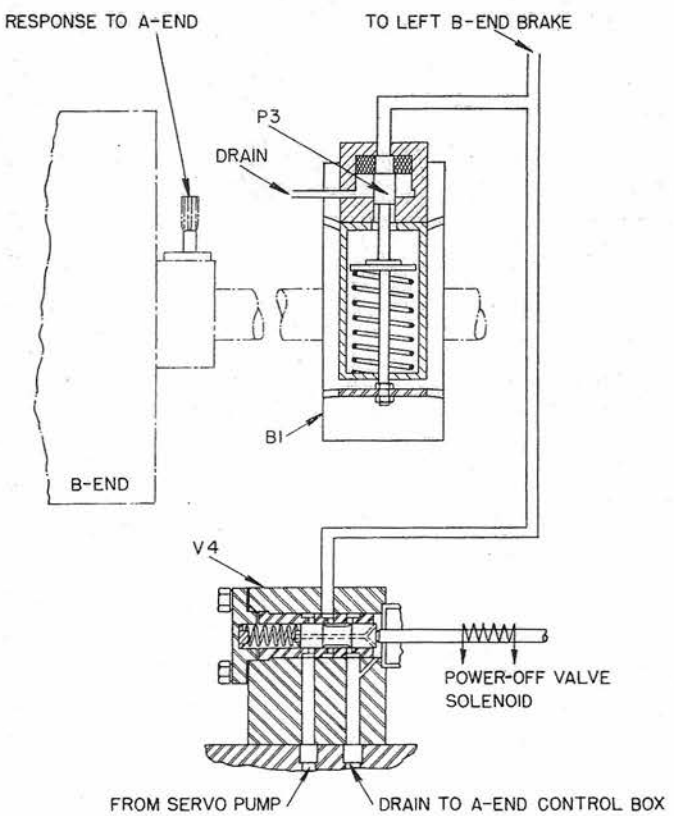

Fig. 12 - Training Gear Circuit Diagram (No. Pump Co.)
Power-off Brake Applied

(e) *Limit stop control*, plate 4. - The device described in paragraph 19 functions at limits of turret train to positively stop the handwheel input. Plate 4 shows left train movement with traveling nut L1 engaged with the left train limit stop. Handwheel displacement of the differential screw has ceased and response drive of the differential nut has started countermovement of the screw, the linkage and V3, so that servo pressure has shifted from pipe 4 to pipe 5. Comparison of left train servo flow as shown in figure 10, with limit stop servo control flow for left train as shown in plate 4, illustrates the extent of control valve shift and the throttling action that gives limit stop servo control deceleration. Any rotation of

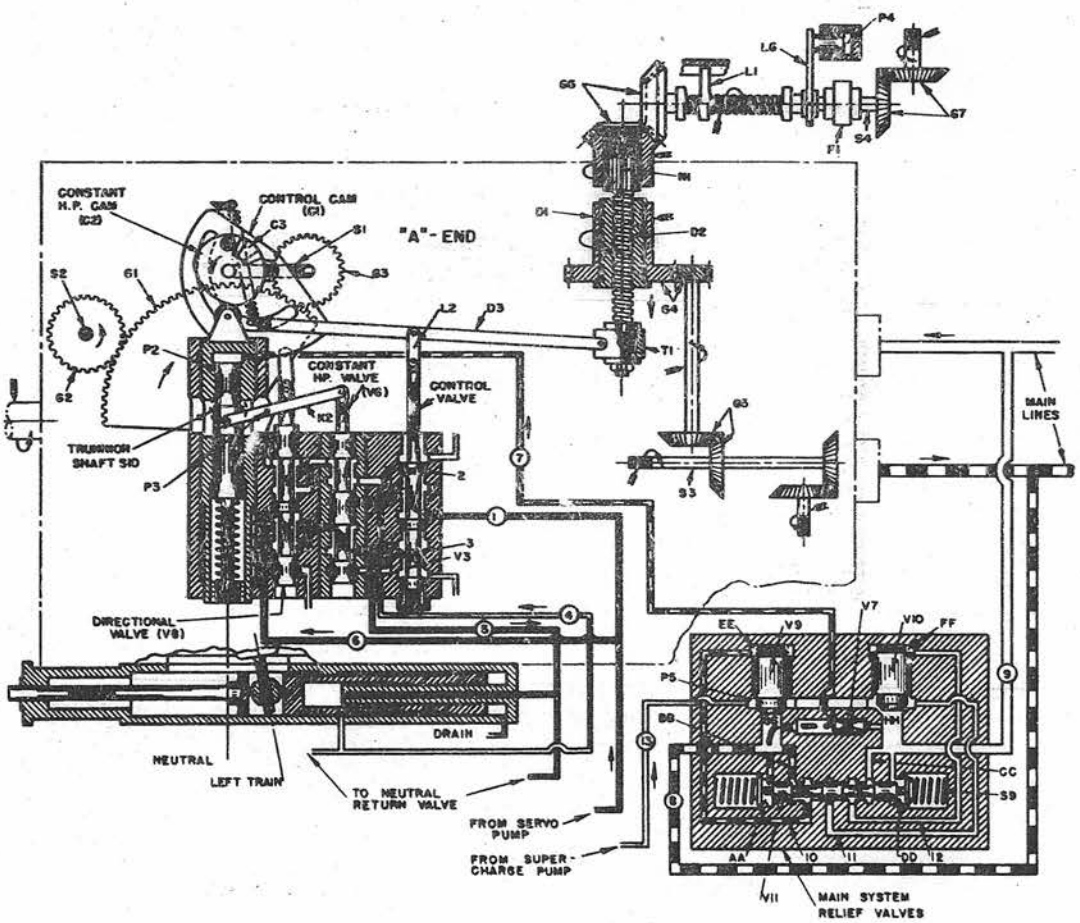

Fig. 13 - Training Gear Circuit Diagram (No. Pump Co.)
Constant Horsepower Control - Left Train

the handwheels in such direction as to normally cause rotation of the limit screw beyond the set limit will cause slipping of the friction clutch. The system is free at all times to resume normal control in the reverse direction.

(f) *Constant horsepower control, left train,* figure 13. - The circuit flow conditions of the diagram of figure 13 are for the reverse direction of those described in subparagraph (c).

(g) *Normal control, right train,* figure 14. - The circuit flow conditions of the diagram of figure 14 are for the reverse direction of those shown in figure 10.

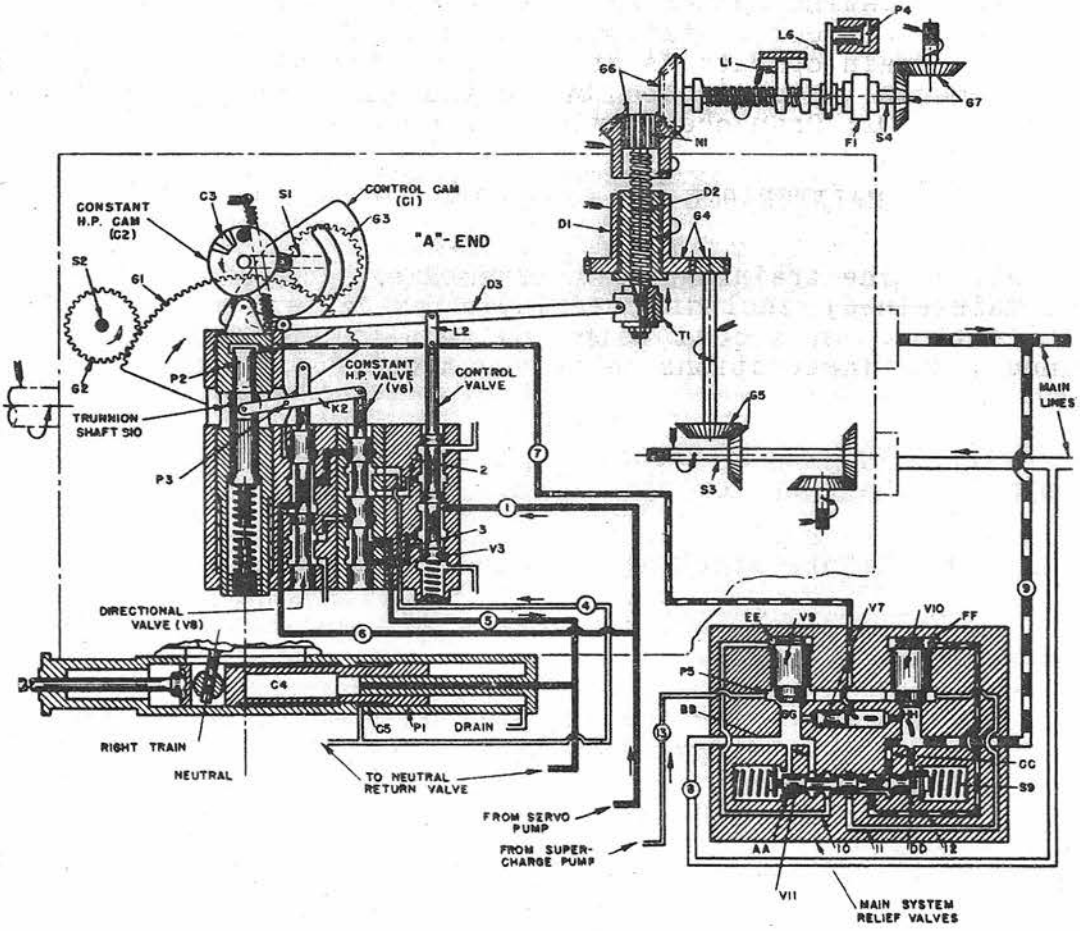

Fig. 14 - Training Gear Circuit Diagram (No. Pump Co.)
Normal Control - Right Train

Training Stops

26. In addition to the mechanically automatic limit stop control described above each turret train movement is provided with positive stops located at limits of train (see par. 5). The stops and hydraulic buffers have design and general arrangement as shown on Bureau of Ships drawing number 274927.

Training Stop Signal Switch

27. Each training gear includes an arrangement of signal switches, cams, signal indicators and firing circuit cut-out provisions, which operate in conjunction with elevating gear signal installations to provide zones of firing cut-out. (Refer to data, par. 5.) The arrangement of these devices is shown on drawing number 238870. Signal light indicators at the turret officer's station, right and left trainer's stations and the train operator's station are provided with circuit arrangements as indicated by Bureau of Engineering diagram BB 55-S65-901; Ordnance drawing number 220489.

MAINTENANCE AND OPERATING INSTRUCTIONS

28. The training gear assemblies are to be operated and maintained, including periodic exercise, adjustment and lubrication, in accord with the regulation of the Ordnance Manual, the instructions below and those contained in chapter XV.

29. *Operating precautions.* - Perform the following when preparing the gear for operation.

(*a*) Before starting the electric motor.

(1) Release and completely withdraw both centering pins.

(2) Lubricate the assembly as specified in the lubrication schedule.

(3) Check and replenish the hydraulic oil supply.

(4) Verify that the filters are clear.

(5) Bring the transmission to neutral.*

---

* Press down on the neutral return hand lever and turn until indicator shows pump is at neutral stroke, then stroke handwheels until clutch slips; - reverse handwheels 2.7 turns.

(*b*) Start the motor and run until A-end valve plate temperature is 110° F.

(1) Verify that the power-off solenoid has been energized and that the brakes are released.

(2) Operate the handwheels slowly for a few degrees train each way from neutral, return to neutral, stop motor and after five minutes remove and replace the 1/4 inch vent plugs in the B-end valve plates.

(3) Start the motor and operate the handwheels into a limit stop. Observe as to normal operation of the servo and limit stop actions.

30. *Hydraulic oil.* - The oil to be used in the transmission hydraulic system is that designated in Ordnance Specification No. 1113. Only clean, carefully filtered oil may be used to fill or replenish the system; fill through a fine mesh wire strainer of at lease 120 wires to the inch. New assemblies should be drained after fifteen hours operation and should then be thoroughly flushed clean and refilled with fresh oil or carefully salvaged oil. Perform test inspection and analysis of oil sample monthly; if evidence of sludge, water or acidity is found, drain, flush and refill with fresh oil.

31. *Filling the hydraulic system.* - A new installation or a drained system should be filled by circulating oil into the control circuit and cases with the servo and supercharge pumps in operation, but with the A-end idle. The coupling between the gear reduction and the A-end shaft should be opened so that the gear reduction auxiliary pump drive may be run independent of the A-end.

If the limit stops have not been adjusted (see par. 37) the control box should be kept dry until the settings have been made by actual operation of the drive. The box is kept dry by closing the valve in the 1/2 inch box drain.

The system is filled by the following procedure:-

(*a*) Remove filler cover (268564-6, on dr. 268350) on the tank.

(*b*) Pour oil through filler strainer until oil level remains constant at the high level petcock.

(*c*) Vent the B-end valve plate plugs.

(*d*) Start and stop the motor-run for periods of one-half minute at a time. Check oil level continuously at the low level petcock. Add oil to the tank as the main system is filled by the supercharge pump. Maintain the high oil level and continue to fill until oil free of air flows from the B-end valve plate vents.

(*e*) Replace the vent plugs.

(*f*) Connect the A-end coupling.

(*g*) Adjust the limit stops (if required).

(*h*) Open the control box drain.

