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FIRE CONTROL EQUIPMENT

FORD RANGE KEEPER, MARK II

CARE AND OPERATION

DECEMBER, 1922

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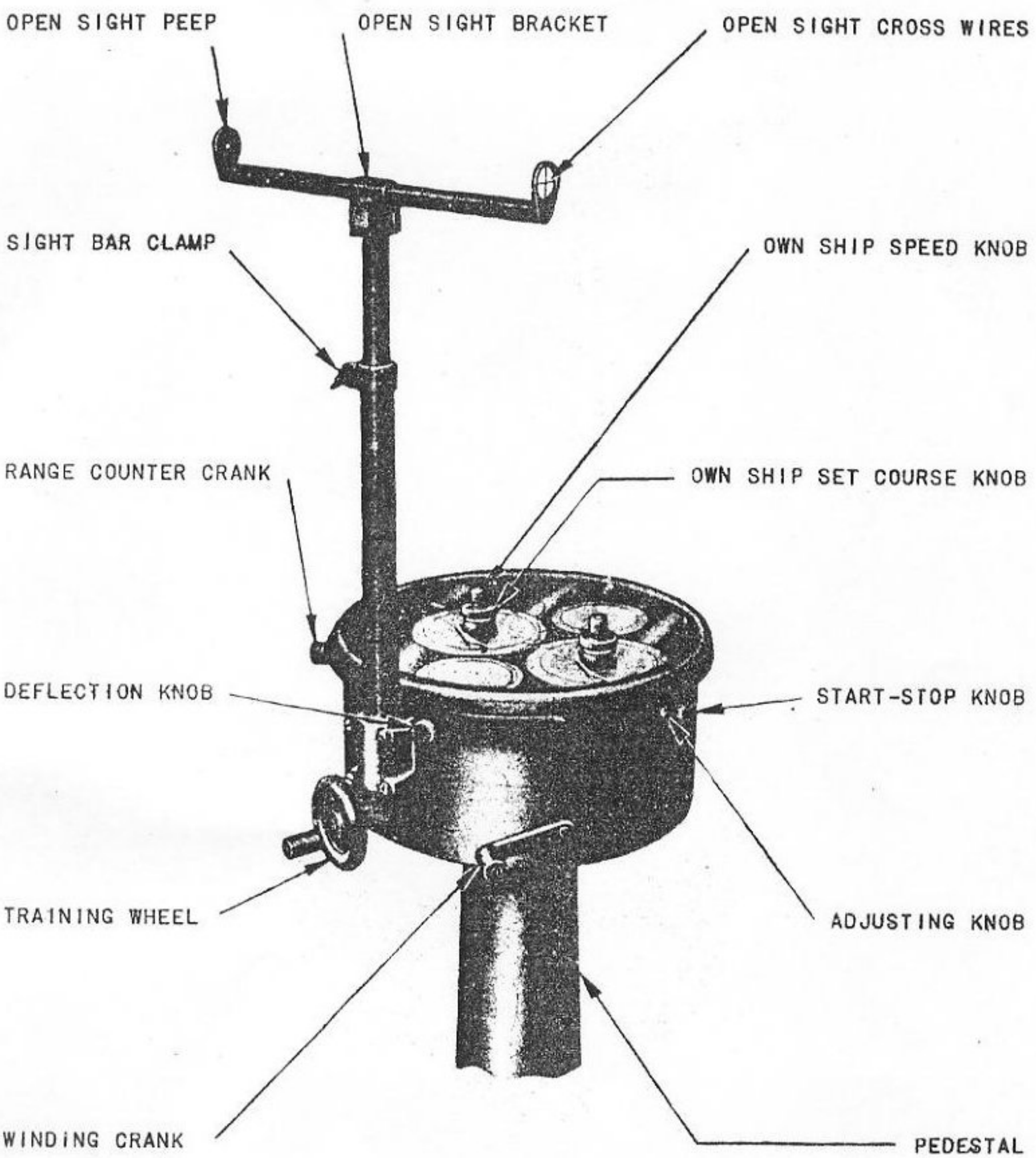

