

CHAPTER 8

INTRODUCTION TO GUN BATTERY ALIGNMENT

This chapter takes up the elements of gun battery alignment, explaining the principal operations required in aligning the equipment and maintaining it in alignment.

Battery alignment is one of the critical factors in the fighting effectiveness of any combat ship equipped with guns or missile launchers. Without proper battery alignment the projectiles and missiles fired will not hit their target when properly aimed—regardless of high crew efficiency, high-power radar and optical equipment, speedy fire control computation, or high rate of fire. Maintenance of accurate battery alignment is a primary responsibility of weapons personnel, beginning when the ship is under construction, continuing so long as it remains in commission—even when the ship is retired to the "mothball" fleet. Battery alignment is not confined to operations at infrequent intervals. Although some alignment operations are performed as infrequently as once every two years, some operations (such as transmission checks) are done every day.

Taking into account in detail all the phases of battery alignment, beginning with the original construction of the vessel, it is evident that the subject is complex and requires close study even by the nonspecialist. This chapter concentrates on principles rather than procedural details, and on alignment afloat, rather than the more complex drydock operations.

BATTERY ALIGNMENT: PURPOSE, DEFINITIONS AND DISTINCTIONS

The purpose of battery alignment is to adjust the guns of the battery and associated fire control equipment so that the lines of sight of the director telescopes and gun sights, the beam axes of the radar antennas, the lines of sight of optical rangefinders, and the bore axes of the guns in the battery, are all parallel when

1. dials are matched with correct follow-the-pointer indications,

2. no parallax corrections are introduced, and
3. no ballistic corrections are introduced.

In a correctly aligned system, all associated gun bores, etc. remain parallel under these conditions throughout all operating motions, and all instrument dials and automatic control equipment measure these motions correctly with respect to the proper reference.

To accomplish this, all these elements must be aligned to a common system of reference points, lines, and planes. Battery alignment can therefore be defined as the process of adjusting all the elements of a weapon system (in a gun battery this includes the director, sights, radars, computer and stable element if any, and the gun mount sights and gun barrels) to these common reference points, lines, and planes, and maintaining them in this relationship.

Note these distinctions:

INTERNAL ALIGNMENT refers to adjustment of the geometrical relationships within an element of the fire control or weapon system, such as a mount's gun bore axis and the mount's gunsight mechanism.

SYSTEM ALIGNMENT refers to the geometrical relationships between two or more major components of a system, for example the bore and sight telescope axis of a gun mount as related to the line of sight of director telescopes.

ORIGINAL ALIGNMENT is the initial alignment made in a fire control and weapons system at the time of original construction and installation. This is a very elaborate and highly accurate series of operations done in drydock by the shipbuilder or fitting-out yard. Original alignment is also performed whenever a new or modified major weapon system is installed (also usually a drydock operation).

DRYDOCK ALIGNMENT OR REALIGNMENT refers to the thorough alignment overhaul and readjustment made when a ship goes through its

regular drydock overhaul period, at intervals usually of two years or longer.

ALIGNMENT AFLOAT refers to alignment operations performed while the ship is waterborne (in port or underway). These operations are performed much more frequently than the relatively elaborate drydock alignment work. Alignment afloat requires standards of accuracy just as high as those of original alignment. The main difference is that alignment afloat must be performed by weapons department personnel with equipment available on the ship.

TRAIN ALIGNMENT refers to adjusting fire control and weapon system elements so that they are in effect all parallel and are all at exactly the same angle to a selected vertical plane.

ELEVATION ALIGNMENT refers to adjusting these elements so that they are parallel and are all at exactly the same angle to a selected horizontal plane. In both cases, alignment as defined assumes that no ballistic corrections or parallax corrections have been introduced. Train alignment is commonly performed separately from, and before, elevation alignment.

ALIGNMENT ERRORS AND THEIR SOURCES

In alignment operations, errors and discrepancies can be traced back to three sources:

1. Human error (observation error).
2. Instrument error (mechanical error).
3. Lost motion.

Human error is caused by factors such as failure or inability of operating or maintenance personnel to match index marks or graduations; tendency to misread, or to read with limited accuracy, scale indications; failure to line target points up exactly with reticle crosshair intersections; and the like. This is necessarily caused by personnel incompetence; incompetence or carelessness may increase this source of error to serious proportions, however. Even the sharpest-eyed, most skillful, and most conscientious person has his limitations. To keep adjustments and observations as free of human error as possible under the usual conditions aboard ship, working personnel take the following precautions:

1. Each observation or measurement is made as carefully as possible. This requires that the

operation itself be carefully prepared and performed. It is important also to use care in reading dials—to count the graduations accurately, and to look at the dial squarely to avoid apparent displacement (parallax effect) of the index or pointer and the graduations.

2. Critical measurements are taken two or more times, and the recorded value taken is the mean (average) of these.

3. Especially critical observations may be taken not only more than once, but by a different individual each time.

Human error may be consistently in one direction and variable in amount, or (as is rather more common) consistent neither in direction nor amount.

Instrument error (often called mechanical error) is caused by some kind of incorrect setting or relationship in the equipment. It may be caused by incorrect adjustment of a part, or wear, or weakening of a spring, or warping of a shaft, or any number of other causes. Such errors may also be caused (in electrical or electronic equipment) by failure or weakening of a tube or capacitor, or other electrical malfunction. As distinguished from lost motion (see below), instrument error is generally consistent in direction and magnitude. When combined with the effects of human error and lost motion, this characteristic may be obscured.

Lost motion is normally caused by wear and deterioration of parts through either use or lack of use. The term applies to looseness or slackness of linkages of all kinds, whether caused by faulty or sloppy engagement of gears, excess end play or shafting, weakening or failure of springs, or other causes. A mechanism may, because of wear or other causes, bind or stick in some ranges of its operation while it has lost motion in others. A minimal amount of lost motion, like a minimal amount of human error, is in most mechanisms impossible to avoid (though spring loading can in some applications reduce it to zero), and designers provide for such minima by necessity. But lost motion must be taken up by resetting of parts, and replacement of worn parts, as required during repair work.

In certain operations, maintenance personnel can virtually eliminate the effect of lost motion (but not lost motion itself) by approaching each critical observation or reading from a given direction. When doing this, if you overshoot, begin again and approach the desired value from the same direction. But if you are measuring

lost motion or actual instrument error itself, you approach first from one direction and then the other, taking a series of readings and averaging to ascertain the values you seek. See the section on alignment afloat for an example of this technique.

Note that these three main types of error don't register separately; they are all nearly always present in some degree. The observations and readings you get include the effects of all three. The effects may either be additive, increasing the net error, or subtractive, partially canceling out and reducing the net error.

INTERNAL ALIGNMENT OPERATIONS

The internal alignment operations that are normally considered within the scope and responsibility of a weapons department aboard ship include the following:

1. Gunsight alignment (which includes boresighting).
2. Tramming (defined later in this section).
3. Bench mark checking.
4. Director sight alignment.
5. Synchro zeroing.

The first two of these (gunsight alignment and tramming) are performed on gun mounts and turrets; numbers 3 and 4 are performed on fire control directors; and the last is done with nearly all synchros. No internal alignment (within the meaning defined earlier in this chapter) is performed on fire control computers or stable elements.

The five types of alignment operations listed above are not the only internal alignment operations that may be required; they are simply the types of alignment operations that can normally be performed afloat by the ship's force. There are other internal alignment operations that may be required in drydock or during ship construction or major alteration. These include aligning the gun trunnions; shimming the director, mount, or turret roller paths to eliminate warping; installing bench marks and tram blocks; and the like. All of these require either the lifting of major armament units like turrets or mounts, or extensive resurveying of the fire control installation's geometry, using special procedures and equipment such as theodolites and transits which are not normally carried aboard combat ships. Operations such as these are not described in this book; they are described in OP 762, Alignment of Ordnance Installations Aboard Ship.

GUNSIGHT ALIGNMENT

Gunsight alignment is that part of battery alignment which involves the mechanical alignment of the parts making up each element — namely, alignment within each mount, turret, or gun of the battery. Gunsight alignment is usually the initial step in battery alignment, and consists of three procedures:

1. **BORESIGHTING.** The pointer's and trainer's telescopes do not lie on the axis of the gun's bore. For firing at short ranges in local control, they must, therefore, be aligned so that their sighting axes intersect the extension of the bore axis at the target. Since the gun bore is only a few feet from the sights, the error which may be caused by parallel alignment is very small. Thus, gunsights may be aligned either to mean battle range for the battery involved or along parallel lines (converging at infinity).

2. **CHECKING FOR LOST MOTION.** The values of sight angle and sight deflection as set on the sights must not contain inaccuracies due to lost motion in the sight mechanism.

3. **CHECKING FOR PARALLELISM OF SIGHTS.** Sight angle or range settings must elevate or depress the sighting axes of the telescopes in a plane perpendicular to the trunnion axes, and deflection settings must move the sighting axes of the telescopes in a plane parallel to the trunnion. In other words, the sights must be aligned for parallelism. This is not normally performed during alignment operations while afloat.

Boresighting

The object of boresighting is to make the sight axes and the bore axis converge at either (1) a specified range or (2) infinity, with the range scale and the deflection scale reading their zero value in either case.

In order to adjust the sights in this manner, a boresight telescope must be used. This is a telescope that may be mounted in the bore of a gun and adjusted so that its line of sight coincides with the axis of the bore. Then by sighting through this telescope and through the sight telescopes simultaneously, the latter may be adjusted to obtain convergence or parallelism.

There are two main types of boresights: the breech-bar type and the type with self-contained optics.

A breech-bar boresight consists of (1) a boresight telescope, (2) an adapter for installing the telescope in the gun, and (3) a muzzle disc used for aligning the telescope on the axis of the bore. With bag-type guns, the adapter takes the form of a breech bar that can be installed across the screw box. A breech-bar boresight can also be used for boresighting a 5''38 gun, but with a different type of adapter. The same boresight telescope can be used in boresighting guns 5 to 8 inches in caliber (except the dual-purpose 6''/47 and the rapid-fire 8''/55), if provided with the proper adapters and muzzle discs.

Boresights with self-contained optics vary in construction, and even in principle of operation, from those that consist merely of a fitting with a small hole for the breech end and another with a pair of crosshairs at the muzzle end to those that convert the gun into a huge (but low-power) telescope. Boresights with self-contained optics are designed to fit specific guns; no parts of them are interchangeable between guns.

The boresighting process with either major type of boresight is substantially similar, except that breech-bar boresight telescopes must first be aligned on the gun bore axis by sighting on the muzzle disc. This step is not necessary when using boresights with self-contained optics. This section describes boresighting with a breech-bar boresight, because it requires this extra operation. Otherwise, once the self-contained optics boresight is installed, the procedure is exactly like that for breech-bar boresights (described later).

Boresight Apparatus: Breech-Bar Type

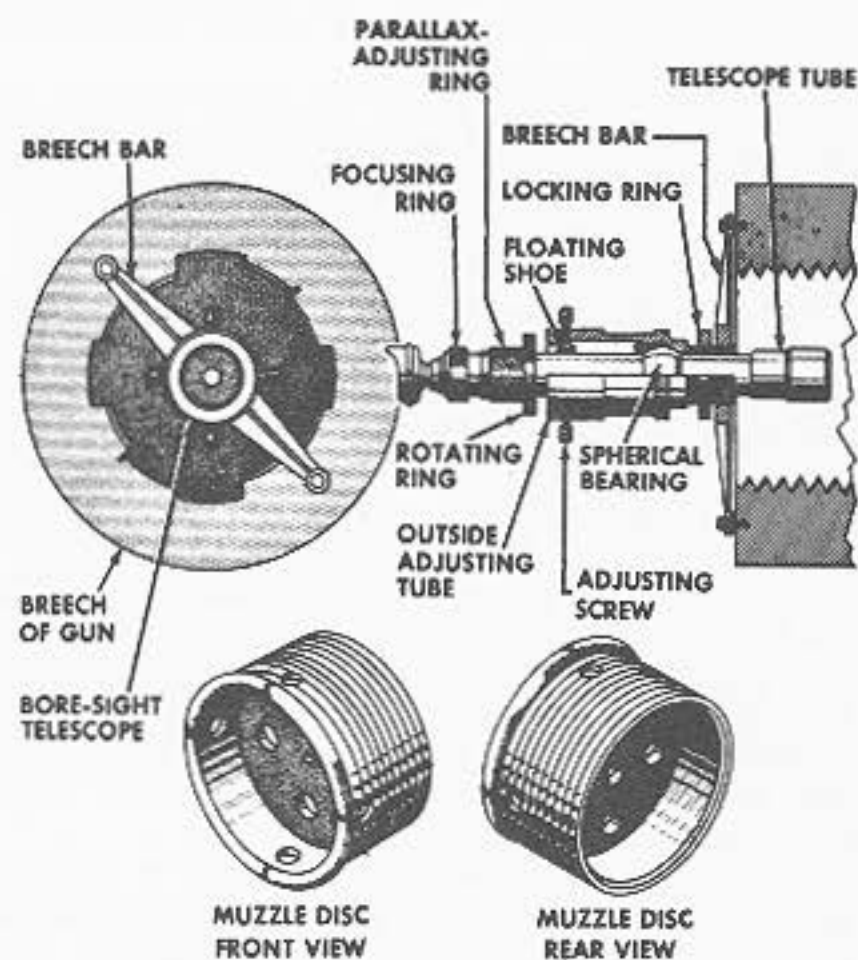
The equipment required at the gun to boresight a bag gun includes—as noted in the preceding paragraphs—a breech bar, a boresight telescope, and a muzzle disc. The equipment and method of mounting on a gun are shown in figure 8-1.

The breech bar is a precision-machined bar which can be attached to the face of the breech by two screws. There is a hole through the midsection to receive the outer tube of the boresight telescope.

The boresight telescope tube is mounted within an outside adjusting tube which screws into the breech bar and is locked by means of the locking ring. Within the adjusting tube, the telescope is mounted in a spherical bearing which permits the telescope to be adjusted in

both the horizontal and the vertical plane by means of four adjusting screws, so that the axis of the telescope can be made to coincide with the axis of the bore. The telescope has three rings near the eyepiece: (1) the reticle focusing ring for focusing the eyepiece to the individual eye, (2) the objective focusing ring for focusing the telescope on the target and eliminating parallax error (apparent target displacement when the eye is shifted about the optical axis of the eyepiece), and (3) the rotating ring, which permits rotation of the telescope about its axis within the outer adjusting tube.

The muzzle disc is a circular casting designed to fit snugly in the muzzle of the gun. Through the center of the disc is a small hole, and around it are four larger holes, arranged as shown in figure 8-1. Etched rings around the edge of the disc provide means for fitting the disc in the muzzle perpendicular to the axis of the bore. Notches are engraved on both disc and gun as index marks. With these index marks matched, one row of holes is aligned vertically and the other horizontally with respect to the gun. The purpose of the disc is



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Figure 8-1.—Boresight apparatus.

merely to assist in the alignment of the bore-sight telescope axis with the bore axis.

Once aligned, the muzzle disc is removed and has no further part in the boresighting of the gun until the final stage, when it is remounted for a recheck of alignment to assure that no error has crept in during the process. Boresights with self-contained optics do not require the use of a muzzle disc in obtaining alignment with the bore axis.

Boresighting Preparation

The general steps necessary in getting the gun ready for boresighting are as follows:

1. Ascertain that the pointer's and trainer's scopes are clear, focused, and free from parallax.
2. Remove all evident lost motion from the sight mechanism (refer to the section on "Looseness of Parts and Lost Motion" that follows).
3. Lash back the breech plug so that motion of the ship will not swing the plug against the boresight apparatus. (For case guns, make sure that the breech block is securely held down.)
4. Install breech bar, boresight telescope, and muzzle disc. (For boresights with self-contained optics, only the boresight components are installed. No muzzle disc or breech bar is required; therefore steps 5 and 6 below are unnecessary.)
5. Focus the boresight telescope and center the crosshairs on the small center hole in the muzzle disc, using the four outer holes to align the crosshairs vertically and horizontally.
6. Remove the muzzle disc.
7. Set the range scale at zero (sight angle scale set at its zero value—usually 2,000 min) and deflection scale at the midpoint (usually 500 mils).

Choosing A Target

A target with a clearly defined and visible point is suitable for boresighting in both deflection (train) and elevation. In the absence of such a target, two targets may be used: one with a clear vertical line of boresighting in deflection, and one with a clear horizontal line for boresighting in elevation.

If the guns are being readied for a specific gunnery practice, the target selected should be at the range specified for that practice. For general use a target should be chosen at about the range at which the guns being boresighted are

most effective, called the mean battle range. Or, if a parallel alignment is desired, a distant target like the moon or a star may be chosen. When the moon is used it is called "shooting the moon." For elevation only, the horizon often makes an excellent target, especially for such guns as the 5-inch and 6-inch, for which it roughly corresponds to mean battle range.

Looseness of Parts and Lost Motion

Before beginning the actual boresighting, check for looseness of parts and for lost motion in the gunsight mechanism.

To check for looseness of parts, first sight on some convenient target. Then manually shake all adjustable parts, and recheck the crosshairs on the target. If the sights are off, tighten the linkage and try again. This check should be performed independently for the trainer's and pointer's telescopes.

To check the sight mechanism for lost motion, set the sights so that the crosshairs are on a target whose position with respect to the gun remains fixed. Use a point on the ship itself or, if the ship is in drydock, a target outside the ship. While this check is going on, keep the gun stationary.

Set the sights at maximum range on the range scale and then return them to their original setting. If there is no lost motion, the horizontal crosshair will return to its exact position on the target. Make a similar check for the vertical crosshair by setting maximum sight deflection, returning to original deflection setting, and observing change due to lost motion, if any.

If there is lost motion in the sight mechanism, it can be removed by taking up excessive play or clearance between moving parts.

Boresighting The Gun

To boresight in train, bring the gun to bear on the target so that the vertical crosshair of the boresight telescope is aligned with a vertical mark on the target. As the ship pitches and rolls, at the instant when the boresight is on, the man at the boresight calls "mark." If the pointer's and trainer's vertical crosshairs are not on target at this instant, adjust the sight deflection input coupling to the telescopes until all vertical crosshairs are on at "mark." Similarly, to boresight in elevation, align the horizontal crosshair of the boresight telescope with a horizontal mark of the target. Adjust the sight angle input coupling to the telescope until all telescopes are on with the boresight telescope.

The sight checker's telescope should also be adjusted in both deflection and elevation.

After boresighting, recheck for looseness of parts. Before securing, place the muzzle disc in the gun (applicable to breech-bar boresights only) to make sure that the boresight line of sight is still coincident with the axis of the bore. If it is not, boresighting must be repeated.

Checking Parallelism of Sights

As mentioned earlier, this is not normally performed as a separate operation except while the ship is at a shipyard, and it will therefore not be detailed here. In one method of performing this check, a flat wooden screen with suitable target markings (called a batten) is secured to the gun barrel near the muzzle, and the parallelism of the sights is checked by observing how accurately the sight reticles follow the target markings as the gun is elevated and depressed.

The boresighting procedure for an infinitely distant target, as described above, adjusts the sights for parallelism with each other as well as with the bore axis.

Other Boresighting Methods

Except for the alignment steps requiring use of the muzzle disc, the boresighting method using self-contained optics boresighting resembles the method described above. Boresighting at battle range rather than infinity is common for smaller gun mounts; this requires either selection of a target at suitable range or the use of marked batten boards mounted on the deck. The batten board method is used relatively rarely and will not be described here.

Tramming

When you measure gun elevation and train, you specify the angle between the axis of the gun bore and a plane parallel to the selected horizontal reference plane (for elevation angle), or between the axis of the bore and a plane through the centerline of the ship and perpendicular to the selected horizontal plane (for train angle).

When a gun mount or turret is installed, its train angle and elevation angle are very carefully measured at selected gun mount positions. The selected positions for train and elevation are accurately designed by metal markers or tram blocks welded to the structure of the gun mount. These selected angles of elevation and

train are recorded in the battery or mount log, and remain on record so long as that ordnance installation remains on the ship. Tramming is the procedure for verifying that when the mount or turret is positioned at the selected angles, the train and elevation indicators display the values prescribed. There is but one elevation angle and one train angle at which any individual mount or turret can be trammed.

Tram blocks are steel blocks welded to the mount structure in pairs, one pair for elevation, one for train. Figure 8-2 illustrates 5"/38 tram block arrangement for a single mount. One of the pair of blocks for elevation is secured to the mount carriage (which does not move in elevation); the other of the pair is secured to the slide (which does). Similarly, one of the pair for train is welded to the mount base ring, which moves in train; the other is welded to the stand, which is secured to the deck. Tramming in train is one operation and tramming in elevation another. These operations are performed successively. Only one tram is used at a time, not two at once.

A typical tram block for a 5"/38 mount is shown in cross section in figure 8-3. Imbedded in the block is a short steel rod whose outer end is cupped to take the tram. The tram block face is covered with a metal cap and packed with grease to prevent corrosion. The block is uncovered only for tramming, and is repacked when the cover is replaced.

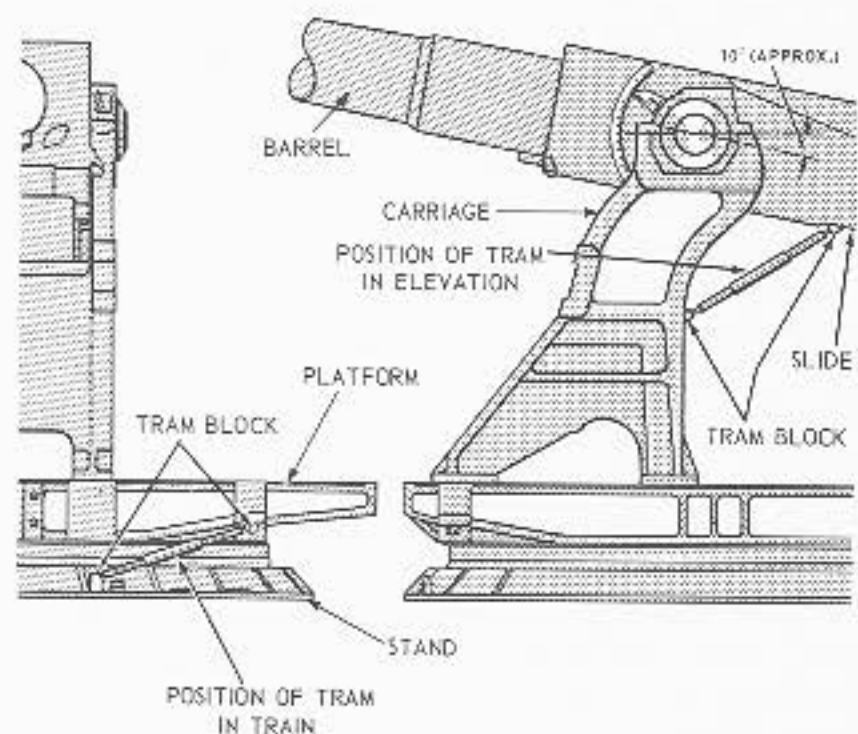
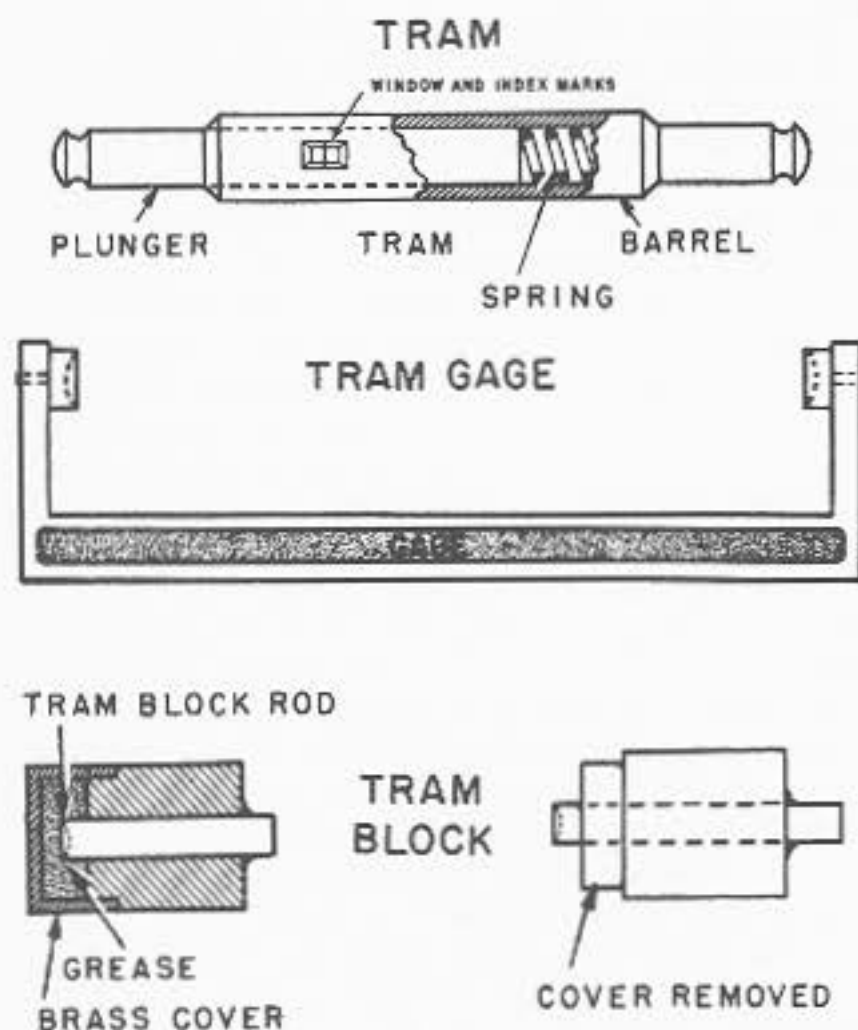


Figure 8-2.—Tramming a 5"/38 single mount in elevation and train.

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Figure 8-3.—Tram, tram gage, and tram block.

The tram itself has two rounded ends. One is part of the body or barrel, and the other is part of the spring-loaded plunger that can move within the barrel. Across a small window in the barrel is an index line. A line on the sleeve is matched up with the barrel index line by moving the sleeve in the barrel.

Here are the main steps for tramming in train:

1. Set the mount parallax indicator (if any) at zero. Train the gun until the train-angle indicator shows that the mount is at the approximate train angle for tramming. The value of the angle is entered in the battery log.
2. Uncover the tram blocks for tramming in train, and seat the ends of the tram firmly in the rods of the blocks. Train the mount if necessary to do this.
3. With the tram ends seated, train the mount carefully in MANUAL to compress the tram until the marks on barrel and plunger line up exactly.

4. Take a reading on the train-angle indicator dial. It should agree exactly with the value given in step 1 above. If not, the indicator should be adjusted until it does.

The tramming operation in elevation is similar to that for train, except that the mount must first be trained to a point at which roller path compensation is zero. (This is 90° from the roller path high point.) This train angle is recorded in the fire control log, or can be read on the roller path compensator dial. Use the elevation tram blocks and elevation angle dial. The same tram is used in elevation and train.

BENCH MARK CHECKING

Director sight alignment is in principle analogous to gun mount boresighting and sight alignment, and bench mark checking of a director is equivalent to gun mount tramming. It is important that the director be bench-mark checked before any guns are aligned with it. A bench mark is an engraved metal plate secured to a fixed point on the ship's structure (e.g., the deck or a fixed bulkhead on the superstructure). When the director is cranked to a prescribed position in elevation and train, the director pointer, looking through his telescope, should see the reticle's crosshairs coincide with the bench mark's engraved target diagram. This is the principle of the use of the bench mark. In practice, the basic procedure is approximately as follows:

1. If the director uses parallax corrections, set these at zero.
2. If the director uses inputs of level and crosslevel, set these at zero.
3. Obtain the bench mark reading from the ship's records.
4. Move the director until the crosshairs of the pointer's telescope are on the bench mark.
5. The train and elevation dials should now read the previously recorded bench mark values. If they do not, the dials must be adjusted until they do agree with the bench mark values, with the crosshairs still on the bench mark.

Because of flexing of the ship's structure while afloat, small periodic errors may develop which cause corresponding discrepancies in bench mark observations. So long as they do not increase systematically in one direction, and so long as they remain small (on the order of 2 to 3 minutes), the weapons officer may choose to ignore them. Whenever a ship is bumped

while mooring or weathers a bad storm at sea, it is a good idea to check bench mark values at the first opportunity.

DIRECTOR OPTICS AND RADAR ANTENNA ALIGNMENT

Present types of gun fire control directors range from small lead-computing types with but one lead-computing sight and no radar to directors with two telescopes, slewing or battery officer's sight, stereoscopic rangefinder, and radar antenna. The details of sight alignment procedures vary from one mark and mod to another, but the principles for all of them are similar, and resemble those brought out in connection with gun mount boresighting. As they apply to fire control directors, these principles can be summarized as follows:

1. One line of sight (in the Mk 37 director, for example, that of the pointer's telescope) is used as a reference for train, elevation, or both. All other lines (in Mk 37 the train telescope line of sight, the rangefinder line of sight, the slewing sight line of sight, and the radar antenna axis) are adjusted to it. The reference line has originally been adjusted on the director bench mark. (See the previous article.)

2. All ballistic corrections are reduced to zero, parallax correction is set at zero, and level and crosslevel are locked at zero.

3. A suitable target is selected at a minimum range of several thousand yards (the exact value is prescribed in the applicable type commander's instructions), and the director is trained and elevated until the reference line of sight is aligned with the target. The other lines are then adjusted so that all are on the same target. An astronomical body is suitable for this operation so far as optical lines of sight are concerned, but not for radar.

4. The radar antenna axis is aligned with the other lines on a distant visible nonastronomical target (helicopter or radar reflector mounted on a motor whale boat) that gives a clear response on the radar tube and provides optically and on radar a good point for alignment. The procedure is first to put the director precisely on target optically, and then to adjust antenna alignment to give optimum "on target" indication in the radarscopes.

5. Dials and synchro transmitters may be aligned at a suitable point in the procedure. All dials should agree with the dial on the reference

line of sight instrument (e.g., in Mk 37 directors this would be the pointer's dial). All synchros should be zeroed to the corresponding dials, in a separate operation.

SYNCHRO ZEROING

Most fire control directors transmit their outputs to other units in the system by means of a-c synchro transmission. The synchro-zeroing phase of internal alignment is designed to ensure that when a given dial or pair of dials read zero, the corresponding synchro transmitters are producing the zero-position voltage pattern. The procedure for verifying the transmitter zero position is to let its output drive a synchro receiver to approximate zero position, then use a sensitive a-c voltmeter to make the fine adjustment. Where synchro transmitters are paired in double speed, each synchro must be zero-checked separately. Because bias voltages from sources outside the synchros are used in some double-speed systems, the zero-checking should be done directly from the synchro terminals, not from terminal boards or other points in the circuit.

Other types of synchros are zeroed by using modifications of this fundamental procedure. For details of all synchro zeroing and other adjustment operations, see MIL HDBK 225 (AS), which supersedes OP 1303.

ALIGNMENT IN DRYDOCK

So far as battery alignment is concerned, the Weapons officer is concerned principally with alignment afloat, rather than with alignment in drydock, which ordinarily occurs only at intervals of two years or more. For this reason, the description of drydock battery alignment operations is presented briefly and without full details. For details, see OP 762 and weapons detailed instructions issued by the Naval Ordnance Systems Command and Type Commanders.

ORIGINAL ALIGNMENT IN DRYDOCK

The original alignment of ordnance installations is made in drydock. Battery realignment in drydock usually takes place during regular overhaul periods thereafter.

Its two principal phases are alignment in train and alignment in elevation. In the following discussion it is assumed that all elements of the system already have been properly installed and are functioning properly, and that these elements are mechanically aligned within themselves.

Alignment in Train

The purpose of battery alignment in train is to adjust the battery so that when the dials are matched and no ballistics or horizontal parallax is introduced, the lines of sight of directors and guns, and the axes of the bores of the guns, are all parallel in train at any angle of train.

The first step in actual alignment in train is to establish a centerline from which to measure horizontal angles. In most cases, because of the interference of the ship's structure, this line will take the form of an "off-set centerline" ashore, parallel to the real centerline of the ship. The centerline is established by use of surveyor's transits.

Next step is to establish the center of rotation of each trainable element (such as gun mounts and directors), so that a transit may be set up to measure the true angle of train of the element. After it has been plotted, the center of rotation must be checked when the element is trained. When verified, the center of rotation is permanently engraved so that it can be used in the future checks. On enclosed mounts, the mark is on top of the shield.

It is now necessary to establish zero train—that is, to set the train dials of each element so that when the dials read zero train, the line of sight or bore axis of each element is parallel to the centerline of the ship, and pointing forward. On the after elements the dials are set at 180° , with elements pointing aft and parallel to the centerline.

With zero train established and the dials set, permanent reference marks must be established. A bench mark and angular reading for each director and a tram reading for each mount or turret are established. At any future time when it is necessary to verify dial accuracy, each element can be trained onto its reference and the dial readings checked, as described earlier in this chapter.

Alignment in Elevation

After battery alignment in train comes alignment in elevation. The purpose of alignment in elevation is to adjust the battery so that at any angle of train, and at any angle of elevation, the lines of sight of directors, the lines of sight of gunsights, and the axes of the bores of guns, will all be elevated by exactly the same angle above a common reference plane. (Again, we assume no vertical parallax or ballistic correction, and that dials match.)

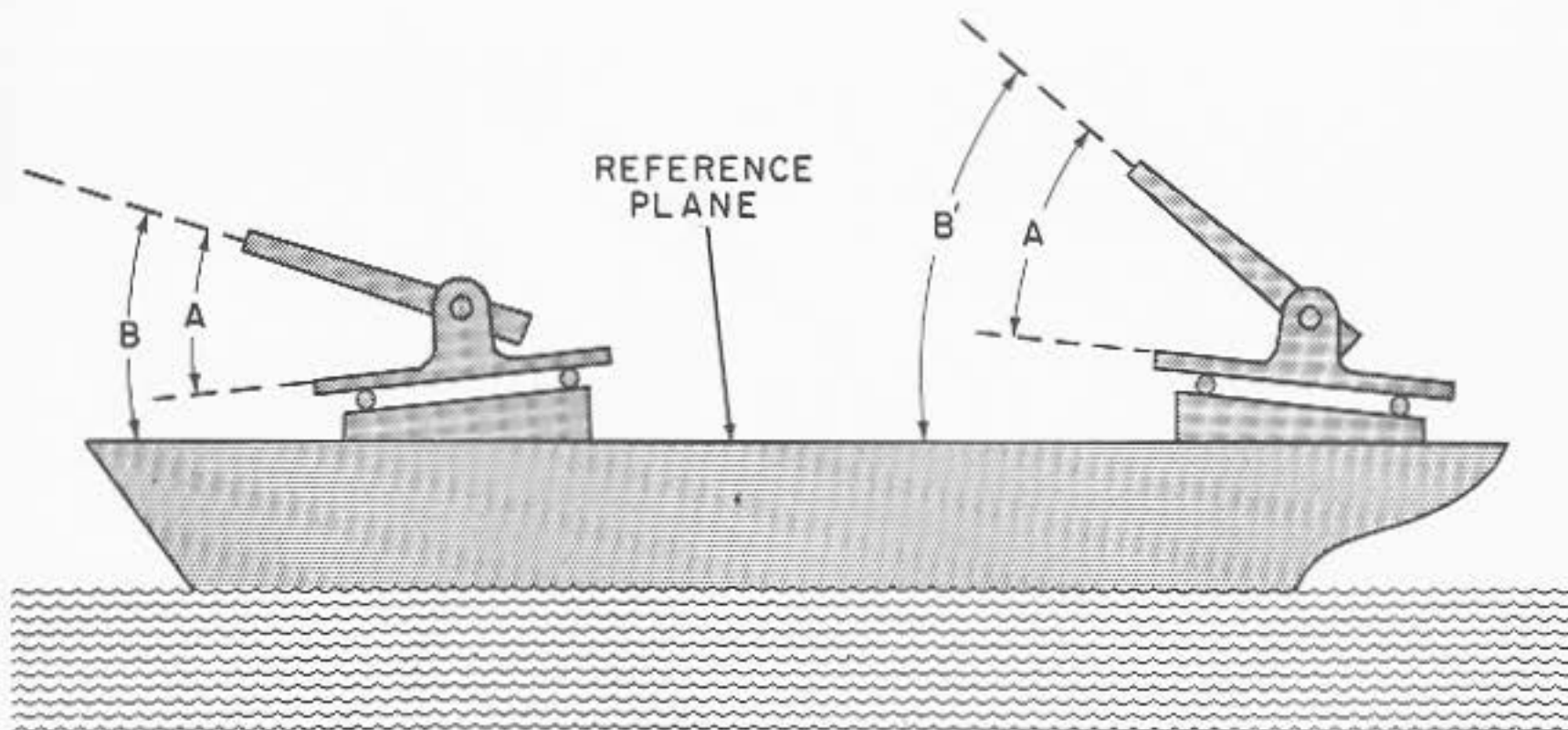
The reference plane chosen is an actual plane on the ship; that is, it is the plane of the roller path (main horizontal bearing) of one of the elements of the battery. Ideally, the plane chosen must have the smallest possible inclination between it and the roller paths of the other elements of battery. The choice of this plane will vary, depending upon the type of ship. Because AA or dual-purpose battery directors can control more than one battery, one standard reference plane for all batteries is necessary.

Elevation alignment is principally concerned with one primary factor—the tilt or inclination of roller paths. The effect of the roller path tilt or inclination on elevation, if not corrected, is shown, greatly exaggerated, in figure 8-4. Each of the two gun mounts in the figure is elevated to the same angle (A) with respect to its roller path, but the angle of each (B and B') with respect to any common reference is not the same.

The principal operation in elevation alignment in drydock is the procurement and interpretation of roller path data. Roller path data are actually a series of readings showing the inclination of a trainable element (usually a gun mount or director) at points all around the roller path, relative to some fixed plane. In drydock this is usually a horizontal plane established by a level. The relationship between any roller path and the horizontal is defined by the amount of tilt at the highest point of the path, and the relative bearing of this point. Figure 8-5 shows this diagrammatically.

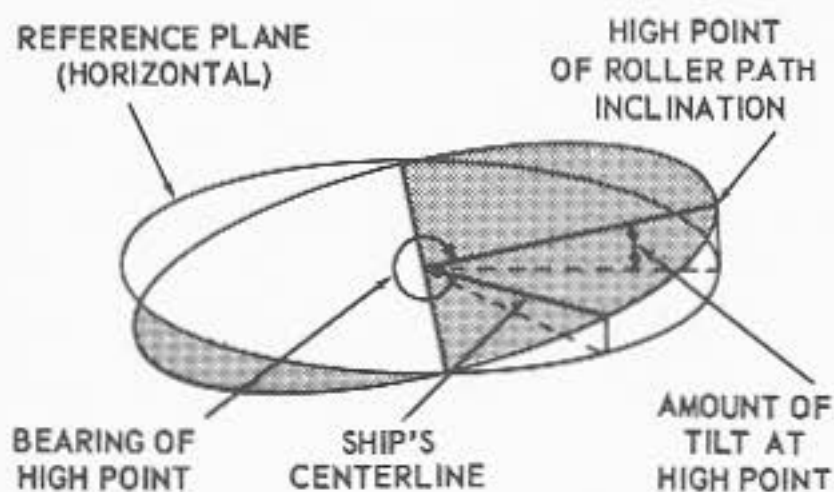
These data are determined by measuring roller path inclination at regular angular intervals through the full arc of train possible with the mount or director, tabulating them, and plotting them on coordinate paper. The general procedure for plotting and interpretation of the data resembles the afloat system alignment procedure described later in this chapter.

The instrument most commonly used for elevation alignment procedures in drydock is the gunner's quadrant. This instrument, which is illustrated in figure 8-6, is a high-precision device designed to measure the angle of inclination of a flat surface with respect to the true horizontal. (The true horizontal is defined as a plane tangent to the earth's surface at the point of measurement.) Two types are in common use; figure 8-6 shows the Mk 3 Mod 1, which is characterized by a vernier scale to give maximum accuracy. The instrument consists of a base, the bottom of which is ground to an accurate plane surface, an arc mounted perpendicularly on the base, an arm containing a spirit



92.46

Figure 8-4.—Effect of roller-path inclination on elevation.



92.47

Figure 8-5.—Relationship between roller path and horizontal.

level, and a clamp arm. The level and clamp arms are pivoted. The clamp screw can secure the level arm at any desired position on the arc. The clamp arm is connected to the level arm by a tangent screw for making fine adjustments. The level in the level arm is a slightly curved graduated glass tube filled with colored alcohol and containing an air bubble. The level arm also carries the vernier scale, which slides along the arc, and a magnifier glass.

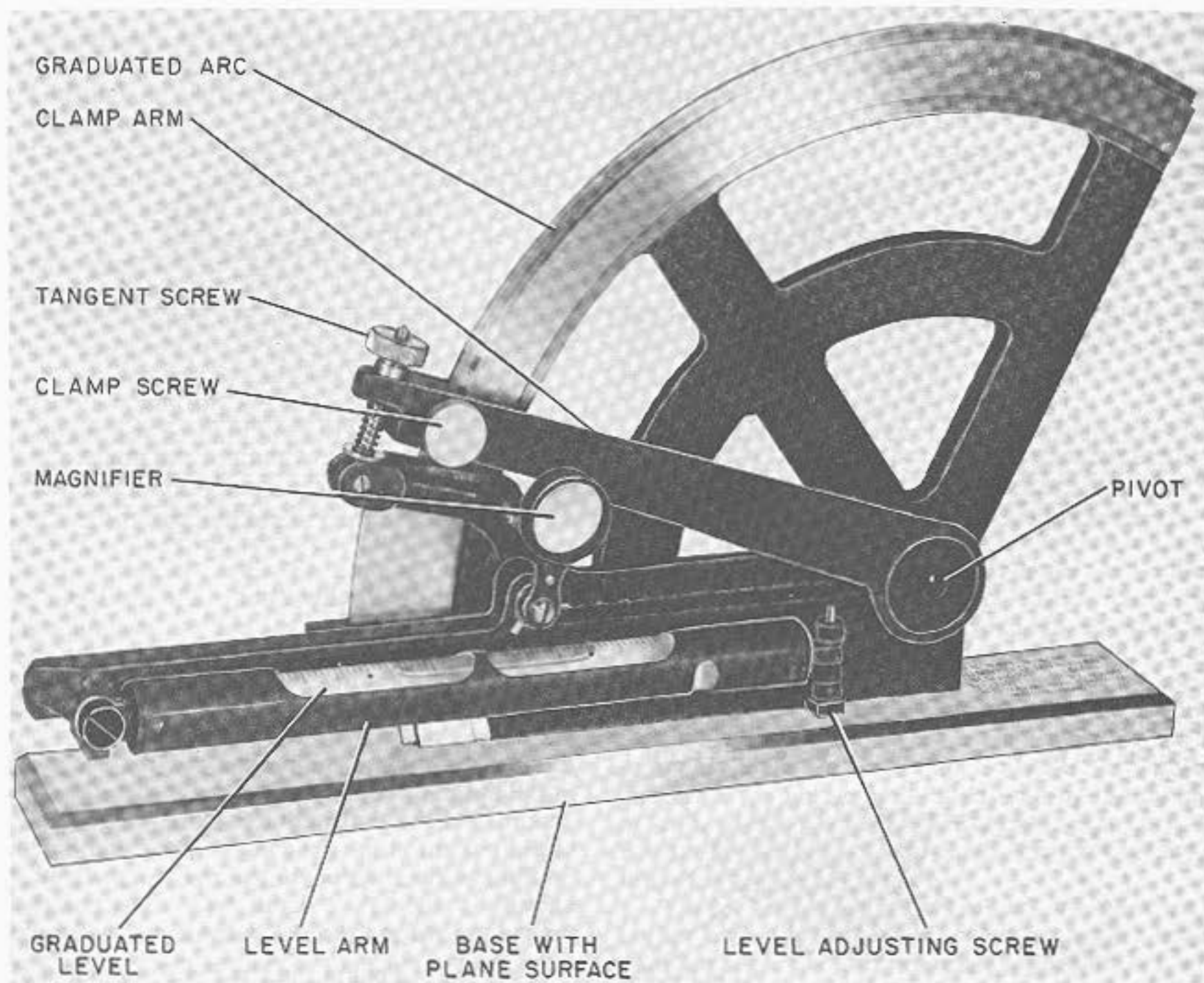
In use, the instrument is placed with its flat base on the surface whose inclination is to be

measured (the slide of a gun, for example), with the quadrant pivot toward the center of rotation, and the level and clamp arms are adjusted until the level bubble is centered in its graduations. Small adjustments can be made with the tangent screw, and the inclination is read with great precision from the graduated arc and vernier.

The other type of gunner's quadrant (not shown) is the Mk 7 drum type. It operates in a manner similar to the Mk 3, but is not as accurate.

In gun mounts and turrets, compensators correct for roller path tilt by adding a compensating tilt algebraically, depending on mount train angle. The amount of the correction is at each point in train equal to the amount of tilt, but opposite in direction. Figure 8-7 shows the dial of a type of roller path compensator used in many 3" mounts. The "B" scale is driven by the training gear and shows the angle (0° is displayed in the figure) between the present position of the mount and the high point of the roller path. The "A" scale index pin, which is set by maintenance personnel, shows the amount of tilt tabulated or plotted for the high point of the roller path. This automatically introduces the proper elevation correction at every train angle. Index "C" shows mount train position (180° is displayed in the figure).

In ships with more than one director, most of the directors are normally equipped with



53.121

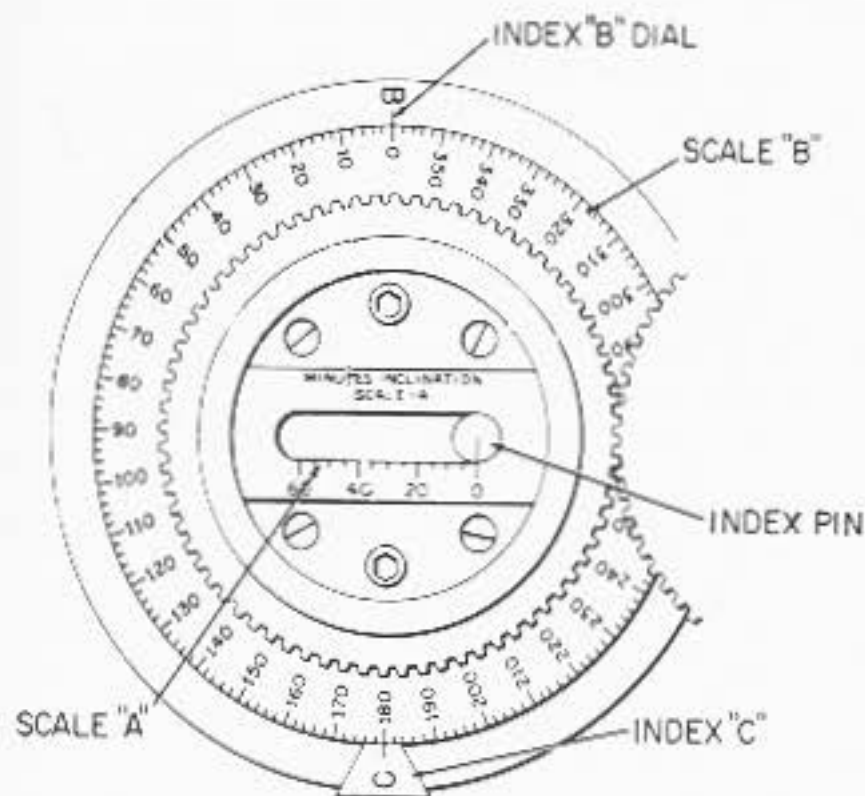
Figure 8-6.—Gunner's quadrant Mk 3 Mod 1 (vernier scale type).

roller-path compensators which in principle function as described above.

After the reference plane of the battery has been established, the next step is to align the stable vertical or stable element so that the plane of its roller path is exactly parallel to the reference plane. This is necessary because the stable element measures continuously the tilt of its roller path (which represents the reference plane) with respect to its gyro-stabilized parts. Since this correction is applied to gun elevation, the stable element's roller path must be parallel to the reference plane, so that its tilt at any instant will be the same as those of the director and the gun mounts.

No roller path tilt corrector is provided for the stable element. Stable element correction is introduced by shimming the roller path until it is parallel with the selected reference plane.

This is a precision operation which requires (1) measurement of tilt with a gunner's quadrant, (2) tabulation and plotting of the tilt data, (3) calculation of the required thickness of the shims to be inserted under the roller path, (4) fabrication, machining, and installation of the shims, and (5) recheck through the full angle of train with the gunner's quadrant. Figure 8-8 shows a stable element with gunner's quadrant installed for checking alignment.



110.83.1

Figure 8-7.—Roller path compensator.

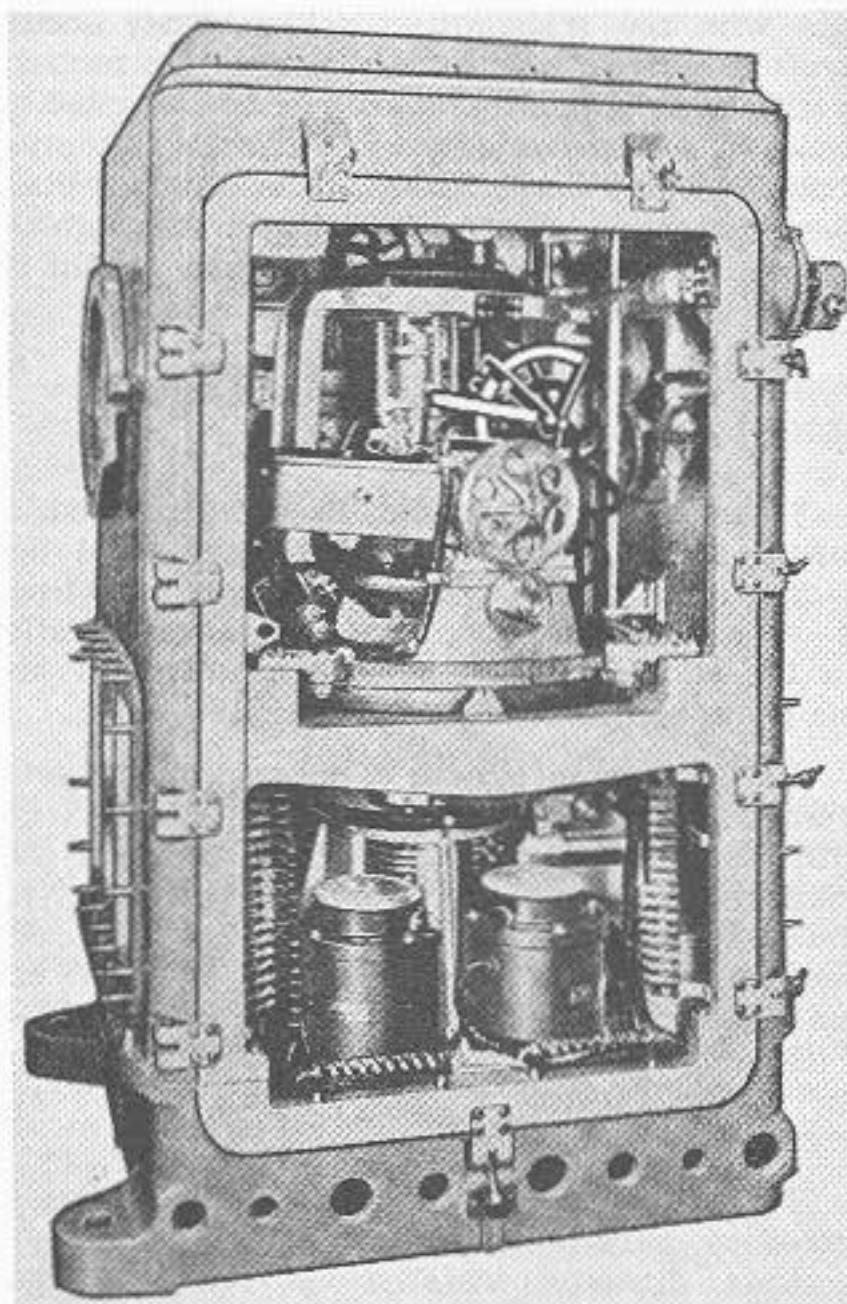
BATTERY ALIGNMENT AFLOAT

Since a ship is not a rigid structure, upon loading and putting to sea the space relationships between elements of a battery change, and correction for these changes must be made. The process involved is known as battery alignment afloat, and must be carried out while the ship is waterborne, by different procedures than those used for the original alignment in drydock.

Before initiating the actual alignment procedures, ensure that all elements are functioning correctly and that all transmission systems are properly adjusted. Have a routine transmission check carried out just prior to the alignment check. (For more detailed procedures refer to OP 2456, Volumes 1 through 8.)

TRANSMISSION CHECK

Before proceeding with the alignment it is desirable to check the synchro transmission system to assure (1) that the transmitters are sending out a correct electrical signal for a given mechanical input, and (2) that the receivers are accurately converting this electrical signal into a mechanical or electrical signal equal to that of the transmitters. It is first necessary to set the synchros to electrical zero. Any of several methods may be used, and each synchro dial



53.128

Figure 8-8.—Gunner's quadrant installed to check alignment of stable element.

should read zero when that synchro is on electrical zero. The next step is to check transmission, which is accomplished as follows:

1. Man the telephones at the stations to be tested.
2. Set the fire control switchboard to transmit from:
 - a. The directors to plot.
 - b. Plot to the gun mounts.
 - c. The directors to the guns directly (bypassing the rangekeeper or computer, where possible).
 - d. The stable element to the directors (to transmit level and crosslevel).

3. Turn each transmitter to various readings (usually in 10° increments) throughout its operating range and compare the received readings with the transmitted values. They should check exactly. Any errors of position, direction, or firmness of position should be investigated by standard synchro methods. Particular attention should be paid to the action of the receiver dials when coming to rest. They should stop quickly and evenly in agreement, and there should be neither sluggishness nor long oscillation.

PURPOSE OF TRAIN AND ELEVATION ALIGNMENT

Train alignment afloat is accomplished to ensure that, with zero settings of sight deflection and parallax, the director and gun lines of sight and the gun bore axes are parallel (in the horizontal plane) when the director and gun are matched at any point in train.

Since it is impractical to use multiple targets, train alignment is checked on a single target with parallax correction. When the gun dial pointers are matched, proper parallax set in, and zero settings of sight angle and sight deflection set in at the guns, the director and gun lines of sight and the gun bore axes will — if the system is properly aligned — converge on any given target, at any range, and on any bearing.

To accomplish this check, it is necessary to introduce parallax both into director train (in multiple director installations) and into gun train. It is therefore necessary to check the parallax system before beginning the actual alignment. Proper correction of parallax errors is important where there are a number of directors and large horizontal distances between units. Hence, all parallax correctors on guns and directors should be checked for:

1. Correct amount of parallax at various bearings and ranges.
2. Correct direction of applied parallax correction.

The purpose of afloat alignment in elevation is identical to that of elevation alignment in drydock. This objective is attained by selecting some plane as the reference plane of the battery, so that the elevation of all units, when measured from that plane or a plane parallel to it, is equal. Again, a single target (the horizon in this case) is used for the check.

SYSTEM ALIGNMENT IN TRAIN (TRAIN CHECK AFLOAT)

After a bench-mark check has been run on the director, it is then possible to proceed with actual alignment of the various battery elements. Preferably, this should be done with the ship at anchor in smooth water. If the battery has never been aligned afloat, a complete train check must be made; otherwise, a preliminary test may be made to determine if a complete check is necessary. The preliminary test is conducted as follows:

1. Establish telephone communication between director and guns.
2. Set the switchboard for normal operation—i.e., director to plotting room, which in turn transmits to the guns.
3. At the computer or rangekeeper, have time motor off and power switch on.
4. Set sight angle on 2,000 minutes and sight deflection on 500 mils (their zero values) on their respective computer counters.
5. Set and lock level and crosslevel at zero.
6. At the guns, set sight angle and sight deflection to their zero values; put the guns in local, hand, or manual control.
7. Select a distant target off one beam. Train the director until the vertical wire is just off the target, so that motion of the ship will carry the wire across the target.
8. Obtain the range to the target by the most accurate means available, and set the parallax correctors to give the proper correction for this range.
9. Match pointers at the guns.
10. As the director line of sight swings on target, the director trainer calls (phone) "mark" to the gun trainer. This is continued, the gun trainer meanwhile moving the gun, from one direction, until both gun and director telescopes are on the target at the same instant. The amount of displacement between the follow-the-pointer dials at the gun is the amount of error and should be recorded. This process is repeated, with the gun trainer bringing his vertical wire on target from the opposite direction, and the error recorded. The algebraic difference between the two errors is the lost motion of the gun. The mean of the two errors is the gun error. The example in table 8-1 illustrates how this is done. Assume that the process is repeated three times. The gun trainer notes the following readings on the call "mark" as he trains his gun onto the target alternately from left and

Table 8-1.—Gun error and lost motion error

(1)	(2)	(3)	(4)	(5)
Approaching from the left	Algebraic difference from director	Approaching from the right	Algebraic difference from director	Absolute difference (between columns (1) and (3) regardless of sign)
1. 010°58' - - - - -	-2	011°02'	+2	4
2. 010°59' - - - - -	-1	011°03'	+3	4
3. 010°59' - - - - -	-1	011°03'	+3	4
Total - - - -	-4	- - - - -	+8	12

110.140

right; the director calls "mark" on target at his train dial reading of 011°00' each time.

The total absolute difference (regardless of sign) in the three sets of readings (total of column (5) figures) is 12; dividing this by the number of observations (3) yields the mean lost motion; 4 minutes. Columns (2) and (4) show the difference in each reading between the director's train dial indication and the gun mounts train dial indication at the instant of the call "mark" (when the director train dial read 11°00'). These values bear algebraic signs. The column (2) total is -4; the column (4) total is +8; the algebraic sum is therefore +4. Dividing this by 3 to get the average, we have the value +1.33' (rounded). This is the gun train dial mean instrument error; it indicates that, disregarding lost motion, the gun train dial tends to read on the average 1.33 minutes higher than the director train dial (for the same target) without ballistic or parallax corrections.

The principle described here applies wherever multiple readings are used to determine instrument errors and lost motion.

11. Repeat the process, using a target on the other beam if practicable, and in any case a target at a widely different train angle from the first, and record the gun error and lost motion.

The gun errors should be equal and small. If they are equal and large (2 or 3 minutes larger than the lost motion), it is an indication

that a constant error exists, and that this error may be corrected by adjusting the train response. In so doing, the dial which shows the actual train of the element (not the dial on the synchro receiver) must be moved. If the errors are not equal, a complete train check is necessary.

The complete train check is exactly like the test described above, except that a series of targets is used, at 10° or 15° intervals if possible.

The complete train check will furnish gun errors which, when plotted with their bearings as abscissas, should show a slightly ragged scattering of points. A line parallel to the abscissa which passes through the mean of these points (i.e., with approximately equal deviations above and below the line) can be considered as the zero error line. Its distance above the abscissa will be the constant error of the system, which can be removed by adjusting the response. If a sine curve results, it indicates errors such as improper parallax settings. If the points are erratic with large deviations from the zero line, it indicates damage to the dial drive shaft, such as a sheared coupling or slipping gears.

SYSTEM ALIGNMENT IN ELEVATION (HORIZON CHECK)

To adjust the battery to its reference plane, it is necessary to compile data on the relative positions of all guns with respect to the reference plane as represented by the line of sight of the reference director. This is done by means

of a horizon check, which compares the elevation angles on the dials of director and guns when all are laid successively on a series of points completely around the horizon. If we compare director elevation and gun elevation at a common point (horizon), after accounting for any known angular divergencies between the two units, such as that caused by the vertical distance between guns and director and the angle of the gun sights with respect to the bore axis (sight angle), their elevations should be equal.

Figure 8-9 shows the essential geometry of this operation. For the moment assume that there is no uncorrected inclination of the gun mount roller path, and that the reference plane is horizontal. The line of sight from the director telescope (which is a little more than 100 ft above the ship's waterline) to the horizon is AB; the line of sight from the gunsight telescope (about 17 ft above the waterline) is CB. Both

lines of sight are depressed below the horizontal; the higher you are above the water, the greater the depression angle or dip will be. (Bowditch's American Practical Navigator has a table of dip values and range to the horizon for many values of height above the water surface.) Figure 8-9 shows a dip of -10' for line of sight AB and a dip of -4' for CB. The dip difference is -6'.

To simplify mechanics of tabulation and calculation, the gun is customarily elevated by an arbitrary elevation angle (in this case, 20') in performing the horizon check. Since the gunsight telescope is depressed 4' below the horizontal because it is pointed at the horizon, the value of sight angle is actually 24' (the sum of gun elevation and gunsight dip).

On the gun mount dials, zero gun elevation (gun parallel to reference plane) is arbitrarily

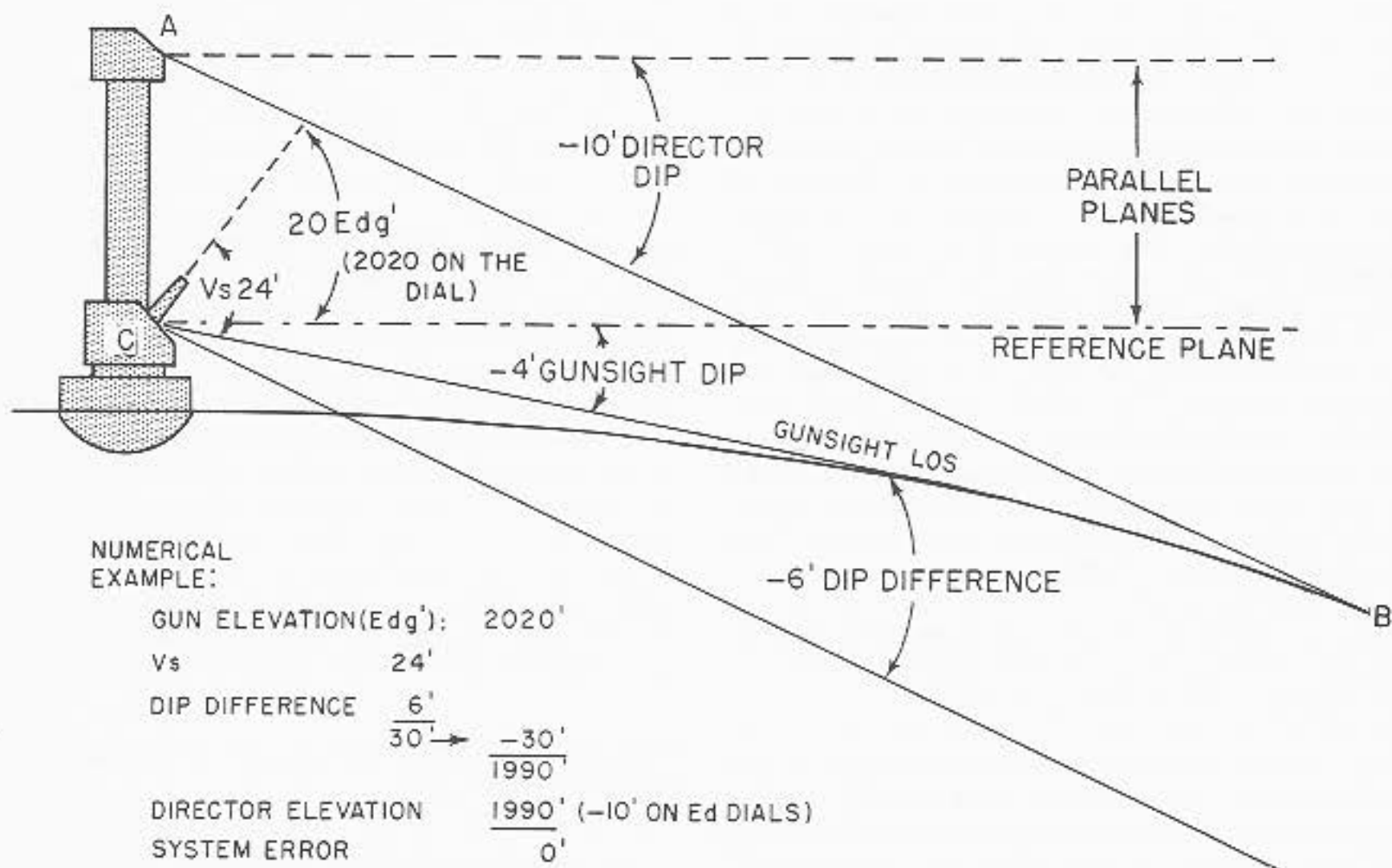


Figure 8-9.—Horizon check for alignment in elevation using mount gun sight. NOTE: Numerical values given to angles are for purposes of illustration. Assume horizontal and reference planes coincide.

called, as you already know, 2,000'. The director line of sight (LOS) is dipped -10' when pointed at the horizon. If roller path tilt is correctly compensated in the gun mount (and in the director if the director has a compensator), then, after applying an algebraic correction equal to the sum of dip difference and arbitrary sight angle, gun elevation should equal director elevation. (The gun elevation value corresponding to -10' director elevation is, of course, 1990'.)

In figure 8-9, if we subtract sight angle (Vs) and dip difference from gun elevation (Edg'), we arrive at line CD of the diagram (see numerical example as well). If CD is parallel to AB, the gun and director are elevated at equal angles above (or below) the reference plane, are aligned in elevation, and there is no system error. Or,

$$\text{Edg}' - (\text{Vs} + \text{dip diff.}) = \text{director elevation (Ed)}.$$

Now, by rearranging these quantities slightly, to:

$$\text{Vs} + \text{dip diff.} = \text{Ed} - \text{Edg}'$$

we can obtain an array of values that provides for checking with minimum time and effort. We simply subtract gun elevation from director elevation (values read at each different angle of train) and the results should equal sight angle plus dip difference (values that are set and remain constant throughout the check).

Steps in performing a horizon check are as follows:

1. Choose a day when the ship has little roll and the horizon is clearly defined.
2. Man stations and phones.
3. Make sure that the synchro transmission system has been checked recently, and that the director has been checked on its bench mark.
4. If possible, use the reference director, which has no roller-path inclination compensator.
5. Record the roller-path inclination compensator setting on the gun concerned. It should

agree with the value determined during the last system alignment check in elevation.

6. Look up the height of gun and director, and compute the dip in the horizon for each. From this information you can compute the dip correction for each gun, by subtracting the dip angle for the gun from that for the director.

7. Set the dials of the computer or range-keeper so that no corrections in elevation are introduced by its mechanism.

8. If the test is to be performed with the boresight telescope, install it. If the gun sights are to be used (the normal procedure), they must have been boresighted recently. Set a positive value of sight angle at the gun and record this setting. The purpose of setting in this sight angle is to ensure that the elevation reading of the gun will be higher than that of the director at all bearings.

9. Train the director to a given bearing; elevate or depress the director line of sight so that it will move across the horizon as the ship rolls. Record for later reference the value of director elevation used on each bearing.

10. Train the gun to the same bearing as the director.

11. The gun pointer depresses his gun until it is approximately on the horizon. When the director sight crosses the horizon, the director pointer calls "mark," and the gun pointer turns his handwheels until his line of sight crosses the horizon simultaneously. When he is on, he checks back to the director exactly on the mark, so that when either one calls "mark" the other will be exactly on the horizon. To eliminate lost motion, always move the director and gun lines of sight onto the horizon from the same direction.

12. When the gun is on, read and record both the mechanical and the follow-the-pointer dials. The follow-the-pointer dials will read the total uncorrected gun error, which should equal the difference between the director elevation and the gun elevation as read from the mechanical dials.

13. Repeat the foregoing process at 10° or 15° intervals throughout the training arc of the gun.

14. Obtain the uncorrected gun error by subtracting the director elevation from the gun reading (never the reverse), and record the result for each bearing.

A sample of data obtained in this way follows:

Bearing	Gun	Director	Difference (uncorrected gun error)
0°	1990	1976	14
15°	1991	1979	12
30°	1993	1982	*11
45°	1993	1981	12
60°	1991	1978	13
75°	1990	1974	16
90°	1988	1968	20
105°	1987	1963	24
120°	1988	1960	28
135°	1990	1958	32
150°	1988	1951	37
165°	1990	1950	40
180°	1992	1950	42
195°	1990	1946	44
210°	1991	1946	**45
225°	1992	1948	44
240°	1991	1948	43
255°	1995	1955	40
270°	1994	1957	37
285°	1995	1963	32
300°	1993	1965	28
315°	1990	1966	24
330°	1987	1968	19
345°	1988	1972	16
360°	1990	1976	14

*High point.

**Low point.

The data tabulated above are plotted by the method shown in figure 8-10. Note that the difference between gun elevation and director elevation varies with different angles of train. If the roller path compensator had been properly set (no uncorrected inclination), these differences would have been constant and the data would plot as a straight line. As it is, however, the differences vary, indicating uncorrected inclination, and the data will therefore plot as a sine curve. The example shown here is for the full 360° arc of train, which is a condition almost never realized in practice. Hence, while both a high point and a low point are shown on our sample curve, only one of these points may be present on the curves obtained in an actual installation.

After plotting and drawing the curve, find the zero axis (i.e., the curve's axis of symmetry, which is parallel to the abscissa or x-axis). Either of two methods may be used:

1. If both the high point and the low point have been plotted, add the high point and low point values, and divide by 2. The resulting value is the ordinate (y-axis value) through which the zero axis passes. Plot this either on the y-axis or on the curve, and draw a line through it parallel to the abscissa. You have now drawn the curve's zero axis.

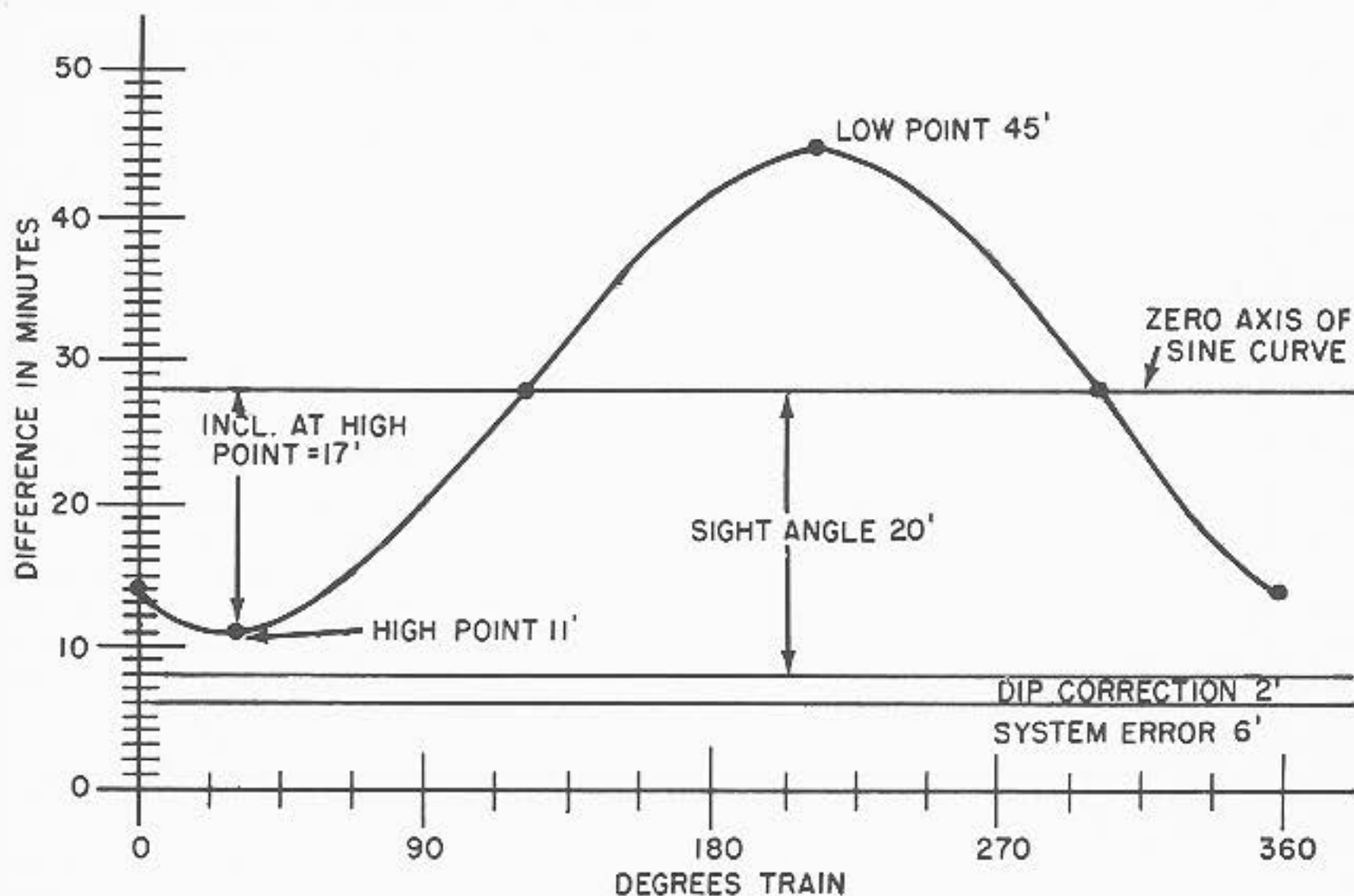
2. The alternate method, which is usable if either the high or low point has been plotted, is to take a point on the sine curve 90° from the high point or the low point, and draw through it a line parallel to the abscissa.

The distance of the zero axis above the abscissa represents the error due to all causes other than roller-path inclination. Figure 8-10 shows how this error is broken up into component parts. Sight angle and dip correction are known values; the remaining error represents the system error. This constant system error can be removed by adjustment of the elevation response at the gun. When this is done, tram values in elevation will have to be corrected.

The low point of the curve represents the bearing and inclination of the high point of the gun roller path, with respect to the reference plane (in this case, the director roller path). If no low point is shown on the plotted curve, it may easily be calculated, since it would occur at a bearing 180° from the high point of the curve. Further, it would occur at the same distance from the zero axis of the curve as did the high point. The bearing of the low point of the curve represents the bearing of the high point of the gun roller path. The distance of the low point below the zero axis of the curve represents the inclination of the gun roller path. In the example shown in figure 8-10, the high point of the gun roller path (represented by the low point of the sine curve) is at 30° train, and the inclination at that point is 17 minutes. Thus, for this example, the following desired data are available:

Bearing of high point. . . . 30 degrees
Inclination of high point . . 17 minutes
Constant error of system . . 6 minutes

Note that the low point of the sine curve is the high point of the gun's roller path. We know



110.85

Figure 8-10.—Sine curve plot of horizon check data.

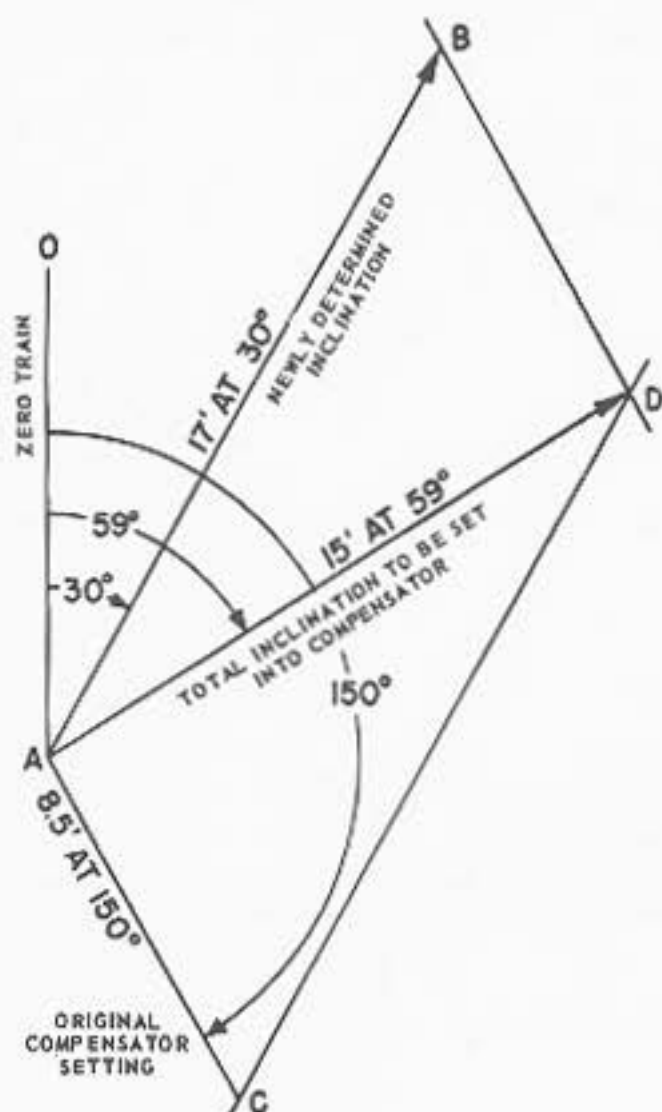
that the uncompensated roller path inclination plots as a sine curve. When the gun is trained to the highest point on its roller path, the actual gun elevation to the horizon will be at its lowest value with respect to the reference plane. This occurs because the gun's roller path has not been completely corrected to the reference plane. In other words, the high point of the gun's roller path has raised the gun above the reference plane, and to elevate to a given target now requires less elevation angle between the gun bore axis and the gun roller path. With gun elevation at its lowest value, the difference between gun and director elevation will be a minimum; a minimum difference is the low point of the sine curve.

CALCULATING CORRECT COMPENSATOR SETTING

The horizon check is usually made with some setting already on the roller-path tilt compensator. The tilt found by the check, therefore, is

not the total inclination but only the uncorrected inclination. It is an additional inclination to that for which the compensator has been set. This newly discovered inclination must be added vectorially to the inclination previously known to exist, in order to determine the total inclination for which the compensator must be set. This may be done graphically, as shown in figure 8-11. In this figure the results obtained previously were used to illustrate the method, which is as follows:

1. The line OA is drawn to represent zero train.
2. The original setting of the compensator (8.5' at 150°) is plotted as line AC. This is done by measuring off the angle clockwise from OA, and measuring the inclination on that line to a convenient scale.
3. The inclination found (17') is plotted as AB on bearing 30 degrees.



110.86

Figure 8-11.—Compensator-setting calculation.

4. CD is drawn parallel to AB, and BD is drawn parallel to AC. These lines intersect at D.

5. A line AD is drawn from the origin to D. This line represents the total inclination. Its bearing (59°) and length (15') may be read according to the previously established scale. These are the data that must be set into the compensator.

It should be noted that compensators are constructed to read the error rather than the correction. Thus, if the error is 15' at 59° , the bearing scale is turned to 59° . Then the inclination of 15' is set on the inclination scale, and the adjustment is completed.

SIMPLE ELEVATION CHECK

When at sea, it is desirable to perform a simple elevation check at frequent intervals. The method is the same as that in the horizon check, except that each gun is checked at only one point on the horizon. The difference between gun and

director reading after correction for sight angle should equal the dip correction. If it does not, an error of some sort is present and must be investigated. Before undertaking a complete horizon check as a result of such disagreement, however, check to see that the transmission system is functioning properly, and that the roller-path tilt compensator is at its proper setting, both for bearing and for inclination.

CHECK OF AUTOMATIC FOLLOWUP SYSTEM

After a battery has been aligned in elevation, a test of the automatic followup system should be made. This involves training on a target, setting up the problem in the computer and positioning the gun in automatic (using computed gun orders), setting the sights according to generated sight angle and sight deflection, and checking to see whether the gun telescopes are on target. If they are not on target, the amount that sight angle and sight deflection must be changed from the computed values to bring the sights on target represents the error of the system. To eliminate trunnion tilt errors when this test is made, it should be done when there is little or no roll.

The preceding discussion of battery alignment has dealt only with gun batteries. Proper alignment is equally important in any other director-controlled battery such as torpedo, missile launcher, etc.; but the methods used will vary with the characteristics of the battery to be aligned.

FIRING CUTOFF MECHANISMS

In terms of the definition of battery alignment at the beginning of this chapter, the battery is aligned when, with the dials matched and parallax on zero, all the lines of sight and the axes of all gun bores are parallel, regardless of the ordered angles of gun train and gun elevation. In practice, however, the battery check is not complete until: (1) the firing cutoff cams in each gun have been plotted, cut, and installed; and (2) the firing cutoff mechanisms have been checked, with the cams installed, to ensure that both the mechanical and the electrical firing circuits are interrupted properly whenever the guns move from a zone of safe fire to a danger zone.

Firing cutoff mechanisms are designed to interrupt the mechanical and electrical firing circuits whenever the guns are trained or

elevated to a position where firing the guns would endanger ship's personnel or damage own ship. They should not be confused with the frameworks of steel tubing or depression-stop cams that are used to limit the movement of some light machine guns to safe zones of fire. Firing cutout mechanisms do not interfere with the free movement of the gun; this is done by the train and elevation limit stops.

The Naval Ordnance Systems Command (NavOrd) has issued strict, mandatory instructions—summarized in the next section—for the guidance of personnel responsible for plotting, cutting, installing, and checking firing cutout cams and mechanisms. In addition, special instructions not detailed here govern particular gun installations.

The importance of firing cutout mechanism layout, adjustment, and maintenance is difficult to overemphasize. Many casualties in which a ship's guns have fired into her own structure have been traced to the neglect of firing cutout mechanisms, or they have resulted from somebody's deliberate bypassing of these mechanisms. Every one of these casualties could have been prevented if the firing cutout mechanism had functioned properly. As was pointed out in the first chapter of this text, safety is a universal objective in all procedures relating to ordnance and gunnery. That is why firing cutout mechanisms must function effectively in all mounts and turrets in which they are installed.

NAVORD REGULATIONS FOR FIRING CUTOUT CAMS

Firing cutout mechanisms are designed to prevent firing into permanent parts of the ship's structure. In plotting the firing cutout cam, all removable parts of the ship's structure such as stanchions, handrails, lifelines, chests, and lockers are disregarded. Such movable equipment as boats, cranes, booms, davits, and hatches are secured in such a manner as to obstruct the line of fire as little as possible. The firing cutout cam is plotted around this secured position of the equipment.

Personnel, such as other gun crews and lookouts, that are stationed within the possible line of fire must be protected by the cutout cam; however such personnel are not normally protected against blast danger. In order that the firing cutout cam may be designed for the maximum possible zone, NavOrd does not approve of cutting cams to protect forestays, halyards, radio antennas, and such top hamper. Peacetime

target practice must be arranged so as to keep the firing clear of these obstructions. In wartime, such hazards must be accepted.

The minimum clearance to be maintained between the extension of the axis of the gun bore and the fixed structure of the ship varies with different size guns. One reason for this is the lag between the time the cutout mechanism functions and the time the guns actually cease firing. For protection of the other installations, the minimum clearance is computed with the other guns and directors at zero degrees elevation and the angle of train at which they are normally secured.

Missile launchers for Terrier, Tartar, and Talos missiles are equipped with firing cutout devices of the type normally used in gun mounts. Terrier and Tartar launchers have an automatic blind zone cutout system incorporated in the missile launcher power drive to prevent pointing a loaded launcher within the nonfiring zones as determined by the ship's structure. Talos launchers also have a blind zone cutout system, similar to that on Terrier launchers, to prevent physical interference of missiles on the launcher with the ship's structure, but not to prevent pointing missiles at the ship's structure. Firing into the ship's structure is prevented by firing cutout devices, as on gun mounts.

TURRET DANGER-ZONE CUTOUT MECHANISM (CAM)

Although danger-zone cutout mechanisms vary in construction between different kinds of turrets, they all serve the same purpose—interrupt the firing circuit if a gun enters a danger or non-firing zone. In a representative 8-inch gun turret, this mechanism functions in response to the train and elevation drives. The train drive rotates a spur gear to which a cam is attached. High points on the cam represent non-firing zones. The elevation drive moves a rack carrying a plunger that touches the cam. When the gun enters a non-firing zone, the plunger rides up on a high point and actuates a rocker arm which is connected—by means of a linkage—to two switches. This action opens one switch, breaking the firing circuit. The other switch closes a circuit to a red-light indicator system, indicating that the gun is in a danger or non-firing zone; at the same time, it opens a circuit to a green light. The green light indicates a safe or firing zone; it lights when the gun moves out of the danger zone and normal firing is restored.

On large caliber guns only the electrical firing circuit is interrupted by the cutout mechanism. The percussion firing circuit is not affected by the cams.

The proper settings for firing cutout mechanisms are outlined in the applicable OPs. Usually the OPs will list the settings for the individual turrets in ships of a class. After the cams are installed, they must be checked by the methods similar to those outlined for smaller guns.

MOUNT FIRING CUTOUT MECHANISMS

All mounts of 5-inch caliber and smaller incorporate mechanisms wherein one cam, referred to as a profile cam, controls the firing circuit when the gun is in or near a danger zone of fire in either train or elevation. The mechanical action of these mechanisms differs slightly from gun to gun, but in principle they are the same and can be considered collectively.

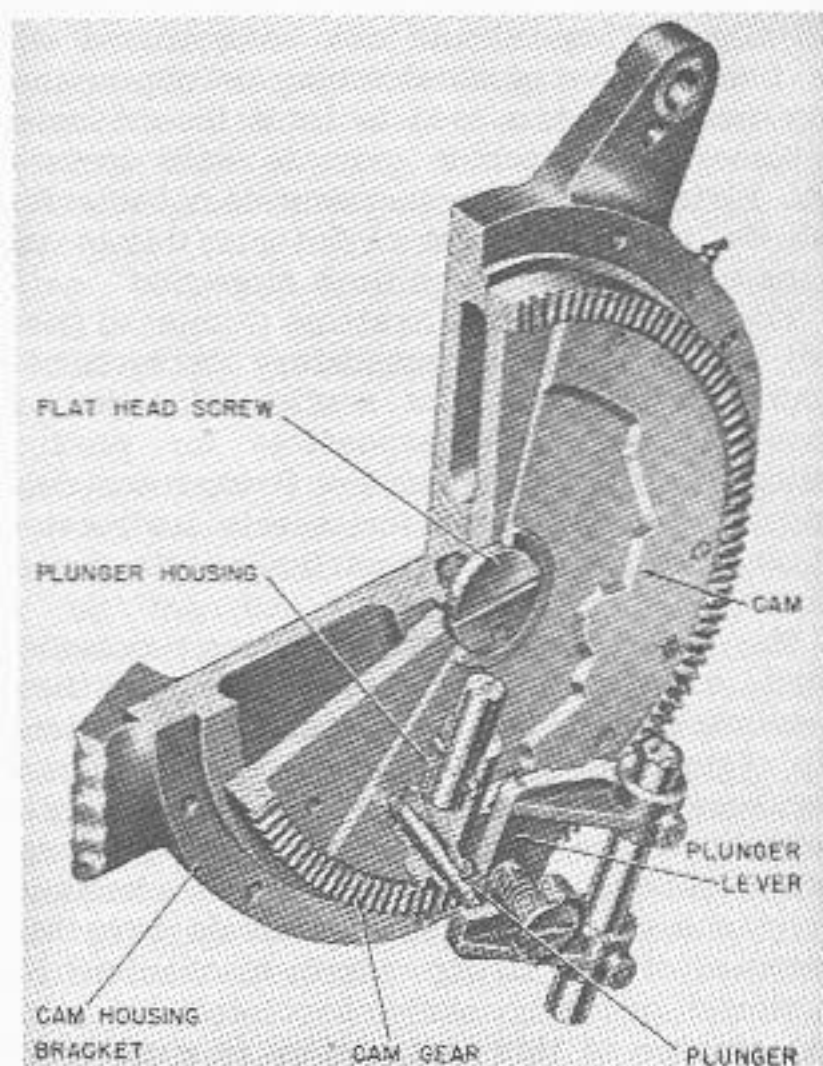
The cutout feature of profile-cam firing cutout mechanism is accomplished by the action of a plunger or cam follower on the face of a disc-shaped profile cam. When the plunger rides up on a high point of the cam, which represents a danger or nonfiring zone, it pushes against the plunger lever, which in turn causes sufficient movement of another lever or levers to interpose a break in the firing circuit. In most guns, this movement interrupts both the electrical and the percussion firing circuits.

Figure 8-12 shows a cutaway view of a typical firing cutout mechanism plunger and profile cam; this one is from a 5"/54 mount. The cam is turned by gun train order at one-to-one speed, while the plunger mechanism moves radially from near the center to the edge of the cam in accordance with gun elevation order. A point near the center of the cam represents maximum gun elevation, and the outer edge minimum gun elevation.

The rise from cutaway area to the raised portion of the cam is a 30° incline. This permits the plunger cam follower to ride from the low surface of the completed cam to the high surface without excessive wear or scoring. Cutout occurs when the plunger is two-thirds of the way up the incline. A switch opens the firing circuit, and a mechanical clutch disconnects the linkage to the firing mechanism from the firing pedal.

PLOTTING, CUTTING, AND INSTALLING THE CAM (PROFILE CAM MECHANISM)

Since the contour of the cam determines where the gun can and cannot fire, it is obvious



53.131

Figure 8-12. —Cutaway view of firing cutout mechanism plunger and cam.

that the most critical step in firing cutout mechanism installation is concerned with plotting and cutting the cam's contour. By far the most important kind of firing cutout mechanism is the profile cam type; therefore the plotting and makeup of this type only will be discussed in this chapter.

The entire firing cutout mechanism, with the exception of the profile cam itself, is assembled and installed on the mount during manufacture. The profile of the cam depends on the obstructions presented from the point of view of its location after installation; hence the cam profile can be determined only after installation. It is necessary first to determine the safe firing zone, i.e., the locus of all gun positions in which firing may be safely performed in accordance with NavOrd standards. This zone must be plotted in such a way that it is immediately usable as a guide in shaping the cam itself. The plot is then transferred to the cam plate blank and cut into the blank. The last

step is installation of the cut cam and verification of its proper functioning. Here is the step-by-step procedure, in brief:

1. Install a boresight in the gun barrel, and sight through it to establish, for each successive 5° increment of train angle, the lowest (and, if applicable, the highest) elevation angle at which it is safe to fire, in accordance with NavOrd standards.

2. As these elevation and train angles are determined, they must be tabulated and plotted on a special polar-coordinate form illustrated in figure 8-13. Note that a different form is issued for each caliber, mark, and mod of gun, and even for the right- and left-hand guns in a twin mount (because their cams turn in opposite directions).

3. Transfer the plot to another copy of the plotting sheet to make a smooth copy. See the

OP or OD on the gun for such information as minimum radius of curves, how wide the cam slope should be, etc. Verify the plot for accuracy.

4. Let the cam be cut in accordance with the verified plot. This is generally done by a navy yard machine shop, not by ship's personnel.

5. Install the cam and check it throughout all angles of train to verify that it complies with NavOrd standards. This can be done by positioning the gun with boresight in place as in step 1, and checking the functioning of the firing circuit and mechanical firing linkage, using a firing circuit test lamp to check the circuit and observing the functioning of the linkage.

For details on the procedure for any specific mark and mod of mount, see the OP or OD on the equipment.

CHAPTER 9

SPOTTING AND NAVAL GUNFIRE SUPPORT

INTRODUCTION: DEFINITIONS

Gunnery operations, rather than principles of weapons and associated equipment, are the principle subject of this chapter. In studying it, bear in mind that operational methods and techniques are broadly determined by the Chief of Naval Operations, and are published as doctrine in NWPs, NWIPs, and related publications, as described in chapter 1, and by other responsible command echelons. The following material is not intended to supplant such sources of doctrinal information.

This chapter takes up the problem of gunfire control where chapter 6 left off, and goes on to discuss certain advanced aspects of fire control in the special situation where naval guns are used against targets ashore, particularly in connection with amphibious attacks.

As chapter 6 stated, not all the factors which affect the flight of a projectile can be precisely evaluated in advance of firing. Even with the best fire control equipment available, experienced gun crews, and efficient fire control personnel, the opening shots may not hit the target. It is therefore necessary to apply corrections (spots) to the initial firing data to bring the shots on the target. The corrections are applied to gunlaying data for subsequent rounds fired. This technique is called spotting.

Before proceeding further, we will define some terms that relate to gunfire support and spotting. Those terms are as follows.

SLOW FIRE. In slow fire, firing is deliberately delayed to allow for application of spots or conservation of ammunition.

RAPID FIRE. In rapid fire, firing is NOT delayed to apply corrections.

SALVO. A salvo consists of one or more shots fired simultaneously by the same battery at the same target.

SLOW SALVO FIRE. In slow salvo fire, the guns are loaded on command and fired together at a fairly slow rate.

RAPID SALVO FIRE. In rapid salvo fire, the guns are loaded on command and fired together at a RAPID rate. (Both slow and rapid salvo fire are used to establish a hitting range to a surface or land target.)

RAPID CONTINUOUS FIRE. Rapid continuous fire is the fastest firing method for 5" guns. The pointer's firing key is locked in the closed position, and the rate of fire depends only on the loading speed.

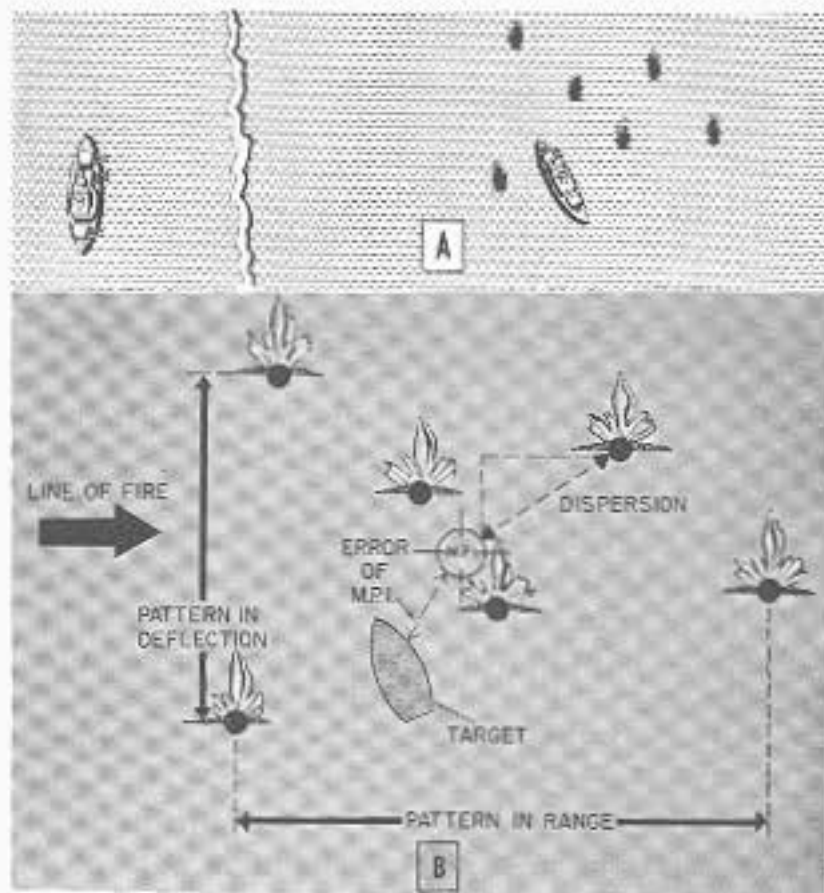
RAPID PARTIAL SALVO FIRE. Rapid partial salvo fire for a turret (6" and above) is synonymous with rapid continuous fire for a 5" gun. (Both of these types of fire will most often be used after the hitting range has been established or, in the case of the 5" gun, against aircraft.)

MPI. The Mean Point of Impact (MPI) is the geometric center of the points of impact of the various shots of a salvo, excluding wild shots (fig. 9-1).

DISPERSION. The dispersion of a shot is the distance of the point of impact of that shot from the MPI. Dispersion in range is measured parallel to the line of fire, and in deflection at right angles to the line of fire, in a horizontal plane. Dispersion in range is positive when the shot falls beyond the MPI. Dispersion in deflection is positive when the shot falls to the right of the MPI. The algebraic sum of the dispersions in range (or deflection) of the several shots of a salvo must equal zero. (See definition of MPI.)

APPARENT MEAN DISPERSION. The apparent mean dispersion of a salvo in range (or deflection) is the arithmetical average of the dispersion in range (or deflection) of the several shots of the salvo, excluding wild shots.

TRUE MEAN DISPERSION. The true mean dispersion is the arithmetical mean of the dispersions in range (or deflection) of an infinite number of shots, all assumed to have been fired under conditions as nearly the same as possible.



53.119

Figure 9-1.—Salvo pattern.

WILD SHOT. A wild shot is a shot with an abnormally large dispersion in range, or deflection, or both.

PATTERN. The pattern of a salvo is the area covered by the points of impact of the shots (except wild shots). The pattern in range is the distance measured parallel to the line of fire between the point of impact closest to the battery and the one farthest away, excluding wild shots. The pattern in deflection is the distance, measured at right angles to the line of fire, between the point of impact farthest to the right and the one farthest to the left, excluding wild shots.

HITTING SPACE. Hitting space (usually measured only in range) for a target is the distance behind the target (measured parallel to the line of fire) that a shot through the top of the target will strike the horizontal plane through the base of the target (fig. 9-2). It includes the projection of the target's vertical height upon the plane of the water plus the target's horizontal dimension in the line of fire (or depth). Hitting space in deflection is the angle subtended by the target.

DANGER SPACE. The danger space for a target is the distance in front of the target,

measured parallel to the line of fire, that the target could be moved toward the firing point, so that a shot striking the base of the target in its original position would strike the top of the target in its new position (fig. 9-2). At most ranges, danger space is virtually equal to hitting space.

STRADDLE. A straddle is obtained from a salvo in range (or deflection) when, excluding wild shots, some of the shots of that salvo fall beyond, (or right and left, respectively, for deflection). The target in figure 9-1A is straddled.

ERROR OF MPI. The error of the MPI is its distance from the target (fig. 9-1) or other reference point, such as the center of the hitting space, measured (in a horizontal plane) parallel to the line of fire for range and at right angles to the line of fire for deflection.

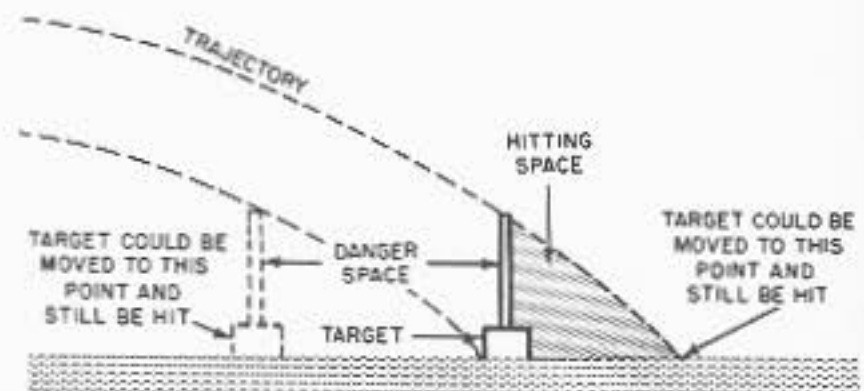
ELEMENTS OF SPOTTING

Now that you are familiar with some of the terms relating to spotting and gunfire support, we will discuss some of the problems encountered in these areas.

DISPERSION AND ITS CAUSES

The problem of spotting is complicated by dispersion. If a battery of guns is fired at the same instant with the same settings in range and deflection (this is salvo fire), the projectiles will not all land at the same point, but will be dispersed over the vicinity.

If the battery of guns were stationary and rigidly fixed in elevation and train, variations in range and deflection would be caused by (1) differences in weight and temperature among individual powder charges; (2) differences in



92.57

Figure 9-2.—Hitting space and danger space in range.

projectile weights; (3) variations in angles of projection (the longitudinal axes of projectiles diverge, in varying amounts, from the continuation of the bore axis as they leave the guns); (4) differences in projectile seating, causing variations in density of loading and initial velocity; (5) differences in erosion among the several guns, with corrections not precisely made. Such causes as these make a certain minimum amount of dispersion inevitable. There are other causes of dispersion which can be prevented. The motion of the ship may result in the pointers and trainers of guns being off target when the guns are fired. The same effect may result from failure to fire exactly simultaneously, causing different guns to fire at slightly different points in the roll.

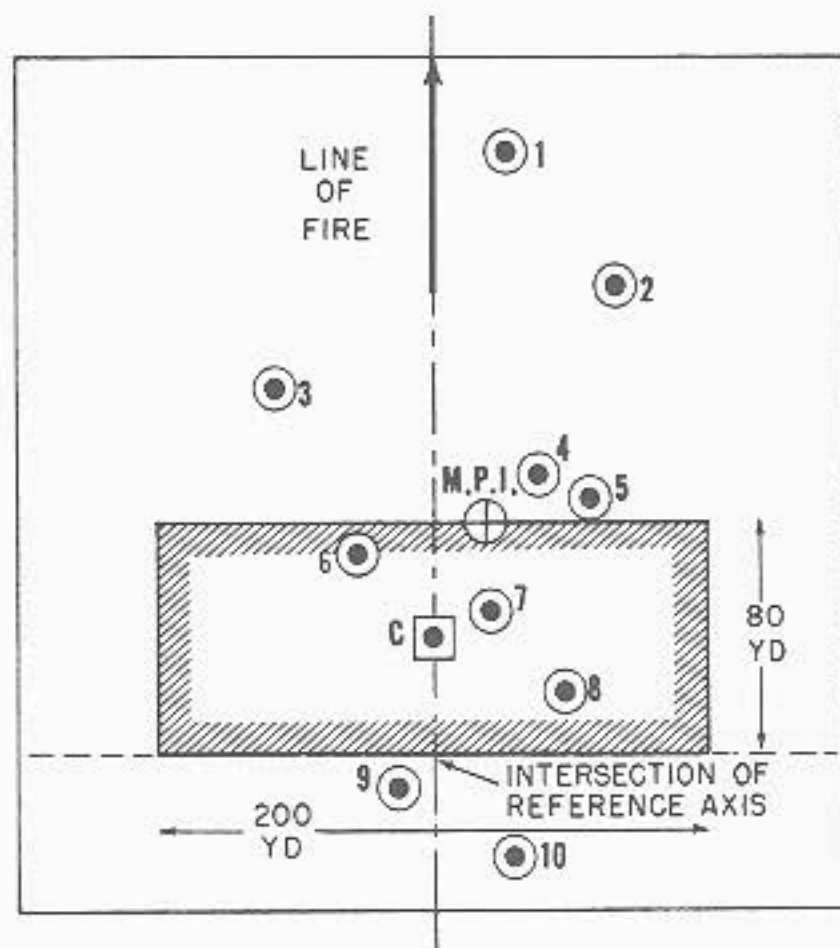
Director-controlled gunfire, although not subject to the same characteristic errors as pointer fire, is subject to its own characteristic errors. All such errors are considered accidental errors. They are revealed by analyses of firings, and their effects are governed by the laws of probability.

For discussion of the laws of probability in general the student is referred to any good text on the subject. Elementary discussions of probability will also be found in most textbooks on statistics. This chapter is primarily concerned with the practical aspects as applied to spotting of gunfire.

DETERMINING LOCATION OF MPI

The definitions discussed earlier will now be illustrated by an example (NOT necessarily typical) representing a salvo from ten 5"/38 caliber guns fired at range 8,500 yards against a target 40 feet high, 600 feet long, and with a beam of 90 feet. The target is situated with its length at 90° to the line of fire (fig. 9-3).

The danger space at this range, from column 7 of the range table (appendix 2, table A2-1), is $40/20 \times 25 = 50$ yards. Since the target "depth" is 90 feet, or 30 yards, the actual danger space is thus $50 + 30 = 80$ yards. For most battle ranges the value of hitting space is the same as that for danger space. Hence hitting space is also 80 yards. Figure 9-3 represents the plan view of the target shown in terms of hitting space, an area 80 yards in range and 200 yards in deflection. The center of the hitting space is at C. (The fact that the target is not rectangular will be ignored.) The points of impact of the several shots are indicated by numbered dots and are identified by table 9-1, which gives the



110.90
Figure 9-3.—Analysis of a salvo pattern.

location of each impact from the reference axes, in this case taken as intersecting at the center of the target's waterline.

The location of the MPI is determined by measuring the distance, in range and deflection, of the point of impact of each shot from convenient coordinate axes, and finding the mean of these distances. It is convenient to refer impacts to axes intersecting at the center of the target's waterline, as was done in the table. The mean of these distances is 80 yards over and 20 yards right, which locates the MPI 80 yards beyond and 20 yards right of the center of the waterline.

If we assume that the error of the MPI is its distance from the center of the hitting space, this is seen to be 40 yards over and 20 yards right.

DETERMINING APPARENT AND TRUE MEAN DISPERSION

In determining apparent mean dispersion, remember that it is the arithmetical mean of the dispersions of the several shots, without regard to sign. Once the MPI position has been plotted,

Table 9-1

Shot No.	Distance from reference axes			
	Range yd		Deflection yd	
	Over	Short	Right	Left
1	220		30	
2	170		70	
3	130			60
4	100		40	
5	90		60	
6	70			30
7	50		20	
8	20		50	
9		10		10
10		40	30	
Sum	850	50	300	100
	50		100	
Diff	800		200	
Mean	80		20	

110.87

the several points of impact are now referred to the MPI to determine individual dispersions and apparent mean dispersion, as shown in table 9-2.