(*i*) Replenish oil in tank.

Note: After the limit stops have been set, the control box drain valve should be opened. When this valve is opened, it will allow oil to flow from the expansion tank into the control box, necessitating the replenishing of the oil supply in the expansion tank.

32. *Maintenance care.* - When pipe fittings, flanges or other units of the hydraulic system are disconnected and open, maintain covers to exclude fouling. Do not remove such protection until immediately prior to reassembly. Observe the instructions of chapter XV as to cleaning pipe, assembling fittings, etc.

33. *Transmission tests and inspections.* - New transmissions or overhauled transmissions must be serviced as follows:-

(*a*) After one week of operation, tighten all bearing and foundation bolts, shaft couplings, pipe connections, etc. Check oil level.

(*b*) After the first month of service, remove, filter and replace oil in the reduction gear, gear boxes and lubricating oil reservoirs. Replenish make-up oil. This operation is essential to remove any foreign matter or abrasive material resulting from initial run-in of the overhauled unit. Lubricate the assembly.

(*c*) Check and clean the oil filters at regular intervals.

34. *Lubrication.* - All parts of the training gear must be lubricated with the lubricants and according to the frequency prescribed by the lubrication chart.

Particular care must be given the reduction gear, checking frequently as to oil level and temperature. Bearings have been damaged in these gears for lack of lubrication (a pump and oil circulating system may be added).

Refer to drawings 243614 and 243615.

35. *Operating trouble diagnosis.* - The causes of various possible operating troubles which may occur in the electric hydraulic system are given in the subparagraphs below. An understanding of these causes and effects will facilitate installing, adjusting and servicing the mechanisms. The "trouble shooting" is in a continuity which avoids extensive disassembly until the more simple causes have been eliminated as the source of trouble.

(*a*) Motor does not start:-

Check position of tilting box. Check controller, circuit breaker and fuses.

(*b*) Drive inoperative due to control pressure failure:-

Check the servo pressure as it enters the control box to see that the proper pressure and volume of oil is being maintained at the control. A clogged filter is often the source of trouble when the servo pressure and volume is reduced.

Check the response shafting from the right B-end to see that it is connected properly and that there is a minimum of backlash in the connecting gearing and shafting. Any lost motion or backlash in the gearing or shafting will seriously affect the operations of the control. Sluggishness in response to operator's handwheels and failure of the B-end to stand in a set position, caused by movement of the A-end tilting box, are symptoms of lost motion.

Check the operator's handwheels and shafting connections to the A-end input shaft for lost motion.

Check the expansion connection from the A-end control box to the expansion tank. This should be shut off and the control box cover should be removed. (The pump may be run with the control cover removed.) After the cover has been removed, the piping in the control box should be examined for breakage or leaks. Examine all linkages and gears for lost motion. If the differential screw (268424-56, dr. no. 268340) has any lost motion it may be taken up by loosening the first locknut, (265800-45) and tightening the second locknut on the adjusting nut (268424-8) until all of the lost motion in the control screw has disappeared. Care should be taken that the parts are not fitted too tight, causing a binding action which is sometimes as detrimental to the functioning of the control as lost motion. If the source of trouble has not been found after following the procedure as outlined above, the next step is to disassemble the control valve body (dr. no. 268344) and inspect it thoroughly.

Trouble shooting on the power-off brake valve should start at the power-off solenoid and control valve (dr. no. 268347) and then proceed to the power-off brakes.

(c) Drive inoperative due to main system pressure failure:-

Trouble shooting on the main hydraulic system should start by ascertaining if the unit loses its make-up or supercharge pressure.

Check the supercharge pump and filter to see that they are functioning properly.

Check the plungers (268409-1, dr. no. 268334) in the main relief valve for sticking, and also the check valve, (dr. no. 268356) from the supercharge pump to the main relief valve. If the trouble is not found at this point it is internal in either the A or B-ends. In order to

check which of the units is the source of the trouble, the slippage or expansion connections should be isolated. In order to do this, the relief valve discharge from the supercharge and servo pump should be piped directly back to the expansion tank and the inter-expansion connections between the units disconnected and the expansion from each unit run directly back to the tank. If the slippage from either of the B-ends does not seem to be abnormal, the trouble will be found in the A-end. This procedure of elimination is advisable because the servo valve discharges directly into the A-end case and it is very hard to discern whether or not an abnormal condition exists in the A-end. The pump or motor which is causing the trouble should be disassembled and examined to find the source of the trouble.

If a condition is encountered where the pump builds up to a certain pressure and instead of increasing, pressure suddenly drops accompanied with an increase in hydraulic noise, it is a sign that the main system is relieving itself. This condition may be caused by lifting of the relief valve or the cylinder barrel in one of the units lifting off of the valve plate. In event the relief valve is relieving, it is usually discernible by sound. Remove the valve and have it tested to determine the exact pressure at which it is functioning. If the relief valve is not the source of the trouble, the slippage and expansion connection may be isolated and the source of the trouble determined by watching the slippage of the units.

If the cylinder barrel in any one of the units is lifting off, a sudden surge of oil will appear in the slip line of the unit causing the trouble. If a valve plate or piston is scored it is usually discernible by increased slippage. If any of these conditions exist in any one of the units, that unit should be disassembled and examined to determine the cause of the trouble.

36. *To check the servo and supercharge pressures.* - The supercharge pressure should be set between 50 to 70 pounds per square inch and the servo pressure between 350 and 450 pounds per square inch. If these pressures are not within these ranges, they may be adjusted on the supercharge and servo relief valve. To adjust the supercharge pressure, remove the valve cap (268394-67) nearest the mounting plate, loosen the locknut and screw in on the adjusting screw to increase the pressure or out to decrease the pressure. The servo pressure may be adjusted in a like manner with the adjustment farthest from the mounting plate.

To check the supercharge pressure or the pressure in either of the main pipes, the gauges may be connected to the 1/4 inch pipe taps in the sides of either B-end valve plate. The servo pressure should be checked in the line between the filter and the servo flange connection (268404-72) on the A-end control box.

Adjustments

37. *Limit stop adjustment.* - The limit stops can only be adjusted with the control box drained. Draining is accomplished by closing the valve in the one-half inch control box drain. Refer to drawings number 268340 and 268341.

With the turret at zero degree train (180 degrees, turret #3) the traveling nut should be in midposition on the limit stop screw.

(*a*) Adjustment of the stop positions is made as follows:

(1) Remove access cover (268431-25)

(2) Under power control train turret to maximum right or left train position desired. This should be one degree ahead of positive stop stopping position.

(3) Unscrew limit stop lock cap (268435-82) and slide the unit within it away from the limit stop.

(4) Screw the limit stop (268435-8) on the limit stop screw until engaged with the traveling nut.

(5) Screw the limit stop lock cap on the stop and lock the assembly with the lockwasher.

(6) Train to opposite limit and set similarly.

If the traveling nut was not set at A-end installation at mid-position of the screw, the above operations should be preceded by the following operations:

Train turret to zero degree position and shut off power. Disconnect the A-end response coupling and adjust the traveling nut to its mid-position by turning the handwheels. (Simultaneously disconnect the regulator response input.) Reassemble the response coupling and reset the servo control valve in neutral position as outlined in the following paragraph.

38. *Handwheel operation to position control at neutral.* The control linkage and control valve may be positioned at neutral by the following procedure.

With power-off manipulate the neutral return device to by-pass the stroking piston and to return the tilting box to its neutral position. Then stroke the handwheels in either direction until the friction clutch slips. Back-off 2.70 turns. The servo control mechanism will then be positioned at neutral.

39. *Brake adjustment.* - The power-off brakes when correctly adjusted have main spring and shoe positions as follows: (Refer fig. 15.)

Main springs. - Distance from end of main spring stud (268440-6) to the adjusting nut (268570-8) should be approximately 1.25 inches.

Brake shoes. - With power-off the shoes should have uniform tight bearing on the drum and screw 268440-137 should be adjusted inward until it just touches the brake shoe, it should then be backed-off one full turn and locked.

Apply the linkage to open the brake and adjust space between shoe and drum by means of stop bolt 268440-3, opposite piston unit only. Then provide 1/32 inch clearance between other stop bolt (adjacent to piston) and the brake shoe lever.

Brake shoes and drum must be clean and free from oil or grease.

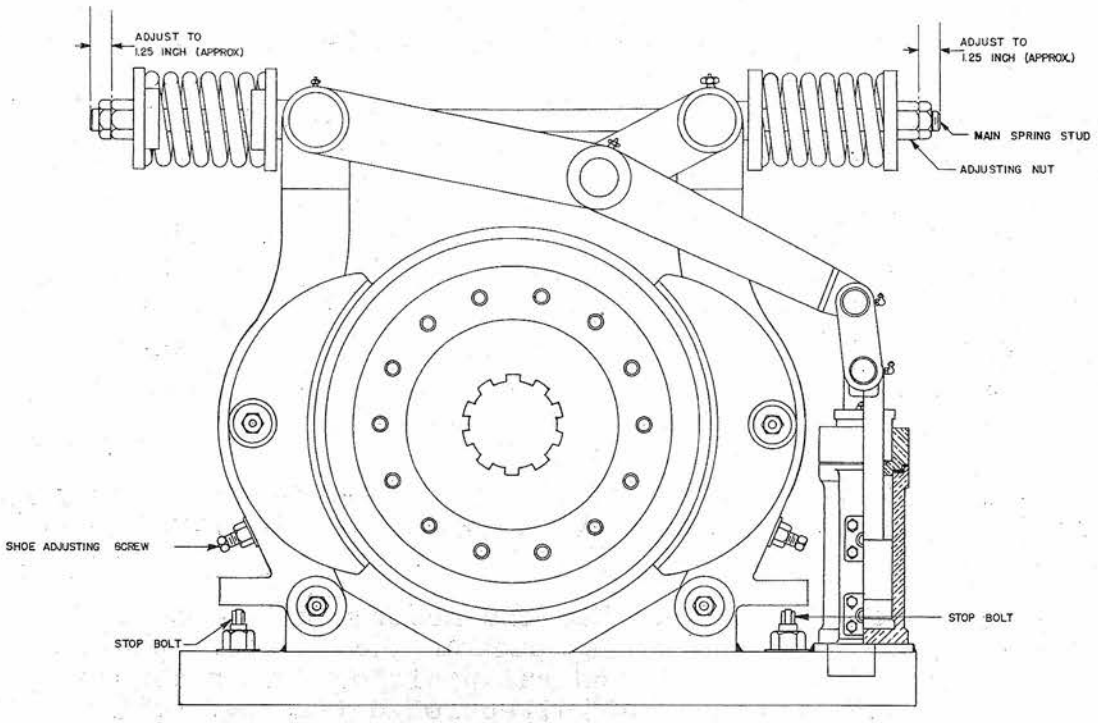

Fig. 15 - Brake Adjustment

40. *Servo pressure adjustment.* - Servo pressure is adjusted as follows: (Refer dr. no. 268336 and par. 36.)

(*a*) Install pressure gauge in the servo line between the filter and the servo flange connection on the A-end control box.

(*b*) Remove valve cap 268394-67 on spring housing. Loosen lock nut.

(*c*) Screw adjusting screw inward to increase pressure, out to decrease.

(*d*) Check pressure at gauge. (350 to 450 P.S.I.)

41. *Supercharge pressure adjustment.* - Makeup pressure is adjusted similar to the servo pressure adjustment. The pressure is checked by installing the gauge in one of the 1/4 inch plugged holes of either B-end valve plate.

42. *Adjustment of main system relief valves.* - To adjust the main system relief valve, remove caps (268409-4, fig. 16) and adjust each side of the valve separately with the spring adjusting screws (268410-8). The proper setting of the relief valve is 1450 pounds per square inch.

To check the main system pressure, install gauge in the 1/4 inch pipe plug taps of either B-end valve plate.