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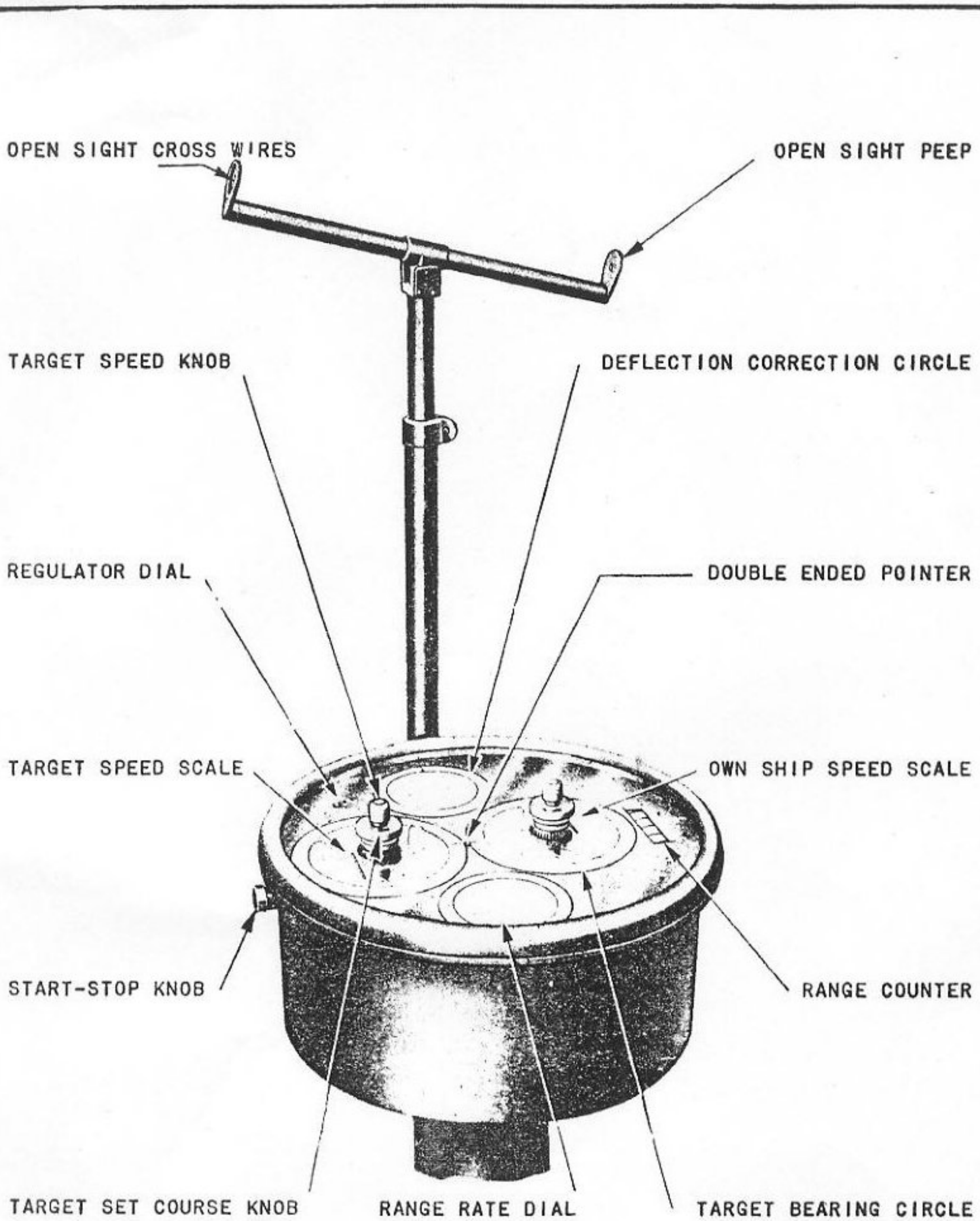
PLATE 2



FORD RANGE KEEPER, MARK II

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FIRE-CONTROL EQUIPMENT

FORD RANGE KEEPER MARK II

GENERAL DESCRIPTION.

1. The Ford range keeper Mark II is an instrument intended primarily for destroyers and light cruisers, though it can be used with any caliber of guns, which automatically combines the known course and speed of the firing ship with the observed range and bearing of the enemy, together with an estimate of his course and speed, in order to obtain the correct range and deflection to which the guns' sight scales must be set. It does not consider drift. It is a clockwork mechanism contained in a casing 14 inches in diameter and 8 inches deep. For convenience in operation it is mounted on a pedestal.

2. The face of the range keeper, protected by a glass cover, contains four dials, a range counter, a revolving pointer called a regulator, and a fixed double pointer indicating the line of fire. The dials are:

(1) Own ship's dial.
(2) Target dial.
(3) Range rate dial.
(4) Deflection dial.

Own ship dial.

3. The own ship dial, $3\frac{7}{8}$ inches in diameter, has scribed on it the outline of a ship. The range keeper must be placed so that this outline is parallel to the fore and aft line of own ship. This is most conveniently done as follows: Loosen the set screws under the casing. Turn the training wheel "J" until the zero of own ship dial is under the double pointer. Rotate by hand the casing on the pedestal until the cross wires of the open sight are on the bench mark indicating the fore and aft line. Secure the set screws. Rotate the instrument by the training wheel until the sight is on the bench mark aft. Now make sure that the 180° mark on own ship dial is under the double pointer. The own ship dial, once set, will always continue to indicate the fore and aft line.

4. The periphery of the dial is graduated clockwise from 0 to 360°. These graduations, by reference to the line of sight pointer, show the relative bearing of the enemy from the firing ship: Surrounding the dial is a ring, graduated clockwise in degrees from zero to 360. This ring is set to agree with the ship's true course so that the graduation corresponding to own ship's true course is opposite to the zero of the dial. Now the double pointer, read against the ring, indicates the true bearing of the target.

5. On the starboard side of the own ship's outline is a speed scale, graduated in knots from zero to 36.

6. Mounted over the center of the dial are two knobs, one within the other, which project through the glass cover. By pressing down and rotating the inner one, Plate 1, marked "Speed," a movable pointer is set opposite the graduation which indicates own ship's speed. By pressing down and rotating the outer knob, Plate 2, marked "Set course," the ring is set to correspond to the compass.

Target dial.

7. This is an image of the enemy which is set at his assumed course and speed. If these are estimated correctly, the deflection and range rate generated will be accurate. The dial has the same dimensions, scales, and outline as the own ship dial. However, the outer ring of the target dial is geared to that of the own ship dial and moves with it in the same direction and amount. The inner knob, Plate 1, operates, as before, to set the target speed, as estimated by the spotter. The outer knob, Plate 1, marked "Set course," serves to set the true target course. This is most conveniently done by setting the relative scale (on the periphery of the target dial) against the fixed double pointer so as to show the target angle as observed by the spotter. The target angle is the relative bearing of own ship from the enemy.

Range rate dial.