Apparent mean dispersion, based on 10 shots, is, according to table 9-2, 62 yards in range and 32 yards in deflection. Based on such a limited number of observations, it is unlikely to be a true measure of accuracy of fire. The true measure of accuracy is the mean dispersion of an infinite number of shots, all fired under the same conditions. This is the true mean dispersion. It is obviously impossible to measure this value experimentally by firing an infinite number of shots, but a theoretical value can be found in the relation

$$D = D' \sqrt{\frac{n}{n-1}}$$

in which D is the true mean dispersion, D' the apparent mean dispersion, and n the number of shots from which D' was obtained. Table 9-3 gives the values of the ratio of D to D', i.e., values of

$$\sqrt{\frac{n}{n-1}} \text{ for salvos of from 2 to 12 shots.}$$

The true mean dispersion, in the above case, is found by multiplying the apparent mean dis-

persion by 1.054. Hence the true mean dispersion in range is $62 \times 1.054 = 65$ yards, and in deflection is $32 \times 1.054 = 34$ yards.

SPOTTING MPI TO CENTER HITTING SPACE

Wide dispersion is apparent in the 10-shot salvo pictured in figure 9-3. Mathematically, however, it is correct spotting procedure to spot the MPI to the center of the hitting space. Shots 4, 5, 6, and 7 would be hits if the MPI were spotted to point C. Shots 8, 9, and 10 would fall short of the target, while 1, 2, and 3 would still be long. Therefore, the next salvo should include at least four hits and probably would have more, since dispersion, as already noted, is subject to many variables. Spotting the MPI to the center of the hitting space is a mathematical attempt to reduce the effect of dispersion variables.

As range increases, hitting space decreases, and as dispersion increases, the probability of hitting decreases. An officer detailed to duties which include spotting should know the dispersion at various ranges up to the maximum range of his battery. He can then determine the probability of hitting a target.

DESIRABLE PATTERN SIZE

If the MPI is at the desired point of impact, a pattern of small dispersion can be expected to yield the maximum number of hits. Where excessive errors creep in, however, excessive

Table 9-2

Shot No.	Dispersion	
	In range yd	In deflection yd
1	140	10
2	90	50
3	50	80
4	20	20
5	10	40
6	10	50
7	30	0
8	60	30
9	90	30
10	120	10
Sum	620	320
Mean	62	32

110.88

Table 9-3

Number of shots in salvo	Ratio of true mean dispersion to apparent mean dispersion
12.....	1.044
11.....	1.049
10.....	1.054
9.....	1.061
8.....	1.069
7.....	1.080
6.....	1.095
5.....	1.118
4.....	1.155
3.....	1.225
2.....	1.414

110.89

dispersion results. If the pattern is so spread that few shots are grouped around the desired point of impact a minimum number of hits is probable. From the standpoint of a maximum number of hits, it would seem desirable to eliminate errors completely so as to have a zero pattern in range and deflection. Such a pattern would be desirable if the MPI were always at the desired point of impact. It is difficult in actual firing, however, to place the MPI at this desired point. Since it would be better to hit with some of the shots than to miss with all, a larger pattern size is better.

In the Naval Warfare Information Publication, NWIP 22-2, there are tables giving the average pattern sizes for the various caliber guns. These tables were constructed from firings conducted at the Naval Weapons Laboratory. Patterns in the fleet should be no larger than those given in the tables.

ACCIDENTAL ERRORS CAUSING SHIFT OF MPI

Since dispersion of individual shots is caused by unpredictable errors, it is logical to assume that no two salvos will be exactly alike. Hence, the MPI of the shots of a given salvo can be expected to differ in location from the MPIs of other salvos.

The average shift between successive MPIs is usually so small as to be difficult for the spotter to estimate. Therefore, the spotter should not be too quick to spot when only one or two salvos seem to wander off the target during a string that is, in general, satisfactory.

CONTROL ERRORS

The only accidental errors so far considered have been those which affect individual guns of a battery. These are known as gun errors and should be distinguished from another class of accidental error which affects the battery as a whole. These are known as control errors and include errors in computing, transmitting of data to the guns, and in director fire, director pointing errors. They are not reflected in increases pattern sizes (i.e., increased dispersion among the guns) but are characterized by increased dispersion or error of the MPIs themselves.

There are four general control inaccuracies which may cause MPI error. These are listed in the order of probable frequency of occurrence and magnitude of effect:

1. Computer set up with incorrect values.
2. Ballistic corrections based on incorrect values (I.V., wind, air density, and others).
3. Battery not properly aligned with director.
4. Indeterminate errors ("Class B" and personnel errors).

Let us now consider each of these sources of control errors.

Incorrect Computer Setup

Determination of target course and speed is made directly from the spotter's estimate of target angle and speed, from CIC, or by rate controlling. Correct values of these two variables are difficult to determine; they are the chief cause of incorrect computer setup, and hence, the chief source of MPI error.

Present range to target is valid only so far as its measurement is accurate. An error in basic range measurement directly causes an error in MPI.

Measurement of own-ship course and speed usually are reasonably accurate, but any inaccuracies result in an error in MPI.

Inaccurate Ballistic Corrections

The computer determines corrections for variations from standard conditions. Determination of these corrections based on incorrect values of ballistic wind, I.V., air density, etc., will give a total ballistic correction that will result in a corresponding error in MPI.

Poor Battery Alignment

Improper alignment between the guns of a battery results in greater dispersion and larger

pattern sizes, but does not materially affect the error of the MPI of a salvo. In contrast, MPI error can be caused by misalignment between the controlling director and the battery as a whole. Such misalignment is generally caused by failure to director-check the battery and all directors. A battery aligned with one director is not necessarily aligned with another which may be in control. Frequent director checks can assist in elimination of this cause of MPI error.

Indeterminate Errors

There are two classes of indeterminate errors.

Some of the computations by mechanical computing elements in fire control instruments are only approximations of the true solutions. These approximations result in "Class B errors," which are small for normal ranges and therefore cause minimum error in MPI. However, at extremely short or long ranges the errors may become large, depending on the instrument concerned, and may seriously affect the MPI. When Class B errors are known to be large, they can no longer be treated as accidental, and steps must be taken to make correction for them.

The other class of indeterminate errors is assignable to control personnel. For example, the director pointer or trainer may be off the point of aim when the salvo is fired. Training and experience can reduce the magnitude of such mischance. Small errors of this type merely cause a slight shift of MPI and should not be corrected by the spotter. The director operator should inform the spotter of larger discrepancies in the point of aim, so that the spotter may distinguish this error from others.

ERRORS AND THE SPOTTING PROCESS

It is not enough for the spotter to detect errors, estimate the spots required, and transmit them. He must be able to recognize the causes of errors by understanding their characteristics and knowing what to expect of the batteries he is working with, and then make up his spots with this information in mind. In summary, we list below the three main types of errors that crop up in gunfire from shipboard, and what can be done about them.

1. Accidental gun errors causing dispersion of shots. These errors are only compensated to the extent of achieving desired pattern sizes. Most of the errors are eliminated by careful design, frequent checks of battery alignment, normal upkeep of the battery, and the training of gun crews.

2. Accidental gun errors causing a shift in the MPI of successive salvos. The shift in both deflection and range is usually small.

3. Control inaccuracies causing error of MPI. It is the primary duty of the spotter to "spot" the corrections in range and deflection necessary to bring the MPI of a salvo to the desired point of impact. He should recognize the first two classes of errors in order to spot the error of MPI caused by control inaccuracies.

FUNCTIONS AND DUTIES OF THE SPOTTER

The spotter has several functions and duties. In order to perform them effectively, he should have the following qualifications:

1. An even, calm temperament, not excitable under stress.
2. Sound judgment.
3. Decisiveness.
4. Alertness.
5. Normal eyesight, hearing, and speech.

PRIMARY FUNCTION OF THE SPOTTER

The primary function of the spotter is the correction of range and deflection errors of the MPI so as to bring the shots on the target. Prompt and accurate correction of initial errors may be the deciding factor in a naval engagement. He bases these corrections on his own observations combined with those of the fire control radar operator. As a rule, in good visibility the spotter will estimate the necessary deflection correction, and range corrections will be obtained from the radar. Under unfavorable conditions both range and deflection corrections will be obtained from the radar.

If radar fails, optical spotting must substitute. In the initial discussion of the spotter's problems, it will be assumed that radar is not available.

GENERAL FUNCTIONS AND DUTIES OF SPOTTERS

Besides his primary function of correcting the fall of shot, there are other functions which the spotter must perform before and during firing. In general these are:

1. Describe the enemy forces (general bearing line, number of ships, deployment, etc.).
2. If he is also acting as the control officer, he estimates the values of range, target angle,

and target speed, and keeps plot informed of all changes to these values.

3. Keep control informed of the tactical situation.

There are other duties which the spotter may be required to perform. Their exact nature will vary with different types of ships. The spotter's detailed duties and spotting procedures are prescribed in the ship's Weapons Department Organization Manual, and in fleet doctrinal publications (NWIPs etc.).

VISUAL ESTIMATE OF TARGET COURSE AND SPEED

To arrive at a solution of the fire control problem, the computer must have target course and speed. Often the spotter can obtain these data by observation through binoculars.

To determine target course, the spotter must be able to estimate accurately target angle (i.e., relative bearing of own ship as seen from the target). To estimate target angle the spotter must know the structural details of all likely targets. Silhouettes of all probable targets are furnished each ship. The spotter should study the details of these visual aids, not only for the purpose of recognizing the enemy, but also for estimating target angle. In estimating target angle, the spotter should make use of prominent objects such as bridges, breaks in the deck, stacks, masts, and other features. By observing the opening and closing of the apparent distance between such details, the spotter can estimate the angle the enemy ship makes with the line of sight.

Target speed can at best be only roughly estimated. Here again, knowledge of enemy ships is valuable, particularly as regards maximum speeds. Target speed may be estimated as about 1 or 2 knots less than the maximum speed of the slowest ship in the formation.

To make the best speed estimates you must have extensive training and experience. The aids used by a spotter in a direct estimation of target speed are smoke from the stacks, bow wave, and stern wake. A spotter who knows his target size can also make accurate preliminary estimates of range by using the mil graduations in his binoculars. (Mils are explained further in the following section.)

SPOTTING IN DEFLECTION

Because it is simpler to make range spots when there is no deflection error (particularly

at long ranges), the spotter customarily calls deflection spots first. The unit used in deflection spotting is the angular mil.

The Mil and How to Use It

You are already acquainted with the angular mil because it is the unit in which gunsight deflection scales are calibrated. There are about 6400 mils to a circle, and 1 mil is about 0.56° , or 3.37 minutes of arc. The reason for using the mil as an angular unit in measuring deflection, rather than using degrees or minutes, is that it has a very useful property. If a distant object appears to an observer to have an angular width of 1 mil, then the actual width of the object is 1/1000th of the range.

Telescopes, binoculars, and other optical devices for naval use often have reticles with mil scales etched on them. If you use such binoculars to look at, say, a 30-foot boat broadside on at a range of 1000 yards, the image you see in the binoculars will have an angular width of 10 mils. Figure 9-4 shows further graphical examples of the relationship between mils and

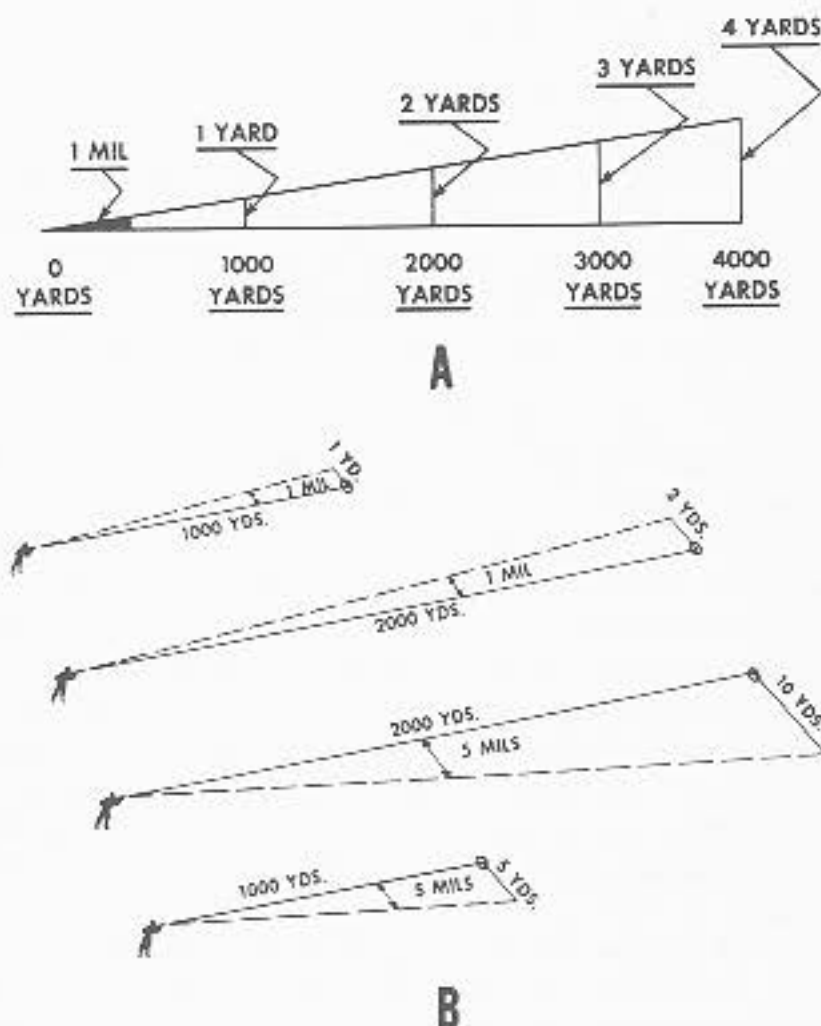


Figure 9-4.—The angular mil and how it is used.

range. Part A of the figure shows how 1 mil subtends different linear distances at different ranges, and part B shows several other examples of the relationship. To bring the use of mils down from this theoretical level, look at figure 9-5. What is the linear size in deflection of salvo A's pattern?

Salvo A at a range of about 11,500 yards subtends 5 mils. One one-thousandth of the range is 11.5 yards; multiplying by 5 (mils) gives an actual pattern width in deflection of 57.5 yards. As a practical matter, of course, it's absurd to specify a pattern width down to a half yard; rounding off, the answer would be about 58 yards.

In estimating deflection spots, use target width in mils as a guide.

Allowing for Splashes

With a high speed surface target, the spotter should bear in mind that the apparent MPI in deflection should be held abaft the point of aim to allow for target travel while the splashes are forming. Do not assume that full splashes form instantaneously at the impact of a salvo. The time lag is only a few seconds at most, but is sufficient to allow considerable movement of a fast target.

SPOTTING IN RANGE

Spotting in range is more difficult than spotting in deflection. There is no convenient angular measure that is uniformly applicable at all ranges, like the almost foolproof mil.

Figure 9-5 is adapted from a typical spotting diagram. It shows schematically how different ranges look to you as an observer 100 feet above the water surface. The lateral broken lines represent ranges in increments of 1000 yards; the diagonal broken lines represent angular mils; and the curved solid line at the right shows the apparent length in mils of a 600-foot broadside target at various ranges. Unfortunately, the natural seascape is not marked with these handy reference lines, but the diagram is a helpful guide in learning how to estimate ranges. It is used in conjunction with such training aids as miniature spotting boards, and with observation during target practice.

The range lines in figure 9-5 represent angular distance below the horizon at which any object would appear from a height of 100 feet, if observed on the corresponding range lines. The distances between the range lines represent

the apparent range differences as viewed by an observer at the height (in this case 100 feet) for which the diagram was constructed.

A study of figure 9-5 shows that salvo A is clearly short, by about 500 yards, of the imaginary extension of the waterline of a target at 12,000 yards. However, the error of salvo B, fired at a target at 19,000 yards, is not so apparent. The 500-yard error of salvo B is difficult to see when compared with the extended waterline of the target. Thus, for shipboard spotting at such a range, the splashes must be in line with some portion of the target before the spotter can reasonably tell whether the salvo is over or short, to say nothing of estimating the amount of the error.

In addition to its use for estimating range and range errors, the spotting diagram shows the number of mils a given target length will subtend at any given range. For example, in figure 9-5 a 600-foot target will subtend 20 mils at 10,000 yards range.

One of the most common mistakes made by the untrained spotter is to underestimate the amount of range error at long ranges, because a given range error will subtend a much smaller angle at long ranges than it does at short ranges. However, with good visibility and from a height of 120 feet or more, the MPI error can usually be estimated with reasonable accuracy at ranges up to 15,000 yards, by observing the position of the bases or slicks of the splashes relative to the target waterline.

METHODS OF SPOTTING

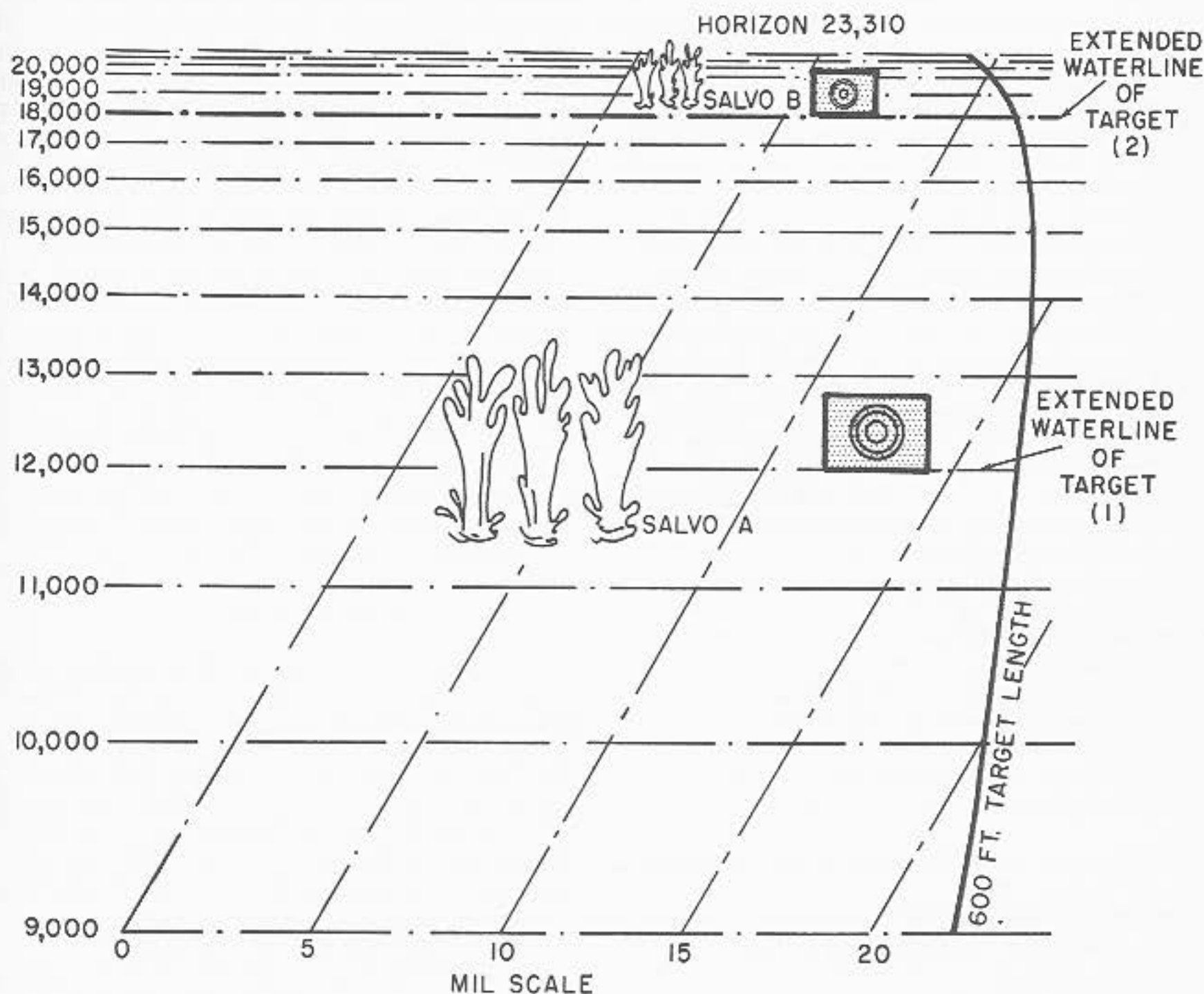
This section is concerned, primarily, with methods of visual spotting and spotting with radar. Before discussing these methods, however, we will discuss some of the terminology used in spotting.

SPOTTING TERMINOLOGY AND MESSAGE PRACTICE

As in other operational communications, there is a prescribed terminology and message sequence for spotting. These are published in fleet operational directives which you will use on active duty. The examples below show the general practice at the present time.

Surface Fire

For surface fire, only range and deflection are spotted. The correction necessary to bring



92.58

Figure 9-5.—Practice diagram for range spotting.

the MPI on target is given in the following terminology sequence.

1. Deflection correction—RIGHT or LEFT, in mils.
2. Range correction—ADD or DROP, in yards.

When no correction in deflection is necessary, only a range spot is made. When no range spot is necessary (regardless of whether a deflection spot is required), the phrase NO CHANGE is used. Typical examples of spot transmissions by telephone are: RIGHT 10, ADD 1,000; LEFT 5, DROP 500; LEFT 10, NO CHANGE; NO CHANGE.

AA Fire

For air targets, corrections to bring the burst on the target are needed in three dimensions. Even well-trained personnel find it almost impossible to estimate errors rapidly in three dimensions. AA spotting is therefore generally limited to correcting for obvious constant system errors.

The proper terminology for spotting in AA fire is as follows:

1. Deflection correction—RIGHT or LEFT, in mils.

2. Height-of-burst correction—UP or DOWN, in mils.
3. Range correction—ADD or DROP, in yards.

Deflection and elevation spots will normally be made by the control officer. Range spots will be made by the rangefinder or radar operator.

Naval Gunfire Support

In shore bombardment, as in AA fire, spots in three dimensions may be necessary. The terms are the same as in the preceding paragraph, but the units are not the same. When naval guns are used to support landing operations, joint forces are involved. The Navy, Army, and Air Force have a standardized spotting terminology for joint operations which will differ from the above in that all corrections for indirect fire are spotted in yards. Deflection and elevation spots must be converted to angular units before being applied to the computer.

Spots in three dimensions are made in the following order:

1. Deflection—RIGHT or LEFT.
2. Height of burst—UP or DOWN.
3. Range—ADD or DROP.

VISUAL SPOTTING METHODS AND TECHNIQUES

There are three methods of visual spotting:

1. The direct method.
2. The bracket-and-halving method.
3. The ladder method.

The method used depends on the type of battery firing, type of target, visibility and range.

Direct Method

Spotting by the direct method is, as its name implies, the spotting of salvos (splashes) direct to the target. This is the most desirable procedure, but its use is limited to shorter ranges and good visibility conditions. For reasonably accurate visual spotting at a range of 15,000 yards, a spotting height of 120 feet is required. The splash must be relatively close to the target, and the rangekeeper set-up fairly accurate.

A thoughtful analysis of the problem with reference to the spotting diagram in figure 9-5 reveals that the greatest limitation of the direct method in visual spotting is in range. Deflection

spots can be made with equal accuracy at any visible distance. If, then, air observation is available, and the plane spots in range with the ship spotting in deflection, the direct method can be used by the battery at any range at which a portion of the splash is visible to the ship-board spotter. Air spotters cannot spot accurately in deflection unless they have a line of sight containing the firing ship and the target.

Spotting the fall of shot at very short ranges differs from other spotting problems in that range errors are not difficult to judge. However, in determining deflection errors at short ranges, consideration must be given to the travel of the target and the spotter's position relative to the line of projectile flight. For example, with the firing ship and target on opposite courses, target to starboard, a shot fired with correct deflection but long in range will appear to the spotter to be in error to the left of the target. Special short-range splash diagrams aid the spotter in this type of firing.

Bracket-and-Halving Method

Bracket-and-halving is used at long ranges when no air or radar spot is available. At great distances it is impossible to tell if a splash is short of or over a target, unless the two are in line. If the splash and target are not in line, the first spot is made in deflection only. When target and splashes are in line in deflection, a range spot is made in such a direction and amount as to "cross" the target definitely. The direction of the next spot is reversed, and the size of the spot is cut in half. This "halving" is continued until a straddle is obtained, at which time it may be appropriate to shift to rapid partial salvo or to rapid continuous fire. The spot should not be reduced below pattern size.

The Ladder Method

When ranging is difficult and visibility poor because of fog, smoke, or darkness, the ladder technique is valuable. Ladders are not particularly adaptable to fast-moving targets. There are many variations of this technique, but the basic procedure is:

1. Fire is deliberately opened short.
2. Succeeding salvos are fired to approach the target in steps not less than pattern size.
3. As soon as the target is crossed, the steps are reversed and halved until the target has again been crossed.

After the target is straddled, a rocking ladder may be used with slow timed fire, or with rapid partial salvo or continuous fire. In a rocking ladder the pattern is shifted back and forth across the target by small arbitrary successive spots, such as +100, 0, -100, introduced at the computer. Its effect is to increase the pattern size, which may be valuable when firing against a target capable of rapid maneuvering. The rocking ladder can be used in conjunction with air or radar spotting, so long as the spotter is kept informed that this technique is being used.

SPOTTING WITH RADAR

Radar spotting has proved to be both accurate and reliable within the range of surface batteries. Radar provides a means of spotting which is independent of conditions of visibility, so that blind spotting is possible with blind firing.

Shell splashes appear on the scope as fluctuating echoes which last for several seconds, depending on the size of the projectile and the range. The large column of water thrown up by the projectile produces the echo. Salvos produce larger or multiple echoes on the scope.

If the projectile stays within the vertical limits of the radar beam, its flight to the point of impact can be followed on the scope on main sweep. The projectile produces a small, weak, moving echo which begins at the edge of the scope and moves out in range toward the target. At the point of impact the echo stops and grows larger as the splash builds up. Echoes from direct hits or near misses will be lost in the target echo, while salvos which straddle the target may envelope the target echo in the midst of the splash echoes on the scope, thereby making it impossible to distinguish individual splashes. Range errors can usually be estimated by radar with greater accuracy than by optical spotting, but deflection spotting with radar is difficult, especially when the error is small. Near misses sometimes merge with and are indistinguishable from the target pip. Consequently, repeated salvos can land with a 2-mil to 5-mil error which is not separately distinguishable but may not be hits. Target practice is used to determine the minimum deflection error that can be detected on a particular radar. When radar is the only means available for deflection spotting, deflection "rocking ladder" should be used. The order of preference in spotting surface fire is usually: RANGE—radar, air, and visual; DEFLECTION—visual, radar, and air. In night action, or action

under reduced visibility, radar normally spots for both range and deflection.

SPOT PYRAMIDING

SPOT-PYRAMIDING is the application of a new spot before the effect of a previous spot has had time to become apparent. It can occur only in rapid fire, when the interval between shots or salvos is less than the time of flight plus the spotting interval. In that case, when a salvo lands there are one or more other salvos in the air. Suppose the spotter makes a spot on the salvo which has just landed. This spot is applied and a new salvo is fired. Then one or more of the salvos which were already in the air lands, and the spotter, forgetting that his previous spot has not had time to show its effect, spots again. This spot is applied to the next salvo fired, with the result that this salvo is overcorrected and will probably miss, as will subsequent salvos until the spotter sees his mistake and spots back again.

The time of flight clock signal helps to avoid pyramiding. A button on a mechanical time clock is pressed in the plotting room when the salvo on which a spot is applied is fired. The clock has been preset to ring just before the time of flight of the projectile ends. Before the salvo lands, the mechanism sounds a buzzer. This is then relayed to the spotter via sound-powered phones.

Because spot pyramiding is common and has a disastrous effect on accurate control of fire, the means used to prevent it must be carefully and correctly operated. For example, if the time-of-flight mechanism operator forgets to press the button for a spotted salvo, and the spotter waits for the signal, he may continue to wait after it becomes apparent that his previous spot was incorrect.

When modern fire control systems are being used to solve the fire control problem, the process described in chapter 6 as rate control is used to make constant corrections to the solution. If spots are applied at the same time as rate control corrections, the effect is the same as pyramiding of spots. Under normal circumstances, AA fire is rate controlled. Hence spotting of air bursts is rare.

SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT: FUNDAMENTALS

In World War II, naval task forces frequently carried out bombardments of enemy installations

on shore. After the ineffective results noted during the Tarawa operation in November 1943, shore bombardment techniques were gradually improved through successive landings at Roi-Namur, Eniwetok, Saipan, Guam, Peleliu, the Philippines, Iwo Jima, and Okinawa. Later, the Korean War and the Vietnam conflict gave frequent opportunities for the refinement of the techniques learned in World War II.

An opposed amphibious landing is one of the most hazardous types of military operations. Until World War II, many military authorities believed that such an operation was too hazardous to be attempted. In part, this belief was based on the Allied failure in the amphibious Dardanelles (Gallipoli) campaign during World War I. Analysts ascribe the failure at least partially to inadequate naval preparation before the campaign.

To be successful, naval gunfire support for amphibious operations must be carefully planned in advance, and must be executed with skill and dispatch. It is vitally important in the period after the troops have landed but before adequate artillery can be brought into action. Its full exploitation can be achieved only if ground, naval, and air personnel understand the organization, basic techniques, capabilities, and limitations of naval gunfire support, and follow the standard procedure which has been agreed upon by the joint services.

PURPOSE OF SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT

Naval gunfire is delivered from ships' batteries not only in support of troop operations, but also to support related naval and air operations, such as mine warfare activities, air-sea rescue operations, reconnaissance and demolition operations, demonstrations, feints, raids, flak suppression during air strikes, and interdiction of coastal roads, railroads, airfields, and troop assembly areas. All these activities rest on the same basic principles as the naval gunfire support of amphibious operations.

The basic task of naval gunfire support units in an amphibious operation is to support the seizure of the objective by destroying or neutralizing:

1. Shore installations that oppose the approach of ships and aircraft to the objective.
2. Defenses that may oppose the landing.
3. Defenses that may oppose the postlanding advance of troops.

These tasks are carried out in the preparation of the objective for the landing, the support of the landing, and in postlanding support.

This section takes up the fundamentals of naval gunfire against shore targets, both in support of troop operations and for other purposes.

TERMINOLOGY: GUNFIRE CLASSIFICATION

Naval gunfire against land targets may be classified in various ways. The classifications are interrelated; terms from several types of classification must be used for a full description. These classifications are based on:

1. Effect sought:
 - a. **DESTRUCTION.** Deliberate and accurate fire, usually delivered at short range, for the purpose of destroying a target, usually a material object.
 - b. **NEUTRALIZATION.** Rapid, fairly accurate fire delivered for the purpose of hampering, interrupting, or preventing enemy fire, movement, or action. Destruction of weapons and personnel is secondary. The effect of neutralization is comparatively temporary; such fire may have to be repeated.
 - c. **HARASSING FIRE.** Sporadic fire delivered during otherwise quiet periods to prevent enemy rest, recuperation, or movement, and in general to lower enemy morale and combat efficiency.
 - d. **INTERDICTION FIRE.** Fire designed to prevent or curtail the use by the enemy of an area, bridge, defile, airfield, route of communication, etc.
 - e. **ILLUMINATING FIRE.** Gunfire employing illuminating projectiles (star shells) to illuminate the enemy, to detect his movements, to aid our own observation, or to facilitate own troop movements.

2. Tactical use:
 - a. **CLOSE SUPPORTING FIRE.** Gunfire delivered on enemy targets which, because of their proximity, present an immediate and serious threat to the supported unit. (Close supporting fire may be as close to friendly troops as 300 yards enfiladed, or 600 yards when the target axis is not parallel to the line of fire.)
 - b. **DEEP SUPPORTING FIRE.** Gunfire delivered on objectives not in the immediate vicinity of friendly forces, to neutralize or destroy enemy reserves and weapons, and interfere with

enemy command, supply, communications, and observation.

c. **PREPARATION FIRE.** A heavy volume of prearranged neutralization fire, delivered just prior to a landing or a ground attack by friendly forces on enemy positions.

d. **COUNTERBATTERY FIRE.** Gunfire delivered against active enemy guns and fire control stations for the purpose of silencing the guns.

e. **PREARRANGED OR SCHEDULED FIRE.** Gunfire formally planned and executed against targets of known location. Such fire is usually planned well in advance and is executed at a predetermined time.

f. **CALL FIRE.** Gunfire delivered at the request of troop units ashore, or of some spotting agency. Call-fire missions must not be interrupted without permission of the unit requesting the fire, except in case of emergency.

g. **OPPORTUNITY FIRE.** Gunfire delivered without formal planning or troop request on newly discovered targets, or upon transitory targets. Targets of opportunity may present themselves to the firing ship at any time, but fire must be delivered only with due regard for safety of friendly troops. Ships executing deep support missions must assure themselves that the target of opportunity is within their assigned sector of responsibility.

h. **RECONNAISSANCE FIRE.** Gunfire delivered in areas where camouflaged positions are suspected or in vital areas where natural cover prevents observation and/or gathering of photo intelligence.

i. **FLAK SUPPRESSION FIRE.** Gunfire used to suppress AA fire immediately prior to and during an air attack on enemy positions.

3. Technique of delivery:

a. **DIRECT FIRE.** Gunfire delivered on a target by using the target itself as a point of aim for laying the guns or director. Direct fire is usually used on targets which can be seen (by optics or radar) from firing ship.

b. **INDIRECT FIRE.** Gunfire delivered on a target which is not itself used as a point of aim for laying the guns or director. Indirect fire is always used on targets not visible from the ship. This fire is spotted by air spotters or shore fire control party spotters assigned for this specific purpose.

4. Type of fire:

a. **AREA FIRE.** Gunfire delivered in a prescribed area. Area fire is generally neutralization fire.

b. **POINT FIRE.** Gunfire directed at a definite material target in order to destroy that particular target.

c. **DEFILADE FIRE (reverse-slope fire).** Gunfire delivered on targets located behind some terrain feature, such as a hill or ridge, which masks the target (fig. 9-6A).

d. **ENFILADE FIRE.** Gunfire delivered on a target in such a manner that the range pattern of the fall of shot coincides with the long axis of the target (fig. 9-6B).

TERMINOLOGY: GENERAL TERMS

Some other general terms used in naval gunfire support operations are:

1. **AMPHIBIOUS TASK FORCE.** A task organization under naval command composed of assault shipping, embarked troops, and supporting naval units and tactical air units.

2. **AMPHIBIOUS TROOPS.** Troop elements assigned to an Amphibious Task Force.

3. **ADVANCE FORCE.** A task organization of ships which conducts operations such as reconnaissance, minesweeping, underwater demolition, diversionary raids, and preliminary bombardment prior to the arrival of the main body of the ATF in the objective area.

4. **ATTACK GROUP.** A subdivision of an ATF, consisting of assault shipping with embarked troops and supporting naval and tactical air units operating to establish a landing force on shore and support its operations thereafter. In an operation involving only one Attack Group, it is also the Amphibious Task Force.

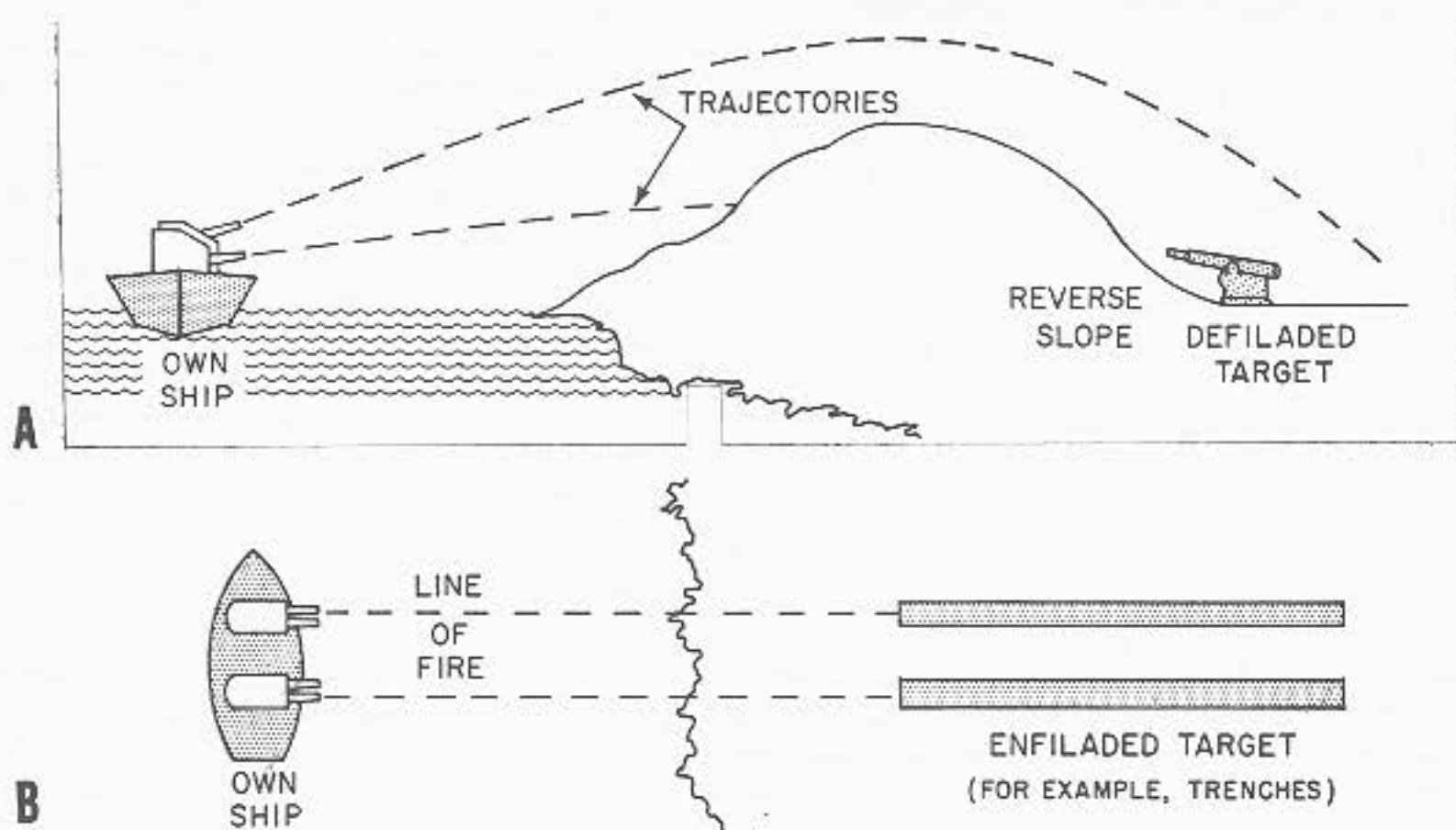
5. **FIRE SUPPORT UNIT.** A group of ships, part of the Attack Group, assigned the mission of naval gunfire support to an amphibious operation.

6. **OBJECTIVE AREA.** A defined geographical area within which is located the objective to be captured or reached by the military forces.

7. **OBJECTIVE.** A physical area or location on the ground, usually a readily identifiable terrain feature, which a troop unit is assigned to capture or occupy. Objectives may be designated as intermediate or final objectives.

8. **D-DAY.** The day on which an amphibious landing takes place.

9. **H-HOUR.** The actual time to the minute at which the leading wave of the landing force



110.91
Figure 9-6.—Types of target.

touches down on the beach; if actual H-hour differs from scheduled H-hour, the actual time of H-hour is broadcast to all ships and troop units by the Amphibious Task Force Commander.

10. ZONE OF RESPONSIBILITY (ZR). The land in the objective area is divided into zones assigned to fire-support units or to individual ships which are responsible for observing, destroying, or neutralizing known enemy installations and for attacking targets of opportunity therein. A ship may fire in its own ZR without clearance from any troop unit, providing the target is not short of an established coordination line. The boundaries of the zone of responsibility should be recognizable both on the terrain and on the map. The boundaries of zones of responsibility of direct support ships should correspond to the zones of action of the landing force units supported. These zones include all land area in the vicinity of the landing forces except the Close Support Area.

11. PRELIMINARY BOMBARDMENT. Bombardment in the objective area delivered by an Advance Force prior to arrival of the main body of the ATF, with the primary purpose of destroying enemy defenses which might hinder or abort the landing.

SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT: FIRE CONTROL

Naval vessels perform shore bombardment missions either in coordination with troop operations (such as amphibious landings, assaults, or—to a limited degree—offensives) or independently (but in coordination with other naval or air units) for such miscellaneous purposes as interdiction or destruction of selected targets. This section takes up the fire control aspects of shore bombardment methods and techniques. A later section concentrates specifically on shore bombardment operations in preparation for and coordinated with troop operations.

FIRE CONTROL ASPECTS OF SHORE BOMBARDMENT

So far as fire control is concerned, naval gunfire against stationary land targets presents much the same problem as firing at a ship dead in the water (or, with respect to terrain features at a significant elevation above sea level, at a helicopter hovering at fixed altitude over a specific point). The following special aspects of the problem are worth noting:

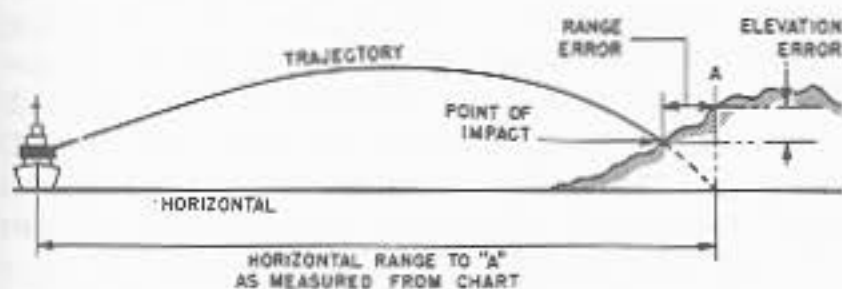
1. Ship's Position. The geographical position of the firing ship must be continuously and

accurately fixed, as from this are determined the range and bearing of the target in many instances when indirect fire must be used.

2. Current Effects. The set and drift of the current will affect the solution of the fire control problem. When determined, drift may be entered into the computer as target speed; the direction of the set is reversed and introduced as target course.

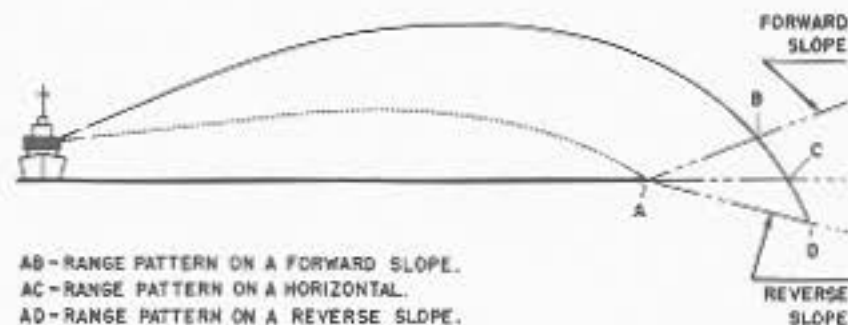
3. Parallax. Unlike normal gunnery practice at sea, it is often necessary to increase the salvo pattern in deflection in order to cover land targets of large area. One method of doing this is to eliminate horizontal parallax correction by setting horizontal parallax correctors at the gun mounts at infinity (i.e., for a target at infinite range) so that gun bore axes are parallel for any specific range.

4. Terrain. Fire control techniques discussed in chapter 6 took into account only own ship and target and the location and velocity of target with respect to own ship. This is necessary because the featureless seascape and the unmarked airspace provide no reference points. On land, however, there are reference points that can be used to assist in laying the guns on target, and in preventing fire on friendly troops, vehicles, and installations. In addition, terrain features complicate correction of the fall of shot. Since solutions assume the point of fall to be in the horizontal plane, the elevation of the target above sea level must be considered in the solution. Figure 9-7 illustrates the errors resulting when the range of a land target is taken from a chart and the target's elevation is not considered. Terrain features also affect the size of the pattern in range; a forward slope decreases it, and a reverse slope increases it. Figure 9-8 illustrates these effects. Consequently, it is clear that shore bombardment almost always involve the use of maps and charts to an extent rarely required in other types of naval engagements.



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Figure 9-7.—Errors resulting from failure to compensate for target elevation.



92.67

Figure 9-8.—Effect of terrain slope on the range pattern produced by ship's guns.

MILITARY GRID REFERENCE SYSTEM

Rapid and accurate means for designating the location of targets are important in shore bombardment. Particularly in naval gunfire support of troop operations, it should be obvious that the troop unit supported and the supporting ship must use a common map. Although they need not be of the same scale, and seldom are, the target maps must be identical regarding terrain features and the method of locating points thereon. Like other techniques of naval gunfire support, the development of a system of target location designations has passed through several stages, following generally a grid-system method. In this method, the land and sea areas at the objective are divided into squares by north-south and east-west lines, which are numbered. These lines are called grid lines.

The Military Grid Reference System imposes vertical and horizontal reference lines over a projection of the earth's surface. Its purpose is to simplify and to increase the accuracy of reporting and plotting in military operations. This grid reference system is based on two projections: the Universal Transverse Mercator (UTM), and the Universal Polar Stereographic (UPS). The UTM is used in the area between 80° south latitude and 80° north latitude; the UPS is used in the polar regions of the earth south and north of these limits. The UTM system divides its area of the earth into a grid pattern with each rectangle in the grid 6° from east to west and 8° from north to south. (Because the grid is rectangular but the earth's surface is not flat, there is some distortion in maps based on the grid, but in any single rectangle this distortion is negligible.)

Each rectangle is called a grid zone, and is designated by a letter and a number (e.g., 2P, 5M, 52S, etc.). The grid zones are broken down

into squares 100,000 meters on a side. These are further subdivided, with the smallest subdivision a 100-meter square. The 100,000-meter square is identified by letters only. In the examples below, CU identifies the 100,000-meter square, and 52S identifies the grid zone. The subdivisions of the 100,000-meter square are systematically identified by letters and numbers, so that in theory any 100-meter square spot on earth can be designated by its number-letter code. This code is called a military grid reference, and it consists of a group of letters and numbers which indicate (1) the grid zone designation, (2) the 100,000-meter square identification, and (3) the grid coordinates; that is, the numerical reference of the point expressed to the desired accuracy. Examples:

52SCU Locating a point within a
100,000-meter square.
52SCU65 Locating a point within
10,000-meter square.
52SCU6957 Locating a point within
1,000 meters.
52SCU693578 Locating a point within
100 meters.

As a matter of practical referencing in a shore bombardment problem, both the grid zone designation and the 100,000-meter square identification are generally omitted. The UPS system in similar fashion permits location and identification of any 100-meter square on the earth's surface near the poles.

Fire-support ships are provided with approach charts and bombardment charts for use on their dead-reckoning tracers. (A dead-reckoning tracer or DRT is a mechanical plotting device, usually located in CIC, that will trace own ship track on a chart or plotting paper to any of a range of scales desired, using as inputs own ship course and own ship speed.) These charts are complete in hydrographic as well as topographic detail, and both have a grid system overprinted on them. These charts are of particular use in indirect fire, to be discussed later.

METHODS OF FIRE AT LAND TARGETS

In conventional gunfire control as described in chapter 6 the target is visible from the ship, either optically or by radar. But this is not always true of land targets; much of the firing any ship performs in shore bombardment will be at targets that nobody on the ship can see through a telescope or a radarscope. Fire at a

visible target is called direct fire; fire at an unseen target is indirect fire.

Direct Fire

Targets visible from the firing ship offer the simplest fire control problem to the ship, and their destruction is easier than targets which require indirect fire. Such visible targets are: point targets, counterbattery targets, targets of opportunity, or area targets. When the target can be seen, the director can furnish accurate target bearing and elevation. These, with a present range which can be measured, ensure an accurate fire control setup which should result in early hits. Direct fire is controlled as it would be for fire against enemy ships except that when the ship is providing call fire support, the fire will be directed, controlled, and spotted by the shore spotter.

Indirect Fire: Use of Bombardment Charts

Indirect fire is employed against targets that cannot be seen by the firing ship. Given an accurate bombardment chart and knowing the exact position of own ship, it is possible to measure range and bearing to any land target that has been designated in advance, and to hit that target without using the director or range-finder.

The ship's position is accurately determined by navigational methods, using positively identified landmarks, and is plotted on the bombardment chart. Since own ship's course and speed are known, future position may be projected ahead along the ship's track by dead reckoning. As in direct fire, because own ship's speed is usually slow (less than six knots), the set and drift of the currents frequently contribute as much movement to own ship as do the propellers. To generate an accurate solution it is essential to use total movement of own ship. To ascertain own ship's speed, CIC keeps a continuous plot by navigational methods; after several plots have been made, the distance traveled is measured against time and an accurate value of speed is calculated. This speed is set into the computer by hand as target speed, and own ship's speed is set to zero. Target course is then set in manually as the reciprocal of drift or true ship's course.

Future positions are projected ahead along the ship's track on the DRT. A future position is chosen, usually one minute ahead, and from this point bearing and distance to the target are

picked off the chart. These values of range and bearing are sent to plot and set into the computer manually. When the ship passes the position chosen, the plotter in CIC gives a "MARK" and the time motor of the computer is turned on. The plotted and computed values of range and bearing are then checked by "MARKING" every 15 or 30 seconds. If the range and bearing agree within reasonable limits (100 yards and $1/2$ degree), plot is ready to fire. If not, the check procedure is repeated and the bearing and range in the computer are corrected until the setup is correct. Plot is then ready to shoot after reporting the gun target line (line between firing ship and target) to the shore fire control party.

Indirect Fire: Point Oscar Method

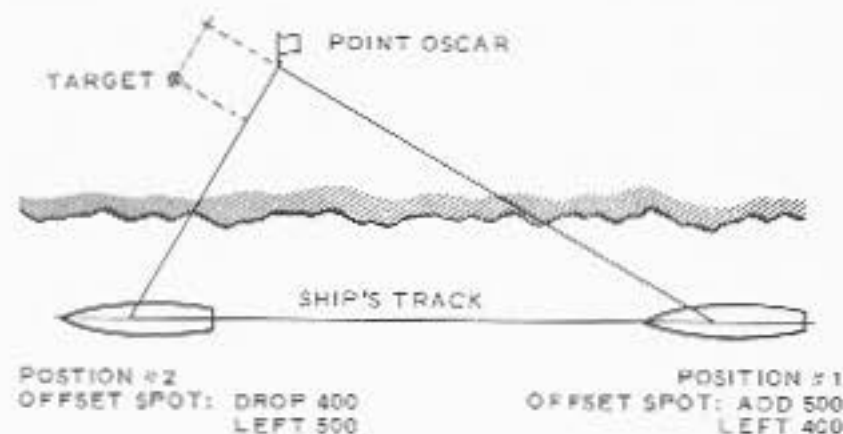
This method of indirect fire was devised primarily for ships with fire control systems incapable of correctly generating range and bearing to a designated grid point. Its use, however, even by the newest ships is advantageous under certain conditions, such as when no shore spotter or air spotter is available for observing the fall of shot. The method requires a visible point of aim (designated "Point Oscar") near the target, as well as the accurate location of the target and Point Oscar on a map.

In practice, the director line of sight is kept continuously trained and ranged on the point of aim (Point Oscar) to give a continuous range and bearing solution to this point. Salvos are initially fired at Point Oscar as a check on the gun ballistic, and as soon as the mean point of impact has been spotted to hit, range and deflection spots necessary to hit the invisible targets are applied.

Since the motion of the firing ship continuously changes the values of the offsets from the point of aim, frequent changes in these offset spots must be made to ensure hitting the target. This problem is illustrated in figure 9-9. One way to determine correct range and deflection spots continuously is to use a small transparent overlay on which are inscribed 100-yard squares drawn to the same scale as the chart. With the center of the gridded overlay on Point Oscar, and the grid lines oriented to the direction of the line of sight from the ship, range and deflection spots to hit the designated target may be read directly from the grid overlay.

Indirect Fire: Radar Beacon

The radar beacon is a portable transmitter-receiver, set up by the shore fire control party,



36.31

Figure 9-9.—Point oscar method of indirect fire, showing necessity for continuous changes in offset spots to hit target.

capable of emitting a characteristic signal when keyed by the transmitted pulse of the ship's fire control radar. This signal is different in frequency from the transmitted pulse, to eliminate the normal echo returns from the shore. The signal is received by the fire control radar when the radar receiver has been tuned to receive the beacon frequency. Extremely accurate ranges and bearings to the beacon may be obtained. It can be tracked manually or in automatic radar control.

The radar beacon is used primarily to aid in the delivery of accurate naval gunfire under all conditions of visibility and to eliminate the errors of normal navigational plotting, using landmarks and other visual navigational aids.

Indirect Fire: Defiladed Targets

Targets which are located on the far slope of a hill or ridge between firing ship and target present a particularly difficult problem to the flat trajectory of naval gunfire. The projectile must clear the crest of the hill but fall steeply enough to hit the target beyond. In this situation (defiladed target) an angle of fall must be chosen which is greater than the angle of the reverse slope. Two solutions are then available. The ship may either increase the range or it may use reduced-velocity charges at shorter range to obtain this selected angle of fall. Figure 9-10 illustrates this problem and its solutions. A is the trajectory produced by standard service charges and is too flat; B is the trajectory which can be obtained by using reduced-velocity



12.23

Figure 9-10. — Problem of hitting a defiladed target.

charges; C is the trajectory which can be obtained with standard service charges by increasing the range.

If the ship must fire over friendly troops on an elevated position between firing ship and the target, it is necessary to determine target elevation, the elevation of the troop position, and the differences between the two.

Indirect Fire: Functions of CIC

The primary function of CIC in naval gunfire support is to keep an exact check on the ship's position and from this to determine ranges and bearings to targets designated for indirect fire. Accuracy of fire, when using the method previously described, depends primarily on the skill of the CIC team. CIC also keeps a record of own troop front-line positions, target locations, and other information pertinent to the support of the troops ashore. It acts as the clearing house for information to and from the shore fire control party and air observer, with whom it has direct voice radio communication. In naval gunfire support, CIC keeps the ship's commanding officer, weapon control, and plot advised regarding the requirements for support; furnishes the information necessary to provide the support; and gives the shore fire control party such information as necessary. In addition to target range and bearing, CIC must determine, from contour lines of the bombardment chart, the elevation of the target above sea level and send this to the plotting room so that range error resulting from this elevation may be corrected in the computer.

On cruisers these functions of CIC are often performed in a section of the plotting room. This leaves the ship's CIC free for other duties it must perform.

SPOTTING IN SHORE BOMBARDMENT

The principles of spotting as discussed earlier in this chapter apply in shore bombardment

spotting, but procedures are different when spots are made by a fire control party ashore.

A spotter ashore must be located where he can best observe the fall of shot. Usually this requires him to be as close as possible to the target; this can present him with a very serious frontline problem of survival. He also has an alignment problem. Spots made by an observer aboard the firing ship are naturally oriented to the line between the firing ship and target (GTL). Spots made from aircraft can be oriented readily to the gun-target line, since both the gun and the target are normally within the aircraft observer's field of vision. But spotters ashore are frequently unable to see the firing ship and, so long as they are required to make their reports in relation to the gun-target line, the value of the information sent by the spotter to the ship is limited.

To simplify this problem for the spotter, the target-grid system for use in spotting the fall of shot on land is used. The target-grid system is part of the standard spotting and general shore bombardment procedure for use within the naval service.

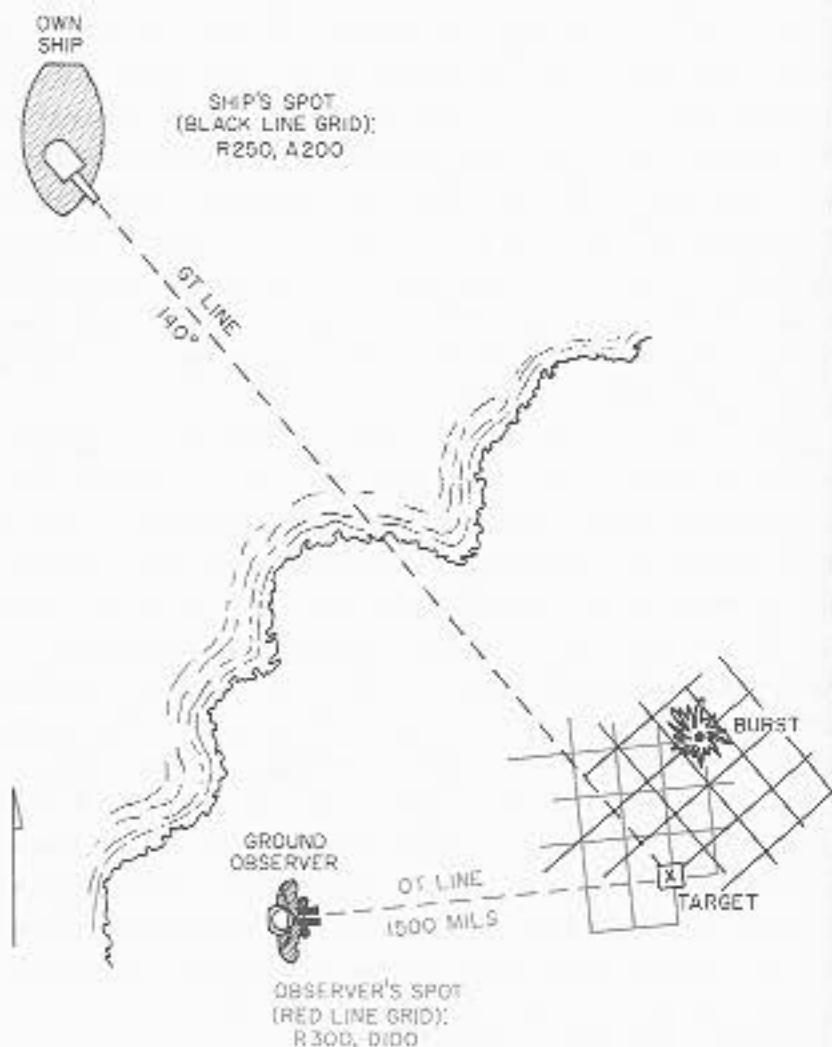


Figure 9-11. — Target-grid spotting problem.

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The system permits the observer to spot the fall of shot just as he sees it along his own line of sight to the target (called the observer-target line), irrespective of the position of the firing ship and of the gun-target line. The procedure is briefly outlined as follows (fig. 9-11):

1. The observer, in his call for fire, must give the bearing from himself to the target—direction OT in the illustration.

2. The observer makes all his observations and corrections with respect to the observer-target line (OTL).

3. The CIC or plotting room crew converts the corrections of the observer to corrections with respect to the gun-target line (GTL).

4. The plotting room crew introduces into the range-keeper (computer) the spots corrected to the gun-target line.

The concrete example which figure 9-11 illustrates is explained in the next section below.

APPLICATION OF THE TARGET-GRID SYSTEM

As stated in the preceding section, the target-grid system permits the ground observer to call his spots with respect to his own line of sight (OTL in figure 9-11), while spots introduced into the ship's fire control system are stated with respect to the ship's line of fire. The practical application of the target-grid system depends on quick, accurate conversion from spots in terms of the observer's line of sight (OTL) to spots in terms of the line from gun to target (GTL). This is done graphically by the grid spot converter, which superimposes a set of coordinates based on OTL upon a set based on GTL.

The converter (fig. 9-12) consists of a transparent circular plastic disc secured by a pivot at its center to a rectangular white plastic piece. Each is printed with a square grid pattern, with the squares on both pieces of equal size, with the words LEFT and RIGHT on either side and the words ADD and DROP on the upper and lower parts. The grid lines on both pieces are numbered; each square represents an increment of 100 yards.

The grid pattern on the white plastic piece is printed in black and inscribed in a circle graduated counterclockwise in degrees; this represents the reference grid for own ship. On the 0-180° line of this pattern is a black arrow. At the top of the own ship pattern appears an additional degree calibration for introducing magnetic variation correction.

The transparent pivoted disc has its grid pattern printed in red; the circumference of its circle (which is concentric with that of the own-ship pattern) is graduated counterclockwise in mils. A red arrow is on the 0-3200 mil line. This is the reference grid for the observer.

The procedure for using the converter is explained below. Figure 9-12 shows the converter set up for the problem illustrated in figure 9-11. Figure 9-11 shows in red the part of the grid pattern that relates to the observer's spots; the black grid pattern relates to own-ship line of fire. Magnetic variation is assumed to be zero.

The procedure is as follows:

1. The converter operator obtains the true azimuth of the GT line in degrees by reading the true target bearing from the computer. He makes a mark with a grease pencil at this azimuth on the lower (black) disc. He then obtains the azimuth of the OT line in mils from the observer (spotter) via CIC. He makes a mark at this azimuth on the upper (red) disc.

2. The operator then rotates the upper disc until the two pencil marks match. (In the figure, GTL is 140° and OTL is 1500 mils.) The red and black arrows now indicate the angular relationship of the observer's line of sight and the ship's line of fire.

3. When a spot is received, the operator starts at the center of the upper disc, which represents the burst, and plots the observer's spot, "Right 300; drop 100," on the observer's reference grid (red), with each square representing 100 yards. The point plotted then represents the target, which is marked with grease pencil.

4. He now goes back to the burst (center) and counts off the squares to the target point as projected onto the lower disc (own ship reference grid). This gives a spot with reference to the ship's line of fire of "Right 250, add 200." This is the spot which is applied to the computer. (R250 is in yards, and must be converted to mils before it can be applied.)

Rectangular coordinate computers, such as Mk 47 and Mk 48, operate on the x/y coordinate principle. Spots are applied as North (y) or South (-y) and East (x) or West (-x) values. Instead of the gun target line, the y axis is used as the reference. This requires that the Grid Spot Converter be changed as shown in figure 9-13. Along the y axis, 0° is labeled as North and 180° as South; along the x axis, 090° is labeled as West and 270° as East.

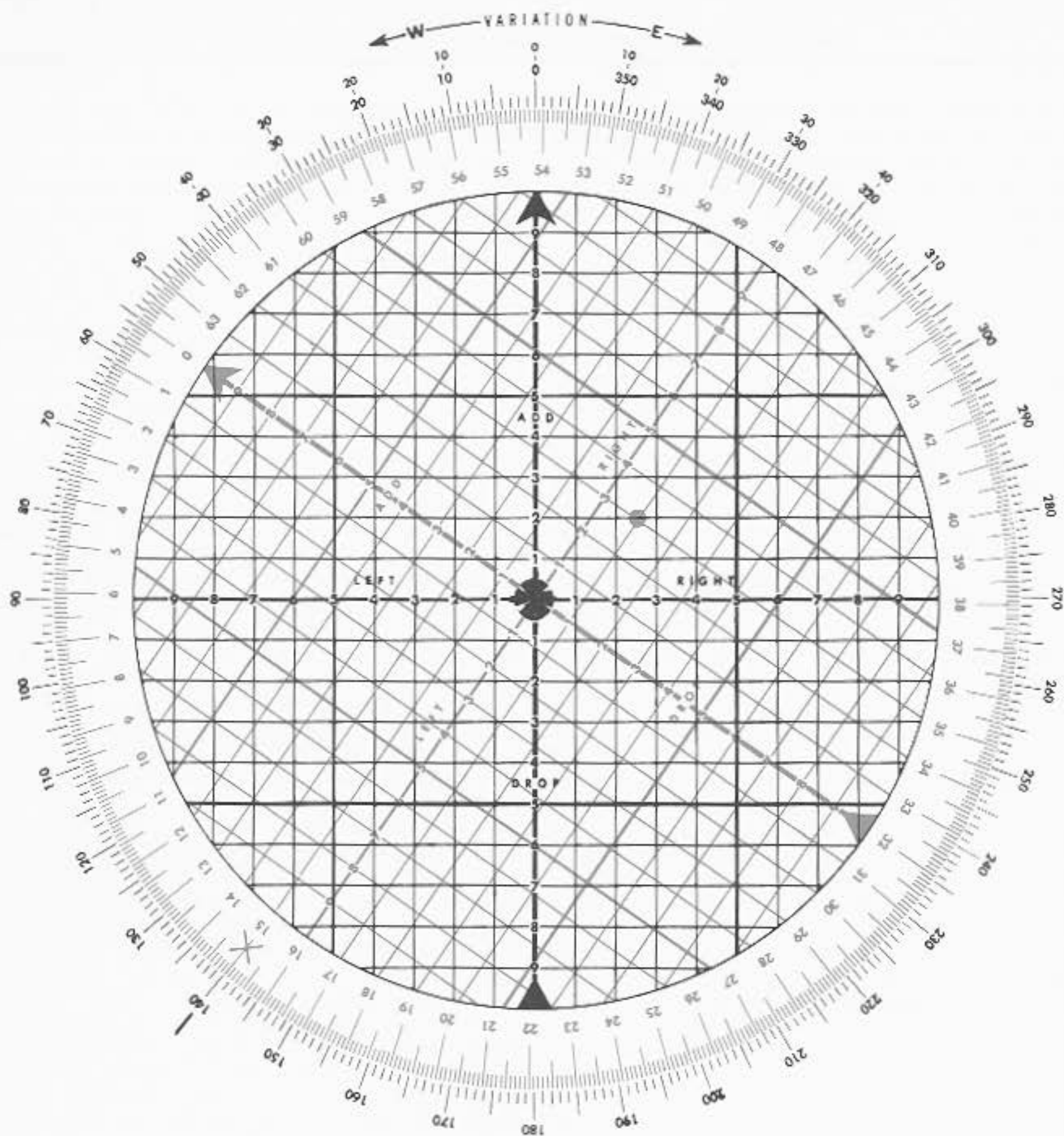


Figure 9-12.—Grid spot converter.

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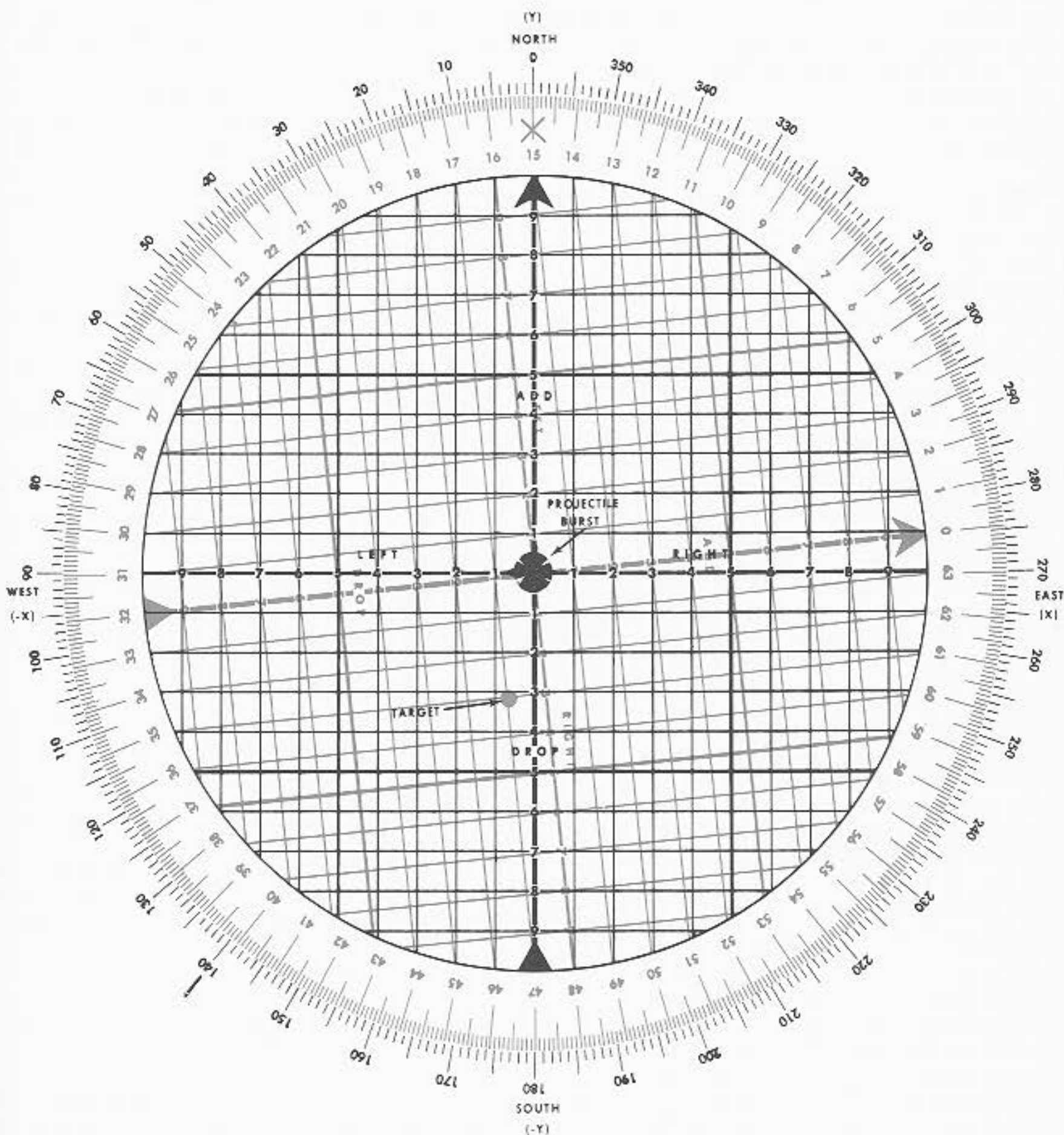
The procedure for spot conversion using the x/y coordinate principle is as follows:

1. Using the same problem as before, mark OTL at 1500 mils on the upper (red) disc (fig. 9-13).
2. Rotate the upper disc until the OTL (1500-mil mark) is aligned with the y axis (North or 0).
3. Plot the received correction on the upper (red) disc as right 300, drop 100.

4. Read converted correction from lower (black) disc as West 75, South 300.

COMPUTERS USED SPECIFICALLY FOR SHORE BOMBARDMENT

Shore bombardment computers are electronic plotting computers which operate in conjunction with the fire control computers in solving the



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Figure 9-13.—X/y-coordinate grid spot converter.

gunfire support problem. They are primarily an electronic DRT, which continuously solves for ranges and for bearings to the target, eliminating all manual plotting. They are fast and give more accurate results. They are particularly effective when used in conjunction with the radar beacon. Some cruisers and new construction DD's are equipped with these computers.

Primarily an "indirect" fire control device, a shore bombardment computer permits blind firing directly from bombardment charts. Figure 9-14 shows the relationship between the shore bombardment computer and the main battery fire control system. The computer provides no ballistic data. It fits into the main battery or 5-inch fire control system between the gun director and the ballistic computer. It receives from the navigating or reference director continuous values of bearing and range to a reference point of aim (either a shore target or a radar beacon). These values establish own-ship position and control the plotting head which continuously indicates ship's track. The tracking head moving underneath a map or the target by means of handcranks automatically inserts the offset between the reference point and target.

The computer then computes the bearing and range to the target. These are transmitted to the ballistic computer, which is operated in the normal manner. The height of the reference point and the target are manually set and used to convert slant range to ground range, and vice versa. Basically, the computer is a triangulation computer which continuously converts bearing and range to a reference point into bearing and range to an offset target.

Since the gun directors train in the deck plane, and thus transmit deck plane bearing information, it is necessary to correct both reference point bearing and target bearing for deck tilt. The computer also computes stabilization signals of level and crosslevel and an aided tracking signal to the navigating director.

Now let us compare the two methods of firing indirect shore bombardment (CIC giving us navigational data and the shore bombardment computer methods). First, let us consider the time element. In the older CIC method it took longer to get a solution because the information had to be plotted on the DRT, relayed to the fire control plotting room by telephone, the put in the computer by hand. In using the shore bombardment computer, inputs of range and bearing are automatic; hence, we have a more accurate first salvo solution in less time. Another factor is that set and drift are no longer required, since

the shore bombardment computer will automatically and continuously compute own ship's position.

Greater accuracy is obtained by using the shore bombardment computer. This is possible because the bombardment chart is laid out on the computer (with inputs in North-South/East-West coordinates), and the fire control radar (instead of the navigational or surface search radar) is used to establish a known range and bearing reference.

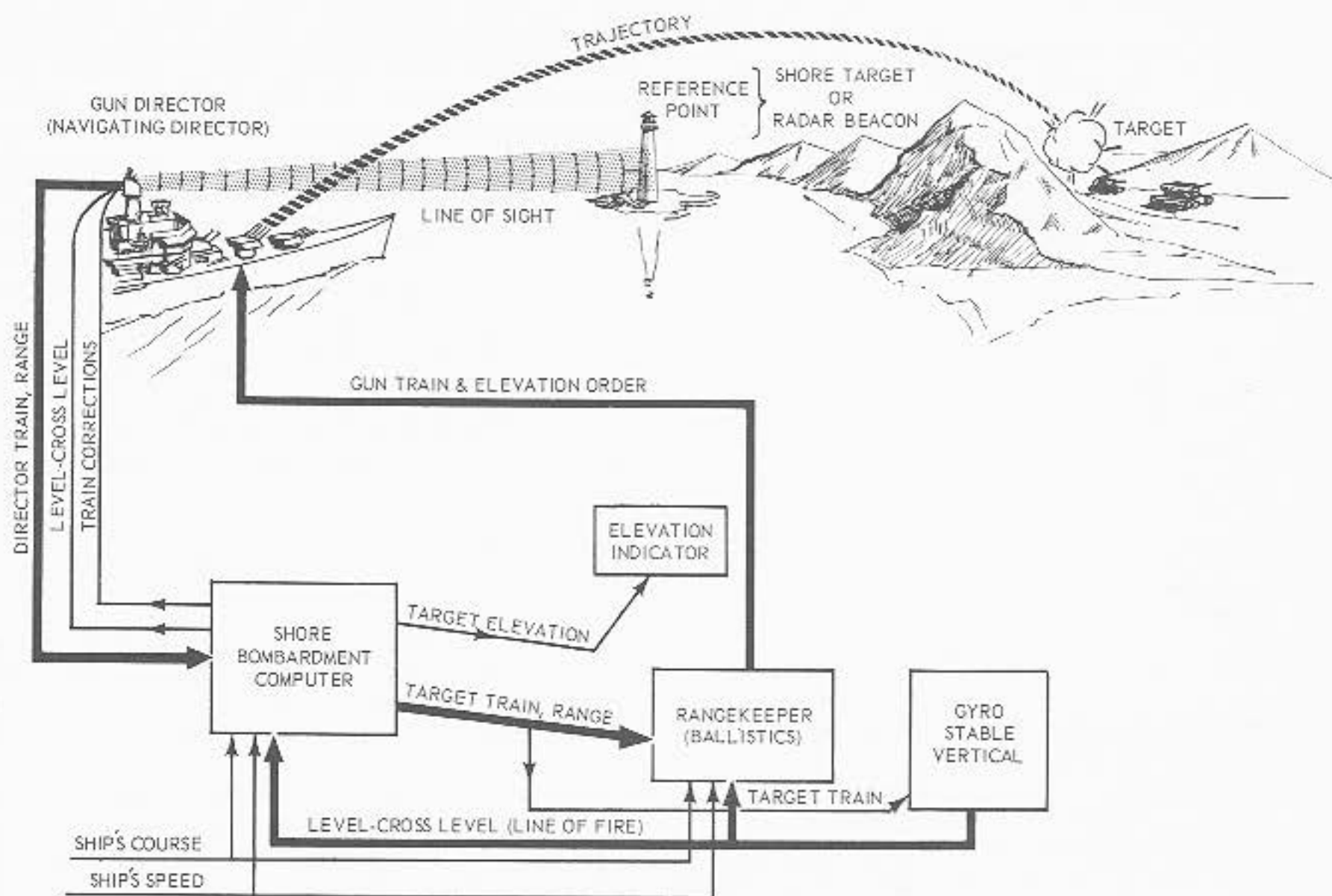
The computer under discussion is the Mk 48. The Mk 47 computer is similar in shore bombardment capabilities; however, it also can be used advantageously in AAW.

SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT: COMMUNICATIONS

Communications in shore bombardment is mainly external. Therefore, only the external aspect of this complex subject will be discussed in this section, and then only briefly. This section can do scarcely more than acquaint you with one corner of this ramified speciality, and even this corner cannot be thoroughly explored here—only surveyed rapidly with attention to a few essentials. Two- or three-day shore bombardment schools are available within the fleet for instructing a ship's "team" in the specifics of shore bombardment communications and procedure.

Figure 9-15 illustrates schematically the communications net (i.e., the participating stations) for a single ship in support of a battalion of troops ashore. The weapons liaison officer (WLO) aboard a ship is located in CIC, where he is connected by battle telephone with plot and the main battery director (the officer usually wears the phones himself) and by radio with the other stations in the net. Most often the radio contact is by voice radio-telephone (R/T) rather than by continuous-wave (CW) code transmission. The officer's voice does not go on the air; he communicates through a radio-telephone operator (not shown in the figure) in CIC, who functions as his talker and also logs the spots and other information received as he gets it.

The radio-telephone transmissions are usually frequency-modulated in the very-high-frequency (VHF) band (e.g., 30 to 300 megahertz) or ultra-high-frequency (UHF) band (e.g., 300 to 3,000 megahertz), although other bands may be used. The shore fire control party uses a portable battery-powered transceiver that can be carried



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Figure 9-14.— The shore bombardment computer.

on the back of one man. With a low power output—which is all that is possible in such equipment—the range is only a few miles, but this is all that is necessary.

The air spotter is usually in a relatively low-speed spotting fixed-wing aircraft (often a light civilian-type one- or two-place plane) or in a helicopter. The spotter and his shore fire control party are in a forward position where they can observe the target area. The naval gunfire liaison officer is usually in a location farther from the target area.

Most of the communication takes place between the spotters and the ship. The naval gunfire liaison officer sets up the net but in general does not participate directly in its functioning unless components in the net are changed, or unless it is necessary to control it for other reasons.

In general, so far as shipboard communication operations in shore bombardment are concerned,

if communications are carried on through CIC, CIC follows these procedures:

1. Locates on the chart the target assigned by the shore fire control party.
2. Furnishes bearing, range, and elevation to control and plot.
3. Checks the computed solution with CIC's plotted solution.
4. Relays spots received from the shore fire control party to control and plot.
5. Plots forward lines continuously and accurately.

SPECIMEN OF SPOTTING COMMUNICATIONS OPERATION

To illustrate an instance of the use of external communications in shore bombardment, table

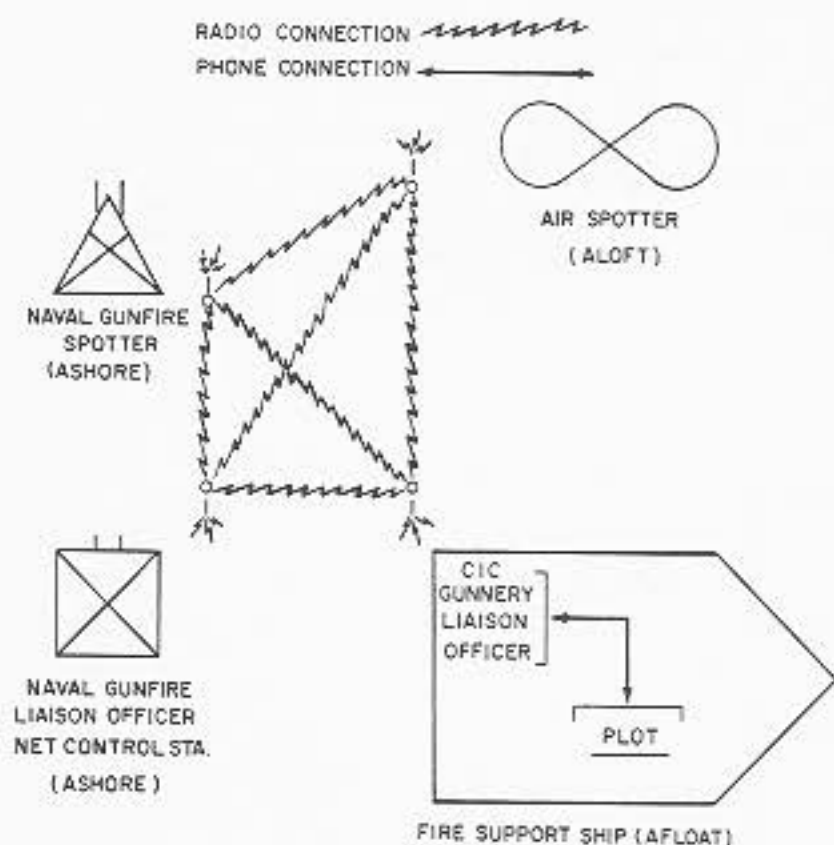


Figure 9-15.—Shore fire control spotting net. Schematic.

9-1 shows a specimen of the voice communication between shore spotter and ship in a simple spotting operation.

The ship's code name is RIFLE; the spotter's code name is EYEPiece. The communications setup resembles that in figure 9-15 except that there is no air spotter and the naval gunfire liaison officer does not participate in the proceedings quoted in table 9-2.

SHORE BOMBARDMENT AND NAVAL GUNFIRE SUPPORT: OPERATIONS

Naval gunfire has many capabilities, advantageous for troop support in landings, which conventional land artillery does not possess. These include:

1. **AVAILABILITY** Gunfire support ships are continuously available before, during, and after the landing, as long as the zone of action ashore is within the range of the ship's guns.

2. **MOBILITY.** Within the limitations of navigation, ships can move rapidly from one area to another as the situation ashore develops. At the same time, the most favorable ranges and lines of fire can be fully exploited, and enemy counter-fire can be evaded.

3. **HIGH RATE OF FIRE.** Power loading and mechanical ammunition supply make it possible to deliver a large volume of fire in a short time. This characteristic is of great value in neutralization missions, where it is necessary to saturate the target area with a large volume of fire.

4. **HIGH MUZZLE VELOCITY AND FLAT TRAJECTORY.** Naval guns, particularly those of heavy caliber, have great penetration and destructive power, especially against installations presenting vertical surfaces.

5. **SMALL DEFLECTION PATTERN.** The comparatively small dispersion in deflection of naval guns makes them valuable for close support of troops when the line of fire can be made parallel to the troops' front line (enfilade fire; figure 9-6B).

LIMITATIONS OF NAVAL GUNFIRE SUPPORT FOR TROOP OPERATIONS

Tactical employment of naval gunfire in support of troops also has certain limitations, which must be considered in both planning and operational stages. The most important are:

1. **Necessity for observation.** Naval gunfire, except for area fire on very large targets, must be observed and corrected to be effective. This requires a spotting agency, such as a ground, air, or shipboard spotter.

2. **Navigational limitations.** Ships are forced to remain in safe, navigable, mine-free waters, and therefore sometimes cannot take advantage of the positions most favorable for the attack of targets. In some cases, ships cannot fire at all on certain defiladed (located on a reverse slope) targets (fig. 9-6A). Obviously, the maximum range inland is limited by the position of the ships, as well as by the characteristics of the weapons used. Further, the fact that the ship is in motion requires the continuous and accurate fixing of the ship's position for delivery of fire on targets not visible from the ship.

3. **Communications limitations.** Radio and visual communications between ship and shore are not as flexible, reliable, or secure as communications by wire or telephone.

4. **Limitations of pattern.** By comparison with artillery, naval guns have a small deflection pattern, a large range pattern, and a flat trajectory. This is an advantage in some respects, but requires careful selection of lines of fire when engaging targets near our own troops. The difficulty of fire against defiladed targets may be overcome by using reduced-velocity

Table 9-4

From	Nature of action	Radio Telephone	Remarks
Ground spotter.	Call for fire.	RIFLE this is EYEPIECE; fire mission; target number nine five zero, over.	a. Target numbers are selected from appropriate instructions contained in operation order.
Ship —	Repetition back	Fire mission, target number etc., out.	
Spotter —	Call for fire continued	Grid six nine three, five seven eight; altitude seven five meters; bearing one five hundred mils; one hundred troops in open; danger close, north west three hundred, high explosive; fuze quick; two guns main armament; adjust fire, over.	b. The spotting may be expressed in mils or degrees, from grid, magnetic, or true north. c. The altitude of the target is always included. Unit of measure is always specified. d. The target description should be brief yet clear enough to permit evaluation by the firing ship and for target intelligence. e. Proximity of friendly troops to target is sent so that the ship can provide for safe firing of the initial salvo.
Ship —	Repetition back.	Grid six nine three — etc., out.	
Ship —	Ready report.	First salvo at southeast, four hundred; ready, one three; fire, over.	Expected position of fall of shot of initial salvo always given when call for fire includes a danger situation.
Spotter —	Fire Command.	First salvo at southeast, four hundred; ready, one three; fire, over.	
Ship —	Repetition back.	Fire, out.	
Ship —	Fire report.	Shot — splash, out —	"SHOT" is transmitted upon firing. "SPLASH" is transmitted 5 seconds before salvo is due to detonate.
Spotter —	Calls the spot.	Right three hundred; drop one hundred, over.	Figure 9-11 illustrates this spot.
Ship —	Repetition	Right three hundred; drop one hundred, out.	

Table 9-4—Continued

From	Nature of action	Radio Telephone	Remarks
Ship —		Shot — splash, out.	
Spotter —		Drop one hundred, over.	
Ship —	Repetition back.	Drop one hundred, out.	
Ship —		Shot — splash, out.	
Spotter —		Left five zero; six guns four salvos; fire for effect, over.	Spotter has enclosed target 100-yard bracket. He halves the bracket, and goes to fire for effect.
Ship —	Repetition back.	Left five zero; six guns four salvos; fire for effect, out.	
Ship —		Shot — splash, out.	Made for first salvo only of fire for effect group.
Ship —		Rounds complete, over.	All fire for effect salvos have been fired.
Spotter —		Spreading fire; left one hundred; add three hundred; six guns four salvos; fire for effect, over.	Spotter wishes to distribute fire over the target area.
Ship —	Repetition back.	Spreading fire; left . . . etc., out.	
Ship —		Shot — splash, out.	Second fire for effect salvo was fired before the first salvo was due to burst.
Ship —		Rounds complete, over.	
Spotter —		Rounds complete; end of mission; 30 troops kia; remainder dispersed, over.	Spotter is satisfied that target is neutralized. No further fire is required.
Ship —	Repetition back.	End of mission . . . etc., out.	

charges or by increasing the range to obtain a greater angle of fall.

5. Limited ammunition capacity. The limited capacity of the ship's magazines, coupled with the fact that a ship must always retain a certain amount of ammunition for its own protection, restricts the ability of any one ship to maintain uninterrupted support over an extended period of time. This disadvantage may be overcome by providing adequate ammunition replenishment and by rotating ships assigned to support missions.

SELECTION OF WEAPONS

Selection of the guns or weapons to be used in naval gunfire support is determined by the nature and size of the target to be engaged, and by the proximity of friendly troops to the target. The 5-inch gun is normally used for close supporting fire; its rapid rate of fire and relatively small pattern size make it an excellent weapon for neutralization and destruction of targets immediately in front of advancing troops. Destroyers are usually assigned close supporting-fire duties because their maneuverability permits them to shift positions easily and quickly and to take positions close inshore for direct fire on targets in coastal areas.

Eight-inch guns, with their great accuracy at long range, are normally reserved for deep supporting fire. The lethal bursting radii of projectiles from these guns limit their employment in close support. Moreover, ships mounting these guns (cruisers) are hampered in responding quickly to fire commands because they are less maneuverable than destroyers, and their fire control organization is more complex. The larger ships also have additional duties. Destructive power of large-caliber projectiles makes them particularly effective against heavy installations ashore.

Six-inch guns are suitable for either close or deep support, but the light cruisers mounting these guns are better adapted for deep support use, since their maneuverability is restricted.

Three-inch and 5-inch guns of DE's and APD's, are suitable for harassing fire missions of the sort often executed against areas remote from our own troops, such as towns, harbors, and coastal air strips. The use of these ships for this purpose provides a necessary feature of support, and releases ships with more accurate fire control equipment for use where precision fire is required.

Three-inch guns are effective for area neutralization where heavier guns are not required.

They are particularly effective against shore-line targets, especially enemy personnel in caves. When such fire is controlled by the dual-purpose gun directors, it is accurate and effective at short ranges; when not so controlled, larger safety margins with respect to own troops must be allowed.

SELECTION OF PROJECTILES AND FUZES

Selection of the projectile type to be used in support of troops depends upon the type of target and the effect sought on that target. Because in shore bombardment a battery is likely to be shifted frequently and rapidly from one target to another (quite likely of different type, requiring a change in ammunition), ammunition-handling personnel should be prepared to change projectiles and fuzes on very little notice.

High-capacity (HC) projectiles are especially for use in shore bombardment. They have great explosive content (at the expense of penetrative ability) and produce a heavy blasting and fragmentation effect. HC is therefore suitable for neutralization or for destruction of relatively light installations.

Antiaircraft common (AAC) projectiles are similar to HC projectiles in explosive and penetrative qualities. Their effective bursting radius of 35 to 50 yards fits them for close-support neutralization fire.

Armor-piercing (AP) and common (COM) projectiles are designed to penetrate armor plate before detonating. Their use in shore bombardment is limited to fire on fixed enemy defenses, such as concrete pillboxes and blockhouses which cannot be reduced by HC projectiles.

Rocket assisted projectiles (RAPs) are used primarily against personnel and light-material shore targets. A secondary use is against enemy shipping at extended ranges.

White-phosphorus (WP) projectiles have been found very useful for screening, incendiary, and antipersonnel effect. They may also be used as "identifying or marker shot" to identify salvos, to permit spotting when the impact burst is invisible due to foliage, or to give a prearranged signal to the troops supported.

Illuminating (ILLUM) projectiles are used to provide illumination only.

Fuzes used with HC, AAC, and WP projectiles may be selected to meet different objectives. Mechanical time fuzes may be used to provide air bursts for maximum effect against personnel and light equipment. They should be

set to burst 25 to 50 feet directly above the target. Proximity fuzes, which require no advance setting, accomplish the same purpose with greater accuracy and less difficult fire control, as they compensate automatically for variations in ground elevation. Point-detonating fuzes also require no advance setting but produce a lower and more concentrated burst, often desirable for demolition. Base-detonating fuzes are, of course, required against armored or other heavy structures.

TARGET INTELLIGENCE

Before the undertaking of any bombardment of land targets, a thorough familiarity with the terrain and hydrographic features of the objective and with the location of profitable targets must be acquired. The study of available charts, maps, aerial photographs, radar PPI simulations, mosaics, and other pertinent information will be necessary for rapid, effective troop support. Normally these charts, maps, photographs, and target information will be furnished each fire-support ship prior to the operation. The systematic destruction of defenses requires the continuous assembly and evaluation of targets known beforehand, and of those discovered in the course of the operation. Damage assessment must be based upon visual observation and photoanalysis. A common error is over-optimism as to the effectiveness of naval fire against land targets.

PHASES OF NAVAL GUNFIRE— SUPPORT OPERATIONS

It is convenient to divide naval gunfire support for a landing operation into three general phases as follows:

1. PRELANDING BOMBARDMENT. This phase, which may commence well in advance of D-day, utilizes quick raids by surface ships to inflict damage and cause confusion, after which the ships retire. Similar strikes may be carried out by aircraft during this phase.

More often the bombardment group will move into position a few days prior to D-day and commence its schedule of prearranged fire which may continue right up to H-hour (the time of landing of the first wave of troops) or may be interrupted by retirement of the bombardment group for reasons of safety.

During this period, the effect sought by the bombardment is destruction of beach defenses,

gun control and observation posts, or any defenses which could effectively oppose the landing. Slow, deliberate, close-range destructive fire is used whenever possible. In this and later phases, the identity of the actual landing beaches may be concealed by a schedule of fire covering other areas. The number of ships engaged in the pre-landing bombardment, its duration, and the type of ammunition expended will depend upon such factors as the number of ships and planes available, logistics (especially ammunition supply), and the nature of the terrain and its defenses.

In addition to its primary purpose of destroying designated targets which may hamper the landing, the force may provide cover for minesweepers, underwater demolition teams, and oceanographic survey vessels. During the night it may engage in harassing fire. During the last hours prior to H-hour it may be called upon for interdiction fire to prevent assembly of reinforcements and prevent their movement into the area of the beaches to man or repair equipment. On D-day, before troops embark, bombardment of strong resistance points is intensified.

The force may also cover final minesweeping operations and the approach of the attack force, especially the transports. When transports are in position, off the landing beaches, fire can be concentrated on strong points which intelligence reports or observation indicate have not been destroyed.

During this period, air strikes are often scheduled to bomb and strafe the beaches. Provisions must be made to control fire so as to avoid hitting friendly planes.

2. SUPPORT DURING THE LANDING. The primary missions of naval gunfire in this phase are to protect the transports while the landing force is embarking in boats, to silence batteries which might destroy the assault waves as the boats move in to the beach, and to cover the actual landing of troops. The barrage must be lifted inland or shifted to the flanks as the troops near the beach to avoid hitting the landing force as well as to neutralize strong points from which destructive crossfire could rake the beaches. In addition to close supporting neutralization fire on the landing and adjacent areas, deep supporting fire must concurrently prevent enemy troop movement toward the landing area and neutralize more remote opposing enemy defenses.

During the last few minutes, as the first wave nears the beach, a final air strike often parallels

the beach, strafing and driving the enemy to cover. Because things happen so fast, and because communications with the troops being supported are rarely adequate in the critical period during and immediately following a landing, most of the supporting fire must be planned in advance, for delivery according to a carefully formulated and coordinated time schedule.

3. POSTLANDING AND TROOP ADVANCE PHASE. Naval gunfire is employed after the landing phase to assist the advance of troops to their final objectives. The postlanding fire schedule must be carefully planned for coordination with the estimated troop advance, but must be capable of quick modification to permit repeating, extending, or discontinuing any portion of the schedule when the advance differs from the plan. Close and deep supporting fire must be scheduled to continue after the landing, to neutralize enemy opposition which would hinder the rapid establishment of organized troops ashore. Scheduled fire after H-hour must last well beyond the estimated time required to establish effective naval gunfire control agencies ashore. With heavily defended objectives, scheduled fire for close support must continue at least an hour after the landing, and for deep support at least 4 hours.

Close supporting fire from ships assigned to them, daily or upon special request, is made continuously available to troop units in the assault. Deep support—including daily destructive fire missions, preparation fire for troop attacks, and night harassing fire—are scheduled for daily execution in fulfillment of troop requests. This phase of naval gunfire support begins upon completion of the prearranged scheduled fire in support of the landing, and continues until naval gunfire is no longer required for support.

PREFERRED PRACTICES IN NAVAL GUNFIRE SUPPORT

Effective support of troops by naval gunfire depends on certain operating principles and techniques of delivery—what might be called tricks of the trade, or recommended operating practice. This section briefly discusses a number of these principles and recommended techniques.

1. PREREQUISITES FOR EFFECTIVE SUPPORT FIRE. Prerequisites for effective support are proper alignment of the fire control system

and gun battery, rapid and reliable internal and external communications, and well-trained ship control, fire control, and gun control personnel.

For optimum effectiveness personnel aboard a firing ship should be thoroughly familiar with the land areas the ship is assigned to cover. This can be achieved through repeated firing, observation, and analysis. Consequently, it is best to avoid shifting ships to different areas of responsibility once their personnel have become acquainted with the areas originally assigned.

2. COUNTERBATTERY FIRE. The first duty of naval gunfire in all phases of support is immediate and effective silencing of heavy enemy weapons which open fire on our forces. Hence, a counterbattery plan anticipating all contingencies must be in constant readiness, and fire-support ships must be ready and alert at all times for the delivery of this fire. If the source of enemy fire is not known, heavy counterbattery fire on suspected sources is delivered until the enemy battery is located. The whereabouts of friendly forces must be kept in mind during such an attack.

3. STEAMING SPEED. Unlike surface or air action at sea, naval gunfire support generally requires moderately low speeds. High speed in a firing ship requires it to make frequent course reversals to remain in its assigned sector, causes inaccuracies in establishing ship's position for indirect fire, takes the ship too quickly beyond effective firing positions, and may result in interference with other activities offshore. The best practice is to select a low speed which will allow good control of the ship and the supporting fire, consistent with the tactical situation and the submarine menace. If necessary, the ship may lie to or anchor, maintaining desired heading by the use of the engines. Best results for indirect fire will be obtained if ships steam on a steady course at constant low speed. However, when extensive counterbattery fire is present, the ship-speed method of gunfire support, developed during the Vietnam conflict, is used. (A description of this method is beyond the scope of this text.)

4. NEUTRALIZATION. Volume of fire required for neutralization of a target area is difficult to establish. The standard volume established before World War II prescribed the equivalent of sixteen 75-mm projectiles per minute per 100-yard square as being sufficient for neutralization. Although the experiences of World War II showed this often to be entirely inadequate, it is still a valuable guide which may be modified as conditions dictate. Experience proved that the

blast effect of bursting projectiles had been highly overrated in neutralizing effect; it was found instead that neutralization primarily depended upon the casualties produced or threatened by flying fragments. Fragmentation effects vary greatly, even in identical projectiles, because they depend on such factors as angle of fall and terminal velocity. For example, the number of casualties may double with an increase in angle of fall from 10° to 60° . Effectiveness of fire for neutralization will also vary with terrain, types of enemy installations, and quality of enemy troops.

5. USE OF ILLUMINATING PROJECTILES (star shells). Illumination of land areas by naval star shells is effective in preventing enemy counterattacks, infiltration, and the movement of enemy troops at night. Its morale-boosting effect on our own troops generally results in requests for exorbitant star-shell expenditures to produce unnecessary illumination of the land area throughout the night. Except during actual enemy counterattacks, star shells fired at a reduced rate and at irregular intervals normally discourage enemy movement. Maximum benefit from the limited supply of star shells available requires judicious control and coordination by troop units to avoid the silhouetting of own forces ashore and afloat. When delivering illumination fire, the line of fire must be so adjusted with relation to our front lines that friendly troops are not endangered by star-shell bodies. Searchlight illumination for troop support is generally unsuccessful; it almost invariably draws enemy fire on the ship employing it.

6. RECOMMENDED PRACTICES IN FIRING. Use direct fire whenever possible. Indirect fire requires more ammunition and time than direct fire for equal destructive success. Indirect fire requires air or ground observation of the fall of shot in order to ensure hits on point targets; this is not essential for direct fire. The effectiveness of naval gunfire is increased by the

employment of an air spotter working with a ground spotter.

Once established, maintenance of the hitting gun range and deflection is essential to effective destructive fire. Periods of continuous slow fire with reduced salvos are therefore preferable to more rapid fire interspersed with relatively long nonfiring intervals.

For decisive destruction of heavy defenses, use, if at all possible, very close-range, slow, deliberate, direct fire. Fire-support ships should usually operate as close inshore as safe navigation, the tactical situation, enemy shore batteries, and the type of fire required will permit.

When close supporting neutralization fire on the landing area in support of troops about to land is scheduled to be shifted on a time basis relative to the estimated time of H-hour, it must be adjusted according to the actual position of the troop landing craft. From reports of landing-craft progress received, but primarily from own observation when possible, fire-support ships must individually determine when their fire is about to endanger troops nearing shore, and accordingly shift the fire from the landing area.

Close cooperation between ships and the troop units assigned for support is essential for information between supporting ships and troop units can ensure intelligent and effective fire support. Of particular importance is the safety requirement that all fire-support ships maintain an up-to-date plot of own troop frontline positions as periodically announced by landing force elements. This not only prevents endangering own troops, but permits selection of the most suitable line of fire with respect to troop lines, and safeguards friendly aircraft operating in the area.

Specific information on all phases of gunfire support in amphibious operations may be found in NWIP 22-2 (latest revision).

CHAPTER 10

AIRCRAFT ARMAMENT

In this chapter, we discuss rockets and their launchers, bombs, and guns used on naval aircraft. Guided missiles are covered in Naval Missile Systems, NavPers 10785 series.

ROCKETS

The use of rockets in warfare is not a recent development; in the thirteenth century they were used by the Chinese in the defense of Peiping against the Mongols. During the first two decades of the nineteenth century an Englishman, Sir William Congreve, developed artillery rockets that weighed up to 24 pounds. The rockets had a range of about 2 miles and were used by the British during the Napoleonic Wars and, in the history of our own country, during the attack of Fort McHenry in the War of 1812.

The revolutionary gun designs later in the nineteenth century, along with the development of smokeless powder, partially eclipsed the further development of rockets as a military weapon until World War II. During World War I, for example, rockets were largely restricted to such auxiliary jobs as signaling, and carrying lines in sea-rescue work. Their only aerial offensive use consisted of tying them to the struts of French and Russian aircraft and shooting them into German observation balloons.

Beginning in the latter part of 1941, the armed forces of Germany, Great Britain, and Russia came out with military applications of the rocket principle. These countries had been working on military rockets for several years before the outbreak of World War II.

Rockets were still much less accurate than guns, but they made up for this shortcoming by the fact that they had no recoil and could be fired from a simple light launcher instead of a heavy gun. They could be used where absence of weight was desirable or a great volume of fire was more important than accuracy. Short-range rockets

were developed for use against shore installations, ships, tanks, aircraft, and personnel. The Germans produced a long-range rocket missile known as the V-2.

By 1941 the United States also had embarked on a rocket program, and began rocket operations in the North African campaign of World War II with the Rocket Launcher M1, popularly known as the bazooka. The year 1943 ushered in the first aircraft rockets; and by the end of the war, a variety of aircraft rockets were in combat use. The rockets to be discussed in this chapter are the present day descendants of these pioneers.

A rocket is a missile propelled by reaction thrust produced by the escape of gases evolved from the burning of self-contained solid, liquid, or gaseous propellants. A true rocket by definition does not, for example, use atmospheric oxygen to burn its fuel.

In general usage, any missile that is rocket propelled can properly be called a rocket. In naval ordnance terminology, however, the unqualified term "rocket" denotes a rocket-propelled missile that is not guided after launching, either by built-in equipment or by command signals from without. Rocket-propelled missiles that are guided after launching are guided missiles, and are covered in Principles of Guided Missiles and Nuclear Weapons, NavPers 10784 series.

Rocket propulsion has two noteworthy characteristics:

1. The propulsion force delivered is independent of atmospheric air, and thus the rocket may be propelled through empty space.
2. The propulsive force is unaffected by the rockets velocity.

PRINCIPLE OF ROCKET PROPULSION

A rocket motor is a metal tube that serves as a combustion chamber. The burning propellant generates hot gas, and the gas pressure within the combustion chamber rises quickly to some

value determined by the amount and characteristics of the propellant and the size and shape of the nozzle (or nozzles). The gas exerts approximately the same outward pressure on each square inch of surface within the combustion chamber; however, the gas rushes out of the nozzle without exerting any force upon the area of the opening, but with exertion of full force upon the corresponding area at the forward end of the combustion. Thus a net force or thrust acts in the forward direction.

A rocket motor is called a reaction motor because its operation is based on Newton's third law of motion: To every action (force) there is an equal and opposite reaction (force). Simply stated, the rocket's propelling force is the reaction of a force acting in the opposite direction.

The conversion of heat energy into kinetic energy is fundamental to rocket propulsion. This poses two basic problems: (1) to generate gas under high pressure and at a constant rate—a problem of chemical reaction; and (2) to direct the high-pressure gases into a high-velocity stream—a problem of nozzle design. Pressure in a rocket motor depends largely on burning rate and escape rate. In solid-fuel rockets, for example, the composition of powder, shape of grain, and rate of burning, which have important relationships to performance as discussed in chapter 4, are also important factors in rocket design.

ROCKET CHARACTERISTICS

The principal factors taken into account in designing a rocket are hitting accuracy, payload weight in relation to overall weight, velocity, time-to-target, type of target, and safety. Many of these factors contend against each other. The guiding factor is the tactical purpose of the rocket.

Lack of recoil is a major advantage of rockets. The force of the propelling gases acts only upon the motor walls. Except for the impinging jet exhaust, no stress is exerted upon the launcher and firing aircraft. Therefore, the launcher may be a relatively simple, light structure.

The rocket carries its propelling forces within it, and a prolonged time of acceleration is possible. This factor eliminates the need for high initial acceleration to attain required velocity. The acceleration given a shell may be approximately 100 times greater than that given a rocket of comparable caliber. Therefore, rocket components may be of relatively light construction.

The mean dispersion of a salvo of air-launched rockets is about 10 to 20 mils (10 to 20 feet at

a 1,000-foot range). This shotgun effect provides high hit probability. Rocket accuracy is comparable to that of a gun on a fixed mount and superior to that of a bomb. This degree of accuracy is all that rockets need. Each rocket carries enough high explosives to destroy the target for which it has been designed.

Modern combat requires the greatest destruction deliverable in the shortest possible time. In this situation, the superiority of rockets over other weapons is decisive.

Characteristics of Trajectory

The trajectory of a rocket differs from that of other projectiles, because a rocket carries its source of power with it. The motor not only increases the size of the missile in relation to its payload but also provides reduced initial velocity, prolonged period of thrust, and increased range potential.

A pilot's personal flying habits are critical to the successful firing of rockets. He must master the aircraft as a launching platform since the rocket trajectory is an extension of his aircraft trajectory and, as such, is sensitive to every variation during the tracking run.

In order to aim successfully at the target, it must be possible to predict the rocket trajectory. The exterior ballistic characteristics of rockets are known, and the trajectory of a rocket launched by an aircraft in unaccelerated flight is relatively simple to predict. The directing forces acting upon the rocket converge in a vertical plane, directing the rocket forward and downward. A skid, however, introduces horizontal influences which destroy this vertical unity, and the trajectory becomes relatively unpredictable. Although the rocket follows the flight path of the aircraft at the instant of release, slight variations of the aircraft will not seriously affect rocket trajectory.

