Ordnance and Gunnery

A TEXT-BOOK

PREPARED FOR THE USE OF THE MIDSHIPMEN OF THE UNITED STATES NAVAL ACADEMY

BY

OFFICERS OF THE U. S. NAVY

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PREFACE

The necessity of revising the text-book of Ordnance and Gunnery having arisen, this book is the result.

It was revised under the supervision of my predecessor, Commander H. K. Hines, U. S. N., and represents the voluntary labor, in their own time, and under considerable disadvantage, of officers of the Department of Ordnance and Gunnery, of the Bureau of Ordnance, the Naval Gun Factory, and Naval Proving Ground.

No attempt has been made to include each individual type of ordnance mechanism with the variations thereon. On the contrary, an attempt has been made to illustrate fundamental principles and general types, believing that to understand these well is in the end productive of greater results than to have a superficial knowledge of many types.

The following officers have written entire chapters: Lieut.-Commander H. C. Mustin, Lieutenant H. T. Winston, Lieutenant B. A. Long.

The following have rewritten or revised chapters of the former text-book: Commanders H. K. Hines and R. H. Jackson; Lieut.-Commanders M. E. Trench, Ridley McLean, and R. W. McNeely; Lieutenants H. Williams, T. L. Johnson, C. R. Kear, H. T. Winston, F. D. Berrien, B. A. Long, W. W. Galbraith, R. P. Craft, W. T. Conn, Jr., and L. H. Lacy.

Acknowledgment is made of the courtesy and assistance of Rear-Admiral N. E. Mason, U. S. N., Chief of Bureau of Ordnance, and of Rear-Admiral Leutze, U. S. N., Superintendent of the Naval Gun Factory.

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U. S. NAVAL ACADEMY,
Sept. 6, 1910.

CHAPTER XII.

NAVAL GUN-SIGHTS.[1]

By LIEUTENANT-COMMANDER H. C. MUSTIN, U. S. Navy.

1. Preliminary definitions.—(1) *The axis of the bore* of a gun is its longitudinal geometrical axis.

(2) *The axis of training of a gun* is the axis of motion of the top carriage in azimuth; this axis must be installed so that, when the ship is on an even keel and normally trimmed, it will be perpendicular to the plane of the horizon.

(3) *The axis of the trunnions* is their common geometrical axis; the slide must be so machined that this axis will be accurately at right angles with the axis of bore. The adjustment of the frictionless trunnions (or, in the case of small guns, the machining of the trunnion-seats) must be such that the axis of trunnions is accurately at right angles with the axis of training. Then, when the ship is on an even keel and normally trimmed, the axis of the bore will move in a plane vertical to the plane of the horizon when the gun is moved in elevation.

(4) *A modern naval sight-mount* is a mechanism, attached to or connected to the gun-slide, that carries two points, called the front and rear sight-points, whose positions relative to each other are rigidly fixed. In Fig. 1 the front sight-point S' is the apex

[1] Captain Bradley A. Fiske, U. S. N., invented the application of the telescope-sight as a permanent part of the gun-mount, in 1892; prior to this telescopes had been used, but they were always removed from the gun before firing.

The development of the telescope as a night-sight was the result of original experiments that were made by Lieutenant-Commander H. C. Mustin, U. S. N., while on duty at the Gun Factory in August, 1905. He also designed telescopes, Marks XI, XII and XIII (prismatic) in 1905-1906. The other inventions of his referred to in the text are as follows: Periscope sight-mount for turret-guns, in 1904; periscope sight-mount for broadside guns, in 1906; focusing-cap, in 1906.

of a cone; the rear sight-point S is the bottom point of a V-shaped notch; the straight line prolonged through these two points is called *the line of sight*. The purposes of the mechanism are as follows:

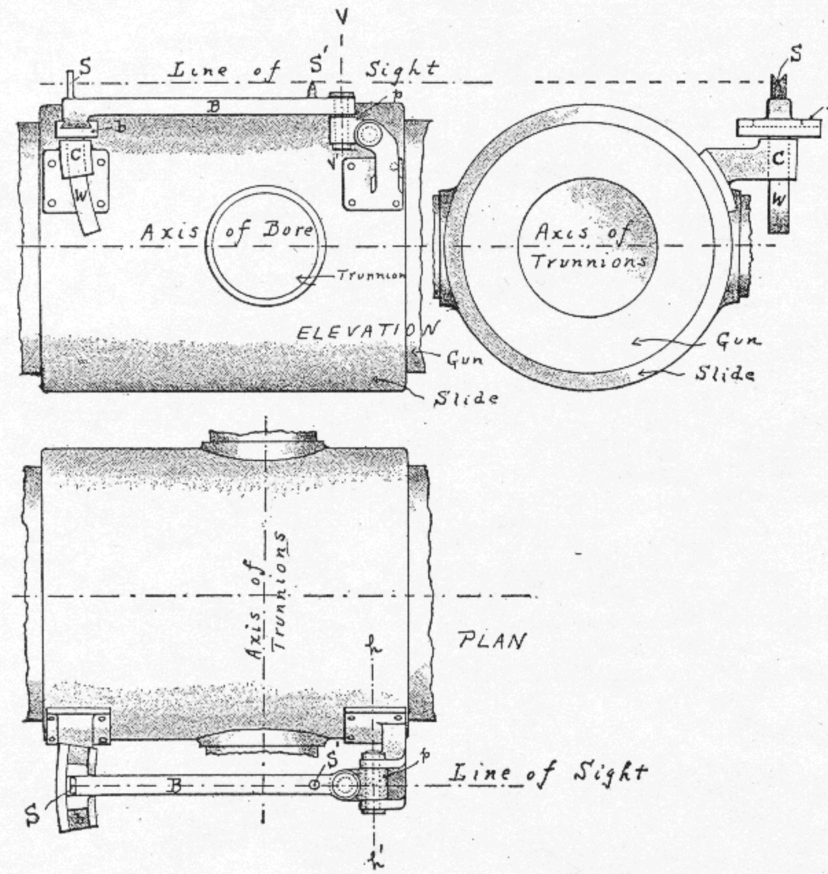

FIG. 1.

(a) To set the line of sight at any specified angle with the plane through axis of bore and axis of trunnions; for this purpose there is required *the horizontal sight-axis hh'*, which necessarily must be installed exactly parallel to the axis of trunnions.

(b) To set the line of sight at any specified angle with the plane through the axis of bore that is perpendicular to the axis of trunnions; for this purpose there is required *the vertical sight-axis vv′*, which must be installed exactly at right angles with the axis of trunnions.

(5) *The trajectory* is the curve described by a projectile in passing from the muzzle of a gun to the point of impact; its downward curvature *MmI* (Fig. 2, elevation) is due to the force of gravity; its lateral curvature *MmI* (Fig. 2, plan) is due to the

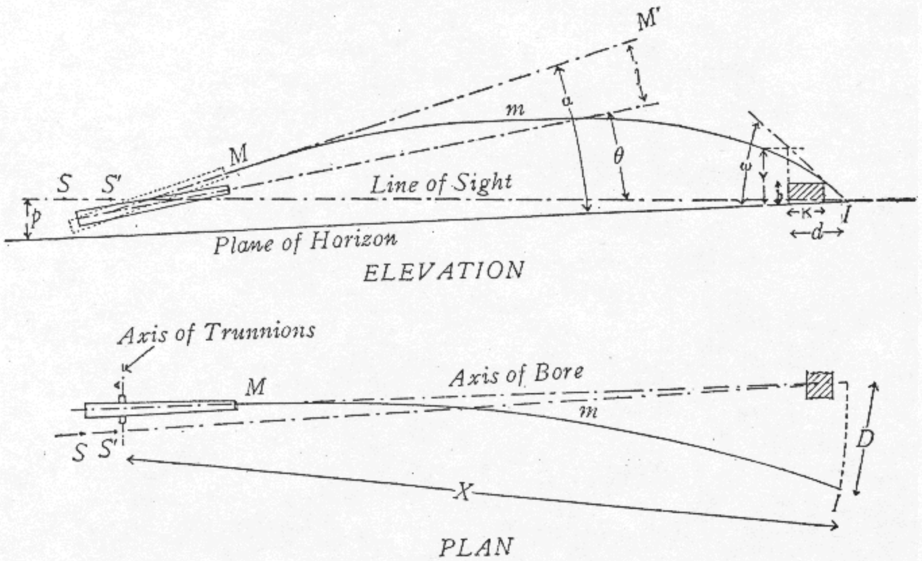

Fig. 2.