8. The range rate dial, 2⅝ inches in diameter, shows the rate of change of range in knots. It is graduated from 0 to 72 "in" and "out" and is read against a fixed reference mark. The position taken by the dial depends upon the courses, speeds, and bearing supplied to the instrument.

Deflection dial.

9. The deflection dial, 2⅞ inches in diameter, is graduated in knots from −22 through zero to 122; 50 is the point of zero deflection. In later instruments the graduation is from 0 to 200, with 100 as the point of zero deflection. It is set automatically, in the manner indicated for the range rate dial. Surrounding the dial is a ring marked "correction," which is graduated from zero to 20, right and left. In instruments (Mods. 2 and 3) fitted with the deflection converter this ring is marked with an arrow to match against the reference mark. The deflection is read against the zero of this ring. The ring is rotated by the deflection knob, Plate 1, in order to introduce initial deflection conveniently.

Range counter.

10. The range counter, reading from 1,000 to 20,950, can be set by hand by crank, Plate 3. When the clock is operating, the counter is automatically driven at the rate in or out indicated by the range rate dial.

Double pointer.

11. This is fixed between the own ship and target dials on the line between their centers. Therefore it indicates the line of fire. Parallel to it is an open sight mounted on the side of the casing.

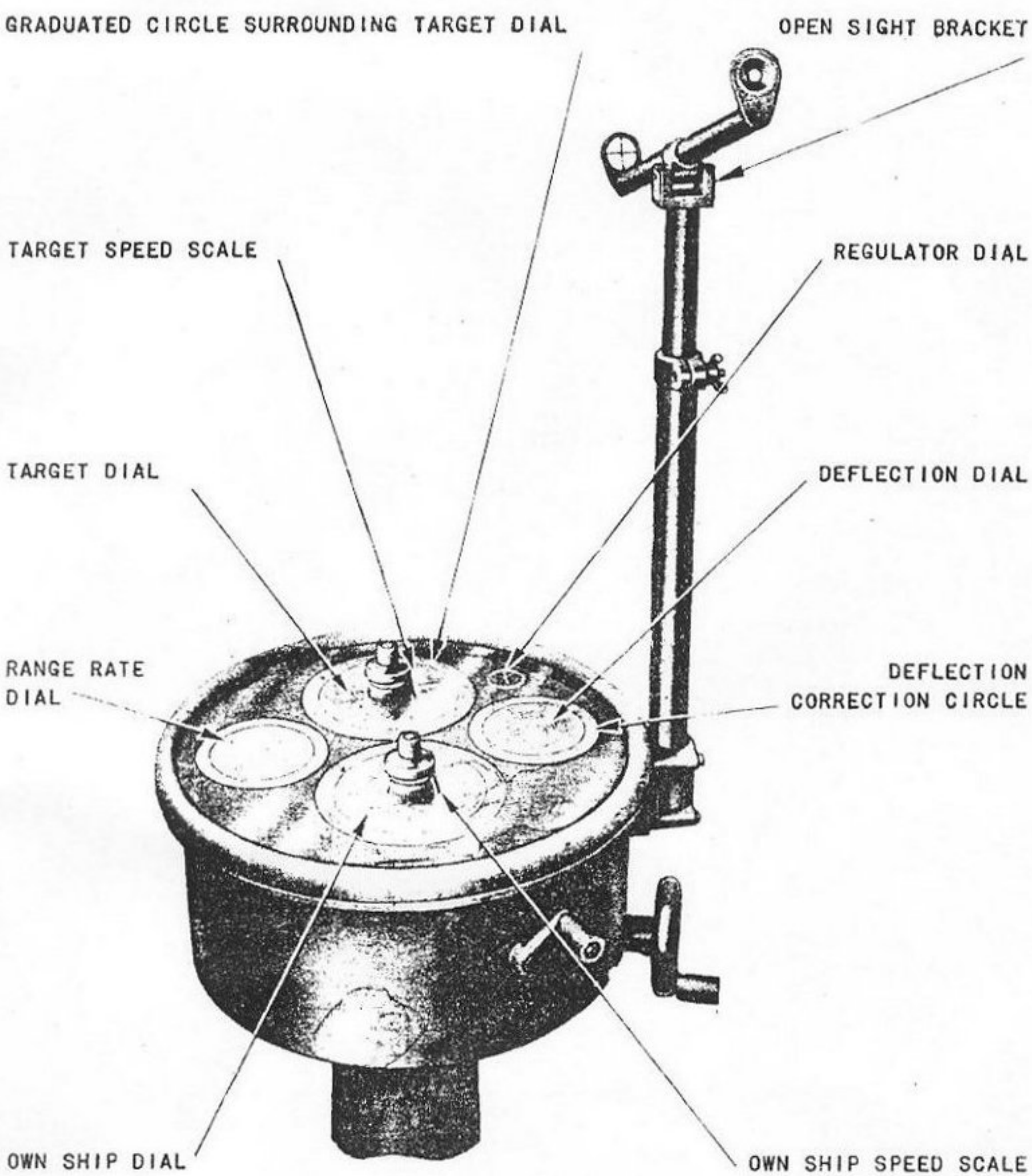
Regulator.

12. This is a small hand which rotates once in twenty seconds when the mechanism is running at the correct speed. Check this from time to time to make sure that the mechanism is running correctly. If it is fast or slow, the solutions obtained will be in error. Speed adjustment is provided by a screw on the axis of the start-stop knob, Plate 1. A telltale beside the regulator shows when the instrument requires rewinding.

SOLUTION OF PROBLEMS.