Launching Characteristics

The accuracy of a ground-launched rocket is affected by the launcher length. The launcher has to be of sufficient length to allow the rocket to build up a velocity that will insure stability. The initial velocity of an aircraft-fired rocket is nearly the velocity of the aircraft; therefore, aircraft rocket launchers may be very short in length with no adverse effect upon accuracy.

The effective launching of a rocket in the direction of the flight line may be upset by local air turbulence which acts to increase dispersion. However, the impact of the windstream along the

flight path tends to correct this yaw. The possible effect of local airflow is considered in the aircraft design.

The following factors affect the placement of launchers upon the aircraft:

1. The effect of turbulent air currents about the launcher upon the initial rocket trajectory.
2. The effect of the jet blast of the rocket upon the launcher and aircraft structures and engines.

ROCKET MOTOR DESIGN

Figure 10-1 shows the external appearance of one common type of rocket. The head contains a high-explosive charge and a nose fuze to initiate detonation. The motor contains the combustion chamber, and houses the propellant charge. Hot

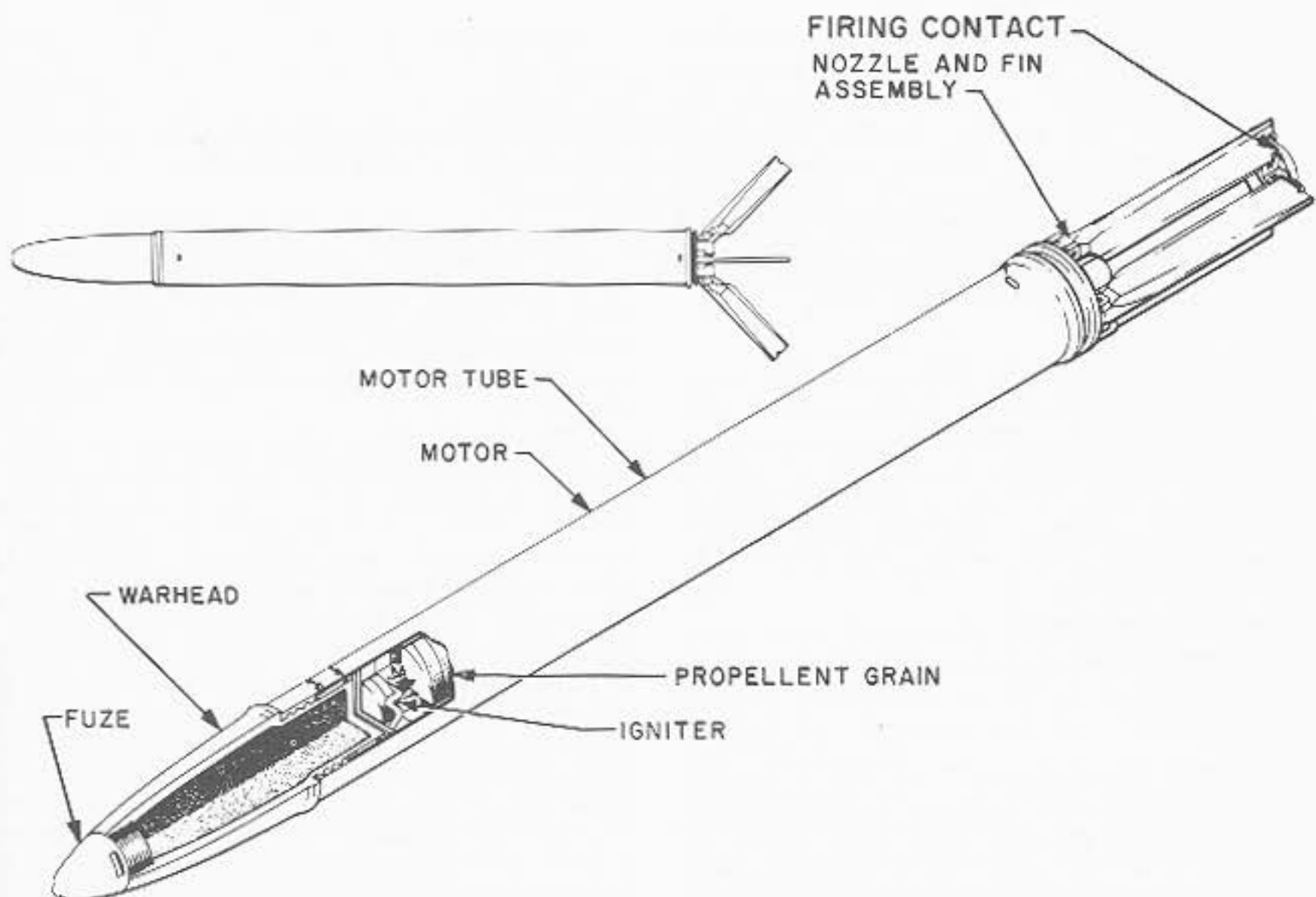
gases from the combustion chamber issue from a nozzle at the after end of the assembly.

The thrust of a rocket motor is, as already stated, an equal and opposite reaction to the thrust developed by the expansion of gases discharged at the nozzle. Since the expansion of gases is maximum in a vacuum, that is where rockets function most efficiently. Rocket motors contain all the essentials for functioning, and do not require atmospheric oxygen for combustion.

The important functional parts of a rocket motor (in the types of rocket discussed in this chapter) are the nozzle, the motor tube, the propellant with its igniter, and the stabilizing features.

Nozzle

The function of the nozzle (of which there are usually several) is to permit the hot gas produced



110.142

Figure 10-1. — Typical airborne rocket.

by the burning ballistite propellant to flow out of the rocket motor, pushing the rocket along as it goes.

For maximum efficiency in developing thrust, gas flow must be non-turbulent. The shape of the nozzle (fig. 10-2) determines the characteristics of gas flow, and hence has much to do with how efficiently the gas flow propels the rocket. For a smooth, controlled trajectory, the nozzle must produce thrust along the long axis of the rocket; and the nozzle must be designed to develop every possible bit of thrust from the flow.

By tapering the rear of the chamber so that it narrows smoothly toward the nozzle aperture, a smooth, non-turbulent flow of escaping gas is created. This tapered section forms the forward half of the nozzle. The tapered extension, forming the after end of the nozzle which leads outward from the nozzle aperture, forces the escaping gas as it expands to furnish additional (about 33 per cent) forward thrust.

Motor Tubes

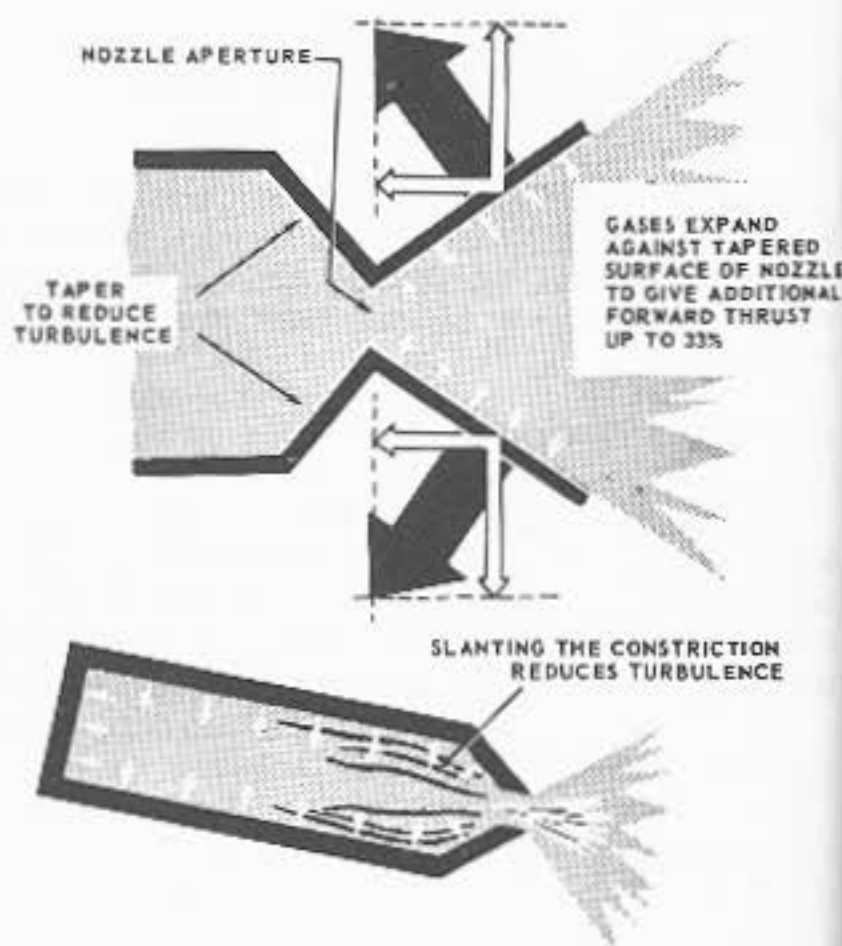
The rocket motor tube contains the propellant charge and igniter. It is a combustion chamber in which the propellant is burned to provide the motive power (hot gases) for the rocket. It generally threads to the rocket or an adapter in the base of the head, and is usually shipped separate from the head. The diameter of motor and warhead is the same.

Propellants

Although a rocket may be propelled by either solid or liquid fuel, airborne rockets utilize only solid propellants. The propellant used is a single-grain, double-based type, consisting of either ballistite or SPCG. The grain is extruded into a perforated star shape (cylindrical with an eight-point star-shaped hole through the center) as shown in figure 10-3.

A salt-coated ballistic rod is suspended in the center of the propellant grain to smooth the burning and suppress the flash, which aids in preventing flameout of the aircraft jet engine.

Inhibitors are designed to restrict or control the flame propagation on the propellant surface. The end inhibitors are molded plastic components bonded directly to the end of the propellant grain. The external surface inhibitor is spirally wrapped ethyl cellulose tape bonded to the propellant surface.



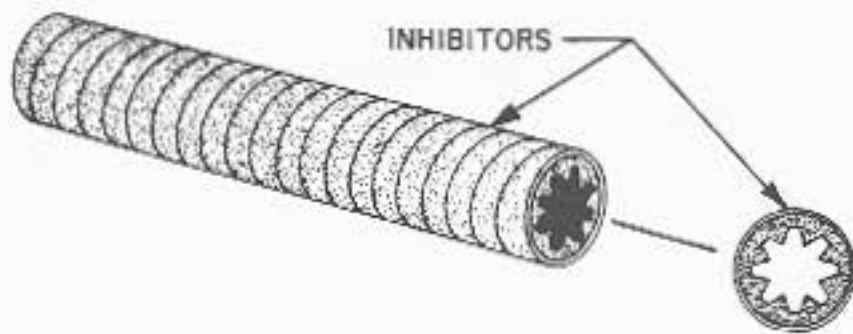
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Figure 10-2. — Features of rocket motor nozzle design (schematic).

PROPELLANT CHARACTERISTICS. — The burning in a solid propellant grain proceeds inward from all ignited surfaces, at a rate determined by the pressure in the motor tube and the temperature of the grain, until most of the propellant is consumed.

Propellant grains burn from about 0.15 to 1.5 seconds, depending on their size, temperature, burning area, and shape. Rate of burning varies directly with initial temperature of the grain. The final velocity attained by two rockets of the same type and launched under the same conditions, except for different propellant temperatures at time of ignition, will be practically the same. However, a rocket launched at 100° F will have attained its peak velocity before the one launched at 40° F. The difference in time required to reach peak velocity will make a difference of a few miles deflection in the trajectories of the two rockets.

Very high propellant temperatures cause such a rapid rate of burning and high pressure that the motor tube may rupture. Very low temperatures cause the grain to burn unevenly, so that spurts of gas called "chuffing" are emitted from the



110.143

Figure 10-3. — Propellant grain.

nozzles or the grain disintegrate, emitting burning slivers of ballistite. When so fired, the rocket will travel only a short distance.

The firing of some rockets is limited to a relatively narrow temperature range compared to that suitable for the firing of guns. The present upper limit for these rockets is about 165° F; the lower limit about -65° F.

Igniter

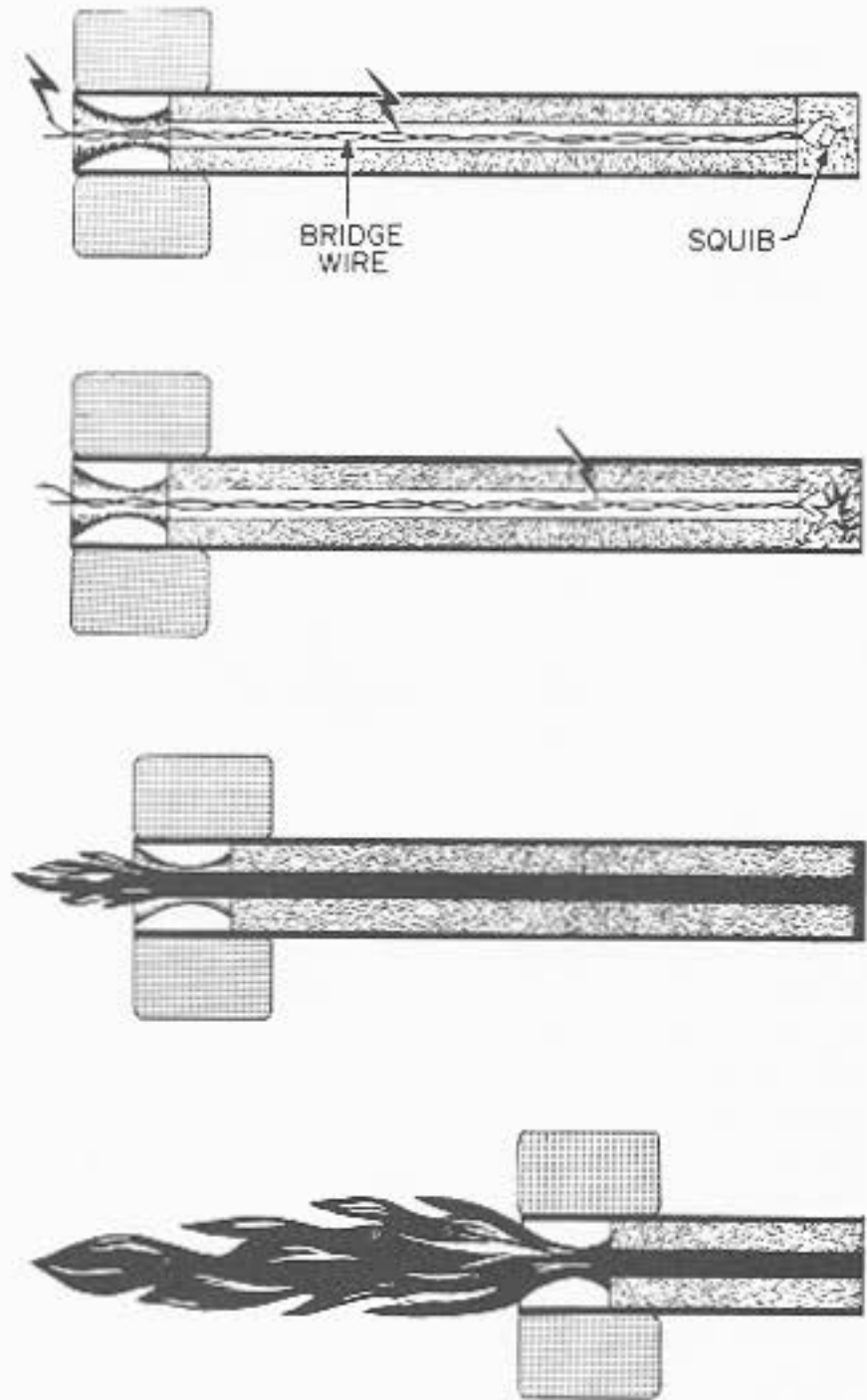
The igniter which sets fire to the propellant grain (fig. 10-4), is located in the forward section of the motor tube adjacent to the grain. It consists of a small container of black powder, an electric impulse heats an electrical filament in the squib which ignites the black powder. This ignition provides just sufficient energy to ignite the propellant without producing undue stress on it.

The igniter is designed to give a response in minimum time with a squib current of 1 ampere or more although as small a current as 0.2 ampere will set off the black powder after a short delay. The nominal resistance of the squib is 1.0 ohm. Therefore, ignoring any line resistance, an emf (electromotive force) of 0.2 volt is sufficient to set off the charge, and 0.75 volt gives satisfactory performance.

The firing impulse is transmitted to the igniter by either a contact disk or a contact band.

The contact disk (fig. 10-5A), which is used with tubular launchers, provides the electrical contact for one of the two igniter leads. The other igniter lead is grounded to the nozzle plate which is electrically connected to the grounded voltage source through the launcher. When the rocket is placed in the launcher, the contact disk is automatically in contact with an electrical terminal which transmits the firing impulse to the rocket.

The contact band (fig. 10-5B), on the forward end of the motor, is covered by a shielding band that must be left in place until just before the



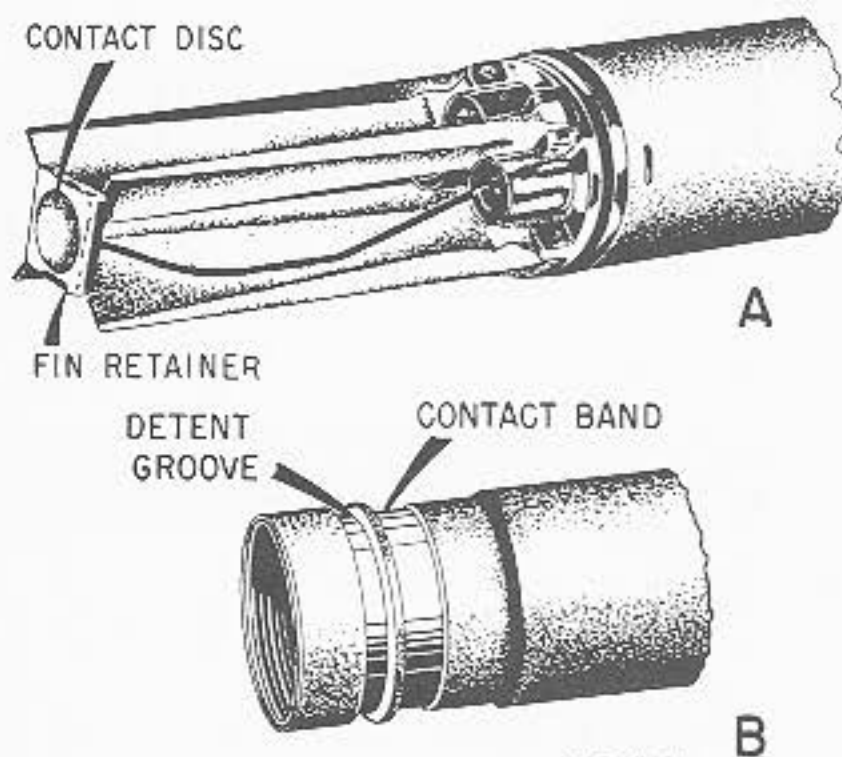
110.95

Figure 10-4. — Igniter operation.

contact band enters the launcher during loading. The shielding band seats in the motor-detent groove and covers the ignition contact band, thereby shorting out the ignition circuit and providing protection against radiofrequency (RF) energy.

Stabilizing Features

A rocket with its center of gravity forward of the nozzle is inherently unstable. If the propellant gas stream develops momentarily an off-center thrust component, or if the rocket as a whole is deflected momentarily by some such accidental cause as a gust of wind, the rocket is likely to



110,144

Figure 10-5. — Electrical leads.

veer or even tumble. To prevent these erratic movements, some form of stabilization must be applied. The classical 18th-century war rocket and its modern Fourth of July descendant used a stick protruding behind the rocket to stabilize it by moving its center of gravity aft. Modern war rockets are stabilized by fins.

Fins provide rocket stability by the action of biting into the windstream, increasing the aerodynamic forces at the rear of the rocket in relation to those at the nose, and causing the center of pressure to shift to the rear. When a rocket yaws, the longitudinal axis of the rocket deviates from its flight path, and the pressure of wind upon the fins exerts a restoring moment which tends to keep the nose directed at the point of aim.

Four or more fins symmetrically fixed at the rear of the rocket comprise the fixed-fin assembly. Fixed fins have the advantages of rigidity and ease of manufacture, but when the size of a rocket is critical, fixed fins are a disadvantage. They extend the diameter of the round, thus limiting the number which may be carried on a given launcher. At the present time, only rocket motors used with guided missiles are stabilized with fixed fin assemblies.

Folding fins (fig. 10-6) are usually hinged in such a manner as to maintain the nominal diameter when in the launcher. Use of folding fins increases the number of rounds that can be

carried and the number which may be fired from a given frontal area.

ROCKET WARHEAD DESIGN

Different tactical requirements demand specific types of rocket warheads to be used with airborne rockets. These warheads are broadly classified as high-explosive (HE), smoke, flare, and practice.

High-Explosive Warheads

High-explosive warheads contain some type of HE material surrounded by a metal case. Within this category are several types of heads, each designed for specific types of targets. These warheads may be divided into the following types (fig. 10-7):

1. HE antitank/antipersonnel (HEAT/APERS).
2. HE fragmentation.
3. HE general purpose (GP).
4. HE antitank (HEAT).

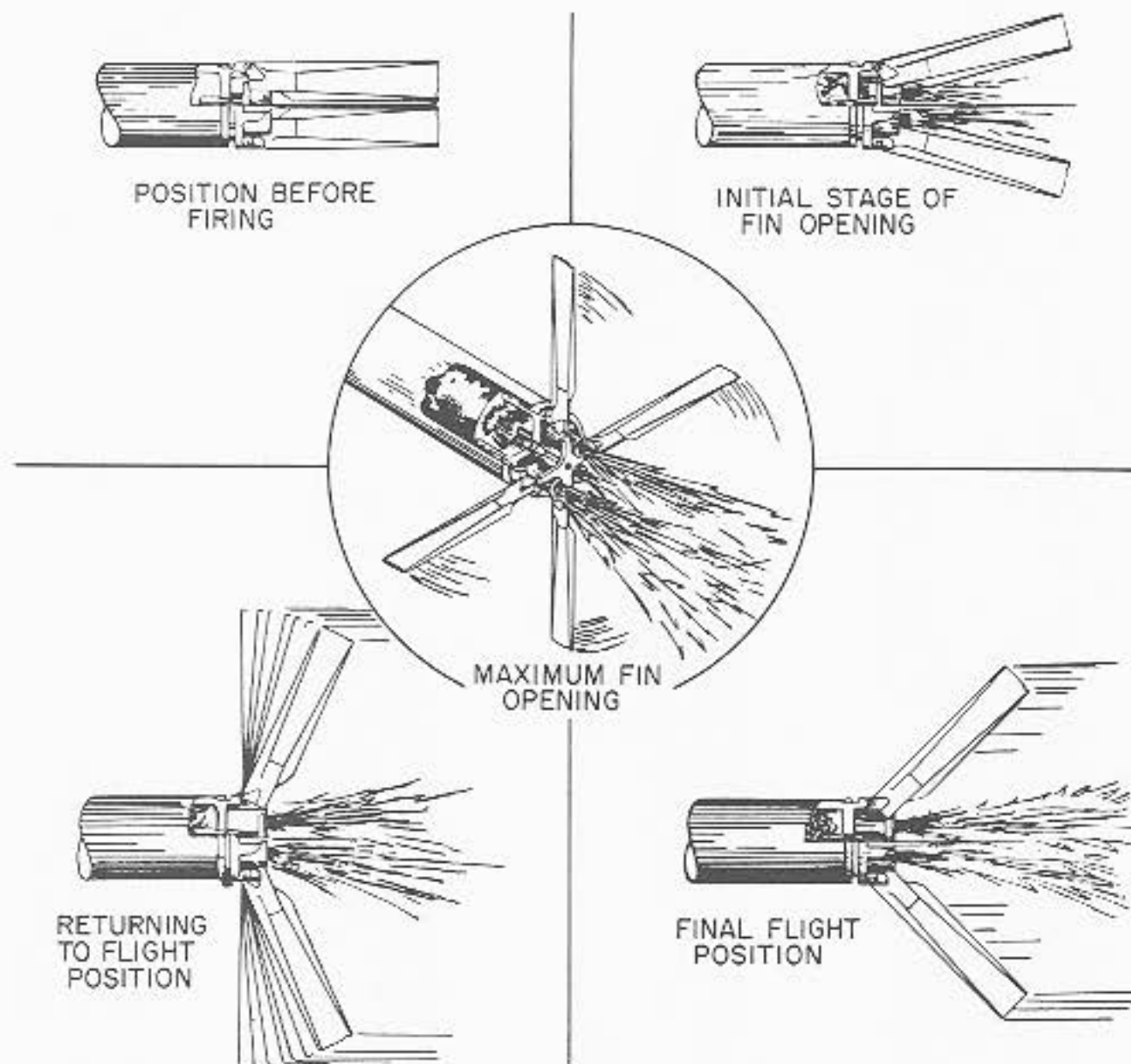
ANTITANK/ANTIPERSONNEL WARHEADS.—The HEAT/APERS warhead (fig. 10-7A) combines the effectiveness of the fragmentation and antitank warheads.

The explosive charge in this type of warhead is detonated at its after end to produce the jet from the cone at the forward end. Detonation by the booster usually is accomplished through transmittal of the explosive impulse by a length of detonating cord that connects the booster charge to the initiating charge, which is adjacent to the nose fuze. The combination of an instantaneous-acting nose fuze and rapid-burning detonating cord permits detonation of the explosive load in time for the shaped charge to produce its explosive jet before being disintegrated by impact on the target.

The warhead in figure 10-7A is fuzed with a proximity fuze.

FRAGMENTATION WARHEADS.—Fragmentation warheads (fig. 10-7B) are effective against personnel and light material targets such as trucks, parked aircraft, etc. The warhead explosive is detonated by either a point detonating or proximity fuze. Upon detonation, the case breaks up into a large quantity of metal fragments that spray the area at a high velocity and cause considerable damage.

GENERAL PURPOSE WARHEADS.—The general purpose (GP) warhead (fig. 10-7C) is a



110.96

Figure 10-6. — Phases of folding fin operation.

compromise between the armor-piercing and the fragmentation designs. Its warhead has a nose section and walls not as strong as those of an armor-piercing warhead, yet stronger than those of a fragmentation warhead. The explosive charge is less than that in the high-explosive antitank warhead.

The GP warhead is for use against a variety of targets. Its maximum penetration may be obtained by using a solid nose plug and a delayed-action base fuze. Its maximum blast effect may be obtained by using an instantaneous-acting nose fuze.

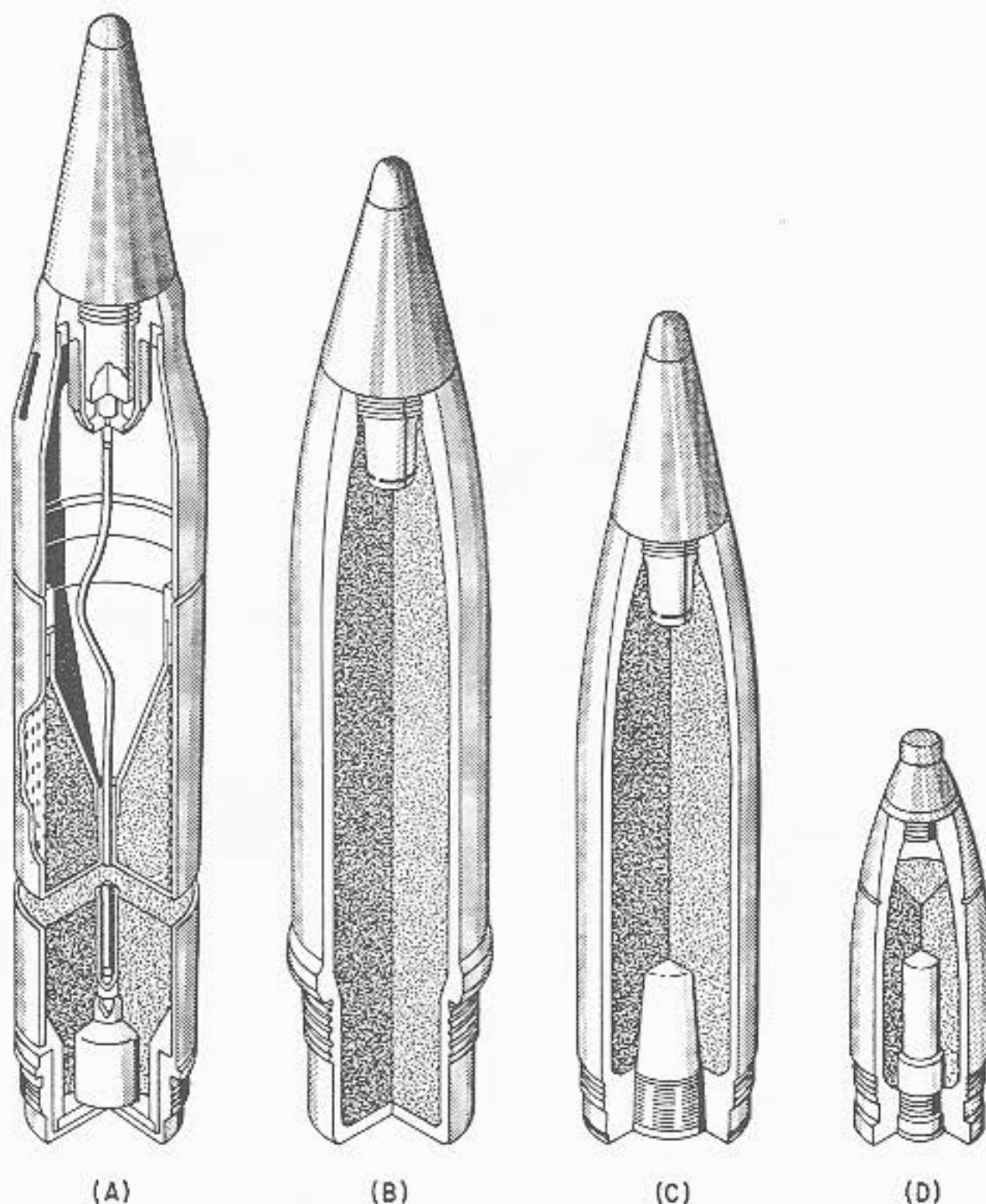
ANTITANK WARHEADS.— The HEAT warhead (fig. 10-7D), developed for use against tanks but equally effective against other armored or fortified targets, employs the shaped-charge principle

of explosives to produce a jet of high-velocity, high-temperature particles.

The explosive jet will penetrate heavy armor (or concrete) but will not produce an explosive blast. The jet will materially increase the temperature behind the armor and, in case of a small enclosure such as the inside of a tank, its searing heat normally will kill the occupants.

Smoke Warheads

Smoke warheads (fig. 10-8) are designed to produce a volume of heavy smoke for target marking. The warhead contains a burster tube of explosive, usually composition B, which bursts the warhead's walls, dispersing the smoke. The warheads are designated SMOKE, followed by the abbreviation for the smoke producing agent it



(A)

(B)

(C)

(D)

110.97(110B)

Figure 10-7. — High explosive rocket warhead: A. Antitank/antipersonnel. B. Fragmentation. C. General purpose. D. Antitank.

contains; for example, WP for white phosphorus or PWP for plasticized white phosphorus.

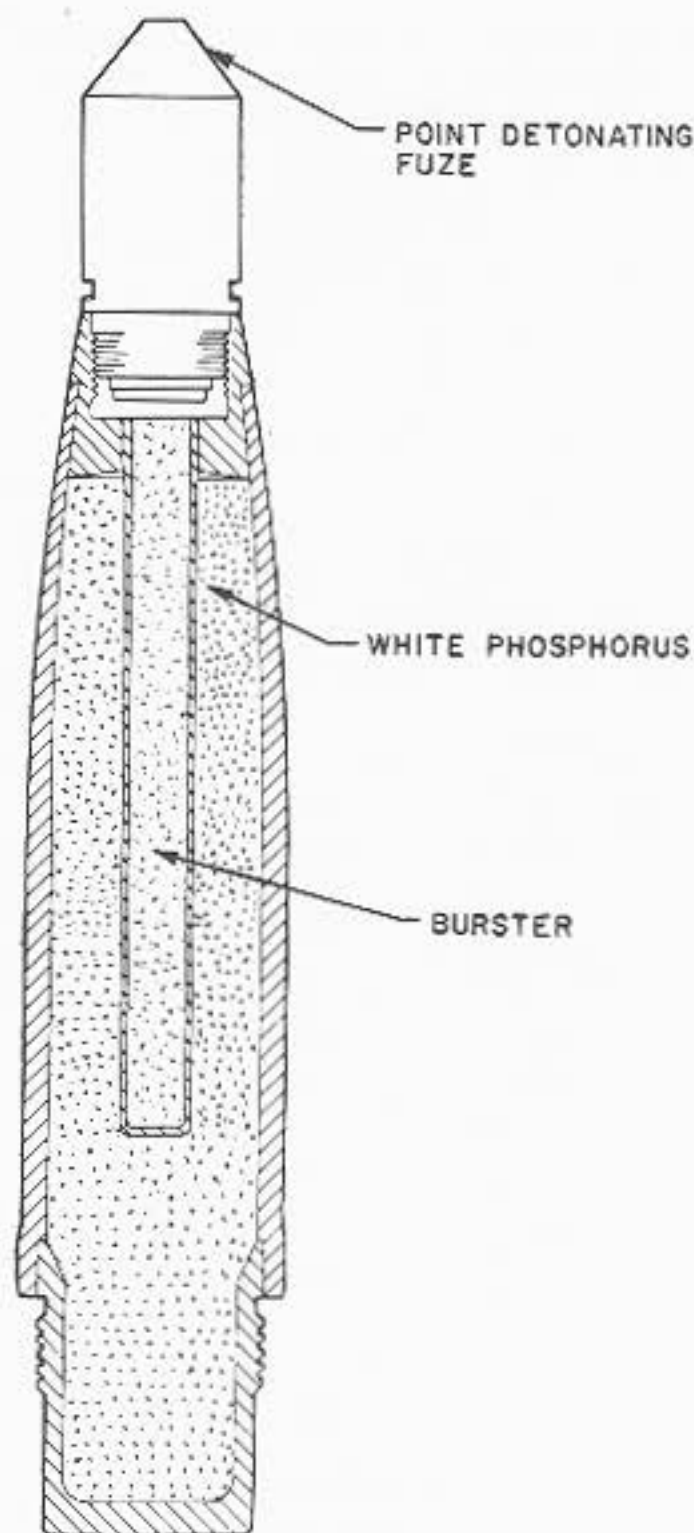
Flare Warheads

Flare warheads (fig. 10-9), designed to provide illumination for tactical operations, consist basically of a delay action fuze, illuminating candle, and parachute assembly. Approximately 15 seconds after the rocket is fired from the launching aircraft, the fuze simultaneously ignites the expelling charge and ignition composition. The expelling charge generates gas pressure sufficient to separate the outer case from the aluminum

base and to shoot it forward, leaving the two inner cases containing the candle and parachute assembly unsupported so that the windstream forces them away from the base. As the rocket continues in its flight, it exerts a pull on an after cable assembly which strips off the deployment bag, allowing the parachute to open and suspend the burning candle.

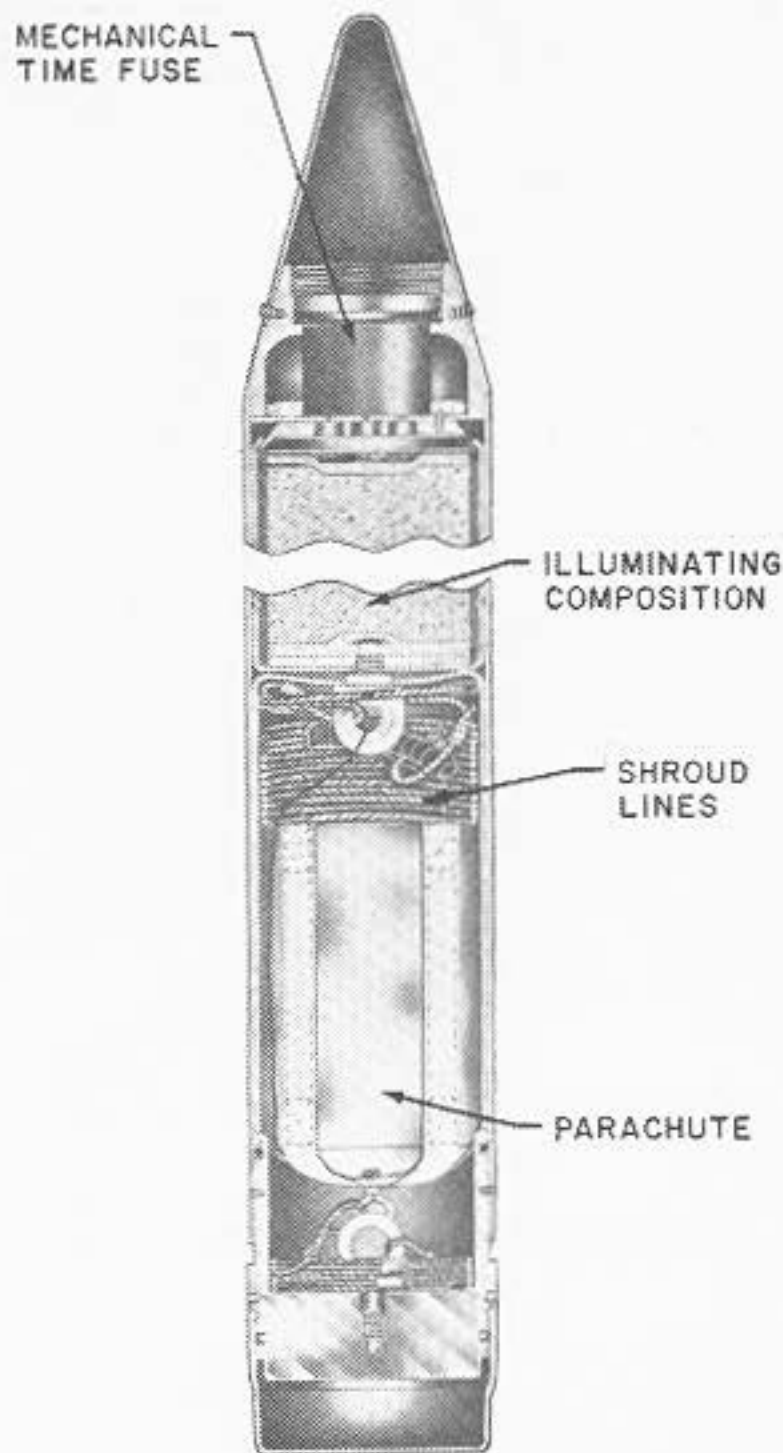
Practice Warheads

Practice warheads (fig. 10-10) are either dummy or inert-loaded service warheads in which



110.145

Figure 10-8. — Smoke warhead.



110.146

Figure 10-9. — Flare warhead.

the weight and placement of an inert filler (such as sand) gives the practice warhead the same ballistic characteristics as those of the explosive-loaded service warhead. A steel nose plug is assembled in the practice heads in place of the nose fuze. Inert loaded heads do not require fuze cavity liners, although some do have them.

ROCKET FUZES

Rocket fuzes are classified primarily according to their location in the warhead: nose fuze or base fuze. They may be further classified by

mode of operation, such as impact firing, mechanical time, or proximity.

Impact firing fuzes are those that function when the rocket strikes a target that offers sufficient resistance to cause crushing or other disarrangement of actuating parts. These fuzes may be located in the nose of the warhead, in which case they are called point detonating fuzes (PDF), or located in the base of the warhead and called base detonating fuzes (BDF). Nose and base fuzes are designed to function either instantaneously or after a short delay that affords the



110.147

Figure 10-10. — Typical practice warhead.

warhead time to penetrate the target before functioning. A typical nose point detonating fuze is illustrated in figure 10-11.

One mechanical time fuze is now available for rocket application. It is designed to sense acceleration, and after a set distance to start a non-settable mechanical timer. At the end of a set elapsed time the fuze initiates the firing train.

Proximity (VT) fuzes are those wherein initiation occurs by sensing—usually by electronic means—the presence, distance, and/or direction of the target.

In general, fuzes contain devices to prevent detonation due to normal transporting, handling, assembling, and launching of the complete rocket. The fuze also is detonator-safe. This means that the explosive train of the fuze is interrupted so that, if the detonator is prematurely initiated while the fuze is unarmed, the booster of the fuze and the explosive filler of the warhead will not be detonated.

In some fuzes, the detonator-safe requirement is accomplished by keeping the detonator out of line with the booster when the fuze is in an unarmed position. In other fuzes, the flash from the detonator is blocked. Arming of a fuze is accomplished by aligning the detonator and booster or opening of the flash path.

AIRBORNE ROCKETS

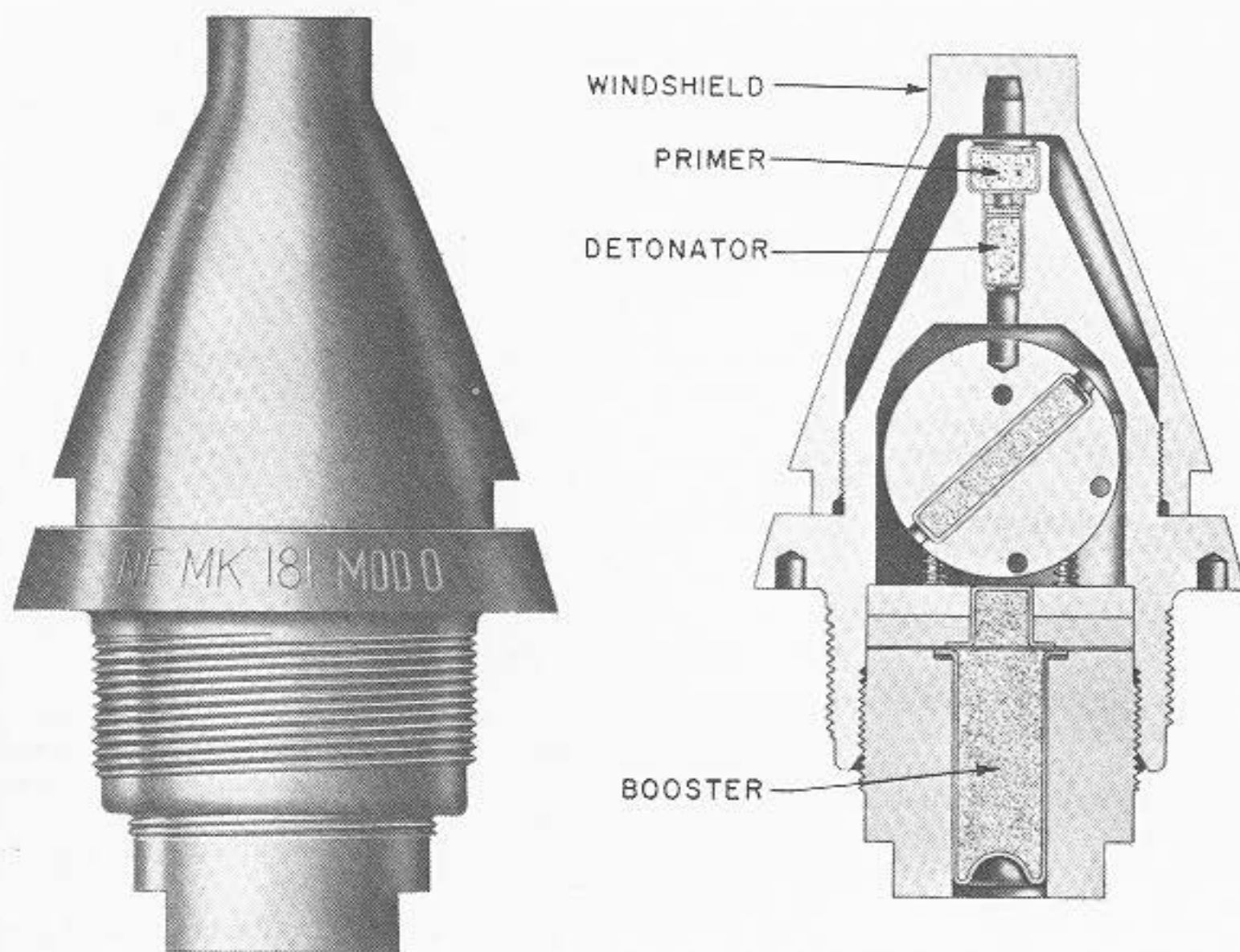
Airborne rockets, consisting of fuzes, warheads, and motors, are combined and assembled in various configurations to meet specific tactical requirements. For example, a rocket assembly consisting of a fragmentation warhead armed with a proximity fuze would be entirely unsuitable for use against an armored tank or bunker. Likewise, the HEAT warhead fuzed with the base fuze would be relatively ineffective against personnel or unarmored targets. With each specific type of target, the right combination of warhead, fuze, and motor can be assembled from the wide variety of available components.

Aircraft rockets are used primarily as forward-firing weapons, which supplement or take the place of forward-firing guns. The virtual absence of recoil in launching aircraft rockets makes possible the use of lightweight gear for such launching, and introduces no stresses inimical to the plane's structures. A modern rocket-firing plane armed with 5.0-inch rockets can deliver one salvo comparable to that of a destroyer. In making such a comparison, however, it must be remembered that the ships can keep on firing, whereas the planes must return to base after delivering their payloads. Generally speaking, rockets provide superior firepower with minimum added weight. The payload of a rocket is less than that of a comparable bomb, but the rocket presents advantages related to accuracy of fire and greater penetration.

2.75-Inch Folding Fin Airborne Rocket (FFAR)

The 2.75-inch FFAR (fig. 10-12) has proven to be an effective weapon against targets such as locomotives, convoys, buildings and bunkers. With the use of the Mk 5 HEAT warhead, the rocket has also demonstrated considerable destructive capabilities against tanks and other armored vehicles.

The 2.75-inch FFAR is designed to be fired in large numbers to produce a shotgun type pattern. Thus, it is carried and launched from packages



110.148

Figure 10-11. — Typical point detonating fuze.

(pods) containing 7 or 19 rounds. (These are described later in this chapter.)

5.00-Inch High-Velocity Airborne Rocket (HVAR)

The HVAR or Zuni (fig. 10-13) is a 5.00-inch, folding fin, high velocity, solid-propellant rocket designed for use by fighter and attack aircraft against ground targets.

Like the FFAR, the Zuni may be assembled in various warhead and fuze combinations. In addition to those combinations authorized for the 2.75-inch, the Zuni may be assembled in variations such as the proximity/fragmentation fuze warhead combination, or in the mechanical time/flare fuze and warhead combination.

Rocket Launchers

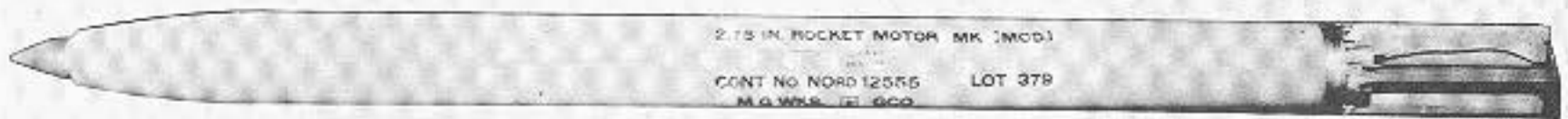
Airborne rocket launcher packages are aluminum cylinders containing horizontally nested

tubes, and are used exclusively with folding-fin aircraft rockets. The design permits multiple loading and launching of the 2.75-inch FFAR and the 5.00-inch HVAR. Aircraft rocket launcher packages provide a means by which rocket motors (and, in some cases, completely assembled rounds) may use the same containers from manufacture to firing.

Frangible paper fairings are used in conjunction with launcher packages. These fairings are attached to both ends of the launcher prior to flight to provide low-drag aerodynamic characteristics. During firing, the fairings are disintegrated by rocket blast and by the forward movement of the rockets.

In most cases, launcher packages are jettisoned after firing, at the pilot's discretion.

2.75-INCH ROCKET LAUNCHER PACKAGES.—The 2.75-inch launcher packages differ



110.98.1
Figure 10-12. — 2.75-inch FFAR.

in capacity, firing capability, and physical dimensions. Those in current use contain either 7 or 19 complete rocket assemblies.

Launchers are shipped with all components assembled. To ready launchers for flight requires only removing shipping hardware and installing the fairings.

The airborne configuration (fig. 10-14) consists basically of three sections—the forward fairing, the center section, and the after fairing.

The fairings fit flush with the outside surface of the center section to form an aerodynamically smooth joint. The forward fairing consists of a one-piece impregnated molded fiber section with an attached metal locking band. The center section contains the suspension system, all electrical circuits, launching tubes with detents, rockets, and the intervalometer. The aft fairing is a one-piece unit assembly similar to the forward fairing but constructed differently because of the function it performs. The rocket blast shatters the nose portion, while the base section remains on the launcher and acts as a choke or funnel to direct debris away from the aircraft.

When the firing switch in the aircraft is closed, electrical power is applied to the system as shown in figure 10-15. Also shown is the firing order of the rockets as they leave the launcher. The firing sequence is 1A, 1B, 2A, 2B, etc. Rocket number 10 is fired last. The firing switch

must be closed for at least one-sixth of a second or a failure to fire may result.

The heart of the rocket launcher is a shunt-fused intervalometer. Electrical power required to operate the intervalometer and ignition system is supplied to the intervalometer by the aircraft's 28-volt d-c armament circuit. The wiring of the intervalometer converts the firing pulse into ripple-firing with a 10-millisecond delay interval between each firing pulse.

5.00-INCH ROCKET LAUNCHER PACKAGES.—The Zuni rocket launcher package (fig. 10-16) is a reusable dual-purpose pod which houses four 5.00-inch motors from the time of manufacture until assembled with warheads and fired at the target.

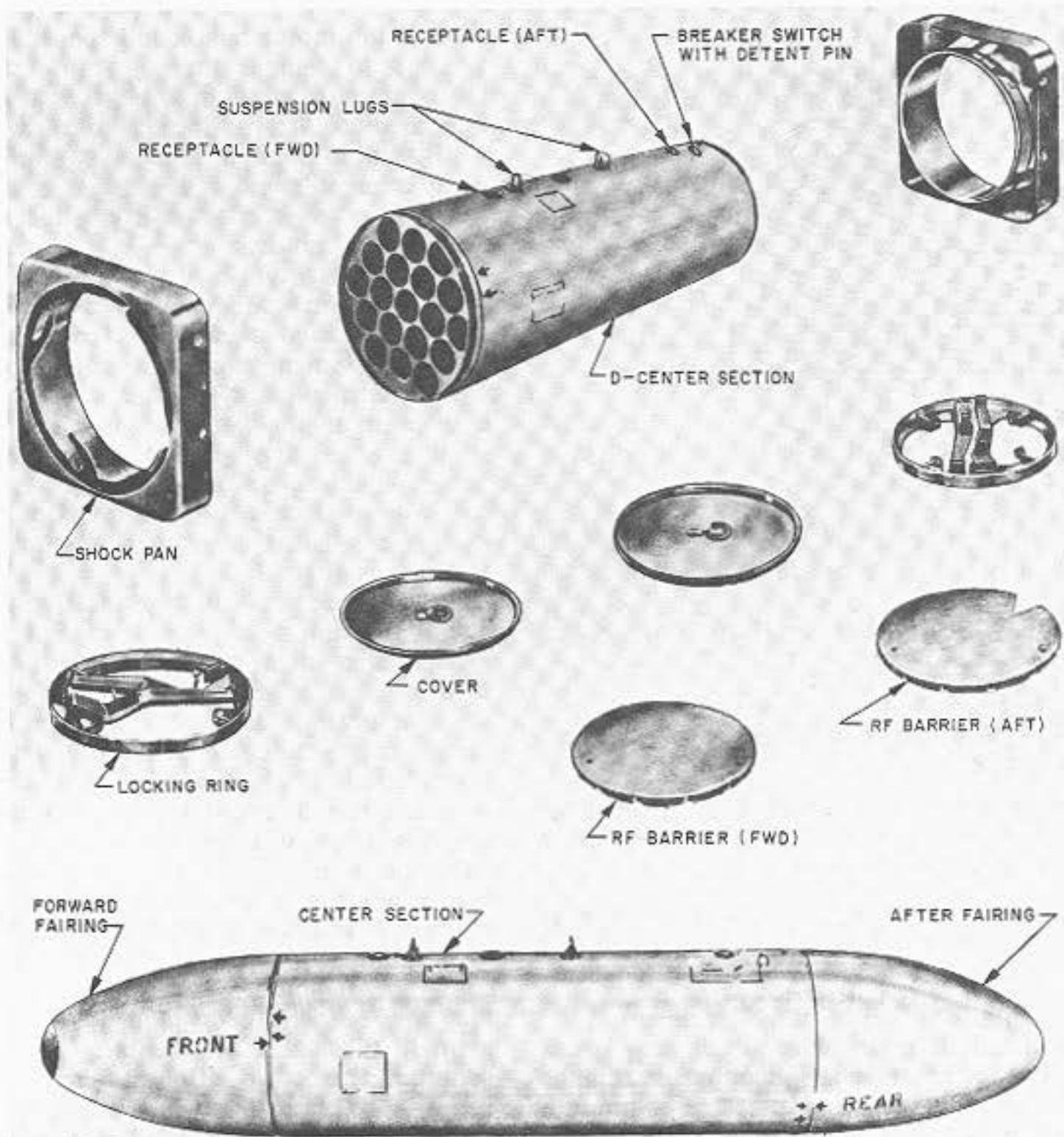
The flight configuration consists of a launcher center section, with the shock pan, cover, and locking assemblies removed, containing four assembled Zuni rockets and a frangible fairing installed and securely locked in place on each end.

The launcher center section contains the four launching tubes, electrical ignition system, suspension lugs, and a sear type detent latch.

Electrical power for the rocket ignition system is supplied to the launcher by the 28-volt d-c armament circuit of the aircraft. Electrical connection between the aircraft and the launcher



110.100.1
Figure 10-13. — 5.00-inch Zuni.



110.149

Figure 10-14. — Typical 2.75-inch launcher package (airborne and shipping configuration).

is made through either of two paralleled receptacle assemblies, located in the vicinity of the launcher center section lugs. As a safety requirement, both receptacles are fitted with shorting plugs and dust caps. A selector switch is located in the after bulkhead of the launcher for preflight selection of either ripple- or single-firing of the rockets. A rotary relay type intervalometer located in the forward bulkhead distributes the firing pulse to the individual rockets and is designed for a 50-millisecond time-delay interval. Electrical connection to the rocket motor is completed in each tube through contact posts

on the detent latch to a contact band on the rocket motor.

Rocket Safety Precautions

The airborne rocket is no more dangerous than any other explosive weapon, but it does have certain peculiar hazards. A completely assembled rocket, if accidentally fired, will take off under its own power in the direction in which it is pointed, with threat of damage to anything in its path. When fired, an assembled rocket expels a blast of burning gas capable of injuring or

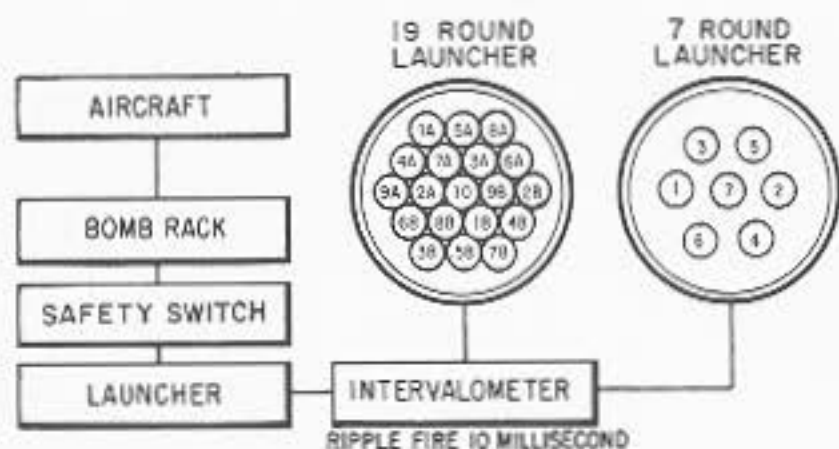


Figure 10-15.—Rocket launcher firing circuit, simplified schematic.

killing anyone it strikes because of concussion or burns.

The following hazards exist in dealing with aircraft rockets:

1. Inadvertent electrical contacts which may set off the rocket.
2. Excessive temperatures or pressures which may cause the motor to explode in a ground fire or in the air when fired.
3. Continued exposure to abnormal stowage temperatures which may cause the propellant to deteriorate, with attendant hazards of possible explosion when the rocket is fired.
4. Rough handling or blows which may break the propellant grain, thus exposing too much surface to burning and leading to possible excessive pressures in the motor when fired.

Generally, a rocket motor without a head attached is unlikely to explode. It does present a potent fire hazard since ballistite or SPCG ignites easily and burns readily. High-explosive heads, either fuzed or unfuzed, present the same risk as do gun projectiles under the same conditions. Rocket, whether completely assembled or disassembled, must be handled with extreme care to avoid damage to parts.

Rocket motors should be stowed in the same manner as smokeless powder. Matches and open flames must never be allowed in the stowage area. Smoking should not be permitted in the loading area within 200 feet of any ammunition.

Rocket motors are not to be fired when the propellant's temperature is outside the safe-firing temperature limits specified on the motor

tube. If the motor has been exposed for more than 1 hour to temperatures outside these limits, the motor is to be maintained within the safe-temperature limits for 6 hours before firing.

Rocket motors must not be stowed in the same compartments with or near apparatus or antenna leads, due to the possibility of induced currents igniting the motor.

High-explosive heads and fuzes (except base fuzes which are permanently installed in the head) must be stowed separately from each other, in the same manner as high-explosive projectiles.

Rocket fuzes shipped in sealed containers are to remain in the sealed cans during stowage. As a rule, noze fuzes are stowed in a ship's bomb fuze magazine, or under conditions specified by the Naval Ordnance Systems Command. Cans should be placed upright in assigned magazines and secured firmly.

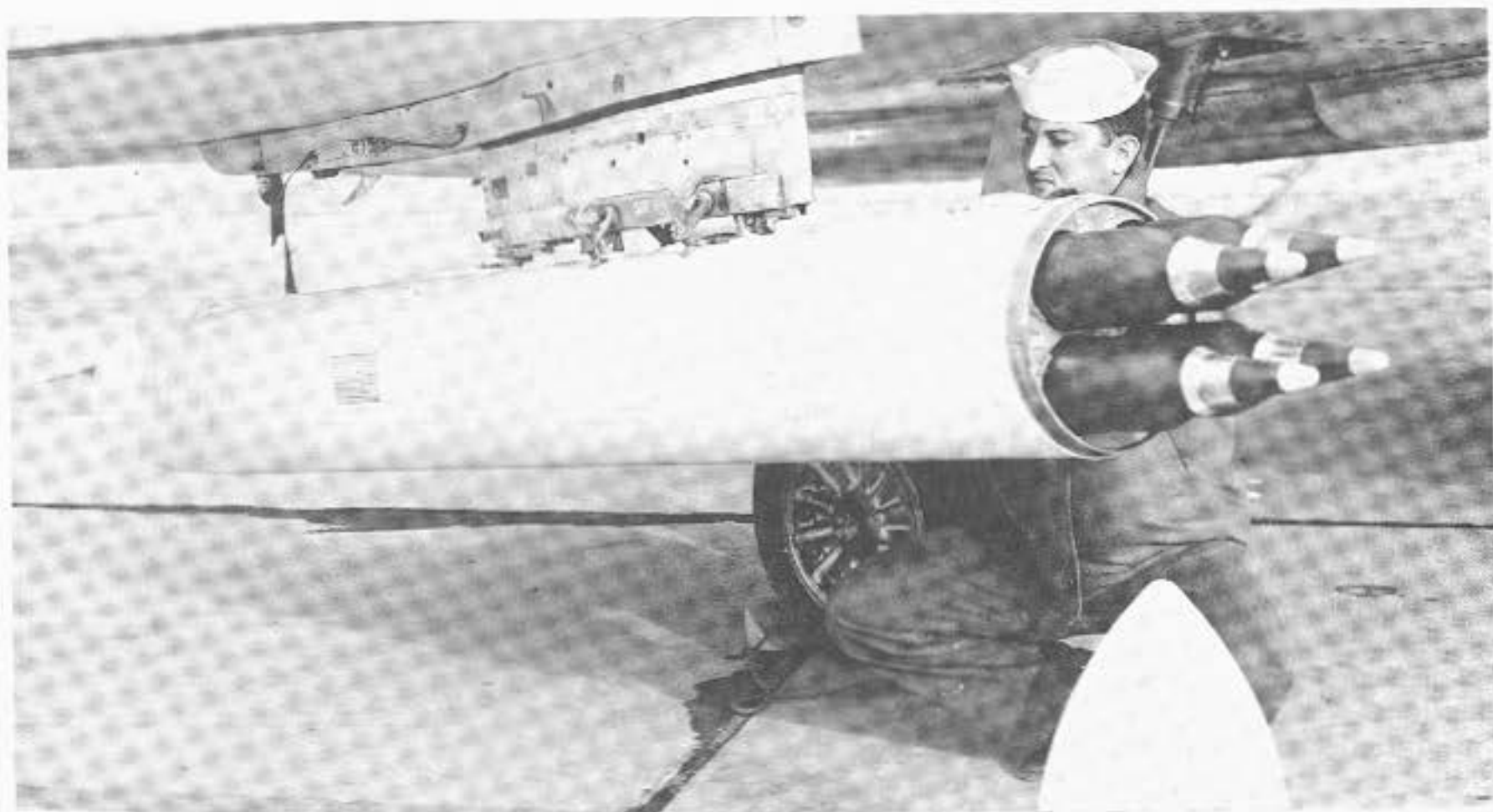
Fuzes are relatively sensitive and must be handled with care to avoid extreme shocks which might cause damage. Operations such as fuzing, unfuzing, assembly, or disassembly of all types of ammunition should be carried on at a distance from other explosives and from vital installations. Only the minimum number of persons and rounds required should be in the vicinity. The ideal situation would be to permit work on only one round at a time, on a deck or at some other location remote from all magazines, ready stowage, explosive supplies, or vital installations.

Examination of the exterior of some fuzes does not indicate whether they are armed. If for any reason it is thought a fuze might be armed, it should be treated as an armed and sensitive fuze. No attempt should be made to remove it from the rocket head. The complete fuzed round should be disposed of by gently lowering it tailfirst into deep water. If available, explosive ordnance disposal personnel should dispose of such rounds.

Disassembly of rocket fuzes is not permitted except as authorized by the Naval Ordnance Systems Command.

AIRCRAFT BOMBS

Aircraft bombs are weapons designed to be dropped upon enemy targets to reduce and neutralize their war potential by destructive explosion, fire, or nuclear reaction. They are used strategically to destroy installations, armament, and personnel, and tactically to provide direct support of our land and sea forces engaged in offensive or defensive operations. Bombs are procured



110.100.2

Figure 10-16. — Zuni (LAU-10A/A) rocket launcher.

both by the Navy and the Air Force, and are used in common by the two services.

This chapter does not take up nuclear bombs. These weapons are discussed in the second volume of this series.

A bomb usually consists of a body, stabilizer, and means of detonation. The body can be filled with either an explosive, chemical, nuclear, or inert filler. Stabilizers attached to the after end of the bomb body consist of sheet metal fabrications.

The efficient destruction of various types of enemy targets requires different types of bombs; these are generally classified according to their filler i.e., high explosive, chemical, napalm, inert, etc.

EXPLOSIVE AND OTHER CONTENTS OF BOMBS

A fundamental characteristic required of the explosive charge of a bomb is relative insensitivity to ordinary shock and heat incident to

loading, transporting, handling, and storing. This insensitivity permits:

1. Adequate safety for the using personnel (when the explosives are handled properly).
2. Maximum target damage by control of the bomb's detonation.
3. Jettisoning bombs from aircraft without exploding, in emergency.

It is evident that these requirements, as with gun projectiles and other explosive devices, make it necessary to use an explosive train in aircraft bombs. In most bombs, the train begins with a detonator containing a small amount of very sensitive explosive. (The detonator is part of the bomb's fuze.) The detonator sets off a rather less sensitive booster; in turn the booster explodes the main charge.

In addition to the different types of explosives required in the individual components of the explosive train of any single bomb, the main charge of any bomb is made up of different explosives, depending on the purpose of the bomb. High explosives used in present types of bombs include TNT, Tritonal, HBX, and H-6. Chemical

agents are chiefly blister gases (vesicants) such as mustard, choking gases such as phosgene (CG), and the blood and nerve gases, hydrocyanic acid (AC). Fire bombs use a mixture of napalm powder and aviation fuel. Practice bombs may be filled with either sand, water, or plaster.

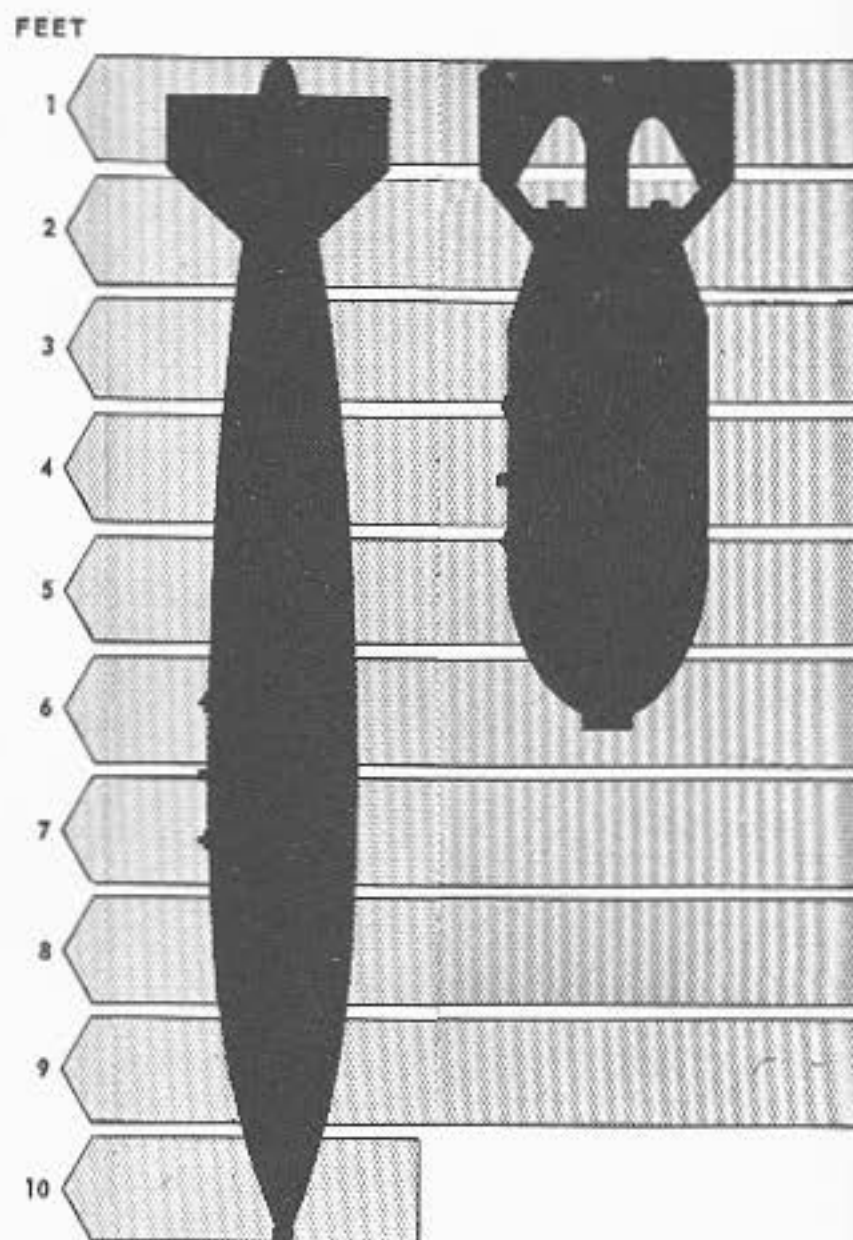
BOMB CONFIGURATION

Aircraft bombs used during World War II and shortly thereafter were designed primarily to provide space for as much bursting charge or other payload as possible without compromising simplicity of manufacture or satisfactory streamlining. This approach resulted in a gratifyingly efficient container whose silhouette was short, compact, and stubby (as can be seen in figure 10-17), economical of bomb bay space, and aerodynamically efficient enough to make the bomb ballistically reliable (i.e., when released from an aircraft under a given set of conditions, it could be depended upon always to land in the same locality).

For subsonic aircraft, this constituted satisfactory performance. But when the speed of bombardment aircraft exceeded that of sound, the hitherto satisfactory bomb shape was found to be poorly adapted to the new conditions either when the bomb was slung under the aircraft's wing or fuselage, or when it was released. Not only was the bomb now a serious detractor from aircraft performance (if carried outside the fuselage), but it could no longer be dropped as accurately. Besides, the mechanical arming wire arrangement used to control bomb fuze arming was apt to tear loose or foul the bomb or parts of the aircraft, causing the bomb either to become a dud or to arm prematurely and become a menace to the aircraft carrying it.

It then became necessary to redesign the aircraft bomb so that it would be satisfactorily streamlined at sonic and supersonic speeds, and so that its fuze's arming could be reliably controlled without danger of its vital parts being damaged by high air speeds. To solve the first problem, the bomb's exterior shape was altered to give it minimum drag at high speed. To solve the second, an internal electrical fuze control system was substituted for the conventional mechanical system.

Figure 10-17 compares the silhouette of a 1,000-pound conventionally-shaped bomb (on the right) with that of a low-drag bomb of the same weight (on the left). The flat forward end on the low-drag bomb indicates that it is set up for a mechanical fuze arrangement. A low-drag bomb



3.119
Figure 10-17.—Silhouettes of a low-drag bomb (left) and a conventional bomb (right).

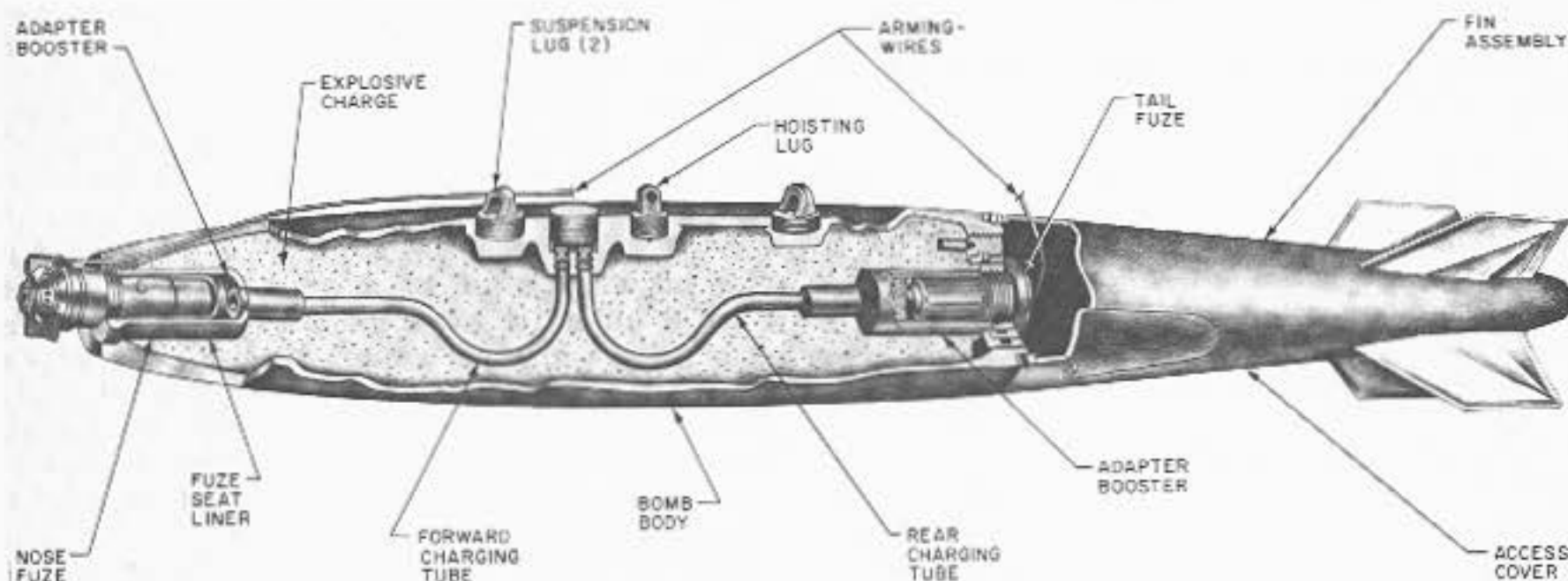
set up for electric fuzing has a smoothly streamlined nose that comes to a point.

BOMB COMPONENT NOMENCLATURE

A COMPLETE ROUND denotes a bomb with all its components as it is suspended from the rack or shackle of the aircraft ready for flight. Some of the major components of bombs are listed below and illustrated in figure 10-18.

BOMB BODY. The bomb body is the container that holds the filler.

FIN ASSEMBLY. The fin assembly is the flight stabilizer of the bomb and usually is made of sheet metal. In newer types of bombs, a conical fin assembly with better aerodynamic properties is used.



110.151

Figure 10-18. — Typical aircraft bomb, cutaway view.

FUZE. Fuzes initiate bomb detonation. They contain sensitive explosives and should be handled carefully.

ARMING WIRE ASSEMBLY. This consists of either a single or double wire attached to a swivel loop, and is used to keep the fuzes safe prior to release of the bomb from the aircraft.

SUSPENSION LUGS. Suspension lugs are screwed into the bomb body either 14 or 30 inches apart, depending upon the size of the bomb.

HOISTING LUGS. These lugs are screwed into the bomb body usually between the suspension lugs, and are used to handle and hoist the bomb.

FILLER. The type of filler depends upon the prospective use of the bomb. The filler charge in high-explosive bombs is usually cast (melted) loaded with the explosive material mentioned earlier.

ADAPTER BOOSTERS. Adapter boosters are explosive loaded bushings threaded on the outside for insertion into the bomb body, and threaded on the inside to receive the fuze. Current general purpose bombs require adapter boosters in the nose and tail when using mechanical fuzes.

CHARGING TUBES. Charging tubes are conduits placed inside the bomb before the explosive charge is loaded. These tubes contain the circuitry which connects the electrical fuzes to the aircraft charging gear.

MARKING AND IDENTIFICATION

Bombs and bomb components are completely identified by standard nomenclature and ammunition lot numbers stamped on all packings as well as on the item itself. Items of Navy designs are designated by the word Mark or its abbreviation (Mk) followed by a numeral. Modifications of the original design are indicated by the term "Mod" and followed by a numeral.

Items of Army or Air Force design consist of the letter "M" followed by a numeral. Modifications to the original design are indicated by the letter "A" and the appropriate numeral added to the model designation.

Certain items have been standardized for use by all services. The model designation of such an item is prefixed by the letters "AN".

The designations T1, T2, etc., indicate a developmental item. While in the development stage, and when a major change is incorporated, the item will take a designation such as T1E1 or T1E2. Such a designation indicates a change affecting military characteristics or installation.

Bombs are painted in various color schemes as a ready means of identification. Color bands, depending upon their color, size, and location, indicate the type of bomb and the type of explosive filler used. Identification markings and the bomb's color provide further identification of it. The color coding system for bombs is described in the sections concerning each type of bomb.

CLASSIFICATION OF BOMBS

Aircraft bombs are classified according to filler as follows:

1. High explosive.
2. Fire.
3. Chemical (gas).
4. Free-falling missiles.
5. Practice.

High-Explosive Bombs

High-explosive bombs are used for the destructive effect caused by blast, fragments, and vacuum pressures created by above-surface explosions, and the mining effect, or earth shock resulting from their detonation.

High-explosive bombs are divided into three main groups as follows:

1. General purpose.
2. Depth.
3. Fragmentation clusters and cluster bomb units (CBU).

General purpose bombs have slender bodies with long, pointed noses. These bombs were primarily designed for external carriage and electric fuzing. However, they still retain the mechanical fuzing capability. An electric fuze may be installed either in the nose or tail fuze cavity. When a proximity function is required, a sensing element is installed in the nose cavity which provides an electrical signal to initiate the tail fuze. GP bombs are equipped with a steel nose plug which is removed when installing a nose fuze or a sensing element. When only a tail fuze is installed, the nose plug is left in place. A base fuze hole shipping plug in the rear of the bomb is removed when an electric fuze is installed in that position.

The loading factor (ratio of explosive weight to total bomb weight) of the general purpose bomb varies from 40 to 60 percent. The explosive filler is either Tritonal or H-6, and is identified by yellow stenciling and a yellow band around the bomb's body. The bomb's body is olive drab. A typical general purpose bomb is illustrated in figure 10-18. Table 10-1 lists the various types and particulars of the current general purpose bombs.

General-purpose bombs may be fitted with a special type of fin assembly (fig. 10-19) which is designed to provide the attacking aircraft with a low-level, high-speed bombing capability without

the normal associated hazards of ricocheting bombs or blast fragments.

The Snakeye fin assembly in figure 10-19 presents a low drag configuration in the closed position. In this position, the bomb performs in the normal free-falling manner. In the open position, however, four paddle-like fins are released and deployed into the airstream, thus slowing and stabilizing the bomb during descent.

The aircraft depth bomb, designed for attacking submarines or underwater targets, was widely used during World War II. In the past they have ranged in size from 325 pounds to 700 pounds; the only one used at present is the AN-Mk 54 Mod 1 (fig. 10-20), weighing approximately 350 pounds and loaded with HBX-1.

Depth bombs have a loading factor of about 70 percent and are armed either for impact or for underwater explosion at a preset depth. The setting range is from 25 to 125 feet.

The desired effect of a depth bomb is to create a pressure wave against underwater targets great enough to crush the hull plates of the target.

Depth bombs are painted olive drab with yellow nose and tail bands.

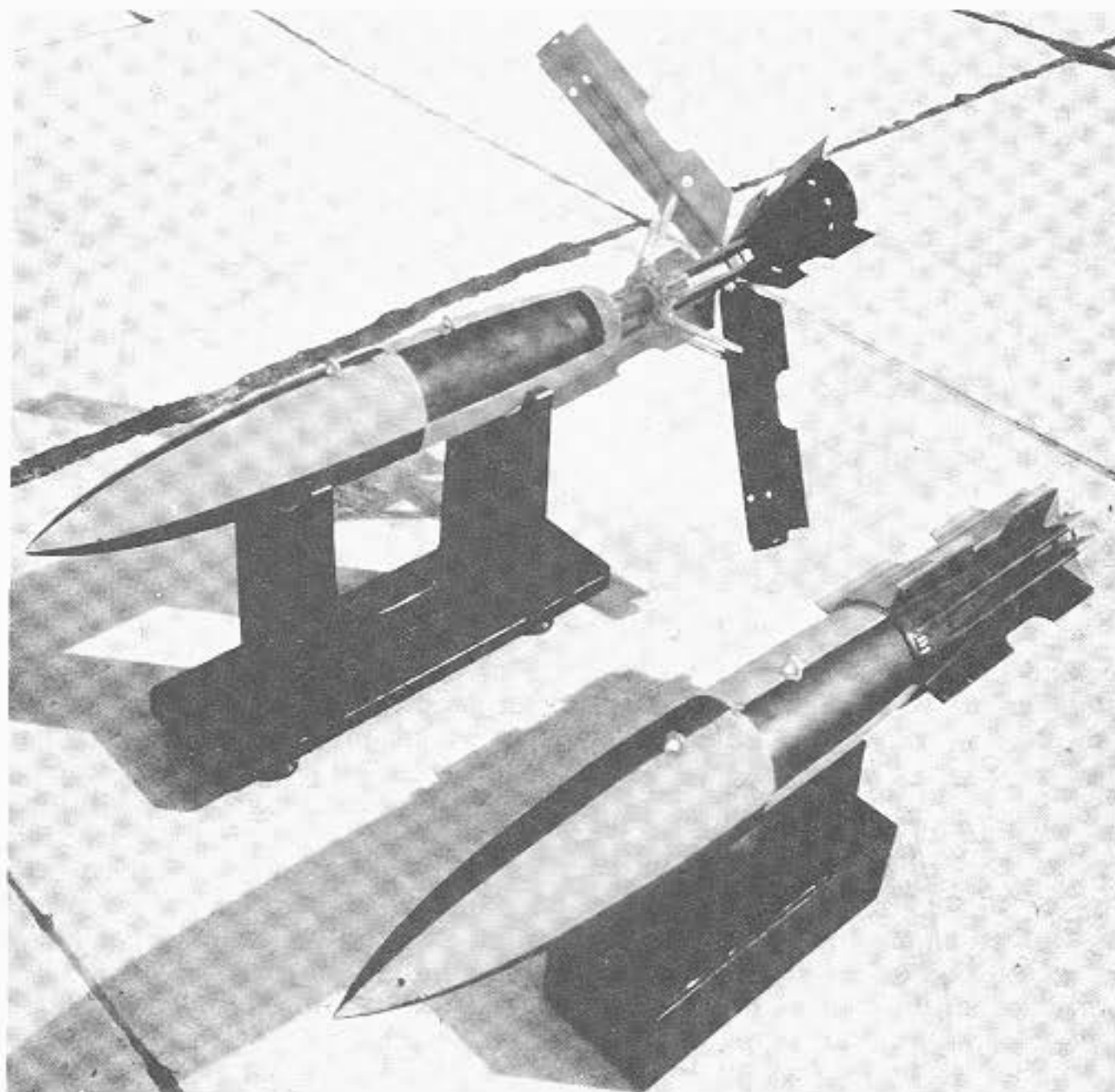
Cluster bomb units and fragmentation clusters are some of the Navy's more recent developments. These units and clusters contain various numbers of small explosive bomblets that are dispersed over a wide area by ram-air action or by the opening of a container by mechanical time fuze action. These bomblets are highly effective against troops, convoys, and other lightly armored targets. Due to their security classification, only limited information is available.

Fire Bombs

Fire bombs (fig. 10-21) are thinskin containers of gasoline gel designed for use against dug-in troops, supply installations, wooden structures, and land convoys. Fire bombs rupture upon impact and the burning mixture spreads and covers the surrounding area. The chief use of the fire bomb is for low-level, high-speed attacks.

Chemical (Gas) Bombs

Chemical (gas) bombs resemble GP bombs in shape and size. The body of the chemical bomb serves as the filling's container and support for the components. These bombs have a full-length burster charge which splits the bomb case and disperses the FILLING over the area to be contaminated. Chemical bombs are fuzed to explode instantaneously upon contact, or to provide an aerial burst.



110.103
Figure 10-19. — Snakeye.

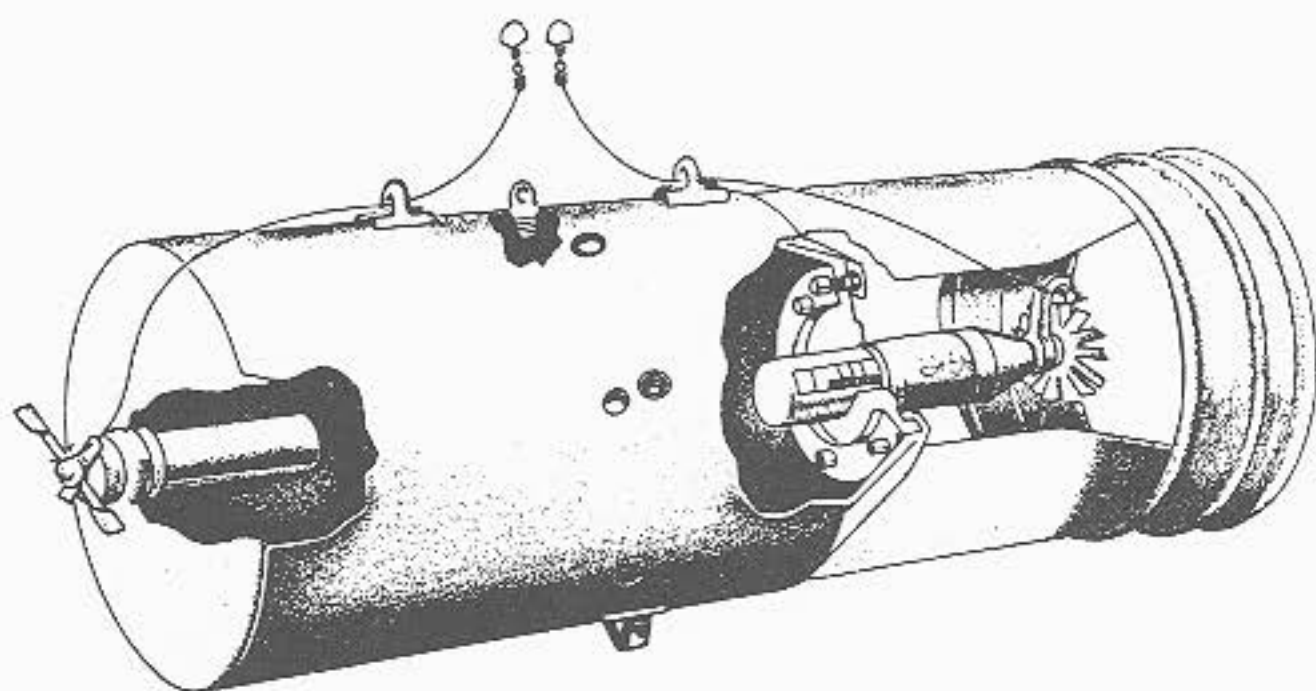
Table 10-1. — General Purpose Bombs

	Mk 81	Mk 82	Mk 83	Mk 84	M117A1
Weight class (pounds)	250	500	1,000	2,000	750
Assembles weight (pounds)	260	531	985	1,970	750*; 799**
Filler weight (pounds)	100	192	445	945	360*; 384**
Assembled length (inches)	74.1	86.9	118.4	151.5	84
Diameter (inches)	9.0	10.75	14	18	16.1
Suspension (inches)	14	14	14	30	14

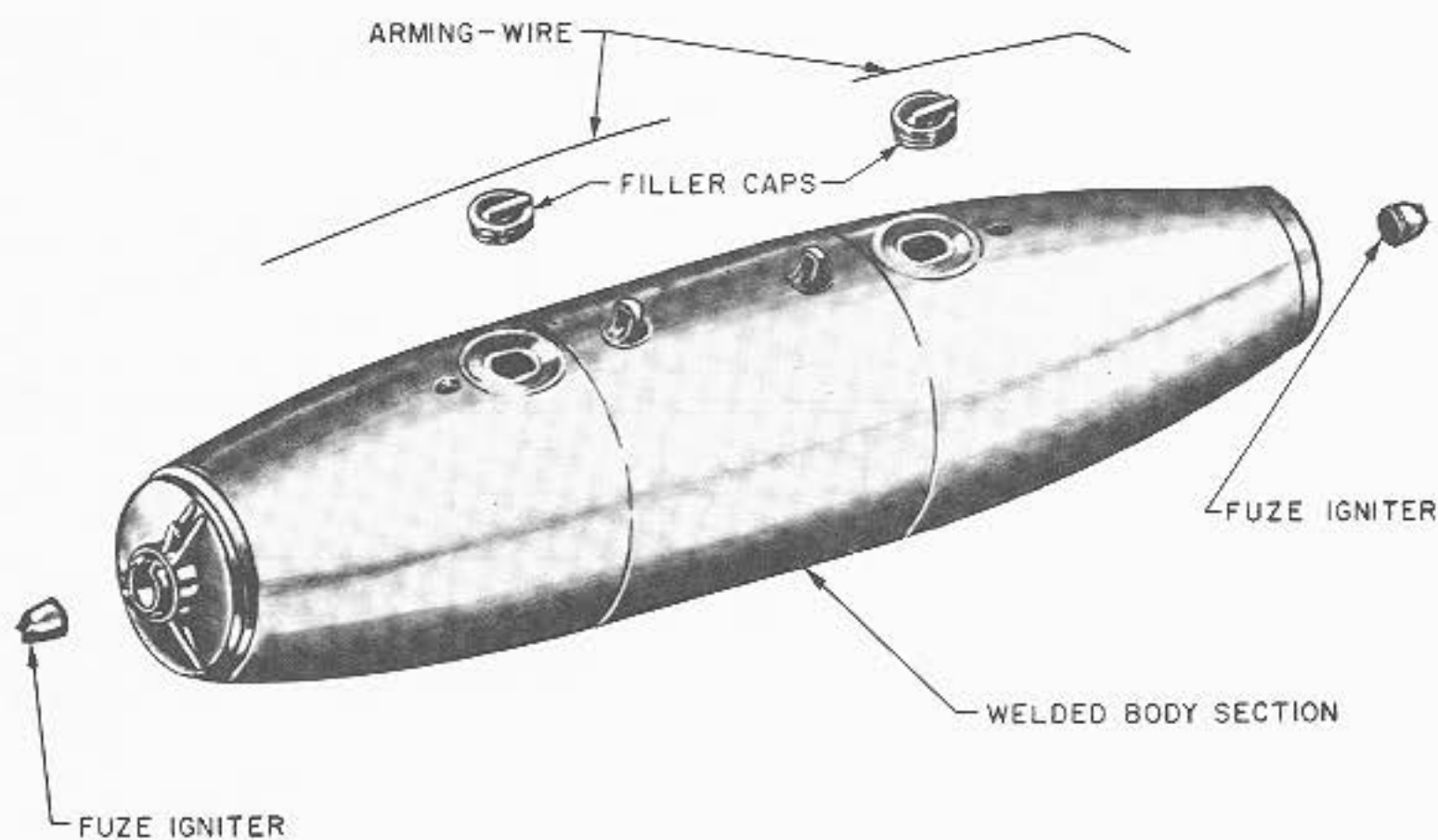
*H-6

**Tritonal

110.141



110.152
Figure 10-20. — Aircraft depth bomb.



110.153
Figure 10-21. — Typical fire bomb.

Chemical bombs are painted gray, and have green or red colored bands to distinguish them from other types of bombs. Also, the weight, type filling, model, and lot number are stenciled or stamped on the bomb body.

Free-Falling Missiles

Free-falling missiles are inert bomblets launched from a cluster container. When released from the aircraft, the container is opened by mechanical time fuze action, and the bomblets are spread over a large area. The container holds approximately 10,000 Lazy Dog missiles which are extremely effective against troops and other lightly armored targets.

The cluster case is olive drab with black identifying stencils.

Practice Bombs

Practice bombs, as the name indicates, are used to simulate the ballistic properties of service type bombs for target practice. The general types are subcaliber practice bombs, with cast-metal or steel bodies; full-scale practice bombs, made of sheet metal and filled with water or wet sand; and nuclear weapons practice bombs.

Practice bombs are used for the training of bombing crews in marksmanship. These bombs may use signals which produce a puff of smoke, making it possible to spot the impact location of the bomb. The use of practice bombs instead of live bombs makes it possible to train crews more economically and safely than would be the case with service type bombs.

BOMB FUZES

A bomb fuze is analogous to a gun projectile fuze. It is a device used to cause the bomb to explode at the time and under the circumstances desired, and to prevent the bomb's explosion at other times. This is accomplished by the use of sensitive explosive elements and the required mechanical or electrical devices.

To achieve different types of control for different types and sizes of bombs, many varieties of fuzes are required.

Normally, fuzes are in a safe or unarmed condition to ensure that they do not detonate prematurely. In an unarmed condition, a fuze cannot cause the bomb to explode. A fuze is ready to detonate the bomb when all parts are set so that the fuze can operate. This is the armed condition, which is usually obtained by

the ejection of an arming pin, the rotation of an arming vane, the closing of a circuit, etc.

In order for the reader to better understand the basic operating principles of fuzes, it is necessary to discuss some of the more common terminology associated with fuzes. These terms include the following:

1. Arming time — the amount of time or vane revolutions needed for the firing train to be aligned after the bomb is released, or from time of release until the bomb is fully armed.

2. Functioning time — the time required for the fuze to detonate after impact or after a preset time. Functioning time can be (a) instantaneous (functioning time 0.0003 second or less), (b) non-delay (functioning time 0.0003 to 0.0005 second), or (c) delay (functioning time 0.0005 second or longer, up to a maximum time for current fuzes of 33 hours).

3. Safe air travel (SAT) — the distance along the trajectory that a bomb travels in the unarmed condition.

4. Proximity (VT) — the action that causes the fuze to detonate before impact when any substantial object is detected by the fuze at a predetermined distance from the fuze.

5. Carrier or detonator safe — a safety feature incorporated in fuzes to insure that arming will not occur in relatively short distance; i.e., the length of a carrier flight deck.

In general, fuzes may be divided into two main classes — mechanical and electrical. These are arbitrary classes only and refer to the primary operating principles. Each of these classes may be further divided into the methods by which functioning is initiated. For example, mechanical fuzes may be initiated by impact, mechanical timers, and hydrostatic pressure; while electric fuzes are limited to impact and proximity action.

Mechanical Fuzes

In terms of modern ordnance, mechanical fuzes are the oldest and most widely used. A mechanical fuze in its simplest form is like a hammer and primer used to fire a rifle or pistol. A mechanical force (impact, spring tension, or water pressure) drives a striker into a sensitive detonator. The detonator in turn ignites a train of succeeding insensitive explosives, and eventually fires the main or filler charge.

IMPACT FUZES.—As previously mentioned, impact fuzes are caused to function by the bomb impacting with the target. The functioning may be instantaneous or delayed, whereby the bomb will not explode until a definite period of time has elapsed. These delays are often desirable in making the bomb more effective. This is important if penetration of the target is desired before detonation. This delaying action is incorporated into mechanical impact fuzes by placing a delay element into the firing train. The delay element is usually a tightly packed mixture of black powder and clay. The amount of delay is determined by the ratio of the mixture.

MECHANICAL TIME FUZES.—Mechanical time fuzes contain clock mechanisms to control the desired functioning. Currently, there are two types in use—one designed primarily for airburst and the other for long delayed action after impact. The type designed for airburst commences the delay after a definite amount of air travel or arming vane revolutions. This delay time is adjustable from 4 to 92 seconds. The long delay action fuze requires impact to start the clock mechanism and is adjustable from 30 minutes to 33 hours.

HYDROSTATIC FUZES.—Hydrostatic fuzes are water pressure activated fuzes used in depth bombs or general purpose bombs against submerged targets. Water, entering ports in the fuze body, acts against a bellows system which releases a spring-loaded firing mechanism. The fuze may be set to function from 25 feet to 125 feet below the surface.

Electrical Fuzes

Electrical fuzes have many of the characteristics of mechanical fuzes, but differ mainly in that an electrical impulse is used to initiate the fuze instead of the mechanical action of arming vane rotation. As the bomb is released, an electrical pulse from the delivery aircraft charges a series of capacitors in the fuze. Polarity, frequency, and magnitude of these pulses determines the various arming and functioning times. When electrical fuzes are used in conjunction with proximity sensing devices, the firing pulse is furnished by the circuitry in the sensing device.

Special Safety Features

To provide safe, effective operation, any fuze—whether mechanical or electrical—should provide the following safety features:

1. It must remain safe during stowage and while handling in the normal loading and off-loading procedures.
2. It must remain safe while being carried aboard the aircraft.
3. It must remain safe until the bomb is released and is well clear of the delivery aircraft.
4. Depending upon the type of target, the fuze may be required to delay the detonation of the bomb after impact for a preset time (functioning delay).
5. It should not detonate the bomb if it is accidentally released or if the bomb is jettisoned in the safe condition.

To provide these qualities, a number of design features are used, most of which are common to all types of fuzes. The most important features are detonator safe, shear safe, and delay arming.

Fuzes that are detonator safe do not have the elements of their firing train in proper position for firing until the fuze becomes fully armed. The elements remain firmly fixed and out of alignment in the fuze body while the fuze is unarmed. This increases safety during shipping, stowing, and handling of the fuze. The arming action of the fuze aligns the firing train.

A shear safe fuze will not become armed if its arming mechanism is damaged or completely severed from the fuze body. The arming mechanism of a fuze protrudes the farthest from the bomb, and might be severed from the fuze body if the bomb were accidentally dropped. Shear safe fuzes afford additional security for carrier operations and for externally mounted bombs.

Delay arming mechanically slows the arming of the fuze. It keeps a fuze in the safe condition until the bomb has fallen a sufficient distance away from the aircraft, thus minimizing the effects of a premature explosion. Delay arming helps to make carrier operations safe because a bomb accidentally released during landing or takeoff ordinarily will not have sufficient air travel to fully arm the fuze.

Fuze Arming

When a bomb fuze is unarmed (safe), it cannot function. In some fuzes, a pin through the striker

(equivalent to a firing pin) keeps it safe; in others, a "safety block" of metal under the striker head, or a screw securing it to the fuze body, performs this function. In "detonator-safe" fuzes, the detonator or primer is out of line with the firing pin when the fuze is unarmed. Some fuzes use a combination of methods.

Mechanical fuzes are usually armed by the rotation of miniature air screws called arming vanes. These are turned by the passage of air as the bomb falls. The function of the arming wire, when used with vane-armed fuzes, is to prevent the vanes from rotating in the plane's slipstream and arming the bombs before release.

Physically, the arming wire is a length of brass or bronze wire with a flat eyelet at one end. Usually two arming wires are used, one for the nose fuze and one for the tail. One end of the wire is threaded through matching hoses in the fuze body and the arming vane. Safety clips (also called Fahnstock clips), slid over the wire next to the fuze, keep the wire from slipping out from between the vanes. The eyelet end of the arming wire is engaged by a retainer on the bomb rack or shackle from which the bomb is suspended. The retainer's functioning is controlled by the pilot's selector switch. If the switch is set on "Safe" when the bomb is dropped, the retainer releases the arming wire with the bomb, so that the vanes cannot rotate and the fuze remains unarmed. If the switch is set on "Arm," the retainer holds the arming wire firmly; the bomb drops without the wire, the vanes turn freely, and by the time the bomb is safely distant from the aircraft, the fuze is fully armed.

Some bomb racks and shackles have several arming wire hooks on them. Thus it is possible to arm one fuze and not the other. This is called selective arming.

Arming of electrical fuzes is accomplished by electrical impulses from the delivering aircraft as mentioned previously.

SAFETY PRECAUTIONS

The hazards of bomb type ammunition are those of the explosives involved, but are considered greater than those of explosive material in bulk form. Bomb type ammunition, when involved in fire, tends to set off a high order mass detonation of all explosive material in close proximity. Evidence accumulated from accidents and from results of special experiments shows that it is possible to explode bomb-type ammunition, particularly those with thin cases,

by impact. Bomb type ammunition should not be dropped, dragged, tumbled, or otherwise subjected to shock. Care should be used in loading and unloading operations to prevent damage to the bomb case, projecting lugs, fuze cavities and threads, etc. Only nonferrous type tools should be used for cleaning fuze cavities or threads, or for scraping off drops or crusts of TNT or exudate.

Fire bombs contain great potential hazards. Personnel handling or coming into close contact with this type of ammunition must exercise caution and obey all safety rules. Vapors from the fire bomb mix are generally toxic and highly flammable; therefore, all safety precautions for handling gasoline must be observed. Fire bombs containing white phosphorus (WP) igniters are extremely dangerous due to the fact that WP ignites upon exposure to air. Fire bombs containing sodium (NA) igniters, ignite upon contact with water and produce caustic and irritating fumes.

Safety precautions for chemicals and chemical bombs vary with the type of chemicals involved and are too numerous to cover in this chapter. Explicit instruction concerning the safe handling, hazards, and other pertinent data may be found in NavOrd OP 2217, Miscellaneous Chemical Munitions (current revision).

Safety involving practice ordnance tends to be overlooked. Of all the accidents and incidents involving ordnance mishaps, the majority can be directly attributed to the mishandling of practice ordnance. Complacency and the amount of items handled often lead to carelessness and accidents. Practice bombs with signals installed must be handled with the same considerations as for live high-explosive bombs. Jarring or dropping the bomb may detonate the signal and result in severe burns or other injuries.

Before handling any type of ordnance, the hazards involved and the necessary safety measures required to safely accomplish the task must be thoroughly understood.

AIRCRAFT GUNS

It was not until late in World War I that anyone visualized the fighting power of an aircraft equipped with automatic guns. During the first part of this period, aircraft were used only for observation purposes and were unarmed. The only protection the pilot or observer had was his sidearm. Rifles were later carried and

fired by the observer, who stood erect in the cockpit.

The first mounted automatic weapons used in combat were adaptations of automatic ground weapons speeded up in rate of fire and fitted with recoil mechanisms to assist in absorbing shock.

The Lewis machinegun caliber .30 was the first automatic weapon to be used in combat aircraft. Later, the Browning machinegun caliber .30 made its appearance, followed by the caliber .50 Browning.

In the meantime, the French Hispano-Suiza 20-mm automatic gun made its appearance. Our Armed Forces began intensive development of a 20-mm aircraft gun about 1937; and a short time later purchased the Hispano-Suiza design from the French. The 20-mm gun was selected as the ideal size aircraft weapon because it was light and compact enough to be mounted in fighter type aircraft, yet it was large enough to fire a high explosive projectile.

Our first model was designated the M1; but before it was ever used, several changes were made, and it became the M2. The M2 was first installed in naval aircraft in 1943 and saw extensive service during the remainder of World War II. However, by this time it had already been decided that a faster firing gun was necessary to compensate for the speedier aircraft that the enemy was producing. This led to the development of the M3, a weapon which came into wide use in 1945. In 1948 when jet aircraft came into use, the Armed Forces realized that a weapon with a higher muzzle velocity and faster rate of fire was necessary. A more effective means of timing gunfire was also desired.

It is an interesting fact that the United States did not introduce, except in experimental quantities, any new type of aircraft machinegun during World War II. The reason for this was the long and tedious program required to develop, refine, and produce a new and reliable service weapon. Our mainstays were the .30 and .50 caliber Browning, and the 20-mm AN-M2 (Hispano-Suiza) aircraft machinegun. Development proceeded on superior automatic aircraft weapons, but the conflict did not last long enough for any to see combat use. Refinement and improvement of the existing machineguns did bring material results. Even today no machinegun in the world can compete with the .50 caliber Browning for reliability.

In the last few years, aircraft weapons have been developed that can very effectively handle certain types of targets that were formerly

attacked with guns. Nevertheless, under certain tactical conditions and against certain targets, the gun is still the optimum weapon. Performance requirements are so demanding, however that only an outstanding aircraft gun can fulfill the requirements of today's aerial warfare. Today the firepower per gun and the firepower per pound of gun must be much greater. The most obvious reason for this is that aircraft speeds have more than doubled in the last few years.

The adaptation of pods for the carrying of guns is in line with the present day trend of multiple external stores capability of aircraft. This trend exists in most high performance aircraft where a variety of stores appear as pods. The gun pod adds to the versatility of an aircraft by permitting interchangeability of its armament, such as guns, bombs, rockets, and guided missiles. By the use of gun pods, another variable choice of weapons is available to complete the tactical mission assigned.

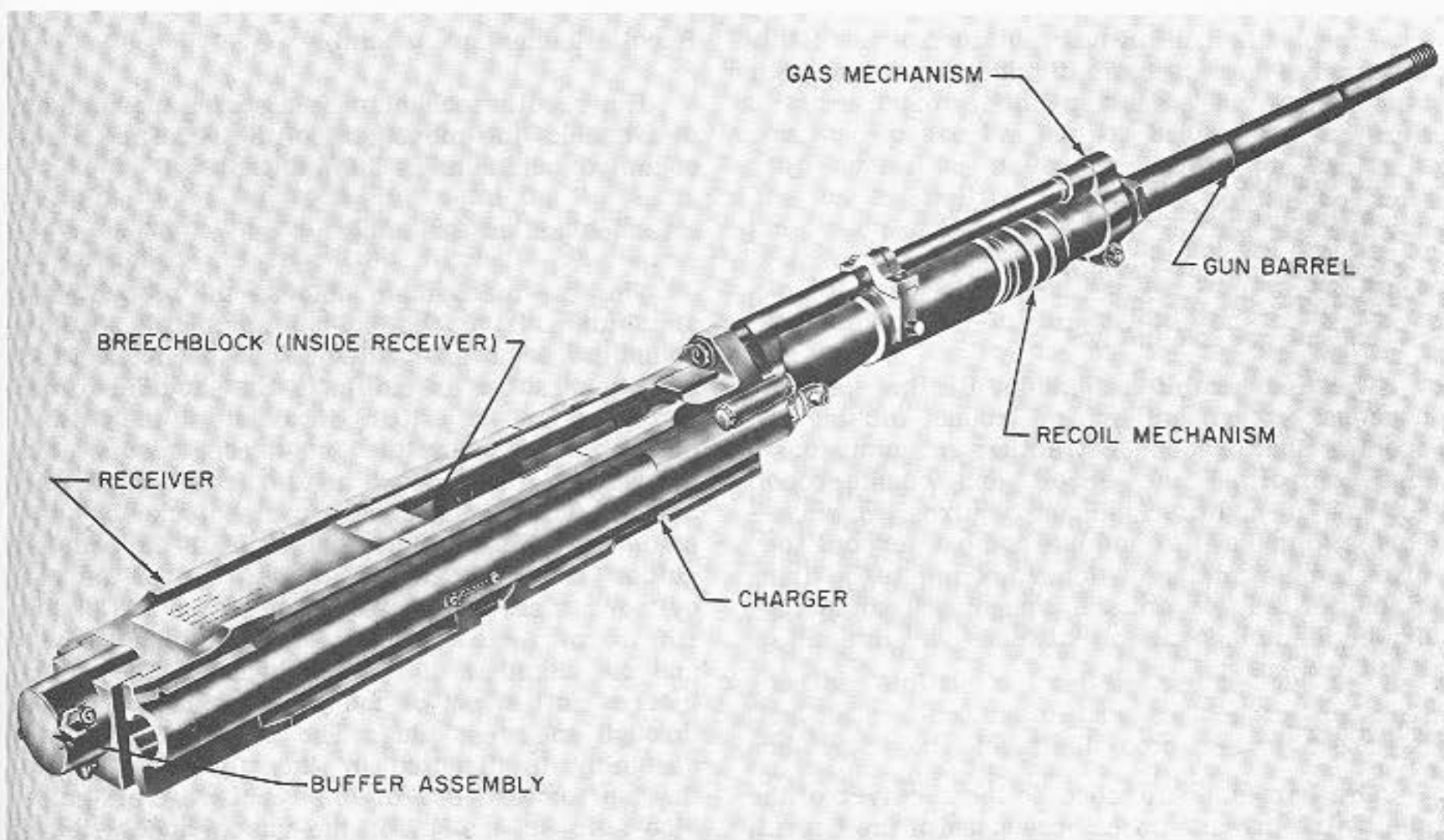
Advances in aerial weapons such as high-speed rockets and guided missiles have limited the use of aircraft guns in current aircraft considerably. Therefore, the coverage of aircraft guns in this text is limited to two guns, the 20-mm aircraft gun Mk 12 and the 20-mm aircraft gun Mk 11 Mod 5, which is a part of the gun pod Mk 4 Mod 0.