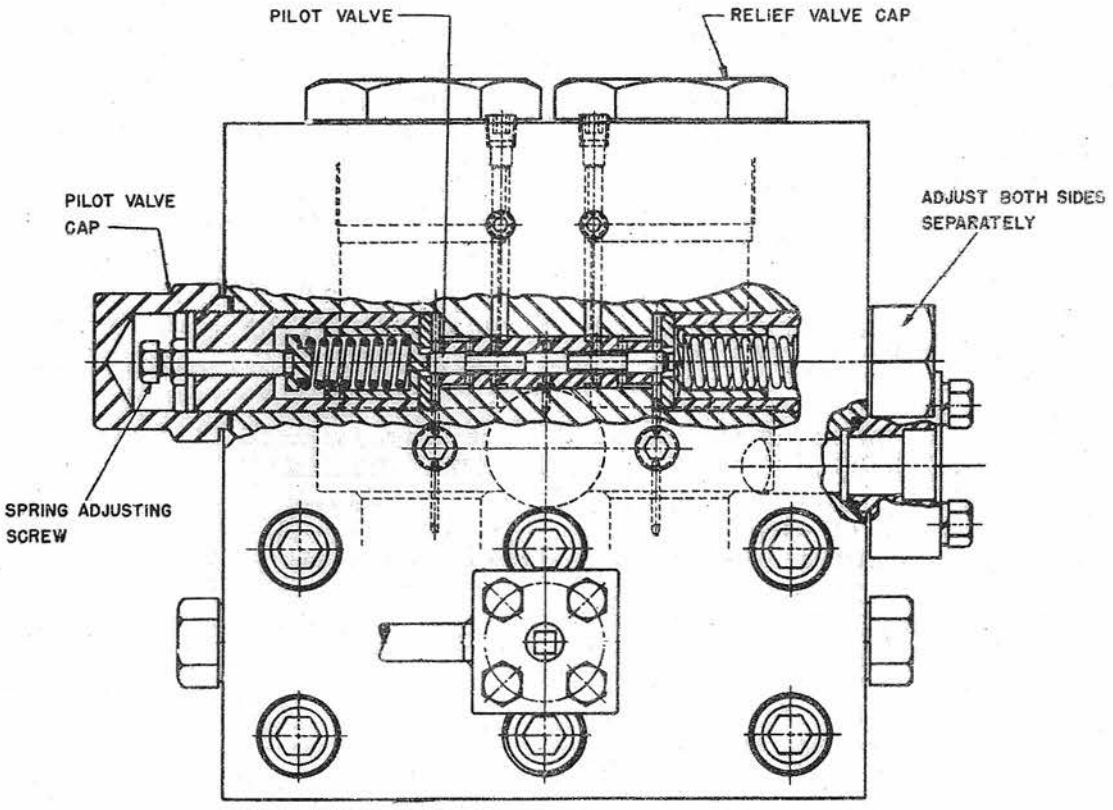

Fig. 16 - Main Relief Valve Adjustment

43. *Adjustment of handwheel friction clutch.* - In event the friction clutch between the handwheel input shaft and the control will not transmit the desired torque for operation of the control, the friction may be increased by tightening the three cap screws (265853-102, dr. no. 268345).

44. *Adjustment of constant horsepower device.** - To adjust the constant horsepower device the cover on the control box housing must be removed. Adjustment may be made by adjusting the adjusting screw (268413-11, dr. no. 268344). This increases or decreases the tension of the pressure measuring piston spring. Increasing the spring load increases the hydraulic pressure required to cause shifting of the constant horsepower valve. The factory setting of the spring as evaluated by the manufacturer is equivalent to electric motor input of approximately 540 horsepower.

DISASSEMBLY AND ASSEMBLY

45. Disassembly of the training gear is apparent from the general arrangement drawings and details with exception of the parts and operations described in the following paragraphs. Reassembly of these parts is, in general, the reverse procedure of that outlined. To aid in reassembly it is desirable to mark all mating parts so that they will be replaced in the same position.

46. *Disassembly of the A-end pump.* - Refer to drawing number 268332.

Remove packing gland nuts (268370-2), packing gland (268370-3), remove the packing and packing cover (268361-84). Loosen all of the housing stud nuts (268370-7) about a quarter of a turn and remove the four inner housing studs leaving the two upper and two lower studs loosened but in place. At this point it is advisable to tip the A-end pump on end, resting on supports under the front end plate (268361-114) with the drive shaft pointing down. (Do not allow the weight of the A-end to rest on the control housing or servo piston housing.)

Remove the remaining pump studs and lift the valve plate (268362-94) off of the housing (268360-100). The cylinder barrel (268357-93) may now be lifted off of the pistons by using the tapped holes in the inner hub furnished for this purpose. When removing the cylinder barrel care must be exercised in holding the connecting rods so that the pistons will not bump each other or other parts in the pump and become damaged when they are freed by the cylinder barrel.

* This adjustment is similar to that shown on figure 8, page 68.

Screw eyebolts into the tapped holes in the upper end of drive shaft (268358-108). The inner assembly of all parts which are attached to the drive shaft including bearing (pc. no. 268374-5) may now be lifted out of the housing as one assembly.

The only part that cannot now be removed from the inside of the pump housing is the tilting box (pc. no. 268364-104). The tilting box cannot be removed until the control has been partially disassembled, the stroking lever (268372-87) released from the servo piston assembly and the front plate removed. In case it is necessary to remove the tilting box, complete removal of all control mechanism from the outside of the pump housing is advisable.

It is not necessary to remove the tilting box from the pump housing to remove the bottom thrust bearing race (268366-46). The tilting box has 3.75 inch 10 NC thread holes tapped into the back under this race. Tilt the tilting box to its maximum angle of tilt and insert the required number of 0.75 inch 10 NC thread tap bolts, 2.5 inch long, (threaded up to the heads) into the tapped holes; use them as jackscrews to push the bearing out of its housing.

In event that it is not possible to tip the pump on end as previously advised, the pump may be disassembled in the same sequence as outlined above with the pump resting in a horizontal position. This method of disassembly is not advised due to the difficulty encountered in removing the parts from inside the housing and in reassembly of the parts.

47. *Removal and disassembly of servo piston.* - Refer drawing number 268339.

Remove access cover, (268401-26), machine bolt (268420-39), two pipe plugs (268403-22) and with the servo piston centered as shown on the reference drawing, drive pin 268402-23 down and out of the stroking slide (268401-10). Remove the nuts holding the servo piston housing to the pump housing, allowing the servo piston assembly to be pulled away from the pump housing as a complete assembly. The complete disassembly is apparent from drawing number 268339.

48. *Disassembly and assembly of control mechanism.* - Complete disassembly or assembly of the control mechanism is apparent from drawings 268340, 268341, 268344 and 268345.

When assembling the control mechanism it is essential that all looseness in linkages and backlash in gears must be kept at a minimum if accuracy in train or a minimum of lost motion is to be expected of this unit.

All valve plungers, valve sleeves, control screws, gears, etc., should be handled with utmost care in assembly or disassembly to prevent damage and consequent failure of the control to function accurately. When removing or assembling oil seals on shafts, extreme care should be exercised so that the seals will not be cracked or stretched. Do not stretch these seals with any kind of tool in order to fit them onto the shafts; always use a sheet of thin brass or other sheet metal as a thimble to start the seal over the end of the shaft, the keys, splines or keyways.

49. *Disassembly and assembly of main relief valves.* - Disassembly and assembly of the relief and make-up valve (A-end) is apparent from drawing number 268334.

It should be noted that any change in the setting of springs 268409-10, will change the pressure at which the valve will operate. When disassembling this valve the setting of the spring adjusting screw (268410-8) should be noted and reset accordingly in assembly. After assembly it is advisable to check the valve with a hydrostatic test pump if one is available. This valve should relieve at 1450 pounds per square inch.

50. *Disassembly and assembly of supercharge and servo pump.* - Disassembly and assembly of the supercharge and servo pump as indicated below should be followed on drawing number 268336. In event this pump is disassembled, it must be noted that the relief valves must be reset to the proper pressure setting upon reassembly.

To disassemble this pump, remove the four hex nuts. Remove the mounting plate (268396-11), bearing plate (268395-1), and the servo cylinder (268395-2). Turn the pump over and remove the relief valve plate (268395-5), bearing plate (268396-52) and the supercharge cylinder, (268396-10). From this same end of the pump, push the driven shaft down and out of the driven gear. Next push the drive shaft (268395-8) down about 3/32 inch until the key in the drive shaft almost touches the liner plate (268396-45). Care must be exercised that the key does not hit the liner plate and damage it. Lift the shaft and gear up and

put a shim under the gear equal to the amount the shaft has been pushed down. Repeat this operation until the gear has been removed from the shaft.

When reassembling, coat the mating sides of the plates with a very thin coat of shellac.

The drive shaft (268395-8) should be turned slowly as the nuts (268394-54) are tightened in order to assure clearance and alignment for the gears. Do not try to run the pump unless it can be turned freely by hand.

51. *Disassembly and assembly of the B-ends.* - Refer drawing number 268333. The disassembly and assembly of the right and left hand B-ends is identical except for the response shaft and gearing mounted on the shaft end of the right hand B-end. After the response has been removed from the right hand B-end and the packing cover removed from the left hand B-end, the disassembly follows the same sequence of operations for both B-ends.

Remove the packing cover or the response housing, depending upon which B-end is being disassembled and proceed as follows:- Loosen the housing stud nuts about a quarter of a turn and remove the two upper and two lower stud nuts on the front cover. Remove the two upper studs from the valve plate end. The two lower studs are screwed into the valve plate and are removed with it. Remove the eight pipe plugs (265870-52) from the front plate. It is now advisable to tip the B-end over so that it will rest on the front end plate with the drive shaft pointing down. Although this procedure is advised and facilitates disassembly, it is not necessary for disassembling the B-ends. When tipping the B-ends over the eight holes containing the socket head cap screws (12-Z-51-170) should not be covered and should be kept open and accessible in order to remove the capscrews after the B-end has been tipped over. Lift the valve plate (268376-58) off of the housing (268375-55) and then lift the housing off of the front end plate.

Remove the cylinder barrel (268378-57) being cautious that the pistons are not damaged as they are freed by the cylinder barrel.

Remove the eight socket head cap screws (12-Z-51-170) which hold the angle box (268380-54) to the front end plate. Screw eyebolts into the valve plate end

of the drive shaft and lift the entire assembly, including the angle box and the front bearing (268374-5), away from the front end plate and then remove bearing (268374-5) from the shaft. The angle box can then be removed and further disassembly is apparent.

When reassembling the response shaft and response gearing on the right hand B-end, extreme care should be exercised to keep the backlash and loose motion at a minimum.

52. *Replacement limits of parts reassembled.* - The A-end pistons should be fitted .005 inch under the bore diameter in the cylinder barrel. The B-end pistons should be fitted .0035 inch under the bore diameter in the cylinder barrel.

All replacement valve plungers in the controls should be ground .001 inch under the diameter of the bore in the valve sleeves. The edges should be left sharp but without burrs.

All replacement sleeves for the valves in the control should have the hole ground and lapped with the port openings sharp but without burrs.

Chapter VII

16-INCH ELEVATING GEAR, MARK 4, MODS. 3, 4, AND 5

General Description

1. The elevating gear installations of each turret of the U.S.S. SOUTH DAKOTA, INDIANA, MASSACHUSETTS, and ALABAMA are three independent assemblies. These are similar designs, identically powered and controlled, differing only as to position and arrangement of subassemblies. They are designated 16-inch elevating gear, Mark 4, Mod. 3, for the right gun, Mark 4, Mod. 4, for the center gun, and Mark 4, Mod. 5, for the left gun.

2. The principal units of each are an electric motor with reduction gear, a hydraulic transmission, response gear, screw and nut oscillating bearing elevating mechine, control gear and servo control mechanism. These are shown in their mechanical arrangements for all assemblies on the schematic diagram of drawing number 231630.

3. The assemblies are principally located below the respective guns, forward and below the gun pockets, in the pan floor and electric deck spaces. The arrangements on those two levels are shown on the plan view sections of the turret at the pan floor and the electric deck, drawings number 231622 and 231623, respectively.

4. The assemblies provide gun elevating limits of movement and speed of laying as follows:

Maximum elevation - - - - - - - - - - - - - - 45°

Maximum depression* - - - - - - - - - - - - - 2°

Maximum speed (average) - 12° of arc per sec.
(Range - 11.5 to 13.8° of arc per sec.)

Loading angle - - - - - - - - - - 5° elevation

ELECTRIC POWER UNIT

5. The three electric motor and speed reducing units are in the electric deck space with rotor and output shafts horizontally positioned, and with drive shaft connections extending forward to the A-ends of the respective hydraulic transmissions. (See par. 10.) The wing units are located beneath their

* Zero degree, Turret No. 2, peacetime; 2 degrees battle; see paragraph 30.

respective guns. (See drs. no. 231626 and 231629.) The center unit is offset from beneath its gun and is located between the parallel divisional bulkheads which are beneath the right hand gun girder box. (See R.H. Box Girder longitudinal section, dr. no. 231627.)

6. Each motor unit is an integral assembly of an electric motor with main shaft reduction gear drive at one end and flange mounted auxiliary pump cluster gear drive at the opposite end of the rotor shaft. It is an elevating gear subassembly of commercial manufacture (Electro Dynamic), designed for use with this drive, with characteristics and specification data as tabulated in paragraph 8.

7. Each power unit is separately controlled through an electric controller (Ward Leonard) mounted in the projectile flat machinery space. Each controller comprises control and protective device arrangements of the following designations:- a 3 pole, 500 volt, type AQB Navy circuit breaker (Westinghouse), manually operated from outside of the controller cabinet; a 3 pole, 440 volt, line contactor, type N-17; an inverse time limit, thermal overload relay (Cutler-Hammer #306) with reset relay; two 250 volt pilot circuit fuses; conventional test links; and, separately mounted, a two element push button control station, type MN-551; a type N80-2, plunger interlock switch; and a type N55 solenoid. The push-button control stations, located at each gun layer's station, are of conventional design with contacts provided to by-pass the overload and auxiliary contacts and allow emergency operation of the motor. In the "start" push-button circuit is the neutral interlock switch (normally open) which restricts starting circuit closure to neutral position of the transmission. Mechanically interlocked with the main controller enclosure is the separately mounted, manually operated, circuit breaker which, when open, de-energizes all controller circuits except the main line contacts and allows the main controller enclosure to be opened. Also in the circuit, the power failure valve solenoid is continuously energized when the motor circuit is closed. The main contactor is of the magnetic type and functions to close the main circuit for motor starting and operation. The inverse time limit overload relay is set to heat the fusible alloy tripping device and open an auxiliary contact when an overload of more than one minute duration occurs. A reset relay renews the contact upon operation to "start".