rotation of the projectile that is imparted by the rifling of the gun. This deviation from the vertical plane of fire is called the *drift,* and is to the right in all our guns.

(6) *The line of departure* is the tangent to the trajectory at the muzzle of the gun; it is coincident with the axis of bore at the instant the projectile leaves the gun (*MM′*, Fig. 2).

(7) *The jump* is the small vertical angle, usually upward, which the axis of the bore describes in the act of firing (*j*, Fig. 2); it is due to a yielding in the supports of the gun, caused by the shock of discharge.

(8) *The angle of position* for a given target is the vertical angle between the plane of the horizon and the line of sight, when the line of sight passes through that target (*p*, Fig. 2).

(9) *The angle of elevation* is the vertical angle that the line of sight makes with the plane through axis of the bore and axis of the trunnions (θ, Fig. 2).

(10) *The angle of departure* is the vertical angle between the line of departure and the plane of the horizon (α, Fig. 2). When the jump and angle of position are negligible, as they are assumed to be in naval gunnery, the angle of departure is the same as the angle of elevation.

(11) *The range* is the linear distance between the gun and the intersection of the trajectory with the line of sight (*X*, Fig. 2).

(12) *The angle of fall* is the vertical angle that the tangent to the trajectory at the point of fall makes with the plane of the horizon (ω, Fig. 2).

(13) *The danger space* of a target whose height is h and whose beam is k is equal to $k + h \cot d$ (*d*, Fig. 2).

(14) *The virtual height* of a target is equal to $d \tan \omega$ (*v*, Fig. 2).

2. The fundamental principles of a sight-mount are illustrated in Fig. 1; every modern naval sight, whatever its type may be, is based on principles shown in this figure. The bar which carries the front and rear sight-points, *S′* and *S*, is called the *pivot-bar.* To meet the first requirement of the mechanism (see paragraph (a), page 183), the *pivot-block p,* to which the front end of the pivot-bar is attached, engages the shaft whose axis *hh′* is the horizontal sight-axis installed exactly parallel to the axis of the trunnions. Vertical motion is imparted to the pivot-bar and to the line of sight by raising the curved bar *W*, called the *sight-bar;* this moves in the casing *C*, called the *sight-bar bracket,* which has a fixed position relative to the bearings of the horizontal sight-axis. The front and rear faces of the sight-bar, and the interior front and rear faces of the sight-bar bracket, are machined to arcs of circles centered in the horizontal sight-axis. It is evident that side faces of the sight-bar and the interior side faces of the sight-bar bracket must be in planes perpendicular to the horizontal sight-axis; otherwise, vertical motion of the sight-bar would cause an appreciable lateral motion of the rear sight-point, and a consequent deviation in the lateral setting of the line of sight. To meet the second requirement of the mechanism (see paragraph (b), page 183), the pivot-bar engages a pin in the pivot-block whose axis is *vv'*, installed exactly at right angles to the horizontal sight-axis *hh'*. Lateral motion is imparted to the pivot-bar and to the line of sight by moving the rear end of the pivot-bar in a groove in the *azimuth-head;* the front and rear faces of this groove and its fitting on the rear end of the pivot-bar are machined to arcs of circles centered in the vertical sight-axis. It is evident that the flat contiguous faces of these parts must be in planes parallel to the horizontal sight-axis and at right angles with the vertical sight-axis; otherwise lateral motion of the sight-bar would cause an appreciable vertical motion of the rear sight-point and a consequent deviation in the vertical setting of the line of sight. The means of imparting motion to the pivot-bar are, for the sake of simplicity in the drawings, omitted from Fig. 1 and the following illustrations of sight-mounts. They are as follows: Vertical motion is given by a worm-wheel, journaled in the sight-bar bracket, that engages a worm on the rear face of the sight-bar; the worm-wheel is connected by mitre-gears to a hand-wheel which has a small crank-handle. Lateral motion to the pivot-bar is given by a worm-wheel on the azimuth-head that engages a worm on the rear end of the pivot-bar; the hand-wheel for lateral motion is similar to the hand-wheel for vertical motion.