20-MM AIRCRAFT GUN MK 12

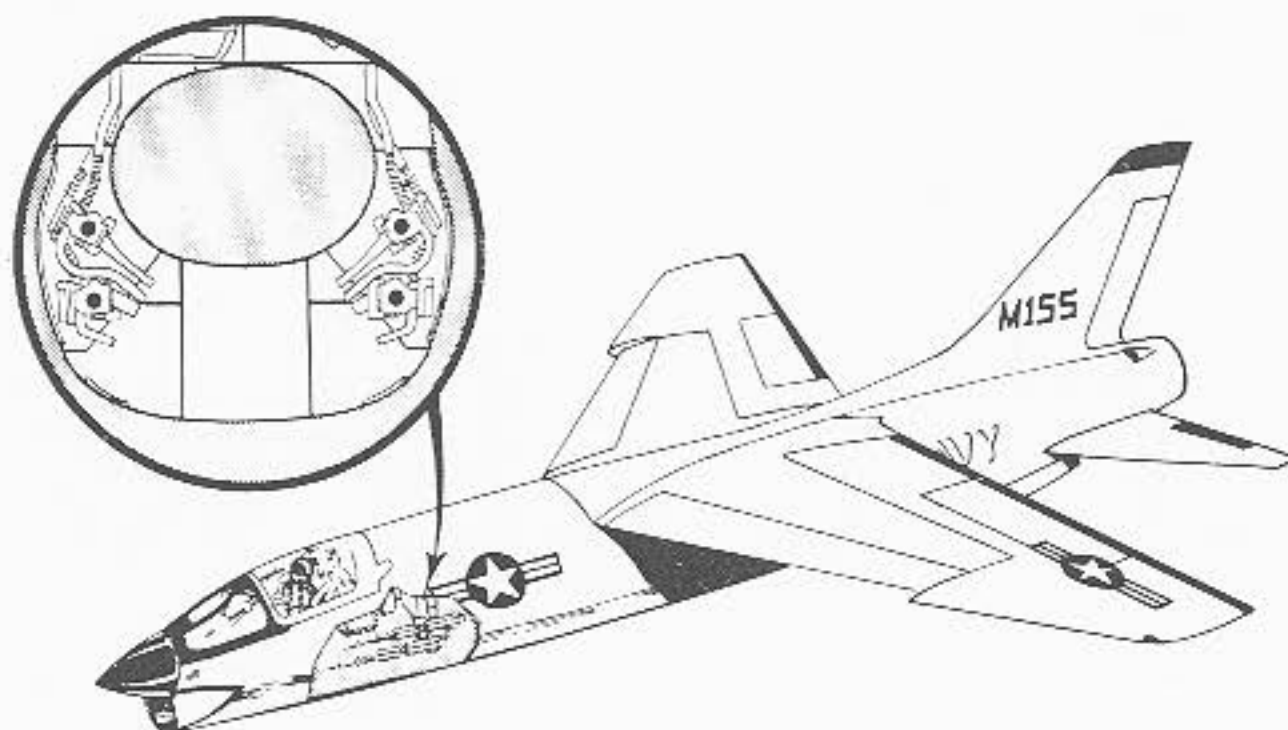
The 20-mm aircraft gun Mk 12 (fig. 10-22) is similar in operating principles to the 20-mm automatic gun M3 used during World War II. The Mk 12, however, fires electric-primed ammunition containing a lighter projectile and a larger powder charge, at a higher rate of fire and an increased muzzle velocity. This weapon is intended for both air-to-ground and air-to-air combat. Figure 10-23 shows the gun installations in the F-8 aircraft.

The Mk 12 gun is an air cooled weapon and operates on both the gas and blowback principles. The gun is electrically fired and continues to operate as long as the firing circuit is closed and ammunition is available. The weapon includes an integral pneumatic charger which is used to operate the breechblock for first round loading, to clear the weapon in case of misfire, and to safety the gun on completion of firing.

The Mk 12 is normally considered to be composed of two major units, the barrel and the



110.154
Figure 10-22. — 20 mm aircraft gun Mk 12.



110.155
Figure 10-23. — 20 mm gun installation.

gun mechanism. However, for purpose of this discussion the weapon is divided into seven major components:

1. Gun barrel.
2. Receiver assembly.
3. Recoil mechanism assembly.
4. Gas mechanism assembly.
5. Breechblock assembly.
6. Buffer assembly.
7. Charger assembly.

These assemblies include all the elements necessary for chambering a round, closing and opening the breech, extracting an empty case, and controlling the recoil and counterrecoil actions. In addition, the gun requires two accessories to make it a complete combat weapon. They are a synchronizing switch, to complete the firing circuit of the weapon, and a pneumatic or spring-driven feed mechanism that feeds the ammunition into the weapon.

Gun Barrel

The barrel is attached to the receiver of the gun by the threads on the breech end of the barrel, and is secured to the receiver by a locking pin which prevents rotation of the barrel after installation. The walls of the chamber are smooth to insure proper gas sealing and extraction. Rifling grooves in the bore extend from just forward of the chamber to the muzzle, interrupted only by the gas port drilled through the top of the barrel.

The exterior of the barrel is tapered in steps from the breech to the muzzle end. An external thread is machined near the center of the gun for attaching the gas bracket and retaining the recoil mechanism. To the rear of this thread is the gas port. An external thread at the muzzle end of the barrel is provided to attach a flash hider, blast suppressor, or barrel support.

Receiver Assembly

The receiver, which is the principal structural element of the gun, houses or supports all of the gun mechanism and provides attaching surfaces for its feed mechanism and gun charger. The charger is on the right side of the receiver and actuates the breechblock for first cartridge loading and safetying action. The gas mechanism (attached to the gun) actuates the breechblock slides to unlock the bolt after firing. The buffer is mounted on the rear of the receiver, and its function is to return the breechblock toward the locked position.

Recoil Mechanism Assembly

The recoil mechanism is a spring mechanism that checks the movement of the recoiling parts of the gun and returns them to battery.

Gas Mechanism Assembly

The gas mechanism unlocks the breechblock and starts it to the rear immediately after a round has been fired. The gas bracket nut secures the gas bracket assembly to the shoulder of the gun barrel. A key fitting into slots in the bottom of the bracket and the gun barrel secures the bracket in its proper angular position on the barrel. The bracket nut is also locked by the same key. The cylinder extension of the bracket guides and supports the piston end of the gas cylinder sleeve assembly. The piston and piston ring form a gas seal between the sliding sleeves and the chamber of the gas bracket. The action insures full effect of the gas pressure admitted through the vent plug. The rear of the sleeve assembly is directed by the guide attached to the top forward end of the receiver. This guide also acts as a stop for the gas cylinder sleeve spring. As the sleeve is forced to the rear by the gas pressure, it contacts a push rod on either side of the receiver. The push rods are aligned with the breechblock slides and unlock the breechblock as they are forced to the rear by the gas cylinder sleeve.

Breechblock Assembly

The breechblock is the reciprocating assembly that loads a round into the barrel chamber, closes the breech, fires the round, and removes the empty case.

Buffer Assembly

The buffer assembly is pneumatically operated. Its function is to absorb the force of the rearward movement of the breechblock, stop this motion, and returns the breechblock to battery. It consists of housing, sleeve, piston, air inlet fitting, check valve, and bleeder valve. Compressed air is admitted to the rear of the piston by the air inlet fitting and the check valve. As the breechblock moves aft and contacts the buffer piston, the check valve closes and traps this air behind the piston. The trapped air is compressed. This retards the rearward motion of the breechblock; and as the breechblock movement is stopped, the trapped air expands and drives the breechblock forward.

Charger Assembly

The charger is a pneumatic mechanism which provides power operation of the breechblock for loading the first round or safetying the gun. The charger piston is actuated by 1,000 psi compressed air from the aircraft. The components of the charger are the charger tube, piston, ram head, and dumping valve. The entire assembly is housed in the charger tube on the side of the receiver. The forward end of the charger tube fits into the charger housing. Six holes are drilled near the rear of the piston tube through an air hose connected to the charger housing. O-rings seal both ends of the charger tube to prevent escape of the compressed air. The dumping valve assembly is screwed into the forward end of the tube.

Synchronizing Switch Mk 1 Mod 1

The synchronizing switch shown in figure 10-24 contains three contacts which operate with the breechblock to complete the firing circuit. The case is composed of two halves bolted together. The electrical components consist of the A, B, and C squibs (two forward and one aft as shown), two connectors, and interconnecting wires. The filler plates may be

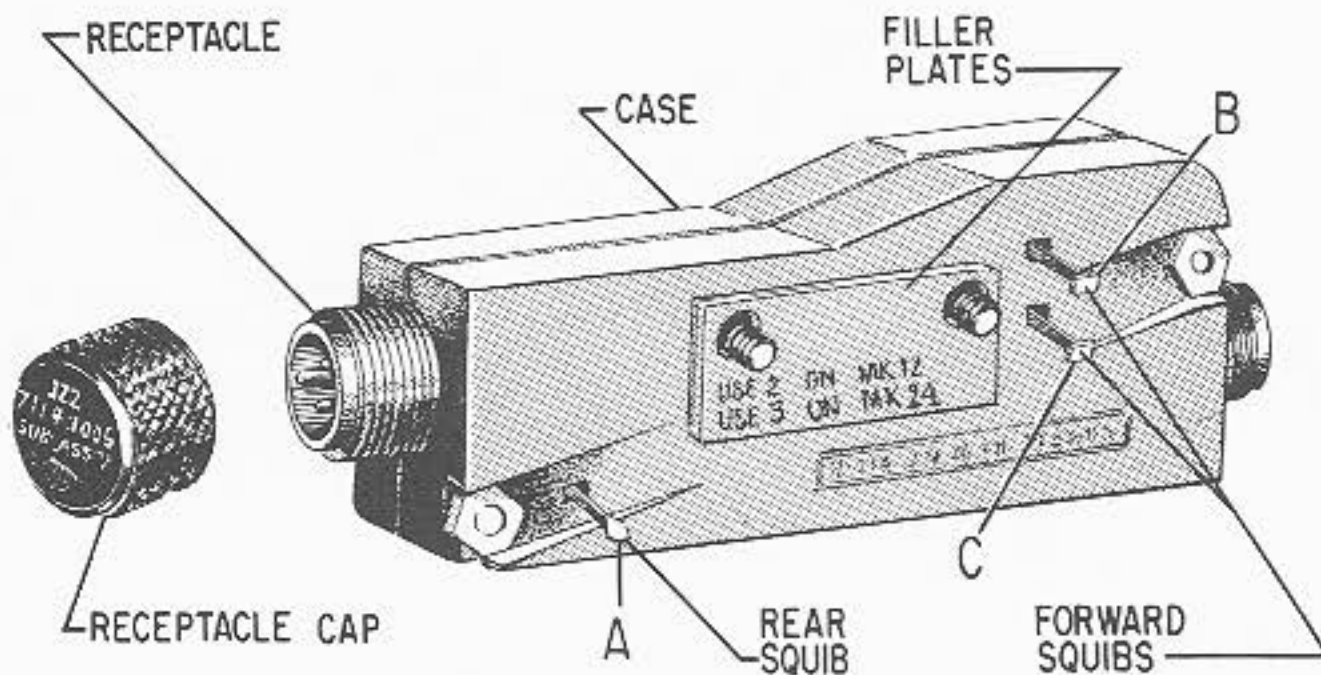
used when mounting the switch to the gun, depending upon whether the receiver of the gun has a recessed or a flat surface. The two forward squibs represent a gap or break in the circuit which must be closed before the gun can fire. The rear squib is the contact for the firing pin which makes contact when the breechblock is in battery. In operation the break between the two forward squibs is closed by the breechblock before it reaches battery position.

Feed Mechanism Mk 7 Mod 2

The 20-mm feed mechanism Mk 7 Mod 2 is powered by an air motor which is supplied with compressed air from the aircraft's air system. It is mounted on top of the gun receiver body and secured by six locking lugs and two tie bar assemblies, (fig. 10-25). The design features include a low profile, light weight, and the ability to sustain a high rate of gunfire. The mechanism can be quickly installed and removed. Identical components are used for right- and left-hand installation.

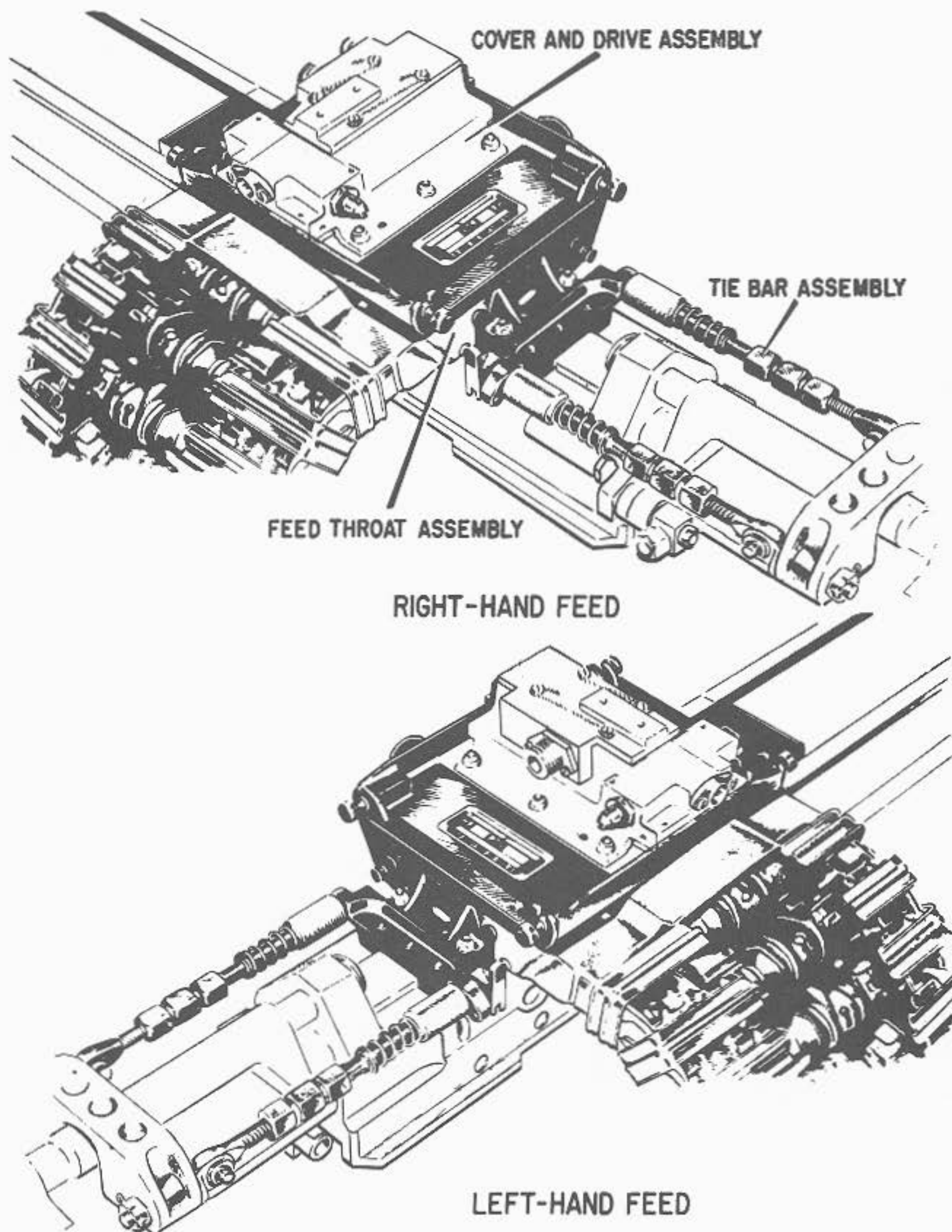
Ammunition Belting System Mk 2 Mod 0

Ammunition belting system Mk 2 Mod 0 is a motor-driven assembly for mechanically linking 20-mm aircraft ammunition in preselected ratios to form a continuous belt.



110.156

Figure 10-24. — Synchronizing switch Mk 1.

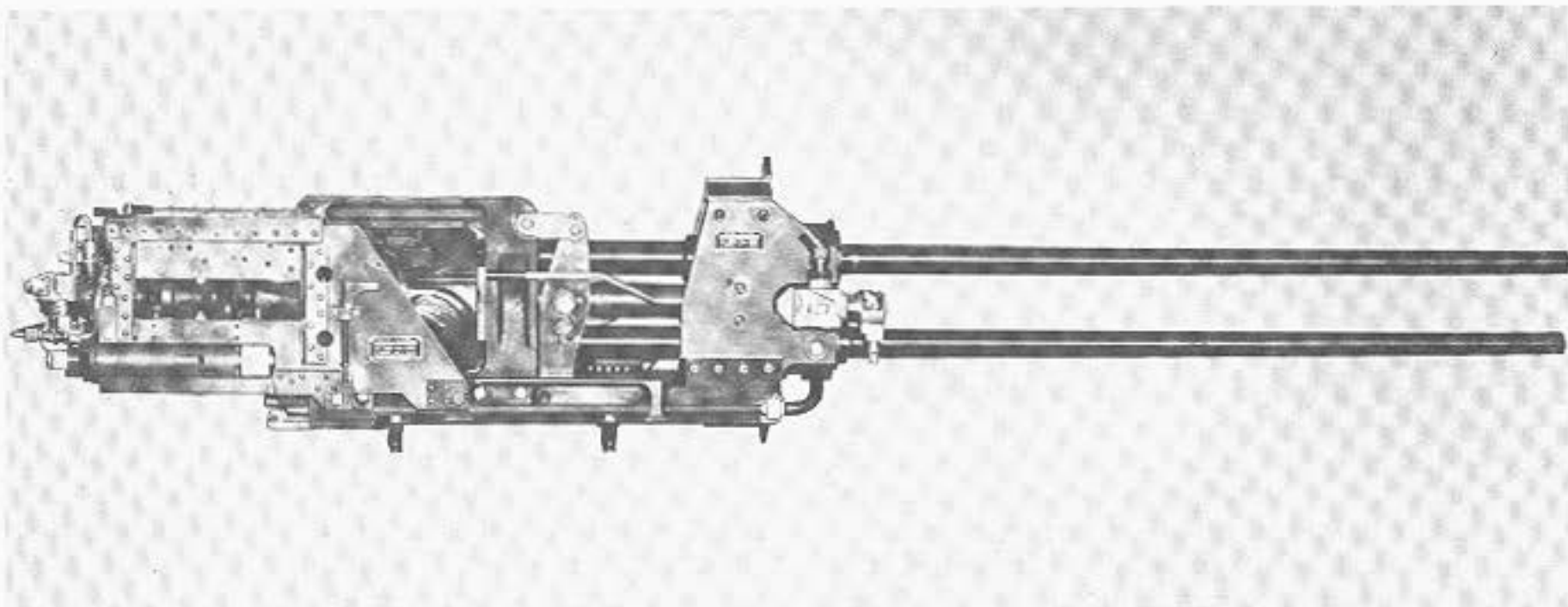


110,157

Figure 10-25. — 20 mm feed mechanism Mk 7.



110.158
Figure 10-26. — Gun pod Mk 4 Mod 0.



110.159
Figure 10-27. — 20 mm aircraft gun Mk 11.

This system automatically performs three functions:

1. It feeds the links and connects them together in a continuous string.
2. It selects and feeds different types of ammunition in preset ratios.
3. It either links or delinks at speeds up to 250 pounds per minute. Normally motor driven, the system may also be manually operated.

GUN POD MK 4

The Mk 4 gun pod with the Mk 11 gun is a 20-mm gun system capable of firing 4,000 rounds per minute. Loaded with 750 rounds the pod weighs 1,285 pounds. It is electrically controlled from the aircraft and is self-powered. Charging, clearing, and ammunition boost functions are powered by a 3,000 psi pneumatic supply inside the pod. Alternate lower rate of fire and automatic charge are optional features.

The advantage of mounting guns in pods instead of within the aircraft fuselage or wings are numerous, including such factors as (1) reduced gunfire blast and vibration, (2) positive clearance of expended cases and links from aircraft, (3) improved accuracy due to a single

mount harmonization, (4) quick turnaround, and (5) safety from gun hazards such as gun gas, double feed, hangfire, and cookoff.

The pod can be flown and fired at speeds up to Mach 1.2 at 10,000 feet and Mach 2.2 at 60,000 feet.

The gun system consists of the gun pod (fig. 10-26), the Mk 6 Mod 4 link, and Mk 100 series ammunition. The 20-mm aircraft gun Mk 11 Mod 5 (fig. 10-27) is part of the gun pod, and in turn is made up of two items: the 20-mm gun mechanism Mk 11 Mod 5 and the 20-mm gun loader Mk 2 Mod 1. The Mk 11 gun is located on the centerline of the pod, with the barrels in a plane through the mounting lugs.

The Mk 11 gun is a self-powered, twin-barrel revolver weapon employing the Marquardt gun cycle. It fires at $4,000 \pm 200$ rounds per minute and is fed by two ammunition belts. The Mk 11 Mod 5 gun described here is the production configuration. It weighs 225 pounds ready to fire, is 78.5 inches long, and has a life exceeding 100,000 rounds. The Mk 11 gun fires the standard Mk 100 series ammunition (as used in the 20-mm Mk 12 gun).

CHAPTER 11

COASTAL AND RIVERINE CRAFT ARMAMENT

Throughout our history coastal and riverine craft have played a very important part in achieving victories, on sea and shore. This has been true from the American Revolution to the Vietnam conflict.

Coastal and riverine craft, many of which were converted from World War II landing craft, have been used extensively in the Vietnam conflict. Their armament, which varies from craft to craft, ranges from .30 caliber machine guns to 105 mm howitzers. This chapter will acquaint you with some of these and their armament, including its operation. Keep in mind that most of these craft are of a temporary nature—activated and built only for use in the Vietnam conflict—and may or may not be in service once the Vietnam conflict is over. However, future involvement in a similar type of warfare may again require their use.

COASTAL CRAFT AND THEIR ARMAMENT

Coastal craft include patrol gunboats (PGs), hydrofoil gunboats (PGHs), fast patrol boats (PTFs), and fast patrol craft (PCFs). (Some coastal craft, such as the PTF and the PCF, also may be used for riverine service.) A representative number of these craft and their armament will be briefly discussed in this section. Again, keep in mind that the armament on one boat may be different from that on another boat of the same type.

PATROL GUNBOAT ARMAMENT

A patrol gunboat's armament consists of a single 3"/50 gun mount forward, a single 40 mm gun aft, and four .50 caliber machine guns in twin mounts atop the pilot house. Ashville Class PGs, except USS Antelope (PG-86) and USS Ready (PG-87), have Mk 63 gun fire control systems (fig. 11-1). Antelope (fig. 11-2) and Ready have Mk 87 weapons control systems. The PG's

weapons are capable of inflicting heavy damage upon light shipping and enemy personnel ashore.

3"/50 Gun Mount

The 3"/50 used on patrol gunboats (fig. 11-2) is a rapid-fire, semiautomatic, enclosed single gun mount. Although the 3"/50 gun was designed primarily for air defense, it can be used very effectively against surface and shore targets.

The 3"/50 gun on a PG is enclosed in a fiber glass shield; 3"/50 guns on other ships may be open mounts or enclosed in either fiber glass or aluminum shields. The description and operation of the 3"/50 gun are covered in chapter 5.

40 MM Mount Mk 3

The single 40 mm mount (fig. 11-3) on the PG is a power driven, electrically controlled, dual-purpose open mount. It is controlled by synchro signals, which drive the mount in train and elevation. The controlling signals may be furnished either by a Local Power Control unit mounted on the carriage (fig. 11-3) or by a fire control director. A Local-Automatic selector switch on the carriage determines which set of synchro signals provides the control.

When the Local-Automatic switch is positioned for local control of the power drives, the gun pointer controls both the train and the elevation power drives by manipulating the handgrips of the Local Power Control unit. The pointer tracks the target with a gunsight that is mounted on the gun mechanism and moves with the gun. He may fire the gun electrically by depressing a foot-operated firing switch or manually by depressing the foot-firing pedal.

When the mount is in automatic control, it will follow the train and elevation gun order signals from the director or computer. Electric power firing of the gun can be initiated by the director operator and controlled by the gun



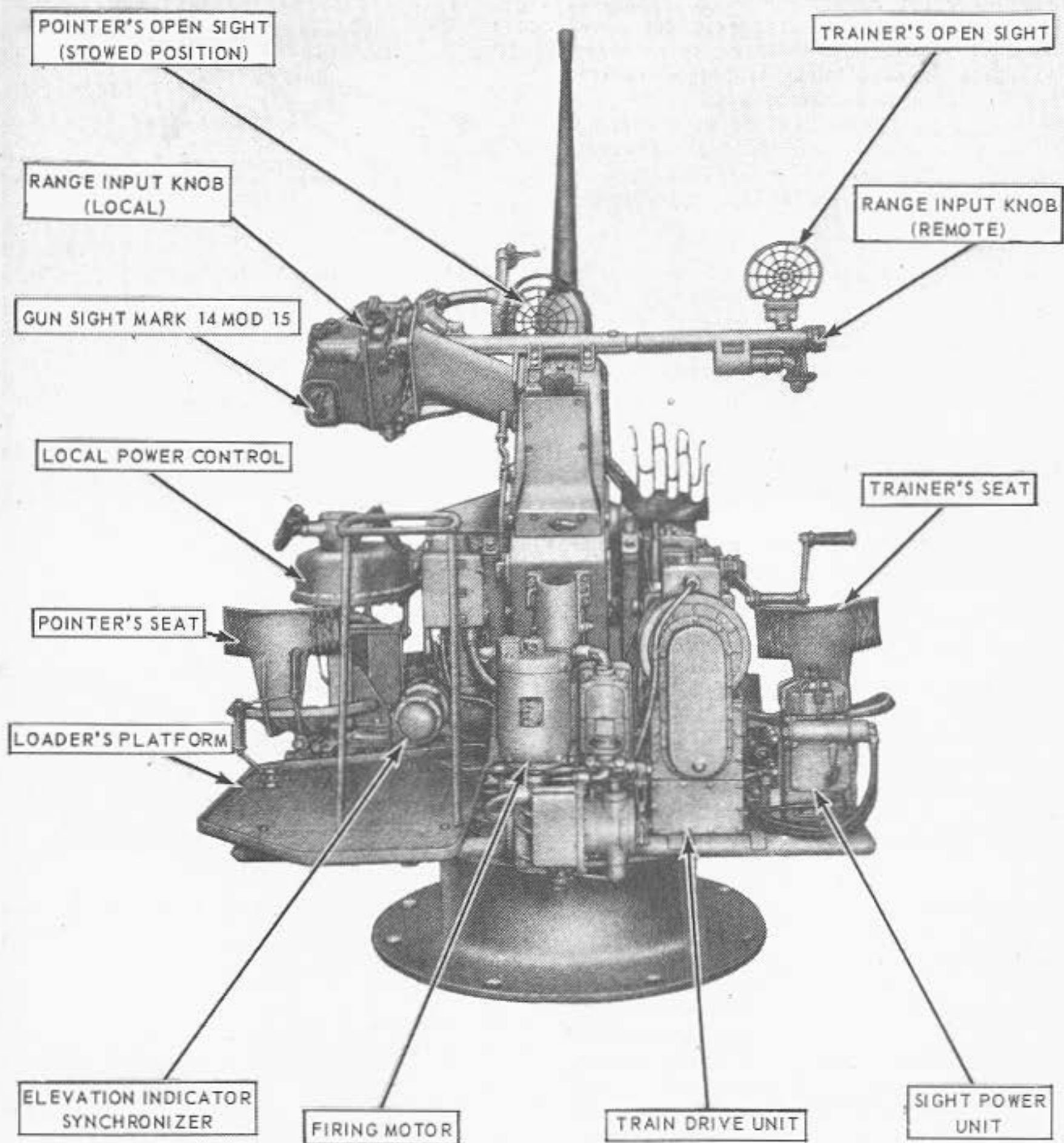
3.269-85

Figure 11-1.—USS Gallop (PG 85), an Ashville Class aluminum-hulled gunboat. She is armed with a 3-inch gun forward and a 40 mm gun aft, and her speed exceeds 33 knots.



3.269-86

Figure 11-2.—USS Antelope (PG 86), with its FCS Mk 87 radome clearly visible above the pilot house.



110,170
Figure 11-3. — 40 mm mount Mk 3 Mod 4, rear view.

crew. Manual gun operation by handcranks is possible whenever power operation is not feasible.

Various safety features such as power-to-manual interlocks, securing pins, firing cut-out cams, power-operated limits, train and elevation positive stops, and buffers are provided. These safety features, along with other features of the mount, are explained in detail in OP 1289.

Some of the components of the 40 mm mount, such as the trainer's and the pointer's open sights, local and remote range input knobs, Local Power Control unit, and the gun sight are shown in figure 11-3.

.50 Caliber Machine Gun (M2HB)

The .50 caliber machine gun on the patrol gunboat is a Browning recoil-operated, belt-fed, air-cooled gun. Although it is primarily an anti-aircraft weapon used by the Army, the Navy has adopted it for use aboard ship, against both surface and air targets.

The mechanism of the weapon and its principles of operation are described in detail in Army Field Manual FM 23-65.

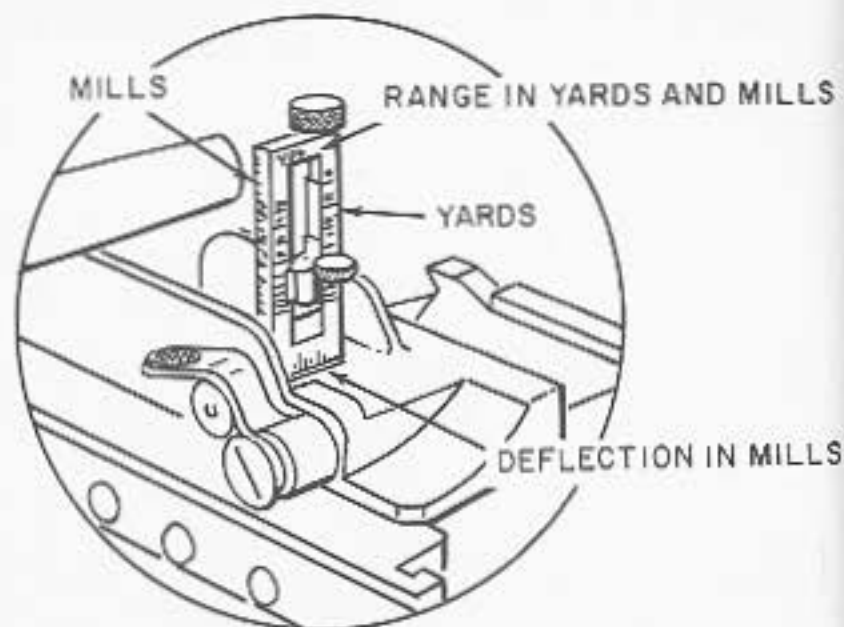
Main characteristics of the .50 caliber machine gun are as follows:

Weight of gun with barrel.	84 pounds
Overall length.	65 1/8 inches
Length of barrel	45 inches
Lands and grooves	8 each
Rate of fire (rounds/minute)	500
Maximum range.	7,400 yards
Effective range	2,250 yards
Cooling	Air
Barrel twist.	Right hand; one turn in 15 inches
Direction of feed	Optional (left or right)
Mode of fire.	Full automatic or semiautomatic
Type of feed.	Disintegrating metallic link belt
Muzzle velocity.	2900 feet/second

An exterior view of the machine gun is shown in figure 11-4, and a closeup of the rear sight is shown in figure 11-5. The sight is a leaf and blade type. It is graduated in both yards and mils for range—from 100 to 2600 yards and 0 to 62 mils. A windage screw allows for a wind correction of 5 mils either to the right or the left.



84.112
Figure 11-4.—Browning .50 caliber M2 machine gun (shown on the ground mount M3).

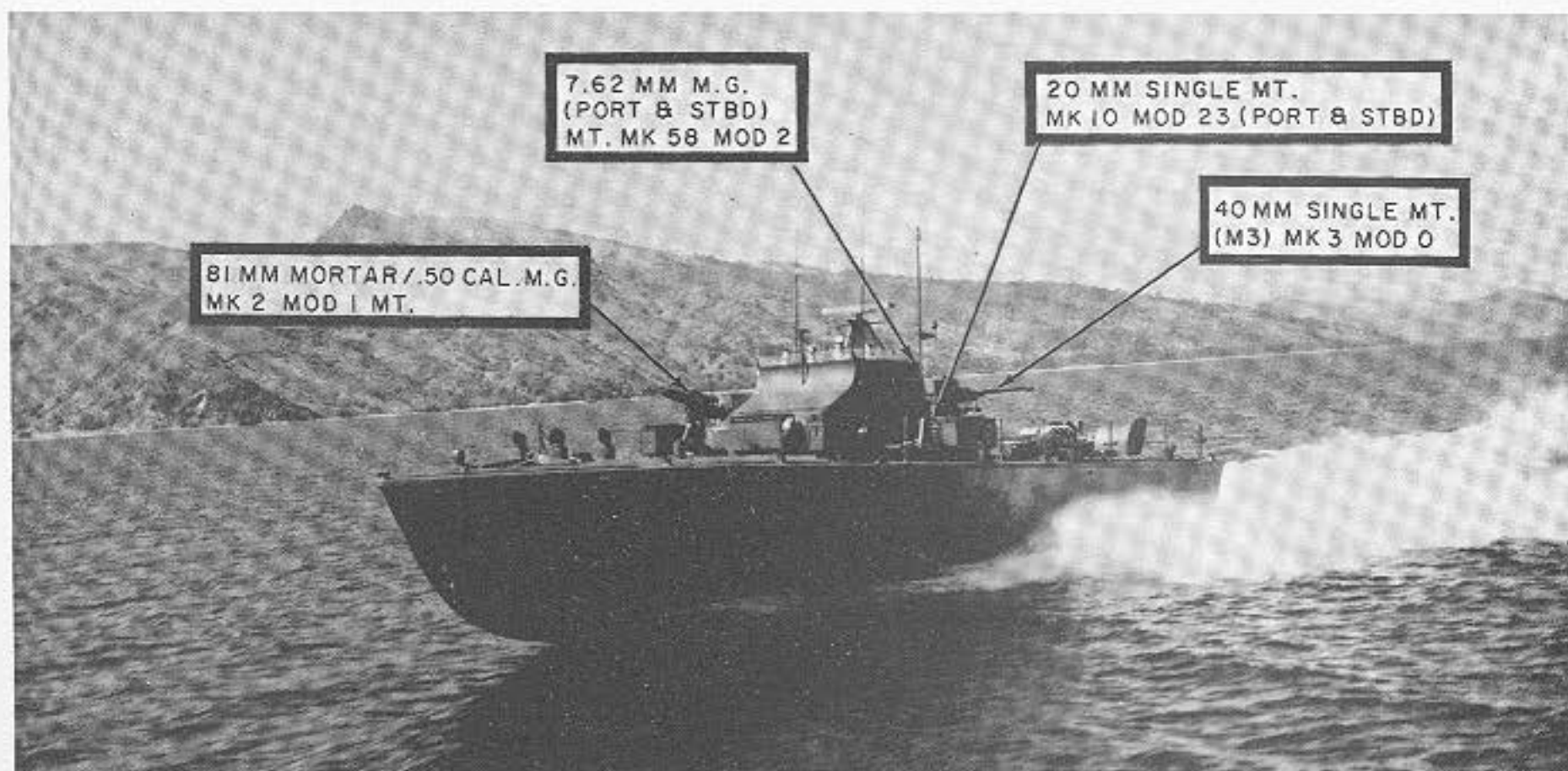


110.171
Figure 11-5.—Sight leaf, metallic sight.

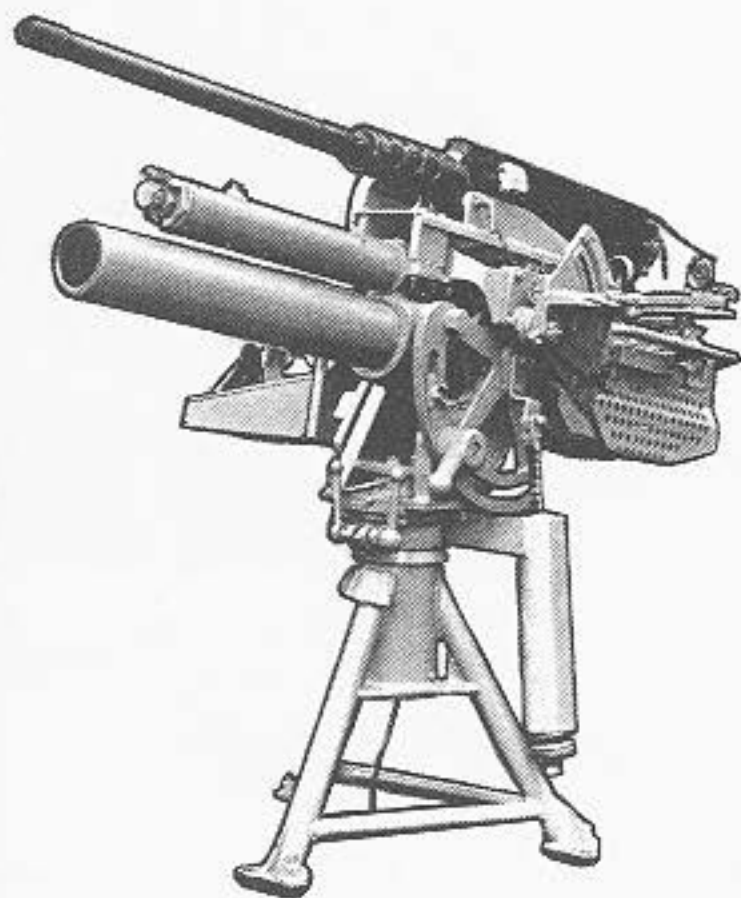
The gun normally uses a left-hand feed, but by changing the position of certain parts, it can be fed from the right side.

FAST PATROL BOAT (PTF) ARMAMENT

Fast patrol boats with hull numbers 17-26 (fig. 11-6) have the following installed ordnance: one 81 mm mortar, a single 40 mm mount, 2—20 mm single mounts, and 1—50 caliber machine gun mounted over the mortar. The 81 mm mortar with its piggyback .50 caliber machine gun (fig. 11-7) is located in the bow section of the boat. One of the 20 mm guns is mounted on the



110.172
Figure 11-6.—Fast patrol boat, 17-26 class.



29.320:84.112
Figure 11-7.—81 mm mortar and piggyback .50 caliber machine gun.

starboard side and the other is mounted on the port side.

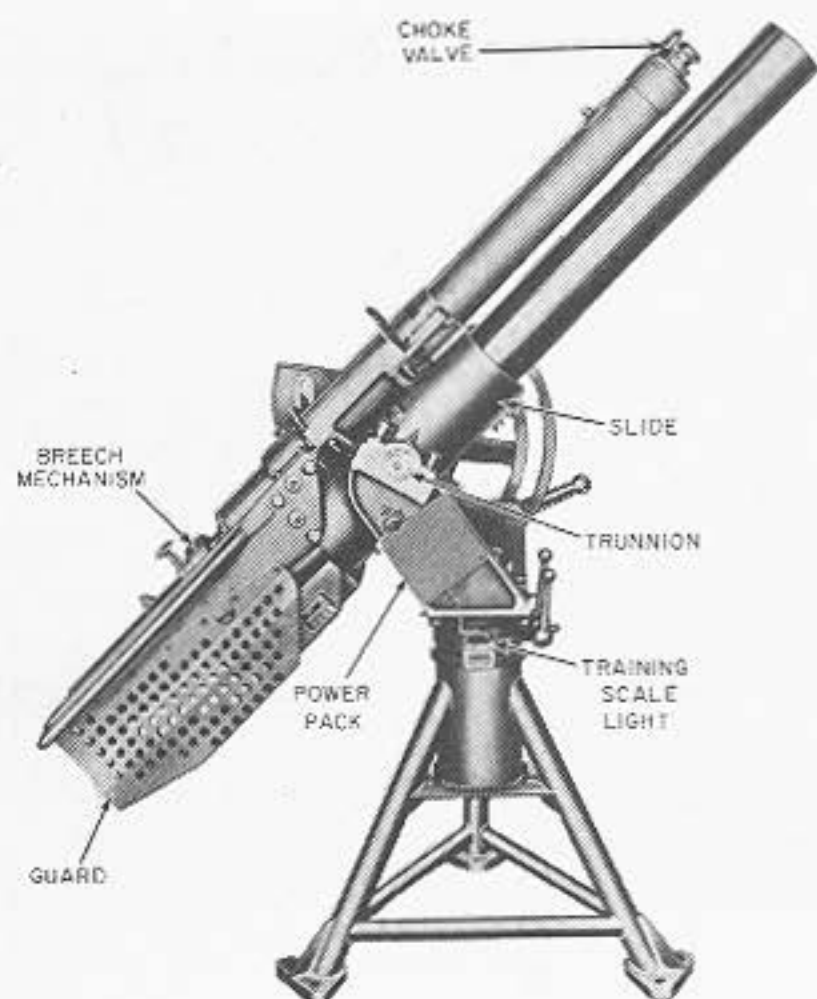
PTFs with hull numbers 3-16 have 2—40 mm guns—one forward and one aft—and 2—20 mm guns—one to starboard and the other to port.

(The .50 caliber machine gun is the same weapon as the one described earlier. Therefore, it will not be discussed further.)

81 MM Mortar

The 81 mm mortar shown in figure 11-7 is a Mk 2 Mod 1 design; the one in figure 11-8 is a Mk 2 Mod 0. The major design difference between the two is that the Mod 1 has the piggyback machine gun.

The mortar is capable of firing high explosive shells, illuminating shells, and white phosphorous (WP) smoke shells. This capability makes it an effective weapon in bombardment, laying smoke screens, and providing nighttime target illumination. Fuzes for the mortar's ammunition are of two types: point detonating and time. However, there are three types of fuze actions because point detonating fuzes can be either super-quick (explode on impact) or delay (activate



29.320.1

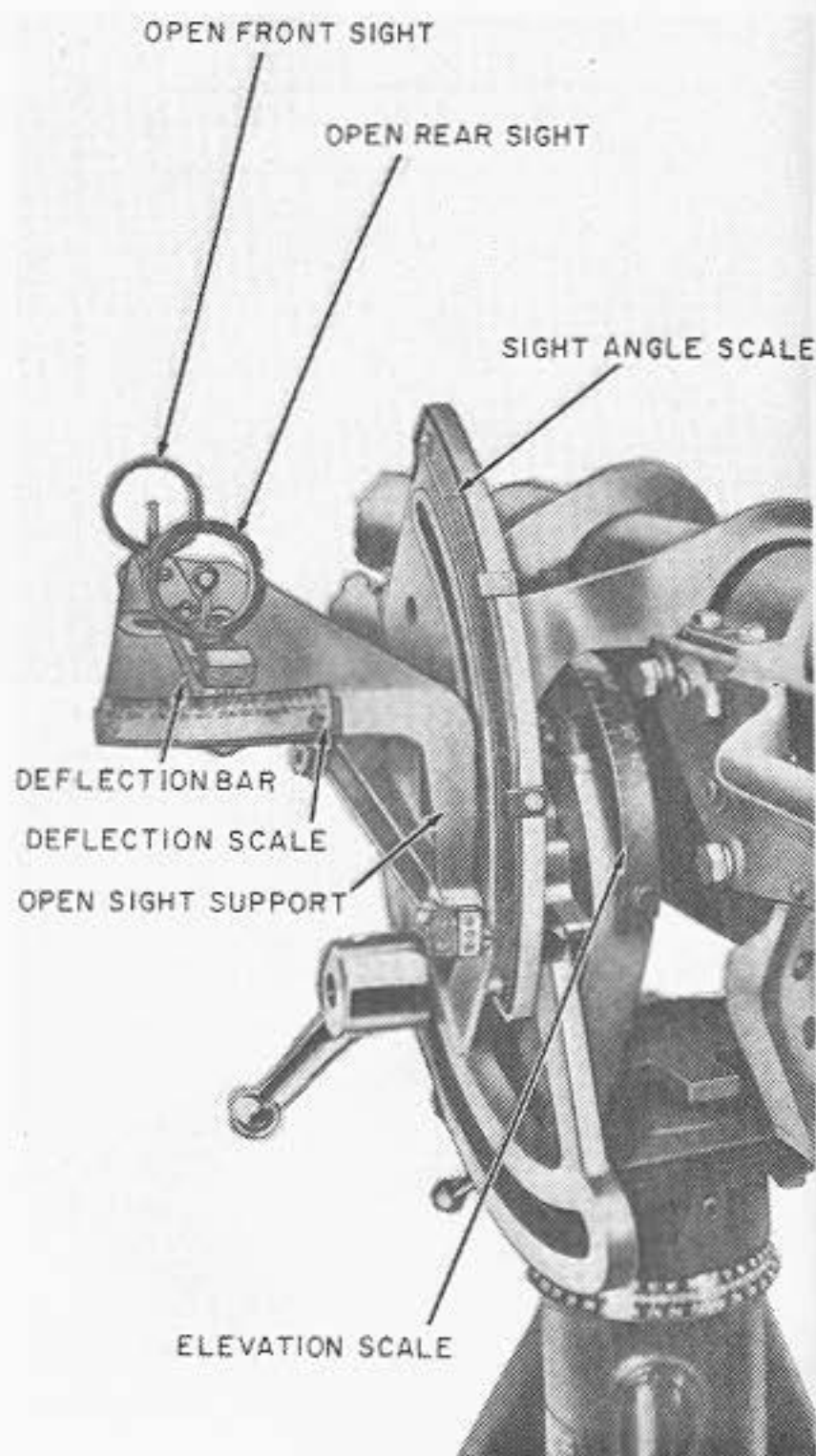
Figure 11-8.—81-mm mortar Mk 2 Mod 0 (right side view).

on impact but explode a fraction of a second later).

The mortar is simple in design. It can be operated by one man, though two usually perform this duty. It is designed for free swinging in both train and elevation for quick change in direction, or it can be fired from a fixed position, by either drop-fire or controlled trigger fire. (In drop-fire, the projectile is fired as soon as it slides down the barrel and hits the firing pin; trigger fire is similar to firing a handgun.)

The 81 mm mortar has an open yoke-type sight mounted at the left side of the slide (fig. 11-9). It is a manually-adjusted arrangement with offset limits of $14^{\circ}20'$ deflection, right and left, and 75° sight angle. The mortar has an elevation scale that is graduated in 5° increments from -30° to $+75^{\circ}$ and a training scale graduated in 1° increments from 0° to 360° .

Additional information on the 81 mm mortar, which is also mounted on Hydrofoil Gunboats (PGHs) and Fast Patrol Craft (PCFs), can be found in OP 1743.



29.320.2

Figure 11-9.—81 mm mortar sight Mk 1.

20 MM Gun

The 20 mm gun on the PTF (and other small craft) was originally designed in the early 1930's for use on aircraft. The first known successful application of this weapon for use on surface vessels was on the Navy's small boats in

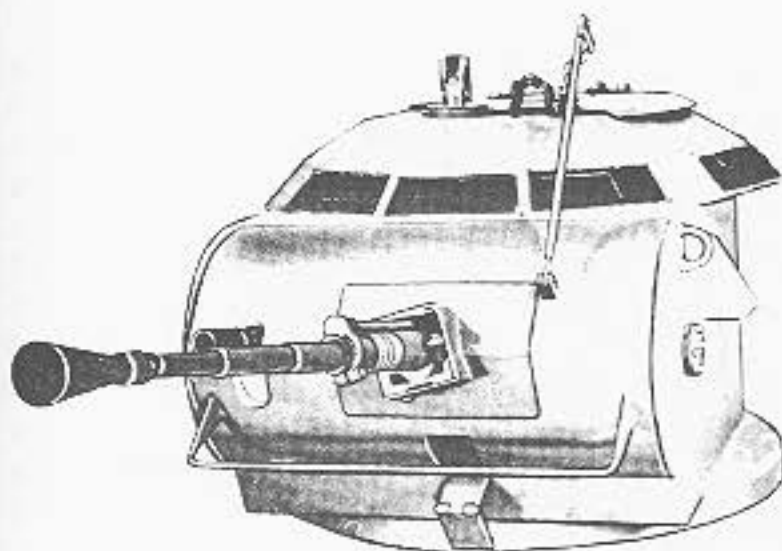
Vietnam—boats such as PCFs, PBRs and ASPBs. The 20 mm gun may be mounted in an open mount arrangement, as on the PTF, or in an enclosed mount (fig. 11-10).

For discussion purposes, the 20 mm aircraft gun may be considered to be divided into seven major components (fig. 10-22) as follows:

1. Gun barrel
2. Receiver assembly
3. Recoil mechanism assembly
4. Gas mechanism assembly
5. Breechblock assembly
6. Buffer assembly
7. Charger assembly

These assemblies include all the elements necessary for chambering a round of ammunition, closing and opening the breech, extracting an empty case, and controlling the recoil and counter-recoil actions. Additionally, the gun requires two accessories to make it a complete combat weapon—a synchronizing switch to complete the firing circuit and an ammunition feed mechanism.

In addition to being useful against aircraft, the 20 mm gun can be used against small craft and personnel. Its primary uses on the Navy's small boats in Vietnam are against personnel and small craft. A detailed description of the 20 mm aircraft gun can be found in Aviation Ordnanceman 3 & 2, NavPers 10345 series or OP 3476.



110,173

Figure 11-10.—Mk 48 gun mount with 20 mm gun and Mk 19 machine gun.

FAST PATROL CRAFT (PCF) ARMAMENT

The fast patrol craft, "swift" type (fig. 11-11), is generally equipped with an 81 mm mortar with a piggyback machine gun mount, aft, and a twin .50 caliber machine gun mount atop the pilot house. Also, they may be equipped with a Mk 19, 40 mm machine gun mounted forward of the pilot house and M60 (7.62) machine guns. PCFs, as well as other small boats, are equipped with hand-carried ordnance such as M79 grenade launchers and handguns, as the need arises.

HYDROFOIL GUNBOAT (PGH) ARMAMENT

Presently, there are two hydrofoil gunboats in service. Both are armed with 1—40 mm gun forward, 4—.50 caliber (two twin mounts) machine guns atop the pilot house, and 1—81 mm mortar aft. Hydrofoil Gunboat Tucumcari (PGH-2) is shown in figure 11-12. Its high speed capability (above 40 knots), ease in maneuvering, and variety of weapons makes it very useful for coastal operations. (Both PGH-1 and PGH-2 are expected to be used for ordnance experimental purposes in the near future.)

RIVERINE CRAFT AND THEIR ARMAMENT

Riverine craft as we know them today consist of a variety of small boats with a variety of armament, much of which is the same as that for the coastal craft discussed earlier. Some of these boats were built specifically for riverine use; others are converted World War II landing craft, commercial craft, and pleasure craft. They include the river patrol boat (PBR), assault support patrol boat (ASPB), monitor (MON), armored troop carrier (ATC), command and control boat (CCB), patrol air cushion vehicle (PACV), and the river minesweeper (MSR). The armament of a representative number of these craft will be discussed in the following paragraphs.

RIVER PATROL BOAT (PBR) ARMAMENT

The river patrol boat shown in figure 11-13 is armed with 3—.50 caliber machine guns and a 40 mm (M79) grenade launcher. The twin machine gun mount is located in the bow section of the boat. The 40 mm grenade launcher is hand carried. The single machine gun is located near the boat's stern.



134.174
Figure 11-11.— Fast patrol craft, "Swift" type.



3.88(134)
Figure 11-12.— Hydrofoil gunboat Tucumcari (PGH 2) with hydrofoils in the water.



3.272

Figure 11-13.—River patrol boat on a routine patrol.

The armament of different PBRs varies. Some PBRs have a 40 mm machine gun mounted over the single .50 caliber machine gun. Others have 60 mm mortars and 7.62 mm machine guns in addition to their .50 caliber machine guns and 40 mm machine gun.

40 MM Grenade Launcher M79

The M79 grenade launcher is a single-shot, shoulder fire weapon. It is breech loading and chambered for a 40-mm metallic cartridge case with internal primer. It is trigger-fired the same as a shotgun. It even resembles a shotgun somewhat (fig. 11-14). Because of its versatility, the grenade launcher is issued to most of the riverine craft, and its primary use is the launching of antipersonnel projectiles against enemy ground forces. The operation and maintenance of the M79 grenade launcher is described in Army Technical Manual TM 9-1010-205-12.

60 MM Mortar

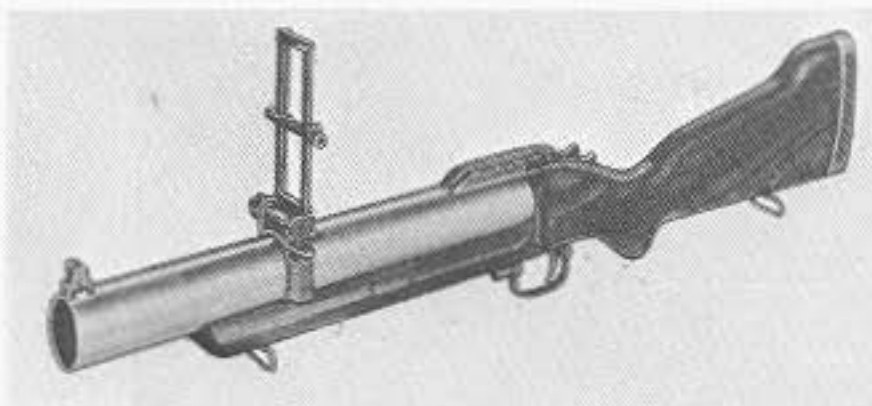
Like the 81 mm mortar, the 60 mm mortar (fig. 11-15) can be used for bombardment, laying

smoke screens, and for providing nighttime target illumination. It too has a recoil-counter-recoil mechanism to reduce brake load and a trigger-firing mechanism.

The main characteristics of the 60 mm mortar are as follows:

Weight.	135 pounds
Length.	54 1/4 inches
Width.	14 inches
Height.	57 3/4 inches
Mode of fire.	drop or trigger
Type of feed.	hand
Rate of fire.	10-18 rounds per minute
Maximum range.	1,850 yards
Effective range.	1,000 yards
Muzzle velocity.	493 feet per second
Barrel twist.	none
Barrel length.	25 5/8 inches
Cooling.	air

Operationally, the 60 mm mortar is similar to the 81 mm mortar. The major differences between the two are the greater muzzle velocity, larger projectile, and longer range of the 81 mm mortar.



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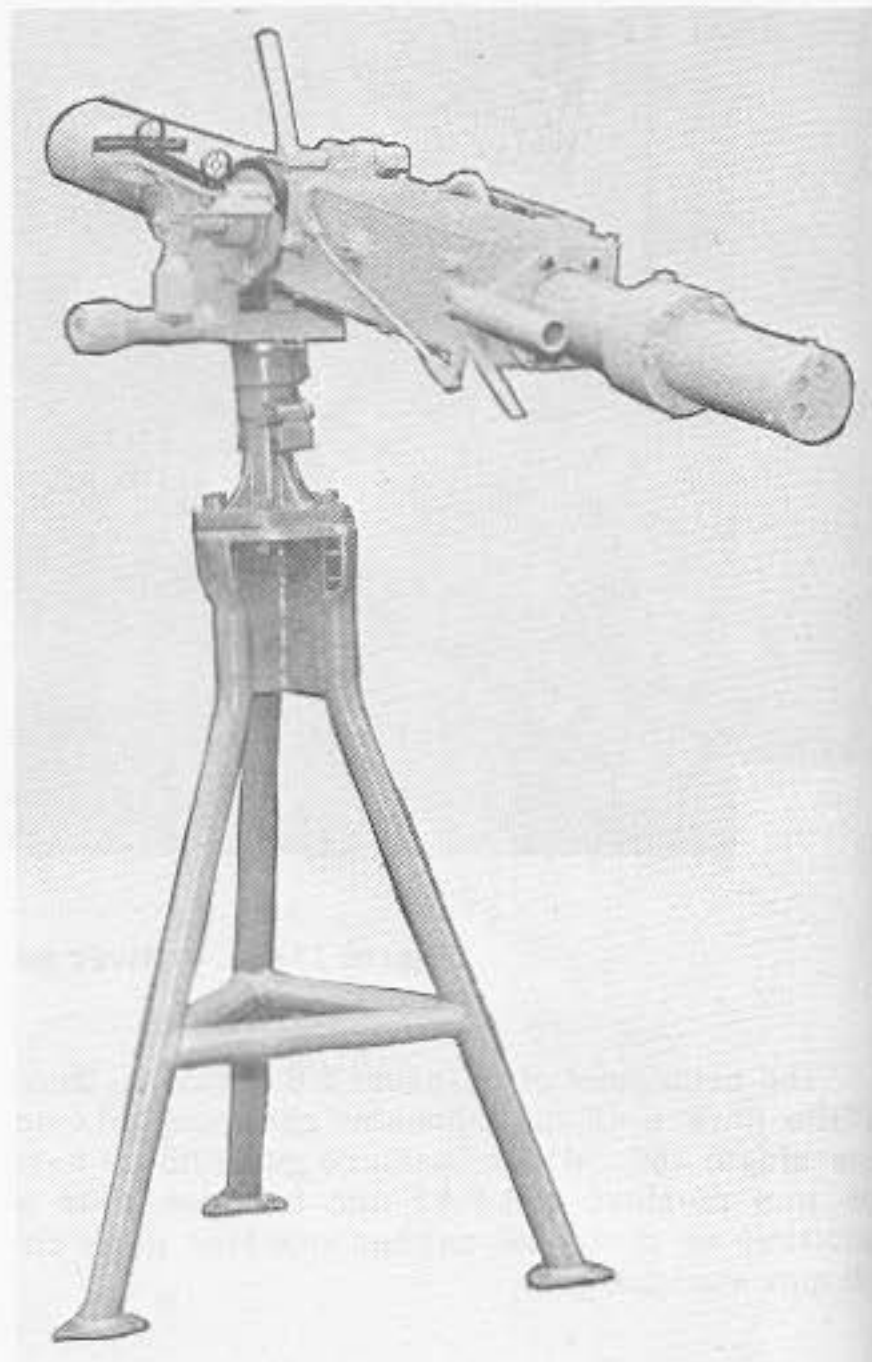
Figure 11-14.—Grenade launcher M79 (left front view).

7.62 MM Machine Gun M60

Another weapon that is commonly used on the PBR and other riverine craft (as well as on some coastal patrol craft) is the 7.62 mm machine gun. This is the Army's machine gun mounted for use on Navy small boats, and it is capable of engaging distant targets (up to 3200 meters) with a heavy volume of controlled and accurate fire.

The M60 machine gun (fig. 11-16) is an air-cooled, belt-fed, gas-operated automatic weapon. The ammunition for this weapon, which fires from the open-bolt position, is fed into the gun by a disintegrating metallic split-link belt. Main characteristics of the gun are as follows:

Caliber.	7.62 mm NATO (.308 caliber)
Weight	22 pounds
Length	43.5 inches
Width.	3 inches
Height	5 inches
Mode of fire	automatic
Direction of feed.	left hand
Type of feed	ammunition can
Rate of fire	550 rounds per minute
Maximum range	3,200 meters
Effective range	1,100 meters
Muzzle velocity	2,750 feet per second
Barrel twist	right hand, one turn in 10 inches
Barrel length	24 inches
Cooling.	air

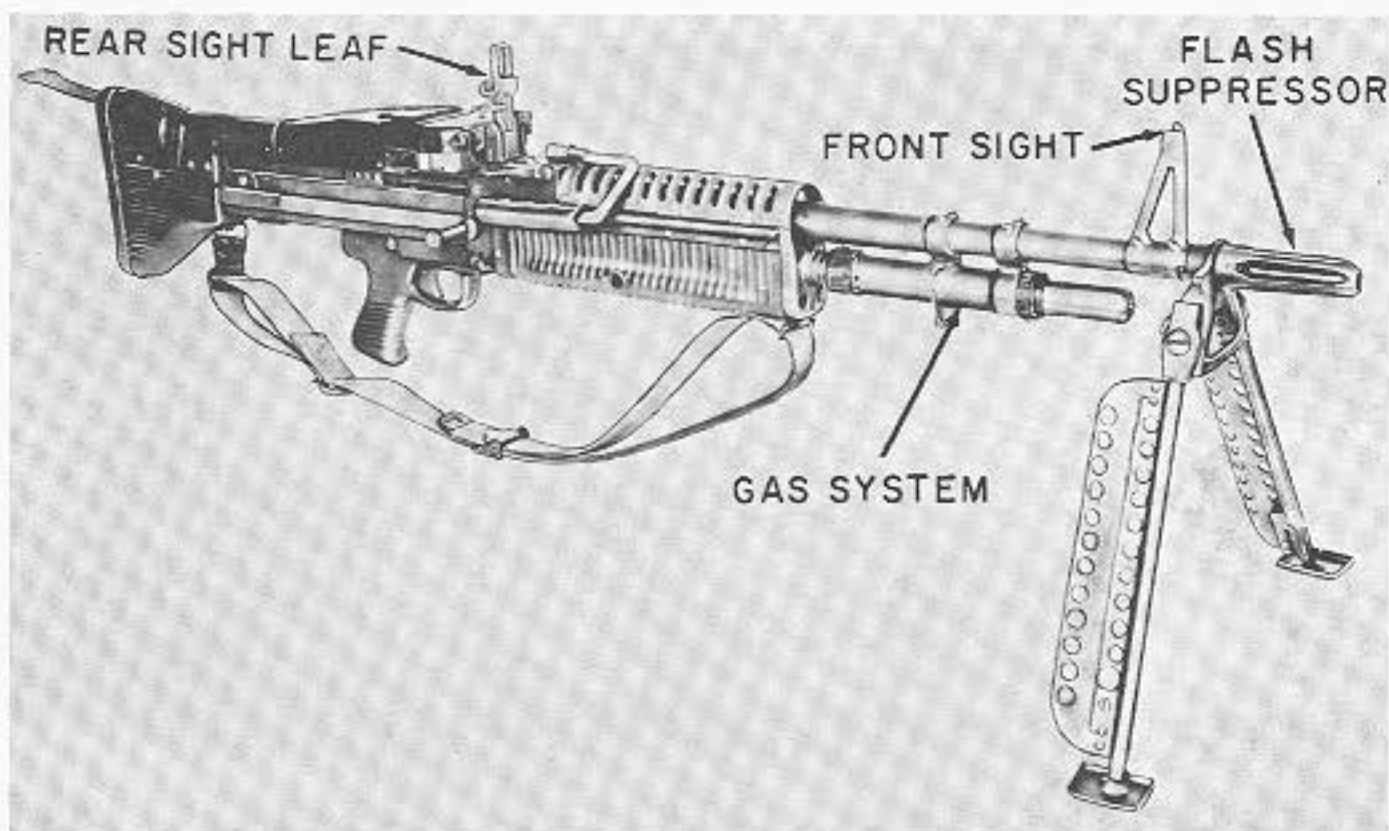


29,320

Figure 11-15.—60 mm mortar.

The M60 has a front sight permanently affixed to the barrel. The rear sight leaf is mounted on a spring-type dovetail base. The range plate on the sight leaf is marked for each 100 meters, from 300 meters to the maximum effective range of 1,100 meters. Range changes may be made by using either the slide release or the elevating knob—the slide release for major changes and the elevating knob for minor changes.

A detailed description of the 7.62 machine gun M60 is found in Army Technical Manual FM 23-67.



45,578

Figure 11-16.—7.62 mm machine gun, M60, bipod mounted.

Miscellaneous Ordnance

Some PBRs, as well as other small boats, carry night vision equipment, small arms, pyrotechnics, and demolition grenades. The night vision equipment (sight) is used to see enemy movement at night or during poor visibility conditions. It is hand held or mounted on the M16 rifle. Small arms carried by the PBR consist of a 12 gauge shotgun, 3—M16 (5.56) rifles, 2—40 mm grenade launchers, a .38 caliber revolver, and an ordnance locator. The small arms are especially useful for boarding and search operations. The pyrotechnics are used for signaling, by smoke or illumination.

The miscellaneous ordnance carried by any boat at a given time will vary according to its assigned mission.

ASSAULT SUPPORT PATROL BOAT (ASPB) ARMAMENT

Armament of ASPBs may vary, but generally it consists of 2—Mk 26 gun mounts (with either .50 caliber machine guns or Mk 20, 40 mm machine guns), 2—20 mm machine guns, and 2—Mk 19 high-velocity grenade machine guns—plus small arms and night vision devices.

The ASPB (fig. 11-17), with its assortment of armament, is used mainly for patrolling in-

land waterways and for supporting troop landings and movements. A description of its armament, except for the .50 caliber machine gun which was described earlier, is in the following paragraphs.

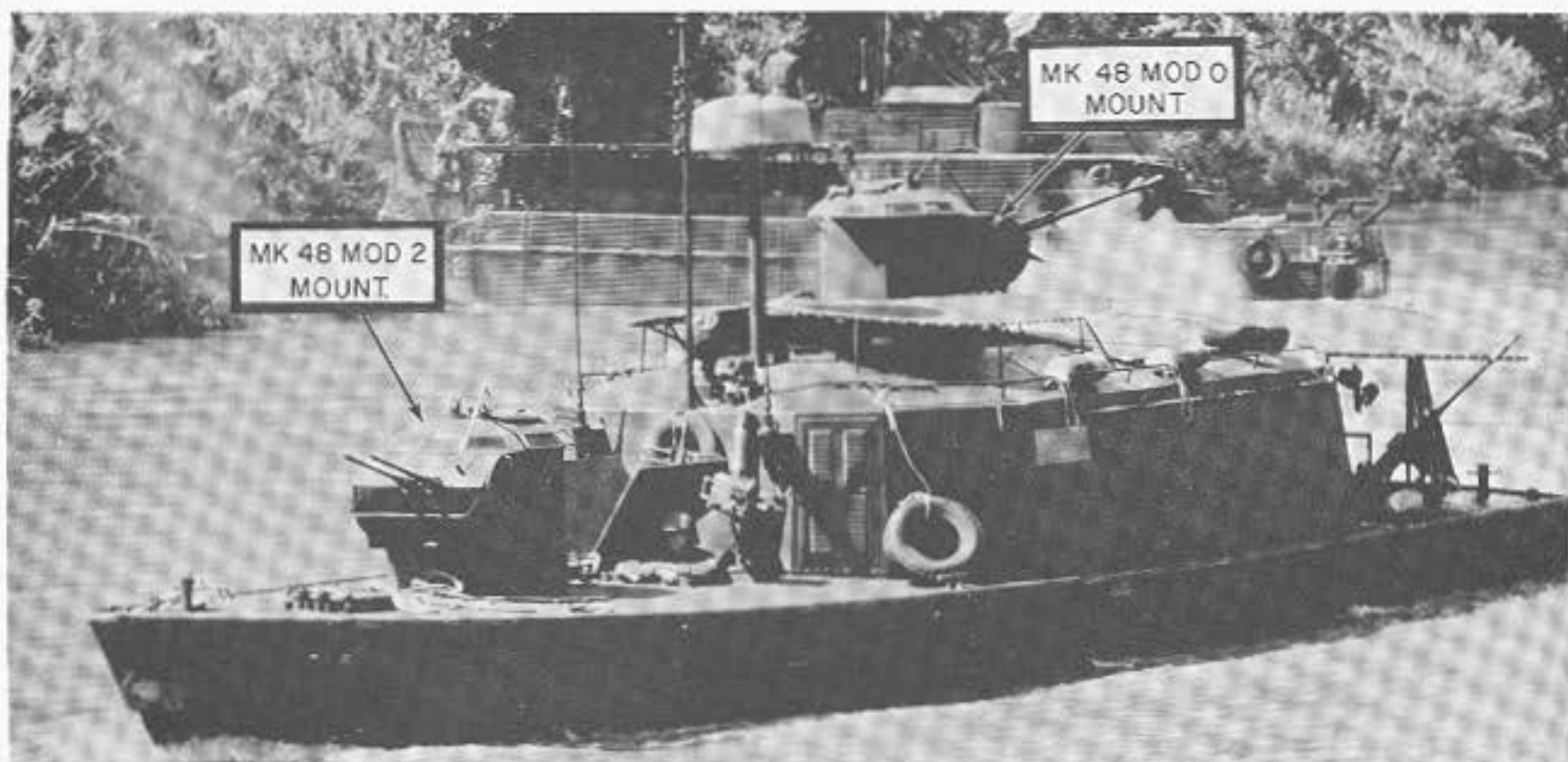
Mk 26 Gun Mount

The Mk 26 mount is a universal tripod, lightweight unit developed for the .50 caliber heavy barrel machine gun and adaptable for mounting other weapons. The mount is quite versatile with respect to location on a variety of small boats. It weighs 205 pounds and is 59 inches high. It can elevate through a 100° arc—from -15° to 85°. Figure 11-18 shows the Mk 26 with a .50 caliber machine gun mounted. The Mk 20 machine gun requires an adapter for its installation on the Mk 26 mount.

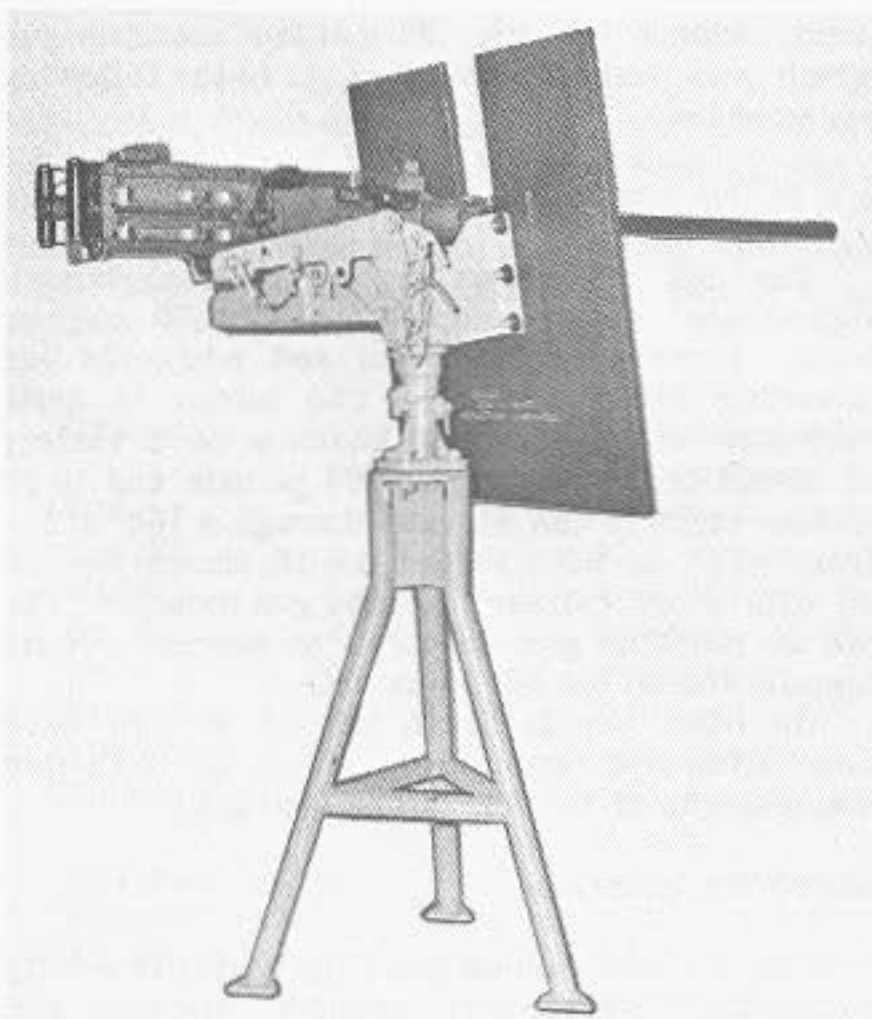
On other small craft, the Mk 26 may have other ordnance mounted—such as the 7.62 mm machine gun or the Mk 20 machine gun.

Mk 20 Machine Gun

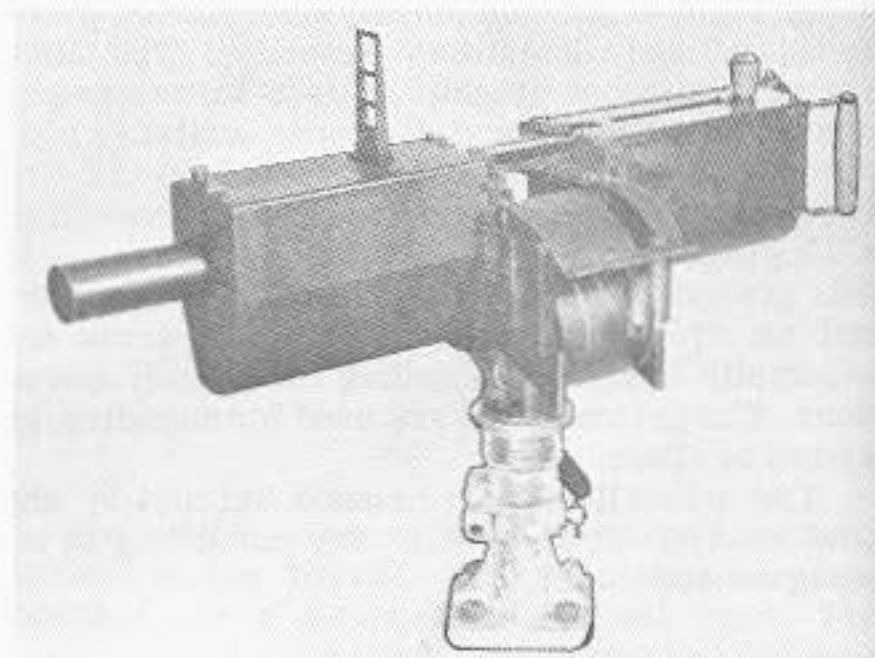
The Mk 20 machine gun (fig. 11-19) is a fully automatic, low-velocity grenade machine gun used as an antipersonnel weapon. It fires the same round as the M79 grenade launcher, and it utilizes a metallic link fed from a 24-round ammunition can. The gun was designed to be



110.174
Figure 11-17.—Assault support patrol boat, on patrol.



84.112
Figure 11-18.—.50 caliber machine gun on Mk 26 gun mount.



110.175
Figure 11-19.—Mk 20 grenade gun (low velocity).

pedestal mounted; however, it is recoilless and lends itself to multiple mounting systems such as tripods or bipods or, if necessary, it may be fired from a hand-held position.

To fire the weapon, the first cartridge is loaded manually into firing position. After that

shot is fired, the remaining operation is automatic or semiautomatic—depending upon the mode of fire.

Following are some characteristics of the Mk 20 machine gun:

Caliber	40 mm
Weight	26 pounds
Length	27 inches
Width	9 inches
Height	7 inches
Mode of fire	full automatic or semiauto- matic
Direction of feed	left hand
Type of feed	mechanical, link
Rate of fire	250 rounds/ minute
Maximum range	400 meters
Effective range	350 meters
Muzzle velocity	230 feet/second
Barrel twist	right hand, one turn in 48 inches
Barrel length	12 inches
Cooling	air

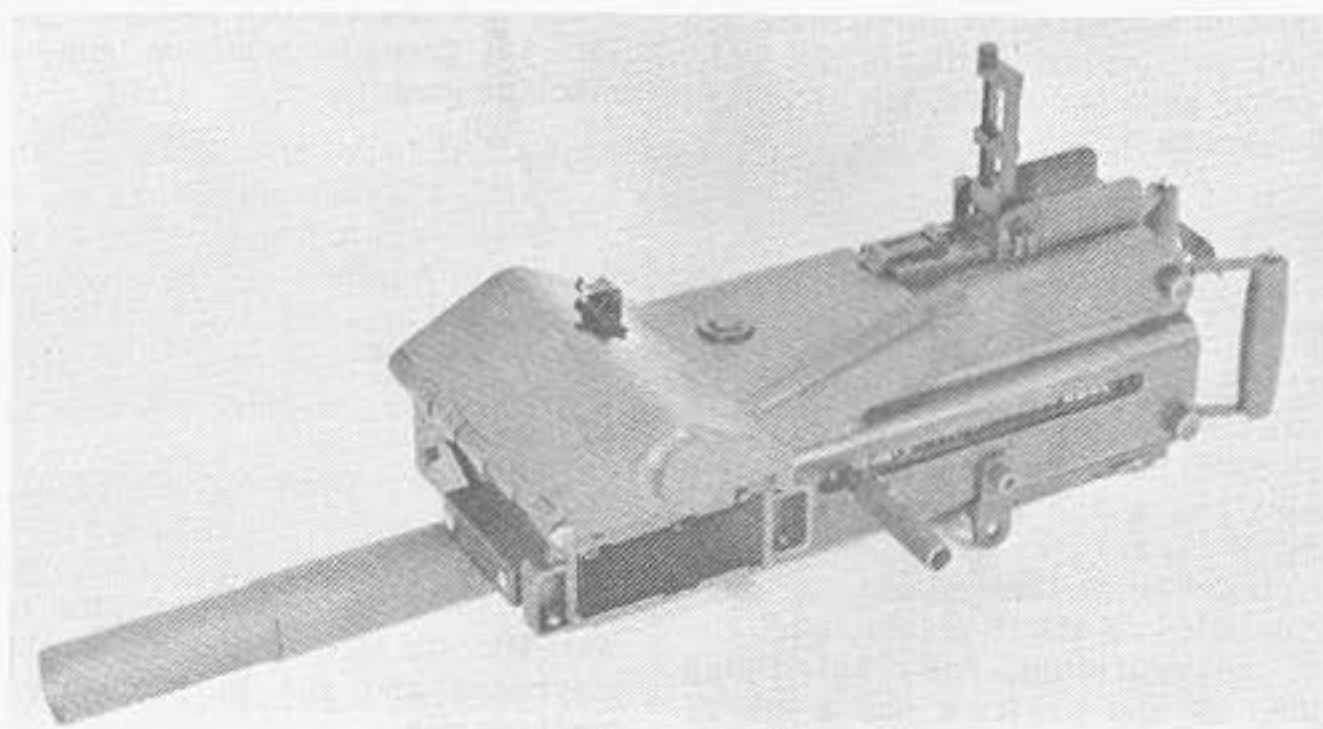
This weapon, with its relatively high rate of fire, can inflict heavy damage upon enemy troops.

Mk 48 Gun Mount

The Mk 48 gun mount is a medium-armored, small-caliber, flexible multiple-gun mount for use on small craft employed in patrol, escort, and support duties. The mount provides fire power effective against other small craft as well as personnel and shore emplacements. It has unobstructed peripheral vision for easy target recognition from all angles.

The Mk 48 mount comes in several mods. Its mod depends upon its ordnance suite. The Mod 0 mount has one Mk 19 machine gun and one 20 mm machine gun; the Mod 1 has one Mk 19 machine gun and two 7.62 mm machine guns; and the Mod 2 has one Mk 19 machine gun and two .50 caliber machine guns.

The ASPB in figure 11-17 has a Mk 48 Mod 2 mount and a Mk 48 Mod 0 mount like the one shown in figure 11-10. The mount is 39 inches above the deck. It is manually operated through 360° in train and can be elevated from -15° to 65° (a total of 80°). It has a periscope-type sight for daytime use and a light amplification type for use at night. The Mod 0 (as stated earlier) has a 20 mm machine gun and a Mk 19 machine gun. The 20 mm gun is identical to those described earlier for the fast patrol boat. The Mk 19 machine gun (fig. 11-20) is a mechanically-fed, blowback-operated weapon designed to fire 40 mm high velocity grenades.



110.176
Figure 11-20.—Mk 19 machine gun.

It can be fired by hand or remotely by using a solenoid. Its main characteristics are as follows:

Caliber	40 mm
Weight	46 pounds
Length	34 inches
Width	8.5 inches
Height	7.5 inches
Mode of fire	full automatic or semiauto- matic
Direction of feed	left to right
Type of feed	mechanical, link
Rate of fire	375 rounds/ minute
Maximum range	2,200 meters
Effective range	1,600 meters
Muzzle velocity	800 feet/second
Barrel twist	right hand, one turn in 48 inches
Barrel length	12 inches
Method of operation	advanced primer ignition
Cooling	air

Although the Mk 19 40 mm machine gun was initially designed for use on the Mk 26 deck mount or on the Mk 48 shielded mount, further adaptation has enabled it to be used in other applications (e.g., by ground forces and in some helicopters).

Miscellaneous ASPB Armament

The ASPB has an allowance of small arms and night vision devices similar to that of the PBR. Additionally, some have two 4 tube Mk 47 rocket launchers (3.5 bazookas).

MONITOR (MON) ARMAMENT

The monitor, a converted landing craft (LCM), provides fire support for riverine operations. It has two basic hull configurations—the HOWITZER and the FLAME SYSTEM. The Howitzer configuration (fig. 11-21) has a 105 mm howitzer mount forward, 2—Mk 48 Mod 0 gun mounts aft (one to port and the other to starboard), and 2—7.62 mm machine guns installed on Mk 26 gun mounts. The flame system configuration has two flame throwers instead of the howitzer and a Mk 20 machine gun in place of one of the 7.62 mm machine guns. Both configurations have small arms and night vision devices.

The heavily armored monitor is popularly referred to as the "battleship" of the riverine fleet. Its 105 mm howitzer or flame thrower gives it added "punch" in routing the enemy.

OTHER COASTAL AND RIVERINE CRAFT AND THEIR ARMAMENT

The Navy has several other types of coastal and riverine craft. Some are used for one specific purpose while others have multiple uses. Whether these craft are in an active or a reserve status depends upon the current requirement. Some of these craft and their armament are as follows:

1. Patrol Air Cushion Vehicle (PACV). The PACV (fig. 11-22) travels on a cushion of air about four feet thick. Flexible air-actuated trunks provide obstacle clearance and ditch-crossing capability over land and improved riding qualities over water. The PACV has been highly successful in its operation in the marshy plains of South Vietnam. It is armed with a twin Mk 56 .50 caliber machine gun mount, two 7.62 mm machine guns, and two 40 mm grenade launchers.

2. Armored Troop Carriers (ATCs). These craft were converted from LCM-6 landing craft. Their main purpose is to transport troops, small vehicles, field artillery, and supplies. Heavily armored, they are fitted with steel helicopter platforms to facilitate evacuation of wounded personnel, logistics resupply, and as emergency landing platforms for damaged helicopters. Their armament consist of 1 or 2—20 mm machine guns, 2—.50 caliber machine guns, 1—40 mm Mk 19 grenade machine gun, and 2—Mk 20 machine guns.

3. Command and Control Boat (CCB). The CCB (fig. 11-23) serves as an afloat command post, which provides command and communications facilities for ground force and boat group commanders. They are heavily armored and are armed with 2—20 mm machine guns, 2—.30 caliber (or 7.62 mm) machine guns, and 2—Mk 19 machine guns.

4. River Minesweepers (MSR). River minesweepers are converted landing craft. They are heavily armored craft that are used for clearing mines from the rivers. MSRs are armed with two Mk 48 Mod 0 mounts amidships—one to starboard and one to port—and a .50 caliber machine gun.

5. Coastal Minesweeper (MSC). The MSC is constructed throughout of wood and other



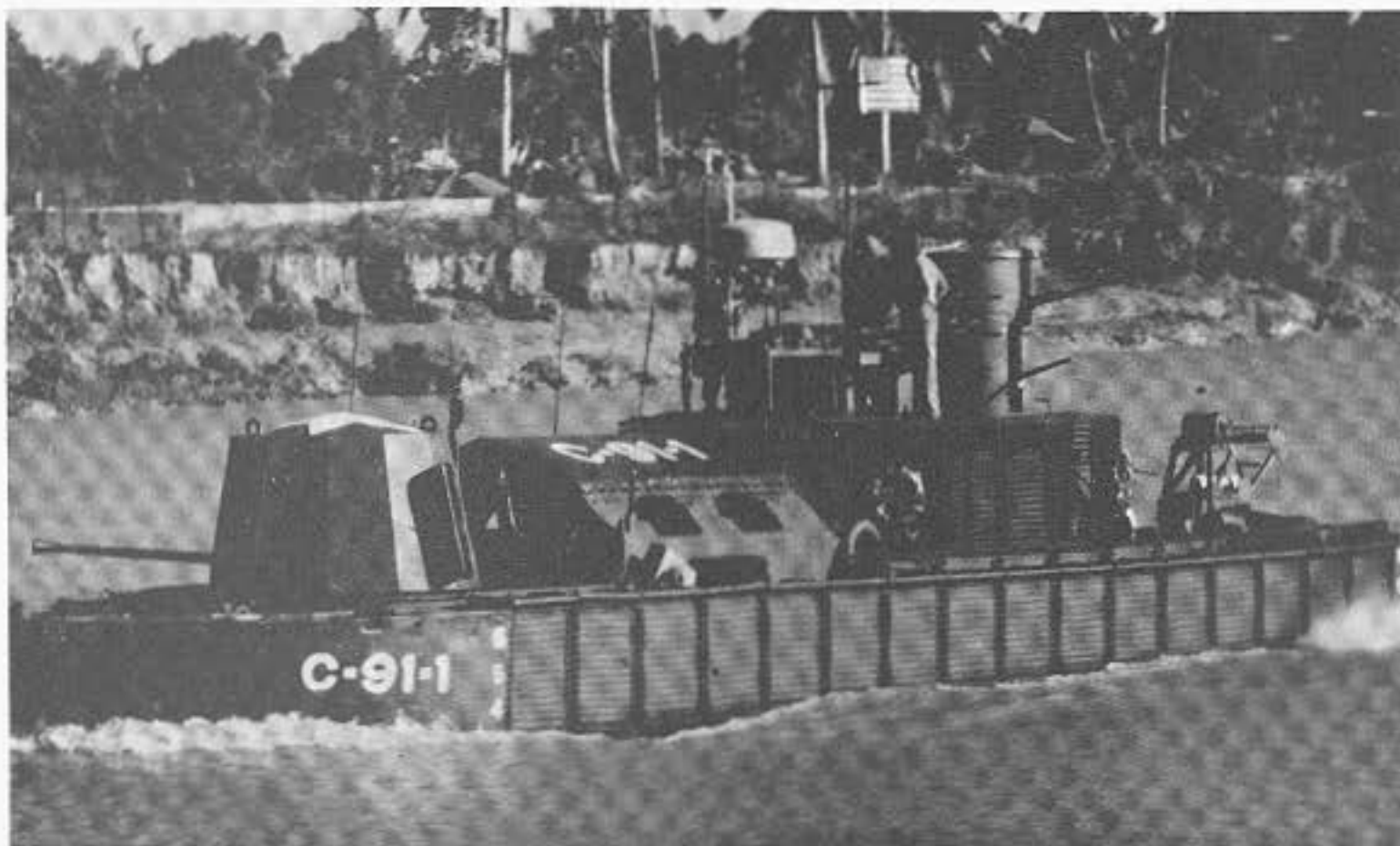
Figure 11-21.—Howitzer configuration monitor.

134,172



110,177

Figure 11-22.—The patrol air cushion vehicle, riding on a 4-foot cushion of air, can patrol or chase over any type of terrain.



110.178
Figure 11-23.—Command and control boat (CCB).



110.179
Figure 11-24.—Bluebird class coastal minesweeper (with twin 20 mm mount forward).



110.180

Figure 11-25.—Albatross class coastal minesweeper (old) has one 40 mm mount forward.

materials with a low magnetic attraction. The Bluebird Class (fig. 11-24) has one twin 20 mm mount forward. The Albatross Class (fig. 11-25) are classified as MSCOs and have a single 40 mm mount forward. (The 20 mm twin mounts shown in the illustration have been removed from active MSCOs.)

These are but a sampling of the various small boats used in coastal and riverine operations. Again, bear in mind that the armament may vary considerably from boat to boat. For example, the armament on one PBR may be quite different from the armament on another PBR.

CHAPTER 12

UNDERWATER ORDNANCE

Underwater ordnance includes weapons used in destroying or disabling an enemy ship by means of an underwater explosion. Weapons employed in underwater warfare include torpedoes, mines, depth charges, depth bombs, hedgehogs, and rockets.

Some of the Navy's most recent developments in rocket-assisted underwater weapons such as Asroc, Subroc, and Astor are discussed briefly in the next chapter. A more detailed discussion of these and other underwater weapons may be found in (the classified publication) Navy Missile Systems, NavPers 10785 series. This chapter is limited to a discussion of torpedoes and mines.

A torpedo is a self-propelled weapon that carries a high-explosive charge to an enemy ship. A mine is a thin-cased weapon filled with high explosives and designed to explode under water when struck or closely approached by a ship. The ancestor of both was David Bushnell's powder keg with contact triggers (caused keg to explode on contact with an object) attached (fig. 12-1), many of which he floated down the Delaware River toward blockading British ships during the American Revolution.

Much emphasis is still being placed on improving mines and torpedoes. One reason is the fact that an underwater explosion can do more damage than an above-water explosion using the same explosive charge. Since water is practically incompressible, it transfers most of the force of an explosive shock directly to the hull of the target ship, whereas air absorbs much of the force of an explosion in the atmosphere.

INTRODUCTION TO TORPEDOES

Credit for the first self-propelled torpedo goes to a Captain Lupius of the Australian Navy. Captain Lupius worked out his idea during the American Civil War, but he didn't have the mechanical know-how to actually build the torpedo.

In 1864 he took his plans to Robert Whitehead, a British engineer. After two years of work, Whitehead produced a short torpedo, 14 inches in diameter, with 18 pounds of dynamite in its warhead. It was powered by a piston engine operating on compressed air at 700 psi. Whitehead's first torpedo ran at 6 knots, for about 100 yards. On some of its tests it ran along the surface; on others it dived to the bottom.

Whitehead invented many of the devices that are found in modern torpedoes. For example, the air system of the Whitehead torpedo was controlled by a stop valve, a charging valve, a starting valve, and a reducing valve. To keep his torpedo running at the proper depth, Whitehead invented a depth mechanism containing a hydrostatic diaphragm and pendulum. (Air-steam torpedoes have all these parts.) To keep his torpedo on course Whitehead invented a servomotor to operate the steering rudders. Whitehead developed the idea of replacing the warhead with an exercise head for practice shots.

While Whitehead was improving his torpedo, other inventors were busy, too. Most of these experimental torpedoes were abandoned shortly after they were tested. Air-steam torpedoes are based on Whitehead's ideas. But three big

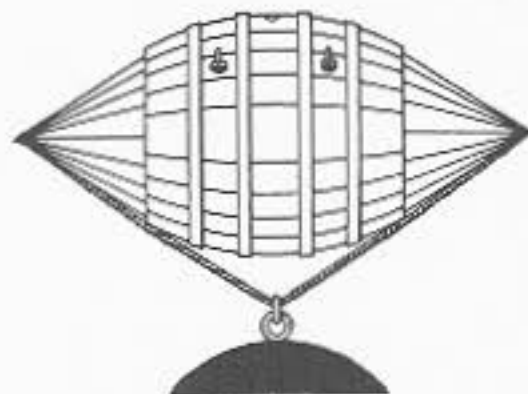


Figure 12-1. — Bushnell's powder keg mine, ancestor of the torpedo and mine.

improvements on Whitehead's basic invention have been made:

- (1) substituting turbines for the piston engine,
- (2) adding fuel to superheat the compressed air, and
- (3) adding a gyroscope to control the steering engine.

As previously stated, a torpedo is a self-propelled weapon. Its principal requirements are, therefore, a charge of explosive and a power plant. As a practical weapon, a torpedo must have a number of other features, including:

1. A shell, or housing, strong enough to support the explosive charge, power plant, and related mechanisms, and strong enough to withstand the shock of launching.

2. A source of energy for the power plant, and for the torpedo control mechanisms.

3. An exploder that will detonate the explosive charge when the torpedo reaches its target, but which will remain inoperable while the torpedo is close to the firing ship.

4. Control mechanisms that hold the torpedo on a preset course, at a preset depth.

5. One or more propellers to drive the torpedo through the water.

6. Tail vanes and rudders, to control course and depth.

7. Homing torpedoes require, in addition, a homing device which will enable the torpedo first to search for the target, then to sense the target as it approaches, and finally to steer itself on a collision course with the target. At present, homing devices function on acoustic principles.

All torpedoes are similar in general exterior appearance. They differ considerably, however, in function and capabilities. Torpedoes may be classified in several ways:

1. By their power plants (air-steam, chemical, electric, or solid fuel).

2. By the vehicle from which they are launched (surface ship, submarine, or aircraft).

3. By speed and range.

4. By the type of exploder used. The impact exploder operates only when the torpedo actually strikes its target. The influence exploder (which will not be detailed in this text) operates when the torpedo passes near its target.

5. By type of control mechanism. The control mechanism in a conventional torpedo holds the

torpedo on a previously calculated collision course with the target. A homing torpedo, after enabling (commencing to search), runs on a preset "pattern-running" course until it acquires the target. It then receives steering signals from the homing system and attacks the target. If the target is lost, the torpedo shifts back to a search pattern until it acquires the target once more.

Although torpedoes are constantly being improved as to speed, accuracy, and lethality, the exterior shape has remained almost the same except for a reduction in length. Most torpedoes are elongated cylinders with relatively blunt noses and tapering tails. Standard diameters are 10, 12.75, 19, and 21 inches. Most torpedo tubes consist of 21" diameter barrels and with the proper equipment can accommodate torpedoes of any diameter. The nose may be either ogival, spherical, or flat. The tapering tail mounts fins with vertical rudders and horizontal stabilizers (the latter corresponding to elevators in an aircraft) as well as either one or two screws (propellers). If there are two screws, they rotate in opposite directions (counterrotation), so that the reaction of a single screw will not cause the torpedo body to rotate. If a torpedo has a single screw, either its tail fins are canted or its body is fitted with canted longitudinal ribs or ridges to produce a torque opposing that of the single screw as the torpedo passes through the water.

FUNCTIONAL ELEMENTS

A torpedo is generally constructed in four sections—head, midsection, afterbody, and tail. Each section is concerned with a specific function. Most homing torpedoes, however, have only three sections; the afterbody and tail are usually combined.

The head may be either a warhead or an exercise head. The warhead contains the main charge and its exploding device, as well as (in a homing or influence-fired torpedo) the acoustic and magnetic sensing elements used in steering the torpedo and firing the charge. An exercise head contains either liquid ballast (water) or solid ballast (lead weights) which is released at the end of torpedo run, causing the torpedo to surface.

The midsection (which may have different names in different types of torpedo) in general houses energy-storing or energy-supplying devices, such as compressed air flasks, batteries, fuel and oxidizer tanks, and the like. It may also contain some controlling devices such as valves

or some guidance equipment. The midsection may actually be constructed as two parts. In air-steam powered torpedoes, it is called the air flask section; in some electric-powered torpedoes, it is called the battery compartment.

The afterbody contains the propulsion engines and gearing and guidance equipment.

The tail includes the fins and control surfaces, the exhaust system (if any), and the screws that propel the torpedo. All standard torpedoes now in active service use screw propulsion.

Torpedoes may be fitted with other accessory parts required for special launching methods. Thus, torpedoes modified for rocket or missile propulsion (such as those used with Asroc) may be fitted with parachutes and buffers to reduce shock when they enter the water, and with special hardware for attachment of airframes or suspension from aircraft.

LAUNCHING METHODS

There are four principal ways to launch a torpedo—by firing it from a tube, by dropping it from a rack, by propelling it part of the way to its target as a rocket payload, or by letting it swim out.

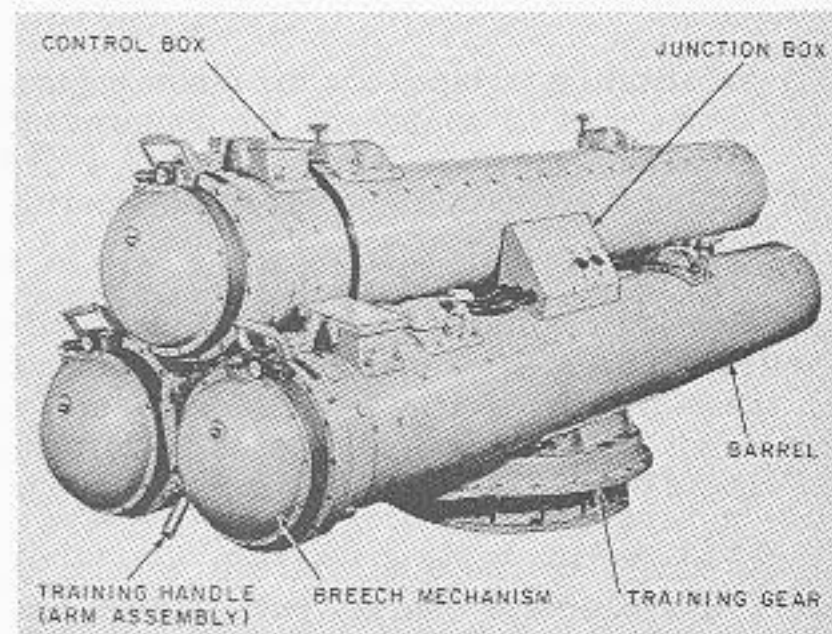
Aircraft drop torpedoes from launching racks; usually, an aircraft carries only a single torpedo. A helicopter can carry one or two torpedoes for ASW work.

The Navy's older destroyers as well as FRAM destroyers, DDGs, and DLGs carry torpedoes in the 3-barrel Mk 32 launcher (fig. 12-2).

The tube is usually carried amidships. It can be trained through a wide arc, so that torpedoes may be fired over either side of the ship. Compressed air expels the torpedoes from the tube with enough force to clear the ship. These 3-barrel tubes have all but superseded an older 5-barrel tubes that used black-powder impulse charges to expel the torpedo.

Some destroyer escorts are fitted with fixed, nontrainable tubes—usually four of them—located above the main deck with their muzzles extending through the sides of the deck house. Others have twin tubes protruding through the ship's stern.

Submarines fire torpedoes from fixed, below-water tubes. On firing, the torpedoes are expelled from the tubes by hydraulic ejection or compressed air or they swim out under their own power. Spare torpedoes are carried in ready racks near the tubes.



3.129(51)

Figure 12-2.—Torpedo tube Mk 32.

The torpedo is an important weapon of all modern destroyers. Torpedoes are the principal armament of many submarines and, under certain conditions, of aircraft. Torpedoes also constitute the payload of more advanced ASW weapons such as Asroc.

The tactical use of torpedoes has changed tremendously over the past few years. Their use in surface engagements is likely to be much less frequent than it was before. The outcome of a battle will most likely be decided before the enemy is within torpedo range.

On the other hand, torpedoes have become very important in ASW. In this application they may be launched from air, surface, or undersea craft to attack a submerged target even when the target's exact position and depth are unknown.

AIR-STEAM TORPEDOES

Although the submarine-launched air-steam torpedo does not represent the most advanced state in the art of torpedo design, it still is used to a limited extent throughout the fleet. The air-steam torpedo also is more suitable for discussion than are more advanced types because of security reasons.

An air-steam torpedo is divided into four main sections: head, air flask, afterbody, and tail. Internally, a fifth (midship) section is permanently joined to the air flask section.

MK 14 TORPEDO

Figure 12-3 shows the Mk 14 air-steam torpedo with principal contents of the main sections.

- The warhead, occupying the forward 4 feet of the torpedo, contains high explosive (HBX) and the exploder mechanism that detonates it.

- The air flask section (fig. 12-4) is the longest part (10 feet) of the torpedo, the air flask itself occupying most of the section. The flask carries the torpedo's air supply at a pressure of 2800 psi. Aft of the air flask is the water compartment, and inside the water compartment is a bulkhead that divides the air flask section from the midship section. The fuel compartment is in the center of the water compartment attached with brackets to the water compartment bulkhead.

- The midship section (fig. 12-3) contains a number of pipes that carry air, fuel, and water from the air flask section to the superheating system in the afterbody. A number of control valves are mounted on the shell of the midship section. Since this section contains many parts that carry the hot gases of combustion, there are holes cut in the shell of the section to allow sea water to flood and cool the parts therein.

- The afterbody (fig. 12-3) contains the torpedo's propelling and controlling mechanisms. These start the torpedo, generate and apply the power necessary to drive it from the time

it is launched until it completes its run, determine the torpedo's vertical and horizontal courses, and maintain it on those courses throughout the run.

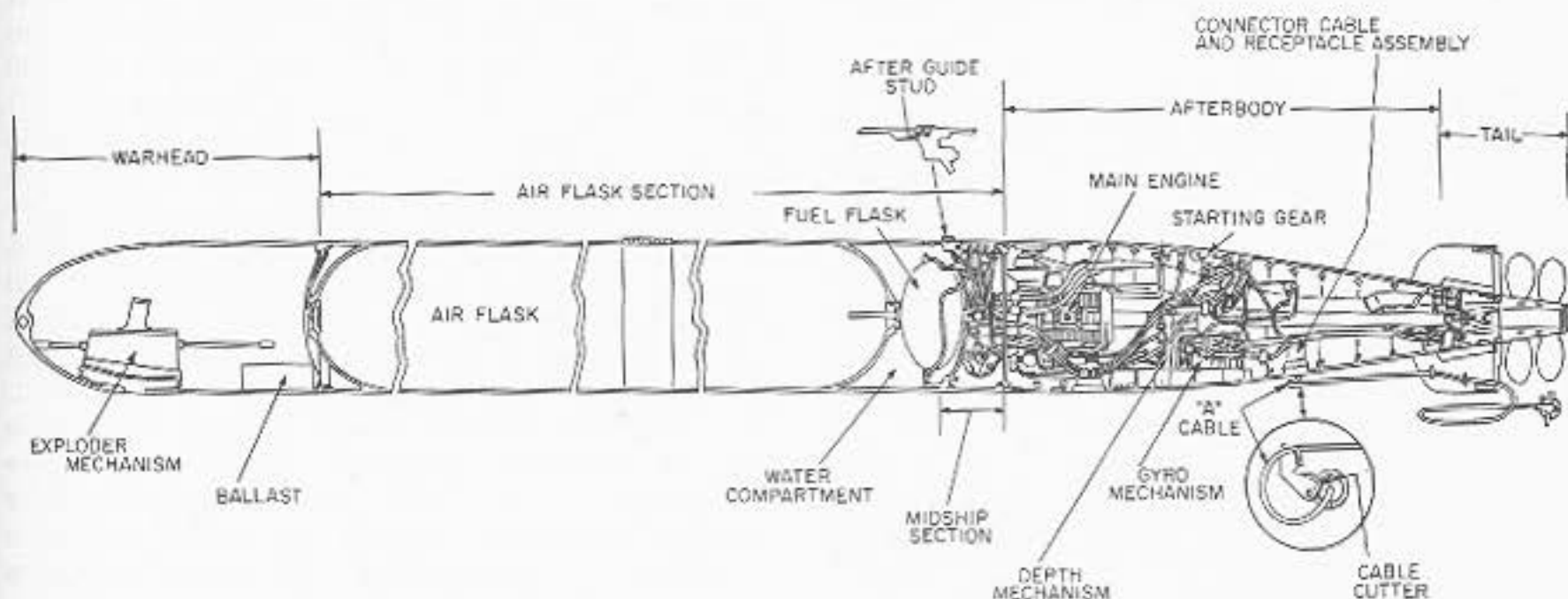
- The heart of the steering mechanism is the gyro. During the run, the axis of the spinning gyro remains rigid in space; that is, it points constantly in the same direction. If the torpedo turns off its set course, the gyro axis will still point in its original direction. That means that when the torpedo turns off course, the gyro will be in a different position relative to the rest of the torpedo. The steering mechanism detects this difference, and sends correcting orders to the steering engine. The steering engine then turns the steering rudders, to bring the torpedo back on course.

- Mounted on the outside of the tail cone are four fins, or vanes, which help to control the path of the torpedo during its run. Located on the after edge of the vertical fins are the two steering rudders, while both of the horizontal fins are on the after edge of the two depth rudders.

The torpedo propellers are mounted on the hollow sleeves at the end of the tail cone.