13. The mechanism is actuated by a double spring similar to those used in phonographs. It is wound by crank, Plate 1. It will run, if fully wound, for 30 minutes, but it is preferable to rewind every 20 minutes. It can be wound while the range keeper is running without introducing any error.

14. Set the own ship dial to the known true course and speed. Until the enemy is sighted keep the target course and speed at the same values as for own ship. Keep the range counter set to the range of visibility or to the probable range for opening fire.



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15. When the target is sighted, train the instrument until the open sight is on the point of aim, by the wheel, Plate 1. Set the target speed and target angle to the values estimated by the spotter by means of target speed and target set course knobs, Plate 1. Set the range counter to the range finder reading.

16. Start the clock by turning start-stop knob, Plate 1, through 180°. Check the regulator to see that it makes exactly three revolutions per minute. If the factors set up in the instrument are correct, the range counter will continue to agree with the succeeding range finder readings. If it fails to retain this agreement, the assumed target course and speed, which have been set on the range keeper, are in error and must be corrected to meet the conditions obtaining.

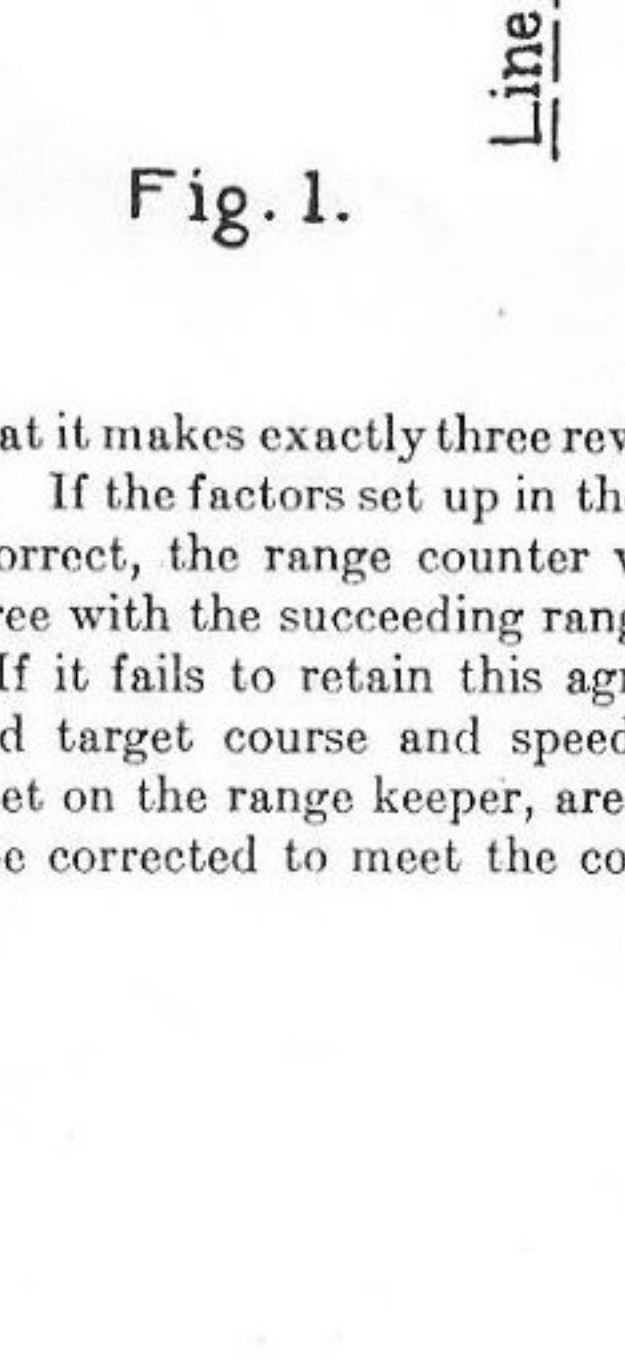


Fig. 1.

17. Introduce the ballistic correction in range by the range counter crank. Apply the estimated deflection due to windage by the deflection knob.

18. Read the range and deflection given by the instrument; send to the guns; open fire.

19. Often it will be found that the initial salvo contains errors both in range and deflection. It is essential first that the correct deflection be known. This is corrected by changing the assumed enemy course and speed. If one of these is considered to be better known than the other, make most of the change in the one which is believed to be the less accurate. As will be explained later, the change to be made is intimately related to the target angle.

20. Necessary spots in range are introduced by turning the range counter crank. Plate 3. One turn clockwise causes a change of up 200 yards. A detent on this shaft indicates 50 yard steps. The first spot in range does not require any change other than the correction introduced by the range counter crank. A second one in the same direction, however, is a positive indication that the range rate is wrong and the assumed enemy course, speed, or both must be changed correspondingly.

21. The operator must remember that the target dial represents the position, course, and speed of the enemy which he believes to be correct. In case the fall of shot indicates that his assumptions were in error, then he must change the course and speed and introduce the range spot by the range counter crank so as to make this assumed target coincide with the actual one.

22. The sketch Fig. 1, shows a vector, AB, the length of which represents the enemy's assumed speed and the position represents his course. The angle D is the so-called target angle. This vector can be resolved into components, BC at right angles to the line of fire and AC in the line of fire.

23. Assuming that the course and speed have been estimated with equal accuracy, the amount which each one must be changed for a given spot depends upon the relative lengths of the two components. If BC is small, the enemy course is nearly in the line of fire. A range spot would then require a change of the assumed speed with little or no change of course. A deflection spot would require a change of course with little or no change of speed. If AC is small, the enemy course is nearly at right angles to the line of fire and the necessary correction is the reverse of that previously considered; that is, a range spot would require a change of course and a deflection spot a change of speed. In case both components are relatively large, any spot at all requires that both course and speed be corrected.