3. Sight-scales.—There are two kinds of scales on every sight; one kind indicates the movement of the line of sight about the horizontal sight-axis; this is called the *range-scale*; the other kind is for indicating the movement of the line of sight about the vertical axis and is called a *deflection-scale*. Sight-scales are either *direct-reading* or *multiplying;* the direct-reading type will be described first.

4. A direct-reading range-scale suitable for the sight-mount in Fig. 1 is shown in Fig. 3. The range-strip, made of white metal, is engraved with the divisions and numbers of the scale;

it is dovetailed to fit in the sight-bar flush with the outer side face, and is adjustable within the limits of the elongated hole for the clamp-screw *E*. The arc of a circle *Y* (shown in broken

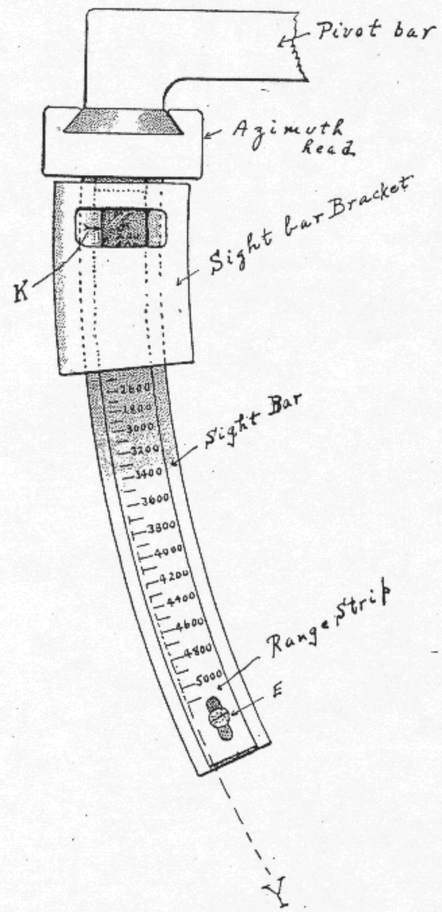

FIG. 3.

lines), which touches the rear ends of the scale divisions and front end of *K*, the reference mark on the sight-bar bracket, is centered in the horizontal sight-axis *hh'*, Fig. 1. This circle gives a basis for laying off the spacing of the scale divisions, which are calculated from data obtained at the proof-firing of the gun. The divisions read in yards of range for certain standard conditions as follows:

(a) Atmosphere of unit density.

(b) Powder charge of a certain weight and index that, at a temperature of 90° F., will give a muzzle velocity of a certain number of foot-seconds.

(c) Projectile of a specified weight and coefficient of form.

(d) Force of wind on the range zero.

For the above conditions, the angle of elevation for every range from 100 yards up to that which will be given by an elevation of 15° is computed and laid off on the arc *Y*, measuring from the

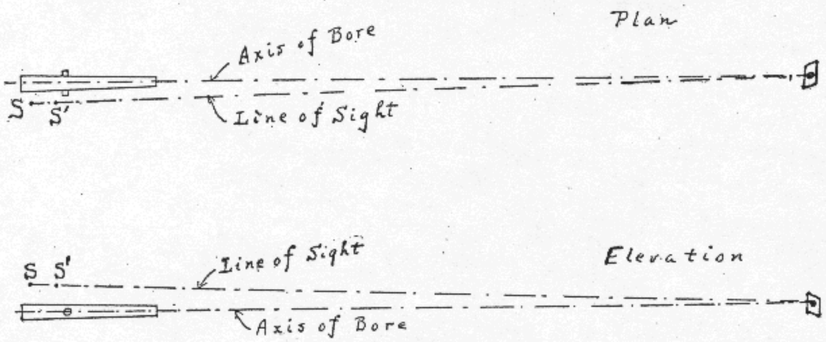

FIG. 4.

zero mark. For instance, under standard conditions, it is determined that a range of 5000 yards requires an angle of elevation of 5° 40′; then an arc of 5° 40′, measuring from the zero division, is laid off, and the division numbered 5000 is plotted.