8. The elevating gear pump cluster (dr. no. 221534) is an assembled unit (Vickers, Inc.) consisting of two vane type pumps, flange mounted and geared to the motor. The two pumps, control pump (dr. no. 221533) and replenishing pump (dr. no. 221531), conform to the specifications listed below.

Data - Electric Motor Assembly

Motor:-
- Type - 60 cycle, 440 volt, 3 phase, squirrel cage induction
- Horsepower - - - - - - - - - - - - 60 (overload rating, 108)
- Speed Class- Constant
- R.P.M. (max.)- 1800
- Rotation (looking at pinion) - - - - - - - - - - Clockwise
- Lubrication- Grease cup
- General arrangement drawing- - - - - - - - - - - - - 231593

Controller:-
- Type - A.C., semiautomatic across-the-line starter, circuit breaker, thermal overload, push button, "power-off" solenoid, interlock combination.
- Phase- 3
- Cycle- 60
- Amperes- - - - - - - 60 (full load), 80 (108 h.p. overload)
- Primary Voltage- 440
- Power Factor -35-100%
- Overload adjustment range- - - - - - - - - - 102-122 amps.
- Short circuit (circuit breaker) setting- - - - - 900 amps.
- Undervoltage - - - - - - - - - - - - - - Drop out voltage 110
  Sealing voltage 360
- General arrangement drawing- - - - - - - - - - - - - 231594

Speed reducer:- (Integral with motor)
- Type - - - - - - - - - - - - - - - - - enclosed spur gear train
- R.P.M., output shaft - - - - - - - - - - 512 (498 full load)
- Rotation, output shaft - - - - - - - - - - Counterclockwise
- Lubrication- Oil bath
- General arrangement drawing- - - - - - - - - - - - - - 231593

Pump:-
- Type - double; vane
- R.P.M. (both pumps)- - - - - - - - - - - - - - - - - - - 1200
- Pressure, replenishing pump- - - - - - - - - - - - 40 P.S.I.
- Pressure, servo pump - - - - - - - - - - - - - - - 350 P.S.I.
- Capacity, replenishing pump- - - - - - - - - - - 18.5 G.P.M.
- Capacity, servo pump - - - - - - - - - - - - - - - 7.5 G.P.M.
- General arrangement drawing- - - - - - - - - - - - - - 221530

9. The connecting shaft between the speed reducer output shaft and the transmission A-end shaft is arranged at both ends with special couplings. These are commercial units which provide floating compensation for slight misalignment. Each is an assembly of splined hubs, which seat on the respective shaft ends, and flanged sleeves which enclose the hubs. The sleeves have annular involute gears enmeshed with gear teeth on the hubs. When installed with flanges bolted, each coupling is partially filled with oil to provide lubrication for the enmeshed gearing.

Hydraulic Transmission

10. The drive transmitting arrangement installed between the preceding described power plant and the elevating nut gear of the oscillating bearing (par. 13), is a hydraulic, variable displacement machine of commercial manufacture (Waterbury Tool Co., Size 20, type K.). It comprises a variable displacement pump (designated the A-end), and a fixed displacement hydraulic motor (the B-end), mechanically separated but having inter-connecting hydraulic pressure leads. Basically these components of the transmission, as shown on drawing number 268100 (A-end) and 268153 (B-end), are the elements which convert input shaft rotation of constant speed and direction to reversible, variable speed, output shaft rotation. They are thus identical to many installations of like function and the same or similar manufacture used throughout the fleet. Specifically they are functionally identical to the transmission units of different manufacture as installed in the elevating gear drives of the U.S.S. NORTH CAROLINA and WASHINGTON. See chapter V.

11. The transmission provides drive speed range and performs under pressures and loads as tabulated in the data below.

Transmission Data

Speed of A-end input- - - - - - -	500 r.p.m.
Speed of B-end output - - - - -	0-500 r.p.m.
Torque load:-	
Normal, rated - - - - - - - - -	2000 ft. lbs.
Max., rated - - - - - - - - - -	2200 ft. lbs.
Pressures:-	
Relief valve setting- - - - -	2100 P.S.I.
Replenishing pump pressure- -	40 P.S.I.
Servo pump pressure - - - - -	350 P.S.I.
Constant horsepower control setting-	108 h.p.
Temperatures:-	
Normal oil operating range -	120° to 175° F.
Max. permitted oil temperature- -	185° F.

12. *A-end.* - The A-end is an assembly of a multi-cylinder rotating pump within a case. The pump comprises a cylinder barrel, having nine parallel axially disposed cylinders, pistons and connecting rods, a socket ring, with connecting rod bearings, and a socket ring bearing assembly which is mounted in a part designated the tilting box. The mounting of these parts on the main shaft (driven by the electric motor) is such that the cylinder barrel is spring compressed against a valve

plate and is keyed to the shaft while the socket ring has trunnion pivot in the main shaft. Thus the socket ring is free to turn in its tilting box bearings and may be adjustably positioned as to angular value with respect to the shaft axis. Such angular movement is imparted to the tilting box through the control arrangements. Tilt of the socket ring from a plane normal to the shaft axis gives piston reciprocation and consequent suction and pump displacement of liquid through the cylinder head ports and through radially aligned, semiannular ports of the valve plate. The latter ports (two) are the pressure and suction ports with leads connecting to the similar ports of the B-end valve plate.

13. *B-end.* - The B-end is a hydraulic motor of positive displacement, fixed stroke and multiple piston type. Mechanically it is a case enclosed assembly similar to the A-end but differs from that unit in that the socket ring bearing lacks angular adjustment. Instead the bearing is a stationary thrust roller track inclined at 70 degrees to its shaft. Thus the stroke is constant and the speed and direction of rotation of the driven shaft varies with volume-rate and direction of hydraulic flow from the A-end pump. The unit also differs from the A-end in that the main system relief valves are housed in the B-valve plate. These are spring loaded differential-piston type, relief valves. They are adjustably arranged so as to by-pass excess high pressure into the suction port of the system. (Refer par. 55 for adjustment.) The B-end valve plate includes two ball-check replenishing valves arranged between the main system leads and functioning to replenish the low pressure side. This replenishment is of different order and is not served from the "Make-up" circuit which supplies the A-end replenishing valves discussed in paragraph 14. A blocking valve of the B-end assembly is actuated and has functional purpose as described in paragraph 28.

14. The electric motor driven transmission described in the preceding, through the medium of hydraulic fluid, provides B-shaft rotation according to controlled tilting movement of the A-end pump. The angle and direction of tilt control the speed and direction of rotation. Mechanical and hydraulic arrangements which actuate the A-end tilting element and thus control B-shaft output are discussed under the heading "Elevating Gear Control Arrangements," paragraphs 18 to 28. The hydraulic circuits there described include servo and replenishing pressure systems that are supplied from the main system expansion-supply tank. The combined systems when filled with hydraulic oil comprise an oil circulating system that dissipates heat developed in the transmission. Of the total oil in the combined systems only that that is between the A and B-end pistons is active in the transmission of power. "Active" oil is replenished, against seepage loss, by low

pressure supplied by the replenishing pump circuit. This circuit delivers oil to replenishing valves located in the A-end valve plate; valve design and port arrangements are such as to always serve the low side of the main system. (See dr. no. 268100.)

15. The output shaft of the B-end is coupled to the elevating screw machine (par. 16) through a flange mounted mechanism designated the upper response drive bracket. This bracket is flange mounted to the oscillating bearing block (par. 16) as well as to the B-end. It encloses a splined quill drive coupling in an arrangement which gives close coupling and yet permits slight play to compensate for misalignments. See drawing number 216429.

Oscillating Bearing

16. The elevating screw and oscillating bearing assembly is a trunnion pivoted unit supported in two journals (bearing blocks) which are wedged and bolted in the turret structure above the pan floor. Aligned with the B-end (as indicated in par. 12) it places the axis of the screw in offset position 20 inches from the vertical plane of the respective gun center line. The bearing is a conventional arrangement of a large cast steel cube enclosing a radially split elevating nut. The two halves of the nut lock together for rotation but have adjustable axial motion to eliminate end play of the screw. The bottom half is driven by a concentrically mounted elevating nut gear which is meshed with the drive pinion. Adjustment of these parts is accomplished by means of threaded upper and lower adjusting nuts located respectively in the top and bottom of the bearing. The lower of these nuts is adjustable for purpose of adjusting the mesh of the nut gear, it is not required for adjustment of the split halves of the elevating nut (to eliminate play in the screw) which is adjusted exclusively by the upper adjusting nut. The nut gear, in addition to driving the elevating nut, is meshed with and drives a pump gear. This gear is mounted in the trunnion opposite from the drive pinion and has provision for tongue coupling to the pump shaft of a small rotary oil circulating pump which is flange mounted to the bearing trunnion. The pump is a lubricating unit which automatically reverses with the change in drive rotation and thus always delivers oil to the top of the bearing. It operates to bathe the nut and screw threads, the nut bearings and the pinion and gears, intermittently, simultaneous with nut gear drive. The discharge of this pump is connected to a cylindrical oil shield, secured concentric to the screw and attached to the upper adjusting nut. Ten screws secure the shield to the nut which has twenty equally spaced tapped holes. Thus the shield and its pump lead may be maintained at approximately the same position with

any varied setting of the nut. Within the shield three threaded wiper elements secured to and rotating with the elevating nut, function to remove oil from the rising screw threads whence it drains downward through the bearing to a screw cover. This cover is attached to a flange on the lower adjusting nut and functions to carry oil past a canvas bloomer which encloses the screw from the bottom of the oscillating bearing to the top of an elevating screw pocket. The pocket is a flanged steel tank assembly attached to and extending from the pan floor to the electric deck. A suction oil lead connects the reservoir space of the pocket with the pump suction. With the gun in stowed position this system is filled with lubricant to the level of a plugged hole accessible from the electric deck.

17. *Elevating screw.* - The elevating screw is a R.H. double square thread screw, 7.75 inches diameter by 149.0 inches long overall (130.65 inches threaded) with lead of three inches. It is secured by conventional bronze pivot pin (no wedge and wedge bearing), at its upper end, to a bracket on the slide. The attachment has offset location as indicated in paragraph 16.

Elevating Gear Control Arrangements

18. Gun elevating movement by means of the preceding described assembly is motion controlled by positioning the tilting box of the A-end. Adjustment of the tilting box is accomplished through automatic control devices or a handwheel control gear mechanism. The automatic controls function only to restore the tilting box toward neutral, whereas the hand control operates between gun limits of movement to provide starting, stopping and all variations of speed control (except when the automatic arrangements "take-over"). Both hand and automatic arrangements control tilting box movement by means of a hydraulic servo control piston, a subassembly of the A-end case with direct connection to the tilting box (see par. 23). Control of hydraulic flow to this servo unit is accomplished by manual and mechanical movement of control devices located in a control case mounted on top of the A-end.

19. These control facilities include input mechanisms connected to the control case and elements within the case which are described in paragraphs 20 to 28 under nomenclature designations as follows: (For schematic arrangement see pl. 5.)

Control Gear (Hand gear)
B-end Response
Follow-up Device
Servo Control
Automatic Cut-off
Constant Horsepower Device

Motor Starting Interlock
Tilting Plate Return Device
Power-off Anti-overhauling Device

20. *Control gear (hand gear).* - The hand control mechanism is a pedestal mounted handwheel drive assembly located at the gun layer's station on the forward electric deck. It includes a bevel gear and shaft system for transmitting handwheel motion to elements of the adjacent A-end control case. It also includes part of the B-end response drive (par. 21), transmitting that shaft movement similarly to the A-end control case and to a gun elevation indicator. The arrangement is shown on drawing number 268147. Handwheel and response outputs are coupled to the follow-up device and limit stop of the A-end control case assembly and operate to position those mechanisms as described in paragraphs 22 and 24. The pedestal is arranged with oil sump, oil circulating pump and distributing manifold system for lubrication of gearing and shaft bearings within the pedestal. The pump is a reversible rotor type (Nichols) with drive take-off from the B-end response system.

21. *B-end response gear.* - A system of bevel gears and shafts transmits B-end shaft speed and direction of rotation from the upper response drive bracket (par. 15) to the handwheel pedestal and thence to the A-end control case. The arrangement of this subassembly is shown on drawing number 231604. It is coupled to a control input at the A-end which drives the control screw of the follow-up mechanism (par. 22). The response drives for the wing gun elevating gears are straight shafts from the pan floor to the handwheel pedestal; the center response arrangement comprises vertical and horizontal shafting to accommodate the offset position of the center gun A-end and handwheel pedestal.