24. The direction of change must be such that the image is moved toward the actual target; i. e., must be moved in the direction in which it is desired that the salvo should go. An "up" spot indicates that the assumed image is short of the target; a right spot indicates that the image is to the left of it, etc.

25. Care must be taken, when changing both course and speed, that only the element requiring correction is affected; that is, if correcting the range rate, make sure that the deflection dial is left at the same value that it had before, and vice versa.

26. In making initial changes it is important that they be large enough to show an immediate result. It is far better to overcorrect at once than to dilly-dally with small variations.

27. For accurate results the trainer must always keep his sight on the target.

28. As an illustration of the foregoing, assume that the target angle "D" is estimated as 125° and the target speed as 20 knots. If at the end of one minute a spot of down 600 is given, with "no change" in deflection, it is known immediately that the deflection as previously given is correct and that the range rate is too great by 18 knots. Thirty-three yards per minute is equal to 1 knot. Bring the range counter down 600 yards by the range crank. Change the assumed enemy course to the right and decrease speed until the range rate is diminished 18 knots while the deflection reading is unchanged.

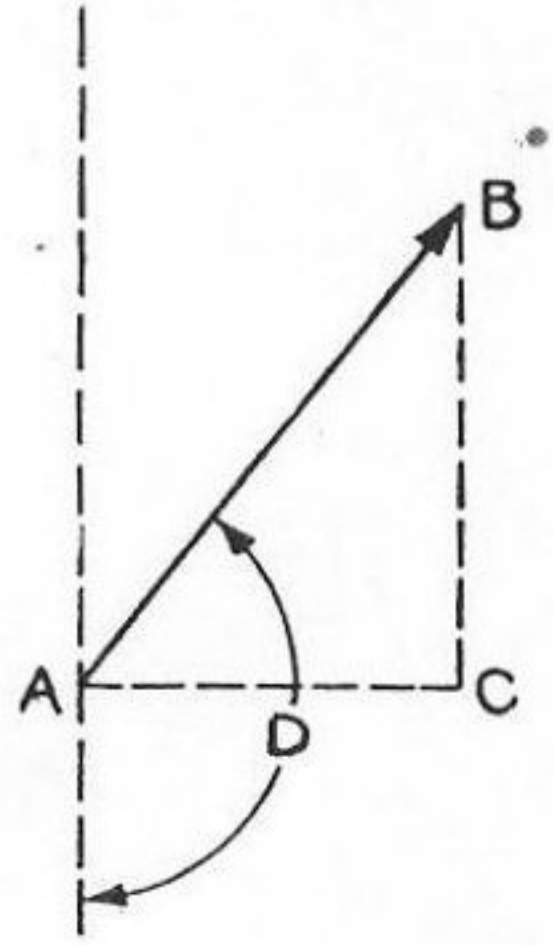


Fig. 2.

UPKEEP ROUTINE.

29. The following routine test should be given weekly to Mark II range keepers afloat (monthly to those in storehouses) to insure the governor and start-stop mechanism against sticking or failure to start when required.

(1) Wind up the spring and turn the start-stop knob Plate 1. If the mechanism does not

function at once, a slight jar will probably start it.

(2) Turn own ship's course through 360° Turn target course through 360°. Move both speed pins through their entire range. Turn bearing crank until the bearing has changed through 360°.

(3) Allow the instrument to run down completely. The winding spring must be left without tension when not in use.

Oiling.

(4) If the range keeper does not start without a jar, it probably needs oiling. This should be done at least every three months (oftener if required) but only by a trained officer or man who has had instruction at the Ford Fire Control School. A high grade of light mineral oil should be used; specification for a suitable oil is appended. Avoid using too much oil. All Mark II and Mark II, Mod. 1, instruments require to be lifted from their casings for oiling. The Mods. 2 and 3 instruments are supplied with an oiling plug in the casing which provides access to the governor, brake pads, and detent.

Caution.

30. If the range keeper does not operate properly, do not allow any inexperienced person to attempt repairs. Ask for one of the fire control repair officers to do the work. Have one of the above officers make a routine examination of the instrument every six months.

31. During freezing weather the range keeper should be mounted in the chart house or other heated compartment to prevent ice from forming on it and to prevent the low temperature from causing unsatisfactory operation.

SEQUENCE OF OPERATIONS.

32. The winding crank, Plate 4, through shaft S–103, winds the double main spring. Further, through shafts S–4 and S–102 and the nut on S–102, it moves the rewind pointer toward the fully wound position. The nut on S–102 engages S–7 so that if one shaft is turned while the other is still the nut will be translated along S–102. When the winding crank is **not** being turned the lower half of the spring casing is held in place by the pawl "FF."