5. Adjustments of the zero divisions are two of the details of *bore-sighting*—a subject which will be described more fully later on. A bore-sight consists essentially of two sight-points placed accurately coincident with the axis of the bore; by means of these and the elevating- and training-gears of the gun, we can lay the axis of bore on a certain mark which is at a mean target-practice or battle range; then, by motion of the pivot-bar we can direct the line of sight to the same mark (Fig. 4).

6. At present we are interested only in the range-scale; this must now be shifted to read zero by shifting the position of the

range-strip or, as is arranged for in some sight-mounts, by shifting the reference mark. After this is done, the gun is said to be bore-sighted in range for the mean range selected. Say this is 5000 yards. Now if we raise the sight-bar to the reading 5000, and move the elevating-gear of the gun until the line of sight is directed to the target, the gun will be at the proper elevation to give a range of 5000 yards under the standard conditions, (a), (b), (c), and (d), Art. 4. Now if the gun is fired under these conditions, from a motionless ship at a motionless target, the projectile will attain a range of 5000 yards; but it will fall to the right of the target an amount *D* (Fig. 2), which is the drift corresponding to 5000 yards range. In the above example we bore-sighted for a mean range of 5000 yards; it is therefore evident that there will be a small vertical pointing-error, when we fire at other ranges, unless we have a sight-mount that has its horizontal sight-axis coincident with the axis of the trunnions. For instance, if the horizontal sight-axis is 5 feet higher than the axis of the trunnions—as it is in some turret sight-mounts—and we have bore-sighted for a mean range of 5000 yards, we shall have a pointing-error 2½ feet low when firing at a range of 2500 yards, or we shall have a pointing-error of 2½ feet high at a range of 7500 yards. But we are better off than if we had bore-sighted by the old method of pointing at a star, and thereby adjusting the line of sight parallel to the axis of bore; this, in the above example, would give us a pointing-error of 5 feet low at all ranges.

7. **Drift-compensation.**—The lateral error *D*, in Fig. 2, due to the drift at a range *R*, represents an angular error, which is practically $\tan^{-1}\dfrac{D}{R}$. To compensate this, we move the rear end of the sight-bar to the left through an angle $\tan^{-1}\dfrac{D}{R}$; then train the gun to the left until the line of sight is again directed to the target *T*, as shown in Fig. 5. The next shot will be a hit, provided we have the standard conditions (a), (b), (c), and (d), Art. 4.

8. A deflection-scale is used primarily for making the drift-compensation; a direct-reading deflection-scale with its mounting, suitable for the sight-mount shown in Fig. 1, is shown in Fig. 6.

9. The pointer P is attached to the rear end of the pivot-bar by the screws a and b, and is adjustable vertically, with reference to the pivot-bar, within the limits of the elongated holes for these screws. The rear surface of the *azimuth-plate* is machined to the surface of the toroid that is generated by the lower end of the pointer P when the pivot-bar is moved about its two axes; this plate is dovetailed into the sight-bar bracket and is adjustable horizontally within the limits of the elongated holes for the clamp-screws c and d. In bore-sighting the gun, after the range-

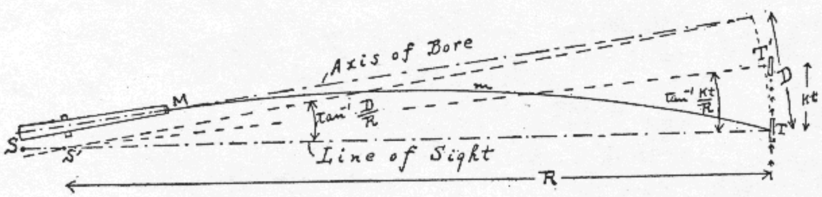

FIG. 5.