22. *Follow-up device.* - The follow-up device is a differential screw and nut, (dr. no. 268103), the former driven as indicated in paragraph 21 while the latter receives handwheel input through a friction clutch and meshed spur gears. This control nut rotation is limited by the adjusted positions of the traveling nut stops described in paragraph 24, the differential nut being positively meshed through gear train with the limit stop screw. Handwheel control input and B-end response operate through this device to actuate a servo-pilot valve which controls oil flow to the servo-piston unit described in paragraph 23. Movement of the operator's handwheel, transmitted to the differential control nut, causes the control screw to be displaced axially within the nut. This displacement is transmitted to one end of a floating link on which rides the servo-pilot valve. Resultant displacement of this valve allows oil to flow from the control circuit to the proper side of the servo piston. This positions the A-end

tilting box to "on-stroke" and the tilting box movement swings the pivot end of the floating link to re-center the servo-pilot valve. The latter action determines the degree of tilting box movement. As the tilting box moves on stroke, the B-end is caused to rotate and through the response gear drive rotates the control screw counter to handwheel displacement of the screw, tending thereby to return the screw to its neutral position. Thus the follow-up device produces tilting box displacement and B-shaft rotation according to handwheel order and the drive continues to follow handwheel motion, but when the latter ceases the device provides graded deceleration until the B-end is brought to a full stop. The device is mechanically automatic and at all positions holds direct relationship with the handwheel and B-shaft speeds, direction and stopping position.

23. *Servo control.* - The tilting box of the A-end is pivoted in the A-end case about a vertical trunnion axis. A tilting box stud normal to this axis extends within the case to an attachment to a control piston as shown on drawing number 268102. This is a double acting hydraulic servo piston, horizontally positioned with the two piston ends seated respectively in a front control piston cap and a rear control piston cap. The latter is a closed cylinder head flange mounted on a seat on the rear of the valve plate, while the former is a stuffing box cylinder head unit, flange mounted on the A-end casehead. The stuffing box and an extension shaft attached to the control piston provide for future receiver regulator attachment and automatic stroking control. This integral assembly of servo control device with the A-end case, casehead and valve plate is actuated through hydraulic control pressure, with cylinder ports and control circuit connections in the two piston caps connected by control circuit pipes to the A-end control case valve block.

24. *Automatic cut-off.* - To limit the travel of the gun in elevation, a limit stop, or automatic cut-off, (dr. no. 268106), is provided in the control mechanism. It consists of a traveling nut on a screw which carries adjustable stops, one for each direction of rotation. This limit stop screw is geared to the follow-up nut and control screw differential and has direct relationship at all times to B-shaft and handwheel turns. When the traveling nut reaches one stop, the handwheel, or signal side of the follow-up differential is held stationary, and the B-end response returns the control screw, servo-pilot valve, and tilting box to neutral, bringing the B-end to a stop. The stops for all guns are adjusted to stop the drive at the elevating limits given in paragraph 4. Those arcs of elevating movement have equivalent turns of limit screw and related values of handwheel as follows:

Total turns, limit stop screw between limits - - - 38.27
Total turns handwheel between stops- - - - - - - - 19.14
Arc of elevation per handwheel turn (average)- - - 2°30'
Handwheel turns to full speed tilt - - - - - - - - - - 2

25. *Constant horsepower device.* - To protect the electric motor from overload a constant horsepower device is provided to limit the input to the A-end. It is a pilot valve opened by active system pressure against spring tension. The tension on the spring is controlled by a cam which swings with the tilting box, and the cam contour is such as to provide a constant horsepower input to the A-end, based on pressure, A-end stroke (volume), and *efficiency* of the hydraulic transmission. Opening of the valve allows control pressure to enter the servo-piston and move the tilting box toward neutral, taking control away from the servo-pilot valve through the simultaneous operation of a selector valve. A-end stroke is reduced to a point where the overload is relieved, at which time the pilot valve closes, and restores control to the servo-pilot valve. If the stroke is reduced to a point below which the pressure reaches that of the main relief valve setting, the main relief valve will operate, maintaining specified maximum torque to resist the overload on the B-end shaft.

26. *Motor starting interlock.* - In order that the electric motor may not be started with the A-end tilting box in an "on-stroke" position, the starter push-button is wired in series with a normally-open plunger type switch, mounted on the side of the A-end. A cam mounted on the control piston is so placed as to lift the interlock switch plunger only when the tilting box is approximately on neutral. The starting circuit may then be completed by the push-button, and the motor started.

27. *Tilting plate return device.* - A hand-operated gear pump is provided as a means of moving the tilting box to neutral when the electric power is off. This pump is mounted on turret structure convenient to the operator, and is tied into the hydraulic control circuit so as to bring the tilting box to neutral from any position. A pointer indicator is provided on top each A-end to show the position of the tilting box.

28. *Power-off anti-overhauling device.* - To prevent drifting of the gun in elevation in the event of failure of electric power, a device is provided to hold the B-end shaft. This unit is a hydraulic arrangement (blocking valve, fig. 17) which functions to block the active system connections to the B-end, and at the same time operates to by-pass the A-end delivery in the event of power failure. Under normal operation this valve is held by pressure from the control pump. In the blocked position the B-end is hydraulically locked, up to a

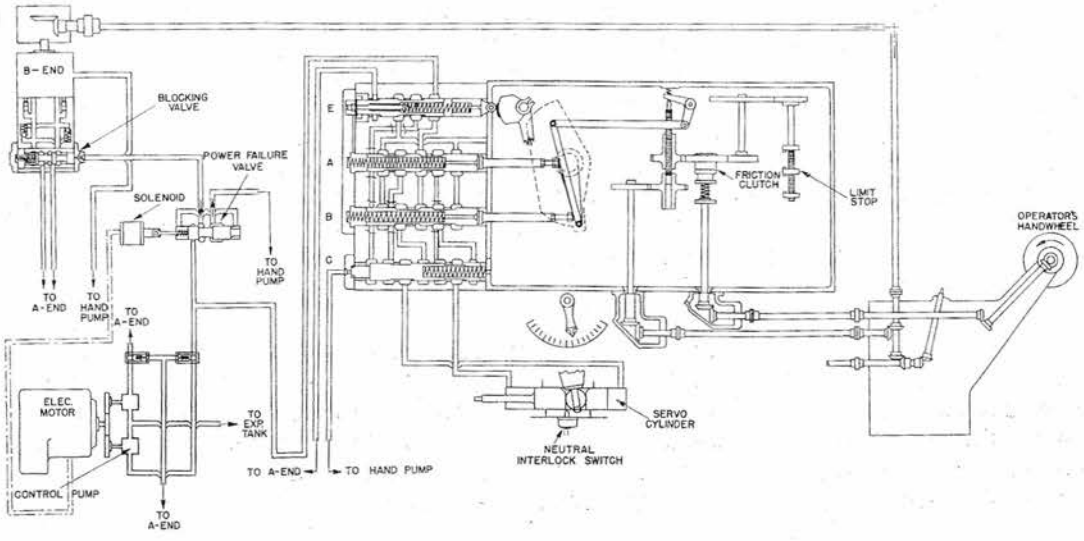

Fig. 17 - Elevating Gear Circuit Diagram (Waterbury)
Power Failure Anti-overhauling Control

torque corresponding to the specified pressure of the relief valve settings. The anti-overhauling device is operated by a solenoid-actuated valve (designated power failure valve) in the main electrical circuit. In the "power-on" position this valve connects the blocking valve to control pump pressure, holding that valve in its normal operating position. In the "power-off" position control pressure is cut off from the blocking valve and the device moves into its holding position.

29. *Supply tank.* - The hydraulic systems comprising main circuit, control and replenishing circuits are supplied from a common tank. This is located above the highest point in the combined systems. It is of 25-gallon capacity and is fitted with filler, strainer and air-vent cap combination and oil level try-cocks.

Danger Zone Cut-out Mechanism

30. In each turret an installation of three pairs of cam operated switches function to open the gun firing circuits and to close signal light circuits whenever their respective gun is laid on own ship's structure. A pair of switches comprises an elevating movement switch and a train movement switch, connected in series (operation of both required before the firing circuit for that gun is opened and the signal light circuit is closed). The arcs of fire controlled by these danger zone cut-out mechanisms (and design details), are shown, for the different turret arrangements for all ships of the class,

on drawings 233706, 238870, 239000 and 239001. All switches are interlock switch designs of two circuit, plunger type, with firing circuit normally bridged and signal circuit normally open. Each elevating movement switch is located on the right deck lug of its gun with plunger roller positioned in the way of an actuating cam mounted on the lower slide shield plate. The three adjustable elevation switch cams of each turret have identical setting within the turret. They actuate and hold switch plungers throughout gun movement in the arc from 0° to 2° depression, turrets 2 and 3, and 2° elevation to 2° depression, turret 1.

The three train movement switches, one from each gun, are mounted on the holding down clip and their actuating cams are attached to the lower roller path. These cams and switches have functional arrangement for the training movement identical to the above described elevating movement devices. See chapters VI and VIII for additional data.

The signal light circuit operates a multiple arrangement of red dial signal lights. These include single dial lights at each gun layer station and three-dial signal light indicators at each pointer's and trainer's stations, at the train operator's station and at the turret officer's station.

Elevating Stops

31. In addition to the mechanically automatic limit stop control described above, each elevating gear includes positive stops which buff elevating movement at limits of gun depression and elevation. These are hydraulic* buffers arranged in the way of stops as shown on drawings number 217204, 230775, 233700 and 233701. The arrangements differ for mounts equipped with cast steel slides (Mark 4) as against those equipped with forged slides (Mark 5). The stops also differ in Turret No. 2 as against the arrangements in Turrets No. 1 and 3. These differences and the stop arrangements are as follows: The elevating stop buffers (all mounts) comprise a pair of buffers mounted on the respective gun girders with plungers positioned in the way of stop bolts on the rear end brackets; the depression stops for cast steel slides are a pair of buffers mounted on the rear caps of the recuperator cylinders with plungers positioned in the way of pads on the turret roof; the depression stop for forged slides is a single buffer mounted between the recuperator cylinders; and the depression stop arrangements for Turret No. 2, are removable pads under the turret roof which function to stop gun movement at zero degree depression. Thus the elevating gears of Turret No. 2 are limited to total movement of 45 degrees when the pads are in place and therefore their limit stop controls (par. 24) must be adjusted accordingly.

* Oil (not glycerin solution as in previous similar buffers), see paragraph 46.

Transmission Control Operation

32. *Normal operation.* - With the circuit breaker handle of the electric controller in the "on" position, and with the tilting box of the A-end in its neutral position, the electric motor may be started by pressing the starter button. After approximately 15 seconds a time-delay switch throws the motor from the starting transformer directly on to the line. The unit may then be put into operation.

33. A gun is depressed by rotating the operators handwheels clockwise when viewed from the operators right. Elevation requires counterclockwise rotation. Referring to the diagrams of plate 5 and figures 17 to 21 it will be seen that rotation of the handwheel is transmitted through connecting shafts and gearing to the nut of the control screw, causing the screw to be moved axially within the nut. The screw displacement is transmitted through a bell crank and connecting link to the free end of the floating link, the other end of which is pivoted on a stud carried on an arm connected to the tilting box. The link is moved clockwise about its pivot in the case of elevation, causing the servo-pilot valve (A) to be displaced by its spring to the right. Oil from the control pump is now admitted to the main servo-piston through pipe HP-2 to the block, in port "c" and out port "d" of the servo-pilot valve (A) to port "f" of selector valve (C), out port "e" and pipe HP-13 to the right end of the servo cylinder, causing the tilting plate to swing clockwise viewed from above. Oil from the left end of the servo is exhausted through pipe HP-12 to port

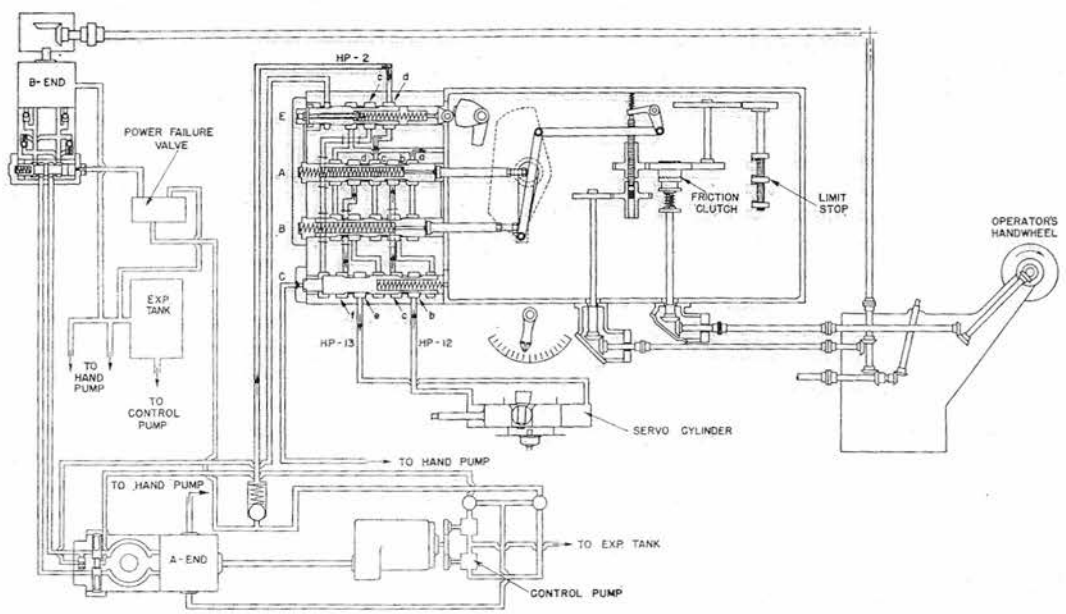

Fig. 18 - Elevating Gear Circuit Diagram (Waterbury)
Normal Operation

"b" of selector valve (C), out port "c" to port "b" of servo pilot valve (A), and out port "a" into the A-end case and thence to the expansion tank. The tilting box will be swung into such position that the servo pilot valve is again centered by the swinging of the pivot end of the floating link as the tilting box swings. The oil flow through the servo pilot valve will then be cut off.