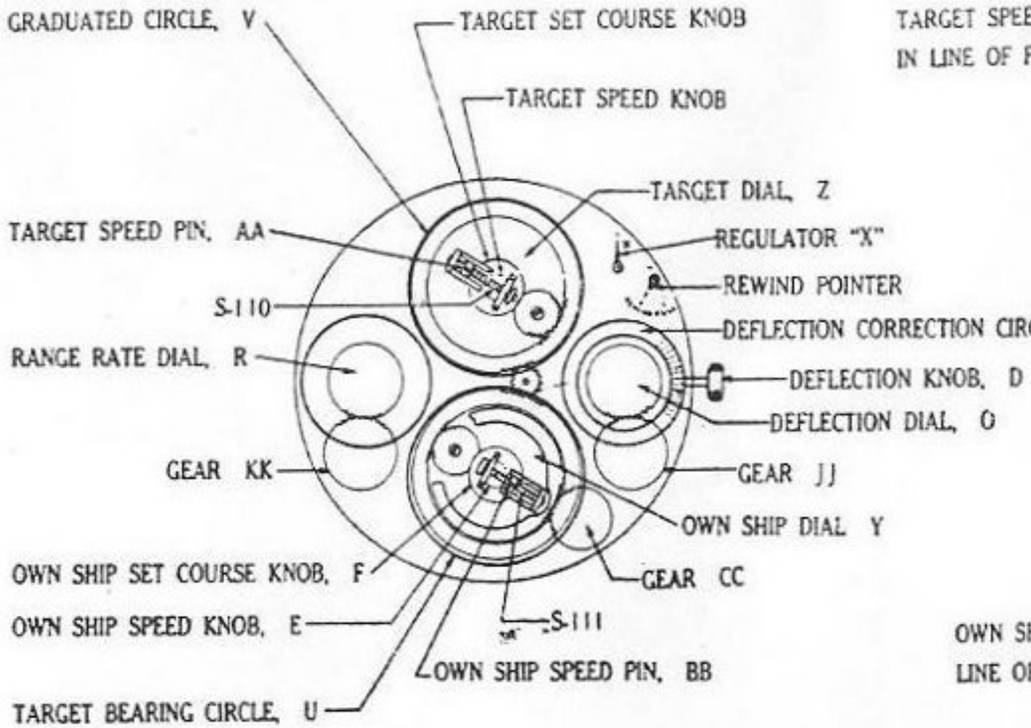
33. Rotation of start-stop knob to the start position releases the governor brake "EE." This permits the main spring to unwind at a constant speed. Through shaft S–3 and its gearing the spring drives the integrator plate. It likewise actuates the regulator "X" and the rewind pointer through shaft S–7, and the governor through shafts S–2 and S–101. The mechanism speed is limited by the bell crank "DD", which is positioned by the screw in start-stop knob. The governor will accelerate until its plate touches the brake pad on "DD" and then retain constant speed.

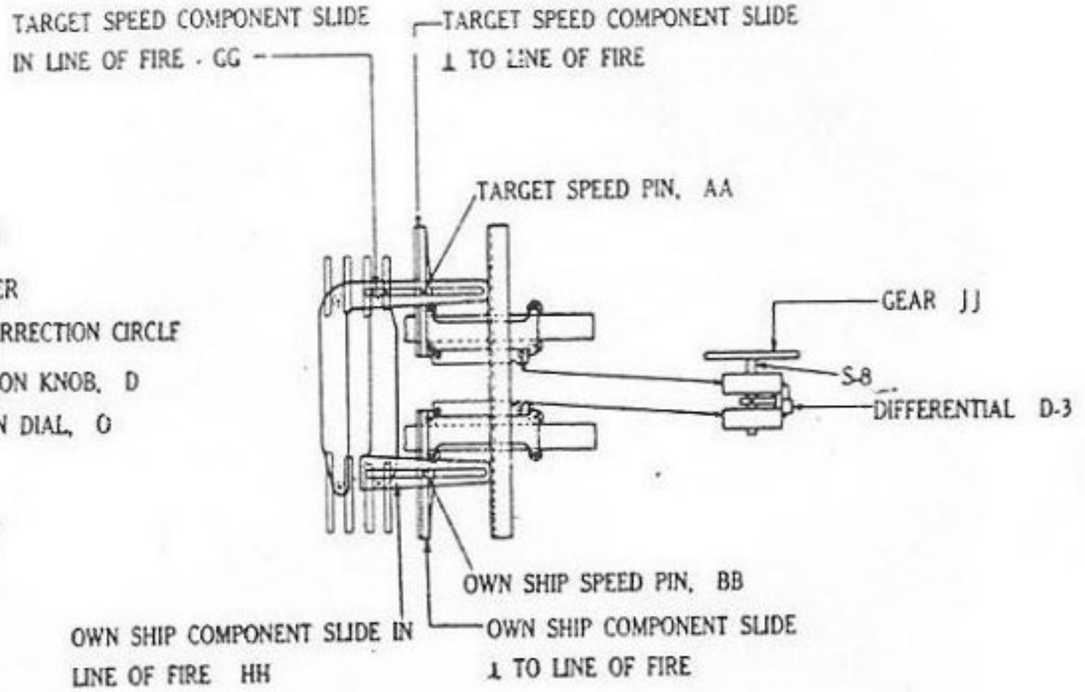
34. Turning range counter knob through S–106, S–6, differential D–2, S–5, and S–104 actuates the range counter. A detent on shaft S–6 indicates every 50 yards change of range.