strip has been shifted to read zero, the next step is to make the deflection-scale read zero. First, raise or lower the pointer P, with reference to the pivot-bar, until the lower end of the reference mark is on the level of the zero mark on the azimuth-plate; then shift the azimuth-plate to the right or left until the center of the zero mark is at the lower end of the reference mark. Fig. 6 shows the sight-bar raised to the reading 1000 yards after range- and deflection-scale adjustments have been made; the lower end of the reference mark is now at the position p; its position for ranges 2000, 3000, 4000, 5000 would be q, r, s, t, respectively, if no lateral motion is given to the pivot-bar. Now if we move the rear end of the pivot-bar to the left from the position p through an arc $pp_1 = \tan^{-1} \dfrac{(\text{drift at } 1000)}{1000}$ to the position p_1, we shall have compensated the drift at 1000 yards range as in Fig. 5. Similarly, we can locate the points p_2, p_3, p_4, p_5, etc., by laying

off the arcs qp_2, rp_3, sp_4, tp_5, etc., which correspond respectively to the drift at ranges 2000, 3000, 4000, 5000, etc., and can lay down a fair curve through the zero mark and the points p_1, p_2, p_3, p_4, p_5, etc. When the sight-bar is raised to any range-reading and the pivot-bar is moved to the left until the reference mark on the

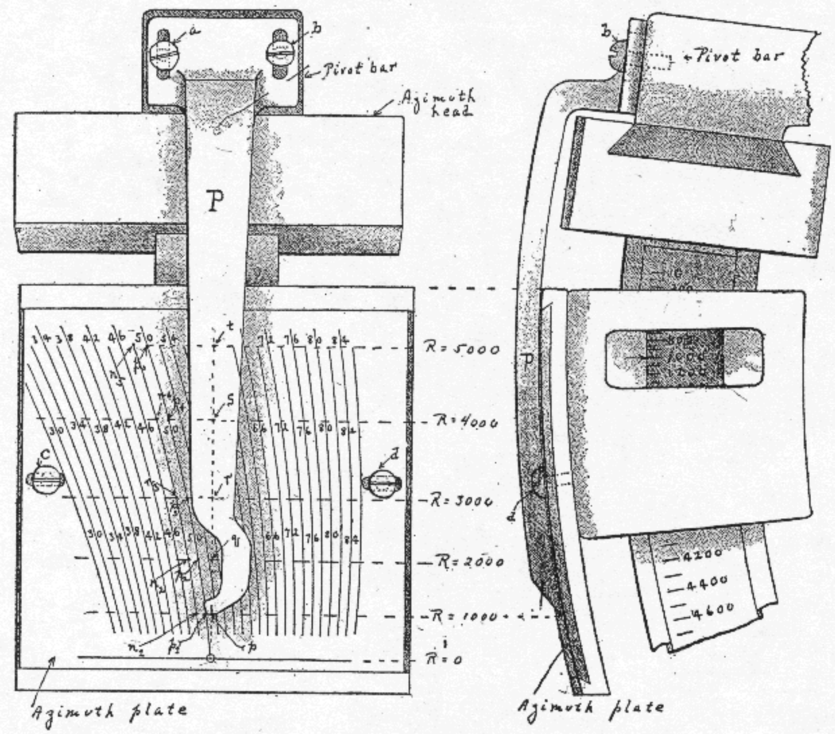

FIG. 6.

pointer touches this curve, a shot fired under the standard conditions (a), (b), (c), and (d), Art. 4, will have no drift error. This curve was formerly called the zero-line, but now, for convenience in sight-setting (as will appear later), it is called the *fifty-line* and is numbered as in Fig. 6.

10. Speed compensation.—Thus far we have considered the ship and target motionless, but, in naval gunnery, either the target or ship or both are steaming ahead. We will examine the