34. As the tilting box is moved to an "on stroke" position the B-end is caused to rotate at speeds approximately proportional to the angular displacement of the tilting box. Response rotation is transmitted to the control screw of the A-end, through connecting shafts and gearing, rotating the screw in such a direction as tends to correct its original displacement by the handwheel, restore the floating link to its neutral position, and re-center the tilting box in its "no stroke" position. In order to maintain the tilting box on stroke and keep the B-end rotating, it is necessary to continue rotating the operator's handwheel, maintaining sufficient rotational "lead" over the response to hold the control screw and floating link in a displaced position. Handwheel lead can be increased to a point at which the control screw displacement is sufficient to cause it to hit one or the other of its stops. Attempting to increase the handwheel lead beyond this point results in the slip clutch in the signal gearing disengaging, preventing damage to the control mechanism. At this point of maximum control screw displacement the tilting box displacement is at its maximum, as are the A-end delivery and the B-end revolutions per minute.

35. When the handwheel rotation is stopped, the B-end and response rotation continue until the signal shaft lead is taken up. This results in returning the control screw to its central, or neutral position in the nut, thereby restoring the free end of the floating link to its neutral position. Movement of the link again displaces the servo pilot valve, moving it now to the left of its centered position and admitting oil from the control pump to the left end of the tilting box servo piston, restoring it to its central, or "no-stroke" movement. When the tilting box reaches its neutral position the pivot end of the floating link re-aligns the servo pilot valve, and oil flow to the servo piston is again cut off. The B-end rotation is stopped simultaneous with the centering of the tilting box which reduces the delivery of the A-end to zero.

36. *Limit stop operation.* - As handwheel rotation is continued during elevation or train, the limit stop screw, being connected through a gear train to the signal input shaft of the control gearing, rotates with it, and threads the traveling nut along the screw toward one or the other stop. When the nut reaches a stop, figure 19, further rotation of the limit stop

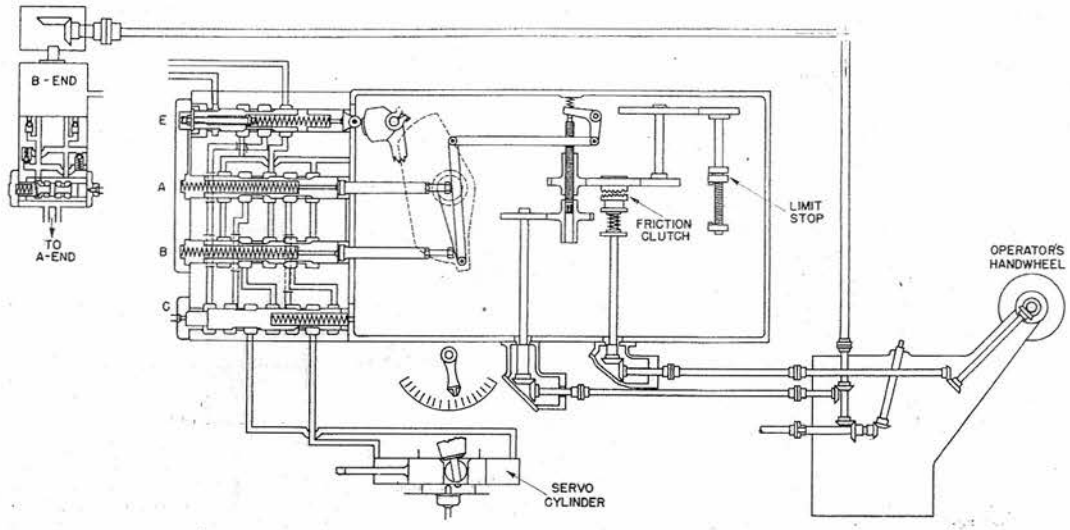

Fig. 19 - Elevating Gear Circuit Diagram (Waterbury)
Limit Stop Control

screw is halted, and with it, further rotation of the signal input. Continued rotation of the operator's handwheel results in disengagement of the slip clutch in the signal input shaft and prevents damage to the mechanism.

Rotation of the signal input having been stopped, any displacement of the control screw, link, and tilting box is at once corrected by continued rotation of the B-end and response shafts, centering the tilting box as described under "normal operation," and bringing the B-end to rest always at the same point of gun elevation.

Handwheel rotation may at any time be reversed, and the unit operated away from the limit stop at full speed and pressure.

37. *Constant horsepower device.* - Referring to the schematic diagram of figure 20, the constant horsepower pilot valve (E) is operated against spring pressure by active system pressure from the A-end valve plate, through pipe HP-14 to port "a", and is applied there on differential diameters of the valve. Excessive active system pressure will cause the valve to move to the right against the spring. The pressure required to open the valve is regulated by a cam operated plunger which varies the amount of compression in the valve spring as the tilting box changes its position. The contour of the cam is such that the correlation of pressure, stroke, and efficiency of the transmission gives a constant horsepower input limit at the A-end.

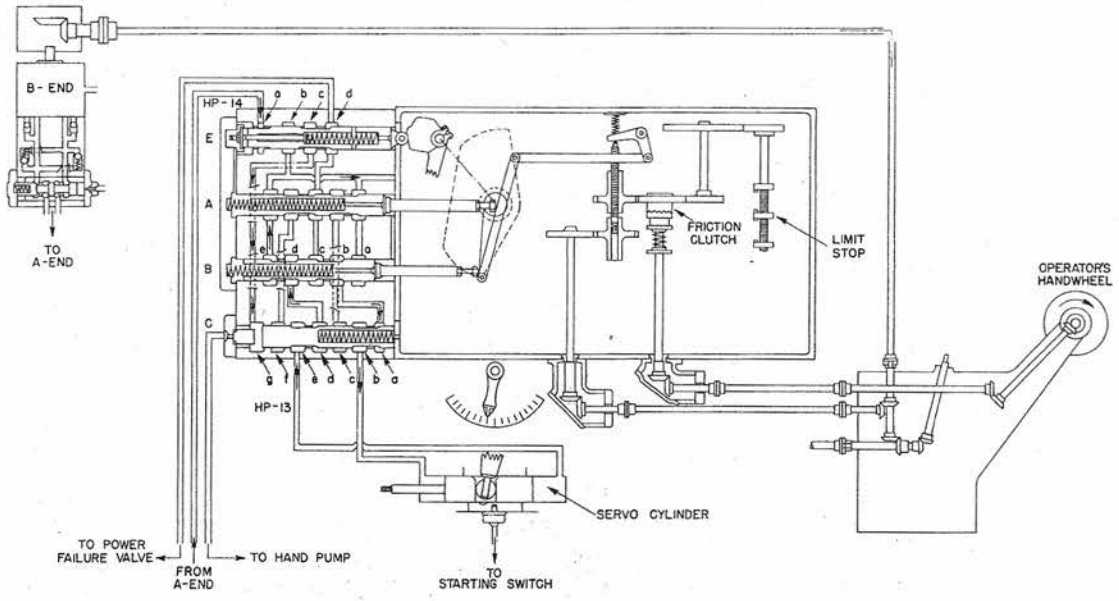

Fig. 20 - Elevating Gear Circuit Diagram (Waterbury)
Constant Horsepower Control

38. At a moment of overload, and being in elevation, the pilot valve (E) is moved to the right by active system pressure. Ports "d" and "c" are thus connected, and "b" simultaneously shut off, allowing control pressure to enter port "g" of the selector valve (C), forcing it to the right. The selector valve acts to cut off the normal circuit of oil from the servo pilot valve (A) by blocking ports "c" and "f" of the selector valve, and transfers control momentarily to the constant horsepower control valve (B) by opening ports "a" and "d" of the selector valve. The tilting box servo piston is thus connected to control pressure through the constant horsepower control valve (B), which acts as a directional control; always moving the servo toward neutral. Being displaced clockwise in this instance the control valve (B) is displaced to the left, and oil from the control line flows from port "c" out port "b", through ports "a" and "b" of the selector valve (C) and to the left end of the servo control piston. moving it toward center. Oil is exhausted from the opposite end of the servo unit through pipe HP-13, ports "e" and "d" of the selector valve, ports "d" and "e" of the control valve (B) and so into the case of the A-end, and to the tank.

39. The movement of the tilting box toward neutral continues until the cam increases the spring pressure enough to close the pilot valve (E) against the existing active system pressure or until the overload condition is removed, allowing

the valve to close. When it does close, ports "b" and "c" are connected and port "d" is cut off, so that the selector valve (C) is restored to its left position by its spring, the oil being vented from port "g" through ports "c" and "b", of the pilot valve (E). This restores the control circuit to its normal position, bringing the servo pilot valve back into action.

40. The spring tension on the pilot valve (E) is adjustable by means of a screw, serving to raise or lower the horsepower level at which the valve operates. The setting is made during factory tests, and should require no further adjustment.

41. *Power failure anti-overhaul devices.* - The operation of these devices is described in paragraph 28, see figure 17.

42. *Tilting plate return device.* - In order to move the tilting box from a displaced position to neutral prior to starting the electric motor, the neutral return hand pump is turned clockwise from the crank side. Referring to the schematic diagram, figure 21, pressure is thus built up in lines P-2 and P-1, moving the selector valve (C) to the right.

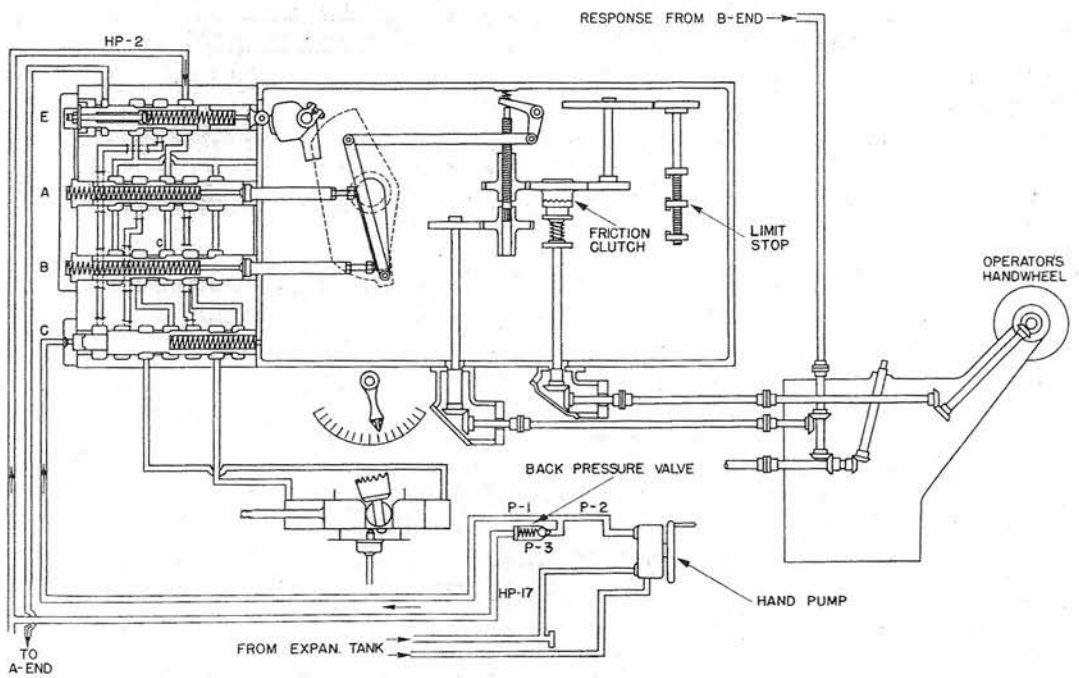

Fig. 21 - Elevating Gear Circuit Diagram (Waterbury)
Tilting Box Manual Centering

The back pressure valve in the pump circuit maintains pressure to hold the selector valve in this position. The hand pump delivery now flows into the main control pump circuit through lines P-3, HP-17, and HP-2, into the valve block. With the selector valve in its right-hand position the circuit to the tilting box servo is the same as described under the constant horsepower device, paragraphs 37 to 40. When the tilting box reaches neutral the control valve (B) is centered, cutting off port "c" so that further delivery of oil to the servo is blocked. This is apparent to the operator in the form of increased resistance to further hand pump operation. Stopping the pump allows the selector valve (C) to return to its normal position. restoring the circuit for normal power operation.

MAINTENANCE AND OPERATING INSTRUCTIONS

43. The elevating machines are to be installed, operated and maintained, including periodic exercise, adjustment and lubrication in accord with the regulations of the Ordnance Manual, the instructions below and the directions contained in the chapter entitled "Hydraulic Equipment".

44. *General instructions.* - When installing, overhauling or servicing the transmission assembly and connected units, comply with the following general instructions.