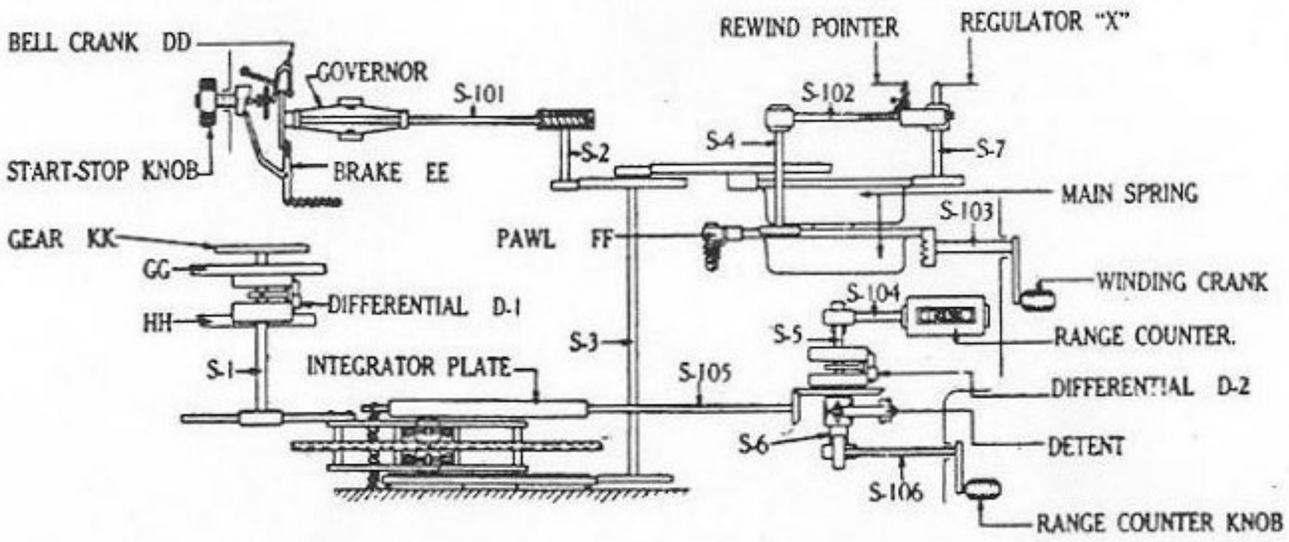
35. The deflection knob sets the deflection correction circle directly.

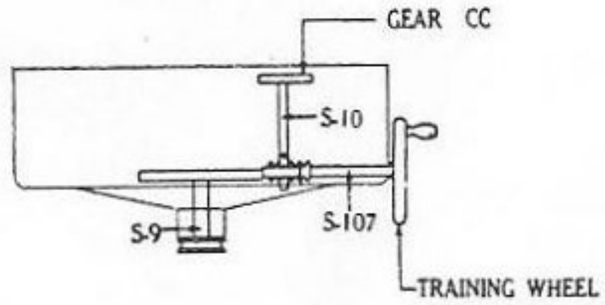
36. When S–9 is secured to the pedestal by set-screws provided, turning the training wheel, rotates the range-keeper casing and, at the same time, S–10. The gear "CC" at upper end of S–10, engages the rack on the lower side of the own ship dial "Y." In installing the instrument the outline on "Y" and, therefore, the shaft S–111, are placed parallel to the fore and aft line of own ship. Because of the rotation of the casing when the training wheel is turned and the reverse equal turning of the dial, the dial and S–111 remain in their original positions.

37. The own ship speed knob, indicated by a dotted line, rotates S–111. This causes the crosshead, on which is carried own ship









Ford Range Keeper Mark II Schematic Diagram

speed pin, to take a position whose distance from the center of the dial represents own ship's speed. The pointer of own ship's speed scale is carried on this crosshead. The knob "F" own ship set course, through the idler which it engages, sets the target bearing circle "U" to the reading corresponding to the own ship's true course. This circle, in turn, drives the graduated circle "V" surrounding the target dial, carrying the target dial "Z" with it.

38. In similar manner the target speed pin "AA" is set to a position corresponding to his estimated course and speed by the target set course and target speed knobs, the former rotates the target dial relative to the ring surrounding it and the latter sets the speed pin at a distance from the center of the dial corresponding to the estimated, speed of the enemy.

39. The target speed pin "AA" positions the target component slides in and perpendicular to the line of fire. Likewise, the own ship speed pin positions the own ship slides.

40. The two component slides in the line of fire "GG" and "HH" engage the upper and lower gears of the differential D–1. The spider of this differential is therefore turned an amount corresponding to the sum of own ship's and the enemy's movements in the line of fire. Shaft S–1, to which the spider of D–1 is secured, sets the range rate dial "R" and also sets the carriage of the integrator. As explained later, the distance of the integrator balls from the center of the plate determines the speed and direction of the roller.

41. The integrator roller, through S–105, D–2, S–5. and S–104 causes the range counter to change at a rate due to the own ship and target speed components in the line of fire.

42. The two speed component slides perpendicular to the line of fire drive the upper and lower gears of the differential D–3. The spider of this differential, having a movement corresponding to the sum of the own ship's and enemy's components perpendicular to the line of fire, positions correctly the deflection dial "O," by the gear "JJ" at the upper end of S–8. It must be remembered that this deflection does not consider drift. The windage is put in by the deflection knob.

MISCELLANEOUS NOTES.

43. The range keeper should be so placed that the operator can see entirely around the horizon. This may require more than one pedestal. It should be protected as much as possible from vibration and blast. If the instrument must be mounted in an exposed position, it should be removed from the pedestal and stowed in a secure place, when not in use.

44. Secure the pedestal firmly to the deck. If the deck is thin a wooden base may be required. Cast iron pedestals are provided; bronze ones may be obtained for locations near a magnetic compass.

45. To remove the works, take off the bezel ring and glass cover. See that the start-stop knob is in the stop position. Take out the four screws at the periphery of the face. Lift the works out by handles provided. Be careful not to rub off the luminous paint with which the dial graduations are marked. Care must be taken not to break the glass cover. If this should occur, do not allow any fragments to get into the works.