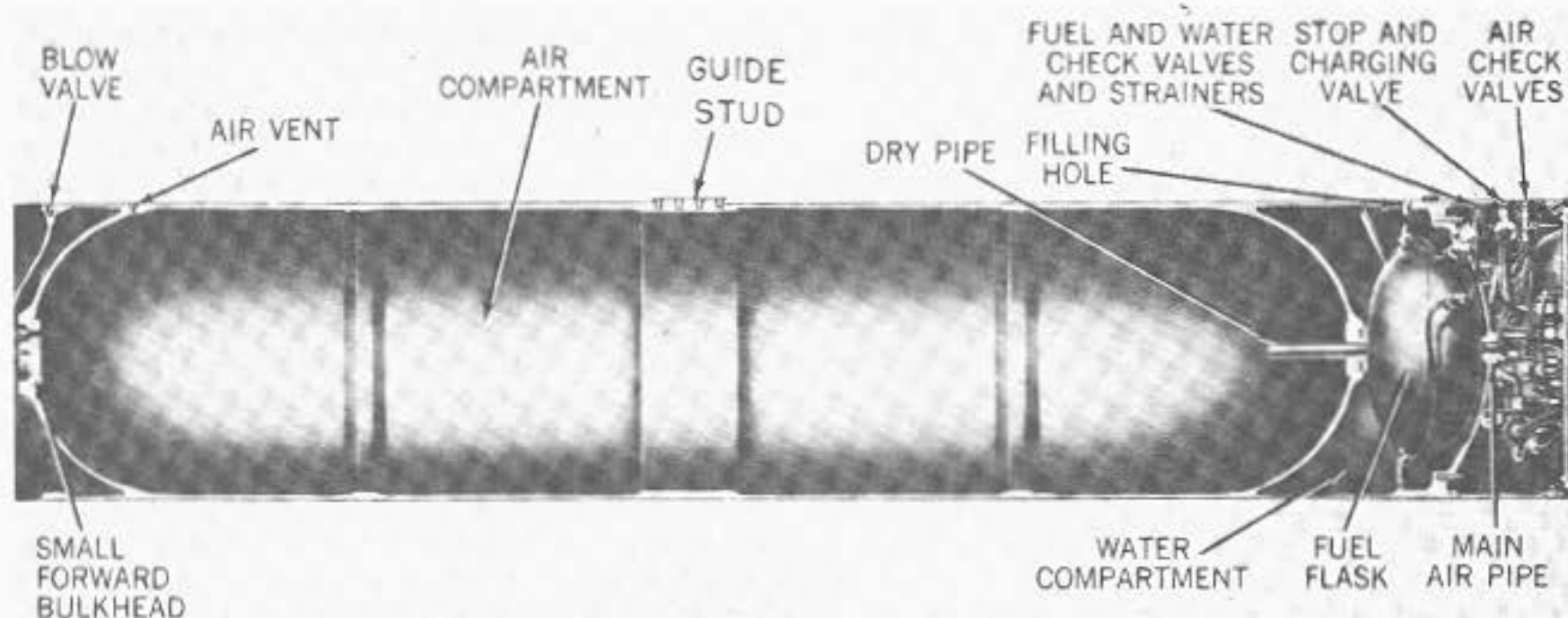
MK 16 TORPEDO

The Navy's only other air-steam torpedo, the Mk 16, is a single-speed torpedo that uses hydrogen peroxide (Navol) instead of compressed



3.126(158)

Figure 12-3. — Mark 14 torpedo.



4.62(110B)

Figure 12-4.— Air flask section of the Mk 14 torpedo.

air to supply the oxygen required for combustion of the fuel. Use of Navol rather than air allows the Mk 16 torpedo to carry a full load of explosive and to have greater high-speed range, without exceeding normal size.

The head section of this torpedo is similar to that described in the preceding paragraphs. The second or flask section contains a small compressed-air flask, a fuel (alcohol) tank, a water compartment, and a Navol tank—the last completely surrounded by the water tank. The main engine, valves, and control devices are located conventionally in the midship section and afterbody.

The source of the oxygen and of part of the water for the combustion cycle of these torpedoes is the Navol, which is a solution of hydrogen peroxide (H_2O_2) in water. Hydrogen peroxide, passing through a chamber containing a catalyst, decomposes with evolution of heat, to form water (steam) and oxygen. The oxygen unites with the fuel (alcohol) in the combustion pot, combustion being initiated by a conventional igniter. The resulting hot gases mix with steam and drive the main-engine turbines. Part of the steam comes from the breakdown of the H_2O_2 and part from additional water from the water compartment which is sprayed into the combustion pot to control the temperature.

By using Navol, the torpedoes require no air except (1) to force fuel, Navol, and water

from their storage compartments to the combustion flask, (2) to drive the gyro, and (3) to operate the steering controls. As no air is fed to the combustion pot, no nitrogen is present in the exhaust to rise to the surface and leave the customary wake. There is, however, a small amount of nonsoluble gas resulting from the combustion of alcohol. This is forced out of the exhaust, leaving a very small wake that is practically invisible except in flat, calm water.

Some mods of the Mk 16 are capable of "pattern-running." This means that after a straight run of predetermined length on a preset course, the torpedo runs continuously at the same depth in horizontal circles of about 300 yards radius until the end of the run or until it hits a target. A control device in the torpedo (called an enabler) can be adjusted to vary the length of the straight part of the run (this is called the enabling run), at the end of which the enabler overrides the gyro steering gear and causes the rudders to steer the torpedo in a circle of fixed diameter. The torpedo can be set to circle to the right or to the left, as desired.

The pattern-running feature makes it possible for the torpedo to menace other ships near its target, if it should miss, and is therefore valuable when the torpedo is used in attacks on convoys. The torpedo can be set to run on a straight course only, if desired.

Note that pattern-running is not to be confused with the circular or helical search pattern

characteristic of homing torpedoes, as discussed below. Pattern-running torpedoes cannot home on targets. Unlike homing torpedoes, pattern-running torpedo exploders arm early in the enabling run. They initiate the war head charge either on contact with or in proximity to the target.

HOMING TORPEDOES

Non-homing torpedoes are designed to follow the course set on their gyro mechanisms, seek the specific depth set on their depth mechanisms, and run in a straight line without deviating (pattern-running torpedoes can also run in circles) until they run out of power. If on a warshot they fail to find a target, they sink.

During World War II, two new features were introduced into torpedo design. The first of these was electric propulsion, resulting in a wakeless torpedo which could not be visually detected from the vessel or target under attack. The second feature introduced completely changed the principles used to guide a torpedo, resulting in a "homing type" torpedo. The homing torpedo is guided by the sound of the vessel being attacked, or by reflected echoes.

A homing torpedo can follow a gyro course, but in general this is done only to get the torpedo to the vicinity of the target. The gyro-controlled run is then called an enabling run, and at the end of it the torpedo exploder is armed, the homing mechanism is activated to search for the target, and the influence device is set to function. The course taken by the torpedo after the enabling run is called the search pattern. The pattern may be helical, zigzag, circular, etc. It may include a fixed depth zone, or the torpedo may search from bottom to surface and back to bottom again. When the homing mechanism detects a target, the torpedo goes into its third stage of functioning—homing. It chases the target, and when it has come within effective range of the target, the influence mechanism operates the exploder to set off the main charge.

For security reasons, no homing torpedo can be discussed in detail here. We can only briefly discuss their principles.

At present, homing torpedoes are acoustic (operated by sound). In general, they are of two types—active and passive.

The active acoustic torpedo is not dependent upon the sound emitted from the target for its

homing information. The torpedo itself generates and transmits the acoustic energy which is essential to its self-directing action. This energy, which has a fixed, controlled frequency and beam width, is reflected by the target in the same manner as sonar. The torpedo is designed to steer on a reflected echo, not on noises created by the target. The echo, after being received, is converted into electrical signals which control the operation of the rudder and elevator control surfaces, causing the torpedo to home on the target.

The passive acoustic torpedo homes on the noise emitted from the target. This noise, after being received by the torpedo, is converted into electrical signals which control the operation of the rudder and elevator control surfaces to steer the torpedo in the direction of the noise source.

The passive torpedo is effective only against targets which create or emit noise. It can often be evaded by the use of simple noisemaker type countermeasures which are used purposely to mislead or misdirect it. The target can also reduce its speed, or stop, in order to present a negligible noise source.

The homing torpedo has the same safety devices as the air-steam type. Its exploder is armed both mechanically and electrically, and remains safe until the torpedo has traveled a safe distance from the firing ship. The homing mechanism also has an arming feature, that keeps it inoperable (with the torpedo on a gyro course) until the torpedo has traveled through a preset enabling run distance. One or more additional safety features not found in nonhoming torpedoes are present in all homing torpedoes.

Homing torpedoes, almost without exception, are powered by electric motors and batteries. In shape and external appearance they are quite similar to the nonhoming torpedoes already described. Most types are somewhat smaller than air-steam torpedoes, in length, diameter, or both. And several types have a single propeller, rather than two.

Homing torpedoes may be launched with or without torpedo tubes. Many homing torpedoes are electrically set; others are preset (i.e., they are dropped in the vicinity of the target, seek the depth set in advance, and go into the preset search pattern without going through the enabling run stage).

The following are brief descriptions of homing torpedoes currently in service:

- The Mk 37 torpedo is electrically controlled and propelled two-speed torpedo with an active-passive acoustic homing system. This torpedo, launched from submarines or destroyers, is effective against either surface or submarine targets. It is launched from above water tubes as an air-ejected torpedo or from submerged tubes as a swim-out torpedo. Some mods are wire guided, making them invulnerable to several enemy countermeasures.

- The Mk 44 torpedo is an electrically controlled and electrically propelled antisubmarine weapon, with an active acoustic homing system. The torpedo can be launched from surface craft or aircraft and is the torpedo payload for Asroc (see chapter 13).

The torpedo is designed to attack submerged submarines traveling at moderate speeds. After enabling, the torpedo searches for a target by active acoustic means while maneuvering in a helical path. Echoes from the target cause the torpedo to steer toward the target until contact is made. If the torpedo loses the target, it searches for a short time in the general direction in which it is traveling and, if unsuccessful in relocating the target, resumes a helical search.

The acoustic homing system of the torpedo also has a passive feature that allows the torpedo to respond to an acoustic noise source whose frequency level is within the sensitivity range of the receiver. During the torpedo's normal search pattern, passive homing on a target noise source aids in target acquisition, increasing the attack capabilities of the weapon.

- Torpedo Mk 45 is the torpedo payload for Astor (antisubmarine torpedo), which also is configured to carry a nuclear warhead. Electrically powered, it may be set for straight runs, or it can be wire guided against submarines or surface ships. Astor can be launched by all nuclear and some conventional (hunter-killer) submarines.

- The Mk 46 torpedo originally was to have been the successor to the Mk 44. The principal difference between the two is the improved propulsive power of the Mk 46, which gives it greater speed, range, and depth capabilities.

TORPEDO TUBES

Torpedo tubes serve the following purposes:

1. House and protect the torpedo (including heating in cold weather) until the instant of firing.

2. Provide means for setting torpedo gyro angle, running depth, etc., as necessary, up to the instant of firing.

3. Expel the torpedo with sufficient force to clear the firing ship, and with such velocity and direction that it will remain on its firing course until its engine develops enough power for self-propulsion.

4. As expulsion starts, trigger the torpedo so as to start its engine and gyro.

These functions apply to submarine tubes as well as above-water tubes. Since, however, the former must also serve as pressure members of the ship's hull, they incorporate additional features which are beyond the scope of this text.

SURFACE TUBES

Above-water tubes may be classed as trainable or fixed. Functionally their performance is similar, but there are structural differences. Fixed tubes are usually mounted so that their muzzles protrude through a bulkhead or some part of the ship's hull. Trainable tubes require large clear deck areas, and in all ships that carry torpedoes they are mounted topside in some such location as the weather deck. From this location torpedoes can be fired through limited arcs of train on both sides of the ship.

During World War II standard destroyer-type ship armament included one or two quintuple (5-barrel) torpedo tubes. A black-powder impulse charge was used to expel the torpedo from the tube in launching. With all tubes loaded, the vessel had 10 torpedoes, plus spares. The torpedoes were all of the conventional air-steam type described earlier in this chapter, normally had impact exploders, and were fired either singly or in salvo against targets. Homing torpedoes, then in an early stage of development, were not a standard part of destroyer armament, and the use of homing torpedoes by surface craft against submerged submarines was not a standard part of U.S. naval doctrine.

Beginning late in World War II and continuing thereafter, this arrangement of deck-mounted quintuple tubes became obsolescent. One cause of this was the need for increased AA armament, which put a premium on topside deck space. After World War II, destroyer-type ships were

fitted with but one quintuple tube mount, and the conventional torpedo load was reduced from 10 to 5. At the same time, newer designs for destroyer and escort craft had torpedo tubes mounted in above-water locations other than the weather deck. In such locations, the tubes had to be housed and fixed (i.e., nontrainable).

With fixed tubes, greater gyro angles must be used in firing than from trainable tubes; and, since torpedoes tend to depart more widely from their predicted courses when fired with large than with small gyro angles, this is a disadvantage. Also, tubes must be carried on both sides of the ship. However, the weight advantage gained by eliminating the training gear, pivots, etc., provides a partial compensation. The interior location permits all tubes to be located in the same compartment of the ship, in which reload torpedoes and quick-reloading gear may also be carried. The newer tube designs use compressed air instead of impulse charges to fire the torpedoes, and are usually fitted with electrical accessories necessary for firing electrically-set torpedoes, including homing types. With the advent of the homing torpedo, the role of the surface-launched torpedo began shifting from surface targets to submerged targets. Today, torpedoes and their launchers are primarily designed for use against submarines.

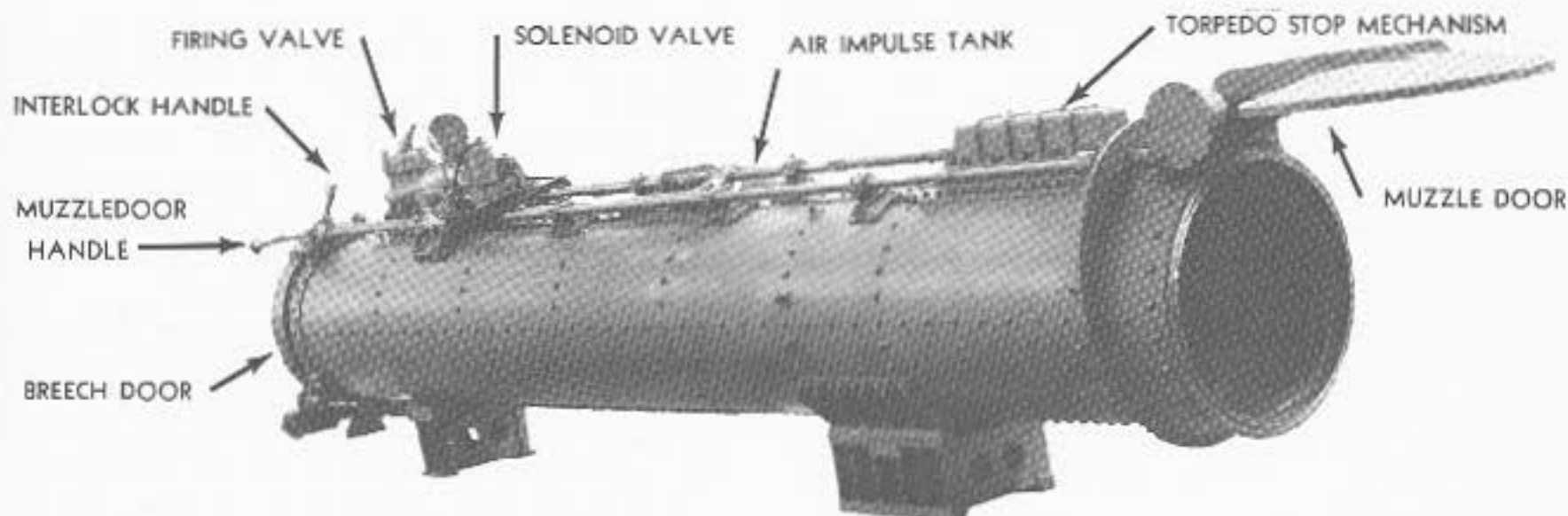
Figure 12-5 represents a single-barrel, fixed-type, non-trainable torpedo tube designed to mount singly or in groups of two or more on each side of a ship. The tubes, constructed of a light-weight aluminum alloy, are mounted athwartship within the superstructure, with muzzles extending through the sides of the deck house. The torpedoes are ejected by a blast of com-

pressed air. The tubes are suitable for launching only torpedoes having electrically set torpedo controls. They were designed to launch 21-inch torpedoes, although adapter rings have been supplied to permit launching a 19-inch diameter torpedo.

There are several versions of the Mk 32 trainable torpedo tube assembly (fig. 12-2). One version is designed to operate with compressed air from the ship's supply; another uses an air bottle and is installed on craft that have no other air supply available. These two are otherwise similar, and are designed for mounting on the weather deck.

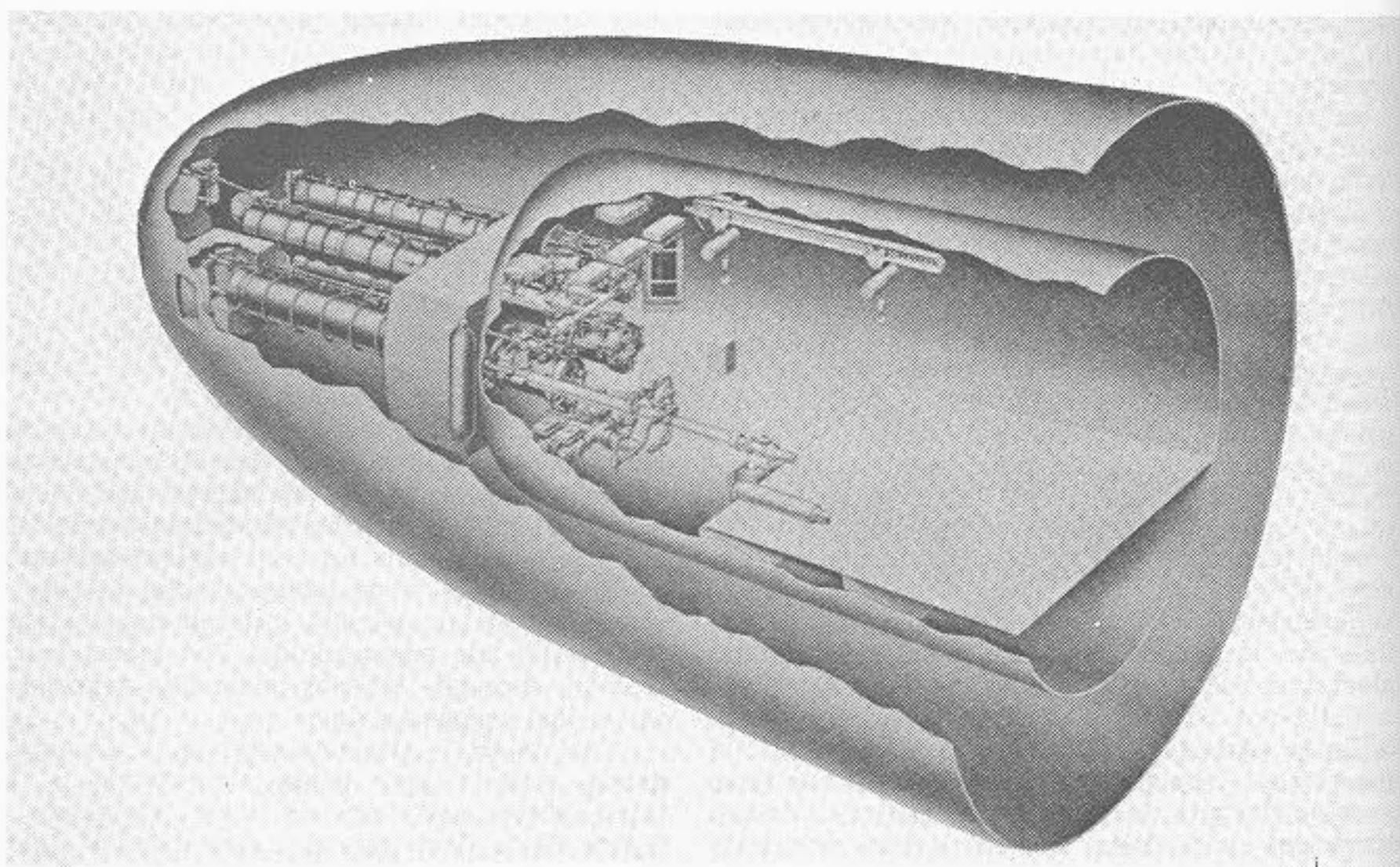
Each tube assembly consists of three separate and independently operated barrel, mounted on a common training gear. The barrels and training gear are equipped with thermostatically controlled electric heating units for cold weather operation. Each barrel is fired independently, usually by an electric firing circuit, although manual firing is possible for emergencies. The mount can be trained through 190° by manually cranking a worm that engages a worm gear.

The barrels are arranged in a triangular group, with a pair below surmounted by the third above and between them as shown in figure 12-2. Each barrel is fabricated of Fiberglass reinforced plastic. The breech mechanism covers one end of the tube, and the muzzle cover is at the other end. Along the top surface of the tube are two access openings (called the large and small cover assemblies)—one toward the muzzle, the other toward the breech. The openings are used for attaching lanyards to the tube for starting the torpedo and for enabling the exploder to arm. The electrical plug used to



110.118

Figure 12-5. — Fixed above-water torpedo tube.



110.160

Figure 12-6.—Mk 65 torpedo tube bow nest.

set signals into the torpedo before launching is located under the breechward cover.

The muzzle cover is a Fiberglas reinforced plastic assembly with a rubber ring which helps to lock the cover closed. The breech mechanism consists principally of a rubber-lined reinforced Fiberglas plastic air flask with controls, valves, and fittings on it. It is bolted in place. The tubes are loaded through the breech end. The firing valve in the breech mechanism releases a blast of compressed air into the after end of the tube to eject the torpedo.

A waterproof aluminum control box contains the solenoid-actuated air valve which controls firing. Buttons protruding from the after side of the box provide for either electrical or manual actuation of the valve. A junction box houses the connection between the ship's supply and the electrical heating systems of the barrels and training gear.

Current mods of the Mk 32 launcher are designed to handle the latest homing torpedoes. A nontrainable version of the Mk 32 consists of

two barrels, one over the other, and is installed in a deckhouse with the muzzles extending through the bulkhead.

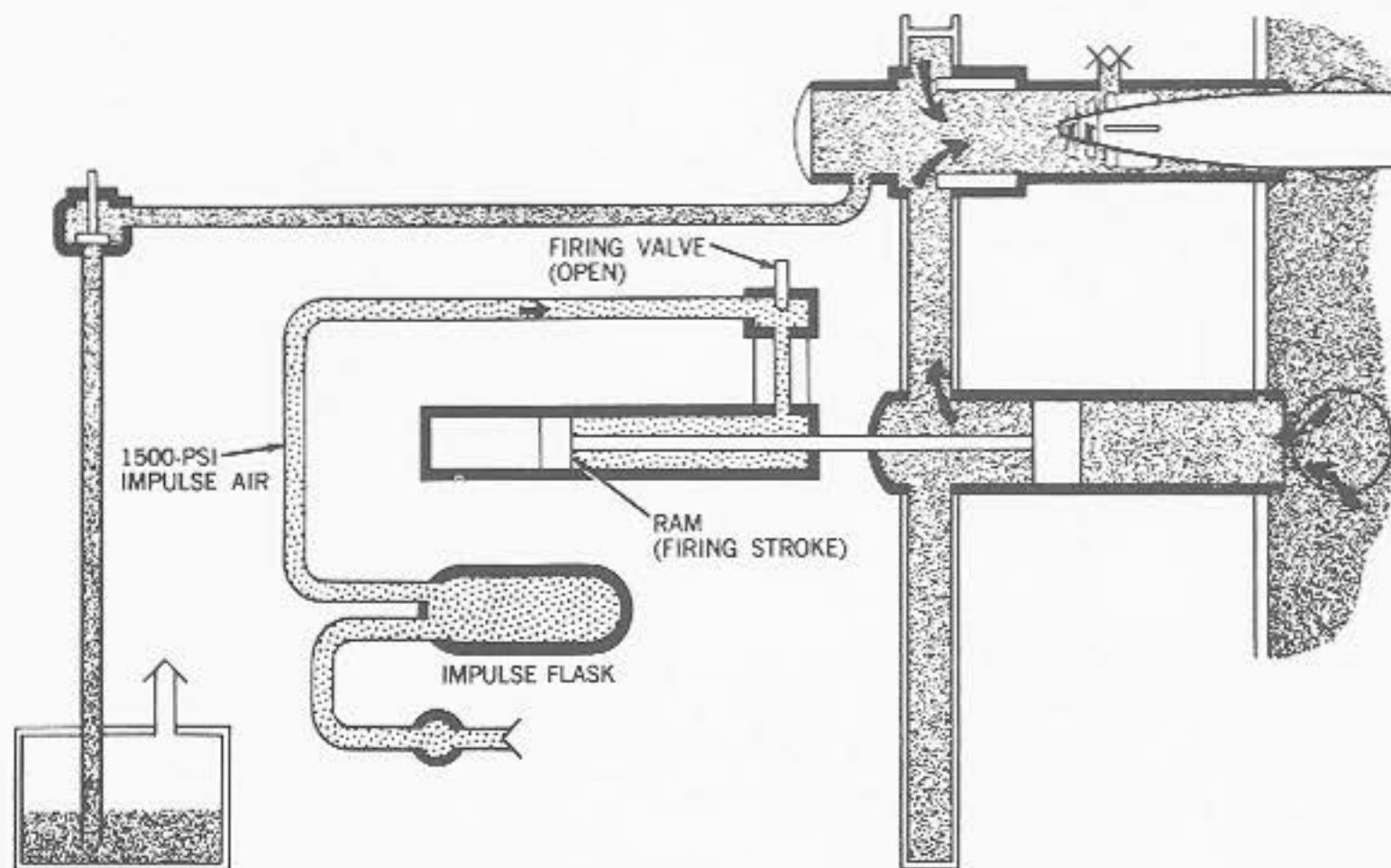
SUBMERGED TUBES

Submarines fire torpedoes from fixed tubes located in the bow, both bow and stern, or amidships.

Older tubes ejected weapons pneumatically by means of compressed air. Newer tubes utilize hydraulic ejection—launching by means of a charge of water. The latter method results in a quieter and bubbleless ejection.

Component parts of submerged tubes are basically the same as surface tubes. There are differences, of course, in tube function and operation. For purposes of discussion, this brief coverage will be confined to the Mk 65 bow tubes.

Bow tubes are referred to as the bow nest. The Mk 65 installation consists of four tubes in two vertical banks (as in fig. 12-6), one port and one starboard of, and parallel to, the ship's



110.161

Figure 12-7.— Method of ejecting a submerged torpedo.

centerline. Each tube can be loaded, flooded, fired (locally or remotely), and drained separately from the others. The tubes penetrate the pressure hull at an angle of 10° from the centerline. Weapons can be launched while the submarine is either submerged or surfaced.

In addition to the usual tube features such as barrel, breech door, and muzzle door, a submerged tube has the following basic components: (1) water 'round torpedo (WRT) tank, (2) blow-and-vent air connections to the tube and WRT tank, and (3) flood-and-drain water connections to the tube and WRT tank.

Rather than dwell on specific tube characteristics, following is a simplified version of what happens to a submerged torpedo tube during basic operations of loading, flooding, ejection, and draining. No attempt is made to include a technical description of the functions of the assorted valves, interlocks, and other controls that must be operated.

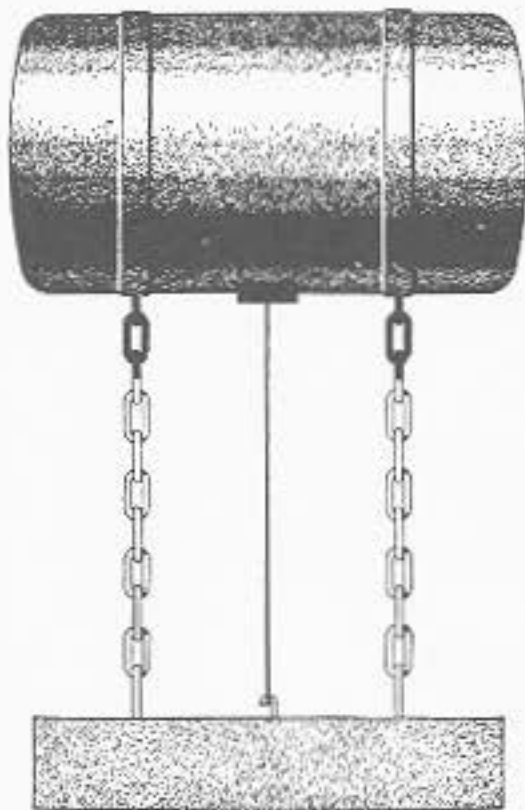
1. Loading: Before a tube is loaded, it is checked to be sure it is vented (vent valve open to permit escape of air) and free of water. The breech door is then opened by hand and the

torpedo is moved from handling tray into tube. The breech door is shut and locked. The ejection pump sea valve is opened (to admit sea water to the ejection pump water cylinder), and the impulse flask is charged with compressed air.

2. Flooding: After loading, water is blown from the WRT tank through an open flood-and-drain valve into the vented tube until the tube is flooded. Tube pressure and sea pressure are then equalized and the muzzle door opened. The tube now is ready for firing (ejection).

3. Firing: Firing (fig. 12-7) causes the firing valve to open, admitting compressed air from the impulse flask into the ejection pump air cylinder, forcing the ram aft. The piston on the seaward end of the ram forces water into the tube abaft the torpedo. Water pressure then forces the torpedo out the tube muzzle and the ram returns to battery.

4. Draining: After firing, the muzzle door is shut and water in the tube is blown (or drained by gravity) through the tube drain valve to the WRT tank. The tube then is vented.



56.2

Figure 12-8.—Confederate harbor mine.

MINES

The Dutch broke the Spanish Blockade of Antwerp in 1585 with what was probably the first floating mine. They called it an "explosive vessel." It was no more than an old ship loaded with gunpowder and ignited by a clockwork-operated flintlock. The British, with the largest fleet in the world at the time, were the first to suffer casualties by the first real mine that was used.

During the American Revolution David Bushnell attempted to break the British blockade of the Delaware River at Philadelphia with floating kegs filled with gunpowder and equipped with contact-firing devices.

Robert Fulton also contributed to mine warfare by proving that a ship has little resistance to an underwater explosion. By the time the American Civil War came along, mines were considered a prime naval weapon. During this war, 27 Union ships were sunk by mines while only 9 were destroyed by gunfire. Figure 12-8 shows a Confederate mine. At the entrance of Mobile Bay, Admiral Farragut shouted, "Damn the torpedoes—full steam ahead!" He was referring to what we now know as mines, not torpedoes.

Mines were considered only a defensive weapon until the Russo-Japanese War of 1904. The



56.3

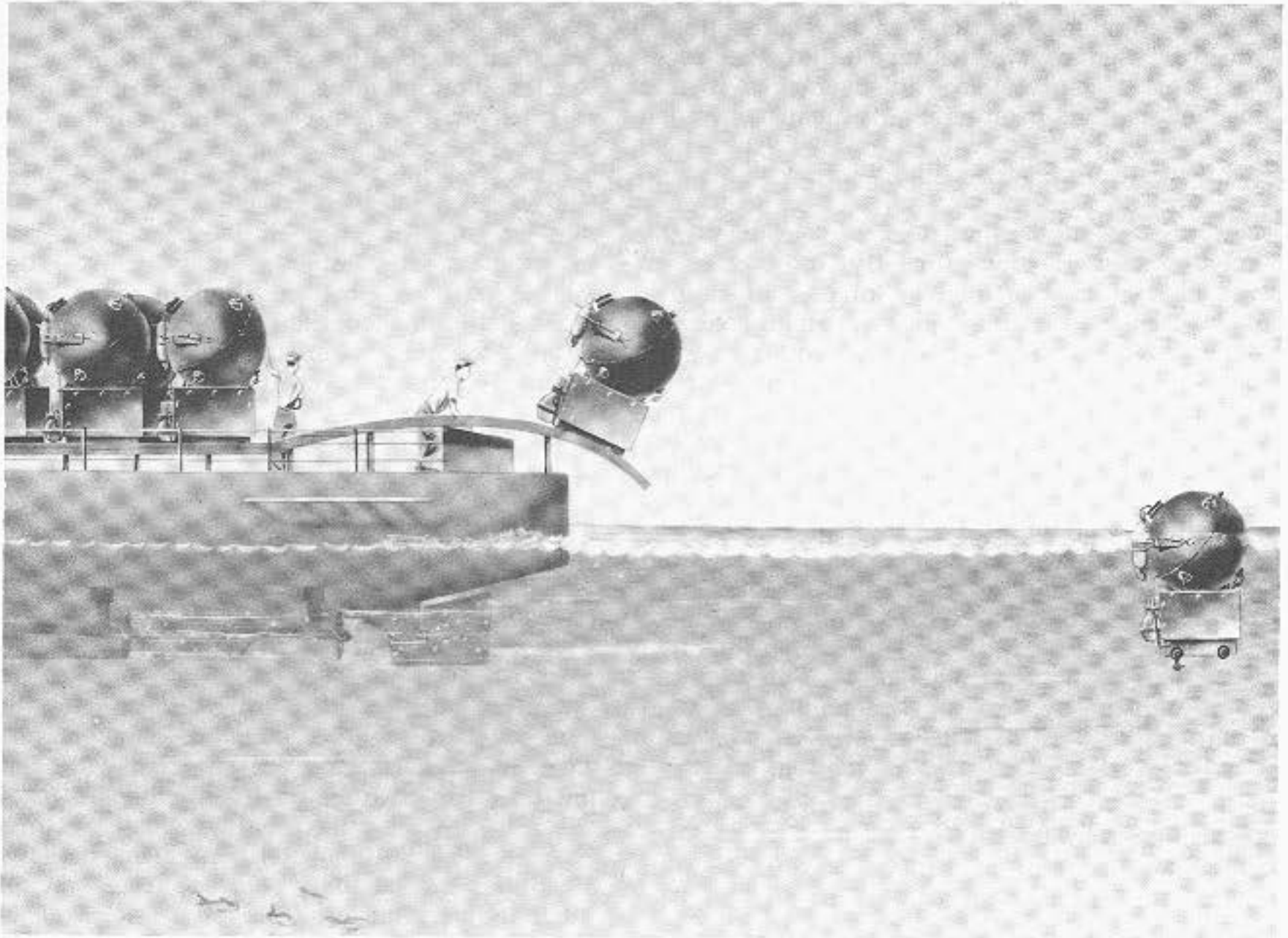
Figure 12-9.—World War I mine and North Sea barrage.

Japanese almost destroyed the entire Russian fleet by luring them into mined waters. This development opened up a new use for mines, although it was not until World War I that offensive use of mines came into being.

During World War I, the allies bottled up the German U-boats in the North Sea by laying a minefield from Scotland to Norway (fig. 12-9). This allowed the allies to use Atlantic shipping routes in comparative safety. Contrary to popular belief, there were more ships sunk by mines than by torpedoes and gunfire combined during World War I.

After World War I there was a slump in mine warfare development. During the period between the two world wars, new mines were designed but not developed to any great extent. At the outbreak of World War II the Germans used a magnetic mine very successfully. Our magnetic mechanisms were so crude that we copied a German device which the British had taken from a captured mine. Since 1940, mines have developed into very complex weapons that have several methods of planting and several ways of being detonated.

Again in World War II, during Operation Starvation (the blockading of Japan), mines sank more enemy ships than all other types of weapons combined. This operation was so successful that it almost stopped Japanese shipping completely. A side effect of this was that civilian morale



56.4

Figure 12-10.—Surface-craft-planted mines.

was broken because Japan could not import enough food. This was the United States' largest and most successful use of offensive mining.

Probably for this reason, mine development has not slackened as it did after World War I. This makes it difficult to keep up with the development of new mines and modifications to the old ones. A detailed discussion of the various mine marks and mods used today is beyond the scope of this unclassified text.

MINE CLASSIFICATION

Mines are classified by types according to (1) the method of planting, (2) the mine's position in the water, and (3) the method of actuation (firing).

Classification by Method of Planting

Method of planting means the method by which mines are put into the water. There are three classifications of mine according to methods of planting: (1) surface-craft-planted, (2) submarine-planted, (3) aircraft-planted.

Mines can be planted by surface craft (fig. 12-10) when secrecy is not of prime importance. High speed minelayers are usually used to do the job. A minelayer can carry a large number of mines, and can lay a large minefield in a relatively short time. Presently, the Navy has no minelayers in commissioned service. In case of war, however, these ships could be reactivated in a short time.

Submarine-planted mines (fig. 12-11) have an advantage over surface-craft-planted mines in that the mining operation can be accomplished with great secrecy, and at great distances from home ports. One of their disadvantages is that once an area has been mined, it must be avoided for the armed life of the mines. Therefore submarines cannot repeatedly mine the same area.

Aircraft-planted mines may be carried on the aircraft internally or externally, like bombs or torpedoes. Aircraft can carry mines into enemy-held areas, and the field can be replenished over a long period of time without danger from previously planted mines. There can be no secrecy in planting this type of mine, but aircraft can plant mines in enemy-held shallow coastal waters that cannot be mined by other means. Blockading of enemy shipping lanes can be very effectively accomplished by this type of mining.

Although each mine is designed for planting by a particular method, and is so identified, aircraft- and submarine-planted mines may also be planted by surface craft when appropriate adaptations have been made. For limited operations, almost any ship or boat can be adapted to plant mines. This flexibility makes all types of mines available for surface planting.

Classification by Position in the Water

By their position in the water, mines may be divided into two categories—moored and bottom.

The moored mine (fig. 12-12) has a buoyant case containing an explosive charge. The case is kept at a predetermined depth by a chain or cable attached to an anchor. This type mine may have either a contact- or influence-firing mechanism. Its main disadvantage is that it may be cleared with comparative ease by mechanical minesweeping gear. (It was for this reason that the bottom mine was developed.) The two most important advantages of the moored mine are: (1) it can be moored close to the surface so that it will be actuated by any ship or boat, no matter how small, that penetrates the mine-field, and (2) it may be planted in waters that are too deep for bottom mines, since the case of a moored mine assumes a position some distance from the bottom. The maximum depth of water in which a moored mine can be planted is limited by the downward pull on the case caused by the weight of the cable and by the drag of tides and currents.

The bottom mine (fig. 12-13) is held on the ocean's bottom by its own weight. It can be planted by surface craft, submarines, and aircraft; but normally surface craft are not utilized to plant bottom mines. This type of mine generally is not effective against surface ships when planted in waters more than 30 fathoms deep. They may be planted in deeper water, however, as antisubmarine weapons. Because this type of mine lies on the bottom, the enemy must use costly minesweeping gear to detect them. Also, the bottom mine is more difficult to detect with locating gear than the moored mine, especially when it lies in soft mud or on a densely growth-covered bottom.

Classification by Method of Actuation

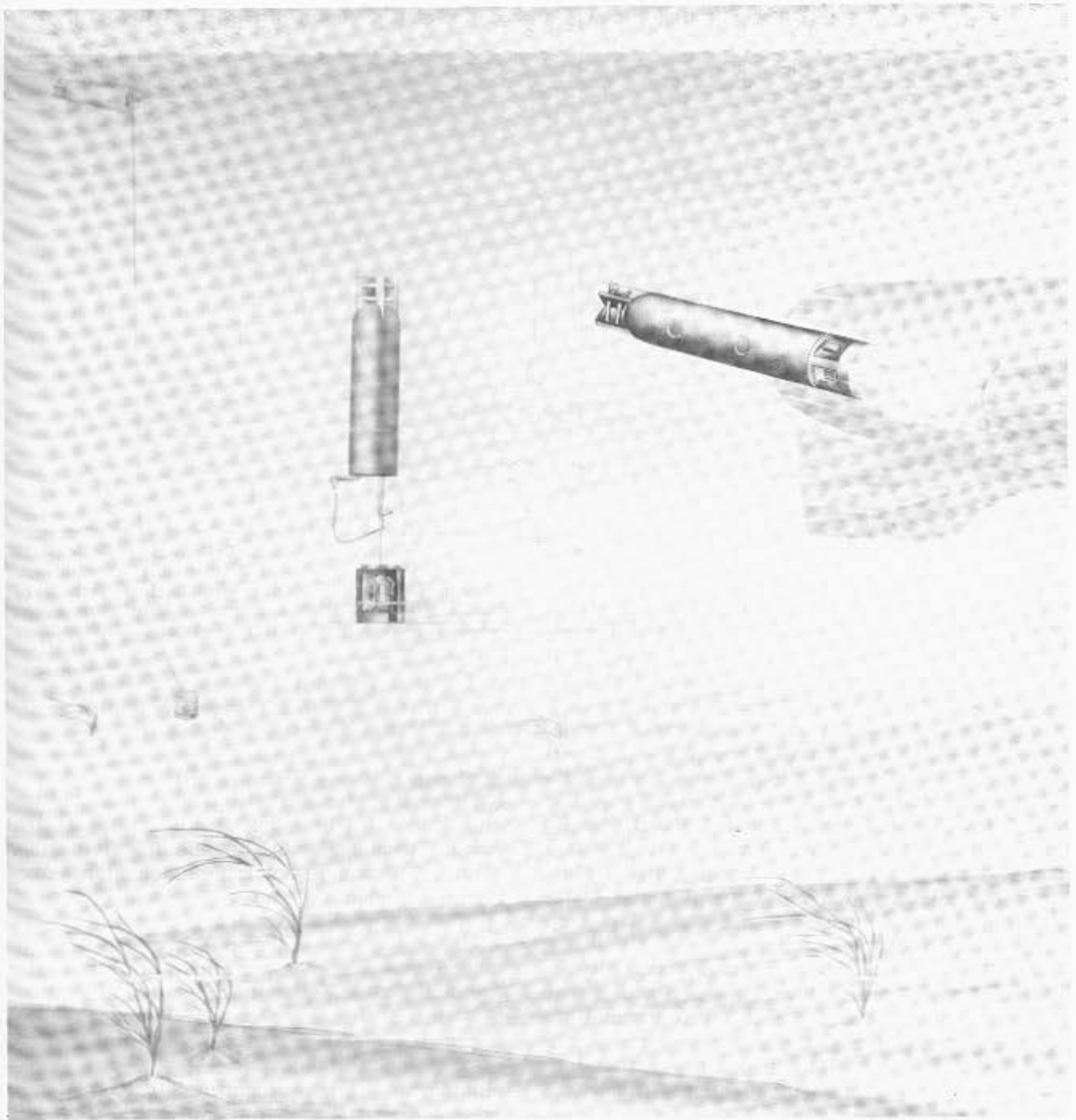
The third way of classifying mines is by the type of firing mechanism or device used to actuate them. The classification is subdivided into (1) contact and (2) influence mines.

CONTACT MINES.—Contact mines are fired by actual contact of the mine case or its attachments with the hull of a ship or any such target. Typical contact-firing devices are switch horns, inertia switches, tension-firing mechanisms, and galvanic action or chemical horns.

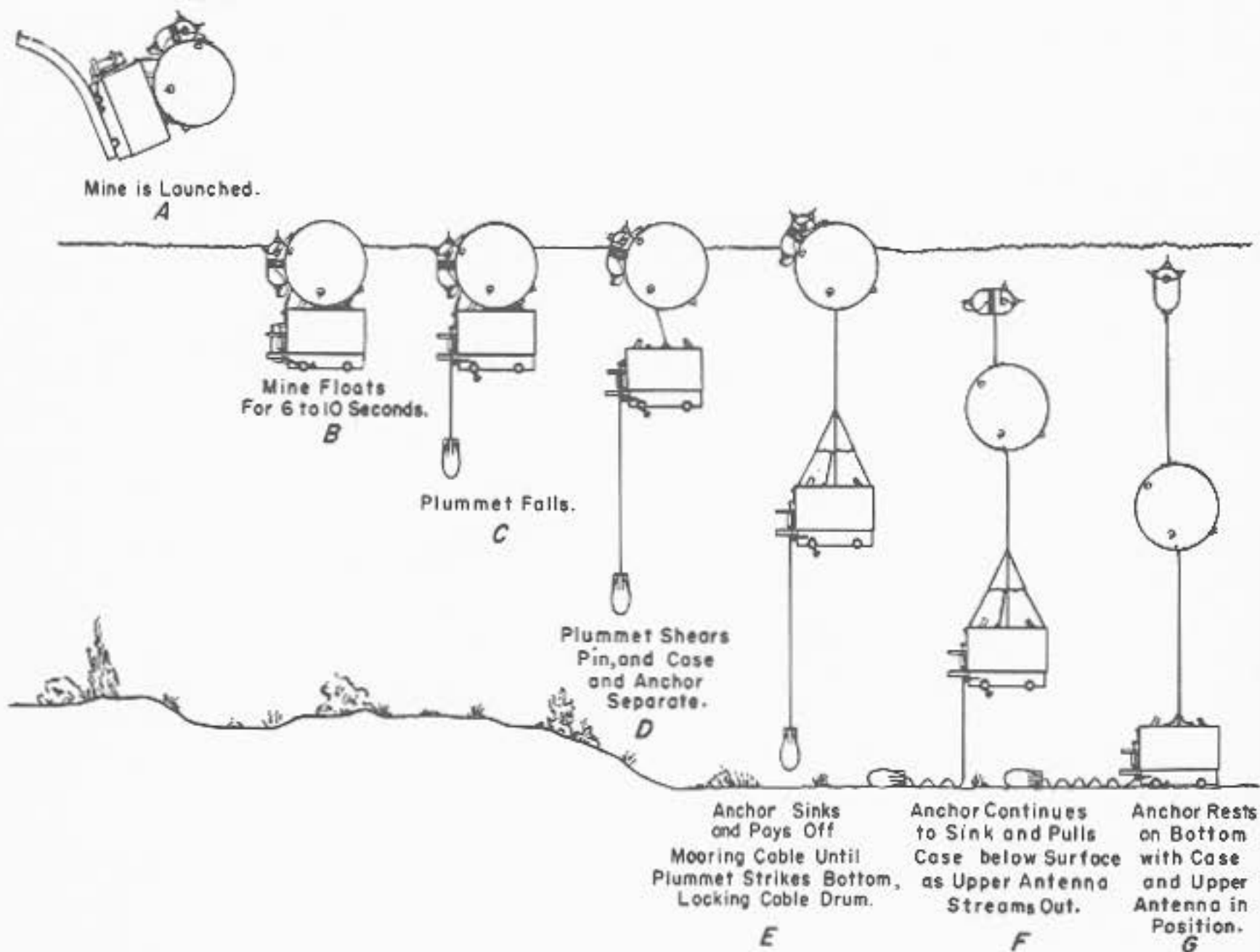
When the switch horn comes in contact with a ship, it mechanically closes, firing the mine. An inertia switch also closes a switch when the ship contacts the mine. A tension-firing mechanism is used only in a mine that destroys enemy sweep gear and fires the mine when the sweep cable pulls up against it. The galvanic action type operates on the principle of the wet cell battery. A steel ship comes in contact with a horn or antenna on the mine, forming a sea cell. The weak current from this sea cell goes to the firing mechanism, initiating the firing of the mine.

The chemical horn also operates on the wet cell battery principle. When a horn is bent, a vial is broken releasing acid to a wet cell battery. The current from this battery fires the mine.

INFLUENCE MINES.—Influence mines are much more complex than contact mines. They are fired by the close approach or passing of a ship. Bottom mines are of the influence type. This type uses several different means of actuation. It may be actuated by (1) sensitivity to



56.5
Figure 12-11. — Submarine-planted mines.



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Figure 12-12. — Sequence of operations in planting a Mk 6 moored mine.

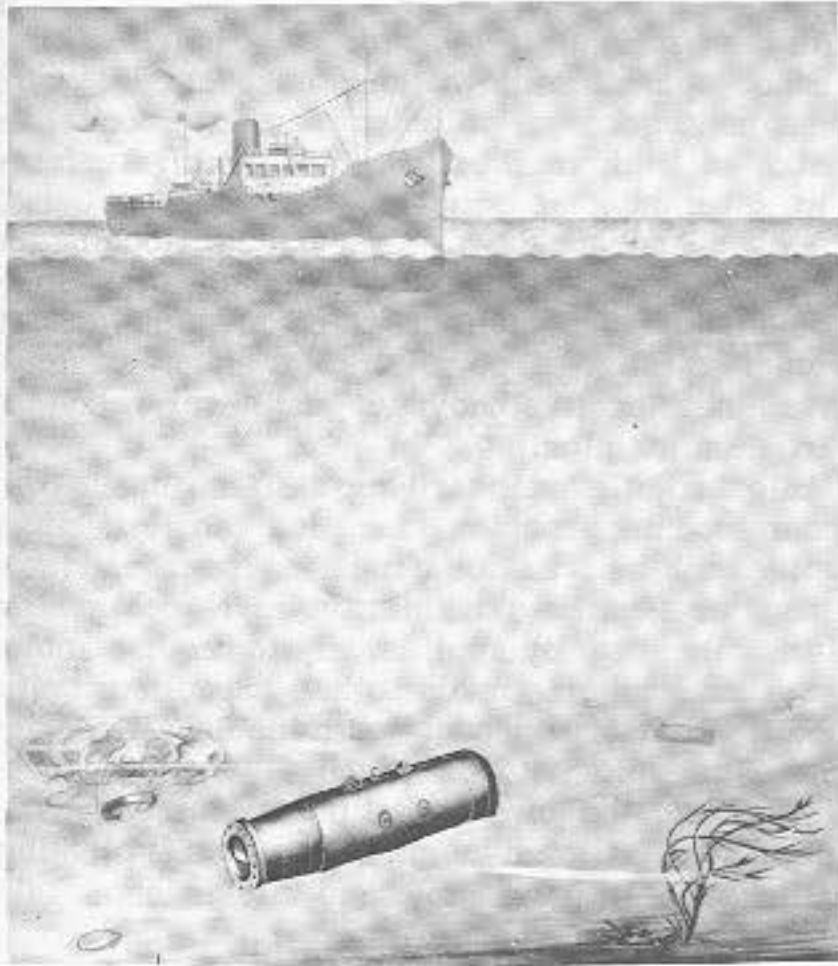
the target ship's magnetic field, (2) by sensitivity to the ship's underwater sound, or (3) by sensitivity to the reduction of water pressure around the mine caused by the passing of a ship. We have mines which may use only one of the above means of actuation, but we also have mines which use a combination of all three. The influence mines have a larger target width, and are much harder for the enemy to sweep than the contact mines. In fact, with combinations of firing mechanisms, the influence mine can be made almost impossible to destroy with mine-sweeping gear. A brief discussion of the different types of influence mines follows.

Magnetic Mines.—The magnetic mine is actuated by a change in the earth's magnetic field surrounding it. A steel ship intensifies the

earth's normal magnetic field. This change in magnitude or direction of the field, if in the proper sequence, will actuate the firing mechanism. The magnetic firing mechanism is of the magnetic induction type.

The magnetic induction mechanism operates on the change of magnetic field of the mine. This mechanism depends primarily on the rate at which the field intensity changes, rather than on the amount of change. A small current is induced in a coil by the changing field. If sufficient potential is developed, a relay is actuated, closing the firing circuit. This type of mechanism is used in bottom mines, in areas where ships are under way at normal speeds.

Acoustic Mines.—The acoustic mine operates on the noise produced by a ship's propeller(s),

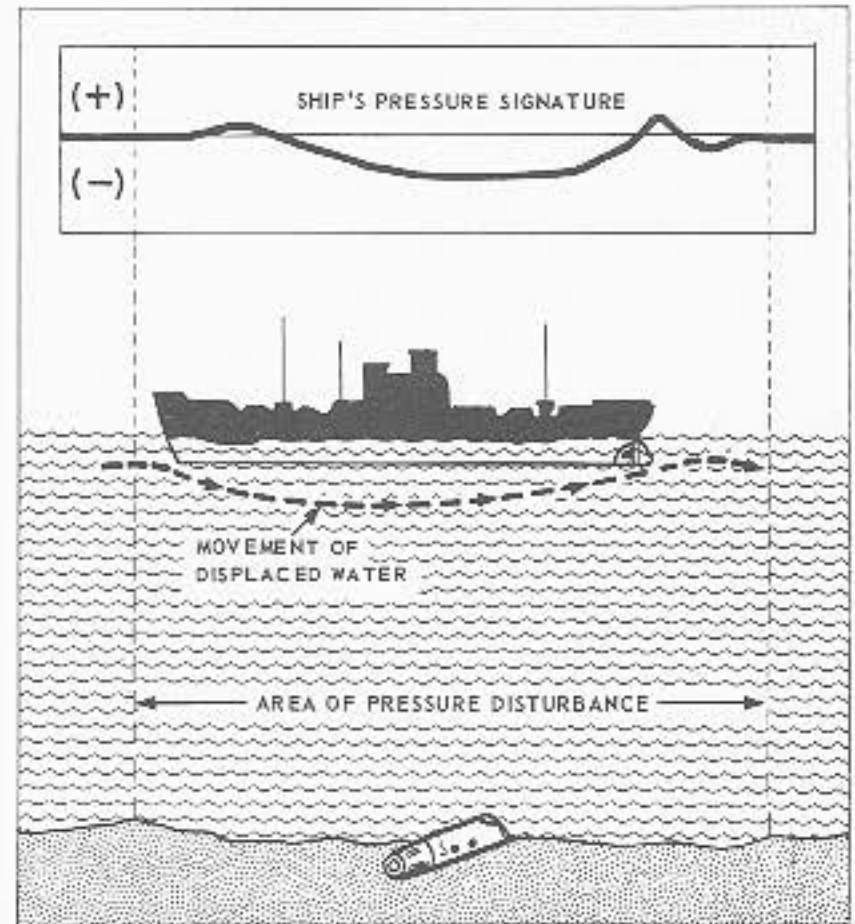


56.9.1

Figure 12-13. — Bottom mine.

engines, and hull. A microphone converts these sound vibrations into electrical impulses, which are fed into an amplifier. The mechanism will actuate only when it receives sound impulses of proper intensity, rate of change of intensity, frequency, and duration. If the noise does not meet the above specifications the mechanism will not actuate, thus protecting the mine from random underwater noises. This mechanism, like the magnetic induction mechanism, is used in bottom mines.

Pressure Mines.—This mine's firing mechanism is actuated by the change in water pressure caused by a moving ship. A passing ship momentarily increases the pressure as the ship's bow wave passes. This increase is followed by a reduction in pressure for a sustained period (fig. 12-14). Contrary to popular belief, it is this reduced pressure, rather than increased pressure, that operates the mechanism. This mechanism is used only in bottom mines, and only in areas where ships are under way at normal speeds. The pressure mechanism is probably the most difficult to sweep.



56.7

Figure 12-14. — Pressure signature.

Combination Mines.—A combination of mechanisms improves the usefulness of a mine in that it is less likely to be actuated by false targets. Also it makes the mines harder to sweep. For the mine to fire, all the incorporated firing mechanisms have to be actuated within a specific time limit. The first mine of this type was pressure-magnetic. It was first used as an aircraft-planted bottom mine and later as a submarine-laid bottom mine. We now have mines that use a combination of all three types of firing mechanisms at one time. Once again, this improvement makes mines of this type almost impossible for the enemy to sweep.

LIFE CYCLE OF MINES

The life cycle of a mine follows the same pattern as that of a living thing. It can be said that a mine is born when it is planted, and lives for the armed life set for it. It dies when it is exploded, or when it is rendered safe by the sterilizer device. Because much of the life cycle is the same for all mines, only one contact type and one influence type will be discussed.

The Mk 6 surface-craft-planted, moored, contact mine is carried on the launching rails of the planting ship (fig. 12-10), on wheels attached to the mine anchor. After the area to be mined is reached, shipping safety features are removed from the mine. When the order is received to plant a mine, the launching crew rolls a mine off the stern of the ship. After the mine is in the water, its case and anchor separate, as in figure 12-12. The anchor sinks to the bottom, and the case finds its mooring depth. At this time the mine cannot be detonated, because of safety features designed to protect the planting vessel. After a predetermined time the mine is armed, and will blow up when any ship comes in contact with it. Mines are designed to render themselves safe after the usefulness of the minefield has lapsed. This safety feature is necessary because it is unlikely that all of the mines in a field will be actuated by enemy ships, and we may later want to use the area for our own ships.

An influence mine is mounted on or in an airplane at its home base. At the proper time the plane will carry the mine to the area to be mined, and drop it as it would a bomb. The mine has a parachute attached which slows it as it drops. When the mine hits the water, the parachute separates from the case, and both case and parachute sink to the bottom. The delay arming safety features start operating to arm the mine. Like the contact mine, this mine can be actuated by any ship, but in the case of influence mines, the ship has to meet certain specifications to actuate the firing mechanism.

MAJOR MINE COMPONENTS

The major components of a mine are the case, the explosive filler, the anchor (if one is used), and the firing mechanism with its accessories.

The mine case provides a watertight compartment for the main charge and the firing system. The bursting charge occupies the main compartment, and in bottom mines will fill most of it. In moored mines, the case must be large enough to provide air space for buoyancy. Smaller compartments in the case house and secure the batteries, firing mechanism, and accessories.

Mine cases are usually made of steel, but a nonferrous metal is required when certain influence firing mechanisms are to be used.

Anchors for various moored mines naturally differ in size, shape, and method of operation. All must be capable of mooring the mine at a

preset depth below the surface. For ease in handling, the anchor is assembled integrally with the case.

The operation of the anchor assemblies during planting of a typical moored mine is illustrated in figure 12-12. Note that this surface-laid assembly has a net positive buoyancy until the case and anchor are separated, flooding the anchor. Conversely, aircraft-planted or submarine-planted assemblies, which are employed in offensive mining operations in enemy waters, have a net negative buoyancy and never reach the surface after planting.

Most of the standard naval mine cases will accommodate a choice of explosive fillers and a choice of the various firing systems and accessories. Because of this, the mark designation of the mine usually applies only to the assembled case and anchor. On the other hand, a specific modification of a production mine usually designates its explosive filler, firing systems, accessories, and the special features which adapt this mine to surface, submarine, or aircraft planting.

MAJOR MINE ACCESSORIES

Mines utilize many separate units to increase their effectiveness. Some of these accessories are safety devices; others increase the efficiency of the planted mine. A few of the more important mine accessories are defined briefly in the following paragraphs.

1. The **EXTENDER** mechanism is a hydrostatically operated device used to hold the mine detonator a safe distance from the booster charge until the mine has been planted.

2. **HYDROSTATIC SWITCHES** are used to close electric contacts by means of hydrostatic pressure working against spring pressure.

3. The **ARMING DEVICE** is an extender and hydrostatic switch assembly which aligns an explosive train and operates electrical contacts when subjected to hydrostatic pressure.

4. The **CLOCK STARTER** mechanism is a hydrostatically operated device used to start the clock delay mechanisms when the mine sinks to a preset depth.

5. **CLOCK DELAY** mechanisms delay the arming of the mine for a preset time after planting. This allows the planting craft time to plant a large minefield before the mines become

dangerous. Clock delays are also used to stagger the arming of mines in a field to improve its effectiveness. Clock delay mechanisms are of two basic types: hand wound and motor wound. Hand-wound clocks may be set to provide a delay in arming of 1/2 to 10 days; motor-wound clocks provide a delay of 3 to 100 days.

6. The STERILIZER mechanism is used to limit the armed life of a mine to a predetermined time. It renders the mine inoperative by shorting out the battery, or in some cases by opening the detonator circuit.

7. BATTERIES used in mines are of the dry cell type. Each is composed of several cells arranged in a waterproof container. The batteries provide the required voltages and current to operate the mine accessories and the firing system to fire the detonator at the proper time.

8. The ACTUATION COUNTER (sometimes called a ship's eliminator or ship's counter) is designed to delay firing the detonator until the firing mechanism has completed its operation a predetermined number of times.

9. SEARCH COILS are used in magnetic induction mines to detect changes in the earth's magnetic field around the mine.

10. The MICROPHONE or HYDROPHONE contains a crystal which changes sound energy into electrical energy to actuate the acoustic firing mechanism.

11. CONTROL BOX is a device which performs switching and timing functions. It ensures that certain requirements are met before the mine will fire.

12. SENSITIVITY SWITCHES are provided to adjust the sensitivity of the firing mechanism of a mine for best use against an intended target.

13. HYDROSTATIC RELEASES are mechanisms used to release a device from a mine, or to separate two cables at a predetermined depth.

14. PARACHUTE PACKS are metal or plastic-and-canvas containers holding a parachute which is used to reduce the impact velocity of an aircraft-laid mine when it enters the water. This protects other mine accessories from damage that would result if the mine were allowed to fall freely and strike the water at high speed.

TYPES OF MINEFIELDS

The subject of minefields is a very extensive one, and space is not available in this text

to cover it fully. More detailed information can be found in the current edition of NWP 26.

A mine is designed to do the same job as a gun projectile or torpedo. The big difference is that mines are rarely used one at a time; a group of mines is used to make up a minefield. The two main purposes of these fields are first, to destroy or disrupt enemy shipping—both combatant and noncombatant; and second, to protect United States and Allied shipping and Allied controlled territories.

The type of field in which mines are planted is dictated by the prevailing situation. The choice of field type is an application of the potentialities of mines and planters to the problems which the situation presents.

Minefields may be divided according to purpose into two broad groups—defensive and offensive—with variations to make them more effective.

Defensive Minefield

A defensive minefield is similar to a defensive football team in that they both try to hold back the opposition. Although defensive mining usually attempts to keep the enemy guessing at all times, in some cases the field is well advertised. This adds to the effectiveness of the field, because the enemy may decide against entering these waters due to the potential danger. The area may still be utilized by our forces and Allies provided with charts showing the mine-free navigable channels. Some of the specific ways in which mines may be used defensively are as follows:

1. In large harbors and anchorages for permanent harbor defense.
2. To protect advance base anchorages.
3. To protect assembly points for convoys.
4. To protect coastal shipping lanes from seaward attack.
5. As a submarine trap.
6. As anti-invasion fields.

Offensive Minefield

The offensive minefield—in keeping with our analogy—can be compared with a football team on the offensive; they both take the action to the opponent. These fields are planted in enemy-held or disputed waters to disrupt enemy shipping.

Offensive minefields do this by destroying or damaging the enemy's ships, or by making areas unusable because the threat of losses is so great.

Offensive fields are subdivided into two groups—uncountered attrition and countered attrition on fields. Uncountered fields are those which the enemy is not expected to counter by minesweeping or hunting, and which are intended primarily to cause damage to enemy ships. Countered attrition fields are of two types: transitory fields and sustained attrition fields.

TRANSITORY ATTRITION FIELDS.—Transitory attrition fields are small, secretly planted fields laid in an area in which traffic is sufficient to give a reasonable probability of a casualty. From the meaning of transitory, obviously this field is designed to last only a short time. The field can be swept easily or avoided by the enemy, and mines that are destroyed are usually not replaced.

SUSTAINED ATTRITION FIELDS.—Sustained attrition fields are laid where they cannot be easily avoided by enemy traffic. They are maintained for a prolonged period of time by replacing mines which have been blown up. If the casualty rate is so high that the enemy cannot afford the losses, the minefield can deny them the use of the channel or area.

Mines are an excellent STRATEGIC weapon in that mining operations can be carried out over a prolonged period without regard to other military activities. Mines destroy the enemy's war-making potential behind their own lines. On the other hand, a mine is a poor TACTICAL weapon because of the lengthy and detailed preparation necessary for planting a minefield. A tactical weapon is one designed for supporting or protecting a single engagement, and time usually does not permit the use of mines for this purpose.

The design of a minefield depends on the purpose of the field and on the countermeasures expected. They are divided into six types:

1. Countered fields are those which the enemy is expected to counter by minesweeping or hunting.

2. Uncountered fields are those which the enemy is not expected to counter by minesweeping or hunting.

3. Protective fields primarily protect what lies behind the field by hindering or preventing the enemy's approach.

4. Attrition fields are those intended primarily to cause damage to enemy ships.

5. Nuisance fields are those where a few mines are laid to harass the enemy.

6. Dual Purpose fields are those having more than one purpose.

MINELAYING

A sudden massive attack by minelaying aircraft is considered to be one of the greatest threats to any maritime power that exists today. So great, in fact, that the possibility of such an attack requires major expenditures of manpower and equipment in conducting counter-measure operations, whether a single mine has been laid or not.

Offensive minelaying by surface craft has comparatively limited application in enemy-held waters. The utmost secrecy can, of course, be obtained by laying mines from submarines. However, a submarine cannot replenish the interior of an existing minefield without itself being exposed to an unacceptable amount of danger. That brings us to the use of aircraft. The aircraft naturally leads in its ability to lay mines suddenly and in great quantity. It is, further, as mentioned earlier, the only craft capable of replenishing a large existing field without danger from the field itself. Offshore shipping lanes can be mined by bombers and patrol planes whenever the depth of water is not too great. Mining of enemy-held rivers and harbors would generally be effected by tactical aircraft under conditions of low visibility or under cover of diversionary raids.

MINE COUNTERMEASURES

Mine countermeasures include all actions taken primarily to protect own or friendly shipping against mines, including (1) reducing the effectiveness of enemy mines, and (2) clearing areas mined by friendly forces, after these areas have served their purpose. The three major types of mine countermeasures are ship treatment (against magnetic and acoustic mines), mine hunting, and minesweeping.

Ship Treatment Against Magnetic Mines

There are two principal methods (deperming and degaussing) of treating a steel ship hull to

decrease the magnetic effects that actuate magnetic mines. Before taking these up, let us consider in more detail the characteristics of a ship's magnetic field.

Any ship's magnetic field can be analyzed into two main components—its permanent field and its induced field.

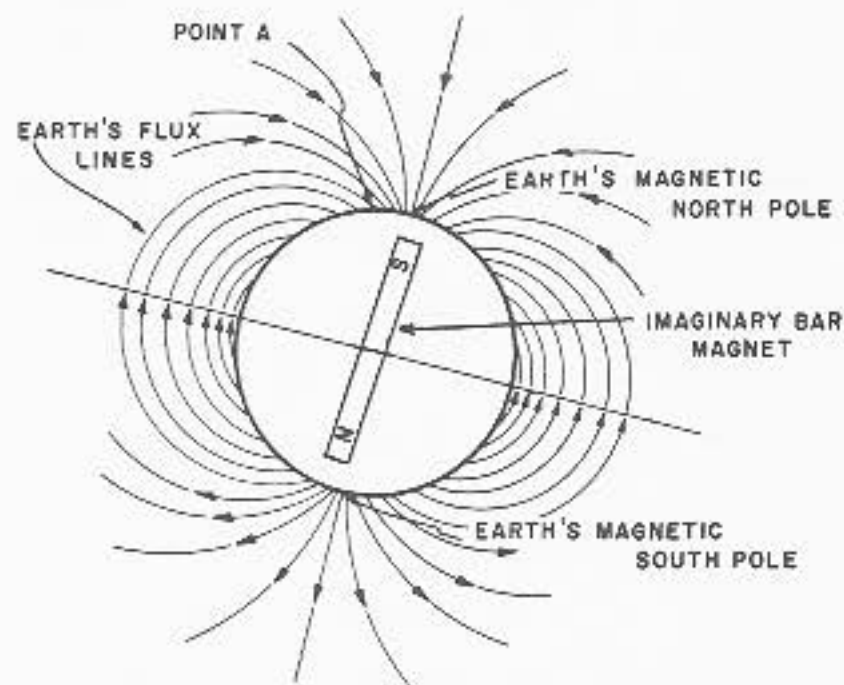
PERMANENT MAGNETIC FIELD.—When a ship's hull is being fabricated in a shipyard, it is subjected to heat (welding) and to impact (riveting). Ferrous metal contains groups of iron molecules called "domains". Each domain is a tiny magnet, and has its own magnetic field with a north and south pole. When the domains are not aligned along any axis, but point in different directions at random, there is a negligible magnetic pattern. However, if the metal is put into a constant magnetic field and its particles are agitated (as they would be by hammering or by heating), the domains tend to orient themselves so that their north poles point toward the south pole of the field, and their south poles point toward the north pole of the field. All the fields of the domains then have an additive effect, and a piece of ferrous metal so treated has a magnetic field of its own. You can demonstrate this by hammering on an unmagnetized piece of steel such as a knife blade in a strong magnetic field; the steel will develop a permanent field. The effect occurs (though to a lesser extent) even if the magnetic field is not strong. Although the earth's magnetic field is not strong, a ship's hull contains so much steel that it acquires a significant and permanent magnetic field during construction.

INDUCED MAGNETIC FIELD.—Imagine a magnetic field as consisting of many tiny "lines of force"¹—running from the magnetic north pole to the magnetic south pole of the field in a closed loop. The earth has such a field, as if it contained a huge bar magnet (fig. 12-15). The magnetic poles do not coincide with the geographic poles, however. Visualize an area of the earth's surface, with the invisible magnetic lines of force more or less evenly distributed

over it. Air and water have low magnetic permeability—that is, they do not conduct magnetic lines of force (or magnetic flux) especially well. Now put a ship's hull into the sea at the point being considered. Ferrous metal has relatively high permeability. The high-permeability hull distorts the field because the magnetic lines of force tend to concentrate in it. If the ship is pointed toward magnetic north, the effect is as shown in figure 12-16, part A; if the hull is pointed eastward, the effect is as shown in part B of the figure.

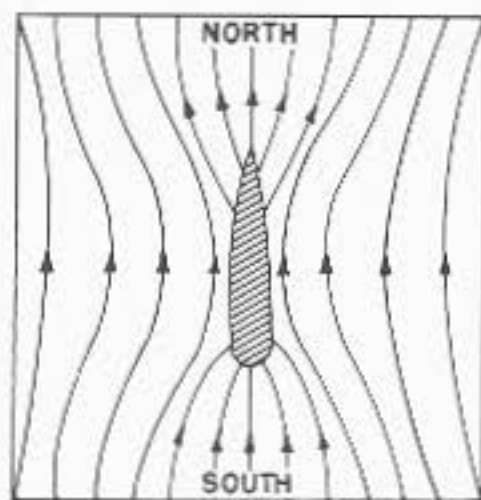
This distortion of the earth's magnetic field (by concentrating part of it in the magnetically permeable hull) is the induced field. As figure 12-15 shows, however, the magnetic lines of force of the earth's field are not parallel to the earth's surface except in the vicinity of the equator. Elsewhere they are tilted with respect to the surface; at the magnetic poles they are perpendicular. The induced field therefore has a vertical component as well as a horizontal. The strength of the vertical component is affected chiefly by the ship's location on the earth with respect to the magnetic poles. Figure 12-16 illustrates the latter effect.

DEPERMING.—The purpose of deperming is not to eliminate a steel hull's permanent magnetic field altogether (this is not practical on a large scale), but to (a) reduce it to a minimum, and (b) make it more or less similar

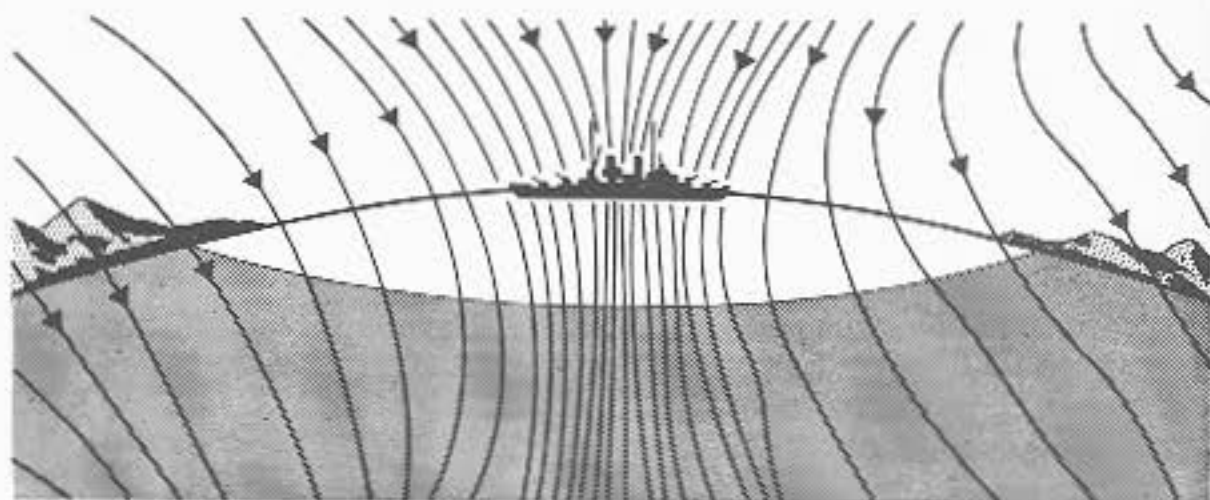


27.104
Figure 12-15.—The magnetic field about the earth.

¹The idea of "lines of force" is intended only as an aid in thinking of the effects of magnetic fields. Their existence has not been physically demonstrated, and the idea should be considered only as a conceptual convenience, not as a physical fact.



A



B

27.105:56.29

Figure 12-16. — A ship's hull distorts the earth's magnetic field.

to others of the same hull type. At a number of locations called magnetic or degaussing ranges, magnetic sensing devices located on the bottom of a channel can detect a ship's magnetic field pattern as it steams past. The recording made of the ship's magnetic pattern is called its magnetic signature. After deperming, a ship's permanent magnetic field has not only been reduced to a practicable minimum, but its signature is similar to that of other depermed ships of the same class. The degaussing installation (described below) can then be set up on a "mass production" basis. The deperming process cannot be described here in detail; suffice it to say it is essentially a large-scale version of the process for demagnetizing a watch.

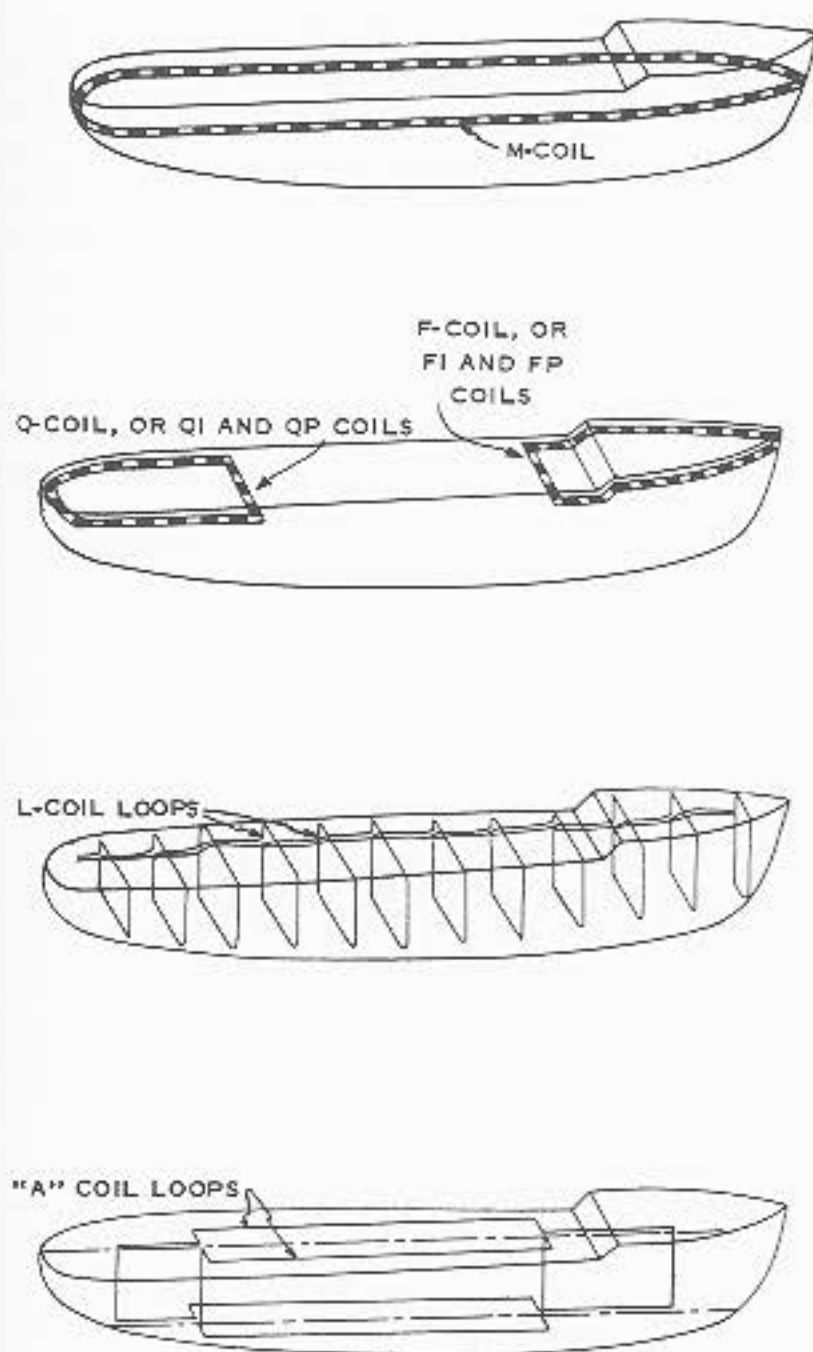
DEGAUSSING. — The purpose of degaussing is to counteract the ship's magnetic field so that (ideally) the magnetic field near the ship is the same as it would be if the ship weren't there. To some extent this can be done by magnetic treatment of the ship using coils temporarily installed. This is not as effective as the more frequent method—using permanently installed equipment, as follows:

1. Degaussing coils.
2. A d-c power source to energize the coils.
3. Means to control the currents in the coils.
4. Magnetic compass compensating equipment to cancel out the disturbing influence of the degaussing equipment on the magnetic compass.

Degaussing cannot be exhaustively described in this text. The interested student is referred to the NavShips Technical Manual. The term "degaussing" is derived from "gauss," the unit of magnetic field strength (in turn, the name of this unit commemorates the German 19th-century mathematician Karl Friedrich Gauss). We can cover here only some high points.

The ship's magnetic field (permanent plus induced) can be analyzed into 6 components. The degaussing installation is designed to produce as accurately as possible an exactly opposing field. This is done by encircling the hull or other parts of the ship's structure by coils of heavy electric cable. The coils are designated as M (main coil), F (forecastle), Q (quarterdeck), L (longitudinal), and A (athwartship). See fig. 12-17. Various combinations of these are energized as required to create the desired fields. The coils are excited either by the ship's d-c supply or by a motor-generator which produces the direct current required. The polarity and current in each coil may be manually controlled, but the present trend is to make the functioning of the system completely automatic, except for manual setting of magnetic latitude and magnetic variation (i.e., difference between the direction to the geographic pole and to the magnetic pole). Such a system may compensate for ship's heading only, or for heading, roll, and pitch, by using servos to vary the d-c inputs to the coils.

Effective though deperming and degaussing are, residual magnetic fields accompany all steel-hull ships, especially larger ones. For such critical work as minesweeping, more drastic



27,107

Figure 12-17. — Degaussing coils.

antimagnetic measures are necessary. Minesweepers therefore may be built with nonmagnetic hulls to reduce magnetic effects to the vanishing point.

Ship Treatment Against Acoustic Mines

Acoustic mines function in response to the underwater sound output of ships. Most underwater noise of ships is caused by movement of the screw blades with respect to the water. At high screw speeds parts of the screw move so fast the water cannot flow around the screw edges fast enough, causing low pressure areas to form, then collapse. These actually are cavities or bubbles of water vapor, and their rapidly

repeated formation and collapse produces water vibration at sonic or subsonic frequencies. Other causes of ship noise are vibration of external parts in the water as the ship passes through, water flow over sharp surfaces or obstruction of the hull, and transmission through the hull, screws, and screw shafting of machinery noises to the water.

The only important design change that could materially change acoustic disturbances caused by ships would be the development of a screw shape that would reduce cavitation or cavitation noise at high speed. Research is now under way on this. For the rest, once the ship's hull has been adequately faired, little can be done so far as design is concerned to reduce acoustic noise output. Noise can be reduced only by reducing screw speed, shutting down noise-producing machinery such as reciprocating pumps, etc.

Minehunting

The methodical detection, location, and neutralization of mines is appropriately called mine hunting. Some craft and their highly trained personnel specialize in this work.

The shipboard devices used in mine detection are called ordnance locators. The sensing component of an ordnance locator is called an ordnance detector. The term ordnance detector can also refer, however, to a small, man-carried ordnance locator in its entirety.

Minesweeping

Minesweeping is accomplished by going over a mined area with mechanical sweeps that physically remove the mines (for example, by cutting mooring cables of moored mines) and with influence sweeps that provide the influence fields necessary to actuate influence mines. In addition to minesweeping ships and crafts, helicopters can be used to sweep mines in some instances.

SWEEPING MOORED MINES. — The Navy uses several types of sweep gear for sweeping moored mines. In the most common type, a wire cable (sweep wire) is towed through the water deep enough to strike the mine mooring. The mine mooring then slides along the sweep wire until it engages one of several cutters spaced at intervals along the sweep wire. The cutter severs the mooring, and the mine bobs to the surface where it can be detonated or sunk by

gunfire. The sweep gear can be streamed to both sides of the ship simultaneously.

Minesweeping cutters are either mechanical or explosive. A mechanical cutter has no moving parts and cuts the mine mooring by means of two saw-toothed blades in the form of a V. It will cut wire moorings up to 1/2-inch in diameter but will not cut chain moorings. Explosive cutters are of two types. One utilizes a shaped charge to cut the mine mooring; with the other type an explosive charge propels a cutting chisel. Some explosive cutters are capable of severing chain moorings up to 1-1/8 inches in diameter.

SWEEPING MAGNETIC MINES.—As defense against magnetic mines, minesweepers are constructed of wood and stainless steel, aluminum, and other nonmagnetic metals which, along with an elaborate degaussing system, gives them a low magnetic signature. A shallow draft also greatly reduces the danger to the minesweeper of moored or pressure mines.

To sweep magnetic mines, the minesweeper streams a buoyant cable (tail), many yards astern or to the side of the ship, through which a powerful direct current is pulsed, at intervals. This sets up a large magnetic field around the cable and influences the mines.

SWEEPING ACOUSTIC MINES.—Sweeping acoustic mines is similar to magnetic mine-sweeping in that the effect of an approaching ship must be produced artificially. This is done by towing a noise maker, of which there are numerous types, astern of the sweeper. In one commonly used type, a direct current motor actuates a striker that strikes a diaphragm to produce sound wave. Current to the motor may be pulsed or modulated to give the effect of an approaching ship. The approaching effect is vital because a sudden sharp noise, such as an explosion, will not fire an acoustic mine; it merely actuates a countermine bypass circuit designed to prevent a mine from being fired by the explosion of an adjacent mine or depth charge.

SWEEPING PRESSURE MINES.—For many years the Navy unsuccessfully attempted to artificially produce the effect of a ship passing over pressure mines in an effort to detonate them. The Navy therefore decided to use a ship itself. The first operational MMS (minesweeper, special), delivered in 1969, sweeps pressure mines as well as acoustic and magnetic types. For protection against pressure-mine detonations, the hull of the Liberty-ship conversion has been strengthened, underwater apertures closed, and hold spaces filled with formed flotation material and water ballast. The bridge is shock-mounted.

CHAPTER 13

ANTISUBMARINE WARFARE

In the words of NWP 24, Antisubmarine Operation, "the basic mission of antisubmarine warfare is to deny the enemy the effective use of his submarines." This is a broad mission and includes not only antisubmarine warfare (ASW) operations but also operations against their supporting forces, operating bases, and construction facilities.

ASW can be considered as having offensive and protective phases. Offensive tasks associated with ASW include destruction of enemy submarine bases, repair facilities, and construction facilities; the prevention of enemy submarine movement from place to place; the destruction of submarines enroute to and from their operating areas; and the destruction of enemy submarines in their operating areas. (The distinction between these last two is important operationally.) Protective tasks associated with ASW include establishment of operating methods which will ensure safe arrival of shipping at destination, and protection of ships and shore installations against submarine attack.

Operations utilized to accomplish the offensive tasks include strike operations and hunter-killer (HUK) operations. Protective operations include naval control of shipping, escort operations, screen operations, support operations, and harbor and area operations. Operations that may be protective, offensive, or both include mining, search, and patrol operations. Note that offensive operations may be protective in purpose; there is no need to make too sharp a line of demarcation between offensive and protective.

The classical concept of the Navy's wartime mission, as expressed early in this text is to maintain control of the seas so that we can use them and at the same time deny their use to the enemy. A recent corollary to this concept adds a new method of attack to the Navy's arsenal—the guided missile launched against major enemy land targets by naval vessels hundreds or thousands of miles distant—and simultaneously lays on the Navy the chief burden of defending U.S.

territories against just such an attack by the enemy.

The submarine has roles to play both in the classical concept of the Navy's mission and in these newer corollaries. An enemy may be capable of pitting against us submarines as advanced as our own, and as well (or even better) adapted to launching guided missiles with nuclear warheads against our own cities. Such activities as the prodigious and continuing production of Soviet submarines show that the military planners of foreign countries are by no means incapable of making similar strategic estimates—and acting upon them.

Against this threat, unprecedented in the history of warfare, it is the Navy's primary responsibility to maintain constant vigilance, and to be continuously prepared to prevent and counter every attack. It is no longer enough to prevent submarine attacks on our own or Allied shipping and naval vessels, important though this is. It has become necessary to protect against missile-carrying submarines wherever they may be. This new dimension added to the concepts of ASW sets up a new requirement. The need is to find and keep under surveillance all enemy submarines before they can reach a spot within missile launching range of our coasts.

Most of what has even now been developed by way of doctrine techniques and equipment cannot be completely revealed in this textbook for security reasons. But the student should realize that a massive effort by the Navy and other agencies, both in and out of the Armed Forces, is under way to solve the problems implied by this threat, and he should realize too that when he is on active duty the chances are very good that he will be called upon to participate in this effort.

Let us now consider briefly the submarine threat as it has been in the past and as it may be in the future. In this article and in the remainder of this chapter we are primarily concerned with how the submarine can be detected,

located, and attacked by surface forces with the aid of friendly air and subsurface forces. The strategic role of the submarine as a guided-missile platform is beyond the scope of this chapter.

In this chapter we are concerned primarily with ASW weapons and associated fire control and detection systems, rather than with operations as such, but operations will be discussed to the limited extent necessary to explain the use of ASW equipment.

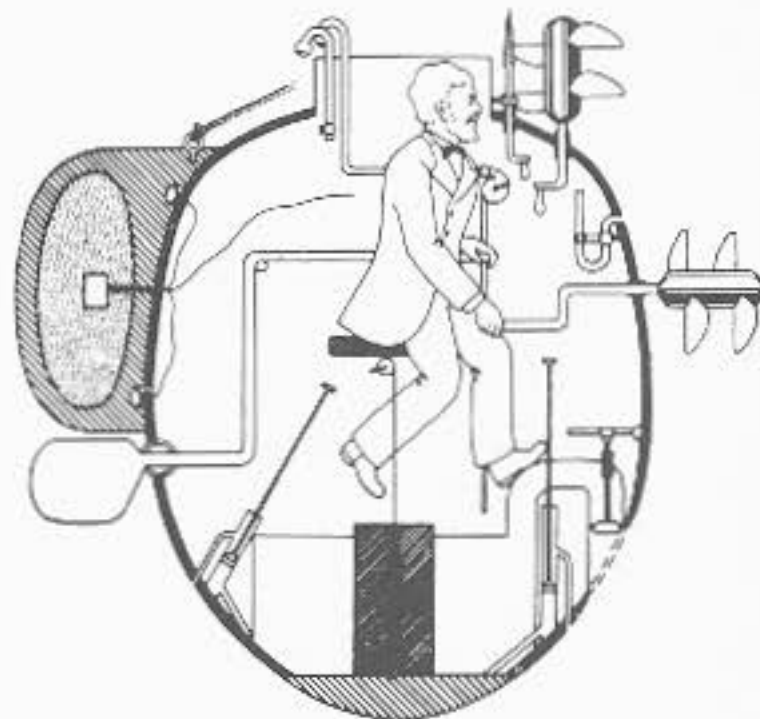
HISTORICAL DEVELOPMENT

The first successful submarine was built in 1620 by Cornelius Van Drebel, a Dutch physician. During repeated trials in the Thames River, he maneuvered his craft successfully at depths of 12 to 15 feet.

Various other European designers of that time constructed submersible craft also. But they failed to arouse the interest of any navy in an age when all concepts of the potentialities of submarine warfare still were far in the future. Most of the early craft were of wooden frames, covered with greased leather or similar material, and propelled by oars. Different methods of submerging were thought of and some were tried. One inventor's design consisted of a number of goatskin bags built into the hull, each connected to an aperture in the bottom. He planned to submerge the craft by filling the skins with water, and to surface it by forcing the water out of the skins with a "twisting rod." Although his vessel was never built, it seems that this was the first approach to the modern ballast tank. Another inventor actually submerged his craft by reducing its volume as a result of contracting the sides through the use of hand vises.

Ideas were plentiful, some fanciful and grotesque, but some contained elements capable of practical application. Lack of full understanding of the physical and mechanical principles involved, coupled with the almost universal conviction that underwater navigation was impossible and of no practical value, postponed the attempt to utilize a submarine in naval warfare during the early period.

A submarine was first used during the American Revolution as an offensive weapon in naval warfare. The Turtle (fig. 13-1), a one-man submersible designed by David Bushnell and hand-operated by a screw propeller, attempted to sink a British man-of-war in New York Harbor.



110.104
Figure 13-1.—The Turtle of David Bushnell, from a drawing by Lt F.M. Barber, USN, 1875.

The plan was to attach a charge of gunpowder to the ship's bottom with screws and explode it with a time fuze. After repeated failures to force the screws through the copper sheathing of the hull of HMS Eagle, the submarine gave up, released the charge, and withdrew. The powder exploded without result, except that the Eagle at once decided to shift to a berth farther out to sea. Although the attack was unsuccessful, the "idea" for a submarine was there, and it grew until the submarine eventually became a potent weapon for attacking ships.

On 17 February 1864 a Confederate hand-propelled submersible carrying a crew of six men sank a Federal corvette that was blockading Charleston Harbor. The Confederate submarine Hunley used a spar torpedo attached to her bow to ram and sink the Union Frigate Housatonic. This is the first recorded instance of a submarine sinking a warship.

The submarine first became a major component in naval warfare during World War I, when Germany demonstrated its full potentialities. The heavy losses inflicted by German U-boats on allied shipping almost swung the tide of the war in favor of the Central powers. Then, as now, the submarine's greatest advantage was that it could operate beneath the ocean surface where detection was difficult. Sinking a submarine was comparatively easy, once it was

found—but finding it before it could attack was another matter.

During the closing months of World War I, the Allied Submarine Devices Investigation Committee, termed ASDIC, was formed to obtain, from science and technology, more effective underwater detection equipment. The committee developed a reasonably accurate device for locating a submerged submarine. This device, a trainable hydrophone, was attached to the bottom of the ASW ship and used to detect screw noises and other sounds that might come from a submarine. Although the committee disbanded after World War I, the British made improvements on the locating device, during the interval between World War I and World War II, and named it ASDIC after the committee.

American scientists further improved on the device, calling it sonar, an acronym for sound navigation, and ranging.

In World War II, submarines sent millions of tons of shipping to the bottom. In what since has come to be known as the Battle of the Atlantic, the U.S. Navy and her Allies teamed together to hunt down undersea raiders, thus gaining one of the important victories of the war.

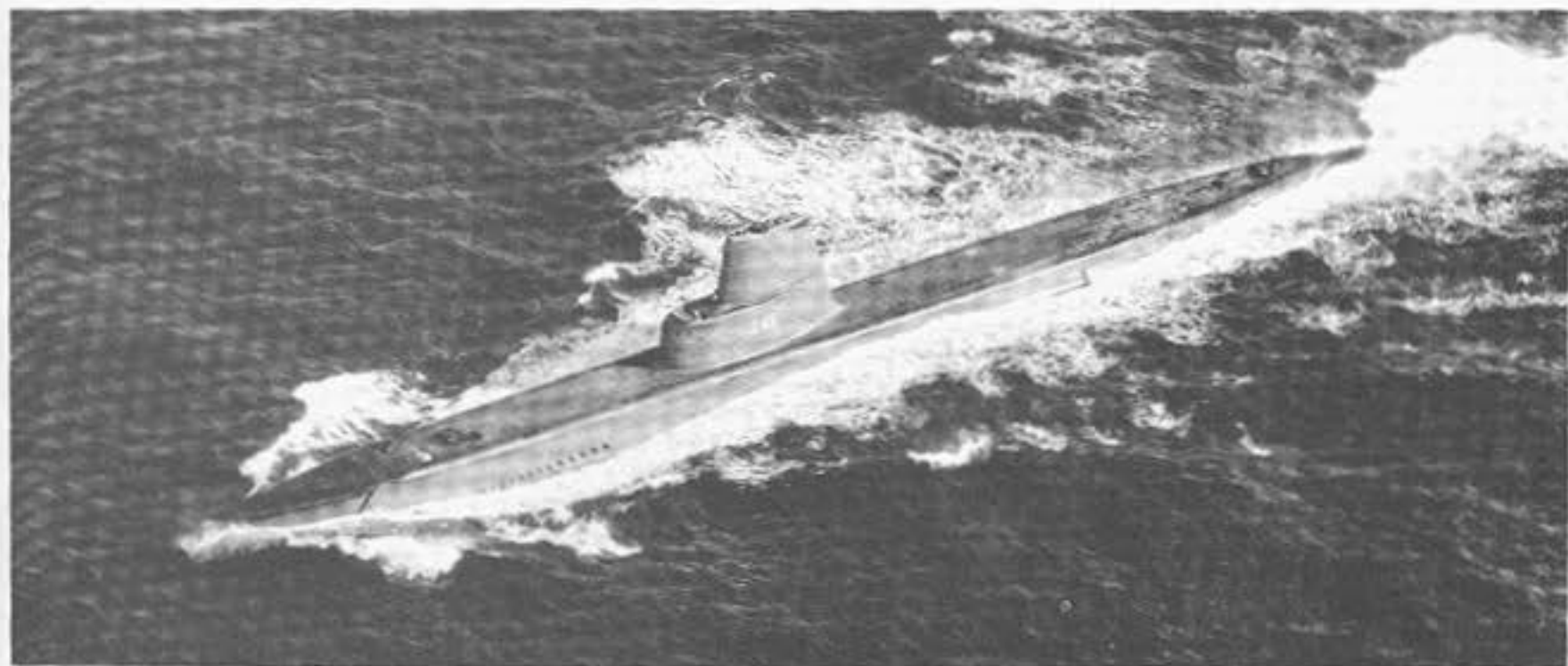
At the end of World War II, the United States improved the snorkel (a device for bringing air to the crew and engines when operating submerged on diesels) and developed the Guppy submarine. The Guppy (short for greater underwater propulsion power) is a conversion of the

fleet-type submarine of World War II fame. A Guppy submarine is shown in figure 13-2. The only change in outward appearance is the superstructure. It was changed by reducing the surface area, streamlining every protruding object, and enclosing the periscope shears in a streamlined metal fairing. Performance increased greatly with improved electronic equipment, additional battery capacity, and the addition of the snorkel.

The world's pioneer nuclear-powered submarine is the USS Nautilus, SSN 571 (fig. 13-3). The Nautilus, commissioned in September 1954, is 320 feet in length and has a standard surface displacement of 3,180 tons. The Nautilus introduced the bulbous bow for better underwater performance. She refueled for the first time in 1957. Like all nuclear submarines she is designed to travel faster under the water than on the surface.

An intensive building program for nuclear ballistic missile submarines has resulted in the addition of many such ships to the operational fleet. The prototype is USS George Washington, SSBN 598, (fig. 13-4).

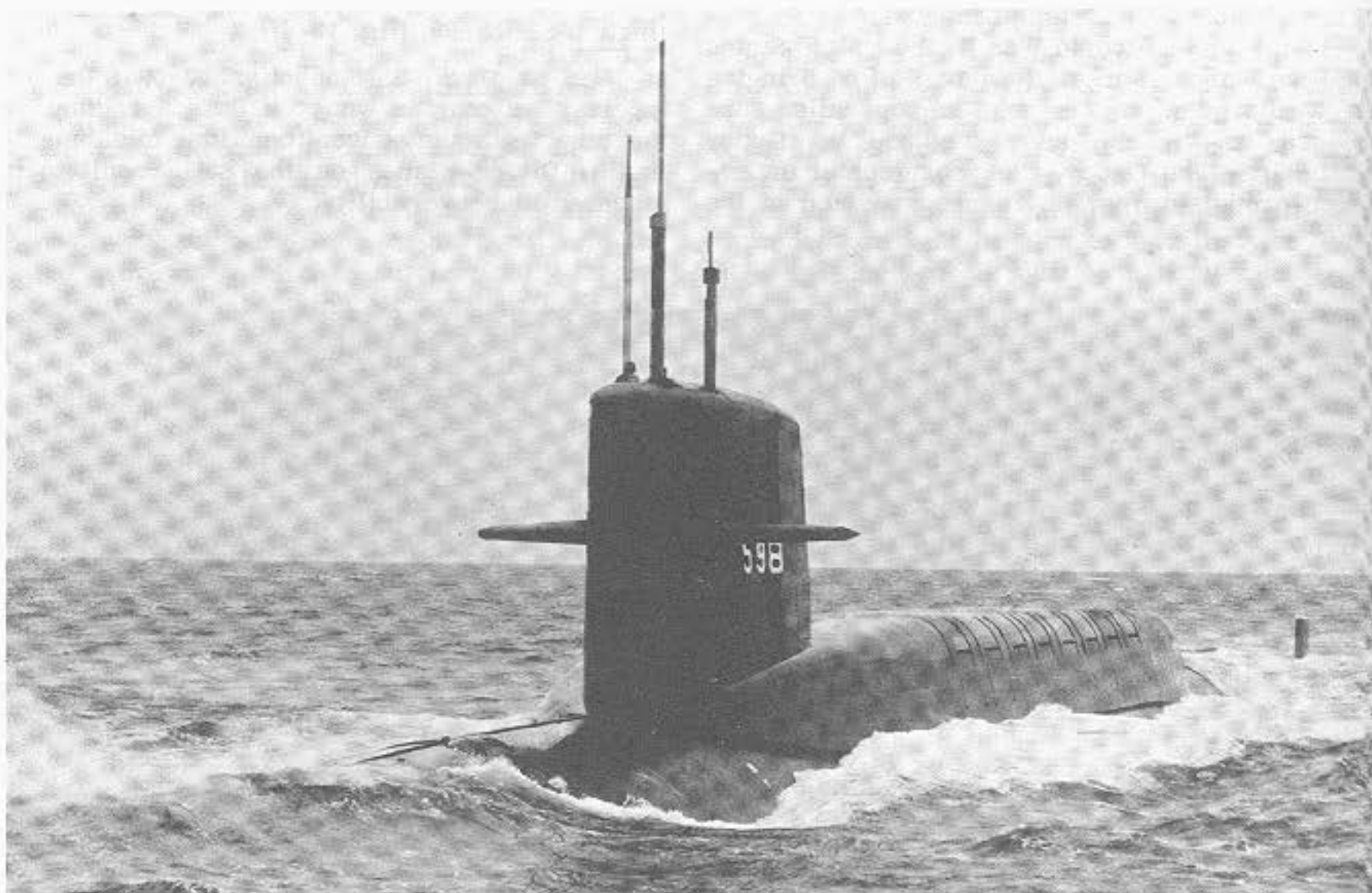
USS Skipjack, SSN 585 (fig. 13-5) is the first nuclear submarine whose hull is a radical departure from the conventional idea of submarine hulls. Diving planes on the sail result in increased maneuverability.



71.1-346
Figure 13-2.—Guppy submarine.



71.1
Figure 13-3. — USS Nautilus (SSN 571).



71.1
Figure 13-4. — USS George Washington (SSBN 598).



71.1

Figure 13-5.—USS Skipjack (SSN 585).

THE SOVIET MENACE

Soviet submarines can in many respects be compared to American types. The Soviet submarine fleet consists of over 400 submarines, most of which are modern, long range units constructed during a massive postwar building program. This program increased steadily after 1950 and reached a peak construction rate of nearly 100 submarines in 1956, after which there was a marked slowdown in submarine construction. It is probable that the Soviets had reached their desired numerical goal and shifted emphasis to improving the quality and strategic capabilities of the submarine force.

The total threat posed by the Soviet submarine force is increasing steadily. This is because the older submarines being phased out have a marginal capability under conditions of modern warfare. The new submarines, which include a growing number capable of launching ballistic missiles, as well as new conventional attack types, are a vastly more dangerous threat. The Soviets now have in operation a number of nuclear submarines. Thus it is reasonable to

suppose and realistic to anticipate that ASW forces opposing them will find the Soviet submarine and its weapons far from backward technologically.

SUBMARINES: ADVANTAGES AND DISADVANTAGES

As seen by ASW forces on the surface, the submarine has the following advantages:

1. Concealment. The submarine is concealed when submerged and is hard to detect because of its low silhouette even when surfaced. A snorkeling submarine or a submarine at periscope depth is visible to a surface or airborne observer, and shows up on radar, but if the sea surface is at all agitated such detection quickly becomes marginal or impossible. Except in certain unusually transparent ocean areas (in localities of the Pacific and Caribbean, for example) a completely submerged submarine is totally invisible to the surface or airborne observer armed only with optical aids and radar. It can be detected by sonar, but this method

has severe limitations, as will be brought out later.

2. More highly trained and developed personnel, both physically and professionally. In virtually all the navies in the world submarine personnel are selected for their superior potential and proficiency, and receive more training in submarine operations than the average naval officer or enlisted man receives in ASW.

3. Passive detection capabilities. Because submarines are so hard to detect, ASW forces must search actively for them, and in the two chief methods of searching, they reveal themselves to the submarines in searching. A radar pulse from a searching ASW vessel can be detected by a sensitive ECM receiver at a much greater range than that at which a submarine's silhouette (or its even less obtrusive antenna, periscope, and snorkel) will return a definite echo. This is particularly true when weather is poor or the sea surface is agitated. A sonar pulse similarly can be heard by a submarine much beyond the maximum range at which the sonar will produce a reliable echo. Lastly, although a submarine snorkeling or on the surface can be seen by surface or airborne observers, usually an observer in the low-lying submarine will see the observer first.

4. Immunity to surface water. A submerged submarine avoids the buffeting of rough surface winds and waves.

5. Reduced noise production. Other things (such as type of listening gear, screw rpm, speed through the water, etc.) being equal, a submarine listening at moderate depth will probably hear a surface vessel before the surface vessel can hear the submarine. At present, the main reason for this is cavitation produced by rotation of the ship's screws in the water. (This phenomenon is explained in the next chapter.) As water pressure increases, cavitation and the noise it produces decrease. A submerged submarine is under greater pressure because of its depth, hence it produces less cavitation noise. It is also true that an electric drive inherently is likely to be somewhat quieter than a steam turbine or Diesel plant, and that conventional submarines generally run at lower speeds submerged than they do on the surface, so that they tend to be quieter even without taking cavitation into account. Recent hydrodynamic investigation indicates that the bow wave (the "bone in a ship's teeth") produced by hull movement on the surface is inherently more

wasteful of power, hence noisier, than movement of water around a Skipjack type hull structure completely submerged in the water. Nuclear-powered boats, which have steam-driven turbines, do create more underwater noise than the electrically driven conventional submarines. Speed and depth capabilities partially compensate for this, however. It seems relatively safe to predict, therefore, that the noise-detection advantage that submerged submarines now have is likely to continue in the future.

6. Speed. With the advent of Nuclear-powered submarines and Skipjack type streamlining, ASW craft no longer hold a speed advantage over the submarine.

Not all the advantages are with the submarine. In the following respects the ASW forces have the advantage:

1. Variety of weapons. Submarines can be attacked with a number of weapons, such as mines, torpedoes, and missiles. Submarines at present have only torpedoes and the recently developed submarine rocket in their antisurface arsenal. Fleet ballistic missiles (Polaris/Poseidon) are not intended for use against surface forces.

2. Vulnerability. Even relatively slight damage to a submarine can force it to surface—relative, that is, to the damage required before a surface ship is put out of action. Slight damage that does not force it to surface may increase its noise output (for example, it may be necessary to start pumps because of a leak) and give its position away to listening observers.

3. Personnel endurance. This is limited by the physical conditions of life aboard a submerged submarine, particularly of the less advanced types, and the combined psychological and physical strains to submarine personnel under attack, even when the attack is not lethal.

4. Number. ASW forces are generally concentrated so that more than one ship plus aircraft attack a submarine. In theory, two or more submarines can work together in an attack, but any attempt at communication between the submarines will give away their position, destroying the submarines' main advantage. Moreover, whereas communication between ASW forces is relatively easy (by radio, flashing light, etc.) and cannot be detected by submerged submarines, communication between submarines is at best likely to be garbled and difficult, as well as tactically disadvantageous.