> Do not drive couplings into main shafts of hydraulic units, motors, or reduction gears. A heavy end blow on the shaft may damage the bearings, or gears.
>
> In leveling units and aligning vertically, use flat shims rather than wedges, to give full bearing under feet.
>
> Do not flush pipe lines or hydraulic equipment with kerosene. Piping must be cleaned by pickling, wire brushing, washing and air pressure drying. See instructions, chapter XV.
>
> Do not connect response shafts until automatic cut-offs are correctly set. See below, under "adjustment of limit stops."
>
> Do not start motor until all equipment is properly lubricated and hydraulic system filled with oil. See below.
>
> When pipe flanges, fittings or other units are disconnected and open, maintain covers to exclude fouling. Do not remove such protection until immediately prior to reassembly.

45. *Operating precautions.* - Perform the following when preparing a new installation or a drained system for operation.

(a) *Preparing the transmission for operation.* - An empty system must be filled by circulating oil through the system without driving the A-end. This is accomplished by the following routine.

(1) Lubricate the motor, reduction gear and auxiliary pump cluster.

(2) Omit the connecting drive shaft between the reduction gear and A-end.

(3) Connect the handwheel control to the A-end control input. Do not connect the response drive.

(4) Fill the supply tank with the hydraulic oil specified in paragraph 47. During this and subsequent operations constantly check the oil level, replenishing as necessary. When completely filled the system requires approximately 50 gallons.

(5) Start the motor. The pumps will immediately draw down the tank level as oil is forced through the A-end and B-end cases. Replenish.

(6) Adjust the control and replenishing pump relief valves to specified pressure. (See par. 8). This adjustment may be made while running by removing the acorn nut on the adjusting screw and increasing or decreasing the pressure setting as required.

(7) Rotate the handwheels back and forth several times. This causes servo control stroke and clears air from the oil lines and valves. During this manipulation check the stroke movement of the tilting box. It should reach the limit of its swing (by the indicator) slightly before the control screw hits its stop. If the movement is shy on one side stop motor and adjust as prescribed in paragraph 56.

(8) After air has been expelled and stroke checked (adjusted if required), the motor to A-end connection shaft may be coupled. Do not connect response. Check all lubrication.

(9) Check oil level and start motor.

(10) Crack air vents in valve plates and pipe lines. When active system has filled close vents and drive B-end slowly in both directions until machine operates smoothly.

(11) Check oil level. If the system is full and vented the unit may be operated to set the automatic cut-off as prescribed in paragraph 57. The response drive is not to be coupled until such adjustment has been completed.

(b) *Before operating* under load, at speed, observe the following.

(1) Release and completely withdraw the slide securing pin.

(2) Lubricate the assembly.

(3) Check and replenish the transmission oil level.

(4) Verify that the filters are clear.

(5) Bring the transmission to neutral.

(6) Start the motor and run until the A-end valve plate temperature is 110° F.

(7) Verify that the solenoid valve has been energized.

(8) Operate the handwheels slowly.

(9) Verify that the elevating screw lubricating pump is lifting oil.

(10) Operate to both limits of gun movement verifying that the limit stop control and all buffers function correctly.

46. *Buffer fluid.* - The elevation and depression stop buffers are designed for and should be filled with hydraulic oil, O.S. 1113. These buffers should be checked for replenishment once per month at which time they should be inspected as to: Full normal spring return of plungers, condition of plunger packing, tightness of body or bracket securing bolts, and alignment of plungers and stops.

47. *Hydraulic oil.* - The oil to be used in the transmission hydraulic system is that designated in Ordnance Specification No. 1113. When initially filling a system use a strainer of at least 120 wires to the inch; do not use cheese cloth or other rags. New assemblies should be drained after fifteen hours operation (or less), and should then be thoroughly flushed clean and refilled with fresh oil or carefully salvaged oil. Perform test inspection and analysis of oil sample from each system monthly. If there is evidence of sludge, water or acidity, drain, flush and refill with fresh oil.

48. *Filling, draining and flushing the transmission system.* - Filling the hydraulic units can be most readily accomplished by use of the auxiliary pumps to drive the oil through the systems as prescribed in paragraph 45. However, if it is not expedient to uncouple the A-end drive shaft, oil may be run in from the tank by gravity. To vent the A-end while filling, open pipe plugs #5 or #6 on top face of valve plate. When gravity filling has been carried as far as possible, the motor may be started and the A-end run on neutral until the auxiliary pumps have purged the remaining air from the system.

Draining the hydraulic units can be done by means of opening the drain plugs located as follows:

B-end - - - -Pipe plug 267928-11 on bottom of case.

A-end - -Pipe plug 267928-11 on bottom of casehead.

Active System - Hex-head plugs 228465-12 on valve plate bosses of A and B-ends.

To fill pump cluster remove filler plug 271730-15 at top of unit and fill with approximately one and one half pints of the oil specified in paragraph 47. Oil should be maintained at the level of the hole marked "Oil Level;" it should be drained and replaced with fresh oil every six months. A drain plug is provided toward the bottom of the pump cluster.

49. *Reduction gear oil, filling.* - The reduction gear case requires 8-1/2 quarts of heavy mineral oil, symbol 2250. The proper level at which this oil must be maintained is indicated by an oil level gauge mark, - read with unit at rest. Leakage and overheating may occur if excessive amount of oil is carried in this unit. Should reducer become overheated, check oil level to see that there is not too much oil in the case; check the alignment. No special precaution is necessary in maintenance except possibly to remove the air vent or inspection cover to see that the oil is being circulated. The oil should be replaced with fresh oil semiannually.

50. *Transmission tests, inspections and exercise checks.* - New transmission units or overhauled transmissions shall be serviced as follows:

(*a*) After the first week operation, tighten all bearing and foundation bolts, shaft couplings, pipe connections, etc. Check oil level.

(*b*) After the first month service, remove, filter and replace oil in the reduction gear, gear boxes and lubricating oil reservoirs, adding the necessary make-up oil. This is to remove any foreign matter or abrasive material resulting from initial run-in. Subsequently follow lubrication schedule.

(*c*) Check and clean all oil line filters at intervals dependent on frequency of service.

51. *Elevating screw lubricating system.* - The elevating screw lubricant prescribed for proper lubrication of the oscillating bearing assembly is heavy mineral oil, symbol 2190. Oil must be carried to the level of the test plug hole in the tank when the mount is at rest and the gun is at zero degree elevation. The oil should be replaced quarterly with fresh oil carefully filtered through a fine mesh wire screen. *Oil level must be checked before operating.*

The system pump can air-lock. Oil flow must therefore be checked at the screened filling plug - *always immediately after starting to operate.* Prime the pump and if necessary open the pump to vent and to permit priming flow to descend to the pump.

52. *Operating trouble diagnosis.* - The causes of various possible operating troubles which may occur in the electric hydraulic system are given in the subparagraphs below. An understanding of these causes and effects will facilitate installing, adjusting and servicing the mechanisms. The "trouble shooting" items are in a continuity which avoids extensive disassembly until the more simple causes have been eliminated as the source of trouble.

(*a*) Motor does not start:

Check position of tilting box, and if necessary use hand pump to return to neutral and close interlock. Check controller, circuit breaker, fuses, etc.

(*b*) Hand pump does not build up pressure:

Check for air in pipe line. Loosen delivery pipe and rotate pump until line is clear of air.

(*c*) Hand pump does not move tilting box:

Check selector valve (C) for sticking. Free if necessary.

(*d*) Noisy operation of auxiliary pumps:

Check for air in suction line. Check oil level in tank.

(*e*) Noisy operation of hydraulic units:

Check for air in active system, by opening air vents in valve plates. Check replenishing pressure.

(*f*) Tilting box movement is sluggish:

Check control pump pressure. Adjust control pump relief valve setting if necessary.

(*g*) Constant H.P. device does not function:

Check for sticking valve. Make sure bronze bushing on differential piston is free. Make sure shuttle valve in A-end valve plate is not stuck.

(*h*) B-end overshoots when stopping suddenly:

Check control pressure and raise setting of control pump relief valve if necessary.

(*i*) Operation is irregular at slow speeds:

Check for presence of air in active system.

(*j*) B-end "hunts", or oscillates slowly with handwheel stationary:

With cold oil the high viscosity will increase the effect of servo pilot valve port lap, and allow slight hunting of the valve and tilting box. This effect will disappear after a short period of operation to warm the oil.

(*k*) Power failure devices do not function:

Check solenoid-operated power failure valve to see that movement of valve and solenoid crank is free. Check elevating unit blocking valve on B-end for sticking.

Adjustments

53. *Elevating screw.* - The elevating screw pin and pin bearing is not adjustable to remove play.

54. *Elevating nut.* - Slack between the elevating nut and screw threads is removed by resetting the upper adjusting nut of the oscillating bearing assembly. To make such adjustment it is necessary to remove the ten bolts of the oil shield and the adjusting nut key before positioning the nut with large spanner. Adjustment of the lower nut (made similarly) for purpose of taking up lost motion in the mesh of the nut gear, is a yard job requiring major disassembly.

55. *Relief valve adjustment.* - To adjust the relief valves for pressure, screw the retainer in (clockwise) to increase the pressure setting, or, screw the retainer out (counter-clockwise) to decrease the pressure setting. The B-end relief valves were set during factory tests to relieve at pressure of 2100 pounds per square inch (equivalent to B-shaft torque of 2200 pounds). *Do not alter springs.*

56. *Control screw limit adjustment.* - The control screw movement is designed to have slight overtravel beyond the positions of full tilting box stroke. If the control screw hits its stop before the tilting box swings to full tilt so that the tilting box is shy of full tilt on one side, adjust as follows:

(*a*) Shut down motor and pumps.

(*b*) Drain down oil so that the floating link and valve stems will be exposed (when the control case cover is removed).

(*c*) Remove control case top cover.

(*d*) If stroke was shy on clockwise rotation of stroking indicator, thread the adjusting screw of the servo pilot valve into the valve stem.

(*e*) If stroke was shy on counterclockwise rotation of indicator, thread the adjusting screw out of the valve stem.

(*f*) Replace cover, start motor and pump, and check adjustment.

(*g*) Repeat until overtravel of control screw is obtained in each direction.

57. *Adjustment of limit stop.* - The traveling nut limit stops are correctly positioned with respect to gun limits of movement as follows:

(*a*) Drain the limit stop section of the control case. Remove cover.

(*b*) Run A-end and rotate B-end slowly until limit of gun travel is reached in one direction. Reverse B-end about one-half turn.

(*c*) Shut off motor, rotate handwheel in direction in which B-end was rotated toward stop, until traveling nut of limit stop reaches stop. Stop should be set at position of maximum travel. During this rotation of handwheel, allow the response shaft of the control gearing to run free.

(*d*) Connect response from B-end. Run unit to check setting.

(*e*) Rotate B-end to other limit of gun travel. Back away approximately one-half turn of B-end.

(*f*) Adjust stop up to position of traveling nut. Check setting.

(*g*) Fill control case with oil and replace cover.

58. *Constant horsepower control adjustment.* - The constant horsepower setting has been made by the manufacturer and should not be changed. The factory setting is equivalent to electric motor input of approximately 108 horsepower. (Refer to pars. 37-40.)

ASSEMBLY AND DISASSEMBLY

59. Removal and reassembly of the elevating screw and oscillating bearing are yard jobs requiring major disassembly of other elements of the mount. Assembly and disassembly of other parts of the elevating gear are apparent from the general arrangement drawings except for the operations described in the remaining paragraphs of this chapter.

60. *Disassembly of the pump cluster.* - Reference drawings number 221530, 221531 and 221533.

To remove pump 221531 from the cluster, remove pump mounting screws 221537-7 and lock washers 196733-1. Then slide pump shaft out of cluster.

Pump shaft 221531-1 may be removed with bearing and packing gland to replace packing 164481-6. Care should be taken upon reassembly to be sure that the packing gland 180232-3 is properly assembled with the large diameter of the gland against the outer race of the shaft bearing.

To dismantle pump first remove screws 180226-6 then the pump head 221531-2, head end bushing 180232-2, rotor 221532-1 with vanes 221531-6, pump ring 229148-1 with pin 164481-7, and the bushing 180232-4.

It is possible to assemble this pump for opposite hand rotation, and care should be taken upon reassembly to check the rotation. The rotation is as indicated by the arrow stamped on the body. It should be noted that there are arrows on both bushings and the rotor and when properly assembled, all three of the arrows will point in the direction of the desired rotation. The vanes are assembled with the chamfer on the trailing edge.

When replacing pump head 221531-2, care should be taken to tighten screws that are diametrically opposite. It is good practice to turn the shaft while these screws are being tightened to insure that the rotor is not binding.

It is essential before reassembly that all parts are carefully washed in a non-acid cleaning fluid to insure absolute cleanliness and freedom from foreign matter.

To dismantle pump 221533 refer to preceding instructions for dismantling pump 221531.

To dismantle pump cluster remove drain plug 191329-9 located at bottom of unit and drain. Remove eight screws 221537-7 allowing pump assemblies 221531 and 221533 to be removed. Removal of pumps allows access for the removal of four (4) screws 206446-3, further removal of ten screws 221537-7 allows the removal of housing adapter 221535-1. Bearings, gears and pinion are thus exposed and may be removed from the

housing. Removal of six screws 206446-3 allows removal of retainer 221537-2 with oil seal 271730-1. Further dismantling of the pump cluster should be evident by referring to the drawings. To check rotation of speed of input shaft remove plug 191329-9 from center of cover 221534-2. Direction of rotation of pinion thus exposed is in the direction indicated by the arrow on the cover.