46. To assemble, lower the mechanism vertically to its position in the case. Before tightening any screws, try the range crank, the deflection knob, and the training wheel to make sure that all gears are in mesh. See that the face plate is completely down on lugs which support it. Be careful to replace the glass cover so that the knobs are exactly in the centers of their respective dials.

47. In testing the instrument at the factory prior to acceptance, the range counter error

must not exceed 20 yards per minute at any rate. The regulator must rotate in 20 seconds with not more than ± 0.3 second error.

48. The Mod. 1 instrument contains a large number of minor variations from the Mark II instrument. The Mod. 2 and Mod. 3 are fitted with deflection converters. The converter serves to change knots deflection to arbitrary or "mils" deflection, in which one mil is an angle whose tangent is one one-thousandth. The converter contains a correction for drift and therefore must be employed with the particular gun for which designed.

49. In the case of range keepers mounted on the Mark VIII director, the instrument is carried by the director and has no provision for independent train or sighting.

50. An integrator is a device for converting a constant angular motion in one direction to a variable angular motion in either direction. It consists of a circular flat steel plate, rotating at constant speed about an axis perpendicular to the flat surface. A carriage, in which are inclosed two steel balls, is constrained to move across a diameter of the plate. The balls are in contact, one vertically above the other. The lower one is in contact with the plate and the upper one with a steel roller. The speed and direction at which the roller is driven depend upon the point of contact between the plate and the lower ball, i. e., upon the distance of the point of contact from the center of the plate. This device is employed to drive the range counter, where the carriage is placed in a position corresponding to rate of approach of the firing and enemy ships.

51. A differential is an arrangement of gears by which two angular motions may be added or subtracted. It consists of two gears, carried loose on a shaft. Between them is a spider, fixed to the shaft, which is connected by gearing to the two loose gears. The two outer gears may be driven independently at any speed or direction. The motion of the spider is dependent upon their motions and upon the gear ratios. This is applied in combining the components of own ship's and enemy's movements in and perpendicular to the line of fire to arrive at the resultant rate of change of range and deflection.

OIL SPECIFICATIONS.

52. An oil complying with the following specifications will be suitable for use in the Mark II range keeper. This is the oil specified for lubricating the Waterbury variable speed gear.

53. It shall be a pure distillate of mineral oil at one temperature. Preference will be given to an oil light in color. It must be free from volatile oils such as kerosene or gasoline and free from all traces of acids, alkalies, and moisture. The viscosity must be such that it will flow readily at 15° F. and possess good lubricating qualities at 350° F.

The specific gravity 0.850–0.870 at 60° F.

Flashpoint, open cup test, not less than 390° F.

Cold test, 0° F.

No visible vapor to be in evidence up to 260° F. at room temperature of 60° F.

Gumming test by the wick feed process shall indicate 100 per cent at end of the first, second, and third days.

Viscosity compared to water at 60° F. shall be as follows, Saybolt standard:

80° F.	86–120 seconds.
100° F.	62– 82 seconds.
120° F.	52– 66 seconds.
180° F.	36– 44 seconds.
212° F.	32– 34 seconds.

SAMPLE PROBLEM.

54. Below is a sample problem for training of range keeper operators. The information given is correct. As the operator becomes more experienced, he may be supplied with incorrect data. Fire may be opened at any convenient time, i. e., two or three minutes after the commencement of the problem. Own ship courses and speeds may be changed

at will to vary the problem. The operator is given the data of his own ship, range and bearing, and required to solve the deflection and rate.

Own ship true course	40°.
Enemy bearing	80°.
Target angle	40.
Windage	Left 5.
Speed	25 knots.
Range	12,000 yards.
Speed	30.

DATA.

Min.	True range.	True bearing.	Deflection.	Rate.
½	11,250	83	81.5	−40.5
1	10,600	86	83.7	−38
1½	9,950	90	86	−35.5
2	9,400	94	88.5	−32.5
2½	8,850	98	91	−30
3	8,400	103.5	93.2	−25
3½	8,050	109	95.5	−20
4	7,750	115	97.5	−14.5
4½	7,550	121.5	98.7	− 8.5
5	7,400	128.5	99	− 2.0
5½	7,500	136	99	+ 5.5
6	7,650	143	98.5	+12
6½	7,900	149.5	97	+18
7	8,250	155.5	95	+23.5
7½	8,700	161.5	92	+27.5
8	9,100	166.5	88.5	+32
8½	9,650	171	86	+36
9	10,300	175	83	+38.5
9½	10,950	178	81	+41
10	11,650	181	79	+42

REGULATION OF TIME OF RANGE KEEPER.

55. For checking governor speed or regulation of time of range keeper proceed as follows:

(1) Train range keeper ahead. (Enemy ship then is dead ahead of own ship.)

(2) Set enemy ship to course 180 relative to own ship.

(3) Set 30 knots speed on own ship and on enemy ship.

(4) Check accuracy of stop watch by comparing it with timepiece of known rate.

(5) Start stop watch when range dial reads some convenient figure such as 9,200 yards.

(6) At end of two minutes read range dial. It should read 5,150 yards because 1 knot per hour is 2,027 yards per hour, 60 knots would equal 2,027 yards per minute, and in two minutes this would equal 4,054 yards.

(7) Adjust speed screw to give above result.

(8) Set enemy speed to zero and repeat above test for four minutes. Same result should be secured.

CHAS. B. MCVAY, JR.,
Chief of Bureau.

NAVY DEPARTMENT,
BUREAU OF ORDNANCE,
December, 1922.