SUBMARINES AND ANTISUBMARINE
WARFARE IN THE FUTURE

No man can say just what warfare will be like in the future, but the outlines that can be conjectured are clear enough to show that naval forces under the sea surface will have much to do with determining who has command of the sea. Based on past experience and on new developments, submarines will likely be used in any or all of the following ways by both sides:

1. To destroy the enemy's navy and merchant marine.
2. To impede or cut off the flow of supplies and troops by threat of attack on merchant shipping.
3. To deny use of shipping lanes and harbor areas to the enemy's merchant shipping and naval units by submarine-planted mines.
4. By causing the enemy to concentrate on antisubmarine warfare, to divert him in greater or less degree from his primary mission of winning the conflict.
5. To mount direct attacks by submarine-launched guided missiles and rockets.
6. To function as pickets.
7. To function as transports in situations where the submarine's special characteristics are important.
8. To function as antisubmarine units.

Though in many respects antisubmarine warfare of the future will resemble that of World War II, there will be great differences. The advent of nuclear-powered ships and submarines, and nuclear weapons creates a growing challenge in the antisubmarine warfare problem of our modern Navy. Detection equipment and tactics are constantly undergoing revision and improvement in order to keep abreast of this changing technology.

Our present ASW ships, such as the destroyer, are formidable adversaries against any submarine. The destroyer can remain at sea for extended periods of time. It carries the latest sonar, electronic countermeasures (ECM), and communication equipment, plus the weapons to go with them and the facilities for reloading under long-endurance wartime conditions. Not only can the destroyer defend itself against enemy attack, but it also can screen and protect other units.

SONAR AND OTHER UNDERWATER
TARGET LOCATION SYSTEMS

Now that we have surveyed the outlines of the problem and in general terms compared the capabilities of the adversaries, submerged versus surface and airborne, we are ready to investigate (still in general terms) how, from the point of view of surface ASW forces, the underwater target can be located and attacked.

We have elsewhere in this book discussed methods of locating and attacking surface targets. When surfaced, the submarine is a surface target, and it is not necessary to discuss further how a surfaced submarine is attacked.

To attack a submerged submarine, it is first necessary to detect it, establish its location and its rate of movement in bearing and depth, and then solve this fire control problem to predict its future location so that an ASW weapon can attack it. When more than one weapon is used, the problem must be solved for each.

The blind time (time elapsed between firing and predicted impact of missile) of ASW weapons is much greater than that for gun and rocket fire control. Therefore, ASW weapons are designed to be effective over a larger area than, say, gunfire at the same range.

The chief method of detection and location of submerged submarines by surface craft is by using sound, which travels underwater about four times faster than it does in air. The primary method of sound detection, sonar, will be treated presently. Magnetic methods can be used by aircraft, but at present, they are not adaptable for use in surface vessels. Other methods that may be under development cannot be discussed in this book.

Although at present underwater target detection and location by surface craft is done by one method (sonar) to the virtual exclusion of others, a variety of weapons can be used to attack the target. Some of these weapons are discussed later in this chapter (to the extent that security classification makes possible).

Echo-ranging equipment, commonly referred to as sonar, is installed on board ships to determine ranges and bearings on submerged submarines by means of sound waves. To a lesser extent, it is used for navigation purposes. In pilot waters, especially in low visibility, it may be used to locate reefs, other submerged objects, and buoys.

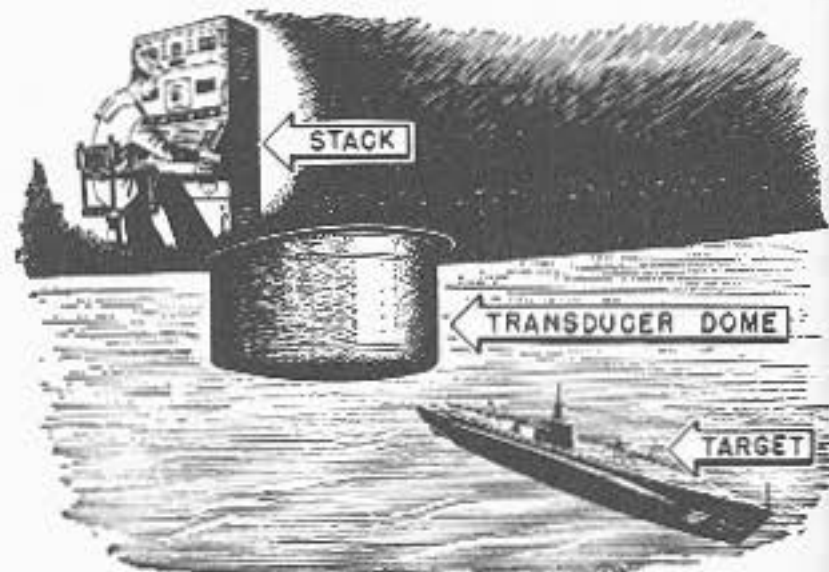
When sound waves impinge on any submerged or partially submerged object, some of their energy is reflected in the manner of an ordinary echo. In active sonar, a sound pulse is projected and, in turn, the echo is received by means of a transducer which is usually located in the water forward and on the keel of the ASW vessel (fig. 13-6). The signal-receiving and indicating equipment (the so-called stack or sonar control indicator) is located in a space known as sonar control. The signal-transmitting equipment, requiring no operator, is generally installed in a space immediately above the transducer.

The principal sonars in use during World War II projected a narrow beam of sound into the water, and target indications were returned as audio responses from a speaker or headset. A thorough search was a slow process in which the operator hand-trained the transducer in increments of $2\text{--}1\frac{1}{2}^\circ$ to 5° , according to search doctrine in force. (This was the "search light" type sonar.)

At the close of World War II, the Navy perfected a new type of search sonar known as scanning or azimuth search sonar. With each outgoing burst of sound, scanning sonar transmits the sound pulse in all directions simultaneously and picks up echoes from any or all points. In addition, scanning sonar offers both video and audio presentation of target information.

The performance of sound waves when transmitted through sea water is a complex study in itself. However, a knowledge of certain features of this subdivision of physics is important in understanding how sonar is used. These are:

1. Speed of sound variations. Temperature and, to a much lesser extent, pressure and salinity differences cause variations in water density which, in turn, cause variations in the speed of sound in sea water. This results in varying values of sonar range which must be taken into account since sound-ranging sonar, like radar, measures range by the time interval between transmitting a pulse and receiving an echo. In addition, variations in sound transmission speed cause the sound beam to be refracted or bent as it passes through the water. This is discussed separately below. The speed of sound in sea water at temperature 39°F , and at normal conditions of salinity and atmospheric pressure is approximately 4800 feet per second. Any increase in pressure or salinity will result in



53,117

Figure 13-6.—Elements of sonar system.

only slight increases in the speed of sound. Any increase in temperature however, will result in an appreciable increase in the speed of sound.

2. Sound beam refraction. As mentioned above, the variations in speed of sound caused by temperature produce refraction of the sound beam. This refraction, unless corrected for, can result in serious errors in the measurement of sonar range, and a reduction in detection range.

3. Attenuation. Sound waves propagated through sea water are attenuated rapidly; hence the range at which detection is possible by sonar is reduced.

4. Echoes. Echoes, both single and multiple (reverberations), are received from marine life, the sea bottom, surface disturbances, and various irregularities in the fluid medium, as well as from submarines.

Although adverse water conditions may limit range and make bearing definition difficult, ASW personnel are trained to get optimum results from their equipment under all conditions. They are trained to predict sound behavior and to apply the results reliably to the antisubmarine problem. Sonarmen quickly classify a contact by its appearance on the cathode ray scope, the quality of the sound, the bearing spread, its relative motion, etc. Sonar research has established certain sound "patterns," based principally on underwater temperatures. With the aid of the bathythermograph (BT), a device for measuring water temperatures down to 900 feet, it is possible to predict the sound pattern and to introduce these data into the sonar system.

SONAR PRINCIPLES

There are two principal modes of sonar operation. Passive sonar listens only; the sounds it detects are those originating with the target. Active or echo-ranging sonar radiates a powerful brief pulse of sound vibration into the water, then listens for the echo. The term "sonar" without qualification denotes active sonar. Any underwater object that returns an identifiable sonar echo or produces a discrete sound is a sonar contact.

As in radar, the listening device can indicate the bearing of the signal source it hears. In active sonar the returning echo is timed and the equipment can indicate the range to the target. The equipment can display a video presentation much like a PPI-scope, and also produces an audible output.

The video presentation of the echo permits quick, accurate determination of target range and bearing; a Sonarman's trained ear can analyze the audio reproduction of the echo and determine (a) the nature of its source and (b) its movement with respect to own ship. Analysis to determine the nature of the echo or sound source (this aspect of auditory analysis of sonar sounds applies to both echoes and original noises) is based on experience with sounds produced under varying conditions by different kinds of sea creatures as well as different kinds of targets and simulated targets. (A submarine can for example release a quantity of air from a torpedo tube; the air bubbles will return an echo and show up on the sonar video presentation.) In addition, echoes from moving targets have doppler. Doppler is a change in frequency in the echo (as compared with the frequency of the original sonar pulse) from a moving target having motion along the line of sound. (Anyone who has heard the change in pitch of a railway locomotive whistle or horn as a fast-moving train passes a stationary listener has heard a rather obvious example of the Doppler effect, which was named after Christian Johann Doppler, a 19th-century Austrian physicist.) Doppler indicates relative target motion.

In sonar, doppler is a rather subtle effect and its consistent detection and evaluation require an ear highly sensitive to audible pitch changes, plus much training and experience with audibly reproduced sonar echoes. Sonar systems produce sound pulses of very high and often ultrasonic frequency (i.e., frequencies beyond those of normal human hearing). To produce sonar

echoes at audible frequencies in the range (in the neighborhood of 800 hertz) to which the human ear is most sensitive and can best discriminate pitch changes, sonar systems use beat frequency oscillators to change the frequency of the received echoes to about 800 hertz.

Equipment designed to function as active sonar can be used passively if desired. Listening devices designed for passive operation only are called hydrophones. (These are normally installed only on submarines.) Underwater telephones (colloquially called "Gertrude") used for voice communication, also work on sound conduction principles, but are not to be confused with sonar.

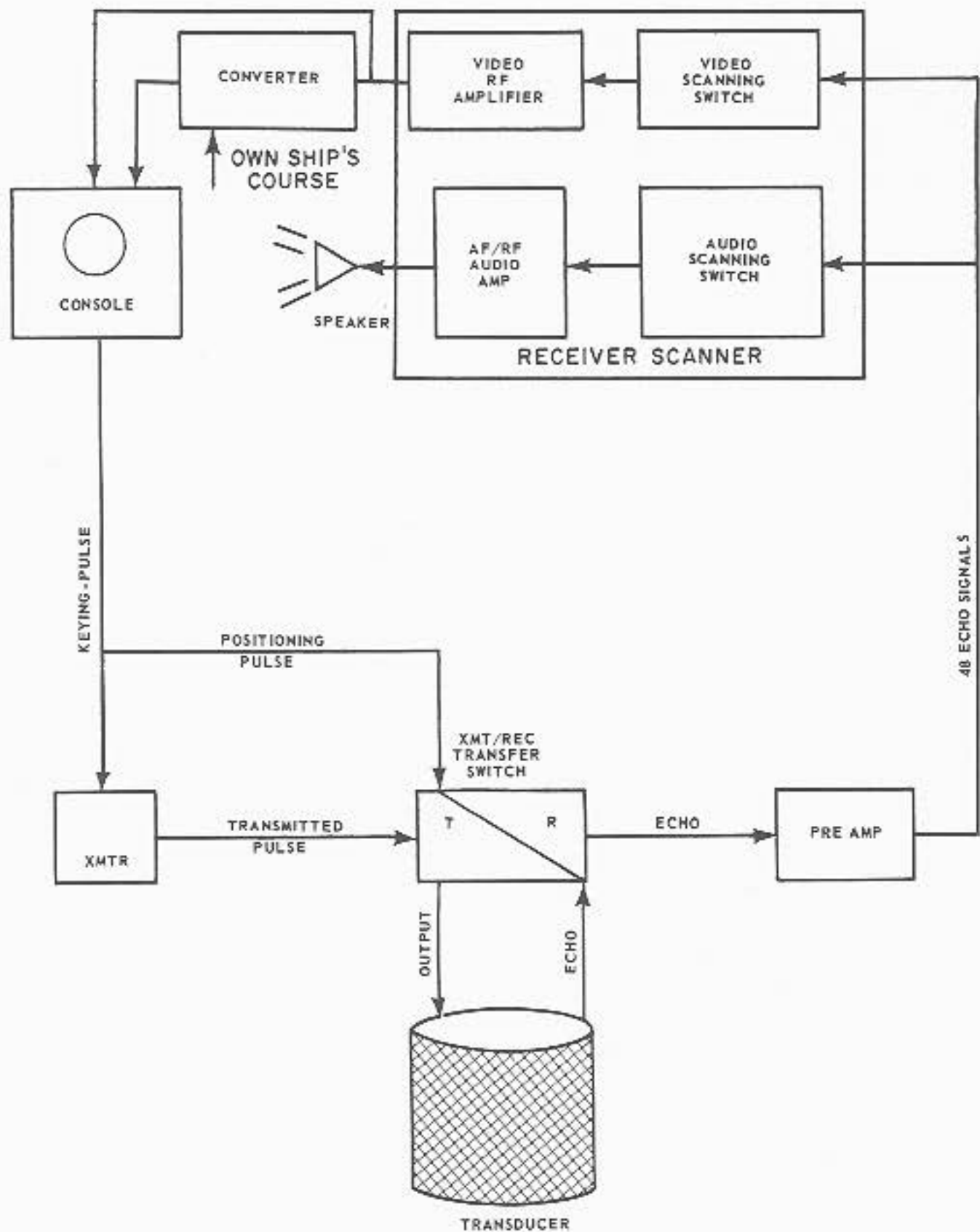
Sonar is the primary means of detecting a completely submerged submarine, and, in general, it is the only means a surface vessel has of detecting an underwater target. Echo-ranging (scanning) sonar is the most effective for ship-board use.

REPRESENTATIVE SCANNING SONAR

A representative scanning sonar (fig. 13-7) includes a console, transmitter, transmitter-receiver transfer switch, transducer, receiver, various amplifier units and switches, and a data converter.

A feature of all modern sonars is that echoes are displayed visibly as well as audibly. The visible display is made by a cathode ray tube (CRT). In some equipment, two CRTs may be operated in two different modes, ship center display (SCD) and target center display (TCD). In SCD mode, own ship is represented by the center of the CRT, and echoes from the target and other underwater objects appear as bright spots about it. In the TCD mode, if the cursor is on target, the bright spot representing the target appears at the center of the display. Depending on range and range scale, own ship may not even appear. The ship center display mode is used in searching; the target center display mode is normally utilized for tracking.

For audio presentation, a returning echo, after conversion to an electrical signal and amplification, is changed to an audible frequency and sent to a headset or loudspeaker near the control indicator, where it is heard as a "ping." The ping is of value in target identification and in the determination of doppler.



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Figure 13-7.—Typical scanning sonar.

The console or sonar indicator control, commonly called the stack, is the heart of the installation. All necessary operating controls are mounted on its face, and near the center is the CRT.

A principal function of the console is to initiate the keying pulse, which is sent to the

transmitter. When the transmitter is thus keyed by the console, it generates a power pulse to the transmit-receive transfer switch.

The transfer switch acts like a gate that, in one position, permits transmission and blocks reception; in the other (normal) position, the equipment can only listen for (receive) an echo.

Transducer

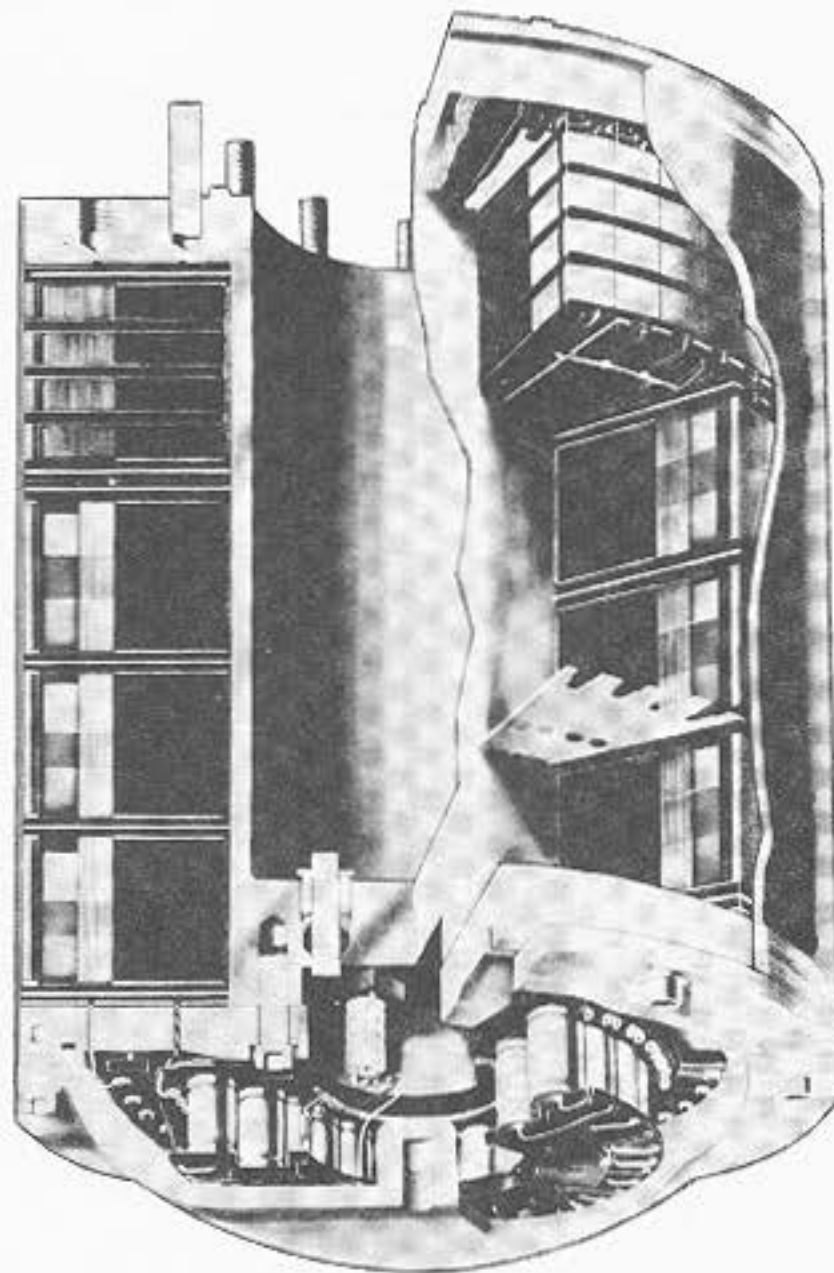
By means of 48 staves (segments of a transducer, similar to electromagnets), the transducer (fig. 13-8) converts the electrically energized signal to mechanical energy and sends it out in the form of a sound pulse. During the silent period between pulses it also acts as the receiver, listening for echoes.

Pulsing may be omnidirectional, meaning that the pulse is sent out in all directions at once, or it may be rotating directional. In rotating directional transmission, several staves are excited simultaneously to produce a sound beam. Several more adjacent staves are excited and produce the next beam. The effect is rather like a series of spotlights mounted in a circle being flashed on and off in turn. The beaming is done so rapidly, however, that the entire 360° arc is covered almost instantaneously. Total energy is applied to the several staves and, thus, is concentrated in each pulse rather than being dispersed in all directions at once. Targets, therefore, can be detected at much greater ranges.

After every pulse, each staff (fig. 13-9) reconverts mechanical energy induced by return echoes to electrical energy and sends a signal to its own amplifier in the preamplifier unit. Because signals from staves that have picked up echoes vary, a reception pattern is determined. This pattern is maintained until presented on the scope.

Some transducers function on the principle of magnetostriction although most now are ceramic type. When certain metals (nickel, in this case) are in a magnetic field, they will change in length slightly, depending on the direction and intensity of the magnetic field. If the magnetic field changes in direction periodically at a given frequency, the metal will change in length in synchronism with that frequency. This is the magnetostrictive effect. This mechanical vibration can be transmitted to the surrounding medium—for example, water. The effect is reversible; that is, vibration picked up from the surrounding medium causes the metal to vibrate similarly, and the resulting change in the magnetic field will induce a voltage in a coil surrounding the metal piece. For transmission of a sound pulse, the coil can be excited by an alternating current of suitable frequency; for reception, the coil can be connected to an amplifier which will amplify voltages induced in it.

Ceramic-type transducers are the most common ones now being built, because of their high



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Figure 13-8.—Scanning magnetostrictive transducer.

sensitivity, high stability, and relatively low cost—plus mechanical properties that allow construction of almost any reasonable shape of size.

Scanning Switches

Scanning switches are the components that give scanning sonar its name. Scanning sonar's goal is to display a full azimuth presentation that, possessing sensitive directivity, provides an accurate target bearing. The means used to achieve the goal are two scanning switch assemblies, an audio and a video.

The two scanning switches have much in common, being roughly comparable to a synchro-mechanism with a rotor revolving within a stator.

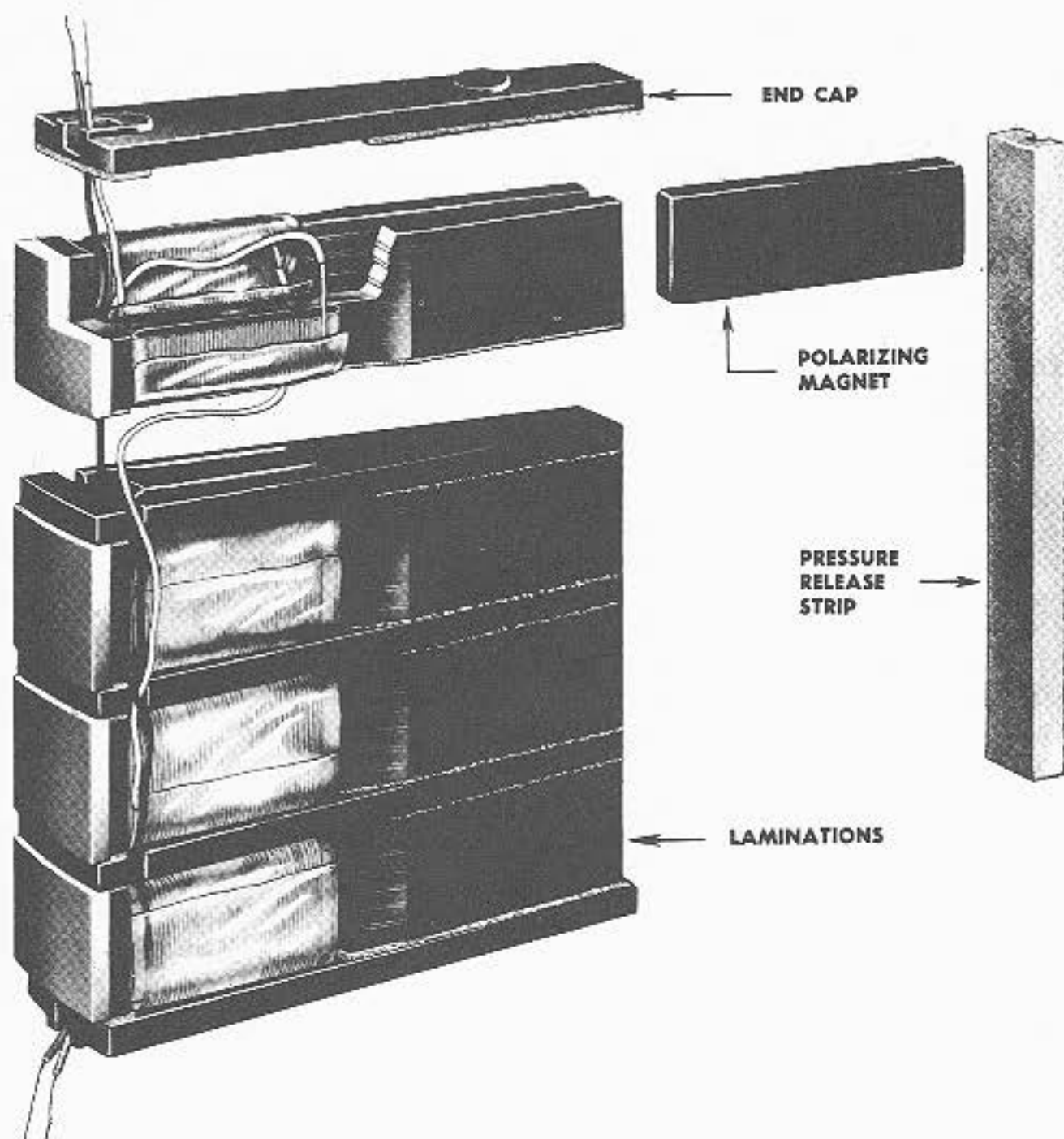


Figure 13-9.— Exploded view of one scanning sonar transducer stave.

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The 48 separate signals enter the stator and generate voltages corresponding to the echo received by each stave and at its exact bearing. When the rotor is matched to any bearing, the signal generated in the corresponding stave passes through the rotor to an amplifier and then either to the audio or video display. Thus, we achieve directional presentation; the scanning switch relays a signal only when trained on the bearing of the returning echo.

AUDIO SCANNING SWITCH ASSEMBLY.—In the audio switch assembly the switch rotor may be trained as desired by the operator. It relays echoes from any 120° arc of the transducer. This

arc (or audio channel) is centered on the bearing selected by the operator's manual control. Signals originating within the bounds of the audio channel are relayed to an audiofrequency/radiofrequency (AF/RF) amplifier.

The AF/RF amplifier increases the strength of the signal so that it yields an audible echo when changed from electric to acoustic energy.

VIDEO SCANNING SWITCH ASSEMBLY.—The video scanning switch rotor is not selective in train, but revolves rapidly at a constant speed (often as much as 3600 rpm). When matched to the bearing of the echo, the video scanning switch relays the electrical current induced in

the staves to an RF amplifier. The video rotor, having a much narrower response arc than the audio rotor, accepts signals received by only one stave at any given instant. It actually scans more than one stave at a time, but lag-line phasing admits the signal from only one stave at any time.

The RF amplifier amplifies the signal so that it can affect electronic printing on the face of the CRT.

Because the scanning switch and the electronic sweep generator are driven by a common constant-speed motor, their rotation is synchronized. Thus, the indications presented on the CRT are realistic representations of returning echoes. Echo pips are printed at the proper bearing because both the sweep and the rotor are matched at the same bearing when the echo is allowed to enter the system. Echo pips are printed at the proper range because the electronic sweep is moved outward from the center of the scope at a rate proportional to the speed of sound in the surrounding water.

The resultant of the actions of the scanning switch and the sweep generator is the presentation on the face of the cathode ray tube. The sweep originates in the center, indicating initially the reverberations at the transducer face. It then continuously expands in a spiral manner until it reaches the outer edge of the CRT (or the end of the range cursor, if some intermediate range setting is used).

Signal Data Converter

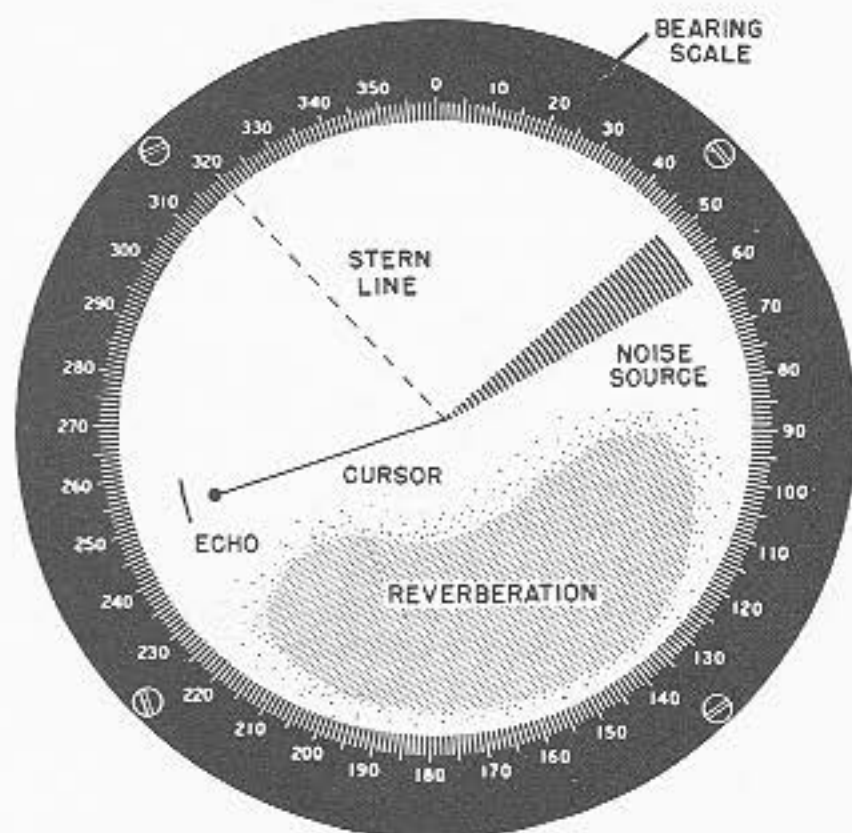
The signal data converter affects the last stage of the reception cycle preceding the actual display of target information. It receives own ship course from the gyro compass, converts this information to usable form, and transmits it to the console where it orients the sweep display on the CRT.

Video Presentation

As stated previously, the video presentation on the CRT may be either ship center display (SCD) or target center display (TCD).

SCD MODE.—Figure 13-10 shows the main features of a typical SCD sonar CRT display. This is a highly conventionalized diagram, and it is not intended to show features realistically.

In the SCD mode, a line (cursor) originating at the center of the CRT and parallel to the



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Figure 13-10.—Typical SCD sonar CRT display.

bearing of the audio scanner, is the first presentation. With this the operator can read on a dial around the CRT's face the bearing of echoes he hears.

Immediately following the printing of the cursor on the CRT, the pulse is transmitted. The electron beam appears and begins the expanding sweep at a rate proportional to the time it takes the transmitted pulse to travel. This expanding sweep is spiral. The electron beam prints as it revolves in synchronization with the rotating video transducer scanner. The angular position of the beam corresponds with the instantaneous position of the video transducer scanner. Presence of an echo produces a bright spot on the face of the CRT, at a point corresponding to the range and bearing of the object reflecting the pulse.

As the pulse is transmitted, a broken line, originating at the pulse presentation, and bearing 180° from own ship's heading, is displayed. This is known as the stern line, and it assists the operator in determining areas for searching.

Since the equipment is alert in all directions because of the rapid scanning feature, a true geographic plot is produced of the area surrounding the ship. Noise sources other than echoes from the transmitted pulse are received also, and are presented as bright spokes or wedges on the CRT at their correct bearing. The operator

can determine range and bearing to a contact by training the cursor to the center of the spot and adjusting its length. The bearing may be read directly from a dial. Cursor length may be varied by a control on the control indicator. Cursor length is proportional to the range and, when the end of the cursor is superimposed on the target echo, range may be read from a dial on the control indicator.

When searching for a target, the sonar system is set so that the two video signals (left and right) from the scanner are added or summed. This provides a broad, easily seen pip for an echo. When the target pip has been identified and the sonar system is set to track it, the system is switched for difference operation. The left- and right-scanner outputs are then subtracted, and the target pip becomes small and sharp so that it can be tracked most effectively.

The video presentation is normally oriented and stabilized. The top of the CRT represents north. Own ship course is received from the ship's gyrocompass. Bearings to echoes are true. Without gyro input, the presentation is in relative bearing, with ship's head at the top of the CRT at 000°. Changes in own ship course will, when the presentation is in relative bearing, cause the entire CRT picture to rotate. When the presentation is in true bearing, the electron beam in the CRT is electrically rotated to keep the pattern it prints oriented.

The video presentation is also compensated to eliminate the effect of own ship roll and pitch, and keep the CRT picture stabilized. Reverberation or minor sound reflections from such sources as surface waves, small fish and other sea life, etc., shows up as small spots or light patterns. Noise sources, as distinguished from echoes (either random or from specific targets), show up on the CRT as radial spokes or wedges rather than pips. Sonars are responsive to a wide range of frequencies; unlike radar, a sonar is not tuned to receive a specific frequency. It therefore picks up all kinds of noise sources. This is called hydrophone effect, and it occurs during active mode operation, as well as in passive or listening mode. Since the CRT indications of noise sources do not arise from timed echoes of the transmitted pulse, there is no blip that shows range to the noise source. The spoke shows only bearing. The spoke can be made broad or sharp by sum or difference reception.

TCD MODE.—In the target center display the contact, instead of own ship, is displayed in the center of the CRT. The expanding spiral sweep presentation is used, but the origin of the sweep (own ship position) is moved to a position off the face of the CRT, and the contact is positioned at the center of the scope.

Only a circular portion of the entire sweep is displayed on the CRT when the contact is in the center, unless range to the contact is within the display limitations of the scope. In that case, both own ship and contact would be presented. When the contact is in the center of the scope, dials on the control indicator show the range and bearing to the contact from own ship.

The stern line remains with the transmitted pulse for both types of display. It is visible when the equipment is in target center display only when own ship's transmitted pulse comes into display range on the CRT. Most display conditions remain the same for both types of display.

Audio Presentation

As stated earlier in this chapter, the returning echo, after conversion to an electrical signal and amplification, is changed to an audible frequency and sent to a headset or loudspeaker near the control indicator, where it is heard as a "ping." This ping is of value in target identification and in the determination of doppler.

The outgoing (transmitted) pulse from the sonar is, so far as possible, suppressed so that it does not show on the CRT or become audible on the sonar's sound reproducers. To determine whether the pitch or frequency of the echo has been changed by the doppler effect, the sonar operator compares the echo aurally not with the original pulse but with the reverberation return, since the average reverberation source is moving at zero speed. (The sonar circuitry electronically compensates for doppler effect in reverberation caused by own ship speed; therefore, doppler depends upon only relative target motion toward or away from own ship.) Since acuity of pitch discrimination varies with frequency, a frequency is selected in the region where human ears are most sensitive to pitch changes—around 800 cycles per second (equivalent to a note in the upper range of the piano keyboard).

Up doppler is the increase in frequency of returning sound waves caused by a target's motion toward own ship. Down doppler is the

decrease in frequency of returning sound waves caused by a target's motion away from own ship. A target which causes up doppler is said to have bow aspect, while a target causing down doppler has a stern aspect. A beam-aspect target has no doppler.

SPECIFIC SONAR SETS

Several different modifications of sonar sets are in use in the fleet today. Two of the latest are the AN/SQS-23 and the AN/SQS-26.

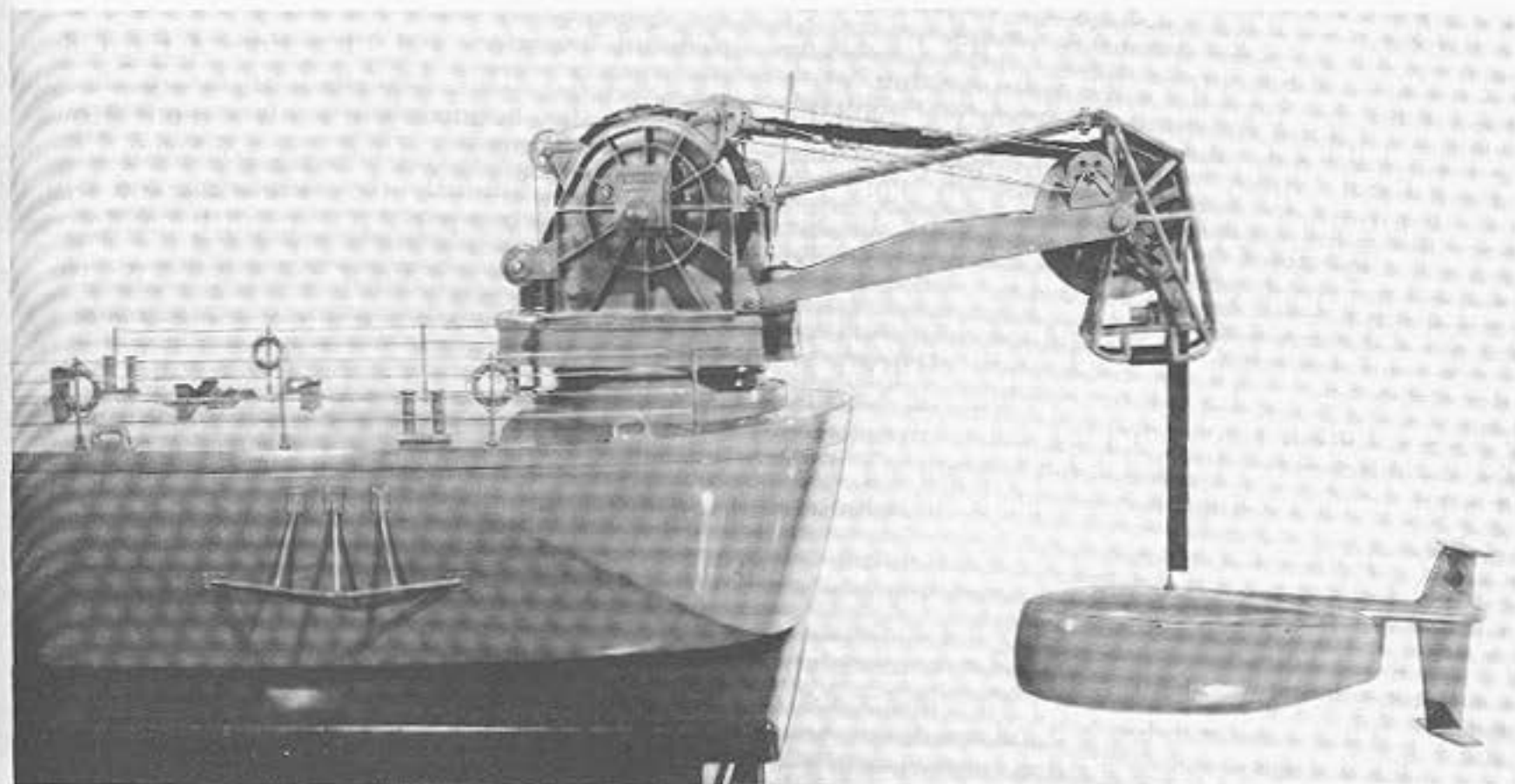
The AN/SQS-23 sonar provides accurate range and bearing information for the fire control system, with ranges greater than those obtained in older systems. The low transmission frequency of the equipment, combined with the rotating, directional transmission and the ability of the transducer to operate at a tremendous power output level, produces a high source level for long range target detection.

The AN/SQS-26 sonar is a long-range, advanced search sonar that represents a radically improved approach in concept and application to present day problems of submarine detection. It is designed to detect all submarines, regardless of their depth and speed and the water conditions.

VARIABLE DEPTH SONAR (VDS)

Without going into the technicalities of the phenomenon, oceanographic conditions frequently are such that there are layers of water with widely varying temperatures. Where these layers meet (layer depth), much of a transmitted sound beam is either reflected or sharply bent (refracted). Submarines operating beneath the layer depth may escape detection because the sound does not reach them or because the returning echo is greatly weakened or mushy. The VDS overcomes this disadvantage because it can be lowered beneath the layer depth, thus improving detection capabilities previously limited by the fixed, hull-mounted sonar.

Older VDS sets consists of a towed transducer operating in conjunction with a shipboard-installed, hull-mounted sonar set. The union is accomplished by providing a transducer within a hydrodynamic towed vehicle, plus a crane-type hoist for lowering, towing, and raising the vehicle (fig. 13-11). The towed transducer is connected electrically to the ship through a cable extending through the center of the tow cable. A switching mechanism in the sonar set permits use of either the hull-mounted transducer or the towed-transducer, or both simultaneously.



51.63

Figure 13-11.—VDS suspended with boom facing aft.

A later type of VDS (not shown) is a sonar set complete within itself. Because it can be made to operate independently of other sonar systems, it is known as the independent variable depth sonar (IVDS).

AIRBORNE SUBMARINE-DETECTING SYSTEMS

Aircraft are used for detecting submerged submarines by means of—

1. Sonar,
2. Sonobuoys, and
3. MAD gear.

Sonar

Sonar equipment (called "dipping sonar") can be used by rotary-wing aircraft (helicopters) to detect submerged submarines. Because it isn't practical to drag sonar equipment through the water at the minimum flying speeds of fixed-wing aircraft, only aircraft that can hover or move at low speeds are suited for sonar detection.

Because of the limited weight-carrying and power-producing characteristics of aircraft, high-powered azimuth type sonar is not carried by aircraft. The equipment is of the "search-light" type which pings on one bearing at a time, must be trained to the required bearing to detect a target, and presents only an audible echo without video presentation. In spite of these limitations, airborne sonar gear is capable of excellent results because it can be transported from one location to another at a much higher speed than that of any surface vessel, and because, although such aircraft as helicopters are noisy, they produce no water-conducted noise. (Most dipping sonar presently used in helicopters is capable of scanning 360° and also of narrowing the search to a selected bearing.)

In a helicopter, the dip or dunking sonar equipment, all except for a ball-shaped transducer housing and the 500-foot cable from which it is suspended, is located in the helicopter fuselage. When the helicopter has reached a location where the presence of a submarine is suspected, it descends to 10 to 20 feet above the water, and the sonar ball is lowered to about 400 feet below the surface. After searching, the

helicopter hauls in the cable. After the cable has been retracted, the helicopter can go to another location. When the submarine is detected and located, the helicopter can "vector in" other aircraft and ASW vessels for the attack, or can itself attack if properly armed.

The search procedure can be completed in a few minutes (especially if the search doesn't encompass the full 360° in azimuth) and the helicopter can be up and away. Present types of submarines have no effective countermeasures against helicopters. This search technique is much more difficult in heavy weather, although improvements in this respect are being made continually. Figure 13-12 shows a helicopter with sonar submerged, searching.

Radio Sonobuoys

Radio sonobuoys are small expendable floating hydrophone or sonar units whose output is radio-broadcast by a small transmitter in the sonobuoy. They are generally dropped to the sea surface by fixed-wing aircraft in the area where enemy submarines are expected to be. Usually more than one is dropped at a time, in a circular pattern around the contact area (as determined by other detection data). An experienced operator, by comparing its pitch (for doppler) as received by each sonobuoy, can estimate the present location and direction of movement of the target. After two to four hours, a soluble plug in the sonobuoy dissolves and allows the unit to sink. While afloat, the sonobuoy indicates its position visually (by releasing red dye into the water or by keeping a lamp lit) and by radar.

Figure 13-13 shows diagrammatically how one type of sonobuoy pattern is initiated by an aircraft in response to surface indication of the presence of a submerged submarine (in this case the oil slick from a submarine that has been damaged). The buoys are planted where they will continue to pick up the submarine's sound as it proceeds underwater. A frequent pattern is a circle of buoys about the area (called the datum) in which the submarine contact is expected.

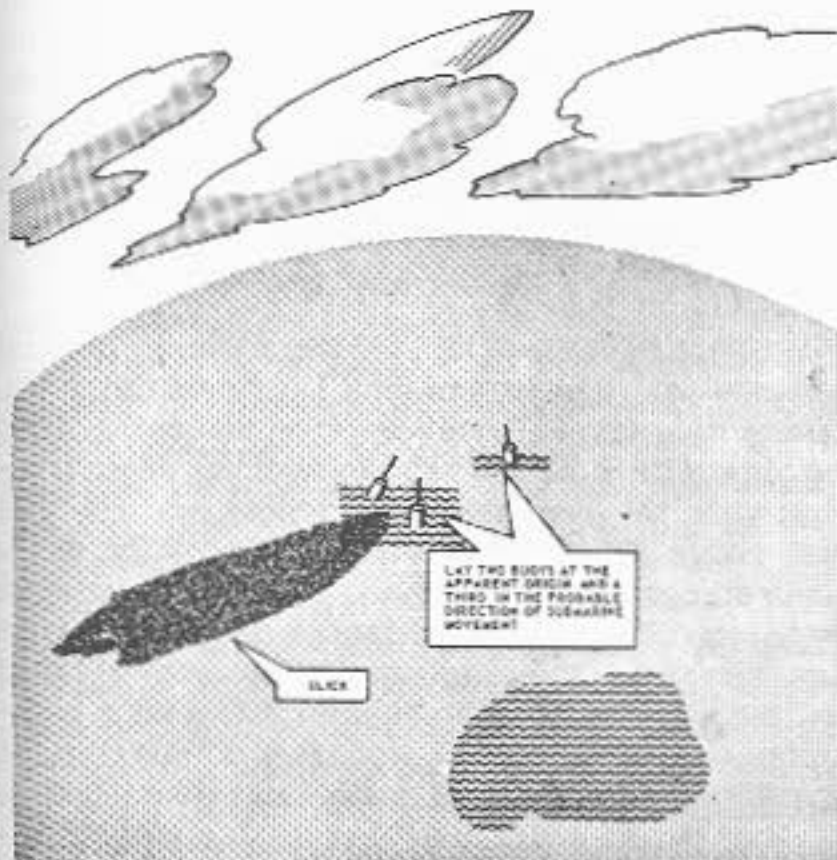
Magnetic Anomaly Detection (MAD) Gear

Any mass of steel as large as a ship's or a submarine's hull will significantly warp or distort the earth's magnetic field in the vicinity.



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Figure 13-12.—Dip sonar in use by helicopter.



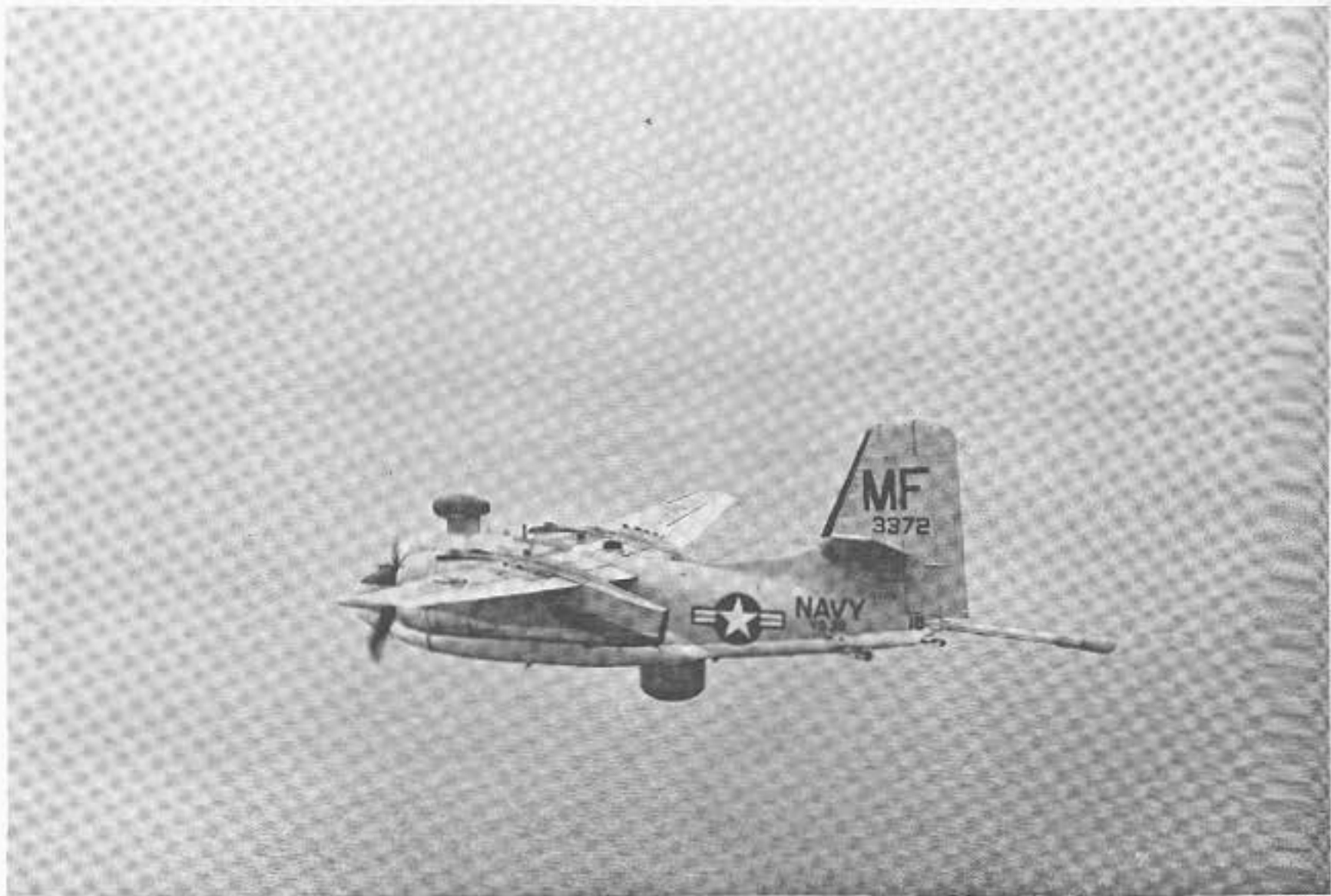
110.106

Figure 13-13.—Radio sonobuoys used to locate submerged submarines.

In influence-type exploder devices in mines and torpedoes, this effect is used to detonate the device when it is quite close to the target. The same principle is used for locating a submarine at a greater distance than this, but the magnetic detecting device must be more sensitive and must be moved at a relatively high speed with respect to the target. For this purpose, MAD equipment is used on fixed-wing aircraft flying at relatively low altitudes (fig. 13-14).

SUBMARINE COUNTERMEASURES

Submarines can and do take specific countermeasures against surface ship and aircraft detection and attack. Some of these countermeasures are similar to those taken by surface ships; these won't be repeated here. Others are designed to make the submarine harder to detect on sonar or hydrophones. Still others are intended to deceive or confuse the attackers. In either case, the result (if successful) is to make the attacker lose contact with his target.



110.107

Figure 13-14.—ASW fixed-wing aircraft fitted with MAD gear.

In practice, the effectiveness of the counter-measure in deceiving the attacker, and the ability of the attacker to penetrate the deceptions and maintain contact, depend principally on the tactical ingenuity of each side. Earlier in this chapter you noted the principal advantages and disadvantages of the submarine as compared with the surface attacker. In ASW, each combatant makes the most of his advantages (including psychological ones) and does his best to overcome the other's stratagems. The variations and combinations possible are endless. ASW has been called a "cat-and-mouse" game. This is not entirely accurate, since the "mouse" is as dangerously armed as his opponent, but in two respects the comparison is apt—one successful blow is likely to decide the issue, and, in contrast to open combat between air and surface opponents, patience and watchfulness over a prolonged period are likely to be the decisive factors.

The list below includes the principal types of countermeasures that submarines can now use.

SUBMERGING. This is the primary natural defense of the submarine against detection. There are several degrees of submerging, from running with deck awash, to snorkel depth (running with the snorkel, periscopes, and antennas just above the water surface, but with the entire superstructure submerged), to periscope depth (with only the attack periscope protruding from the surface), the shallow submergence (about 60 to 100 feet), to deep submergence (at a maximum or "test depth" for the submarine). A snorkeling conventional submarine can continue to run on Diesels and charge its battery. Although it presents a reduced target to visual and radar search, its propulsion machinery is at its noisiest. At any speed exceeding a couple of knots the protruding parts develop a wake

that grows proportionally more noticeable with speed, particularly if the water is smooth. And in very cold weather the Diesel exhaust through the snorkel forms a plume of white vapor. When the submarine is slightly deeper, at periscope depth, the periscope by itself is much harder to spot than the snorkel and associated gear, but it and its wake are still detectable, even if marginally, to radar and eye. At shallow depths (down to 100 feet or so) a speeding submarine does cause noticeable turbulence on the surface if the sea is relatively calm, and its hull can sometimes be spotted visually by aircraft. When the submarine is deeply submerged, its presence is rarely betrayed by any evidence on the surface. Where the sea bottom is not deep, a submarine can rest on the bottom next to a wreck, reef, or turbulent area to present virtually no target to echo-ranging sonar.

SILENT RUNNING. To avoid detection by hydrophone, submarines must reduce noise radiation as much as possible. Chief sources of noise are echo-ranging sonar, operation of propulsion machinery (particularly Diesel engines), operation of other machinery such as ventilating gear and pumps, cavitation produced by rotation of screws above certain critical speeds, and screw noises from other causes (such as deformed blades). A submarine commander can order any of several degrees of silent running, ranging from reduction of running speed and shutdown of echo-ranging sonar to complete stoppage of all machinery and even prohibition of the crew's talking above a whisper. Silent running conditions are ordered, of course, only when the submarine is submerged. A submarine snorkeling or running on the surface under Diesel power is at least as noisy as any similarly powered surface vessel. Electric drive at the same speed is much less noisy. Nuclear submarines, as previously mentioned, are as noisy or noisier than conventional submarines; however, they are capable of running at much greater depths.

A submarine running silent can still attack by releasing a "swim-out" homing torpedo against a surface attacker. Firing a conventional torpedo is a noisy procedure that requires forcing a large air bubble out of the torpedo tube along with the torpedo. A "swim-out" homing torpedo propels itself out of its tube, runs upward to set depth and begins to search for its target (while the submarine dives), and homes on the surface ship's screw noises.

USE OF THERMOCLINES. A previous section has explained how the path of sound waves in sea water is distorted by differences in water density. Submarines are fitted with recording bathythermograph units which function whenever the ship dives, so that the presence of thermoclines (interface between warmer and colder water layers) is continuously indicated. The submarine can dive under a thermocline and in most cases cause the attacking vessel to lose contact entirely. The new VDS sets, discussed earlier, make it more difficult for the submarine to use a thermocline as a countermeasure.

HIDING BENEATH SURFACE VESSELS. Because a sonar is relatively "deaf" in the area directly below it, a submarine can find concealment directly below its attacker. Or a submarine can hide directly below some other ship, using the surface vessel's screw noises and turbulent wake to mask its own sonar echo. In this position the submarine can use swim-out, homing torpedoes, as described earlier.

FALSE TARGETS. A mass of air bubbles is detected by sonar as a target. Submarines can eject air through their torpedo tubes to create a false target for the benefit of surface sonar. The target doesn't last long, and it betrays its nature to a sharp sonarman because it has no doppler, but it can distract the attacker long enough to cause loss of contact. A German-originated device specifically designed to eject bubbles for this purpose was called the "Pillenwerfer," which is sometimes used to refer to similar devices on our own submarines.

Another type of false target is the beacon. This is a small battery-powered screw-propelled torpedolike device that can swim out of a torpedo tube and continue until its battery runs down. It emits a continuous or intermittent noise simulating a submarine's screw, sonar pings, or other sounds. A number of different sounds can be produced. After ejecting this device, the submarine usually heads downward and in the opposite direction, while the beacon moves at 1 or 2 knots in the direction in which it was projected. A beacon not only distracts passive sonar search, but also can attract ASW homing torpedoes intended for the submarine.

Submarines can also eject quantities of oil and debris to simulate their own destruction, and thus motivate surface attackers to call off the attack.

ASW WEAPONS

Older types of ASW weapons include, in addition to older versions of homing torpedoes, older depth charges and hedgehogs. Because these are obsolescent, they are mentioned only briefly.

A depth charge essentially is merely a container filled with about 200 pounds of high explosive, and designed to explode at a predetermined depth. It is extremely difficult to obtain a direct hit with a depth charge; and, to be fatal, the explosion must occur within about 20 feet of the target.

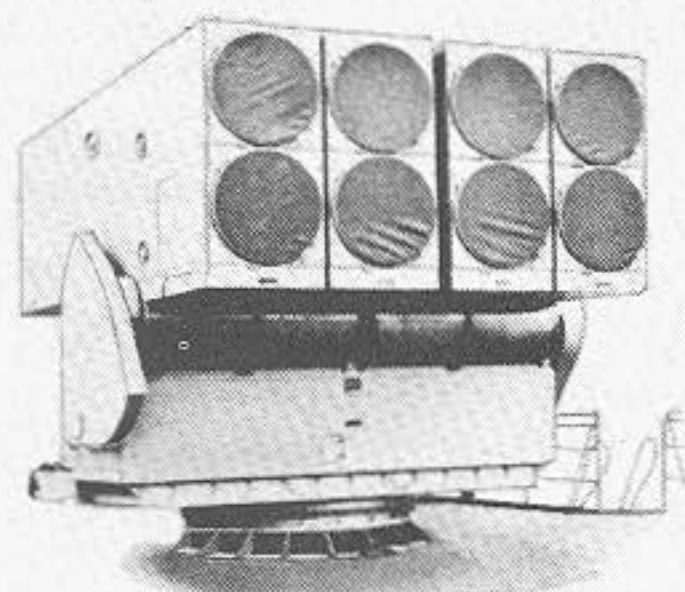
An improvement over the depth charge is a 7.2 inch diameter mortar-type projectile called the hedgehog. Hedgehogs are mounted in groups of 24 and are fired in pairs; a salvo results in a circular pattern over the apparent position of the submerged target. This weapon has no depth setting and explodes only on contact. Because the charges have a fixed range, the pattern can be launched successfully only when the ship reaches correct firing range.

The Navy's primary operational ASW weapons today are (1) antisubmarine rockets (Asroc), (2) submarine rockets (Subroc), (3) antisubmarine torpedoes (Astor), and (4) conventional torpedoes.

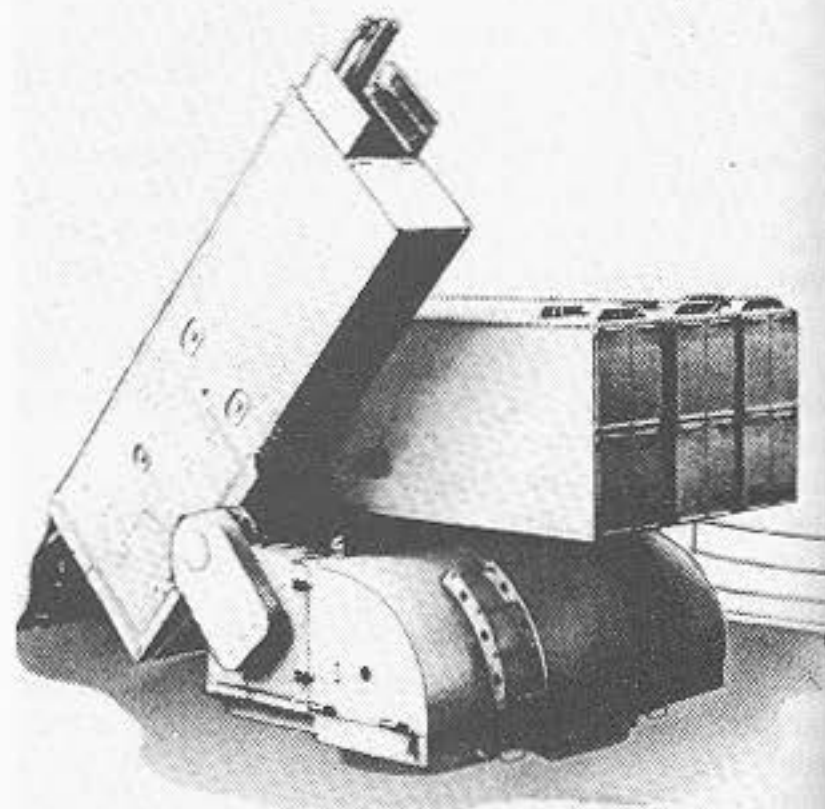
ASROC

The Asroc (whose launcher is shown in figure 13-15) is a supersonic, shipboard-launched, solid-fuel, rocket-propelled antisubmarine ballistic projectile. The missile has two configurations—one with a depth charge and one with a torpedo.

The goal achieved by Asroc is the destruction of submarines at long ranges. This objective is achieved by delivery of a torpedo or atomic depth charge through the air to a point in the water from which it can either attack under the most favorable circumstances or have the submarine within its lethal radius (fig. 13-16). The payload is a part of an unguided missile which is propelled by a rocket motor and stabilized by an airframe throughout its powered flight. Separation timers jettison the airframe and motor after a preset time. From separation to water entry, different methods of stabilization are employed, depending on the payload. The depth charge descent is stabilized by a fin network during the entire drop. The torpedo also has such a network, but it employs, in addition, parachute stabilization. Besides stabilizing the torpedo descent, the parachute also decelerates it to a safe water entry velocity



LEFT REAR



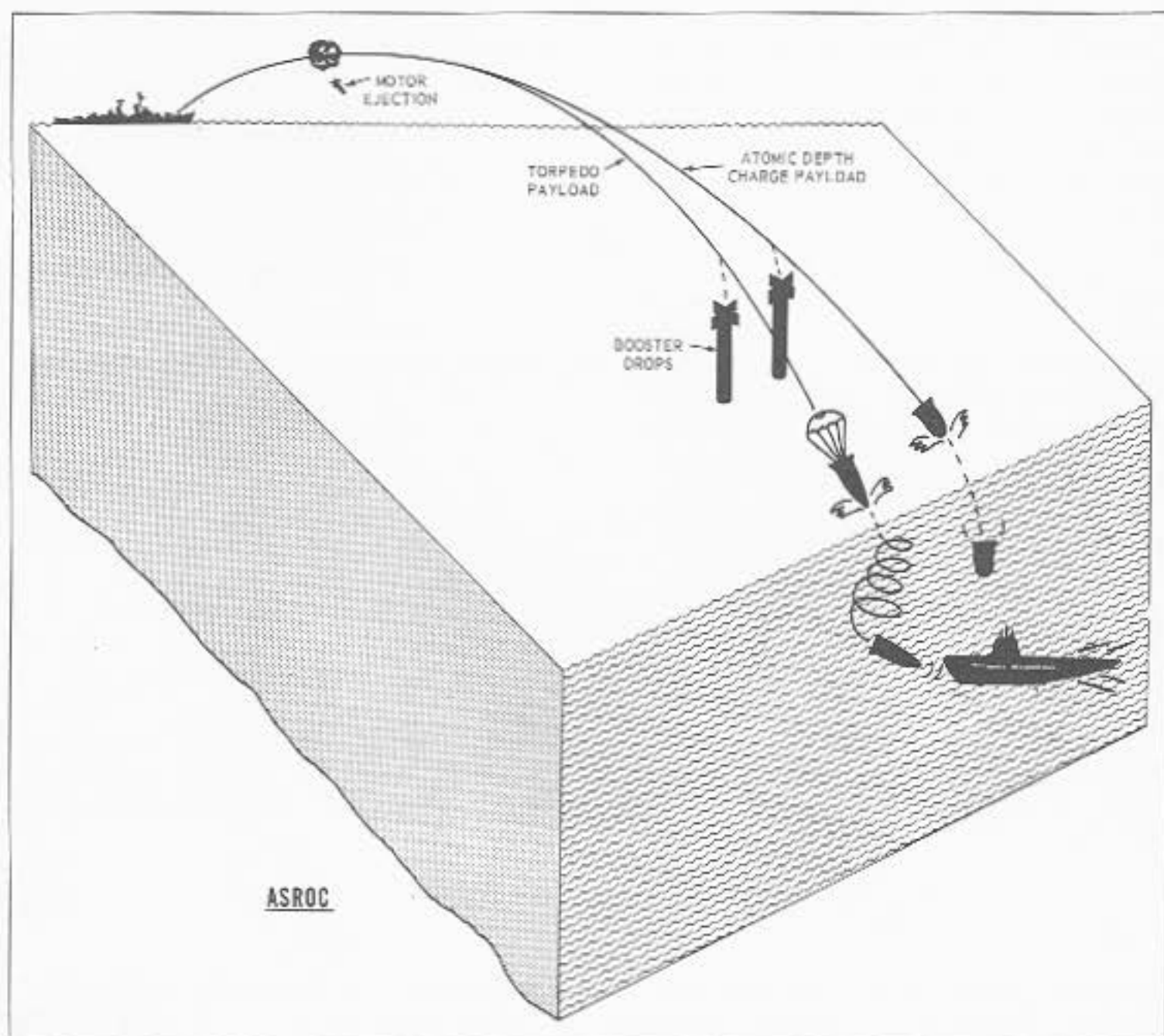
RIGHT FRONT

15.106

Figure 13-15.—Asroc launcher.

to avoid damaging the highly sensitive electronic components.

Before the missile is launched, the submarine is located by sonar, and the range, bearing, and other pertinent data are transmitted to the fire control system. The fire control system automatically computes the anticipated target position, sets a time-to-separate into the timers on the airframe, and keeps the launcher trained



15.114

Figure 13-16.—Asroc.

on the desired water entry point, so that the missile can be fired at will by simply closing the firing circuit.

SUBROC

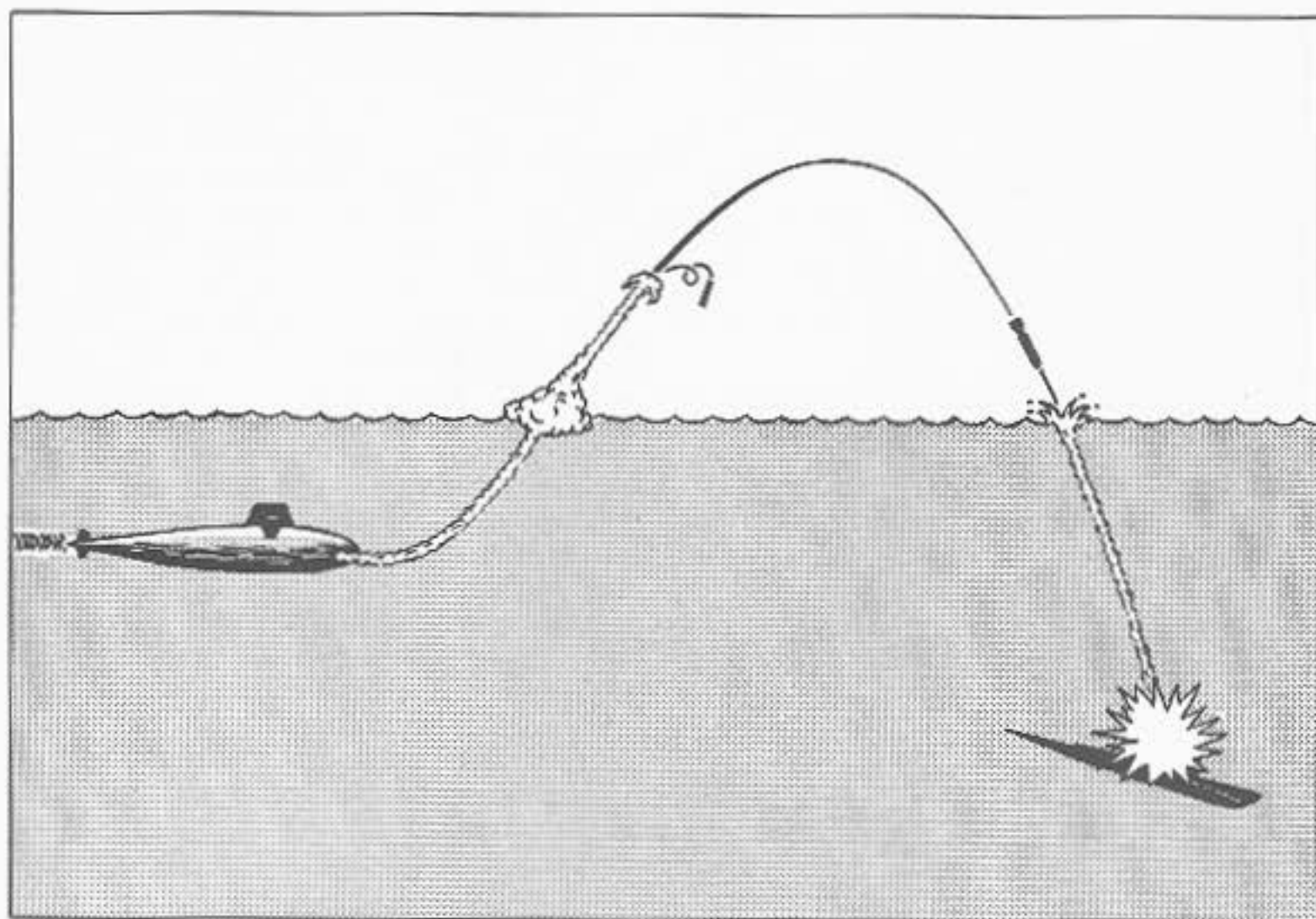
The Subroc (the acronym for submarine-launched rocket) is an antisubmarine weapon with a nuclear warhead. It is launched from a submarine torpedo tube by conventional methods. As shown in figure 13-17, after clearing the submarine, a rocket motor ignites and propels the weapon upward and out of the water. An inertial guidance system then directs Subroc toward its target. At a predetermined range, the motor and depth bomb separate, the latter

continuing toward the target area. Upon reentry into the water, the bomb sinks to a preset depth and the warhead explodes.

Although Subroc is designed primarily as an antisubmarine projectile, the target may be either a submarine or surface ship. The Subroc system can fire missiles in rapid succession, an important defense against enemy wolfpack tactics. In essence, Subroc may be considered a submarine-launched Asroc.

ASTOR

The antisubmarine torpedo (Astor) is an underwater-to-underwater or surface, wire-guided, electrically powered, high-speed torpedo



42.227

Figure 13-17.—Artist's view of the trajectory of Subroc.

deployed aboard hunter-killer submarines. It can carry a conventional or nuclear warhead and can be used against surface or underwater craft.

REPRESENTATIVE UNDERWATER FIRE CONTROL SYSTEM

Because many operational aspects of specific fire control systems are classified, this section describes in general terms the functions of what may be considered a representative underwater fire control system. The discussion following does not apply specifically to all fire control systems on all ships; the aim is to describe the main elements of most systems in order that the reader will understand their functions and how they work together.

A representative fire control system (FCS) solves the attack problem, generates launching orders, prepares a weapon for firing, develops designation data for tracking a projectile by radar,

and provides a means for command to control missile fire. A fire control group consists of (1) an attack console or director, (2) a stabilization computer, (3) a position indicator, and (4) one or more relay transmitters.

ATTACK CONSOLE

The attack console is a computer in the data processing center of the FCS. In addition to receiving target data from sonar, it may be able to act on target bearing and range from missile or gun FC radars.

The console receives information such as (1) own-ship course and speed, and (2) target range, relative bearing, depth, course, and speed. There may be other inputs, depending upon the type of weapon to be launched; most inputs are generated electronically, while others may be inserted manually. The console displays the attack problem on the console geographic plotter section, combining target data with ballistic

and own ship motion to provide (depending on the weapon to be employed) —

1. Generated data for sonar tracking and position keeping.
2. Launcher train and elevation orders.
3. Missile or torpedo set-in orders.
4. Range and bearing for torpedo attacks.
5. Director designation for in-flight tracking.

From received target motion quantities the console computes aided sonar bearing and range tracking information and sends it to sonar. If sonar loses contact, the operator places the console in the position-keeping mode, and attack problem computations continue from the last observed target range, bearing, course, and speed values already entered into the computer.

Depending on what the inputs to the computer are and the weapon(s) to be controlled, the console solves the attack problem and transmits to the weapon the firing signal and the stabilized weapon train angle. It also transmits to the bridge the course to steer for the attack. (More precisely, it puts out corrections to own-ship course.)

STABILIZATION COMPUTER

The stabilization computer receives roll and pitch data from the ship's gyrocompass, target bearing from sonar, and apparent depression angle from the attack console. From these quantities the computer generates stabilized sonar train and depression orders and transmits them to sonar. Input and output stabilization data are displayed on dial indicators on the front panel of the computer.

POSITION INDICATOR

A position indicator on the bridge provides command with an indication of the source of contact (sonar or radar); a continuous display of own ship, target, and weapon tactical information; an indication of firing readiness; and for some weapons a control by which the commanding officer approves the payload selection. For the last, unless command activates the "approved" control, the attack console cannot generate a firing command.

RELAY TRANSMITTERS

In general, relay transmitters receive input data at a particular frequency, then convert it to a different frequency (operating voltage) for transmission to other equipments. There are many types of relay transmitters depending on the purpose for which utilized. This brief discussion, of course, is concerned only with FCS relay transmitters.

One type of relay transmitter tests, programs, and monitors the ignition and separation assembly data of a selected missile. After the missile is selected, the transmitter tests the power supply, thrust cutoff velocity time channel, and airframe separation time channel to ensure missile readiness for firing. If missile check results are unsatisfactory, another missile must be selected.

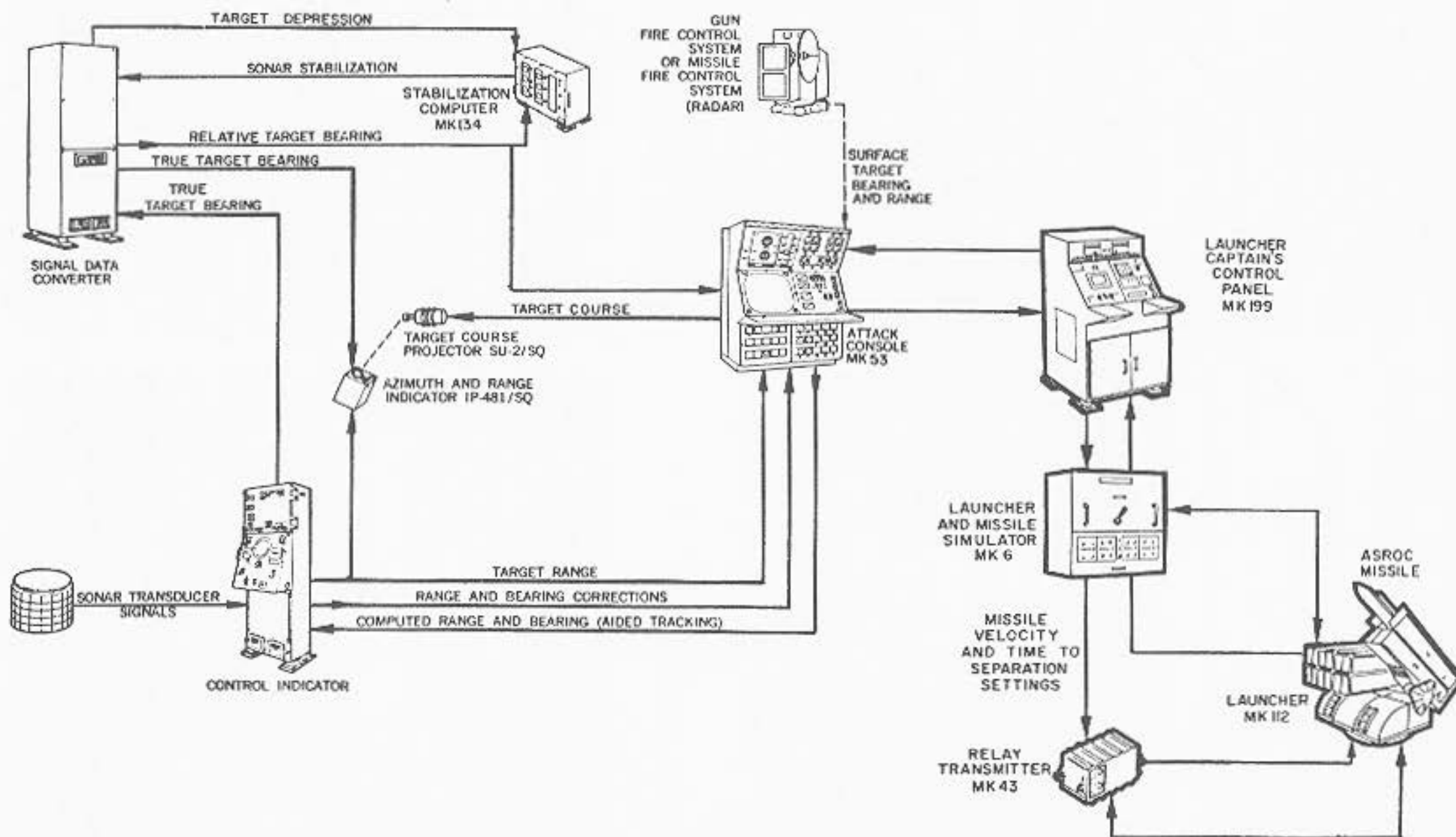
A second type makes the attack console compatible with gun or missile FCSs and weapon direction equipment. This transmitter is used during (1) missile or target tracking and (2) missile designation. For the former, the transmitter converts single-speed synchro target or missile bearing data into two-speed synchro signals for transmission to the attack console. When the transmitter is utilized for missile designation, water entry point quantities and airframe separation time are received by synchro transmissions from the attack console. Designated missile elevation is set in manually.

FIRE CONTROL SYSTEM MK 114

The Mk 114 fire control system (FCS) is used, primarily, to control weapons launched against underwater targets although it can be used to control weapons launched against surface or air targets. A representative Mk 114 FCS is shown in figure 13-18. As illustrated, the system receives inputs from sonar and gun fire control or missile fire control radar for computing target information. (Keep in mind that this is only a representative Mk 114 FCS; other modifications of the system may or may not have the same components as this one.)

The following components make up the Mk 114 FCS:

1. Attack Console Mk 53.
2. Stabilization Computer Mk 134.
3. Position Indicator Mk 78.
4. Relay Transmitters Mk 43, Mk 44, and/or Mk 45.



15.184:.85

Figure 13-18.— Data flow between sonar and fire control and between fire control and Asroc.

All units function the same as those described in the preceding section.

FUNCTIONS OF THE UFCS IN AN ASW ATTACK

The ASW attack is one that takes a maximum amount of cooperation between different stations. The attack team includes underwater battery plot, the sonar control room, the conning station, CIC, and the weapon mounts. They are connected by the sound-powered battle telephones.

When a contact is made, it is plotted and evaluated by CIC, which informs the captain on the bridge of the range, depth bearing, and speed of the contact. The captain decides whether to attack and which weapon to use. The sonar operator keeps the sonar on the contact at all times. The attack director operator sets up the director and sets the various inputs for the particular weapon designated. CIC maintains a track of the contact and supplies the director operator with the initial target course and speed.

The attack director operator and sonar operator work closely together until they achieve a solution and so inform the conn and CIC. Conn steers the ship along the course as directed by the attack director and gives the order to fire.

Trainable weapon mounts are automatically driven in train and will follow the solution of the attack director. CIC maintains a plot of sub movement. (CIC can be of invaluable help to underwater battery plot by keeping them informed of the direction of maneuver of the submarine.)

There are two types of ASW attacks—urgent and deliberate—and the use of one or the other depends on the tactical situation. An urgent attack is a harassing attack on a submarine and is delivered in the minimum possible time. An urgent attack is made on a submarine which is in position to menace any ship in the body of a force or formation. The urgent attack normally consists of an attack that is destructive in nature and employs all weapons that will bear. Accuracy is usually sacrificed for speed.

Preparation for a deliberate attack begins even while the urgent attack is in progress. A deliberate attack is delivered when the tactical situation allows time to obtain accurate weapon data. The most effective antisubmarine weapon required by the tactical situation is used.

The deliberate attack is, therefore, a concentrated attack to kill. Any consideration other than the destruction of the submarine is ignored.

ANTISUBMARINE UNITS, FORMATIONS, AND OPERATIONS

Antisubmarine forces include surface craft, aircraft, submarines, and shore installations. In this section we shall study the ASW capabilities of such units—particularly surface craft—and then briefly investigate how they are used in formations designed for ASW. This discussion is intended only as an introduction, not as a substitute for NWP and related publications, which are the primary sources of tactical doctrine.

SURFACE CRAFT

Since the advent of modern submarines, the surface ship has been the primary vehicle of antisubmarine warfare. It is now meeting strong challenges from improved submarines and the most advanced ASW helicopters.

A primary advantage of the surface ship is its available manpower. It has more men on board than any other type of antisubmarine craft. This not only allows more efficient operation, but also enables the ship to perform other tasks and functions at the same time that it is engaged in ASW operations. The great versatility of the surface ship also gives it a marked advantage over aircraft and submarines. Additionally, the surface ship has a greater variety of detection equipment: active and passive sonar, radar, ECM, sonobuoys (occasionally), and visual.

Some other advantages and characteristics of the surface ship are (1) a great variety of weapons, (2) the ability to conduct all-weather operation, and (3) a highly accurate and stabilized fire control system. (The accuracy of surface ship fire control equipment is equal to or greater than any other antisubmarine craft.)

These characteristics best adapt destroyer-type vessels (DDs, DDGs, DEs, and frigates) to the following ASW functions:

1. To search for submarines (either on patrol, in hunter-killer operations, or while escorting), to establish their location, and to engage in direct attack upon them.

2. To coordinate ASW attacks with other surface vessels and with aircraft (rotary-wing, or fixed-wing).

The five broad types of ASW operations in which the destroyer-type vessel may engage are:

1. ASW strike operations.
2. Hunter-killer operations.
3. Patrol of assigned areas while continuously searching for submarines.
4. Escort of merchant vessels or other naval vessels not adapted to ASW search and direct attack.
5. Mining.

Larger ships like aircraft carriers and cruisers are not designed to mount ASW weapons. Some of the converted missile cruisers, however, now have Asroc.

The appearance of new equipment and weapons and the modification of their older counterparts have resulted in the demand for more modern versions of ASW units. These may be brand new units or highly modified ships or submarines of our ASW forces. Some examples of ASW units follow.

Many ships of the DD type have undergone improvements through the fleet rehabilitation

and modernization (FRAM) program. (Figure 13-19 shows a Forrest Sherman class DD which has gone through the FRAM program.) Included in the program is the latest in ASW equipment such as a variable depth sonar (VDS) and Asroc.

Newer destroyer-type ships such as DEGs, DDGs (fig. 13-20), and DLGs (fig. 13-21) also have the latest in ASW armament.

THE AIRCRAFT CARRIER IN ASW

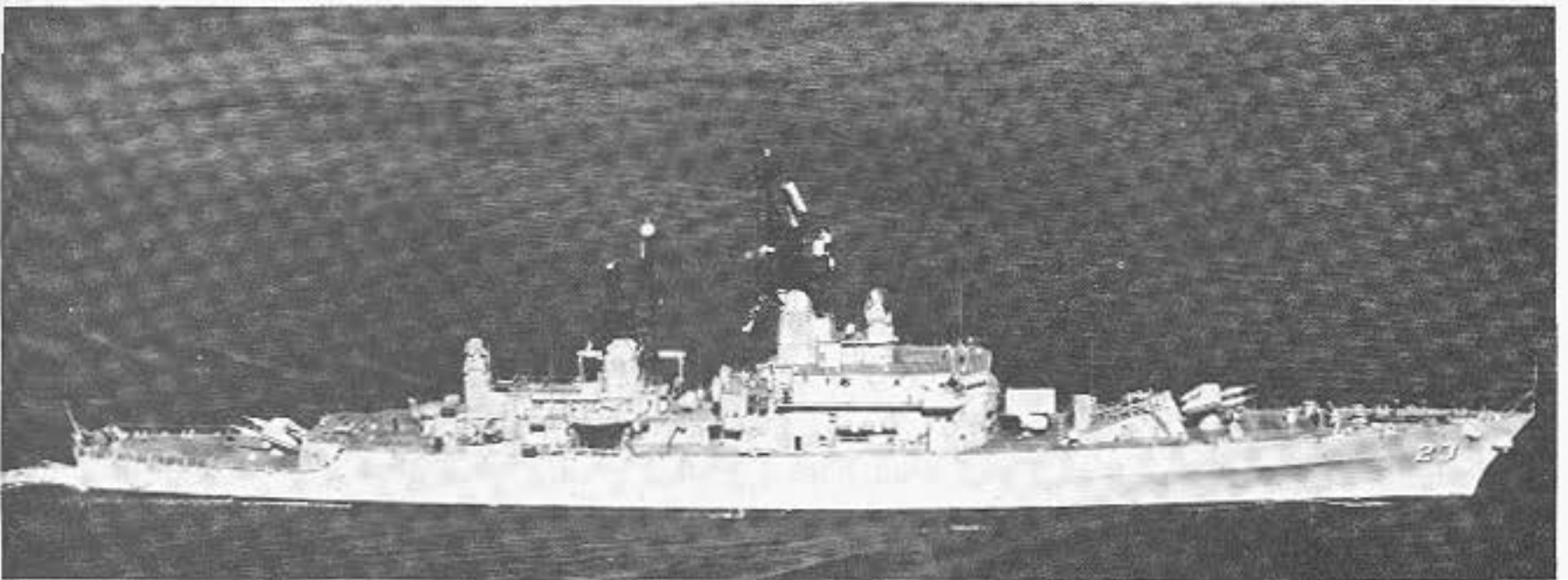
Carrier task forces are the principal offensive formations of the Navy. The mobile airpower of carriers is used for employment against submarines and their bases, surface ships and their yards, aircraft and their airfields, and for support of amphibious, land, and air operations as well. Its importance in carrying out the mission of the Navy paradoxically makes the carrier an ASW liability because, basically, the carrier has no direct defense against submarine attack. We lost but one attack carrier to submarines in all of World War II. However, if we consider the advances made in submarine capabilities since then, its menace increases dramatically. To take the most devastating conceivable combination potentially available at the moment, we must protect against a fast advanced type of submarine armed with rocketborne target-seeking torpedoes, perhaps



3.75-943
Figure 13-19.—USS Blandy (DD 943).



3,77-20
Figure 13-20.—USS Goldsborough (DDG 20).



134,84
Figure 13-21.—USS Halsey (DLG-23).

with atomic war head. To protect the fast carrier task force against this threat demands inclusion of CVS-type carriers (equipped with aircraft designed for ASW operations), a circular screen of destroyers, an outer screen of submarines, and inner screen of destroyer "pouncers," plus radar picket destroyers, and radar picket submarines. (Figure 13-22 shows such a

formation.) The ASW capability of a carrier is in the aircraft aboard, not in the ship itself, although some carriers have AN/SQS-23 sonar sets.

The CVS-type carrier with hunter/killer team is the most effective offensive antisubmarine force yet devised. It will be described later in this chapter.



110.114(110A)

Figure 13-22.—Typical task force steaming formation with two aircraft carriers, a cruiser, and circular destroyer screen.

AIRCRAFT IN ASW

Aircraft, including such fixed-wing types as fighter planes, patrol bombers, and seaplanes, plus helicopters, have the ability to investigate distant contacts rapidly and are completely invulnerable to submerged submarines. However, unfavorable weather can ground aircraft, both carrier and shore based, and high seas can reduce radar and visual detection probabilities to the vanishing point.

FIXED-WING AIRCRAFT (fig. 13-23) have radar and ECM equipment which are effective if the submarine exposes all or part of itself above the surface. Against submerged submarines they can use radio sonobuoys. An experienced sonobuoy operator can distinguish one type of submarine from another and even recognize the type of propulsion plant. Under good

sound conditions a sub proceeding at high speed on Diesels has been heard as far as ten miles. The use of sonobuoys is restricted, however, because only a limited number can be carried in the plane. Finally, fixed-wing aircraft have MAD (Magnetic Anomaly Detection) equipment, but MAD is only effective when the submarine's position is fairly accurately known.

Fixed-wing aircraft can attack submarines with depth bombs (similar in principle to depth charges launched from surface vessels, except that they are fuzed to explode either hydrostatically on reaching a certain depth, or on contact with a solid target). Present doctrine includes as a normal method the use of homing torpedoes by aircraft against submarines.

The antisubmarine helicopter is also an efficient search unit and is capable of attack as well as detecting and locating. It carries



134.95(110B)

Figure 13-23. — Fixed-wing type aircraft in ASW.

sonar equipment and homing torpedoes. The ASW helicopter mission is to:

1. Detect, track, and destroy submarines, singly or in conjunction with other aircraft or surface forces.
2. Provide ASW search and screening service for task convoy escort, and harbor defense forces.
3. Operate with ASW hunter-killer forces.

SUBMARINES IN ASW

The submarine is itself an effective antisubmarine vehicle. It operates in the same medium with and shares the target's advantages of concealment and passive detection. It can, like the target, take advantage also of the sound refracting properties of sea water, and it can track the target with less distraction caused by this phenomenon. Like the target submarine, it can go deep enough to escape the effects of surface waves and winds. It can hover silent and motionless for long-range passive listening.

The submarine can be employed in protecting the capital ships of a fast carrier task force, in detecting enemy submarines while working with a hunter-killer group, and in supplementing and protecting radar picket destroyers. Submarines can precede a fast carrier strike force into enemy waters to function as antisubmarine screens and as minelayers.

Like any other vehicle, the ASW submarine has limitations. To find the enemy submarine, the ASW submarine must be deep, but to communicate this information to the surface forces it must be shallow. To maintain the silence essential for most effective listening, it must not move. But to get information to someone who can do something about it, the ASW sub must break off the contact or expose its location by surfacing to communicate. And of course, an ASW submarine is always faced with the nerve-racking possibility of being mistaken for the enemy by its own force. These disadvantages will in some degree be overcome by developing new communication methods which will enable the submarine to remain in positive, rapid, and reliable voice communication with the remainder of the force while remaining submerged. Successful multiship coordinated operations depend on reliable communications and the submarine cannot participate until adequate communications have been developed and made available to the forces afloat.

The most effective antisubmarine submarine is the nuclear. These ships have as their strong points the counterparts of the two major weaknesses of conventional submarines. Nuclear ships are fast, whereas conventional submarines must operate at very slow speeds unless they are to be forced to surface or snorkel in a short time.

Furthermore, nuclear submarines can go out and remain submerged on station for extended periods, whereas conventional submarines must have recourse to the surface frequently for battery recharging. Conventional submarines must also withdraw to friendly waters to refuel, unless they desire to take the risk of surfacing in enemy waters to refuel.

ASW SHORE INSTALLATIONS

Shore installations cannot participate in the offensive ASW operations that the mobile units so far mentioned can perform, but they have important defense functions. They have cognizance over harbor defense submarine-detection systems using radar, sonar, magnetic loops (large rectangles of cable laid across the ocean floor which detect any distortion of the earth's magnetic field caused by an iron or steel body crossing the cable), heralds (a passive sonar system), hydrophones, and sonobuoys. Nets and mine fields are used in actually blocking submarines and torpedoes.

An ideal harbor defense detection system consists of magnetic detection loops (or early warning hydrophones) to seaward, hydrophones or sonobuoys to back up the loops, and heralds (long-range operator-controlled sonar near the approaches to the harbor, and short-range sonar units guarding the inner harbor). Surface and air patrols are responsible for the ocean areas to the approaches of the harbor.

ANTISUBMARINE OPERATIONS

Since we are primarily interested in ASW as it relates to destroyer type surface vessels, let us consider briefly those types of ASW operations in which such vessels participate. These are the ASW strike, hunter-killer operations, ASW patrol and search and protective escort or screening. (Destroyer vessels also perform ASW mining, but this operation does not involve ASW detection equipment or weapons and is not taken up in this text.) The limited general discussion to which this text is confined is not

to be considered a substitute for study of doctrinal publications such as NWPs, NWIPs, and related instructions issued by such authorities as CruDesLant.

ANTISUBMARINE STRIKES

The ASW strike can be considered the remedy to the submarine problem. Just as it is more effective to destroy the breeding places of disease-bearing mosquitoes than it is to swat at them even with very efficient swatters, it is more effective to destroy or reduce the enemy's ability to fabricate submarines than to attempt to destroy those already at sea. Even the most efficient ASW campaigns of the past did no more than keep the enemy submarine population in check.

ASW strike operations are offensive operations directed against bases and installations which produce and maintain enemy submarines. If successful, they not only reduce or prevent production of submarines, but also make it progressively more difficult for the enemy to keep in service the submarines he has.

ASW strikes differ substantially from other attack operations only in the nature of their targets.

HUNTER-KILLER OPERATIONS

A hunter-killer (HUK) operation is a sustained ASW search and attack by an organized group of naval units in an area in which submarines are thought to be located. Any combination of ASW ships and aircraft may be used.

In the typical hunter-killer operation the CVS-type carrier, screened by five or more destroyers, will employ embarked fixed-wing ASW search aircraft and helicopters in an offensive search patrol. When either the aircraft or the surface screen contacts a submarine, the detecting unit will become the contact area commander (CAC), and a search attack unit (SAU) of at least two destroyers will be detached to assist in the development of the contact. In the meantime, the aircraft will attempt to develop the contact in an effort to localize and destroy the submarines. If initial detection is accomplished by visual sighting, radar detection, or possibly by MAD or ECM (electronic countermeasures) gear, it will be localized by employment of electronic countermeasures such as sonobuoys (fig. 13-13). If the target position can be accurately located, the attack aircraft may attack with one of its weapons

such as an atomic or conventional depth bomb, homing torpedoes, or rockets. Decision as to who takes command in the contact area is made on the spot and it can change from one unit to another as the situation develops. Generally, it rests in the unit with the best over-all picture of the situation or the strongest contact with the submarine.

Hunter-killer operations are divided into three phases:

1. The extended search by aircraft, resulting in a contact and attack on the submarine by aircraft.
2. The approach of the SAU to the submarine contact area (datum) to cooperate with the aircraft, if the aircraft attack has failed.
3. The local search and attack by a search attack unit (SAU) in cooperation with the aircraft.

Once a contact has been definitely established as an enemy submarine it must be attacked until destroyed.

Figure 13-24 shows schematically the sequence of operations in one type of attack. In part 1, fixed-wing aircraft conduct a systematic search of the area, finally detecting a surfaced submarine by radar. Next, as its status and identity are investigated, the submarine dives, and the aircraft drops a group of sonobuoys so that it can keep tracking the submerged target while it calls in surface units of the hunter-killer group and directs (vectors) them toward the sub. By this time it is necessary to reestablish the location of the submarine. The ships and aircraft do this in cooperation. The ships search by sonar; helicopters may use dunking sonar units; the other aircraft may drop more sonobuoys. When the target submarine is located, the ships attack, using depth charges, rockets, homing torpedoes, and such other weapons as are considered appropriate.

This attack pattern is more or less typical, and variations of it apply in the other operations described below.

ASW SEARCH

ASW search is the systematic observation by ships or aircraft of a particular area where submarines are thought to be located. Ships are more effective at detecting submerged submarines, but are much slower at it because

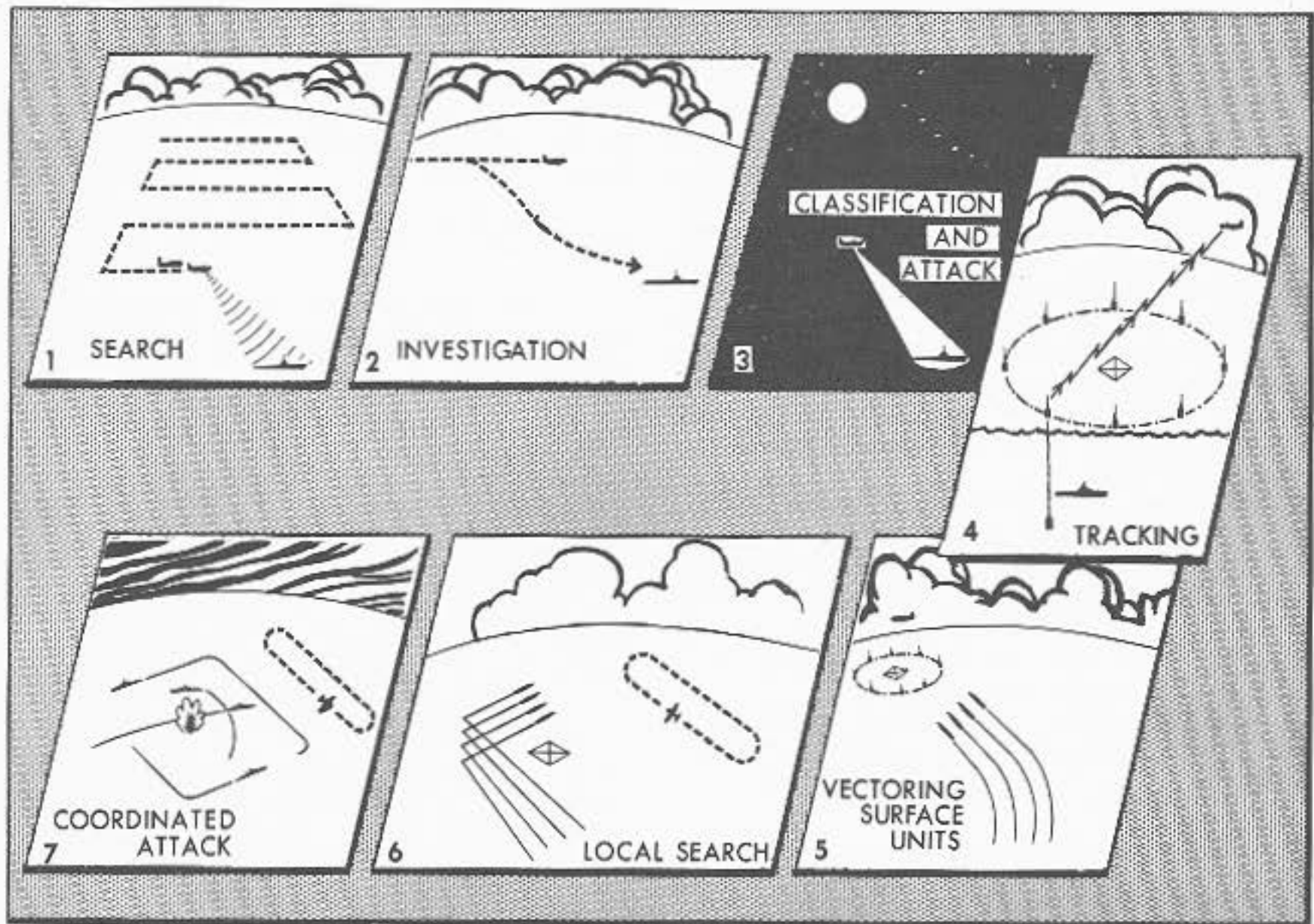


Figure 13-24.—Hunter-killer operation. Schematic.

of their relatively low speed (compared to aircraft) and limited radius of visual and radar coverage. Two or more ships usually work together in search because they can provide mutual support in an attack and because a submarine can evade two ships only with much more difficulty than it can evade one.

Fixed-wing aircraft can survey a wide area relatively quickly, and can efficiently detect surfaced and snorkeling subs, but their ability to locate submerged submarines is quite limited. Such devices as sonobuoys are effective at tracking submerged submarines only when they have been dropped fairly close to the submarine. However, search by fixed-wing aircraft has the additional advantage of forcing submarines to keep submerged; this can handicap a conventional submarine's operations.

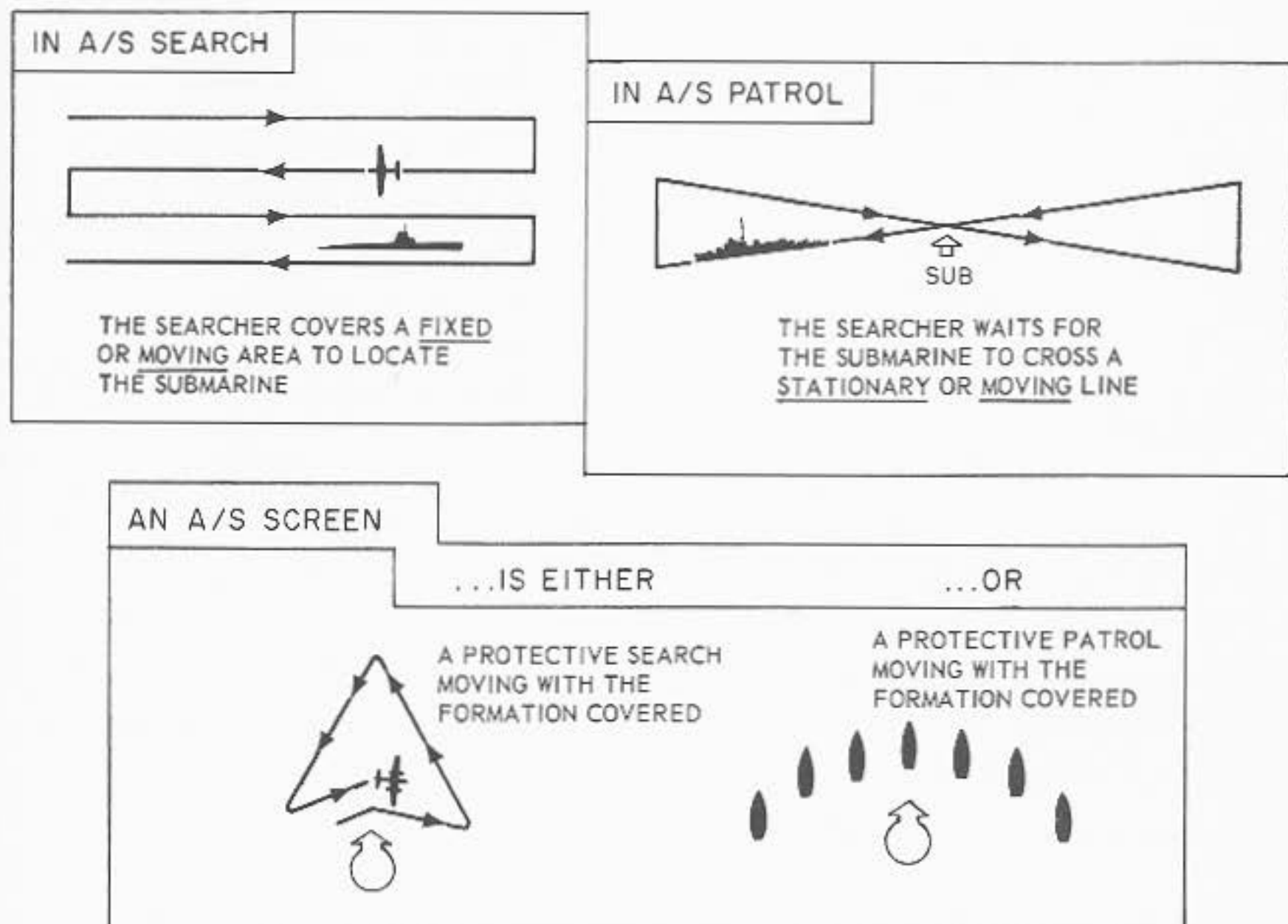
Helicopters can use dunking sonar to search actively for submarines.

ASW PATROL

An ASW patrol operation is a systematic and continuous surveillance along a line, either stationary or moving, to detect submarines attempting to cross it. Patrol operations are actually closely related to search, and similar methods are used. Figure 13-25 illustrates the distinction between patrol and search.

ESCORT OR SCREENING OPERATION

To provide maximum protection against enemy aircraft and submarines, during wartime ships do not traverse the open sea singly, but



110.116
Figure 13-25.—ASW search and patrol. Schematic.

in groups. A formation of naval vessels is called a force; a formation of merchantmen is a convoy. Around the group to be protected is a screen made up of destroyer-type vessels, and an area constantly being patrolled by aircraft. The screen is concentrated in the forward part of the formation. Figure 13-26 shows in simplified schematic form how a screen protects a convoy. Figure 13-22 is a photograph of a task force and screen.

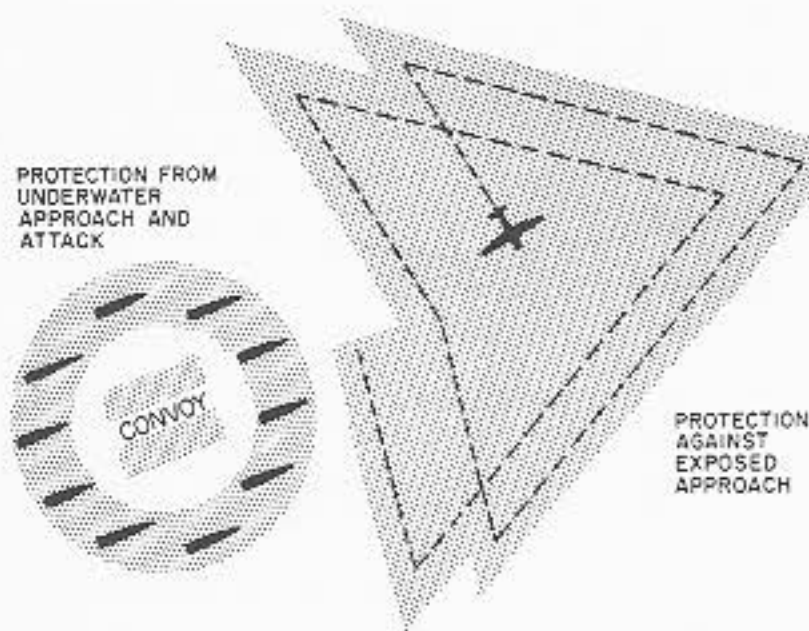
DESIGNATION OF ASW FORCES

Forces to conduct ASW operations are designated in accordance with their mission. A force assigned to locate and destroy submarines at sea may be designated as a search, patrol, or hunter-killer force. A force assigned to close an

enemy submarine base, or to close a strategic strait to enemy submarines, may be designated a mining force or a patrol force, according to the type of operation. A force assigned to protect shipping at sea against enemy submarines may be designated an ASW search, patrol, escort, or support force, depending on the type of operation. A screening unit can be part of a force, or it can be designated as an escort force. The list can be extended to include forces for the defense of harbors, fixed sea areas, or a coastal area.

EMPLOYMENT OF ASW FORCES

In addition to protecting a fast carrier task force (as mentioned previously) an ASW force may be used in various numbers and combinations for antisubmarine operations. This text



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Figure 13-26.—ASW escort operations.
Schematic.

will take up singleship, multiship, and hunter-killer antisubmarine tactics.

SINGLESHIP ASW ATTACKS

In determining whether to make an urgent attack or a deliberate attack, the commanding officer or the OOD must consider the tactical situation and make a decision almost immediately upon sonar contact. The considerations for arrival at this decision are stated in Allied Naval Maneuvering Instructions (ATP-1) and in NWP 24. In general, the considerations depend upon the assigned task of the ship gaining contact and the degree of immediate threat to protected ships, own ship, or other ships in company.

Although an initial contact may be made while the ship is at general quarters, it is more probable that the normal cruising watch will be set.