Care should be exercised upon reassembly not to injure the oil seal.

61. *Hand gear pump disassembly.* - Reference drawings number 221538 and 221541.

To dismantle gear pump 221538, remove screws 196825-6 allowing pump to be removed from the bracket. Removal of the two dowel pins 221538-6 and 221538-5 and twelve screws 190958-3 allows access to inside of pump. Pump shaft 221540-2, bearing 221540-7, spacer, oil seal and packing can be withdrawn from pump. Further dismantling should be evident from the drawings furnished.

Care should be taken upon reassembly to assemble spacer 221538-4 with raised portion toward the bearing.

Care should be exercised upon reassembly not to injure oil seal.

62. *Relief valves, disassembly.* - Reference drawings number 221525, 221527, 221528 and 221529.

To dismantle relief valves remove acorn nut, jam nut and unscrew retainer to release tension on spring. Removal of four (4) screws in top cover and four (4) screws in bottom cover allows spool, spring and washer to be removed using relief valve puller 290409-4 to pull piston 290226-4.

63. *A-unit disassembly.* - Reference drawings number 268100, 268101 and 268102.

Drain the entire system.

Remove all piping and remove entire control assembly 268103.

Remove end caps 290224-1 and 290225-1, and control shaft extension 290225-2.

Remove shaft cap 290207-1 and oil seal 268203-28.

Remove main case bolts 290231-3.

Up-end unit on stand with valveplate end up, and block tilting box approximately in neutral.

Remove auxiliary case bolts and lift off valveplate 290227-1.

Lift out entire rotating group.

Take off neutral interlock switch assembly and cam 290221-6.

Unfasten stud pin 290208-5 and knock out stud 290212-6.

Withdraw control piston 290222-1.

Remove trunnions 290209-5 and 290212-2, and lift out tilting box 290210.

To disassemble the rotating group, proceed as follows:

Compress barrel spring 290221-4 and unscrew barrel nut 228463-25 using barrel nut wrench 290409-3 and wrench pin 228469-6.

Withdraw main shaft 290214 and socket ring 290217 with piston and connecting rod groups from barrel.

Remove piston and rod groups from socket ring using ring socket cap nut wrench 290409-5 and piston socket cap nut wrench 290409-2.

Remove screws 267926-18 from trunnion bearing blocks 290216-5 and slip socket ring 290217 off of shaft.

Knock out retainer pin 40891 from universal joint.

Drive out main shaft pin 290213-4, driving toward small end of taper, which is marked with a file mark.

The disassembly of other items of the A-end is obvious from inspection of the reference drawings.

64. *B-unit disassembly.* - Reference drawings number 268153 and 268154.

The sequence of operations for disassembling the B-end is as follows:

Drain the system.

Remove blocking valve assembly 268155.

Remove shaft cap 290209-1 and oil seal 268204-5.

Withdraw bearing retainer 290208-1 and bearing outer race and roll group.

Remove main case bolts 290231-6 and turn unit valve-plate end up on suitable stand.

From this point follow procedure outlined for A-unit.

65. *Disassembly of the control gearing.* - Reference drawings number 268103 to 268106, inclusive.

Drain the system and remove valve block assembly.

Remove top cover 290320-1 and all cover plates except end cover 290316-1. Remove gear boxes 268108. Remove stud 290308-3 and floating link 290307-5. Remove tilt box arm 290317-3 from its shaft.

Take off bearing retainer 290299-5 and draw tilt box shaft down out of the housing. Remove end cover 290316-1.

Remove bearing cap 290294-2, locknut 228463-20, and draw out response shaft 290309-2, leaving gear 290293-2, spacer 290291-2, and ball bearing 290291-32 behind as it is passed through opening.

Remove locknut 228463-18 and pinion 290300-3, and draw idler shaft 290300-2 out of housing, threading off all gears, bearings, and spacers which it carries, as it passes through opening.

Remove bearing cap from signal shaft and locknut from inner end of shaft. Draw shaft 290306-3 out, slipping off gear 290312-3 and its bearings 290291-3, and also clutch 290299-2 and its spring 290303-5.

Take off bearing cap 290297-4 and turn control screw 290297-3 until it projects as far as possible out of control nut 290307-2. Draw control screw response gear 290312-1 out until its outer bearing can be taken off, and disengage it from sliding spline of control screw. Pass it back into housing and out side or top.

Remove screws from bearing retainer 290312-2 and slide out entire control screw and nut assembly, complete with control screw signal gear 290295-2 and all bearings.

Remove limit stop end covers 228466-25 and 290315-4, and locknut 228463-20. Thread limit stop nut 290313-3

to the right as far as possible, and slide entire assembly out to the left until all gears and spacers can be released from right end of shaft and taken out. Take off left bearing 290314-3, limit stop 290312-4, and clamp 290314-6, and slide shaft back to the right as far as possible. Thread limit stop nut 290313-3 to the left until it can be removed from the screw and the machined slipways. The shaft may now be drawn out of housing to the left.

66. *Handwheel pedestal disassembly.* - Reference drawings number 268147 to 268151, inclusive.

Drain oil pump through plug 267928-12.

Remove all cover plates.

Disconnect oil tubing at fittings 290378-5 and take out block.

Disconnect delivery pipe fitting 228414-2 and remove pump bracket 290365-1 and pump assembly complete.

Remove outside screws 228466-27 and pull out indicator drive shaft 290366-2 and gear assembly.

Remove screws holding cap 290368-3 and draw out signal output shaft 290369-2 and its bearing 267983-3 assembly complete.

When removing oil seal 268204-1 from shaft, use smooth thimble over spline of shaft to prevent cutting seal.

Remove screws 268202-32 from cap 290368-3 and by rotating cap and retainer 290368-4 to bring flat side into position remove screws 228466-42 from front bearing head 290368-1. Take off head and response output shaft 290370-1 assembly complete.

Take off locknut 228463-19 from lower response shaft 290364-1, and screws from cap 290327-1. Draw out shaft slipping off gears 290364-4 and 290365-2.

Remove locknut from lower end of response input shaft 290366-1, and screws from top cap 290366-5. Slip off gear 290367-3 from lower end of shaft and draw entire remaining assembly up through top of housing.

Take off handwheels 290372-1 and 290272-1 by removing screws 290372-2. Pull out shaft 290374-1 through

right hand side. Take off bearing retainer 290375-1 and bearing 290372-3.

Take off locknut from upper end of shaft 290371-1 and remove gear 290371-4. Take off lower bearing cap 290371-3 and draw shaft assembly out through lower hole.

Separate pedestal at gasket joint between two main halves by taking out screws 228466-40. Remove screws 290368-2 and draw out pinion 290369-3 and its assembly complete.

67. *Assembly of A-unit.* - Reference drawing number 268100.

Assemble universal joint in main shaft 290214.

Assemble pistons 290221-2 and rods 20847 in sets, and assemble groups in socket ring 290217-1. Ball joint clearance should be approximately .001 inch at each end of rod. Use socket wrenches 290409-5 and 290409-2.

Assemble socket ring group to main shaft by means of trunnion bearing blocks 290216-5 and set screws 267926-18.

Place barrel spring 290221-4 and barrel keys 290221-5 on main shaft and lower assembly into cylinder barrel 290219-1, entering pistons in their proper bores simultaneously.

Compress barrel spring 290221-4 and tighten barrel nut against shoulder of shaft. Use barrel nut wrench 290409-3.

Assemble case 290199 and casehead 290203, and turn open end up. Lower tilting box 290210 into place and insert trunnions 290212-2 and 290209-5 with bearings.

Assemble bushing 290221-3 and stroking piston 290222-1 in case.

Place radial and thrust bearing in position, and lower rotating group in case.

Oil surface of cylinder barrel and place valveplate 290227 and roller bearing 268203-15 in position. Insert auxiliary case bolts and main bolts.

Assemble bushing 290221-1, cap 290225-1, and shaft extension 290225-2. Make sure tilting box moves freely. Attach flange 290224-1.

Insert casehead bearing 268203-16, oil seal 268203-28, spacer 290207-3 and cap 290207-1.

Attach cam 290221-6 and interlock switch 268109.

Assemble and attach replenishing valve block 290226-1.

68. *Assembly of B-unit.* - Reference drawings number 268153 and 268154. For rotating group assembly refer to A-unit instructions, paragraph 67.

69. *Assembly of the control gearing.* - Reference drawings number 268103 to 268106, inclusive.

Assemble one limit stop 290312-4 and clamp 290314-6 to limit stop screw 290313-1 and thread it up close to shoulder in middle of shaft. Insert through left opening into its compartment and slide it to right until nut 290313-3 can be started on the screw thread end running in the machined ways. Thread the nut up close to the stop.

Slide assembly to the left until bearing 290314-7, gears and spacer sleeves can be assembled on shaft over its right hand end. Make up tight with locknut 228463-20, and put on cap 290306-4.

Thread on left limit stop 290312-4 and clamp 290314-6, and assemble bearing 290314-3, retainer 290314-8, and cap 290315-4 on left end.

Put on cover 290321-1 and check for freedom of movement.

Assemble bearings 290299-3 on control screw gear 290295-2 and tighten with locknut 267927-19. Assemble control screw 290297-3 and nuts 290307-2 and 290297-2 with gear 290295-2 and tighten adjusting nut 228463-21 until screw moves freely but without shake or backlast. Add retainer 290312-2, spacer 290303-3, and retainer plate 290306-2, and assemble entire group in housing with bearing 290298-5.

Place bearing 290294-4 on splined end of control screw response gear and assemble in housing, engaging sliding spline of control screw 290297-3. Insert outer bearing and fasten bearing cap 290301-4.

Assemble bearing 290291-4 on signal shaft 290306-3 with locknut 228463-21, and insert through bearing hole. Thread on clutch and its parts, and gear 290312-3 with its bearings and spacers. Hold clutch spring 290303-5 compressed by means of a wire or suitable clamp. Draw assembly up tight with locknut 228463.

Insert idler shaft 290300-2 into housing, threading on all gears and bearings as it passes through opening. Add drive pinion 290300-3 and locknut 228463-18, and draw up tight. Attach locknut 228463-20 and cap 290306-4.

Insert response shaft 290309-2 through bearing hole, thread on gear 290293-2, spacer and bearing, and draw up tight with locknut. Add bearing 290291-4, and locknut 228463-21.

Assemble tilting box shaft 290317-1 in position and insert and fasten its bearings.

Attach tilt box arm 290317-1.

Attach stud 290308-3 and floating link 290307-5.

Assemble roller arm 290313-2, link lever 290296-3, and lever shaft 290315-5 to end cover 290316-1, and attach to housing.

Hook up lever links 290307-4.

Assemble and attach stop plunger 290296-4 and housing 290308-2.

Attach all remaining covers and caps except top cover.

Assemble indicator and top cover 290320-1.

Attach valve block 268107 and top cover 290320-1.

Attach gear box assembly 268108.

70. *Assembly of the elevating handwheel pedestal.* - Reference drawings number 268147 to 268151, inclusive.

Assemble bevel pinion 290369 with bearing retainer 290370-2, and insert in place in pedestal housing 290361-1.

Bolt together two main parts of assembly-pedestal housing 290361-1 and main gear case 290358-1.

Assemble pinion 290371-5 on intermediate shaft 290371-1 with bearing and locknut, and insert through lower opening in gear case. Secure lower end with cap 290371-3, and assemble upper bevel gear 290371-4 and bearing on upper end of shaft.

Assemble bearing 290372-4 and handwheel 290372-1 on shaft 290374-1 with screw 290372-2. Insert in place, and attach bearing with retainer 290375-1 and cap 290375-2. Attach handwheel 290373-1.

Assemble response input shaft 290366-1 to its upper bearing 228442-5, with retainer 290366-4, cap 290366-5, pinion 290367-1, and spacer 290355-4. Insert through top hole, and after securing in place insert lower bearing 228288-5 and miter gear 290367-3. Secure with locknut.

Attach bearing 267983-3 to lower response shaft 290364-1, and insert in retainer 290333-3. Slide endwise into gear case, threading on miter gear 290365-2, bearing 267983-3, spacer 290352-4, and gear 290364-4. Fasten with locknut 228463-19. Attach cap 290327-1.

Assemble upper response shaft 290370-1 complete in front bearing head 290368-1. Use thimble to pass oil seal over shaft spline. Attach entire unit in place on gear case.

Assemble bearings 267983-3 and retainer 290368-4 on signal output shaft 290369-2 and insert into gear case, engaging internal spline in gear. Attach cap 290368-3. Use thimble for oil seal.

Assemble indicator drive shaft 290366-2 with its bearings 228288-5 and retainer 290369-1, and insert in place.

Make up lubricating pump 290197 and bracket 290365-1 assembly together with intake strainer 228330-4 and elbow 290351-3. Attach in place. Install lubricating tubes.

Attach and hook up lubricating manifold block.

Fasten all cover plates. Attach hand grip 290375-3.