In a normal cruising watch, sonar control is manned by an ASW watch officer (supervisor), search sonar operator, and standby operator. The sonarmen assigned to a cruising watch must be capable of controlling any type of ASW attack on a submerged submarine, must be able to evaluate any evidence of submarine counter-attack, and have sufficient tactical knowledge and ability to recommend course changes and maneuvers. Sonar is usually the only ASW station manned in a normal cruising watch. (This of course does not include the OOD or CIC officer.)

The members of the general quarters ASW attack team man their stations as soon as

possible after initial contact is made. At the moment contact is made on an enemy submarine it is imperative that every effort be made immediately to gain the advantage and exploit it by attacking until the submarine is sunk. If the contact is in a position to menace any ship in the main body of the force or formation, an urgent attack is immediately delivered. Deliberate attack follows when the formation is no longer in immediate danger.

Tests at sea have demonstrated that with favorable sonar conditions a single ASW ship, capable of 27 knots or more, and equipped with high-power low-frequency sonar, can hold contact on a freely evading high-speed, deep-diving submarine. Ship's ASW attack speed, however, is commensurate with the ship's effective sonar speed (normal around 20 kts.) These tests have demonstrated that a single ship can attack and repeatedly reattack with Asroc and similar stand-off weapons with much greater maneuvering safety than she could if another ship were in close proximity. However, the principle of mutual support makes it desirable to have a second ship in the vicinity ready to be called in to take over the attack.

When ASW attacks are to be by ahead-thrown weapons, rocket-assisted missiles, or atomic depth charge, the safety of friendly aircraft is a prime consideration. Low-flying aircraft such as MAD equipped planes or helicopters using dip sonar may be endangered when the ASW ship uses such weapons.

MULTIPLE SHIP ASW ATTACKS

Initially, ASW was effected by singleship attacks. The ASW attack was a battle of ship against boat and captain against captain. Experience taught us that the exchange rate of surface ship for submarine was too costly. A more efficient and successful method of attack was required. Finally, tacticians evolved the concept of the multiship attack. By constant training and experimentation, well-defined and effective multiships tactics have been developed.

A multiship ASW action is any ASW action involving two or more ASW ships maneuvering to a prescribed plan. The plan is designed to maintain the offensive by maximum rapidity of attack and continuous contact on the submarine. It is employed to maximum effectiveness in close-in attacks when two ships using ahead-thrown

weapons work the submarine over until it is destroyed, or contact is lost and cannot be regained, or the ASW action is terminated by higher authority. Successful two-ship coordination depends on rapid and reliable voice communications and complete exchange of information and intentions. Additional ships if available are employed as supporting ships by putting them on a circle around the contact or on a fence prepared to take over the attack or commence a search if contact is lost.

The new concept in ASW employs the long-range, standoff technique. This of course is due to the recent and continuing development of long-range ASW weapons, such as Asroc and Subroc. The destruction of submarines at long range is desirable; however this ideal situation will not always be possible. Thus, single and multiship ASW attacks may still be used when the situation arises.

FUTURE OUTLOOK

No individual piece of equipment or type of weapon can solve the ASW problem. Now, and in the future, the task group commander must employ his various ASW units, either singly or in a combination, to attain their greatest advantage. Each type of ship, submarine and air-

craft has its particular function; each has its definite limitations. For example, a destroyer has great underwater tracking and attack ability against enemy submarines, but is limited in speed; moreover, its performance is hampered considerably by rough seas. By the same token, the submarine is a superb sonar-detection vehicle, and can operate deep enough to escape adverse sea conditions that plague surface ships. Diesel submarine endurance capability, unsupported, approaches 60 days. This exceeds that of any conventionally propelled destroyer type. Nuclear types of course far exceed this figure.

Constantly weighing the array of weapons at his disposal, the task group commander selects the one (or the combination) that best accomplishes the task at hand.

Tactics will change with new developments of detecting equipment and weapons. Today, however, and in the near future, it still will require the combined efforts of all types of ASW units to meet the submarine threat.

Our ASW forces of the future will include many ships and weapons unfamiliar to us now. But the most advanced hardware, alone, will never assure victory. At the base of the tactical problem are the officers and men who will put this hardware to use.

CHAPTER 14

ORGANIZATION AND COMMUNICATIONS

The military potential that any modern U. S. combat ship possesses is a function not only of the trained personnel and powerful armament aboard, but also of how they are organized to accomplish the mission the fleet has assigned to them.

In the preceding chapters, you learned the fundamentals of the "conventional" weapons that make up the modern U.S. Navy's shipborne arsenal. This chapter presents the fundamentals of shipboard battle organization on combat ships, and briefly describes the communications system through which the ship's fighting potential is coordinated for its most effective employment.

FUNDAMENTALS OF SHIP'S ORGANIZATION

Any ship's organization is based fundamentally on instructions issued as NWP's by the Chief of Naval Operations, particularly NWP 50, Shipboard Procedures, and NWIP 50-1, Battle Control. Standard organization manuals issued by Atlantic and Pacific Fleet type commanders (e.g., Commander, Cruiser-Destroyer Force Atlantic) follow these CNO instructions as a guide, and individual ships set up their organization structures in accordance with these. An individual ship's organization is promulgated in the Ship's Organization and Regulations Manual and the Battle Organization Manual. Other organization media such as charts and posted ship's bills are based ultimately on these sources. For details on shipboard organization not discussed in these pages, consult these sources.

A ship's organization may be based on its complement or its allowance. The complement includes the officers and men (by number, rank, and rate) assigned by the Chief of Naval Personnel to the ship in time of war. The allowance (a smaller number) itemizes the personnel assigned to the ship in peacetime. (The actual population of the ship is the on-board count or

manning level; this may be yet another number, or it may correspond to the complement or the allowance.)

In compliance with NWP's, a ship's organization normally is set up in five major parts—the battle bill, the administrative organization, the watch organization, the organizational bills (administrative, operational, and emergency), and the ship's regulations. We are here primarily concerned with the ship's organization as it functions in battle (or simulated battle) and related operations; from this point of view the most important parts of the organization are the battle bill and some parts of the organization bills.

A bill, by the way, is a written directive that prescribes a procedure for performing some operation, such as berthing the ship, or for dealing with some specific situation or emergency, such as fire, or for performing battle operations. A bill lists the things to be done, the material needed, and who is to take action. It identifies these last not by name but organizationally by billet or other organizational designation.

PURPOSES AND PROMULGATION OF BATTLE ORGANIZATION

The purpose of the battle organization on any ship is to:

- (1) Organize the ship for battle and for war-time cruising by assignment of personnel to duty stations under the various prescribed degrees of readiness.
- (2) Define communications between battle control stations within the ship, and provide information on interior communication system.

Type commanders, under the direction of fleet commanders-in-chief, are not only responsible for furnishing to ships of the type an

appropriate outline of battle organization, but also for coordination between commanders of the same type in different fleets. This assures a practical uniformity of battle organizations for all ships of a type. Thus, interchange of personnel between ships or of ships between fleets does not present a major problem.

BATTLE CONTROL STATIONS

The key elements of a ship's battle organization are the battle control stations. The commanding officer must rely on officers at battle control stations for the execution of his commands. Most primary stations control secondary stations.

The eight primary battle control stations in combat ships of the Navy include:

1. Command control
2. Ship control
3. Operations control
4. Primary flight control
5. Weapons control
6. Engineering control
7. Damage control
8. Mine countermeasure control

Figure 14-1 shows communication lines between primary and secondary control stations. Since the diagram is a general one, it applies to specific types of ships only insofar as the type possesses the elements concerned. Primary flight control, for example, obviously doesn't apply to a destroyer. However, the organizational principle of using primary and secondary battle control stations as key points or nuclei about which the battle organization is constructed applies universally.

COMMAND CONTROL

Command control is exercised by the commanding officer at his battle station, which may be on the bridge or in commanding officer's tactical plot. From this station he directs the ship's course of action in battle by exercising control over all the primary battle control stations. Matters of paramount importance to the commanding officer during battle are the orders of his seniors in tactical command, conditions within the ship that affect his ability to carry out those orders, and information on external developments which have a bearing on the battle. His main responsibilities are to inform

primary battle control officers of his objectives and to render decisions in matters having major influence on the combat effectiveness of the ship.

SHIP CONTROL

Ship control is under the immediate direction of the officer of the deck who is located on the bridge. The main functions of ship control are:

1. Conning the ship, as ordered by the commanding officer.
2. Maintaining operational control of tactical maneuvering communications.
3. Keeping other battle control stations informed of ship's maneuvers, present and anticipated.

Ship control receives direct assistance from CIC, commanding officer's tactical plot, a navigation detail, a signal detail, tactical voice radio operators, lookouts, steersmen, telephone talkers, and messengers. An efficient and dependable ship control aids command control by permitting the commanding officer to concentrate on the larger problems in fighting the ship.

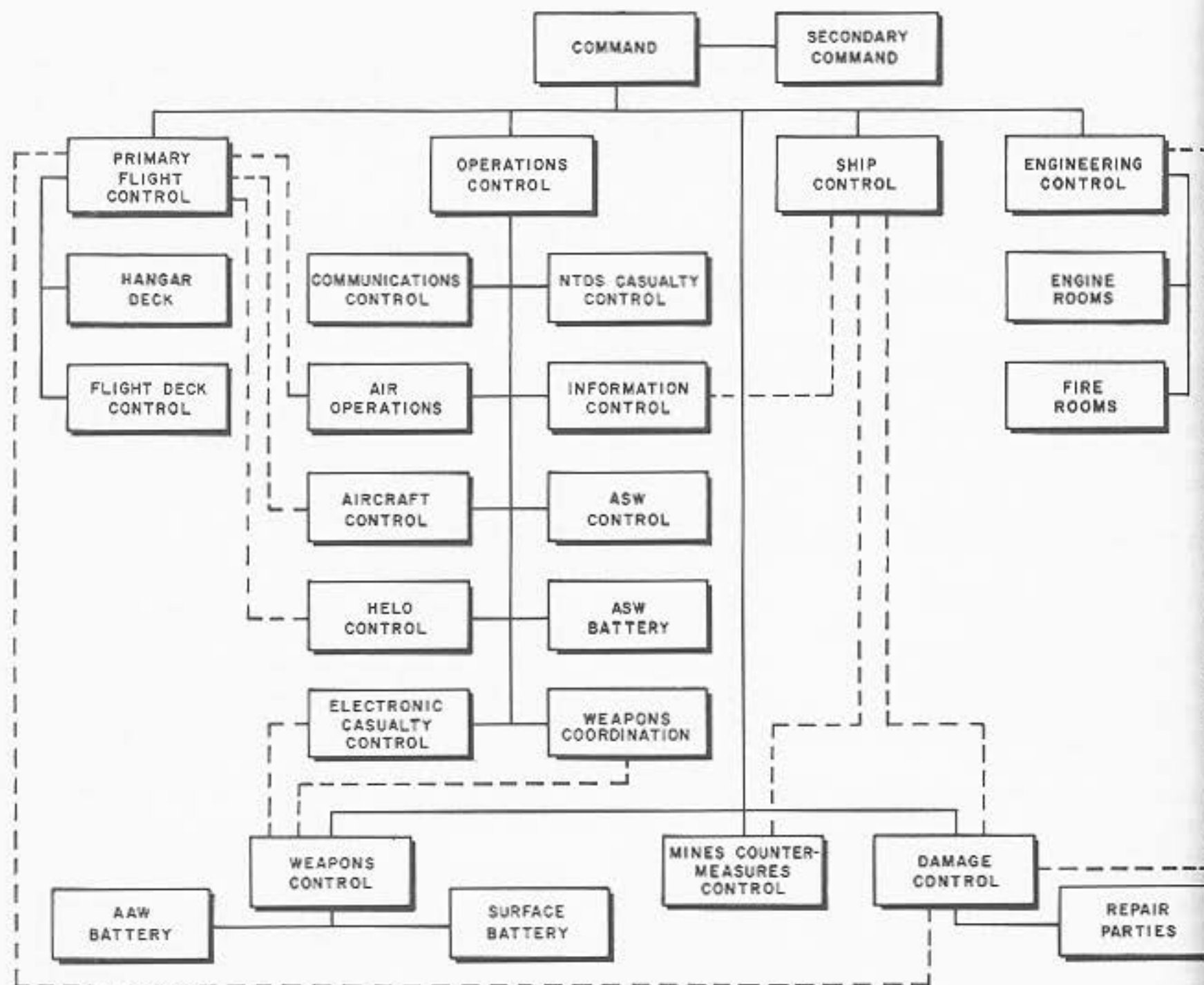
OPERATIONS CONTROL

The primary objective of operations control is to assist command control in planning the correct course of action and to assist command and key battle control officers in executing that plan. Operations control is collectively applied to those activities under the cognizance of the ship's operations officer, which are:

1. Communications control
2. Air operations
3. Aircraft control
4. Electronics casualty control
5. NTDS casualty control
6. Information control
7. ASW control
8. Weapons coordination

Operations control emanates from the ship's CIC which, on many ships, is the operations officer's battle station. The principal battle functions of operations control are to:

1. Keep command control informed of the tactical situation.



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Figure 14-1. — Representative battle organization chart.

2. Assist ship control in carrying out its functions.

3. Perform operational evaluation.

4. Operate voice radio circuits.

5. Conduct radar search, identification, and tracking.

6. Analyze and/or conduct electronic countermeasures.

7. Plan operational schedules for aircraft (aboard aircraft carriers).

8. Perform aircraft control duties.

9. Assist sonar search and tracking (ASW ships).

10. Perform combat intelligence duties.

11. Assist weapons control in target acquisition and designation.

12. Assist torpedo control in solving torpedo attack problems.

13. Obtain weather and aerological data.

PRIMARY FLIGHT CONTROL

Primary flight control consists of the control of shipboard aircraft handling and those operations incidental to launching and recovery of aircraft. During flight operations, the air officer is responsible for these operations, as well as the visual traffic control related to these functions. The air officer's battle station is primary fly. He receives his orders here directly from command control. During routine flight operations, the assistant air officer is

also stationed at primary fly. Under battle conditions he is at secondary fly.

WEAPONS CONTROL

Weapons control is under the direct and positive control of the weapons officer. The weapons control station (fig. 14-2) provides centralized coordination and monitoring of missile systems and gun batteries. Located here is the equipment which furnishes displays and controls for selecting and tracking targets, for evaluating and processing data, for assigning targets to fire control systems, for loading the launcher, and for firing missiles at the optimum time.

Target indications are presented on the target selection and tracking consoles. The selected targets are tracked by operators and the target data sent automatically to a director assignment console. Here the relative threat of the targets is again evaluated, priority of engagement determined, and assignment of a missile or gun fire control director made. At the same time, loading of the launcher is ordered for the top priority target from the weapon assignment console if director assignment has been made to a missile fire control system. Targets unsuitable for missile engagement are assigned to gunnery fire control equipment for separate processing.

ENGINEERING CONTROL

Engineering control is the engineer officer's battle station. Located at main engine control or a central control station, he supervises control of the main propulsion plant and auxiliary equipment.

The principal battle functions of engineering control are to:

1. Supervise the operation and maintenance of the main engineering plant.
2. Exercise casualty control procedures.
3. Keep command control informed of the main engineering plant casualty status.
4. Assist damage control in such functions as flood control, maintaining stability and trim, fire fighting, damage repair, and maintenance of watertight integrity.

DAMAGE CONTROL

The Damage Control Assistant (DCA) exercises control from his battle station in damage control central. On some ships damage control

central is located in a central control station with engineering control. On other ships it is in a separate compartment of its own or at a designated repair party station.

The damage control battle organization is composed of damage control central; repair parties for hull, propulsion, weaponry, and air; and battle dressing stations. The weapons department, among others, is responsible for control of damage to its own equipment. There must be no doubt in the minds of the ship's personnel as to who is responsible for taking either normal or emergency action for damage control. Each officer and man must be familiar with the damage control organization of his ship and his own responsibilities to it.

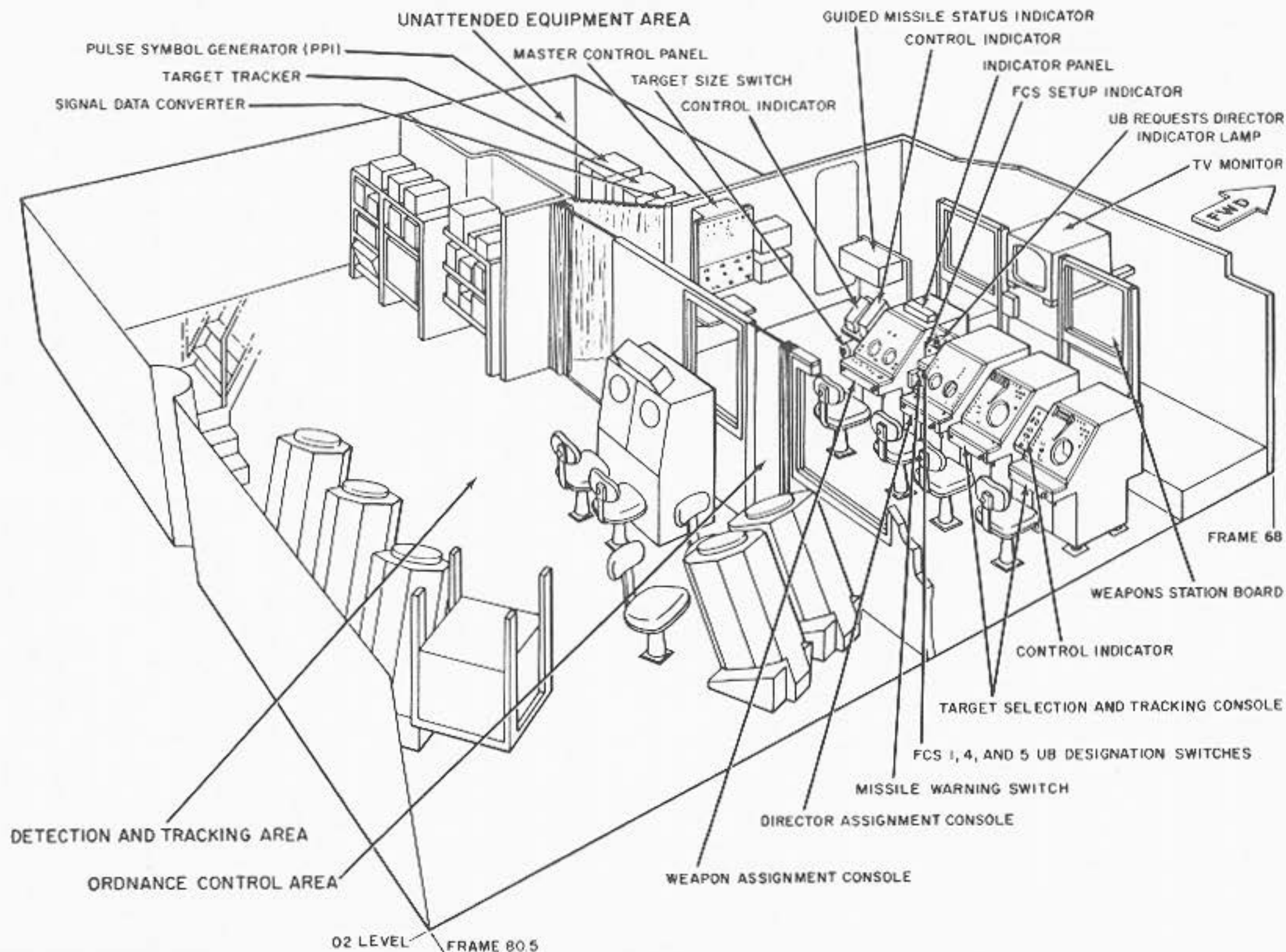
There are two principal phases of damage control. They are the preventive phase and the action phase. The preventive phase begins with the preliminary design of a ship and continues through the construction, organization, maintenance, and operation of the ship. Efforts on the part of all departments in maintaining material readiness, training of personnel, and exercising readiness doctrine help place the ship in the most favorable condition to withstand damage. The action phase begins after the ship is damaged. This phase requires the damage control battle organization to take steps to promptly restore the offensive and defensive potential of the ship. The action taken is the cumulative result of the training and material preparations conducted during the preventive phase.

MINE COUNTERMEASURES CONTROL

Mine countermeasures control is a collective term applied to all minesweeping and minehunting functions which are within a ship's capability to perform.

Minesweeping procedures consist of sweeping an area of water for mines, either by covering it or traversing it with mechanical or explosive gear which physically removes or destroys the mines or by producing the influence fields necessary to actuate the mines. Direct control of minesweeping operations is exercised by the mine countermeasures officer whose battle station is on the bridge or in CIC except when actually using or recovering minesweeping gear, at which time he is on the fantail.

Minehunting includes all measures for detecting, accurately locating, identifying, and clearing mines individually. This clearance may be accomplished by explosive destruction, rendering mines safe and disposing of them, or



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Figure 14-2. — Weapons control station.

by sweeping. Overall control of minehunting functions is exercised by the operations officer, whose battle station is in CIC. Mine disposal is the function of qualified Explosive Ordnance Disposal personnel and is under direct control of the officer in charge of the EOD team.

Channel conditioning, which includes all measures for the clearance of mines and mine-like objects in areas and channels planned to be used in time of war, is a part of minehunting when not specifically assigned to an EOD team.

BATTLE ORGANIZATION IN U.S. NAVY SHIPS: OPERATIONAL ASPECTS

During battle there seldom is time for lengthy consideration of the problems presented. To arrive promptly at a satisfactory solution, it is necessary that the more probable contingencies be anticipated and provided for. A basic weapons doctrine in writing, promulgated by the type commander, helps prepare the ship to:

1. Overcome surprise.
2. Develop maximum effective fire power in a minimum of time.
3. Make use of all automatic features of the equipment provided.
4. Simplify methods of control and provide each echelon with a clear-cut delineation of responsibility and authority.
5. Ensure automatic and instantaneous shift to secondary or auxiliary methods, with the replacement of personnel as necessary in the event of casualty or damage.

In concrete terms, weapons doctrine for his ship gives to a junior officer acting as director officer (or in some similar station) instantaneous guidance in answering and acting upon such urgent questions as the following—questions that demand quick action when you're faced with what may well be a genuine enemy target:

1. Must I get the captain's permission to open fire?
2. At what range may I open fire?
3. If there are several targets, how do I decide which to fire on first?

And there are many other decisions that your ship's weapons doctrine is designed to guide you in making when your ship is in action. Weapons doctrine specifies not only what you are to do

in any of a number of given circumstances, but also indicates what you may expect of others, as well as what others expect of you. On any U.S. Navy ship you will find a special file or compilation of weapons doctrine, which you are expected to learn and follow without delay. Your ship's doctrine is in turn based on more general doctrine to be found in NWIP 50-1 and in directives issued by type commanders and other competent authorities.

THE SECTION AND THE BATTLE BILL

The primary organizational unit of the ship for administration, watch standing, and liberty is the section. Each division is broken down into three approximately equal sections, each completely adequate to maneuver and fight the ship within the limitations of the available personnel. Each ship assigns an adequate number of properly rated and qualified men (assignments are shown on the watch, quarter, and station bill) to man stations for any eventuality, including the stations for getting underway (Special Sea and Anchor Detail) and proceeding to sea for limited operations, as may be required by weather, surprise hostile activity, or other emergency situations.

Assignment of all personnel to individual battle stations is made in the battle bill, which is in chapter 3 of each ship's Battle Organization Manual. Officers are assigned by billet (job title). Enlisted personnel are assigned by billet number. A billet number is made up of a series of numerals, or a combination of letters and numerals, which indicate a man's division, his section, and (usually) his seniority or precedence in his section. As an example:

<u>Billet No.</u>	<u>Description</u>
1-204 - - - - -	1st division, 2nd section, 4th in seniority.

The battle bill lists the stations which must be manned under battle conditions and indicates the personnel requirements for manning those stations. The numbers, ranks, and rates of personnel assigned to battle stations by the battle bill should agree with the ship's wartime complement and peacetime allowance lists. The battle bill's summary is useful to division officers when making up the division watch, quarter, and station bill.

WATCH, QUARTER, AND STATION BILL

The watch, quarter, and station bill is the division officer's summary of the assignments of personnel to duties and stations specified in the battle bill and in each of the other ship's bills, which are contained in the ship's Organization Manual. One of the goals of the bill is to attain a smooth transition from one condition watch to another, thereby eliminating confusion and conflict of watches. Its primary purpose is to inform division personnel of their assignments. Technically, this is considered accomplished when it is posted on the bulkhead in the division. In practice, the division officer should disseminate this information to the men in his division, especially where there is a large proportion of new men.

The watch, quarter, and station bill shows for each billet the name and rate of the individual assigned, the station he is assigned for cleaning and maintenance, where he is quartered, his assignments in all condition watches (including Condition 1 or General Quarters—this is his battle assignment), and his assignments in specific operational and emergency bills. Figure 14-3 shows a common form of this bill in which the assignment information is entered on cardboard strips that slide into grooves in the billboard.

CONDITIONS OF READINESS

Conditions of readiness is a general descriptive phrase referring to a ship's ability to meet the preparedness requirements for

combat. An Officer in Tactical Command (OTC) may order a condition of readiness for any of the following requirements: amphibious assault, antiaircraft, antiship, antisubmarine, damage control, engineering, or aircraft. Conditions of readiness do not describe any particular combat situations and do not establish a specific watch organization and operational arrangement. The phrase is frequently incorrectly used as if it were synonymous with either degree of readiness (discussed next) or condition watch (discussed later).

DEGREES OF READINESS

The objective of all watch organizations is security of the ship for all probable conditions. Secondary to this objective is the need for an optimum degree of efficiency in administration of the ship. To maintain such security, or readiness, and ensure the needed efficiency, requirements for specified degrees of readiness are set down. The amount of security furnished the ship is normally adjusted to the demands of the current situation by use of the six general degrees of readiness, which are as follows:

1. Complete readiness for immediate action.
2. Temporary relaxation from the first degree of readiness to enable personnel to rest and to permit designated personnel to draw and distribute action meals at their action stations.
3. A part of the armament ready for immediate action, the remainder on short notice.
4. A part of the armament ready for immediate action, the remainder at prolonged notice.

DIVISION					
NAME	RATE	BERTHING & LOCKER		CLEANING AND MAINTENANCE	BILLET NUMBER
		LIVING COMPARTMENT	BUNK & LOCKER NO.		
D. L. JOHNSON	BMC	A-308 L	51-12	IN CHARGE	3-101
E. HAMILTON	BM 2	C-205 L	11-2	IN CHARGE MAIN DECK PORTSIDE	3-102
P. L. KELLY	SN	C-205 L	7-3	AFTER CREWS HEAD	3-103

Figure 14-3. — Part of watch, quarter, and station bill.

5. Peacetime cruising—no armament manned.

6. No armament manned, ship in port under peacetime conditions.

The general degrees of readiness, as described above, define the nature of the tactical situation in terms of the probability of attack and/or battle action and relate this situation to the combat capability of own forces required to meet the threat. General degrees of readiness apply to the WHOLE UNIT, whether an individual ship or a task force.

Particular degrees of readiness delineate the specific requirements for the battle organization components with an INDIVIDUAL UNIT. Condition watches are derived from the particular degrees of readiness.

A modification of a particular degree of readiness is assumed by the amphibious types for the conduct of amphibious operations. This is evidenced by their addition of a condition called 1A (one alpha). It represents an entirely different organization which is used to embark and debark amphibious troops and equipment.

CONDITION WATCHES

The condition watches established in the watch, quarter, and station bill are derived from the particular degrees of readiness promulgated in the Battle Organization Manual. Condition watches apply to specific shipboard watch organizations which satisfactorily meet the degrees of readiness prescribed in certain situations. They provide the optimum personnel/operational combination. The following tabulation shows the condition watches associated with each general degree of readiness.

General degree of readiness	Condition watch
First	I
Second	IE
Special or third	II
Fourth	III
Fifth	IV
Sixth	V

Battle readiness includes conditions I, IE, and II. Under condition watch I, for example, all ship's personnel man their individual battle stations. Condition I corresponds to General Quarters the full battle readiness condition. Under condition watch IE, the requirements are

relaxed enough to permit the men to have their meals and brief relief periods at staggered intervals. Condition II includes two general degrees of readiness, special and third. The special degree of readiness is for limited action; the third degree of readiness is in effect when part of the armament is ready for immediate action, and the remainder is on short notice.

Condition watch III corresponds to a state of wartime cruising readiness. Ship's personnel man the wartime cruising watch stations, including part of the ship's armament, on a one-watch-in-three basis.

Condition IV is used for peacetime cruising. Condition V is for in-port, peacetime conditions.

INTERIOR COMMUNICATIONS

A reliable and easily operated interior communications (IC) system is essential to the functioning of the battle organization. Through the IC system, command control directs all elements of the ship's combat power; primary control stations pass orders and reports; and subordinates exchange information necessary to perform their duties.

The signals transmitted in IC systems include (1) verbal transmission by voice or legible words, (2) nonverbal audible or visible signals (such as alarms) intended for personnel, and (3) electrical signals (such as synchro signals or relay currents) to be received and utilized directly by electrical or mechanical devices. This section is not concerned with the third type of signal, which has been already discussed in connection with the functioning of fire control systems.

VERBAL IC SYSTEMS

The number and complexity of verbal IC systems aboard a ship depend upon its size, type, function, and communications needs. However, on all ships the systems are organized along parallel lines, and similar code designations are used, so that, for example, the 1JV sound-powered phone circuit aboard a light cruiser has its counterpart (though somewhat simplified, because the ship is itself less complex) aboard a destroyer, and is almost identical with its similarly designated circuit aboard another ship of the same class.

The principal verbal IC systems aboard combat ships that will be studied in this section are:

1. Battle (sound-powered) telephones.
2. Announcing (MC) systems, both one-way and multichannel.

Other systems are also used, but are relatively less important in weapons operations. These include the ship's service dial telephone, voice tubes, messengers, pneumatic tubes (to carry written messages), Teletype systems (with large-screen projection of the printed tape at the receiving point), Telaugraph, special telegraph systems like the engine room telegraph, and closed circuit television.

BATTLE (SOUND-POWERED) TELEPHONE SYSTEMS

The most important IC system is the sound-powered battle telephone system, in which the speaker's voice creates the power that transmits the message. No outside source of power is required. This system is therefore more reliable in emergencies than any that depends upon electric power supplied externally.

Battle telephones are set up as groups of connected stations rather than as individual stations. When a telephone is plugged into its jackbox it is automatically connected with all other stations that are plugged into that circuit. The connected groups are called circuits. Circuits in turn are organized into systems: (1) primary, (2) auxiliary, and (3) supplementary.

There is a standard method of designating, by symbols, every circuit in each of the three systems. The primary battle telephone system uses circuit designations JA to JZ. Typical examples are:

- JA — Captain's battle circuit
- JC — Weapons control circuit
- JK — Fuze setters' circuit
- JW — Range circuit

Numerals preceding the two-letter designations (2JW) are used to identify individual circuits with the same function but pertaining to different batteries (or similar subdivisions for nonweapons circuits). Numerals following the two letters indicate stations on the circuit. For example, 2JW2 refers to a particular battery's range circuit, station 2.

Auxiliary battle telephone circuits are assigned circuit numbers similar to their primaries, but preceded by the letter X; for example, XJA for the captain's auxiliary battle circuit, or X1JC for the auxiliary turret control circuit. Circuits of the supplementary telephone system are assigned designations such as X1 and X2J through X407J.

PRIMARY CIRCUITS

Primary circuits are the main channels of communication for controlling armament, engineering, damage control, and maneuvering of the ship. When the ship is at general quarters, each station on a primary circuit is normally manned by either the officer in charge of the station, one of his assistants, or a telephone talker reporting to the officer in charge of the station. These men normally wear headsets, so that they may maintain a continuous watch on the lines. In addition to those headsets which are plugged into individual circuits, control officers may wear headsets which are connected to selector switches which enable them to cut into any one of several circuits in which they are directly interested. At other stations control officers may have available to them handsets with which they may intermittently communicate on one or more circuits normally covered for them by talkers. (A talker is an enlisted man assigned, as a principal duty, to man a battle phone station for an officer at a control station.)

All primary circuits for the ship's armament can be controlled and interconnected by switchboards in the plotting rooms, as well as by selector switches. With these switchboards, control circuits may be shifted to parallel the transmission of information or orders by synchro. They also make it possible to tie circuits together, as may be done during wartime cruising when not all stations are fully manned, or to provide emergency communication facilities between stations not normally connected, and to isolate circuits or individual stations when necessary as, for example, in case of casualty.

In the plotting room a Fire Control Technician is normally assigned to the fire control switchboard, and an I.C. Electrician to the battle telephone switchboard. When control is switched from one station to another, they reset both boards. This means changing over the synchro and indicator circuits of one or more batteries to connect them to one or more other batteries. The ordnance control telephone circuit (JC) must be switched likewise. This is done by making

cross-connections on the switchboards. The personnel in the plotting room take care of the plugging and switching involved. Personnel in the director and at the guns know what is going on, but they play no part in the actual switching operation. The I.C. switchboard crew takes care of interconnecting other affected circuits as required.

AUXILIARY, SUPPLEMENTARY, AND EMERGENCY CIRCUITS

The auxiliary battle telephone system is a standby system which duplicates the most important primary circuits and is intended for use in case the latter become inoperative. It does not have switchboards. Therefore, in case of a casualty at the switchboard, the auxiliary circuits may still be available for use. The wiring of the auxiliary circuits is separated as much as practicable from the wiring of the corresponding primary circuits to prevent battle damage to both circuits. As the auxiliary battle telephone circuits are not ordinarily continuously manned, they are generally equipped with handsets and receptacles to connect headsets, when necessary.

Supplementary circuits are those either not important enough or not extensive enough to be included in the primary system. Most supplementary circuits include only two or three stations. They are equipped with handsets and are usually accompanied by circuit-E buzzer systems. In mounts and turrets most supplementary circuits are concerned with ammunition service. Thus, the supplementary circuit found in 5-inch enclosed mounts is the X17J, which connects the top and bottom of the lower ammunition hoists. Turrets may have more elaborate supplementary telephone circuits for internal use. The Salem class 8-inch turret has nine supplementary circuits. One of them connects the turret officer with gun positioning and sight-setting personnel, and the others connect various stations of the ammunition supply system with the gun captains and turret officer. Supplementary battle circuits have no switchboards, but selector switches can be used to interconnect some supplementary circuits or to tie them into primary circuits.

Emergency sound-powered systems consist of portable telephone lines with sound-powered telephones attached. This emergency equipment is generally kept on reels located at strategic points throughout the ship and the phones may be unreeled to serve as a standby in case of

failure of normal sound-powered communications during battle.

BATTLE ANNOUNCING (MC) SYSTEMS

There are two characteristic types of battle announcing systems. One is the central amplifier system, consisting of one or more microphones and loudspeakers. The other type is the intercommunications ("intercom") system, designed to provide two-way transmission of orders and information between stations. Both types use electronic amplification.

The main announcing system for the ship is the 1MC, or general announcing system operating under the authority of the Officer of the Deck, over which word can be passed to all parts of the ship.

The 21MC is the captain's command announcing system. This system provides for two-way transmission of ship control orders and information between interested key stations, including the primary and secondary conning stations, battery control stations, air defense stations, combat information center, and others. Other electronic amplification systems of interest to weapons personnel are listed in table 14-1.

Central amplifier type MC systems have an advantage over telephone communications in that they transmit orders or information simultaneously to all personnel at a station. Since, however, their continued use results in excessive noise levels, they are normally employed only for urgent and simple messages.

Intercoms, like general announcing systems, have the advantage of attracting the attention of all hands at a station simultaneously. They similarly have the disadvantage of raising noise levels, although this disadvantage is lessened by the fact that messages are heard only at the one station addressed. They are used to parallel telephone communications in the case of urgent and short messages, and are also frequently used to regain communications when a station fails to answer on a battle telephone circuit.

The sound-powered telephone system has been adapted, in certain cases, so that when desired, the voice on the sound-powered telephone circuit can be electronically amplified and put through speakers. Such a combination of the battle telephone with electronic amplification has the advantages of an intercom and a

Table 14-1. — Weapons announcing (MC) systems

CIRCUIT	SYSTEM	USED PRIMARILY ON
Central Amplifier Systems		
29MC	Sonar Control Information	Surface Ships
46MC	Aviation Ordnance and Missile Handling	Aircraft Carriers
Intercommunications Systems		
27MC	Sonar Control	Submarines
30MC	Special Weapons	Aircraft Carriers
32MC	Weapons Control	Surface Ships
47MC	Torpedo Weapons Control	Submarines

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telephone. It is used primarily at battery control stations for communications to gun mount personnel. This has replaced MC systems in these stations on most all ships.

SIGNAL SYSTEMS

Telephone and announcing systems are primarily voice communication systems. Besides these, modern combat ships are equipped with several systems of signals for special purposes:

1. Train Warning Signals. Safety regulations require that before any turret or enclosed mount is moved in train, a warning signal must be sounded so as to inform personnel to keep clear. The only exception is that the signal need not be sounded during general quarters. The train warning signal circuit is independent of all other IC circuits, and consists of a push-button control switch at the mount captain's station, bells outside the mount, and the necessary wiring and power supply.

2. Call-Signal System (circuit E). The call-signal system (circuit E) parallels the supplementary battle telephone circuits and voice tubes. It is not used independently; it always parallels a voice communication line. It consists of power-supply units, pushbutton switches, and buzzers or bells.

3. Cease-Firing Signal. The order to cease fire is normally given by sounding a special signal consisting of a loud, low-pitched, penetrating buzz produced by an electrically driven device, in addition to transmitting the order in

words. This signal is usually transmitted over independent reproducers at the mounts or turrets. In certain machinegun systems this circuit can be so interconnected with the headsets of gun crews' telephones that they will hear the cease-fire signals in their phones as well as over the reproducers installed at the mounts.

4. Salvo Signals. The salvo signal is a variable-pitch buzz produced electrically by special apparatus. Salvo-signal reproducers are installed where they can be heard by the crew in the gun compartments. There is no salvo-signal circuit for the machinegun battery.

ALARMS

The IC system includes a number of alarms for use in alerting or signaling personnel with regard to a specific dangerous condition. The number and type of alarms vary with type of ship. Four main alarms are:

1. Collision alarm
2. Chemical attack alarm
3. General alarm
4. Sonar alarm

The above listed alarms are connected into the ship's 1MC circuits. The closure of an alarm contact maker anywhere in the ship will sound any one of the four alarm signals over all circuit 1MC loudspeakers. The alarms are listed

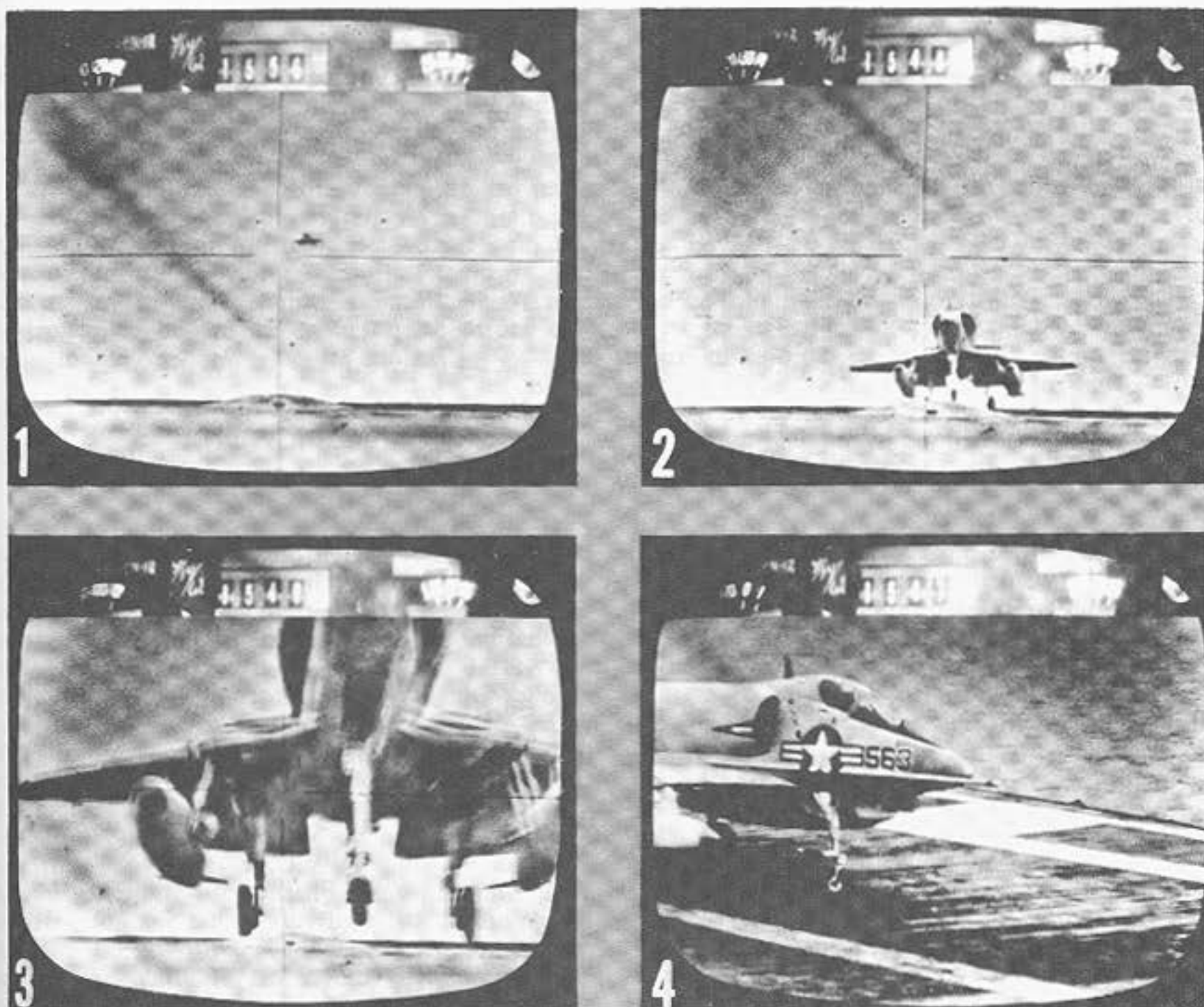
in the order of their priority which is automatically controlled by relays in the audio amplifier. Any alarm takes priority over voice announcements.

If an alarm is being sounded and a higher priority alarm contact maker is closed, relays operate to cut off the alarm signal being sounded and cause the higher priority alarm to be sounded instead. Conversely, the closure to a low priority alarm contact maker has no effect on a high priority alarm that is being sounded. The system operates to generate the alarm

signals as long as the alarm contact maker is held closed (except for general alarm which is sounded for a predetermined 15-second interval after momentary closure of the general alarm contact maker).

A few independent alarm systems used on board ship are:

1. Emergency steering alarm
2. Fire alarm
3. Carbon dioxide (CO₂) alarm



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Figure 14-4. — Pilot Landing Aid Television (PLAT) showing a videotaped jet carrier landing.

CLOSED-CIRCUIT TELEVISION

One of the most prevalent Navy uses of closed-circuit television (TV via cable) is data display. Instantaneous and accurate data are sent by a TV camera mounted in CIC to receivers in weapons control, commanding officer's tactical plot, flag plot, and the air control section of CIC via a high resolution, closed-circuit television system. The addition of television equipment has done much to eliminate the time-consuming link formerly associated with the transfer of bogey data by sound-powered telephones. Telephones are still used for action commands and to provide an audio backup for visual information. They continue to be the information link to anti-air warfare stations that do not have a critical evaluation assignment.

Pilot Landing Aid Television (PLAT) has been installed aboard almost all U.S. Navy

aircraft carriers. This closed-circuit television system aids in landing aircraft, and records landings on videotape for immediate playback and analysis by pilots. Figure 14-4 shows a sequence of photographs taken from a shipboard television monitor displaying a jet carrier landing. A television camera mounted in the center line of the carrier deck spots the plane at the beginning of its landing approach, and follows it to the touchdown. A second TV camera on the carrier's superstructure then takes over. Crosshairs on the monitor assist the landing signal officer in talking the pilot down to a safe landing. Minute-by-minute records of time, air speed, wind velocity, and flight number are shown on the dials at the top of the screen. Audio recordings of the conversations between the pilot and the landing signal officer are made on the same tape along with the video information. The tape is a complete record of each landing, day and night.

CHAPTER 15

THE JUNIOR WEAPONS OFFICER

This chapter is not so much the finale to this textbook on "conventional" naval weapons as it is an introduction to the first stage of your probable career in the weapons department of a U.S. Navy ship, regardless of what armament it carries. It introduces to you some of the practical day-to-day details that fill a naval officer's life on board ship. This chapter is principally focused on what you as a junior officer in the weapons department can expect to experience.

In the remainder of this chapter, assume in all cases that we are discussing a surface combatant ship other than an aircraft carrier. Where there's a choice between a large ship and a small one, assume a small one like a destroyer or destroyer escort. (Exceptions will be indicated or apparent from context.)

KNOW YOUR SHIP

Aboard many ships, one of the first things the commanding officer might tell a new officer to do is perform some orientation assignment like locate and map on a large sheet of paper all the watertight doors on the ship or trace certain communication lines. Some commanding officers put new officers through a fairly detailed and time-consuming "geographical" orientation course of this kind. This is not arbitrary. If your CO doesn't tell you to do it when you report aboard, you should do it on your own. You should get to know the ship's layout and characteristics even better than you knew the dwelling you lived in ashore—unless you traced all the plumbing and utility lines at home. This information isn't hard to find. It's in the ship's damage control and general information books, which are available from your department head or the Engineer Officer. You should learn the ship's organization and procedures just as soon as you are able. (You can get these from the ship's organization manual, from the ship's

general information book, from NWP 50, and from other sources that the executive officer or your department head can provide if you ask for them.) Get the ship's tactical data folder and the appropriate NWPs to find what your type of ship, and your particular ship, can and is expected to do.

KNOW YOUR DEPARTMENT

Don't forget the department of which you're a member. Get to know the watch, quarter, and station bill, and the relevant parts of the ship's organization manual on which it's based. If you're assigned to a division in the weapons department, get to know just what material your division is responsible for, and study the Current Ships Maintenance Project (CSMP) file and other ordnance files—and read the log books too—so that you will at least have some acquaintance with the armament aboard. Find out also about the training program—how it works, what records are being kept, the training policies of the weapons officer, the commanding officer, and the executive officer.

There is much more to be said on the points of self-study, initiative, and inspiration than there is space for here. Remember especially that to do your job, you need self-training; for this you need initiative; and if you have initiative, it will seldom be necessary for your superiors to tell you what to do, because you'll know it, and do it.

THE JUNIOR OFFICER

Soon after you report aboard ship the commanding officer will assign you a billet (a job title). If you are assigned to the weapons department, your billet could be anything from a junior division officer to assistant weapons officer. You would most likely be assigned as

a departmental assistant, such as fire control officer. (Other assistants are listed in a later section.) There is a good chance you will be a division officer as well, depending on the number of officers in the weapons department and the organization of the department. (The division officer's responsibilities and the practical aspects of his duties are discussed later.)

By understanding the weapons officer's duties and responsibilities you will better understand your own. Your specific duties may be a portion of the weapons officer's duties or, as assistant weapons officer, you would be involved with nearly all the duties of the weapons officer. In any case you need to understand them eventually so you will be prepared to become the weapons officer yourself some day.

THE WEAPONS OFFICER'S RESPONSIBILITIES

The weapons officer directs activities of the weapons department; advises and assists the commanding officer on weapons operations and problems; directs operation, maintenance, and repairs of all weapons and weapons direction and control equipment; supervises care, handling, stowage, and use of explosives; interprets and applies ordnance regulations and directives issued by technical bureaus and higher command; establishes a weapons department training program, organizing department drills and exercises; ensures performance of deck seamanship operations such as anchoring, mooring, fueling at sea, cargo loading, and care and maintenance of equipment connected therewith; and inspects spaces assigned, including exterior surfaces of the ship, to ensure proper care and maintenance. The weapons officer's responsibilities are also discussed in general terms in chapter 1. In chapter 9 they are discussed with regard to spotting and shore bombardment, and in chapter 14, they are discussed in connection with battle organization.

ORGANIZATIONAL RELATIONSHIP OF THE WEAPONS OFFICER

The weapons officer reports to the commanding officer for the employment and readiness of system (except on ASW aircraft carriers) and deck seamanship equipment. These are operational responsibilities. The weapons officer is

responsible to the executive officer for administrative matters.

Now, how about those directly responsible to the weapons officer? You already know that on most ships the fire control officer is not the only officer assistant that the weapons officer has. The weapons officer can have any or all of the following assistants, depending on the type of ship and its organization:

1. Assistant weapons officer
2. Gunnery assistant
3. First lieutenant
4. Gun battery officer
5. AA control officer
6. Fire control officer
7. Missile officer
8. CO of Marine Corps detachment
9. ASW officer
10. Nuclear weapons officer
11. Warrant officers
 - a. Fire control gunner
 - b. Ordnance gunner
 - c. Missile ordnance gunner
 - d. Missile test and repair officer
12. Division officers

The functions of some of the primary departmental assistants mentioned above are described at length in the following articles. The names give you an indication of their areas of responsibility. Under them are the division officers (though on smaller ships or where the allowance is limited some of the departmental assistants may double as division officers). One of the departmental assistants usually functions as assistant weapons officer when necessary. He has much the same relationship to the weapons officer as the executive officer has to the ship's commanding officer.

FIRST LIEUTENANT

The first lieutenant supervises and directs the deck force in performance of seamanship functions and evolutions; gives direct commands, or delegates responsibility for immediate supervision to the ship's boatswain or petty officers, during various evolutions such as mooring, docking, anchoring, fueling, or transferring personnel and cargo at sea; assigns boats and boat crews in compliance with ship's boat schedule; supervises readiness of boats and survival equipment by frequent inspection, and orders repairs or replacements as required (with the

exception of power boat engines and engine compartments, which are the responsibility of the engineering department); directs preservation of weather decks, ship's exterior, running gear, ground tackle, and bosun's stores; arranges for the training of deck divisions, scheduling drills and classes in deck seamanship, boat handling, and marlinespike seamanship; recommends transfer, reassignment, and promotion of deck personnel; directs the preparation of weekly, monthly, and quarterly reports as required; and maintains files and records for reference by deck divisions.

FIRE CONTROL OFFICER

The fire control officer directs the division of the weapons department concerned with operation, maintenance, and repair of weapons and guided missile weapons control equipment and systems; assigns personnel to operation and maintenance duties on all weapons control equipment and systems; establishes and supervises training programs, scheduling classes and drills; supervises division personnel, administering liberty, leave, and transfer; and approves assignment of weapons control personnel to the watch, quarter, and station bill.

MISSILE OFFICER

The missile officer directs the operation, maintenance, and repair of guided missile installations and associated equipment; establishes and supervises a training program for guided missile personnel, scheduling drills and organizing firing practices; ensures compliance with maintenance and repair instructions; inspects missiles and missile battery, and supervises major repair tasks and alterations; directs operation and maintenance of guided missile launchers, loading systems, and loading/launching control systems; directs assembly, tests, and maintenance of guided missiles and components; interprets current directives from technical bureaus and higher commands concerning guided missile battery doctrine and regulations; and supervises preparation of the required records and reports.

ASW OFFICER

The ASW officer directs employment, operation, and maintenance of all antisubmarine equipment in the weapons department; assists the commanding officer during antisubmarine search

and attack; directs the operation, care, and maintenance of all antisubmarine equipment, including search and attack sonar, fire control equipment, weapons, attack aids, torpedo countermeasures, and underwater communications equipment used in identification and classification of submarines; supervises and trains personnel assigned to the department or to anti-submarine stations in sonar search techniques, submarine contact evaluation, operation of equipment, and antisubmarine doctrine; and advises superior officers on all matters concerning antisubmarine operations.

NUCLEAR WEAPONS OFFICER

The nuclear weapons officer plans and executes maintenance and repair of nuclear weapons, components, and testing and handling equipment assigned; directs and coordinates functions of the nuclear weapons division; directs overall functions of assembly teams; ensures that prescribed quantity and quality of nuclear weapons are maintained; directs a training program within the division; ensures that adequate safety and security measures are carried out; and supervises maintenance of records and preparation of reports required.

THE DIVISION OFFICER'S GENERAL RESPONSIBILITIES

In general terms, the division officer is responsible for carrying out the policies of the commanding officer as amplified by the executive officer and department head. He is responsible under the head of department for the organization, administration, and operations of his division. The division officer reports to the head of department for the performance of his assigned duties. All personnel in his division report to him; if junior division officers are assigned they also report directly to him.

SPECIFIC AREAS OF RESPONSIBILITY

In more specific terms, the division officer's responsibilities can be divided into six main categories:

1. Organizational responsibilities
2. General administration

3. Personnel administration
4. Material responsibilities
5. Training
6. Miscellaneous

In the next three sections we'll discuss practical aspects of these responsibilities.

ORGANIZATION, ADMINISTRATION, AND MISCELLANEOUS

From the six areas of division officer responsibility mentioned in the preceding section, we'll attempt to concentrate on those aspects that specifically involve the weapons department and the ship's armament. This text is primarily concerned with these aspects rather than with those that apply to all departments and officers in general. If we do this, it becomes clear that of the six, the two areas that are most peculiar to the weapons department and the ship's armament are material and training. These two are therefore taken up in detail in the next two sections. In the present section, we discuss, rather more briefly, the four areas which, though important, are also of more general application in all departments, not merely the weapons department. These are: organization, administration, personnel, and miscellaneous responsibilities of the division officer. So far as possible we'll concentrate on the aspects of these areas that are specifically applicable to the weapons department.

DIVISION ORGANIZATION

Figure 15-1 illustrates schematically the organization of a representative fire control division aboard a destroyer (DD).

Many of the elements of this organizational scheme you have seen before. You already know that under the department head are the division officers. The division officer will generally be an ENS or a junior LTJG. If he has a junior division officer it will most likely be a junior ENS. On a large combatant ship (such as a cruiser or aircraft carrier) the division officer will generally be a LT or LTJG assisted by a junior division officer with a rank of ENS or possibly LTJG plus one or two warrant gunners to assist with technical problems of fire control and weapons operation and maintenance.

The leading petty officer in the division is usually a Chief Gunner's Mate, but he may be a Chief Fire Control Technician. The remainder

of the division consists of three watch sections, each under a section leader. Section leaders function as military superiors as well as technical supervisors.

During peacetime, personnel on board are frequently lower in rate than the allowed billets call for. Where the divisional organization chart calls for a chief petty officer, quite often you will find a Petty Officer First Class in the slot. The same holds true all the way down the line. A Petty Officer Second Class often fills the billet of a First Class. Very often you will find strikers performing the duties of a Petty Officer Third Class.

In figure 15-1 the second section is broken down in detail; the other two sections are set up similarly, except that the distribution of rates and ratings is not identical. At times there are not enough crewmen aboard to fill and the allowed billets. Depending on the personnel on board and their qualifications, a billet may be filled by a man with a lower rate or a related but different rating. For example, a Gunner's Mate Second Class may fill a Gunner's Mate First billet or a Fire Control Technician's billet.

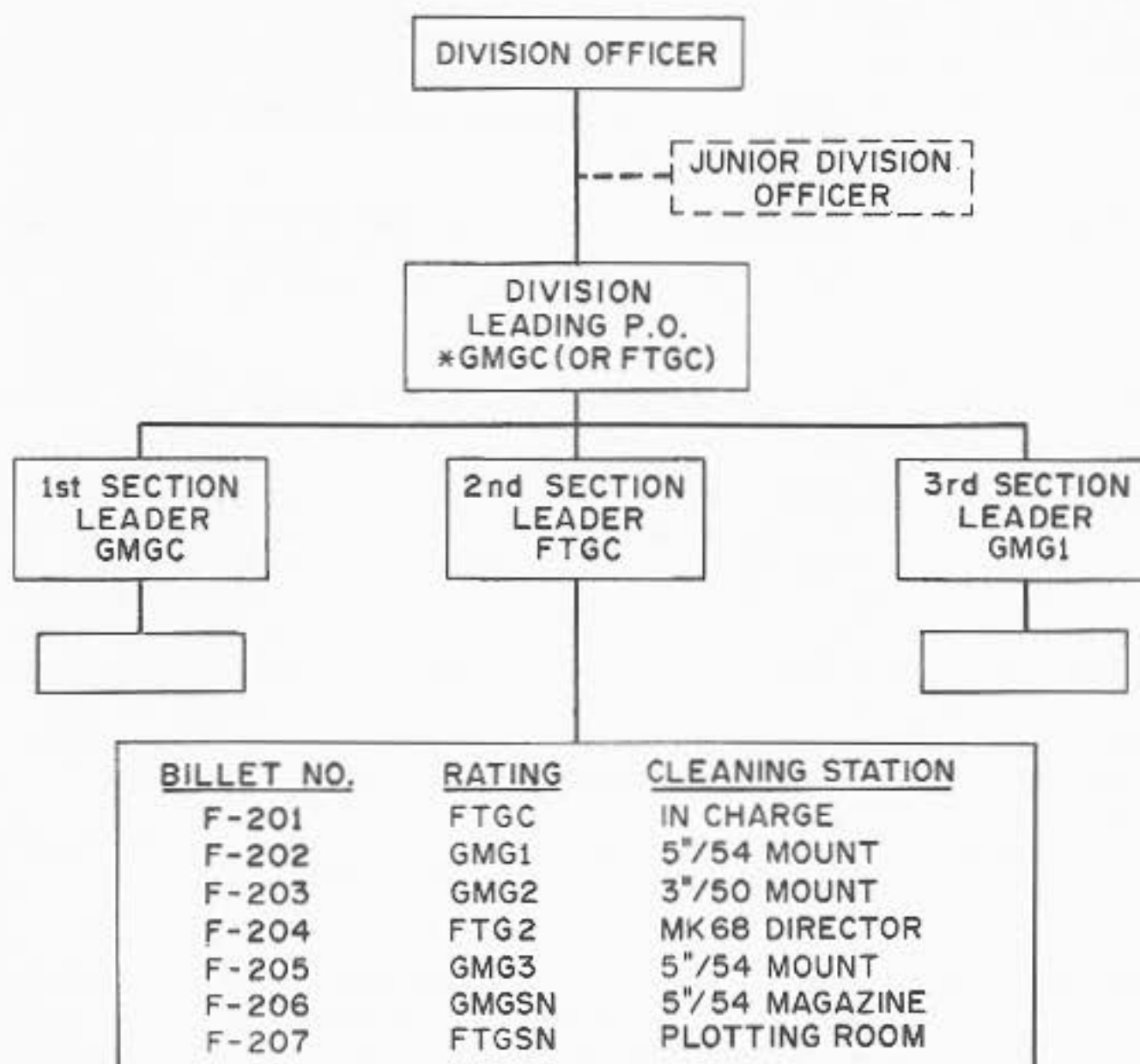
ST1 stands for Sonar Technician 1st Class. Sonar Technician is a rating—the designation of a specific group of specialist. First Class is a rate, corresponding to a pay grade. (The distinction is worth remembering.) The ST1 may supervise a Sonar Technician Striker—a non-petty officer who is in training for ST G or ST S Third Class.

The organizational arrangement of personnel, which is taken from the ship's organization manual and shown on the watch, quarter, and station bill, is used for administrative purposes, including the assignment of personnel to cleaning stations (as shown in figure 15-1). Personnel are withdrawn temporarily from their cleaning stations for specific evolutions covered by ship's bills, which we will discuss next.

SHIP'S BILLS

A ship's bill is the method of establishing assignments of ship's personnel to duties or stations for the purpose of executing specific evolutions or accomplishing certain functions. In general, a bill includes the following information:

1. Statement of purpose
2. General information
3. Assignment of responsibilities



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Figure 15-1. — Representative organization of F division aboard a destroyer.

4. Statement of organization
5. Assignment of personnel
6. Procedures

Bills are classified as:

1. Administrative
2. Operational
3. Emergency

Since all officers must be familiar with the ship's organization manual, they must be acquainted with all the ship's bills, even those for which they have no direct responsibility. Table 15-1 gives a partial list of the bills used on a typical destroyer along with the title, purpose, and organizational designation of the officer responsible for preparing it.

SHIP'S PROCEDURES

Like bills, the term procedures also has a special meaning in this context. A procedure is a written statement of a series of coordinated steps by an organizational unit for the accomplishment of a specific function. Shipboard procedures are classified under one of the following categories:

1. Personnel
2. Accountability
3. Operating

Personnel procedures include such matters as disciplinary measure, leave and liberty, petty officer evaluation, training, how to deal with visitors, the handling of U. S. mail, etc. Accounting procedures cover such matters as

Table 15-1.—Summary of Ship's Organizational Bills

BILL	PURPOSE	RESPONSIBILITY
	To establish procedures and assign duties for:	
Personnel Assignment Bill.	Assignment or reassignment of officers and enlisted men to billets within departments and divisions of the ship.	Executive Officer.
Berthing and Locker Bill.	Assigning berthing and locker facilities.	Executive Officer.
Cleaning and Maintenance Bill	Maintenance, preservation and cleanliness of the exterior and interior of the hull, hull fitting, machinery, and equipment.	Executive Officer.
Special Sea Detail Bill	Getting underway and returning to port.	Navigator.
Replenishment at Sea Bill	Fueling, rearming, provisioning, or transferring personnel at sea.	First Lieutenant.
Rescue and Assistance Bill	Rendering emergency assistance to persons or activities outside the ship.	Engineer Officer.
Landing Party Bill	Conducting limited field operations, policing during an emergency, and participating in parades and ceremonies.	Weapons Officer.
Visit and Search, Prize Crew, and Boarding and Capture Bill	Investigating, salvaging, and taking possession of another ship.	Operations Officer.
Towing Bill	Towing or being towed by another ship.	First Lieutenant.
General Emergency Bill	Controlling the effects of a major emergency or disaster suffered by the ship, such as collision, grounding, internal or external explosion, nuclear contamination, earthquake, storm or battle damage.	Engineer Officer.
Man Overboard Bill	Recovering one man or a small number of men from the water.	First Lieutenant.
Nuclear, Biological, and Chemical (NBC) Defense Bill	Provide an organization, prescribe procedures, and assign responsibilities for proper and effective action when involved in NBC warfare or in NBC weapon accident situations.	Engineer Officer.

material inventories and surveys, and accounting for mess, welfare, and recreation funds. Most of these are set forth in chapter 9 of NWP 50(A), Navy manuals on correspondence and filing, and OPNAV and SECNAV instructions.

Table 15-2 is a partial list (with references) of representative operating procedures aboard a destroyer.

MISCELLANEOUS (COLLATERAL) DUTIES

Besides the assigned departmental duties and the regular military duties of the division officer (such as underway watches, in-port watches, and GQ assignments), all officers are assigned collateral duties (secondary duties). These include serving on committees and boards (such as the audit board, the recreation committee, courts-martial boards, and officer candidate examining boards) and performing some special

function such as intelligence officer, photographic officer, classified material control officer, or legal officer.

On a destroyer a division officer might expect on the average to have two or three such collateral assignments. On ships with more personnel, like cruisers and carriers, some of these duties (such as legal officer or education officer) may be assigned as primary duties.

MATERIAL

As a junior officer assigned to the weapons department, much of your daily activity will be concerned with the material readiness of your division. The complexity of modern naval weapons requires a program of constant testing and maintenance to ensure system operability. The Navy's material management program is centered about the Navy Maintenance and Material Management (3-M) System. The 3-M System, a relatively new maintenance program, can be

Table 15-2. — Shipboard operating procedures

TITLE	REFERENCES OTHER THAN FLEET AND TYPE DIRECTIVES
Jettison procedures	Chapter 9, NWP 50(A)
Strip ship procedures	Chapter 9, NWP 50(A)
Scuttling the ship	Chapter 9, NWP 50(A)
Emergency destruction of classified matter	Chapter 9, NWP 50(A)
Steering casualties	Chapter 9, NWP 50(A)
Operations with helicopters	NWIP 41-6
Fog navigation	Chapter 9, NWP 50(A)
Darken ship procedure	
Security against sneak attack procedure	
Repel boarders procedure	
Dry docking procedures	(a) BuShips Manual Chapter 7 (b) USNR 1948 Articles 0749, -790, 0791, and 2030
Mediterranean moor procedure	
Small boating procedure	

a source of difficulty for those who do not understand its function and operation. Several books that explain the intricate details of the system are available. However, because of its importance in the management of the shipboard ordnance organization, let us take a look at the 3-M System to see how it relates to a junior officer in the weapons department and review some of the documentation used in weapon maintenance.

ADMINISTERING THE MAINTENANCE PROGRAM

By definition the 3-M System is "a shipboard management system which, when fully implemented and properly used, provides for (1) orderly scheduling and accomplishment of maintenance, and (2) reporting and disseminating of maintenance-related information." Simply stated, the system is a tool with which maintenance personnel manage their resources. What are resources? As a maintenance manager you have three resources—men, material, and time. Any maintenance action will require the use of all three. You must have the material on which, or with which, to perform the maintenance, and you must have men with a given amount of time to do the job.

Planned Maintenance Subsystem

To be an effective manager, you will need some means of planning, scheduling, and managing the use of your resources. This idea of scheduled maintenance is not new. A look at the plan of the day from one of our revolutionary war frigates would show a time set aside for "exercising the crew at quarters" (general quarters drill). It was during these drills that the guns were checked to ensure they would fire if needed.

This action is called planned preventive maintenance, a maintenance action performed to locate potential trouble spots, and is the Planned Maintenance Subsystem (PMS) portion of the 3-M System. This type of maintenance reveals troubles while they are small and easily corrected, before they develop into major casualties. The PMS provides for three actions: planning, scheduling, and management. PMS material, such as work schedules, maintenance cards, and other maintenance documentation, provides Navy-wide

maintenance standards based on engineering experience and prescribes procedures and techniques for accomplishment of maintenance. The tools of the PMS are discussed in detail in OPNAV publication 43P2.

Maintenance Data Collection Subsystem

If you managed a civilian business, you would need records to document the usage of your resources. These records would provide you with information to use in improving your business operation. The operation of your Navy requires a tremendous "maintenance business." To analyze how our three resources are spent—and thereby improve the operation of our naval arsenal—we must have records that will indicate the performance of our equipment and the use of men, material, and time. This record is achieved with the second portion of the 3-M System called the Maintenance Data Collection Subsystem (MDCS). The MDCS provides a means of recording the expenditure of our resources associated with minor corrective maintenance, major repairs, and authorized alterations to equipment. It also provides a method for processing maintenance action and logistic information and disseminating this data for use by activities concerned with the management of naval material.

HISTORY OF MAINTENANCE PROGRAM

Operation of the 3-M System as related to weapons can be better understood by examining the different maintenance documentation associated with weapons and by reviewing the history of the system's development.

Little maintenance documentation was needed with the preventive maintenance system used in the days of the sail. Weapons were simple, and parts used for repairs were obtained from the local economy. As more complex weaponry came into use, better documentation was required. The Bureau of Ordnance (forerunner of the Naval Ordnance Systems Command) began to develop and publish ordnance pamphlets (OP's) which described the operation of various weapons. The books became known as OP's and were eventually assigned numbers which identified the OP to a particular weapon or

subject. Ordnance data sheets (OD's) also were issued, giving some of the specifications, and engineering data of different equipments.

Ordnance Pamphlets

OP's written prior to the 1950's contained very little information concerning preventive maintenance. These books usually had three major sections: (1) Introduction, (2) Theory of operation, and (3) Maintenance. One of the OP's from this period concerned the 8-inch, Triple-Gun Turret. In the electrical system maintenance section the only preventive maintenance described was a periodic check of the wiring for looseness, moisture, and chaffing. This was not much, considering the amount of electrical machinery in an 8-inch turret. No schedule was given as to when this maintenance should be accomplished. As weapons became more complex, OP's and OD's were improved. The OP's that were published in the 1940's contained checklists to be followed when preventive maintenance was performed.

Ships Maintenance Program

The Navy began to document and record maintenance actions during this period and a maintenance program called the Current Ships Maintenance Program (CSMP) was brought into operation. The CSMP did not describe how or when a maintenance action was to be accomplished. As maintenance supervisors determined that a maintenance action was necessary, entries were made to that effect on a card and were filed in a loose leaf binder. When the action was accomplished, the card was removed and destroyed after the maintenance action was recorded on the permanent CSMP record (ordnance history cards for weapons equipment). This system lacked good scheduling and allowed for little planning ahead, except for major repairs and overhaul. Routine day to day maintenance was accomplished in whatever manner the petty officer in charge of the equipment thought best.

Satterwhite System

Different bureaus of the Navy Department tried different maintenance programs. One, instituted by the Bureau of Ordnance, was developed by a Chief Fire Controlman named Satterwhite. This system, known as the Satterwhite

System of Maintenance, was designed to ensure that adequate preventive maintenance was accomplished daily, weekly, monthly, or as often as necessary on the Mk 56 Gun Fire Control System. Complete, easy to understand instructions were provided for each step of the maintenance action along with a list of tools and the number of men required. The Satterwhite system also provided for recording the maintenance performed, but only at the local level. CSMP cards were still used for permanent records.

Integrated Maintenance Plan

Along with the different maintenance programs adopted by the various Bureaus, Fleet Commanders published some maintenance instructions. Since these were published at the fleet level, several different maintenance programs could be found in effect on the same type of equipment. In the early 1960's the complexity of the Navy's surface missile systems required that a standard maintenance plan be put into effect for all fleets. The Bureau of Naval Weapons (another forerunner of the Naval Ordnance Systems Command) attempted to standardize the maintenance of all surface missile systems by issuing the Integrated Maintenance Plan (IMP).

The IMP was to achieve better operability through better maintenance documentation. Complete testing procedures, engineering information, and troubleshooting techniques (along with a scheduled preventive maintenance routine) were made a part of the IMP documents. Special OP's were published with more emphasis placed on maintenance and less on theory of operation. In addition to the standard OP number, these documents also carried the letters "IMP" to identify them as Integrated Maintenance Plan documents.

One of the most significant advantages introduced by IMP was the establishment of Daily Systems Operability Tests (DSOT). Prior to IMP, individual units of a weapon system were checked daily for proper operation (e.g., computer, radar, director, and gun), but dynamic operation of the entire system was not usually monitored. DSOT checks overall material readiness by monitoring the operation of all equipments of the system functioning as an integrated unit. The DSOT method of checking system performance has been incorporated in the 3-M system.

THE 3-M SYSTEM

Weapons department personnel were not the only ones having maintenance problems. All departments having maintenance-related responsibilities were finding maintenance of the new ships of the 1960's more complex. A Navy-wide system of planned maintenance and maintenance documentation was needed. In the mid-1960's the Chief of Naval Operations placed into effect the 3-M System, to be used by all departments, aboard all ships, in every fleet.

The 3-M System is intended to assist Navy operational and technical commanders (and division officers) in attaining and maintaining optimum fleet readiness through the efficient and effective use of available resources. Specific objectives of the system are to:

1. Define and achieve uniform maintenance standards, criteria, and procedures.
2. Assist operating forces (a) by promoting effective utilization of available manpower, material, and maintenance opportunities and (b) by reducing the total administrative burden on maintenance personnel.
3. Document the requirements for and the accomplishment of maintenance and the utilization of maintenance resources.
4. Increase knowledge of current ship's configuration and identify desirable changes to existing configuration or improvements in new ships design through information gained by documentation of maintenance actions.
5. Improve maintainability and reliability of equipments.
6. Accurately identify the cost of maintenance in terms of manpower, material, and funds, and minimize these cost through management effectiveness.

With the innovation of the 3-M System, OP's are being revised to conform to 3-M requirements. Most of the OP's associated with surface missile systems have been revised and are now labeled PMS/SMS (Planned Maintenance System/Surface Missile System). Some IMP publications are still available but most have either been included in or superseded by PMS/SMS documents. OP's for some gun systems are being revised to conform to 3-M requirements. Special subject OP's (such as safety precautions, ammunition handling, and other nonmaintenance subjects) are unaffected by 3-M. The Index to Ordnance Publications, OP O, contains a listing of all OP's and OD's showing current status

(superseded, canceled, PMS/SMS, etc.) and availability. Any of the publications we have mentioned can be used as an aid in meeting PMS requirements. Where there is a difference between stated requirements of the PMS and other technical publications (OP's), the PMS requirements prevail.

The 3-M System is not a cure all for maintenance and does not diminish the need for good management and leadership. Neither is it a passive system. It cannot succeed without active, aggressive supervision at all levels, from operational commander to the workcenter supervisor. As division officer (or junior division officer) you must take the initiative and ensure that all requirements of the 3-M System are met.

Maintenance Organization

In order to derive maximum benefit from the 3-M System, the aggressive type of positive leadership must be built into the ships organization. While there is no single master plan which will ensure optimum effectiveness in all classes of ships, there are certain organizational concepts and responsibilities which must be adopted by every ship in which the 3-M System is installed. Let's review these basic responsibilities as outlined in OPNAV 43P2.

COMMANDING OFFICER.—The Commanding Officer is responsible for ensuring that ship's maintenance is accomplished in accordance with the procedures of the 3-M System, and that the system functions effectively within his command. He will make certain that all appropriate personnel receive adequate 3-M training and meet with the Executive Officer, 3-M Coordinator, and other maintenance managers to review the status of material readiness, discuss 3-M matters, and provide necessary guidance and coordination.

EXECUTIVE OFFICER.—The Executive Officer is responsible to the Commanding Officer for the overall organization and operation of the ship's 3-M program. He provides the overall supervision and coordination required to ensure system effectiveness. To accomplish these goals he acts as chairman for periodic 3-M meetings with department heads and the 3-M coordinator to review and monitor 3-M operation. He drafts ships directives concerned with 3-M and ensures that all departments comply with these instructions. In addition, he

coordinates incorporation of 3-M training into the ship's training program and establishes an effective program for assigning job control numbers and for filing MDCS information.

THE 3-M COORDINATOR.—The 3-M coordinator is responsible to the Executive Officer for coordination and direct supervision of all facets of the ship's 3-M program. Where personnel resources permit, this will be the primary duty of an officer or senior petty officer who has had formal training in 3-M. The 3-M Coordinator works with the various department heads and department 3-M assistants to ensure that the effectiveness of the ship's 3-M program is maintained.

DEPARTMENT HEAD AND DEPARTMENTAL 3-M ASSISTANT.—Each department head is responsible for the effective operation of the 3-M System within his department. As an aid to managing his 3-M responsibilities, the department head will assign an officer or competent petty officer the duty of departmental assistant. Both should be formally trained in 3-M. Unless otherwise directed by Fleet or Type Commander, the department head must personally supervise all cycle and quarterly scheduling of departmental maintenance and ensure proper supervision of other departmental 3-M functions, as follows:

1. Regularly inspect the 3-M operation within the department, including weekly review of the departmental maintenance control board.
2. Emphasize to the personnel of his department the importance of properly scheduled maintenance and the proper documentation of the maintenance performed.
3. Ensure departmental personnel are properly trained and motivated concerning the 3-M System, and that departmental 3-M training records, files, and publications are properly maintained.
4. Conduct periodic meetings with division officers and work center supervisors to ensure continuing knowledge and necessary coordination, in 3-M matters.
5. Assist division officers and work center supervisors as necessary in obtaining 3-M supplies and scheduling weekly maintenance.
6. Personally sign cycle and quarterly schedules prior to posting.

SUPPLY OFFICER.—The supply officer will coordinate the efforts of his department to best support the ship's maintenance effort.

DIVISION OFFICER.—The division officer is responsible to the department head and should be formally trained in the 3-M System. He will assist the department head in scheduling maintenance required for the equipment under his cognizance as follows:

1. Ensure, by daily inspections, that weekly schedules are in accordance with the departmental quarterly schedule and the required maintenance is being properly performed and reported
2. Incorporate 3-M training into the divisional training plan and maintain up to date 3-M training records for his division
3. Ensure that MDCS documents generated within his division are complete, accurate, and promptly submitted
4. Assist the 3-M Coordinator as necessary in all matters concerning 3-M within his division
5. Conduct periodic meetings with all divisional work center supervisors and keep the department head informed of the status of 3-M within the division

WORK CENTER SUPERVISOR.—The Work Center Supervisor is responsible to the division officer for the effective operation of the 3-M System within his work center. He shall have received formal 3-M training, and his duties shall include the following:

1. Personally schedule weekly work center maintenance and supervise its proper accomplishment
2. Ensure status-of-work center maintenance is correctly reflected on the departmental maintenance control board
3. Ensure division officer or department head is advised concerning inability to complete scheduled maintenance, and any other problems in 3-M operation
4. Maintain an adequate supply of 3-M materials within the work center
5. Ensure that all required MDCS documents from his work center are correct and promptly submitted
6. Ensure maximum use of the 3-M System as a training aid within the work center, and ensure that such training is properly reflected in the training records
7. Maintain control and accountability of JSNs (Job Sequence Number) within the work center

MAINTENANCE PERSONNEL.—Maintenance personnel are directly responsible to the work center supervisor. Their duties include (but are not limited to):

1. Reading the weekly schedule and performing PMS actions as scheduled each day
2. Being knowledgeable in the procedures for filling out maintenance action documents
3. Informing work center supervisor of completed PMS actions and any problems encountered in performing them

In order to perform your duties related to 3-M you must work closely with the department head and work center supervisor and assist them as necessary in scheduling the work of your division. Let's discuss some of the 3-M items you should become familiar with in order to carry out these duties.

3-M TOOLS

The Planned Maintenance System Manual is a publication used primarily by the department head in planning and scheduling maintenance for his department. A table of contents for each maintenance group within the department is included along with a page for each system, subsystem, or component within the maintenance group. Also, the manual contains a brief description of the maintenance requirements and the frequency with which maintenance is to be effected for all components and equipment. The frequency code is: D-daily, W-weekly, M-monthly, Q-quarterly, S-semiannually, A-annually, C-overhaul cycle, R-situation requirement. The manual contains index pages (group maintenance manual) for each maintenance group within the department—engine room, fireroom, electrical, and auxiliary. Manuals are compiled individually for each ship, thereby assuring a tailored system.

CYCLE SCHEDULE.—The cycle schedule is a visual display of preventive maintenance requirements based on an overhaul cycle. All the maintenance items listed in the cycle schedule are within the capabilities of ship's force for onboard equipment.

The cycle schedule contains a list of components for each maintenance group. It schedules the semiannual, annual, and overhaul cycle maintenance requirements based on quarters after overhaul. The cycle schedule also lists the quarterly and monthly requirements that must

be scheduled each quarter. The department head uses the cycle schedule in making out the long-range or quarterly schedule.

QUARTERLY SCHEDULE.—The quarterly schedule is a visual display consisting of two identical quarterly schedule forms. One is for current quarter; the other is known as the subsequent quarterly schedule. The cycle schedule and both quarterly schedule forms are contained in the same visual display holder and correspond, line for line. The entire display is called the maintenance control board. The control board shows the overall preventive maintenance program for the department. The control board usually is located outside the department head's office.

WEEKLY SCHEDULE.—The weekly schedule is another visual display for use in connection with the PMS. It is posted in each maintenance group's work area, along with a copy of applicable pages from the PMS manual. For example, a weekly schedule that applies to maintenance of equipment in a certain area is posted in that area's fire control radar room.

The weekly schedule assigns specific personnel, by name, to perform specified maintenance tasks on particular components on a definite date. Listed on the weekly schedule are the components that are the responsibility of a particular maintenance group. The weekly schedule is used by the supervisor of the working area to assign work and to record the completion of work.

MAINTENANCE REQUIREMENT CARD.—The maintenance requirement card (MRC) is a card, 5 inches by 8 inches in size, on which the preventive maintenance task is defined in sufficient detail that assigned personnel can perform the task without difficulty. Each maintenance requirement card lists rating and rate level of personnel who should perform that particular task; safety precautions that must be observed; the time, tools, parts, and materials required for the task; and detailed procedures for performing the task.

MDCS DOCUMENTS.—In addition to the various schedules and MRC cards there are certain MDCS documents with which you should be closely acquainted. These include: requests for material, manhour accounting documents, work supplement cards, and maintenance data forms. The exact use of these documents will vary from ship to

ship. All are described in the Maintenance and Material Management Manual, OPNAV 43P2.

Perhaps the most important of these MDCS documents is the Maintenance Data Form. This is a multipurpose form used to report maintenance-related actions. Basically, it can be used for three purposes:

1. To report routine maintenance action by work center personnel
2. To report maintenance that has been deferred for various reasons, such as lack of parts or need for outside assistance
3. To request the assistance of a tender, shipyard, or other activity

When used to report maintenance accomplished by work center personnel, the Maintenance Data Form is submitted to the ship's Maintenance Data Collection Center (usually maintained by the 3-M coordinator or engineer officer). This form will then be used to submit a composite ship's maintenance report to a Navywide Maintenance Data Collection Center (MDCC).

If a maintenance action must be deferred for some reason, the Maintenance Data Form is submitted in a manner similar to the completed action just described. One portion of the form is retained on board for subsequent documentation of additional data, while another portion is forwarded to the Navy MDCC. When the defined maintenance is finally completed, or is canceled, work center personnel inform the ship's MDCC which will forward appropriate forms to the Navy MDCC.

The Maintenance Data Form can also be used as a work request. The work request is primarily intended for requesting assistance in accomplishing maintenance actions; but it is also used to request services or assistance not directly related to maintenance, such as diving and utility services. After the work request has been screened by the division officer and department head, it is submitted to the ship's MDCC for inclusion in the ship's work package. High priority work requests will receive immediate attention, but a major portion of the work requests are held for a regularly scheduled yard (shipyard) or tender (repair ship) availability.

Most commanding officers and most weapons officers take pride in how much work the ship's force can do without formal aid from tender or shipyard. The more maintenance work the ship's force can do (and this includes repairs and

alterations as well as upkeep), the better condition the ship and its equipment will be in, the better the crew will know the ship and its equipment, and the lower will be the cost. But there are things that the crew cannot do while a ship is in active operation at sea; so periodically, every ship has a yard or tender availability period.

YARD AND TENDER AVAILABILITY PERIODS.—Yard and tender availabilities are not an every-Monday-and-Thursday affair. Attack carriers, for example, ordinarily will run about two years between overhauls. This means that every big repair and alteration job **MUST** be taken care of during the availability period. (It is well to note at this point the difference between a repair and an alteration. A repair is work necessary to restore a ship or article to serviceable condition without change in design, materials, number, location, or relationship of the component parts; an alteration is any change in the hull, machinery, equipment, or fittings which involves a change in design, materials, number, location, or relationship of component parts of an assembly regardless of whether it is undertaken separately from, incidental to, or in conjunction with repairs.) Shipyards and tenders are busy places and always have plenty of work. Once the availability period is over, the ship cannot come back a day or two later because some job wasn't completed or was overlooked in the hubbub. Thus, a good deal of careful preparation is necessary well in advance. One part of this preparation is inspection by the Navy's highest inspection authority—the Board of Inspection and Survey. This Board conducts acceptance inspections and trials of new ships. It also inspects active ships every three years to determine the state of their maintenance, and it recommends any alterations that may be necessary. And there are other inspections, such as the arrival inspection made by yard engineers whenever your ship arrives at a naval shipyard for overhaul.

The main part of preparation rests with the ship's personnel. It begins with compilation of a work list. The work list is made up of work requests. The division officer and leading petty officers draft the requests, and from them a work list is made. Several weeks before the ship arrives at the yard or tender, the commanding officer holds a conference of department heads, and at this conference the weapons officer adds his requests to the list that will be submitted to the yard or tender, via the type commander.

The list includes also the items discovered by the inspections made shortly before the availability period is scheduled to begin.

If possible, shipyard estimators and engineers inspect the ship in a prearrival inspection before the ship enters the yard. When the ship arrives at the yard there are conferences between the department heads and the shipyard representatives to determine just which jobs will be done, and how. Or, if the ship has come some distance, the preoverhaul inspection becomes an arrival inspection that is done while the arrival conferences are going on.

The yard or tender availability period is a time when a great deal of work can be done that is impractical or inadvisable to try to do (except in an emergency) when the ship is fully operational. This doesn't mean getting the tender or yard to do ship's force work. If the weapons officer is one of the many that take justifiable pride in the self-reliance of their crews in such matters, this would not improve your reputation with him. But you can get assistance from yards and tenders on ship's force jobs. Sometimes their maintenance and repair personnel work up special time-saving jigs and tools for specific operations. If you can, it is wise to take advantage of these during the availability period.

In naval shipyards the formal line of contact between the yard and a ship is through the engineer officer of the ship and the ship superintendent assigned by the yard to your ship during the availability period. The weapons department's line of contact to a ship is by way of the weapons officer, the engineer officer, the ship superintendent, and the shopmaster of the shop concerned.

Tenders are also organized into departments, but the setup is different. The weapons officer's contact would be the ordnance repair officer in the tender, and the division heads on the ship have direct contact with the divisions on the tender that they have business with (such as the machine shop, optical shop, fire control shop, and so on). Some tenders also use a ship superintendent similar to the shipyard's.

SHIP ARMAMENT INVENTORY LIST

Another important document concerned with material is the Ship Armament Inventory List (SAIL). The SAIL, which is produced on data-

processing equipment, indicates a ship's ordnance inventory and Ordnance Alteration (OrdAlt) status. It lists in sequence the following: all items pertaining to missile launchers, turrets, mounts, rocket launchers, projectors, torpedo tubes, and depth charge release equipment; all items pertaining to fire control equipment, target designation systems, and weapons direction systems; all items pertaining to missile test and telemetering equipment; and all items pertaining to target control systems.

Each ship has two copies of the SAIL. Prior to a scheduled overhaul, one copy should be annotated with OrdAlts that have been completed since the last printing; this copy should be sent to NavOrd about seven months prior to the scheduled availability. The other copy is kept on board. After the availability is completed, the SAIL is annotated to indicate all changes, deletions, additions, and corrections, and a copy is forwarded to NavOrd. Changes made at other times are reported on the SAIL Change Report, NavOrd Form 8000/2.

TRAINING

In any department on board ship no factors affect performance more than the efficiency and spirit of its personnel. The efficiency and spirit of the personnel depend heavily upon training. Training starts at the lowest level, goes right up to the highest, and is never finished. At all levels it must be a continuous, progressive, and challenging process, designed around realistic problems and situations, and intelligently handled to create and maintain interest and enthusiasm.

All this applies as much, if not more, to the weapons department as to any other. One of the duties of the weapons officer is the supervision and direction of the employment of ordnance equipment. It is the junior officer's duty to implement this program by proper training of personnel. There are several requisites for an effective training program. The junior officer must be completely familiar with the ordnance equipment for which he is responsible. This includes not only operating procedures, but theory and design characteristics as well. He must ensure that petty officers and other key personnel, who will conduct instruction on station, are themselves competent and well informed. The junior officer must carefully appraise his men and assign them stations in accordance with their capabilities, both mental

and physical. Some information can be obtained from each man's service record, which is available in the ship's office. The division officer should supplement this with a division notebook—which should contain detailed data on each man in the division—as well as a copy of the division watch, quarter, and station bill.

Finally, the junior officer cannot neglect his own training. He must apply himself continually and learn not only his job but the jobs of those who are immediately senior to him.

THE NAVY'S TRAINING PROGRAMS

The Navy has many training programs. One of them is concerned with your studying this book right now. To the division officer aboard ship, the important programs can be considered in three categories:

1. Team training programs for the ship's personnel
2. Individual training programs for enlisted personnel
3. Individual training programs for commissioned officers

Team training programs are those in which groups participate for group training. There are more varieties of team training programs than can ever be summarized here. They range all the way from fleet maneuvers including thousands of men and scores of ships and aircraft, to loading drill practice in which only three or four men are participating.

Individual training programs may actually involve group study and instruction, but are concerned with teaching the individual.

The Navy's training programs are not confined to schools—even special Navy schools—though the Navy does make use of schools. To get a quick picture of the Navy's training programs, let's trace briefly through the training of an enlisted man, then that of an officer. In reading both of these discussions, bear in mind that we are here particularly concerned with what you may expect to encounter aboard ship in the weapons department. Do not consider these brief summaries as a complete exposition of the whole picture.

CAREER OF AN ENLISTED MAN

Training of an enlisted man starts soon after induction. When he's inducted, he's a Seaman Recruit (SR). This is the bottom of the ladder. He goes to boot camp (more formally known as recruit training school), where he learns the basics of Navy life. In boot camp, the SR is not only trained, but tested and screened. He takes intelligence tests, test of ability to use numbers, mechanical and other aptitude tests, interviews, etc. Then he's evaluated and screened on the basis of these tests, and this to a considerable degree determines his career in the Navy. For example, the scores on his tests determine whether he is eligible to try for certain ratings. Electronics Technician and Fire Control Technician strikers, to specify two such ratings, must have passed their tests with relatively high minimum scores in general intelligence, ability to handle numbers, and mechanical aptitude.

It's at this stage also (if it hasn't been done before) that a recruit is shunted into the particular branch he's interested in and qualified for, such as seaman apprenticeship, construction apprenticeship, or medical apprenticeship, to mention a few. As he rises in any of these fields, he becomes more specialized. Recruits with especially favorable test scores and backgrounds may at this stage be "designated" for even greater specialization. Thus a recruit with experience in precision machinery or electronics, and good intelligence and mechanical aptitude scores may go direct from boot camp to specialized "class A" school from which he graduates as a "designated striker" to be assigned to the weapons department as soon as he reports on board ship.

More frequently, however, the recruit when he emerges from boot camp has been advanced to apprentice (Seaman Apprentice or SA, if he's been assigned in that branch) and is sent to a ship, where he becomes part of the deck force. (On a destroyer, this would be the first or second division.) After several weeks or months of observing him, his division officer and the petty officers immediately over him can fairly accurately appraise his career potentialities, and he can be transferred from the deck force to some group in which his talents and interest can be best employed. After 6 months as an SA he can take a written test, which is given by the ship, to become an SN, assuming he

meets all other requirements. He can become a designated striker as an SA or SN provided he meets all the requirements.

To get the rate he's striking for, the candidate for advancement to petty officer third class must:

1. demonstrate that he can actually perform the practical requirements of the rate as evidenced by the Record of Practical Factors, NavPers 1414/1.

2. successfully complete the required military and professional correspondence courses. If required, the striker must also have attended a service school (more about this later).

3. pass a written servicewide examination on the technical aspects of the rate and rating he's striking for and on the military requirements for the rate.

4. be recommended for promotion by the ship's commanding officer. In effect, this is the equivalent of saying that he must be considered qualified by his supervising petty officers (PO's) and have been recommended by his division officer.

5. have been in grade and in the Navy the required minimum time.

BuPers directives promulgate all these requirements in detail. The list above is only an abbreviated review.

The striker's chances for advancement depend on his examination score (item 3 above) and other factors such as length of service, proficiency marks, and awards, which all together determine his score total. If he has a passing mark, this can qualify him for advancement to petty officer third class for the particular specialty (rating) he's striking for, but he isn't automatically moved up to this rate. Instead, the names of all those who took the examination are arranged in the order of their standing, and those highest in the list are advanced until the Navy's requirements for this particular rate and rating are satisfied.

The advancement of petty officers continues step by step (no skips permitted) in this general pattern through all the grades up to the highest (Master Chief Petty Officer). It is worthwhile for the division officer to remember that many an able man can fully qualify for advancement but not actually be advanced, simply because in his rating there are fewer available billets than qualified candidates for advancement.

Although the top of the enlisted ladder is Master Chief, it is well to note that certain

qualified enlisted personnel may enter the officer ranks through programs such as Warrant Officer, NESEP, NROTC, OCS, and the Naval Academy (fig. 15-2).

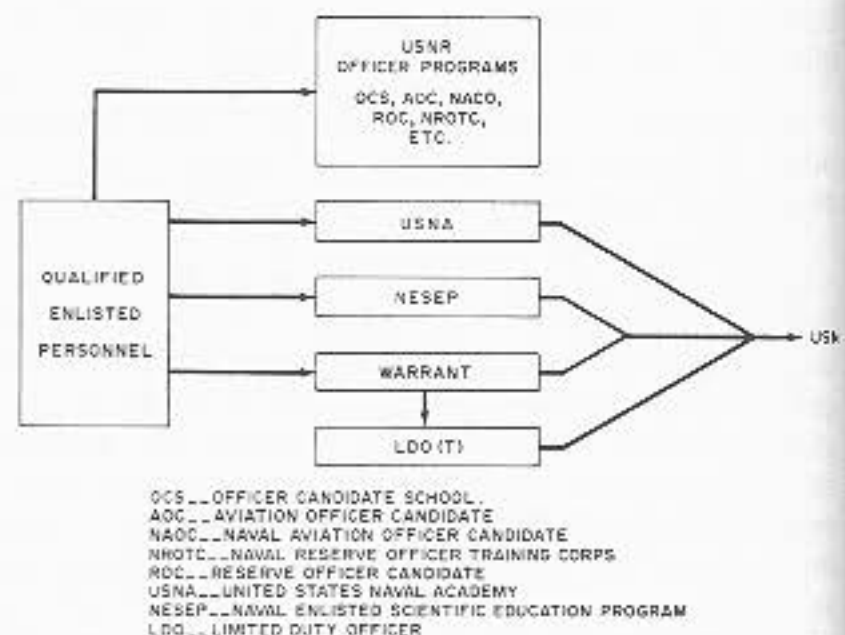
CAREER OF AN OFFICER

Let's now glance briefly at how an officer rises in the ranks. In contrast to the picture in the preceding article, where in a sense you're outside of the frame of reference, you're right in the middle of this one.

For an officer, the bottom of the ladder is the rank of ensign. Some attain this rank from (as the preceding section pointed out) enlisted or warrant status, by way of OCS (Officer Candidate School). Others are Naval Academy graduates or NROTC or other college officer training graduates.

We won't go into the details of the complex machinery of officer promotion, but you probably know already that an officer is selected (i.e., declared eligible) for promotion before actually being promoted. To ensure himself of actual promotion, a selected officer must be prepared for it. Aside from the obvious matter of knowing his job and doing it so that it will do him credit, he must also train himself systematically, so that he will be ready for promotion when it looms ahead. Here are some aspects of this training preparation.

1. CORRESPONDENCE COURSES. United States Armed Forces Institute (USAFI), Navy,



110.166
Figure 15-2. — Enlisted-to-officer programs.

and other correspondence courses are recommended for all officers to help prepare themselves for advancement and to broaden their knowledge. This is not a requirement for advancement, however it may influence the selection board (LT and above) favorably if an officer has completed some correspondence courses. Both the fleet and the Bureau of Naval Personnel have correspondence courses available. Fleet administered courses prepare the student for specific officer assignments, such as officer of the deck, weapons officer, and communications officer. BuPers administered courses take up technical subject areas such as military justice, naval engineering, damage control, and the like. It's best for an officer to take courses voluntarily, but his commanding officer may require him to take certain course—for example, if the ship hasn't enough navigators, you may be required to take the navigator course so that you can qualify without delay and alleviate the shortage. Since in normal practice an officer can take only one course at a time, and completion of a course may take a year or more, it is clear that a career-conscious officer must plan far ahead—even if he is an ensign and his name is not scheduled to go before a selection board for promotion. BuPers publishes lists of Navy correspondence courses. USAFI publishes lists of correspondence courses with subjects at both high school and college levels, and a list of correspondence courses available from civilian colleges and universities cooperating with USAFI.

2. POSTGRADUATE COURSES. The Navy has arrangements for officers with some experience to take postgraduate training on college campuses (which may lead to a degree) or at the Navy postgraduate school at Monterey, California.

3. OTHER NAVY SCHOOLS. The Navy has other officer training courses on specific subjects such as damage control or defense against nuclear, bacteriological, or chemical (NBC) attack. These are generally much briefer than the first two types of courses mentioned above, and are offered by BuPers.

The next section in this chapter will indicate the self-training and orientation that the junior officer should consider himself responsible for when he first reports aboard his ship.

SHIPBOARD TRAINING

Now let us see how the Navy's training programs fit into the Navy career patterns. Both

shipboard training and training in Navy schools have individual training and team training aspects.

Individual training aboard ship is concerned with such activities as taking correspondence courses, and sometimes even (especially aboard larger ships) with organization of formal classes. Usually, however, individual training in which an instructor teaches students occurs in such situations as where an FT1 or FTC teaches a couple of strikers how to tear down an instrument servomechanism, or to troubleshoot a malfunctioning electronic circuit, etc. In addition to such job training, both enlisted and officer personnel can take broader courses offered by USAFI; for example, many men who did not finish high school before they joined the Navy have done so through USAFI.

Navy schools are also a form of individual training. School attendance is required for advancement in rate in certain ratings. In highly technical ratings, such as FT and ET, it is almost a must. Schools are always desirable and helpful for advancement in rating. A man who graduates from a Navy school is valuable to the Navy and at the same time helps himself get ahead.

Team training on board ship may be either operational or in maintenance work. (The latter would include such work as boresighting or other battery alignment operations which require a team of men working together.) Operational training can occur either aboard ship or ashore, and may involve a team of almost any size. Aboard ship, operational team training includes such activities as GQ drill, loading drill (on gun mounts), drills in various bills, and CIC drill. Operational drills have enormous potential training value. However, for the value to be realized, the leaders of the drill (and this quite often means the junior division officer or the division officer) must function imaginatively, but with a lively sense of the businesslike purpose of the drill. Other operational training includes gunnery exercises, multiship exercises (such as ASW drill), and the like. One aspect or another of team training will, in fact, dominate your duty hours aboard ship,—or if it doesn't, it should. It is consequently the aspect of your work as division officer that should get maximum attention, and certainly the maximum amount of constructive thought.

Fortunately, team training can go on even when the crew is not on board ship. All ships must periodically go to a tender or naval shipyard for overhaul and heavy maintenance work.

Yard work generally means several weeks in which the ship, even if not actually in drydock, cannot be operated because its machinery and armament are partly or completely disabled, and there is no ammunition or fuel aboard. During this period, even if a portion of the crew is on leave, some may be sent to fleet training schools which specialize in specific weapons such as the 3"/50. Other fleet training activities ashore give quick, intensive short courses (aboard "school ships" temporarily assigned for this purpose, or in shore facilities) in UB plot operations, CIC, spotting, etc.

Following every yard period comes a period of underway "refresher" training (generally for 5 to 6 weeks) in which the crew (many of whom have been replaced during the yard period) goes through a complete series of training sessions at sea, while at the same time the ship is put through its paces to check its overhaul. This culminates in the Operational Readiness Inspection (ORI) in which officers from the highest echelons of the Fleet check the ship and its crew in every aspect of operational preparation. Although we have called the ORI a "culmination" of underway refresher training, this by no means implies that the training program can come to a standstill; it is in fact only the beginning of a continuous, endless process.

You as a junior division officer or division officer will have your area of responsibility in every training program that affects the weapons department — and few do not affect it.

WEAPONS EXERCISES

One of the most important aspects of team training is the weapons exercise. The most important objective in weapons exercises is to train personnel in the most effective use of the ship's armament. Another important objective is the development of new doctrines, techniques, and procedures to keep pace with new targets and new equipment. Hence the conditions under which they are held are made as realistic as possible, to eliminate artificialities which might lead to false conclusions.

Publications promulgated by CNO prescribe the weapons exercises now used in the fleet. Separate publications prescribe the training exercises, procedures, and reports required, including outlines of the specific tactical situations which precede the firing. These publications are confidential, and are in the custody of the Registered Publications System (RPS) Custodian. They may be signed for and drawn for study.

Frequent reference to the weapons department files will keep the officer posted concerning past weapons performance as well as current doctrines and procedures.

Just as important as the firing exercise operations themselves are the reports that must be made of the operations, and the analysis of the reports. Too frequently reports of weapons exercises lose their significance and serve merely to represent additional paper work to the junior officer. Remember that it is necessary to make an accurate appraisal of the effectiveness of the ship's armament, and that to do so requires careful, detailed analysis of accurately compiled reports.

Sufficient data must be taken during the exercise to permit postfiring analysis. It must be carefully assembled and even more carefully checked. If the report indicates an ineffective battery, every last detail must be scrutinized to ascertain the cause — which must then be corrected.

EFFECTIVE NAVAL LEADERSHIP

"Leadership lights the way. Ignore it and your limit is the work of your own two hands. Learn it, and your limit is the world and the sky above it." The above quotation (of unknown origin, and not to be taken literally) emphasizes what leadership can accomplish.

Naval leadership means the art of accomplishing the Navy's mission through people. Effective leadership is based on personal example, good management practices, and moral responsibility. The United States Navy has long been distinguished for the high quality of its officers and men. The following discussion points out the requisites of being a leader, for improving on leadership capabilities, and for exercising leadership qualities.

THE LEADER

Few people are born leaders. The majority of leaders (in civilian life as well as in the military) have utilized their innate abilities to best advantage, learned their jobs thoroughly, and applied common sense to the task at hand. These men have thus earned for themselves the respect, admiration, and loyalty of their superiors and subordinates alike — they have become leaders.

The best military leaders are characterized by patriotism, valor, integrity, ability, initiative, imagination, judgment, loyalty, dependability,

tact, self-control, and, above all, a "can-do" attitude to accomplish a mission despite the obstacles.

Don't let this formidable list daunt you. Leadership is a prerequisite to success, and fortunately most men willingly accept direction from their seniors.

LEADERSHIP DURING OFFICER TRAINING

The Navy cannot produce all-around leaders in the various officer candidate schools (the U.S. Naval Academy, NROTC Schools, OCS, ROC, etc.); it can give them the best leadership education possible at the academic level. Beyond this, you can become a good and successful leader only from practice and training aboard your ship or station.

As college students in the NROTC program or candidates in OCS, you should be developing your leadership potential. If you aren't, now is the time to start working at it. Leadership is not bestowed upon anyone automatically upon graduation or through being sworn in as a commissioned officer. Leadership must be learned through exercise.

LEADERSHIP ON BOARD SHIP

Leadership has been defined many ways. One popular version is: "The ability to have others do what you want them to do because they want to do it."

The naval weapons concept that you have studied doesn't eliminate the individual; paradoxically it increases the responsibilities and capabilities required of the operating personnel. The effectiveness of any weapon system depends on the knowledge and operation of the component parts of the system by the operating personnel. As a result, the junior officer has to be a combination technician, tactician, leader, and follower.

Why is the "can do" attitude so important? Because it's results, not technical potentials, that count. The command that utilizes its equipment to maximum effectiveness will defeat a more technically advanced adversary whose personnel are not as proficient employing its weapons to maximum effectiveness.

We can never afford to blame our technical and tactical ineptness on equipment. Nor can we rationalize that better equipment will make up for our shortcomings. Former Chief of Naval Operations Admiral Arleigh Burke emphasized on many occasions that "the fleet must always do the best with what it has."

LEADERSHIP FOR THE JUNIOR OFFICER

As a junior officer you may be assigned tasks below your potential. This is a normal evolution—minor responsibilities diligently and efficiently performed lead to more challenging and interesting assignments. It is commendable and essential to set a high goal to strive for, but the higher the goal the more devoted and patient you must be. There is always room for one more industrious, conscientious, imaginative officer in any wardroom. Learn your own job regardless of what it may be. Prepare yourself for additional responsibilities and it won't be long before you will be floated up as a department head.

The standards of the Navy are set by your superiors, but the successful attainment of those standards depends upon the cooperation of the junior officer in insuring that those standards are understood and complied with.

As a junior division officer in the weapons department—or any department for that matter—you will find that you are expected to learn on the job and perform tasks that you were not adequately taught. Junior officers' ability to learn on the job affects the operations of a department in a large combat ship—but it can make or break the entire command the size of a destroyer.

The Navy shows great tolerance and forbearance to the junior officer who conscientiously and industriously carries out his duties, who is not afraid to dig for the information he needs, and who in every way evidences a sincere desire to do his best as a naval officer. Every ship's complement is composed of such numbers, ranks and ratings of officers and men as are required to operate the ship most effectively in war and in peace. There is never room for deadwood. Keep in mind what Admiral Sims once said, "We believe it is the duty of every officer to study his own character that he may improve it, and to study the characters of his associates that he may act more efficiently in his relations to them."

APPENDIX I

GLOSSARIES

This appendix is in two parts. The first part is a general glossary which lists in alphabetical order some terms and abbreviations used in this text, plus a few others. The second part is an alphabetical listing of all surface and AA gun fire control symbols — each with a brief explanation — in common use at the present time.

The general glossary is intended as a convenience to the student in home study and other situations where standard authoritative Navy reference sources are not readily available. It is not intended to supplant or supersede authoritative sources. Nor should it be used for general reference. The definitions of most of the terms and symbols included in this appendix, regardless of what they denote in general use or in other technical areas, apply primarily to Navy usage.

To avoid inconvenient length, the glossary entries are mostly brief and do not usually go into detail regarding derivations, shades of meaning, limits of application, etc. For further information on any entry, or for information on any term not in the glossary, you should look it up in the index to determine if there is further discussion in the text and should then go to other reference sources if necessary.

PART I—GENERAL GLOSSARY

AA: Antiaircraft.

AAC: Antiaircraft common (projectile).

Aberration: Distortion in optical lens or mirror.

a-c (or a.c.): See alternating current.

AC Device: In mines, an anticountermining device that prevents a mine from detonating because of a nearby explosion.

ACP: See NWP.

Acquisition: The process of accepting a designation, acquiring the target, and initiating target tracking.

ACTH: See Arbitrary Ballistic Correction.

Actuation Counter: A device used to complete the electrical circuit to the mine detonator after a preset number of firing system actuations.

ADF: Auxiliary detonating fuse.

Advance Range: Present range combined with the corrections and predictions necessary to compensate for own ship and target motion during the time of flight, plus ballistic corrections and spots.

A-End: The variable-output pump in a hydraulic speed gear.

AF: Audio frequency, especially with regard to sonar signal fed to loudspeakers or headphones.

Afterbody: The part of a torpedo between the midship section and the tail. Usually contains propulsion and guidance equipment.

Aiming: The process of establishing target position in bearing and elevation.

A. Aim is classified as to TYPE by the instrument employed:

1. Radar Aim describes determination of target bearing and elevation by radar.
 - a. Partial Radar Aim describes determination of bearing by radar and determination of elevation by stabilizing equipment.
2. Optical Aim describes determination of target bearing and elevation by optical instruments.
 - a. Partial Optical Aim describes determination of target bearing by optical instrument and elevation by means of stabilizing equipment.
3. Generated Aim describes the generation of target bearing and elevation, and corrections thereto for deck inclination, by means of a computer and stabilizing equipment.

B. Aim is classified as to METHOD by the manner in which the aiming system is operated.

1. Continuous Aim describes continuous measurement of target position in bearing and elevation.
 - a. Continuous Automatic Aim describes automatic continuous aiming instrument.
 - b. Continuous Aided Aim describes continuous aiming with the aiming instrument positioned by signals received from the computer and with the resulting position corrected by the operators.
 - c. Continuous Manual Aim describes continuous aiming with the aiming instrument positioned by hand, using either direct manual drive or local power.
2. Intermittent Aim describes periodic measurement of target position in one element and continuous measurement in the other.
 - a. Selected Elevation describes determination of target position continuously in bearing and intermittently in elevation.
 - b. Selected Train describes determination of target position continuously in elevation and intermittently in train.

Airborne Early Warning (AEW): AA search by craft other than own ship.

Airburst:

1. An explosion of a bomb or projectile above the surface, as distinguished from an explosion on contact with the surface or after penetration.
2. The explosion of a nuclear weapon in the air at a height greater than the maximum radius of the fireball.

Air Flask Section: In an air-steam torpedo, the midship section.

Air-Steam Torpedo: A torpedo propelled by a turbine engine driven by a mixture of air and steam.

Alternating Current (a-c is the abbreviation used in this text; other texts may use a.c.): Current (or voltage) that periodically reverses polarity in a circuit. Commonly, if the value is plotted on a graph against time, the result will be a more or less smooth sine wave; this is the characteristic output waveform of

transformers and generators. Alternating current supplies on ships are generally either at 60 Hz or 400 Hz.

Altitude: The vertical component of slant range. (Since this definition disregards the curvature of the earth, it should not be applied beyond the limits of present gun fire control systems.)

Amatol: A mixture of ammonium nitrate and TNT.

Ammunition: A contrivance charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological, or chemical material for use in connection with defense or offense, including demolitions.

Ammunition Details: Components of a round of ammunition.

Amplidyne (Generator): A highly variable-output d-c generator identified with this trade name.

Amplidyne System: A system in which a small signal regulates output of a d-c amplidyne generator that feeds a servo motor.

Amplifier (Electronic): A device that uses a component such as a transistor or electron tube to increase the magnitude (of voltage, current, or power) of a signal.

Amplitude: Distance through which a particle is displaced in vibration; a measure of amount of vibration.

AN/: Army-Air Force-Navy designation.

Analog Computer: A computer which solves a certain type of problem by using electrical or mechanical analogs whose end output represents the solution. Cf. Digital computer.

Angle of Climb or Dive: The vertical angle between the horizontal and the direction of motion of the target measured in degrees at the target.

Angle of Incidence: Angle between an incident light ray and the normal at an optical surface.

Angle of Reflection: Angle between normal and reflected ray.

Annunciator: An alerting device used to indicate to personnel that target designations are pending.

Antisubmarine Barrier: The line formed by a series of static devices or mobile units arranged for the purpose of detecting, denying passage to, or destroying hostile submarines.

Antisubmarine Warfare (ASW): Operations conducted with the intention of denying the enemy the effective use of his submarines.

Antisubmarine Warfare Forces: Forces organized primarily for antisubmarine action. May be comprised of surface ships, aircraft, submarines, or any combination of these and their supporting systems.

- Apparent Mean Dispersion of a Salvo in Range (or deflection):** The arithmetical average of the dispersion in range (or deflection) of the several shots of the salvo, excluding wild shots.
- Apparent Wind:** Wind apparent at the observing station; the resultant of the true wind and the motion of the observing station.
- Arbitrary Ballistic Correction:** An empirical correction in range or deflection to compensate for all indeterminate errors in the fire control problem. It is obtained from an analysis of previous firings. This is commonly referred to as ACTH (arbitrary correction to hit).
- Area Fire:** Support gunfire delivered in a prescribed area. Usually used in neutralization support fire.
- Armament:** See Ordnance.
- Armature Reaction:** Magnetic field produced by induced armature current in a d-c generator.
- Arming:** As applied to explosives, the changing from a safe condition to a state of readiness for initiation.
- Arming Wire:** A wire harness used to initiate arming of a weapon.
- A/R Scope:** A type of fire control radar display.
- A/S:** Antisubmarine (adjective).
- Asroc:** AntiSubmarine ROcket. A surface ship-launched, rocket-propelled, nuclear depth charge or homing torpedo.
- Astor:** AntiSubmarine TORpedo. A submarine-launched, long-range, high-speed, wire-guided, deep-diving, wakeless torpedo capable of carrying a nuclear warhead for use in anti-submarine and antisurface ship operations.
- ASW:** Antisubmarine warfare.
- ATP:** See NWP.
- Attack Director:** Electromechanical analog computer used to solve underwater fire control problem.
- Attrition Mining:** Mining primarily for the purpose of destroying enemy ships.
- Audio:** Audible signal, or electrical signal that eventually is used in production of audible signal.
- Autofrettage:** A method for prestressing gun barrels by radial expansion.
- Auto(matic) Control:** Control of a gun mount entirely and directly through remote signals from a fire control system.
- Automatic (Gun):** Case gun in which some of the propellant's energy is used to open the breech, eject the empty case, and load the next round.
- Auxiliary (Explosive or Propellant):** Substance used in intermediate stages in an explosive train.
- Axial-Piston Pump:** A pump that consists of a group of cylinders in a barrel, arranged parallel to the axis of the barrel's rotation.
- Axis of Bore:** The extension of the central axis of the gun bore. It is tangent, at the muzzle, to the trajectory of a projectile fired from the gun.
- AXP:** See NWP.
- Azimuth:** The horizontal angle in mils measured from grid north to the OT (observer-target) line.
- Azimuth Search Sonar:** Sonar system that radiates transmitted pulse in all directions and scans spirally in 360° of azimuth.
- Bag Ammunition:** Gun ammunition with propellant in fabric bags and with separate projectiles and primers.
- Ballistic Corrections:** Corrections in range and/or deflection to compensate for known or predicted errors, for drift, for wind, and for all variations from standard range-table conditions.
- Ballistic Cross Wind:** The horizontal component of the ballistic wind at right angles to the target bearing.
- Ballistic Density:** The single air density, determined by computation, which would have the same range effect on the projectile as the actual densities throughout the trajectory.
- Ballistic Missile:** A guided missile designed to follow for a substantial part of its flight a ballistic (free or unsteered) trajectory.
- Ballistic Range Wind:** The horizontal component of the ballistic wind parallel to the target bearing.
- Ballistics:** The science that deals with the motion, behavior, appearance or modification of missiles or other vehicles acted upon by propellants, wind, gravity, temperature or any other modifying substances, conditions or force.
- Ballistic Trajectory:** The trajectory traced after the propulsive force is terminated and the body is acted upon only by gravity and aerodynamic drag.
- Ballistic Wind:** The effective wind, determined by computation, of such force and direction that its action on the projectile during the time of flight will be the same as the combined actions produced by the various true winds acting in the strata through which the projectile will pass as it moves along the trajectory.

Barrage: Barrier of fire executed on predetermined firing data. The initial shots are placed across the probable path of the target.

A. Barrages are classified as to method by the manner in which position of the bursts is varied.

1. **Line-of-Sight Barrage** is a barrage using fixed fuze setting and varying sight settings, with each shot so directed that bursts will occur in the instantaneous line of sight to the target.
2. **Fixed-Zone Barrage** is a barrage fired with fixed sight settings. Once the target has passed through the zone of fire, a second zone may be selected and a new barrage fired.
3. **Creeping-Zone Barrage** is a barrage in which the fuze settings are varied in such a way as to advance along the track slower than the actual target advance.

Barrel (Gun): Part of gun structure that contains the bore.

Base Length (of Rangefinder): Distance between windows.

Base Ring: Base section of rotating structure of gun or rocket mount. Also called "deep section ring" or "lower carriage."

Base Surge: A cloud which rolls out from the bottom of the column produced by a subsurface burst of a nuclear weapon. For underwater bursts the surge is, in effect, a cloud of liquid droplets which has the property of flowing almost as if it were a homogeneous fluid. For subsurface land bursts the surge is made up of small solid particles but still behaves like a fluid.

Basic Mechanisms: Elementary components of machinery, including various basic machines.

Bathithermograph: A recording thermometer that shows water temperature at various depths.

Batten Board: Flat screen with target markings, sometimes used in boresighting.

Battery: All guns, torpedo tubes, searchlights, or missile launchers of the same size or caliber are used for the same purpose, either installed in one ship or otherwise operating as an entity.

Battery Alignment: Alignment of weapons and fire control equipment to a common system of reference lines and planes under specified conditions.

Battery Compartment: In an electric torpedo, the midship section.

Battery Control: The direction of the employment of all the mounts or turrets of a similar caliber or purpose in a vessel. It is concerned with the disposition of the mounts or turrets with respect to the fire control stations of the battery, the interior communications plan to be used, the designation and acquisition of targets by the battery or group, and the standard procedures to be employed. The Battery Control Officer is assisted by Group and Sector Control Officers, and by CIC Weapons Liaison Officers.

1. Battery Control is classified as to type by the manner in which the command of the battery is exercised.

a. **Collective Battery Control** is that type of battery control in which the direction of the employment of the battery is centralized.

(1) **Divided Battery Control** is that form of dispersed control wherein a battery with two directors is divided into forward and after batteries for command purposes. This form of control is associated with centerline, single purpose batteries.

(2) **Sector Battery Control** is that form of dispersed control in which a battery with multiple directors is divided into sectors for control purposes.

2. Battery Control classified as to method prescribes the grouping of the mounts or turrets with fire control stations, command communications channels between fire control stations, and procedures for designation and acquisition. For a particular vessel the groupings are prescribed in the battle bill.

Battery Position: Recoiling parts of gun in position for gun to fire.

Battle Announcing System: A system of microphones, amplifiers, and loudspeakers used for internal communication aboard ship.

Battle Bill: A table listing stations to be manned and personnel required under battle conditions aboard ship.

Battle Control Stations: Primary key points of ship's battle organization.

Battle Telephone: Sound-powered telephone.

Bazooka: A small infantry-launched rocket originally designed as an antitank weapon.

BDF: Base detonating fuze.

Beach Defense Mine: Bottom mine laid in shallow water to destroy landing craft.

Beacon:

1. A self-propelled noisemaker ejected by a submarine to distract A/S attack.
2. A radar signal transmitter used to establish a reference point or for other purposes. (Also called Racon.)

Beam Rider: A missile guided by a radar or radio beam.

Bearing Rate: Rate of change of target bearing from own ship caused by the relative motion of own ship and target. It may be expressed in knots (linear measure) or in degrees per minute (angular measure).

Bell (Gun): Thick part of gun muzzle (not on all guns).

Bench Mark: In battery alignment, a reference point on own ship structure used for aligning battery directors.

B-END: The hydraulic motor in a hydraulic speed gear.

Bill: A written directive that prescribes a procedure for performing some operation, or dealing with some specific situation. It lists what is to be done, material needed, and who does it.

Billet: A specific duty or station assignment to which an individual may be named, or a combination of such assignments to which a single individual is named.

Billet Number: A code designating a crewman's division, section, and precedence.

Binary: Having only two alternatives, such as, ON or OFF. (A binary number consists of 1's and 0's. The binary numbering system uses the base 2; the decimal numbering system uses the base 10.)

Biological Weapon: An item of material which projects, disperses or disseminates a biological agent including arthropod vectors.

BL: Blind-loaded projectile. Equivalent to plaster-loaded or sand-loaded.

Black Powder: An explosive mixture (used usually as an auxiliary) made up of carbon, sulfur, and saltpeter.

Blank Ammunition: Gun ammunition lacking projectiles.

Blasting Cap: Demolition charge initiating device.

Blind Time: Time lapse from instant of firing of an A/S weapon till it reaches predicted position of submarine target.

Blip: Element of radar or sonar video presentation. Also called "pip."

Blipology: Interpretation of cathode-ray tube displays.

Blowback: Escape, to the rear and under pressure, of gases formed during the firing of the gun. Blowback may be caused by a defective breech mechanism, a ruptured cartridge case, or a faulty primer.

Bomb: A missile containing explosive or chemical filling generally dropped from an aircraft.

Booster:

1. A unit in an explosive train which causes detonation of the main charge.
2. An auxiliary or initial propulsion system which provides initial thrust.

Boresafe (Fuze): A fuze designed to arm only after the projectile passes the gun muzzle.

Boresighting: Adjusting sights to be parallel with gun bore axis or to make their lines of sight intersect gun bore axis at some specified range.

Bottom Mine: A mine designed to be laid on sea bottom. Formerly called ground mine.

Bourrelet: Annular part of a projectile forward of the rotating band.

Bracketing: A method of adjusting fire in which a bracket is established by obtaining an over and a short along the spotting line, and then successively splitting the bracket in half until a target hit or desired bracket is obtained.

Breechblock: Gun mechanism element that blocks chamber when gun is fired. Also called "plug."

Brisance: Rapidity with which an explosive develops its maximum pressure.

Brush: Contact used with slip rings and commutators.

B-Scope: A type of fire control radar display.

BT: Abbreviation for bathythermograph.

Built-up (Gun): A type of prestressed gun barrel.

Burnout: The point in time or in the missile trajectory when combustion of fuels in the rocket engine is terminated by other than programmed cutoff.

Burster: Bursting charge or explosive load in a projectile, mine, torpedo, etc. Final unit in an explosive train.

Caliber: Nominal diameter of projectile or mating gun bore, or diameter of rocket head.

Call Fire: Fire delivered on a specific target in response to a request from the supported unit.

Call for Fire: A request for fire containing data necessary for obtaining the required fire on a target.

CAP: Combat Air Patrol.

- Capacitance (C):** The property of a particular type of electrical nonconductor that permits it to store energy when opposite surfaces of the nonconductor are maintained at different voltage potentials.
- Carbamite:** A stabilizer used in SPCG.
- Carrier Striking Force:** A naval task force composed of aircraft carriers and supporting combatant ships capable of conducting strike operations.
- Cartridge Case:** (See Case Ammunition.)
- Case Ammunition:** Gun ammunition with propelling charge and related components in a metal or plastic cartridge case.
- Cavitation:** Formation of partial vacuum on certain parts of fast-rotating ship screws; this causes inefficiency and considerable acoustic disturbance.
- CD Mechanism:** In mines, a clock delay device to delay arming for a period after planting.
- Cellulose Nitrate:** (See Pyrocotton.)
- Center of Burst:** A point about which the bursts of projectiles fired under like conditions are evenly distributed.
- Central Amplifier System:** A type of battle announcing system.
- Centrifugal Force:** In a rotating object, radial thrust away from center of rotation caused by inertia.
- Chamber (Gun):** That part of the gun in which the propelling charge is located when the gun is ready to fire.
- Chase (Gun):** (See Gun Chase.)
- Chemical Agents:** Substances used in munitions for signaling, screening, asphyxiation, or chemical attack. The three main varieties of chemical agent are war gases, smokes, and incendiaries.
- Chemical Torpedo:** A type of air-stream torpedo that uses hydrogen peroxide to support fuel combustion.
- Chronograph:** Any of several devices used to measure and record velocity of a gun projectile after it leaves the muzzle.
- CIC:** See Combat Information Center.
- Closed-Circuit Television:** (also Closed-Loop Television) A television installation in which the signal is transmitted by wire to a limited number of receivers.
- Closed-Loop Servo:** A servosystem in which a servomotor is employed to amplify a comparatively weak signal. It is composed of an error detecting device, an error signal amplifier, and a motor. Input signals and the response of the motor are compared by the error detecting device. The resultant error is amplified and drives the motor. The motor rotates in such a direction as to cancel the error signal.
- Close Support Area:** Area between friendly front lines ashore and the near limits of zones of responsibility.
- Close Support Fire:** Fire placed on enemy troops, weapons, or positions which, because of their proximity, present the most immediate and serious threat to the supported unit.
- Closure Mining:** Mining primarily for the purpose of preventing passage of enemy ships.
- Cock:** A plug type valve seated in a pipe. A petcock is generally used to open or close a drain or other type of exhaust opening in a system.
- Collimating Lens:** A lens used to produce parallel light rays.
- COM:** Common (projectile).
- Combat Information Center (CIC):** The agency in a ship or aircraft manned and equipped to collect, display, evaluate, and disseminate tactical information for the use of the flag officer (if embarked), commanding officer and certain control agencies. Certain control, assistance and coordination functions may be delegated by command to the Combat Information Center.
- Combustion Flask (Torpedo):** Compartment in which fuel-air mixture burns.
- Commutator:** Rotating contact system consisting of a ring-like arrangement of insulated metal bars, or other groups of discrete contacts which are touched sequentially by a brush as a rotor turns.
- Compensator Wedges:** Thin optical prisms used in optical rangefinder.
- Complete Round:** All ammunition details required to fire one shot.
- Compression Waves:** See Longitudinal Waves.
- Concentration Area:** A limited area on which a volume of gunfire is placed within a limited time.
- Conditions of Loading:** In interior ballistics, the powder used, the weight of charge, the density of loading, the volume and shape of the powder chamber, and projectile weight.
- Condition Watch:** Aboard ship, a personnel disposition based on degree of readiness.
- Conical Scan:** In radar, a type of antenna beam scan used for target tracking. The scanning is characterized by having a fixed tilt angle. The axis of the radiofrequency beam generates a cone whose vertex angle is usually from five to ten degrees.

- Conservation of Energy, Doctrine of: Except for nuclear reactions, the quantity of energy in the universe remains the same, but may be converted to different forms.
- Constriction: Narrowed part of gun bore.
- Contact: In AA or A/S search, a detected potential or actual target.
- Contact Mine: Mine that will explode when target touches the mine or one of its sensitive components such as an antenna. Contact firing mechanism may be mechanical, galvanic, or electrochemical.
- Control: Authority, less than full command exercised over the armament or a portion thereof.
- Control Indicator: See Sonar Control Indicator.
- Controlled Mine: Mine controlled from a station ashore.
- Control Units: See Weapon System.
- Conventional Weapons: Nonnuclear weapons. Excludes all biological weapons, and generally excludes chemical weapons except for existing smoke and incendiary agents, and agents of the riot-control type.
- Convergent Lens: A lens that causes parallel light rays entering it to converge.
- Convoy: A formation of merchantmen (usually under naval protection).
- Cool Propellant: Propellant that burns at relatively low temperature.
- Coordinate Converter: An electromechanical instrument used to compute bearing and range from north-south east-west position. It can also compute the north-south east-west position from director train and range information.
- Cooper Fouling: Metal residue deposited in gun bore by erosion from rotating bands.
- Cordite N: See SPCG.
- COSAL: COordinated Shipboard Allowance List. An allowance list of consumable parts required to support a ship's on-board equipment. It is determined by a physical inventory of the on-board equipment on an INDIVIDUAL ship basis.
- Counterbattery Fire: Support fire directed against enemy weapon emplacements for the purpose of silencing them.
- Countermeasures: That form of military science which by the employment of devices and/or techniques has as its objective the impairment of the operational effectiveness of enemy activity.
- Countermining: The detonation of mines by nearby explosions, either accidental or deliberate.
- Counterrecoil: Movement of recoiling gun parts toward battery position. This is accomplished by a "counterrecoil mechanism" or "recuperator."
- Counterrotation: Rotation in opposite directions.
- cps: Cycles per second. (See Hertz.)
- Creep: Forward thrust on fuze parts caused by gradual slowing of projectile in flight.
- Critical Angle: At angles of incidence greater than the critical angle, all incident light is reflected back into glass. (This property is called "total internal reflection.") The value of the critical angle depends on the refractive index of the glass.
- Crosshairs (or Crosswires): Reticule marks consisting of a pair of mutually perpendicular lines (horizontal and vertical).
- Crosslevel Angle: Inclination of the battery reference plane with the horizontal, usually measured in a plane perpendicular to the plane in which level is measured. The latter plane may be either the vertical or a plane perpendicular to the reference plane, depending on the design of the control equipment.
- CRT: Cathode-ray tube.
- CS Mechanism: In mines, a clockstarter device that starts or stops the timing mechanism in the mine.
- Cycle: An interval of time during which a sequence of a recurring succession of events or phenomena is completed, such as a complete performance of a vibration.
- Cyclonite: See RDX.
- Damping Generator: A-c or d-c motor-driven tachometer type generator in a servo system, whose output opposes the signal which drives the motor. Also called "stabilizing" or "feedback" generator.
- Danger Space: For a material target this is the distance in front of the target, measured parallel to the line of fire, that the target could be moved toward the firing point, so that a shot striking the base of the target in its original position would strike the top of the target in its new position.
- Dash: Drone AntiSubmarine Helicopter. Small, lightweight, remotely controlled helicopter capable of operating from a destroyer and delivering an antisubmarine warfare weapon to an enemy submarine. It provides destroyers with a standoff weapon.
- Dashpot: A hydraulic braking mechanism.
- Data Transmission System: System (usually electrical) for conveying precise fire control and navigational data from one point to another.

- Datum:** In ASW, a reference point at which a submarine was last contacted.
- D/C:** See Depth Charge.
- d-c (or d.c.):** See Direct Current.
- Dead Time:** Time interval between fuze setting and firing of gun.
- Decibel (db):** Difference expressed logarithmically between two sounds, or a sound and an arbitrary reference level. $N = 10 \log A/B$.
- Decoppering:** Process of removing copper fouling from gun bore.
- Deep Section Ring:** See Base Ring.
- Deep Support Fire:** Fire directed on objectives not in the immediate vicinity of our forces, for neutralizing and destroying enemy reserves and weapons, and interfering with enemy command, supply, communications, and observations.
- Defensive Minefield:** Mines laid to deny friendly waters to enemy.
- Defilade Fire:** Gunfire delivered on shore targets located behind some terrain feature.
- Deflection:** The lateral angular correction (converted to the deck plane where necessary) which is applied to the target bearing in the deck plane to obtain gun train order.
- Deflection Modulation:** A principle of radar indicator functioning in which the electron beam is deflected to show a blip.
- Degaussing:** A method of reducing a ship's magnetic field by use of several types of coils carrying direct current around parts of the ship's hull.
- Degaussing Range:** An installation containing magnetic sensing devices. Ships steaming past the sensing devices cause their signatures to be recorded.
- Degree of Freedom:** Ability to rotate on an axis.
- Degree of Readiness:** Status of ship's complement, plant, and armament under specific conditions.
- Deliberate Attack (ASW):** Concentrated attack to kill.
- Delivery Device (in Weapon System):** See Weapon System.
- Demolition Agents:** Explosives used in demolition equipment other than ammunition.
- Density of Loading:** Ratio of powder weight to that of a volume of water which will fill the powder chamber at a specified temperature.
- Deperming:** Reducing the permanent magnetic field of a ship's hull.
- Depth and Roll Recorder:** A device that records a torpedo's running depth and angle of roll during the run.
- Depth Charge:** An underwater explosive used against submarines.
- Designate Hooks:** Visual representation of designated target position, used in some types of target designation systems.
- Designation Indicator:** An equipment which displays radar or television video on the face of a kinescope (cathode-ray tube).
- Destruction Fire:** Fire delivered for the sole purpose of destroying material objects.
- Destructor:** A small, special purpose explosive charge used to destroy equipment in danger of capture, and to destroy weapons for safety reasons.
- Deterrence:** The prevention from action by fear of the consequences. Deterrence is a state of mind brought about by the existence of a credible threat of unacceptable counteraction.
- Detonation:** Violent chemical action (oxidation and recombination) initiated by a shock and producing a shock wave, heat, and gases.
- Detonator:** Initiating device in an explosive train.
- DI:** Delayed ignition (tracer).
- Differential:**
- Cylinder. A piston-cylinder hydraulic device used to develop either equal thrust with unequal pressure or unequal thrust with equal pressure.
 - Mechanical. A gear arrangement used to add or subtract mechanical inputs.
 - Synchro. Either of two types of synchros used to develop a mechanical or electrical difference between or sum of two inputs.
- Digital Computer:** A computer, mechanical or electrical, that performs mathematical operations by counting. Cf. Analog computer.
- Diode:** A two-electrode electron tube containing an anode and a cathode or a two-element semiconductor.
- Dip:** Apparent depression angle of the horizon at sea; varies with height above sea level. Dip difference is the difference in dip at different heights.
- Dip Sonar:** Airborne sonar equipment lowered into the water for sonar observations from hovering helicopter. Sometimes called "dunking sonar."
- Diphenylamine:** A stabilizing compound used to retard deterioration in single-based powder.
- Dip-Needle Mechanism:** A type of magnetic mine firing mechanism.
- Direct Current (d-c is the abbreviation used in this text; other sources may use d.c.):** Current (or voltage) that does not reverse polarity periodically. (See Alternating Current.) A direct current or voltage may fluctuate, or

it may be interrupted but it is still direct current.

Direct Fire: Gunfire delivered on a target ashore, visible to the firing ship, which uses the target itself as an aiming point.

Director: A fire control unit that establishes location of target and may furnish gun orders or other weapon positioning information.

Direct Supporting Fire: Fire delivered in support of part of a force, as opposed to general supporting fire which is delivered in support of the force as a whole.

Dispersion (of a Shot): The distance of the point of impact of that shot from the MPI of the Salvo. Dispersion in range is measured parallel to the line of fire, and in deflection at right angles to the line of fire in a horizontal plane.

Distress Signal: A dual-purpose pyrotechnic device.

Diversionary Attack: An attack wherein a force attacks, or threatens to attack, a target other than the main target, for the purpose of drawing enemy defenses away from the main effort.

Doctrine (Naval Warfare): A working principle or rule of combat that has been developed theoretically and proved by experience. Procedures are methods used to put the doctrine into effect.

Domain (Magnetic): See Magnetic Domain.

Dome: Underwater sonar transducer housing.

Doppler Effect: Apparent change of frequency of sound (or any other form of wave motion) when the source and the observer are in motion relative to one another.

Double-Base Powder: Solid rocket propellant usually composed chiefly of nitroglycerin and nitroguanidine.

Double-Speed (Synchro) Operation: Use of two parallel synchro systems, usually one operating at 1:1 ratio with input, and one at 36:1 ratio with input, for greater accuracy. Cf. Single-Speed (Synchro) Operation.

Dredger Hoist: A type of ammunition hoist used between handling rooms.

Drift: (1) Deflection of projectile trajectory by interaction of gravity, air resistance, and projectile spin. (2) Rate at which water current flow moves a ship with respect to the land. (See also Set.)

Drifting Mine: A mine with no provision for maintaining a fixed position after planting. It is free to move with the waves, current, and wind. Drifting mines may watch at the surface or may be kept at a set depth by

depth control devices. They are to be distinguished from floating mines which are moored mines that have broken loose. Drifting mines are no longer used by the United States.

Drone: A vehicle—land, sea, or air—which is remotely or automatically controlled.

DRT: Dead-reckoning tracer. An electromechanical automatic plotting-tracking device which continuously displays own ship position and track on a chart. Some types may also show own ship heading.

Dummy Director: Test servo (usually synchro) signal generator.

Dummy or Drill Ammunition: Ammunition without explosive or propellant.

Early Warning: Target information obtained before radar or optics aboard own ship acquires the target. Early warning data may be transmitted from picket ships, AEW system, radio communications, shore based observers, or operational orders.

Echo: The signal reflected by a target to a sonar or radar set to indicate target position.

ECM: Electronic countermeasures.

Effective Range: The maximum distance at which a weapon may be expected to fire accurately to inflict casualties or damage.

Effort Arm: Distance on lever arm from fulcrum to point at which effort thrust is applied.

Electrical Firing: Firing a primer by electricity.

Electrical Resolver: A special type of rotating induction device which can function as a component solver or vector solver. It contains two rotor windings 90 electrical degrees apart and two stator windings also 90 electrical degrees apart. The resolver may be used for the following purposes:

1. Resolution—to solve vectors for right angle components.
2. Composition—to combine right angle components to produce a vector.
3. Combination—to combine several vectors to produce a single sum vector.

Electric-Setting Torpedo: Torpedo whose control settings are made through servomechanisms and relays which remain connected to the fire control system until the instant the torpedo is fired.

Electric Torpedo: Unless the context clearly indicates otherwise, this term conventionally denotes a torpedo equipped with electric propulsion gear. It does not denote "electric setting" unless the context requires it. For the sake of clarity, the ambiguous term "electric torpedo" is best avoided.

- Electron Tube:** A device in which conduction of electricity is provided by electrons moving through a vacuum or gaseous medium, within a gastight envelope.
- Elevating Arc:** Gear sector on slide used to elevate gun.
- Elevating Gear:** Mechanical, hydraulic, and electrical equipment used for elevating a weapon.
- Elevating Nut:** Part of a screw type gun elevating mechanism.
- Elevation:** Movement of a weapon in a plane perpendicular to the deck. Also properly called "pointing."
- Elevation Alignment:** Adjustment of fire control and weapon system elements so that they are in effect all parallel and all at exactly the same angle to a selected horizontal plane.
- Elevation Rate:** Rate of change of target elevation (position angle) in degrees per minute.
- EMF:** Electromotive force; usually equivalent to voltage.
- Enabling (of Torpedo):** Activation for pattern running or homing; in latter, exploder is also armed.
- Enabling Run:**
1. The straight portion of a pattern-running torpedo's run.
 2. The portion of a homing torpedo's run that ends when the search pattern starts.
- Energy:** Capacity for Doing Work: Kinetic energy is energy in being, as that of a falling projectile or burning propellant. Potential energy is energy that can be released, such as that in a chemical propellant that has not been fired, or in a projectile about to descend from the peak of its trajectory.
- Enfilade Fire:** Gunfire on a ground target whose long axis is parallel to the line of fire.
- Equivalent Service Rounds (E.S.R.):** Standard unit of measurement of number of rounds fired from a gun for purposes of estimating resultant wear.
- Erector (Lens or Prism):** Optical element which inverts a real image.
- Erosion (Gun):** Wear in a gun bore.
- Error of the Mean Point of Impact:** The distance of the MPI from the target or other reference point, measured parallel to the line of fire for range and at right angles to the line of fire for deflection.
- Error Recorder:** Recording device used to show servo system performance.
- Error Signal:** In a servo, the difference between order signal and response. Error signal is fed into the servo's amplifying device.
- E-Scope:** A type of fire control radar display.
- ETF:** Electrical time fuze.
- Ethyl Centralite:** See carbamite.
- Evaluation of Weapon System or Component:** Study and appraisal of effectiveness of weapon system or component.
- Exercise Head:** That section of a drill torpedo or mine filled with inert and instrumentation materials, which enables training of personnel and recovery of weapons for evaluation.
- Exploder:** In a torpedo, the analogue of a projectile fuze.
- Explosion:** See Detonation.
- Explosive:** Any material that can detonate and is commonly used so that it will detonate.
- Explosive D:** Ammunition picrate. A notably insensitive explosive.
- Explosive Ordnance Disposal Unit:** Personnel with special training and equipment who render explosive ordnance safe (such as bombs, mines, projectiles, and booby traps), make intelligence reports on such ordnance, and supervise the safe removal thereof.
- Explosive Train:** Explosive units designed to function in sequence.
- Exterior Ballistics:** See Ballistics.
- Exudate:** Explosive oily substance, potentially dangerous, given off by cast TNT in storage.
- Eye-piece (Lens):** See Ocular Lens (Telescope).
- Fairing:** Structural additions to improve streamlining.
- Fanfare:** A device towed by surface ships to produce a false signal to distract enemy submarines.
- Farad (f):** Basic unit of capacitance measurement. The farad is too large a unit for practical work, so two smaller units—microfarad and picofarad (micro-microfarad)—are generally used. A microfarad is equal to one-millionth of a farad, and a picofarad is equal to one-millionth of a microfarad.
- Feedback (Servosystem):** Signal from servo output fed back to input to regulate servo action.
- FFAR:** The 2.75-inch folding-fin aircraft rocket.
- Fin-Stabilized Rocket:** A rocket stabilized by aerodynamic surfaces on its tail.
- Fire Control:** The organized system by means of which the offensive power of armament is controlled.
1. Fire Control is classified as to type by the system employed. For each type of fire control, the battle bill of the ship specifies the instruments to be employed.
 - a. Primary Fire Control. The system provided to control before damage occurs to this system; it prescribes the utilization of the principal system.

- b. Secondary Fire Control. An alternate system to give greater flexibility of control.
- c. Auxiliary Fire Control. A system provided solely to substitute for a primary system in case of damage.
- d. Local Fire Control. Control of a single gun mount or a turret from a local station in or adjacent to the mount or turret.

2. Fire Control is classified as to method by the procedures employed in the direction of the fire of the battery.

- a. Direct Fire Control. The control procedure employed when the target is observed from the firing vessel visually or by radar.
- b. Indirect Fire Control. The control procedure employed when the target is unobserved by the fire control instruments of the firing vessel.
- c. Offset Fire Control. The control procedure employed when a point of aim of known relationship to the target is observed from the firing vessel.

Fire Control Computer: Electronic or electromechanical device which receives mathematical data and puts out fire control problem solution data. Alternately some types may be called "rangekeeper."

Fire for Effect:

- 1. Fire which is delivered after the mean point of impact or burst is within the desired distance of the target or adjusting/ranging point.
- 2. Term in a fire message to indicate the adjustment/ranging is satisfactory and fire for effect is desired.

Fire Mission:

- 1. Specific assignment given to a fire unit as part of a definite plan.
- 2. Order used to alert the weapon battery/area and indicate that the message following is a call for fire.

Fire Support Area: An appropriate maneuver area assigned to fire support ships from which to deliver gunfire support of an amphibious operation.

Fire Support Group: A group of ships in an attack force, assigned a naval gunfire support mission.

Firing Cutout Mechanism: A device to protect own ship structure from being fired on by own ship weapons.

Firing Lock: A mechanical unit, part of the gun, which houses the firing pin or striker which contacts or strikes the primer.

Firing Pin: Metal pin that can fire primer either by electrical contact or by percussion.

Fishtailing: The weaving action of a torpedo as its steering engine throws the rudder over to right and left alternately to keep it on course.

Fixed Ammunition: Ammunition in which the cartridge case is permanently attached to the projectile.

Fixed Tubes: Torpedo tubes that cannot be trained with respect to the ship's structure.

Flammable Agent: See Inflammable Agent.

Flareback: Ignition of residual gases in a gun bore just after firing.

Flask Pressure Air: Air supplied direct from the torpedo air flask without reduction of pressure.

Flight Gear: In mines, any of several braking devices to reduce water impact of mines dropped from aircraft.

Floating Mine: Any mine which has broken loose from its mooring and floated to the surface. This is to be distinguished from a drifting mine which never was moored.

Fluid: A material that continuously adapts its shape to fit its container. Unless otherwise indicated, in this text the term "fluid" is equivalent to "liquid," but not to "gas."

FM:

- 1. Chemical agent. (See Lacrimator.)
- 2. A type of radio transmission in which carrier frequency is modulated.

Focal Distance (or Focal Length): Distance from center of lens to focal point.

Focal Point (Of Convergent Lens): Point at which parallel rays entering lens will meet after they emerge.

Follow-Up: See Servo.

Force: A pull or push on a material object that causes or tends to cause the object to move or (if moving) to change its direction or rate of motion.

Forcing Cone: See Origin of Rifling.

Foul Bore: Gun bore occupied by residual gases after firing. In small-arms weapons, a bore contaminated by excessive solid residue.

Frequency: Number of vibrations per unit time (generally, seconds).

FS: See Lacrimator.

Fulcrum: Pivot point of lever.

Fundamental: Lowest principal frequency of sound with recognizable pitch.

Fuze: A mechanical, electrical, electronic, magnetic, or combination device used to initiate

the first element in an explosive train in a projectile at the time and under the circumstances desired. It is designed to prevent initiation at other times.

Fuze Setter: A device for adjusting time fuzes just before firing.

FXP: See NWP.

Gain: In an amplifier, ratio of output signal strength to input signal strength.

Gas Ejector: Pneumatic device that blasts air through gun bore after firing.

Gate: In radar, the movable notch, or step, used to measure the range to a target as presented on the radar range scope. When the target is gated, the radar range dial indicates the measured target range.

Gauss: Unit of magnetic field strength.

General Announcing System (IMC Circuit): Public-address system under control of OOD.

General Requirements: Requirements applicable to all Navy ordnance or other equipment. General requirements include reliability, safety, simplicity, maintainability.

Generated Target Bearing (Relative or True): The relative or true bearing of the target as determined in a computing instrument from previous positions of own ship and target and established rate of change of bearing.

Gimbal: A metal ring or similar support free to rotate on a pivot.

GP: General-purpose (bomb).

Grass: Visible "noise" in radarscope presentation.

Grid Lines (or Zones): See Military Grid Reference System.

Grid Spot Converter: Graphic computer which converts spots from observer ashore into terms usable by ship's battery.

Group Control: The control of a specified group of a battery. It is concerned with the type and method of fire control, the procedures to be employed, and the acquisition and destruction of designated targets, as well as the detection of undesigned targets appearing in the sector of fire. Group Control is exercised by the Group Control Officer, assisted by Director Officers, Mount Captains or Turret Officers, and CIC Liaison Officers.

Guided Missile: A missile whose course may be altered during flight (as by a target-seeking radar device).

Gun: Essentially, a tube closed at one end, from which a projectile is ejected by gases from a burning propellant. The term properly applies to the tube or barrel only, but is often applied to the entire mount assembly.

Gun Chase: Outer section of a gun barrel between the slide cylinder and the muzzle bell.

Gun Defense Zone: Zone about the ship to a slant range of 10,000 yards and, for the 60° cone overhead, to an altitude of 15,000 feet.

Gun Elevation: The vertical angle between the horizontal plane and the axis of the bore.

Gun Elevation Order: The signal transmitted to the gun indicating the gun elevation above the deck plane, measured in a plane through the bore axis perpendicular to the deck plane.

Gun Firing: The process of shooting a gun or guns.

A. Gun Firing is classified as to MEANS by the firing system employed.

1. Electric Firing provides for the shooting of a gun by an electrical system controlled by either:

a. Local Key provides for firing by means of a key actuated at the gun mount or turret.

b. Master Key provides for firing by means of a key actuated at a station remote from the mounts or turrets, such as a director or control station.

(1) Automatic Key is a form of master key firing in which an automatic contact maker is employed to fire at a selected firing point.

2. Percussion Firing provides for the shooting of guns by a mechanical firing mechanism at the gun mount or turret.

B. Gun Firing is classified as to type by the rate at which guns are shot.

1. Rapid Fire is that type of fire in which no check fire is used for purposes of applying corrections.

2. Slow Fire is that type of fire in which the fire is deliberately delayed to allow for the application of corrections or to conserve ammunition.

3. Deliberate Fire is that type of slow fire which is executed on a prearranged time schedule.

C. Gun Firing is classified as to method by the manner in which individual guns are shot with respect to the other guns of the battery.

1. Salvo Fire is the simultaneous firing of all guns ready and aimed at the same target.

2. Full Salvo Fire is the simultaneous firing of all guns of a group.

3. Split Salvo Fire is the firing of less than the full number of guns in a multiple gun mount or mounts at a given instant.
4. Partial Salvo Fire is the firing of less than the full number of mounts or turrets (in multiple gunmount batteries) at a given instant.
5. Continuous Fire is the firing of each gun without regard for the readiness of other guns of the battery.

Gun Housing: See Housing.

Gun Laying: The process of positioning guns in train and elevation in a predetermined relationship with respect to the line of sight. The line of sight may be established at an aloft director or generated in the plotting room, or it may be established at the gun.

A. Gun Laying is classified as to type by the manner in which guns are positioned:

1. Continuous Gun Laying. Guns are positioned continuously in accordance with the computed signals and loaded at any position.
2. Intermittent Gun Laying. Guns are positioned when loaded, but must be returned to a specified position after firing for loading.

B. Gun Laying is classified as to method by the means by which guns are positioned.

1. Automatic Gun Laying. Guns are positioned automatically by remote control systems in accordance with signals received.
2. Indicator Gun Laying. Guns are positioned locally in accordance with signals received. Positioning may be effected by either local power or manual drive.
3. Local Gun Laying. Guns are positioned locally, by gun-sight telescope. Positioning may be effected by either local power or manual drive.

Gunnery: Operation and control of all elements of armament.

Gun Range: Range listed in the range table corresponding to gun elevation.

Gunsight Alignment: Includes those operations in battery alignment that involve the mechanical alignment of the parts making up each element—viz, alignment within each mount, turret, or gun of the battery.

Gun-Target (GT) Line: An imaginary straight line from a weapon to a target. (Same as Weapon-Target Line.)

Gun Train Order: Signal transmitted to the guns indicating the angle in the reference plane from own ship's bow clockwise to the perpendicular plane through the axis of the bore.

Guppy: A modified fleet-type submarine. Acronym from Greater Underwater Propulsion Power (project).

Gyroscope (Gyro): A device which uses the rotational inertia of a spinning wheel to establish a reference direction or plane in space, or to provide displacement in another direction proportional to any force that tends to twist the wheel's axis.

Hand Control: On certain electric-hydraulic gun mount power drives, a mechanical-hydraulic servo control by mount personnel.

Handling Room: Compartment aboard ship used for transporting and to some extent for stowage of ammunition.

Hang Fire: Accidental delayed ignition of primer, igniter, or propelling charge.

Harmonic: Any frequency higher than the fundamental of a sound; a frequency with relatively simple mathematical relationship to a fundamental frequency. Also called "partial."

Harassing Fire: Sporadic support fire designed to disturb the rest of the enemy troops, to curtail movement and, by threat of losses, to lower morale.

HBX (—1 and —3): Explosive mixtures of TNT, RDX, aluminum powder, and desensitizer.

HC: High-capacity gun projectile. Equivalent to HE in Army nomenclature.

Head (Liquid Pressure): Hydrostatic pressure.

Head (of Torpedo): See Warhead and Exercise Head.

Headlight: A light in a torpedo exercise head which is illuminated at the end of the run to assist the torpedo recovery crew to locate the torpedo.

Hedgehog: 7.2" antisubmarine warfare, ahead-thrown, short-range weapon.

Henry (h): Unit of inductance or mutual inductance.

Hertz (Hz): Term for cycles per second, used in describing frequency.

Hexogen: See RDX.

H/H: See Hedgehog.

High Explosive: Any detonating compound or mixture, such as Explosive D, TNT, RDX, HBX, etc.

Hitting Gun Range: Gun range corrected for the error of MPI.

Hitting Space: The distance measured parallel to the line of fire between a shot striking the top of the target and one striking the waterline on the engaged side of the target.

- Hoisting Lug:** A lug used for hoisting a bomb into aircraft. Not used for suspending the bomb in the aircraft.
- Holding-Down Clips:** Parts that secure base ring against being tipped out of training circle.
- Homing:** The final stage of a homing torpedo's run, in which it steers itself toward a target it has detected. Applied also to any target-seeking device.
- Homing Torpedoes:** Torpedoes with target-sensing capabilities.
- Horizon Check:** Comparison of elevation dial readings when battery element is laid successively on a series of points on the horizon.
- Horizontal Plane:** A plane tangent to the earth's surface or parallel to such a plane.
- Horizontal Range:** Horizontal component of slant range.
- Horizontal-Type Torpedo Engine:** Torpedo engine in which the turbine axis is horizontal rather than vertical (the more conventional arrangement in gas-stream torpedoes).
- Housing (Gun):** Chief support of recoiling gun parts; houses breech mechanism.
- H-Type Torpedo Engine:** See Horizontal-Type Torpedo Engine.
- Hunter/Killer Force:** A naval force consisting of an antisubmarine warfare carrier, associated aircraft and escorts combining specialized searching, tracking, and attacking capabilities of air and surface antisubmarine warfare units operated as a coordinated group for the conduct of offensive antisubmarine operations in an area of submarine probability.
- Hunter/Killer Operations:** Offensive antisubmarine operations in a submarine probability area, combining the best searching, tracking, and attacking capabilities of air, surface and subsurface units and forces in coordinated action to locate and destroy submarines at sea.
- Hunting:** In servosystems, a tendency for the output to oscillate because of weak signal, insufficient feedback, excessive gain, or malfunction.
- HVAR:** 5-inch high-velocity aircraft rocket.
- Hydraulics:** Study of behavior of liquids in enclosed systems. In this text, this is expanded to include the study of liquids at rest in open systems (hydrostatics).
- Hydraulic Speed Gear:** Combined A-end and B-end, with accessories, piping, etc.
- Hydrogen Eliminator:** A device on electrically driven torpedoes which is designed to dispose harmlessly of hydrogen evolved by lead-acid storage batteries. Also called a "hydrogen burner."
- Hydrophone:** Underwater listening device; passive sonar.
- Hydrostatic Pressure:** Pressure developed by weight of liquid above the point of measurement, as distinct from applied pressure transmitted through the liquid.
- Hydrostatics:** Behavior of liquids in open systems. Cf. Hydraulics.
- Hz:** Abbreviation for hertz.
- IFF:** Identification friend or foe—a means of challenging and identifying aircraft and ships by radar.
- Igniter:** Unit in a propellant train that sets off the propellant.
- Illuminating Projectile:** A projectile containing a chemical flare and parachute. Abbreviation: Illum.
- IMP:** Integrated Maintenance Plan is a part of PMS which in turn is a part of the Standard Navy Maintenance Management System.
- Impact Action Fuze:** A fuze that is set in action by the striking of a projectile or bomb against an object, e.g., percussion fuze, contact fuze.
- Impulse Charge:** A charge using black powder as a propellant; formerly used to eject depth charges and torpedoes from their launching devices.
- Incident Ray:** Ray (usually of light) striking a surface or boundary.
- Independent Mine:** Mine actuated automatically after planting and arming.
- Index (of Propellant):** A blend of several lots of propellant powder.
- Indicator-Receiver-Regulator:** (Usually abbr. to "indicator-regulator"). Controlling equipment for weapon mount power drives. Some types are called "receiver-regulators."
- Indirect Fire:** Support from fire delivered on a target ashore which is not itself visible from the ship, or available for use as a point of aim.
- Inertia:** Resistance of a mass to acceleration.
- Inflammable Agent:** An incendiary chemical agent, such as WP (white phosphorus).
- Influence Exploder:** Any type of exploder that functions when the torpedo is close to the target.
- Influence Explosion:** See Sympathetic Explosion.
- Influence Mine:** Mine that detonates when target approaches or passes near. Such mines may

have magnetic, acoustic, or pressure-sensitive mechanisms.

Inherent Corrections: Fire control problem corrections for motion of gun platform, parallax, and divergence of gun mount roller paths from deck plane.

Inhibitor: Plastic strip used to slow the burning rate of solid rocket propellant.

Initial Ballistic Correction: That part of the ballistic corrections not automatically compensated for by the fire control system.

Initial Forcing Pressure: Propellant gas pressure required to initiate movement of projectile in gun base.

Initial Velocity (I.V.): Speed of projectile in feet per second at muzzle of gun.

Instrument Servomotors: Small fractional horsepower a-c servomotors.

Intensity Modulation: A principle of radar indicator functioning in which the electron beam is intensified to show a blip.

Intensity (of Sound Vibration): Equivalent to amplitude of vibration. (See Amplitude.)

Intensive Incendiary Bomb: Incendiary bomb using thermite.

Intercept Search: A type of passive ECM.

Intercom System: Two-way type of battle announcing system.

Interdiction Fire: Fire designed to deny the enemy ashore the use of a given route of communication, airfield, bridge, etc.

Interdirector Designation: The transmission of repeat-back information of a director to another director for the purpose of tracking the same target.

Interior Ballistics: Projectile motion and behavior while in the bore of a gun.

Internal Alignment: Adjustment of geometrical relationships within an element of a fire control or weapon system.

Jamming: Radiating interference or deceptive signals.

Jettison: To eject explosive weapons for safety reasons.

Joystick: In target designation equipment, a component used to control the output signal of dual potentiometers. These signals position designator symbols on a display and are used for transmitting target position coordinates to the converter.

Kinetic Energy: See Energy.

Lacrimator. A chemical agent that causes weeping and irritation of the throat and lungs.
Example: CH (Chloracetophenone).

Ladders: A succession of salvos fired with known and predetermined changes between successive salvos, to ensure early establishment of hitting gun range and deflection in surface fire, to serve as a yardstick for covering an area target, or to increase pattern size.

A. Ladders are classified as to type by the element in which laddering takes place.

1. Deflection Ladders are ladders fired with predetermined changes in deflection on successive salvos. They are seldom used in our Navy, except for covering area targets or in radar spotting when the discrimination of fire control radar makes a deflection rocking ladder advisable.

2. Range Ladders are ladders fired with predetermined changes in range or successive salvos.

3. Elevation Ladders are ladders fired with predetermined changes in elevation between successive salvos. They are seldom used in our Navy.

B. Ladders are classified as to method by the manner in which the predetermined arbitrary corrections are introduced.

1. Initial Ladders are ladders in which, in addition to known increments or steps, the number of salvos is definitely known. This number is greater than two, and the steps are sufficiently large, so that the target will be located within the limits of the ladder.

2. Add Ladders are fired with the initial gun range less than the best range and with successive steps of the ladder fired with increasing ranges, each increasing range spot not less than the pattern size.

3. Drop Ladders are fired with the initial gun range greater than the best range and with successive steps of the ladder fired with decreasing ranges, each decreasing range spot not less than the pattern size.

4. Continuous Ladders are fired with a continuous application of spots, applied in such a manner as to move the salvos back and forth across the target.

a. Spotter-Controlled Ladder is a form of continuous ladder in which the spotter or observer determines all or part of initial direction, when to change direction, size of first ladder steps, and when the ladder is reversed. For simplicity, the size of

steps of the first ladder and successive ladders is usually prearranged. The initial correction of the first ladder may be directed by doctrine or other orders.

- b. Rocking Ladder is a form of continuous ladder in which the number of steps of the ladder before reversal of direction and the size of the steps are both specified beforehand. The object is to increase the pattern size and still maintain sufficient projectile density to ensure hits. The steps of the ladder are never larger than the pattern size, and the number of steps is such as will ensure covering probable ranging and aiming errors and target maneuvers during time of flight. If used with continuous fire the steps are applied at regular predetermined time intervals; if with salvo fire, after each salvo.

Lame's Law: States relationship between tangential tension and radial pressure with variation of radius in cylinder under fluid pressure.

Land (in Rifling): High part between grooves.

Laws of Reflection:

1. Angle of incidence equals angle of reflection.
2. Normal, incident ray, and reflected ray all lie in the same plane.

Layer Depth: The depth from the surface to the top of a sharp negative gradient. Under positive gradient conditions, the layer depth is the depth of maximum temperature.

Lethal Gas: A type of poisonous chemical agent injurious when breathed or on contact. Example: Phosgene.

Level Angle: Inclination of the battery reference plane with the horizontal, measured in a plane that contains the line of sight. The latter plane may be either the vertical or a plane perpendicular to the reference plane, depending on the design of the control equipment.

Lewisite: See Vesicant.

Light Ray: An imaginary line used to show the direction in which a light wave is moving.

Limpet Mine: A mine attached by a diver to the hull of the enemy ship.

Line of Fire (LOF): The straight line joining the gun and the point of impact (or burst) of the projectile. As used in safety precautions for target practices, the line of fire is assumed to include all points near the bearing of the line of fire.

Line of Sight (LOS): Straight line joining the sight and the point of aim.

Line of Sight Coverage: The distance to which radar is limited because the radiated waves do not follow the curvature of the earth.

Liner: A cylindrical insert in the gun tube, in which (in some guns) the rifling grooves are engraved.

Loading Dead Time: The time between the instant a projectile is removed from the fuze pot and the instant of firing that projectile. For practical purposes, when firing mechanical-time-fuzed projectiles, the average loading dead time of the battery is the dead time for which correction must be made.

Loading Factor (of a Bomb): Ratio of explosive weight to total bomb weight.

Lobe: In radar, a plot of all points in the radar beam which present an equal signal from an identical target, assuming antenna bearing remains fixed.

Local Control: Control of a gun mount through signals originating at the mount.

Lock Combination Primer: A separate-loading primer that fits into a firing lock.

Lock On: Signifies that a tracking or target seeking system is continuously and automatically tracking a target in one or more coordinates (i.e. range, bearing, elevation).

Logic: As applied to electronics, the basic principles and applications of truth tables, interconnections of on-off circuit elements, and other factors involved in mathematical computations in a computer.

Logic Circuit: A computer circuit that provides the action of a logic function or logic operation. It gives a "yes" or "no" answer to a question.

Longitudinal Waves: Vibrations parallel to direction of wave front movement, causing alternate rarefactions and compressions (compression waves).

Look: In magnetic firing devices used in underwater ordnance, an actuating pulse caused by the change in earth's magnetic field resulting from movement of the firing device or a ferrous target with respect to each other.

LOS: Line of sight. (See also Sight.)

Low-Drag Bomb: An aircraft bomb streamlined for minimum drag at supersonic speed.

Lower Carriage: See Base Ring.

Low-Speed (Synchro): Synchro rotating in 1:1 ratio with input. Also called "coarse" unit.

- Machine, Basic: Any device that helps to do work. There are only six basic machines: the level, the block and tackle, the wheel and axle, the inclined plane, the screw, and the gear. Complex machines are merely combinations of two or more basic machines.
- MAD (Magnetic Anomaly Detection) Equipment: Underwater target detection equipment of magnetic type carried by fixed-wing aircraft.
- Magazine: Compartments aboard ship designated for ammunition stowage.
- Magnetic Domain: Group of molecules that acts as a magnetic unit in a magnetic substance.
- Magnetic Flux: Magnetic lines of force; magnetic field strength.
- Magnetostriction: Change in shape in a metallic object caused by a magnetic field.
- Maintenance and Material Management (3-M) System: An integrated management system which provides for orderly scheduling and accomplishment of maintenance and for reporting and disseminating significant maintenance related information. It is composed of the Planned Maintenance Subsystem (PMS) and the Maintenance Data Collection Subsystem (MDCS).
- Major Caliber (Gun): Gun of 8-inch or larger caliber.
- Manual Control: Local control and positioning of a gun mount without use of power equipment.
- Mass: Quantity of matter in a body.
- Massing of Fire: Fire from a number of weapons, or from two or more ships, directed against a single target.
- MCC: Maintenance of close contact (a type of sonar transducer coil).
- MDCS: Abbreviation for Maintenance Data Collection Subsystem.
- Mean Battle Range: Range at which a gun is most effective. This range is the one at which the gun sights may be boresighted.
- Mean Point of Impact: The geometrical center of points of impact of all projectiles which are fired or released at the same aiming point at approximately the same time.
- Merry-Go-Round:
 1. Drum magazine in Mk 108 rocket launcher.
 2. Rotating cage used in ammunition transfer in some 5-inch gun mounts.
- Micron: 1/1000 mm.
- Mil: Unit of angular measure in naval gunnery, used to specify sight deflection. One mil is the angle whose tangent is 0.001 (arc tan 1/1000), or about 0.06° (3.44'). With 6400 mils = 360°, the mil is used by ground artillery spotters to specify target bearing.
- Military Grid Reference System: Method of designating areas of earth's surface by a standard pattern of perpendicular grid lines.
- Military Requirements: Statement of nature and capabilities of weapon or allied equipment and systems. Capabilities are related to the purpose or task assigned to the equipment etc. in question.
- Mine: Underwater explosive weapon actuated when approached or touched by a target.
- Mine Countermeasures: All methods for preventing or reducing damage or danger to ships, personnel, aircraft, and vehicles from mines.
- Mine Hunting: The branch of mine countermeasures based on determining the positions of individual mines and concentrating countermeasures on those positions, as opposed to techniques directed at a more extensive area suspected of containing mines.
- Minor Caliber (Gun): Gun of caliber over 0.60 inch but under 4 inches.
- Misfire: Failure of primer to ignite when firing action is initiated.
- Mk (Mark): Mark (followed by a number) identifies an equipment design type. To identify a particular model, it is necessary to specify modification (mod) number in addition.
- Mobile Mine: A submarine-planted, hybrid weapon combining features of an electric torpedo and a mine.
- Mod: Short notation for modification.
- Momentum: Tendency of a mass in motion to continue moving.
- Moored Mine: A mine having a buoyant case that is held at a predetermined depth after planting by a cable or chain attached to an anchor.
- Mount (Gun): The structure which supports the gun and enables it to be elevated, trained, and fired.
- MTF: Mechanical time fuze.
- Multi-Based Powder: Gun propellant composed chiefly of nitrocellulose, nitroguanidine, and nitroglycerine.
- Multivibrator: A relaxation oscillator that uses electron tubes or transistors and other electron devices to provide a square wave output.
- Mustard (Gas): See Vesicant.
- Napalm: A powder employed to thicken gasoline for use in flame throwers and incendiary bombs.

Naval Gunfire Liaison Team: Personnel and equipment required to coordinate and advise ground/landing forces on gunfire employment.

Naval Gunfire Spotting Team: The unit of a shore fire control party which designates targets, controls commencement, cessation, rate and types of fire, and spots fire on the target.

Navigational Range: The best distance to the target, used in post-firing analysis.

Navol: H_2O_2 (hydrogen peroxide) in high concentration, used to supply oxygen for fuel combustion chemical torpedoes.

NavShips Technical Manual: Naval Ships Systems Command Manual. Technical compilation on shipboard equipment, some of it related to ordnance.

Navy Light: A hand-held pyrotechnic device.

Negative Buoyancy: Tendency to sink.

Negative Temperature Gradient: Density pattern in sea water tending to bend sonar sound path downward.

Neutralization Support Fire: Support Fire intended primarily to hamper or prevent enemy movement or action.

Newton's Laws of Motion:

1. A body at rest tends to remain at rest and a body in motion tends to continue moving in a straight line unless the body is acted on by some unbalanced force.
2. Acceleration of a body in response to a force is directly proportional to the force, inversely proportional to the body's mass, and in the direction of the force.
3. To each action there is an equal and opposite reaction.

Nitrocellulose: See Pyrocotton.

Nitrocotton (Nitrated Cotton): See Pyrocotton.

Noise:

1. Unorganized sounds.
2. Signals other than and interfering with the signal desired.

Nominal Initial Velocity: The initial velocity assigned a new gun with the propellant at a temperature of $90^\circ F$.

Nonautomatic (Gun): Gun in which none of the energy of the propellant is used to perform breech operations or ammunition loading or ejection.

Nonfrag: Nonfragmenting projectiles used in AA gun practice. They produce a colored smoke but no fragments when they detonate.

Nonhoming Torpedo: A torpedo without target-seeking capabilities.

Normal: Perpendicular to a surface or boundary.

Nose Cap: Armor-penetrating part of AP projectile.

Nuclear Weapon: A device in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both.

Null: In servo terminology, equivalent to servo signal level. "Zero" implies complete absence of a signal; "null" implies no perceptible signal, although noise and other random nonsignal voltages may be present.

Nutate: To oscillate through a small angle in a specific pattern.

NWIP: See NWP.

NWP: Naval Warfare Publication. (Also called COMMTAC (COMMUNICATIONS — TACTICAL) publications.) Any of a series of Navy publications on doctrinal and related matters. Related publications include Allied Tactical Publications (ATP's), Allied Communications Publications (ACP), Fleet Exercise Publications (FXP's), Allied Exercise Publications (AXP's), and Naval Warfare Information Publications (NWIP's).

Objective: An area or location which a troop unit is assigned to occupy or capture.

Objective (Lens): Telescope lens which forms inverted real image.

Observer-Target (OT) Line: Line joining the naval gunfire shore spotter and the target.

Ocular Lens (Telescope): Lens which makes an enlarged visual image of real image formed by objective lens.

OD: Ordnance Data—BuWeps publications containing reports of inspection and test data, primarily for use by inspectors and research personnel. ODs also contain ordnance equipment lists which provide planning information for the Bureau of Naval Weapons and the Bureau of Ships.

Offensive Minefield: Minefield laid in enemy waters to prevent movement of ships or to destroy them.

Otter: A type of underwater kite used in mine-sweeping.

Offset Centerline: In drydock battery alignment, a line established ashore parallel to the drydocked ship's centerline.

Ogive: Forward curved or conical part of a projectile.

Ohm's Law: Current in a circuit is directly proportional to total voltage and inversely proportional to total resistance of the circuit.
 $I = E/R$.

- Oil Gel:** Sticky combustible liquid that constitutes the active ingredient in scatter incendiary bombs.
- OP:** Ordnance Pamphlet—The basic BuWeps publication relating to specific ordnance equipment or data for field and fleet use.
- Opportunity Fire:** Fire delivered impromptu on newly discovered or transitory targets.
- Optical Axis:** Axis of a lens, on which light rays are not bent when entering or leaving the lens.
- Ordalt:** ORDNance ALTeration. A prescribed change in ordnance equipment.
- Order Signal:** In a servo, a control signal from outside the servo.
- Ordnance:** Weapons and physical equipment pertaining to them. Aboard ship it includes everything referred to as "ship's armament."
- Ordnance Allowance Lists:** Lists of required ordnance material for naval organizations afloat and ashore.
- ORI:** Operational Readiness Inspection.
- Origin of Rifling (in a Gun):** Where the rifling lands start, just forward of the chamber. Approximately the same location as the "forcing cone."
- OT:** Observer-Target line from ground observer to target ashore (used in target-grid system).
- OTC:** Officer in Tactical Command.
- Oxidation:** Combination of oxygen atoms with other atoms or atomic groups (molecules).
- Parallax:** The angular difference which results from making observations or computations to one target from two different stations. Train, or horizontal, parallax is the angular difference measured in the horizontal plane. Elevation, or vertical, parallax is the angular difference measured in the vertical plane.
- Parallax Error (in a Telescope):** Apparent target displacement when the eye is shifted about the optical axis of the eyepiece.
- Partial:** See Harmonic.
- Pattern (of a Salvo in Range):** The distance measured parallel to the line of fire, between the shot of the salvo, falling or bursting at the greatest distance from the firing point and the shot falling or bursting at the shortest distance, excluding wild shots. In deflection it is the distance measured at right angles to the line of fire between the shot falling or bursting at the greatest distance to the right and the shot falling or bursting at the greatest distance to the left, excluding wild shots.
- Pattern Running (Torpedo):** An alternative type of run possible with some nonhoming torpedoes. Consists of a straight enabling run followed by a period of running continuously in circles of fixed radius.
- PDF:** Point Detonating Fuze.
- Pellicle:** A half-reflecting half-transparent optical unit.
- Percussion (Fire):** Firing a primer by mechanical impact.
- Permeability:** Ability to conduct a magnetic field.
- Phase:** Angular relationship between two alternating currents or voltages, e.g. between a signal voltage and a reference voltage, when the voltage or current is plotted as a function of time. When the two are in phase, the angle is zero, and both reach their peak simultaneously. When out of phase, one will lead or lag the other; at the instant when one is at its peak, the other will not be at peak value, and (depending on the phase angle) may differ in polarity as well as magnitude.
- Phosgene:** See Lethal Gas.
- Pillenwerfer:** Bubble-making device used by submarines to create a distracting target.
- Ping:** Transmitted or received sonar pulse.
- "Ping" Sonar:** Active sonar.
- Pinger:** An ultrasonic transistorized transmitting device used in locating lost drill torpedoes and mines.
- Pip:** Element of radar or sonar video presentation. (Preferred word is blip).
- Pitch:** Ship movement in response to wave motion measured in a vertical plane containing ship's centerline. In fire control, it is the instantaneous value of the angle between the reference plane and the horizontal, measured in a fore-and-aft vertical plane. Note: For purposes of naval gunnery both roll and pitch are measured and recorded as rates; that is, in terms of amplitude per unit time, ordinarily as total degrees of roll (or pitch) per minute.
- Pitch (Sound):** Audible quality of sound which depends on the sound's dominating frequency.
- Plan Position Indicator (PPI):** A CRT or screen which displays target position, director position, and designation symbols. The data appear as a result of a rotating sweep moving at a rate fast enough to prevent fading of this information. It indicates azimuth by direction of the radial line, and range by the distance of the echo signal from the center of the screen.

- Planned Maintenance Subsystem (PMS):** A part of the 3-M system that pertains to the planning, scheduling and management of resources (men, material, and time) to perform uniform maintenance upon equipment.
- Plaster-Loaded or Sand-Loaded Ammunition:** Like service ammunition but with inert load in place of burster.
- Plug:** See Breechblock.
- Plug Gage:** Instrument used to check adequacy of clearance in gun bore.
- PMS:** See Planned Maintenance Subsystem.
- Point Fire:** Support gunfire directed at a specific target for its destruction.
- Point of Aim:** That point on a target at which the sight is directed.
- Point Oscar:** Method of indirect fire.
- Pointer:** One who moves a weapon in elevation.
- Pointing:** See Elevation.
- Polaris:** An underwater/surface-launched, surface-to-surface, solid-propellant ballistic missile with inertial guidance and nuclear warhead.
A-1—1200 nautical mile range.
A-2—1500 nautical mile range.
A-3—2500 nautical mile range.
- Poseidon:** A ballistic missile similar to the Polaris A-3, with single or multiple target-destruction capability.
- Position Angle:** The vertical angle between the horizontal and the line of sight to an elevated target.
- Positive Buoyancy:** Tendency to float.
- Potential (of a Propellant):** Total work that the gases of combustion could perform while expanding from solid state to the space they would occupy when fully expanded to atmospheric pressure and cooled to a specified temperature.
- Potential Energy:** See Energy.
- Powder Fouling:** Propellant residue left in gun bore and chamber after firing.
- Power:** Time rate of doing work.
- Prearranged or Schedule Support Fire:** Gunfire formerly planned against targets at known locations.
- Predicting:** The process of determining future target position. Predicting operations are accomplished in computers simultaneously and automatically with tracking.
- Preheater (Torpedo):** Coil of tubing in turbine exhaust, used to heat air being fed to reducing valve.
- Preliminary (Shore) Bombardment:** Bombardment of objective area by an advance force to destroy enemy defenses.
- Preparation Fire:** Prearranged neutralization support fire delivered just prior to a ground attack or landing by friendly forces.
- Pressure:** Force per unit area.
- Present Range:** The best available measurement of the range to the target.
- Primary Explosive:** Any very sensitive explosive, such as mercury fulminate, DDNP, nitromannite, lead azide, lead styphnate, tetracene.
- Prime Mover:** A driving machine, such as an electric motor.
- Primer:** First unit in a propellant train.
- Prism:** Optical light-transmitting element with flat surfaces. May utilize total internal reflection.
- Prismatic Sight:** Any sight using prisms in its optical system.
- Procedure (Naval Warfare):** See Doctrine.
- Programming:** Setting up automatic equipment to perform operations in prescribed sequence.
- Proof Run:** A torpedo exercise run made before issue to the fleet.
- Propellant (Adjective):** Relating to or functioning as a propellant.
- Propellant Train:** Propellant-igniting units designed to function in sequence. Analogous to explosive train.
- Propelling Charge (Propellant):** Any mixture or substance that reacts or burns rapidly (usually incorporating most of its oxygen) but does not detonate, and is commonly used to propel a rocket, gun projectile, etc.
- Prototype:** An early (usually the first) installed model of equipment; model for later quantity production.
- Proximity Fuze:** A fuze designed to detonate a projectile, bomb, mine, or charge when activated by an external influence in the close vicinity of a target. The variable time fuze is one type of a proximity fuze.
- PSI:** Abbreviation for pounds per square inch.
- Pyrocotton:** Principal constituent of single-base powder. A form of nitrocellulose.
- Pyrotechnics:** Munitions designed to produce light or smoke for illumination or signaling.
- Quality:** Characteristic "color" of sound that depends on harmonic content, method of production, etc.
- Radar:** Radio Detection And Ranging equipment that determines the distance and usually the direction of objects by transmission and return of electromagnetic energy.

Radar Scope: CRT used as radar video display device. The following types are used:

- A Scope. An indicator with a horizontal or vertical sweep indicating range only. Signals appear as vertical or horizontal deflection on the time scale.
- B Scope. Type of presentation on which the signal appears as a bright spot with azimuth angle as the horizontal coordinate and range as the vertical coordinate.
- E Scope. A modification of the B scope. Signal appears as a bright spot with range as the horizontal coordinate and elevation as the vertical coordinate.

PPI Scope. (See Plan Position Indicator.)

Radially Expanded (Gun): A type of prestressed gun barrel.

Radiofrequency (abbreviated RF or r-f): A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes.

Range: Distance between two points—a station on own ship to a target or some other designated point.

Rangefinder: Optical device for measuring range to a target.

Rangekeeper: See Fire Control Computer.

Range Marks: In target designation displays, pips or traces superimposed on the video signal and supplied to a cathode ray tube at specific intervals to show calibrated range indications.

Range Rate: Rate of change of range in yards per minute caused by relative motion of own ship and target.

Range-Table Initial Velocity: The initial velocity for which the range table is computed.

Ranging: The process of establishing target distance from the firing ship.

- A. Ranging is classified as to means by the instrument employed:
 1. Radar Ranging describes determination of target distance by radar.
 2. Optical Ranging describes determination of target distance by a rangefinder.
 3. Generated Ranging describes the generation of target distance by a computer.
 4. Estimate Ranging describes the determination of target distance by estimation.
 5. Navigational Ranging describes the determination of target distance by navigational means.

B. Ranging is classified as to type by the frequency with which the range is established.

1. Continuous Ranging is that type of ranging in which target distance is continuously established.
2. Intermittent Ranging is that type of ranging in which target distance is established at intervals.

C. Ranging is classified as to method by the procedure employed to operate the instrument.

1. Manual Ranging is that method of ranging in which the ranging instrument is operated by hand.
2. Aided Ranging is that method of ranging in which the generated change of range is introduced into the ranging instrument and upon which corrections are superimposed manually by the rangefinder or radar operators, as required.
3. Automatic Ranging is that method of ranging in which the instrument automatically determines target distance of an acquired target.

Rapid Fire (RF): RF guns are those in which loading, firing, empty-case ejection, and breech operation are performed automatically by power from a source other than the propellant, and other than manual.

Rate of Climb: Rate of change of altitude measured in feet per minute or in knots.

Rate of Fire: The number of rounds fired per weapon per minute.

RDX: A high explosive. For composition, see appropriate OP. Main constituent of compositions A, B, C, Hexogen, Cyclonite.

Real Image: An optical image that exists where perceived.

Recoil: Rearward thrust on gun produced when gun fires; movement of gun parts in response to this thrust.

Recoil Mechanism: Mechanical or hydraulic brake that absorbs some of the energy of recoil.

Rectifier: A device that converts a-c volts to pulsating d-c volts. To accomplish this, a unidirectional component such as a gas tube, metallic rectifier, vacuum tube, or semiconductor diode is used.

Recuperator: See Counterrecoil.

Reduced-Pressure Air (Torpedo): Air supply at around 125 psi, used to sustain gyro spin.

Reference Plane: An arbitrarily chosen plane, usually within the ship, from which angles of elevation of all battery elements are

- measured. In practice, it may be the plane containing one of the battery roller paths, or it may be an imaginary plane.
- Reference Supply:** A-c voltage of specified frequency and phase supplied to energize synchro and a-c servo systems. Usual reference frequencies are 60 cps and 400 cps.
- Reference Voltage:** Ship's a-c supply, used to energize power supplies and a-c servomotor fields.
- Refraction:** Bending of light or sound beam when passing through media of different density.
- Refractive Index:** Ratio of optical density of a light-transmitting medium to that of a vacuum.
- Relative Target Bearing:** The bearing of the target from the firing ship, measured in the horizontal plane from the bow of own ship clockwise from 0 degrees to 360 degrees.
- Relief Valve:** A valve that automatically opens to relieve excessive pressure. A safety valve is a type of relief valve.
- Repeat Back:** In target designation procedure, a report from director to designator affirming that target is being tracked.
- Repeat-Back Hook:** Visual feature of some types of TDS, used to show director position.
- Repeater:** Duplicate indicator.
- Resistance (R):** The opposition offered to current flow in a d-c circuit. In a-c circuits, resistance is the real component of impedance (the total opposition to current flow in a-c circuits).
- Resistance Arm:** Distance on lever arm from fulcrum to load point.
- Response:** In a servo, the movement effected by servo operation, or a signal based on it. This signal is fed back to the error-sensing device at the system input. Also called "feedback."
- Restricted Weapons:** Nuclear, biological, and chemical weapons (sometimes called NBC weapons).
- Reticle:** A reference mark or pattern in an optical system, visible to the user of the system.
- Returnable Quota:** A quota under which a crewman sent to school from a ship is returned to the ship after his training is completed.
- Reverberation:** In sonar, multiple echoes that tend to mask the target echo.
- RF (Guns):** See Rapid Fire.
- Rifling:** Spiral grooves in the inner surface of the gun bore.
- Ring Sight:** A type of nonmagnifying sight using concentric rings to aid in establishing lead angle.
- Ripple Switch:** A rotary multiple-contact switch used to fire a salvo of hedgehog charges in rapid succession.
- Rocket:** A missile not guided after launching propelled by reaction thrust evolved from burning of a fuel with oxygen supplied by the rocket.
- Roll:** The instantaneous value of the angle between the reference plane and the horizontal, measured in an athwartship vertical plane.
- Roller Path:** Roller bearing on which a weapon mount or fire control element trains.
- Roller Path Compensator:** A mechanical device which automatically introduces a compensating tilt at all train angles to correct for tilt of a roller path.
- Roller Path Data:** Tabulated measurements of inclination of a trainable battery element at various train angles.
- Rotating Band:** Annular part (usually of copper) on a projectile which is engraved by the gun bore's rifling when the projectile is fired.
- Rotor:** A part that revolves in a stationary part such as the rotating member of an electrical machine.
- Run-Down Gyro:** A torpedo gyroscope mechanism which coasts for the duration of the run after an initial spinning impulse.
- Safety Link:** Metal link designed to hold gun in battery when counterrecoil system fails or is deactivated.
- Safety Valve:** See Relief Valve.
- SAIL:** See Ship Armament Inventory List.
- Salvo:** One shot or several shots fired simultaneously or nearly so by the same battery at the same target.
- Salvo Buzzer:** A buzzer operated by the computer time-of-flight mechanism to warn of impending salvo burst or splashes.
- Salvo Latch:** Mechanical interlock designed to prevent accidental opening of gun breech in event of misfire or hang fire.
- Sand-Loaded Ammunition:** See Plaster-Loaded Ammunition.
- SAP:** Semi-Armor-Piercing (bomb).
- SAU:** In ASW, a search attack unit.
- Scanning Sonar:** See Azimuth Search Sonar.
- SCAR:** A type of 2.25-inch aircraft practice rocket.
- Scatter Incendiary (Bomb):** Oil-gel loaded incendiary bomb.

- SC Device:** A search coil used in a magnetic induction mine to detect passing ships by their distortions of the earth's magnetic field.
- SCD (Sonar Display):** Sonar display of PPI-type using own ship as center.
- Screening Fire:** Support gunfire using smoke projectiles to obstruct enemy view of friendly units and movement.
- Sea Battery:** An electric battery in which sea water is the electrolyte.
- Seapower:** "That portion of a nation's overall power which enables it to use the sea in furtherance of its interests, objectives, and policies." (NWP 10A)
- Searchlight Sonar:** Sonar System (now largely supplemented by azimuth sonar except for special applications) in which pulse is transmitted and received in a narrow beam.
- Section:** Primary organizational unit of a ship's crew.
- Sectional Density:** Weight of gun projectile per square inch of bore.
- Sector Control:** The control of one group of a battery, or two or more groups of different batteries, each of which is assigned the same sector of fire. It is concerned with the acquisition and destruction of designated targets appearing in the sector. Sector Control is exercised by the Sector Control Officer, assisted by Group Control Officers, and CIC Liaison Officers.
- Sector of Fire:** A specific area assigned to a unit or to a weapon to cover by fire.
- Self-Destroying Fuze:** A fuze designed to burst a projectile before the end of its flight.
- Semiautomatic (Gun):** Case gun in which some of the propellant's energy is used to open the breech, eject the empty case, and close the breech when the next round is loaded.
- Semifixed Ammunition:** Ammunition in which the cartridge case is not permanently attached to the projectile.
- Separate-Loading Ammunition:** See Bag Ammunition.
- Service Ammunition:** Complete ammunition assemblies fit for service.
- Series Motor:** An electric motor whose field winding is in series with the armature winding.
- Servosystem Or Servo:** Any of a variety of systems in which a relatively powerful driving unit responds to a relatively weak signal, and in which the response is fed back to the sensing device at the input end of the system so that it may be compared to the incoming signal and the operation of the driving unit controlled correspondently. A "servomechanism" (also called "follow-up") is usually an electrical arrangement of this kind in which the mechanical output is produced by an electric servomotor.
- Servomotor:** The unit in a servosystem that drives the load, especially the electric-drive motor in a servomechanism or in gun elevating or training gear.
- Set:** Direction of ship's drift due to ocean or river current. (See also Drift (2).)
- Setback:** Rearward force exerted on fuze parts when projectile accelerates.
- Shimming:** Method of obtaining a proper level or a correct spacing tolerance by adding thin strips.
- Ship Heading Line:** Visual display of own-ship heading in TDS.
- Ship Armament Inventory List (SAIL):** A listing of all armament on a particular ship. Each ship has a SAIL tailored to its specific requirements. The SAIL also lists the status of all applicable OrdAlts.
- Shore Fire Control Party:** A specially trained unit for control of naval gunfire in support of troops ashore, consisting of a spotting team to adjust fire and a naval gunfire liaison team.
- Sight:** Optical device that establishes line of sight (LOS) to target and provides for positioning of weapon or director with respect to LOS.
- Sight Angle:** The vertical component of the angle between the line of sight and the axis of the bore.
- Signal-To-Noise Ratio:** Mathematical statement of signal strength as related to interference.
- Signature:** The characteristic magnetic pattern of a ship's hull as it moves past a magnetic sensing device.
- Silent Running:** Aboard a submarine, the state of operating in which a minimum of noise is radiated.
- Simple Elevation Check:** Horizon check performed at but one point on the horizon.
- Single-Base Powder:** Gun propellant composed of nitrocellulose, stabilizer (diphenylamine), and ether-alcohol mixture.
- Single-Speed (Synchro) Operation:** Use of one synchro system to transmit shaft rotation data in 1:1 ratio with original signal. Cf. Double-Speed (Synchro) Operation.
- Sinking Detonator:** A means of rendering a mine safe.
- Slant Range:** Distance to an aerial point or target.

Slide: Structural support for all parts of gun mount that move in elevation.

Slide Cylinder (of Gun): Cylindrical after part of barrel.

Slipring: Rotating annular contact.

Small Arms (Caliber): 0.60 inch or smaller.

Smokeless Powder: SPCG or single-based gun propellant.

Socket Ring: A part of an axial-piston pump which can be adjusted to regulate pump output.

Sonar: Use of sound in underwater target detection and location. (Acronym from S**OUND** N**AVIGATION** and R**ANGING**.) Sonar may be active (radiating pulses) or passive (listening only).

Sonar Control Indicator: Main control component in a sonar system, at which a Sonarman is stationed.

Sonar Dome: Sonar transducer housing.

Sonics: Sounds audible to the normal human ear.

Sonobuoy: Floating radio transmitter dropped from fixed-wing aircraft and fitted with underwater microphones. Used in ASW.

SPCG. A multi-base gun propellant. Also called Cordite N.

Spend Brass: Used cartridge cases.

Spigot: Part of hedgehog projector; by extension the entire hedgehog projector.

Spin-Stabilized Rocket: A rocket stabilized by rotation about its long axis.

Spiral Scan: An r-f beam which traces out a special pattern that is caused by the wobbling motion of the antenna about its axis. It is used for search and acquisition.

Spot: Correction to be applied to gun position in order to hit target.

Spot Pyramiding: Application of a new spot before effect of a previous spot has had time to become apparent.

Spotter: An observer who reports the results of naval gunfire to the firing agency and who also may designate targets.

Spotting: The estimation of the required correction of range, elevation, deflection, and fuze range to hit the target. The Spotter is the person actually observing the fall of shot or burst and making the estimates of required corrections. A Spot is the correction estimated by the Spotter.

A. Spotting is classified as to means by the station from which the observation is made:

1. Ship Spot indicates that the spotter is stationed in the firing ship at a designated spotting station.

2. Local Spot indicates that the spotter is stationed in the firing ship at or adjacent to a mount or turret.
 3. Shore Spot indicates that the spotter is stationed ashore.
 4. Air Spot indicates that the spotter is stationed in an aircraft or airship.
- B. Spotting is classified as to type by the manner in which observations are made:
1. Visual:
 - a. Eye Spotting is the term used to indicate observations made by eye without the use of optical instruments.
 - b. Optical Spotting is the term used to indicate that observation is assisted by optical aids, including ordinary binoculars, spotting binoculars fitted with mil scales, spotting glasses, or stereoscopic range finders.
 2. Radar:
 - a. Radar Spotting is the term used to indicate that the observation is made by radar.
- C. Spotting is classified as to method by the manner of estimating the error of burst or impact.
1. Direct Spotting is that method in which the spotter's correction is based on his estimate of the error of the mean point of impact from the target. A direct spot may be made on the fall of shot of one salvo or as the result of an observation of an initial ladder.
 2. Bracket and Halving is a method used in visual spotting at extremely long ranges, from low spotting stations, or with poor illumination, when the spotter can determine whether the shots are short or over, but the amount of error cannot be estimated with reasonable accuracy. On observing the initial fall of shot, a spot is made which is believed to be sufficiently large to ensure crossing the target. If the next salvo crosses the target, the following spot is applied in the opposite direction (towards the target) but is half the amount of the initial spot. Successive spots are in the same direction until the target is crossed again. When this occurs, the direction of the spots is again reversed and again halved. The process is continued until the target is located within the pattern.

- Squirrel-Cage Motor:** A type of a-c induction motor with a cage-like conductor arrangement in the rotor.
- SS:** Illuminating projectile (Star Shell).
- Stabilization Computer:** A device that develops pitch and roll corrections for the UFCS.
- Stabilization:** The technique of correcting for deck inclination.
- Stabilizing Generator:** See Damping Generator.
- Stable Element:** Gyroscopic device which maintains a reference horizontal plane. Related similar device for similar purpose is called "stable vertical."
- Stack:** Sonar unit for producing transmitted pulse and reproducing echo.
- Stand:** Foundation of gun mount or missile launcher. Incorporates training circle, and is secured to ship structure.
- Standard Navy Maintenance Management System:** A plan of action to improve the management of maintenance and material resources in support of the Operating Forces of the Navy. (Superseded by the 3-M System.)
- Star Gage:** Instrument for measuring wear in gun bore.
- Star Shell:** See Illuminating Projectile.
- Stator:** A stationary part in or about which another part (the rotor) revolves, such as the stationary member of an electrical machine.
- Stave:** A group of magnetostrictive transducer elements arranged parallel to the long axis of a sonar transducer.
- Sterilizing Device (SD):** A device that automatically deactivates a mine firing system when a selected time has elapsed after planting.
- Stereoscopic Rangefinder:** An optical rangefinder using stereoscopic vision as its principle.
- Storage Register:** A register in the internal memory of a digital computer, which stores one computer word.
- Straddle:** This is obtained from a salvo in range (or deflection) when, excluding wild shots, a portion of the shots of that salvo fall or detonate short and other shots of the salvo beyond the target (right and left, respectively, for deflection). (In naval gunfire support this may be known as a Bracketing Salvo.)
- Striker:** A nonrated man training for a rating.
- Subroc:** SUBmarine ROcket. Submerged, submarine-launched, surface-to-surface rocket with nuclear depth charge or homing torpedo payload, primarily anti-submarine.
- Subsonics:** Sounds below audible range.
- Superelevation:** The angle the gun must be elevated above the line of sight to compensate for the curvature of the trajectory caused by the force of gravity acting on the projectile.
- Superheater (Torpedo):** See Combustion Flask.
- Supervisory Control:** The direction of the overall employment of the ship's armament. It is concerned with the disposition of the batteries to best meet existing conditions, the interior communications plan to be used, the selection and designation of targets for batteries or groups thereof, and the designation of standard procedure to be employed. Supervisory control is exercised by the Weapons Officer, assisted by his Battery Officers, and by CIC Liaison Officers.
- Support Fire:** Fire directed by ships or other afloat units at targets ashore, usually in support of ground troops operations.
- Surface Burst:** An explosion of a nuclear bomb or projectile at the surface of the earth; also the explosion of a nuclear weapon at an elevation above ground such that the fireball touches the ground.
- Suspension Lug:** A lug used for supporting a bomb in its aircraft.
- Swim-Out:** An alternate method of launching torpedoes, in which the torpedo propels itself out of an underwater tube instead of being ejected.
- Sympathetic Explosion:** Detonation of an explosive mass by shock wave of another detonation in the vicinity.
- Synchro:** Any of five types of rotatable induction devices that can produce a unique voltage pattern corresponding to any shaft position, or reproduce the shaft position from the pattern, or control a servo to do this. They are used in data transmission systems and as computing devices.
- Synchronous Motor:** An a-c motor designed to operate "in step" with the a-c supply; hence it has a constant-speed characteristic limited in accuracy only by the steadiness of the supply frequency.
- System Alignment:** Adjustment of geometrical relationship between two or more major components of a weapon system.
- Talos:** A shipborne, surface-to-air missile with solid-propellant rocket/ramjet engine. It is equipped with a nuclear or nonnuclear warhead, and command, beam-rider homing guidance.

Target-Grid System: Method utilizing a grid spot converter device to make spots observed by ground parties available without delay to ship fire control systems.

Tartar: A shipborne, surface-to-air missile with solid-propellant rocket engine and nonnuclear warhead.

Tachometer Generator: A generator whose voltage output is directly and precisely proportional to its rate of rotation. Frequently used as a Damping Generator.

Tail (of Torpedo): Aftermost part of a torpedo. Carries propellers and control surfaces.

Talker: Enlisted man assigned to man a battle phone for an officer at a control station.

Tampion: Plug inserted in gun muzzle to protect bore.

Target Acquisition: The process of positioning the tracking apparatus of a control system so that a designated target is gated in the radar or fixed in the optics or open sights.

Target Angle: The relative bearing of own ship from the target, measured in the horizontal from the bow of the target clockwise from 0° to 360°.

Target Designation: The selection of the targets which are to be taken under fire, and transmission of the requisite information for acquisition to the selected fire control station or stations.

A. Target Designation is classified as to type by the station originating the designation.

1. Command Designation is the designation of a target by a command station.

a. OTC designating a ship to take target under fire.

b. CO of a ship designating target to be taken under fire.

2. Control Designation is the designation of a target from a fire control station.

3. Local Designation is the designation of a target by mount or turret personnel.

B. Target Designation is classified as to method by the procedure employed for designation.

1. Automatic Designation is the designation of the target by means of instruments which transmit sufficient data to the selected gun fire control system to result in target acquisition.

2. Partial Automatic Designation is the designation of the target by means of a partially automatic system which must be aided by coaching in order that the

selected director will be positioned to acquire the target.

3. Verbal Designation is the designation of the target by voice or telephone.

Target Evaluation: Estimates of target intent, degree of threat, and type of attack to be delivered, based on plots of a target position.

Target Indication: A manifestation, to command and control, of targets approaching into or appearing in the area of gunfire. It includes all information available for proper designation, including the presence, identity, location, size, number, course, speed, and estimate of intent, plus any additional evaluated factors which are necessary for proper designation.

A. Target Indication is classified as to type by the means by which target presence is manifested.

1. Radar Indication describes manifestation of target presence by radar.

2. Visual Indication describes manifestation of target presence by visual sighting.

B. Target Indication is classified as to method by the system employed to display target presence.

1. Automatic Indication is indication of targets by means of an electromechanical system capable of indicating in one display all targets appearing in the area under investigation.

2. Manual Indication is the indication of targets by means of a manual plot of all targets observed or reported in the area under investigation.

Target (Projectile): See BL.

TCD (Sonar Display): Sonar display of PPI type using target as center.

TDS: Target Designation System.

TDT: Target Designation Transmitter.

Temperature Inversion (in Sea Water): A cooler layer of water overlying a warmer one.

Terrier: A surface-to-air missile with solid-fuel rocket motor. It is equipped with radar beam rider or homing guidance and nuclear or nonnuclear warhead.

Test Depth: Maximum depth for a submarine or underwater weapon.

Tetrode: An electron tube containing four elements (electrodes)—plate (anode), cathode, control grid, and (usually) a suppressor grid.

Tetryl: An aniline-based organic compound used as a high explosive.

TH: See Thermite.

Thermite (or Thermate): A mixture of iron oxide and aluminum, often used as a filler in incendiary bombs.

Thermocline: Layer of sea water in which density changes rapidly with depth.

Theta (θ): Greek letter used to designate a selected angle.

Thrown Weapons: Small contact or proximity fuze ASW explosive devices thrown by a rocket or mortar device from attacking surface ship.

Thyratron: A special type of high-output gas-filled electronic tube.

Time Base: Length of full-width sweep (A-scope radar presentation).

Time Fuze: A fuze which contains a graduated time element to regulate the time interval after which the fuze will function.

Time of Flight: Time elapsed from projectile's firing till its impact or explosion.

TNT: Trinitrotoluene. A high explosive.

Torch Pot: In a torpedo exercise head, the torch pot gives off smoke to assist the torpedo recovery crew to recover the torpedo at the end of a run.

Torpedo: A self-propelled underwater weapon whose explosive warhead is detonated upon contact with or in proximity to a waterborne or subsurface target. A torpedo may be a component of a more complex weapon, for which it serves as the terminal stage. (Examples: Astor, Subroc, Dash.)

Torpedo Mines: See Mobile Mines.

Torpedo Tube: A torpedo launching device tubular in configuration, from which the torpedo is normally ejected by compressed air.

Torque: Twisting effort, expressed in pound-feet.

Torque Motor: A motor whose armature movement is restricted to less than one revolution, and whose output is a torque proportional to its input.

Total Internal Reflection: See Critical Angle.

Tq: Underwater fire control symbol for dead time.

Tracer: Pyrotechnic device on projectile which shows projectile track when in flight.

Tracking: The process of establishing the path of target motion with respect to the firing ship; it is accomplished by combining the data obtained by the aiming and ranging processes.

A. Tracking is classified as to type by the form of tracking employed.

1. Direct Tracking is that type of tracking in which target path is established by

direct observation (radar, optical or sonar).

2. Indirect Tracking is that type of tracking in which the range, bearing, and elevation of the target are generated by the computer and its associated equipment.

3. Offset Tracking is that type of tracking in which the target path is established by the direct observation of an intermediate point of aim in known relationship to the designated target.

B. Tracking is classified as to method by the manner in which the computers are employed to determine the path of target motion.

1. Automatic Tracking is that method of tracking in which the target path is established by use of radar for aiming and ranging and without manual operation of any of the tracking controls in the fire control system.

2. Automatic Lead Computing is that method of tracking in which the process of aiming automatically generates a solution of target motion. This method of tracking is associated with instruments using gyros to measure the angular velocity of the LOS.

3. Rate Control is that method of tracking in which the computer's generated path of estimated target motion is made to coincide with the observed path of target motion by comparing the observed and generated rates of motion.

a. Automatic Rate Control is that method of rate controlling in which the generated target motion is automatically corrected to agree with the observed target motion by a rate-control mechanism operated by the director operators.

b. Semiautomatic Rate Control is that method of rate controlling in which the generated target motion is automatically corrected to agree with the observed target motion by a rate control mechanism operated by the computer operators.

c. Manual Rate Control is that method of rate controlling in which the generated target motion is corrected to agree with observed target motion by changes to target course, speed, and angle of climb introduced manually by the computer operators.

- Train:** The movement in the horizontal plane of a gun mount or launching equipment.
- Train Alignment:** Alignment of fire control and weapon systems elements so that they are in effect all parallel and all at exactly the same angle to a selected vertical plane.
- Trainer:** One who moves a weapon in azimuth.
- Training Circle:** A large circular gear at the base of trainable weapon equipment.
- Training Gear:** Mechanical, electrical, and hydraulic equipment used to move weapon equipment in azimuth.
- Tramming:** Procedure for verifying train and elevation dial accuracy on gun mounts.
- Transducer (Sonar):** Device that translates sound waves into electrical signals, and vice versa.
- Transistor:** An active semiconductor device having three or more electrodes (elements). Transistors can perform almost all the functions of electron tubes.
- Transmission Check:** In fire control system alignment, the process of verifying that the data transmission system is functioning with the accuracy required.
- Transmission Loss:** Signal strength lost in transmission.
- Transverse Waves:** Vibration at right angles to direction of wave front movement.
- Traverse Plane:** A plane determined by a point of aim and the elevation axis of the sight.
- Trench-Warfare Ammunition:** Ammunition for certain types of infantry weapons.
- Triode:** A three-electrode electron tube. It has a plate (anode), cathode, and control grid.
- Triple-Based Powder:** See Multi-Based Powder.
- Tilt Box:** A part of an axial-piston pump containing the socket ring.
- Tritonal:** A mixture of TNT and aluminum powder.
- True Target Bearing:** True bearing of the target from the firing ship.
- True Wind:** Wind as it exists with respect to the earth and independent of any motion of the ship.
- Trunnions:** Part of the gun mount slide. The center of rotation in elevation movement.
- Trunnion Tilt:** Instantaneous inclination of the axis of the trunnions to the horizontal.
- Truth Table:** A table that describes a logic function by listing all possible combinations of input values and indicating for each combination the true output values.
- Tud:** In underwater fire control, symbol for time to fire.
- UB Plot:** Underwater Battery Plot.
- UFCS:** Underwater Fire Control System.
- Ultrasonics:** Sound above normal human audible frequency range. Usual upper limit of audibility is taken to be about 15 kHz (15,000 Hz) ("Supersonics" used in this sense is no longer correct.)
- Underwater Demolition:** The destruction or neutralization of underwater obstacles; this is normally accomplished by underwater demolition teams.
- Unit Replacement Principle:** Replacement of complete subassemblies by others in event of failure in the field, instead of replacement of failed or defective components only.
- Universal Motor:** A motor (usually fractional horsepower) that can be operated on either a-c or d-c.
- Upper Carriage:** The part of the gun mount rotating structure that contains the trunnion bearings.
- UPS:** Universal Polar Stereographic (military grid system).
- Urgent Attack (ASW):** Attack on submarine which is in position to fire torpedoes.
- USNMI:** U.S. Navy Maneuvering Instructions.
- UTM:** Universal Transverse Mercator (military grid system).
- Vacuum Tube:** See Electron Tube.
- Variable Time Fuze:** A fuze designed to detonate a projectile, bomb, mine, or depth charge when activated by external influence other than contact in the close vicinity of a target.
- VDS:** Variable Depth Sonar. A device on the fantail of a destroyer to lower a sonar transducer to a variable depth to search below the layer depth.
- Vehicle:** The carrier or delivery device in a weapon system.
- Vertical Plane:** A plane perpendicular to the horizontal. It may pass through any designated line or point.

Very Light: A projected pyrotechnic device.

Vesicant: A chemical agent that blisters the skin, such as lewisite and mustard.

Video: Visual signal presentation, or electrical signal which eventually forms a part of a video presentation.

Virtual Image: An optical image that does not actually exist at the location where it appears to be.

Voltage Regulator: A device that maintains the voltage of a voltage source essentially constant regardless of variations in input voltage and load.

VT: Proximity (fuze).

Wander Marks: Reticle marks used in stereoscopic rangefinder.

Warhead: 1. That part of a missile, projectile, or torpedo that constitutes the explosive, chemical, or other charge intended to damage the enemy. 2. A major assembly, which includes either the nuclear or thermonuclear system, high explosive system, chemical and biological agents or inert materials.

Warhead Section: A completely assembled warhead including appropriate skin sections and related components.

Watch, Quarter, and Station Bill (WQ & S Bill): A chart showing for each billet the name and rate assigned, cleaning and maintenance station, and assignments in condition watches and specific bills.

Waveguide: Radar wave conductor.

WDE: Weapons Direction Equipment. It usually consists of one or more Target Selection and Tracking Consoles, a Director Assignment Console, a Weapon Assignment Console, and the necessary cabinets to house power supplies and computer units.

WDS: Weapons Direction System. It is made up of WDE and units that support its function.

Weapon: The destructive unit in a weapon system. Except for guns, the weapon is the unit that actually destroys the target (commonly by explosion).

Weapon System: The combination of a weapon (or multiple of weapons) and the equipment used to bring the destructive power of the weapon against the enemy. It includes units to—

1. Detect, locate, identify the target.
2. Deliver or start delivery of weapon to target.
3. Control delivery unit or weapon.
4. Destroy the target (weapons).

Weapons Doctrine: General instructions on course of action to be taken by officers supervising weapon operations in specific tactical situations.

Wear Gage: Instrument for measuring erosion at origin of rifling in minor caliber guns.

Weight: Amount of gravitational pull on a body.

Wild Shot: A shot with an abnormally large dispersion in range, or in deflection, or in both.

Wind Direction: Direction from which the wind is blowing.

Window: Projectile that ejects foil strips to make a deceptive radar target or screen.

Windshield: Thin metal fairing over nose of AP projectile.

WLO: Weapons Liaison Officer. The weapons department representative in CIC.

Work: Force acting against a resistance through a distance, resulting in movement of a load against a resistance, or acceleration of a mass.

Working Pressure Air: In a torpedo, compressed air at a pressure around 500 psi.

WP: White phosphorus.

Yoke (Gun): In bag guns, the equivalent of the gun housing.

Zero Length Rocket Launcher: A rocket launcher (used today only in aircraft) which does not support the rocket after the burning propellant has begun to move the rocket.

Zone of Responsibility: A predetermined area of enemy terrain which supporting ships are responsible for covering by fire on known targets or targets of opportunity and by observation.

Zuni: An air-to-surface unguided rocket with solid propellant. Can be armed with various types of heads, including flares, fragmentation, and armor piercing.

PART 2—GLOSSARY OF FIRE
CONTROL SYMBOLS

This is a special glossary designed for the convenience of those desiring to understand the derivation of fire control symbols or to know the meaning of specific symbols used in AA and surface gunnery. It does not include all of the symbol variations used in AA and surface gunnery, nor does it cover symbols used in underwater fire control or in guided missile fire control. For detailed authoritative treatment, refer to OP 1700, which, in its three volumes, explains all fire control values, their symbols, and their derivation.

Symbols are used in fire control to provide a concise way to represent values which otherwise would require extended definition. Fire control symbols are made up of capital letters standing for basic quantities; and lower case letters, arabic numerals, and the prime (') are used as modifying symbols. For example, "So" is made up of a basic symbol "S" meaning "speed" and a modifying symbol "o" meaning "of own ship." Hence, the symbol So signifies own ship speed. The prime (') before a quantity denotes measurement from a normal plane. After a quantity, it denotes measurement to or in a normal plane (a plane perpendicular to the deck). (Bear in mind that some publications still may be using the old fire control symbols, the ones that are used in this book's predecessor.)

BASIC SYMBOLS AND DEFINITIONS

Symbol	Definition
A	Angular movement in elevation.
B	Bearing (of target, unless modified) measured in the horizontal plane.
C	Course, measured in the horizontal plane.
D	Rate of
E	Elevation (of target, unless modified) measured in the vertical plane.
Ei	Level angle.
Eu	Angle of depression (pertaining to the line of sight).
F	Missile offset angle.
G	Gyro angle.
H	Distance (between two points).
I	Angle of inclination (useful only as a rate).
L	Sight deflection; total lead angle between line of sight and line of fire.

Symbol	Definition
M	Linear movement.
P	Gun parallax displacement.
Ps	Director parallax base length.
R	Range.
S	Lateral angular movement.
T	Time.
U	Velocity.
V	Sight angle.
W	Wind rate.
Y	Radius of turn.
Z	Crosslevel angle.

COMMON BASIC SYMBOL-MODIFIERS
AND DEFINITIONS

Symbol	Definition
a	Apparent; expressing rates and angles of apparent wind.
b	Bearing.
d	Deck; quantities measured in, from, or about axes in the deck plane.
e	Elevation.
g	Gun.
h	Horizontal.
k	Earth; quantities expressing earth's rate.
o	Own ship.
p	Prediction.
q	Heading; the compass head of own ship or target.
r	Range.
s	Line of sight.
t	Target.
v	Vertical.
w	Wind; of or due to wind.
x	East-West measurement.
y	North-South measurement.
z	Of or due to cross level.
'	Prime (before quantity); measurement from a normal plane.
'	Prime (after quantity); measurement to or in a normal plane.
"	Double prime (before quantity); measurement from a plane normal to the slant plane.
"	Double prime (after quantity); measurement to or in a plane normal to the slant plane.
1	Present position.
2	Future position.
3	Advance position.
4	Aiming position.
5	Fuze computation quantities.

QUANTITY MODIFIERS

(These modifiers are used before or after parentheses.)

Modifier	Name	Before The Parenthesis	After The Parenthesis (NM denotes no meaning)
a	Advance	Portion of quantity measured to advance position	NM
b	Ballistics	Superelevation or drift	Superelevation or drift correction
c	Computed or Generated	Value of quantity computed or generated in mechanism	NM
d	Designated	Designated value of quantity	NM
e	Estimated or Error	Estimated value or error	NM
f	Function	Function of a quantity	NM
g	Dead Time	Correction due to dead time	The quantity corrected for the effect of dead time
i	Increment	An increment of a quantity	NM
j	Computational Addition or Partial	A computational addition to the quantity	A partial value of the quantity
k	Earth	NM	Referred to earth frame
l	Initial	The initial value of the quantity	NM
m	Relative Motion	The portion of the quantity accounting for relative motion between own ship and target	The quantity corrected for the effect of relative motion between own ship and target
o	Observed or Measured	Observed or measured value of a quantity	Referred to a frame rigidly attached to own ship
p	Gun Parallax	Portion of quantity accounting for gun parallax	Quantity corrected for the effect of gun parallax
<u>ps</u>	Director Parallax	Director parallax portion of quantity	Director parallax correction
q	Corrective Input or Spot	Corrective Input or Spot	NM
r	Rate Control	Rate control correction to a quantity	The quantity including the rate control correction
s	Selected	Selected value	Referred to inertial frame
u	Initial Velocity Loss	Portion accounting for change in initial velocity	Corrected for change in initial velocity
w	Wind	Effect of wind	Correction for effect of wind

PRINCIPAL FIRE CONTROL
QUANTITIES
(Selected items only are listed.)

- A. Relative angular movement in elevation. The difference in elevation from the horizontal plane between the present line of sight and line to the future target position, measured upward to the line to future target position in a vertical plane. (Symbol was previously used for target angle.)
- B. Relative target bearing. The angle between the vertical plane through own ship centerline and the vertical plane through the line of sight, measured in the horizontal plane clockwise from the bow of own ship. (Previously called Br.)
- Bd Director train (stabilized sight). Angle between the vertical plane through own ship centerline and the vertical plane through the line of sight, measured in the deck plane clockwise from the bow of own ship. (Previously called B'r.)
- Bd'. Director train (sight not stabilized). Angle between the vertical plane through own ship centerline and the normal plane through the line of sight, measured in the deck plane. Positive angles are measured clockwise from own ship centerline. (Previously called B'r'.)
- Bog Gun parallax angle. Angle between normal plane through reference line and normal plane through gun parallax base line, measured in the deck plane clockwise from reference line.
- Bos Gun parallax angle. Angle between normal plane through reference line and normal plane through director parallax base line, measured in the deck plane clockwise from reference line.
- Bot. Target angle. Angle between vertical plane through the relative target speed vector and the vertical plane through the line of sight, measured in the horizontal plane clockwise from the target speed vector. (Previously called A.)
- Bwy True direction true wind. Angle between the north-south vertical plane and the vertical plane through the direction from which the true wind is blowing, measured in the horizontal plane. Positive angles are measured clockwise from North. (Previously called Bw.)
- By True target bearing. Angle between the north-south vertical plane through the line of sight, measured in the horizontal plane. Positive angles are measured clockwise from North.
- c(B) Generated relative bearing. (See definition of B.)
- c(E) Generated target elevation. (See definition of E.)
- Co Own ship course. Angle between the north-south vertical plane and the vertical plane through own ship centerline, measured in the horizontal plane. Positive angles are measured clockwise from North.
- Cqo Own ship heading. Angle between the North-South vertical plane and the vertical plane through own ship centerline, measured in the horizontal plane. Positive angles are measured clockwise from North.
- Cqt. Target heading. Angle between the North-South vertical plane, and the vertical plane through the target centerline, measured in the horizontal plane. Positive angles are measured clockwise from North.
- Ct Target course. Angle between the North-South vertical plane, and the vertical plane through the target speed vector (referred to the frame used by the fire control system), measured in the horizontal plane. Positive angle is measured clockwise from North.
- Cw. True course true wind. Angle between the North-South vertical plane, and the vertical plane through the direction toward which the true wind is blowing, measured in the horizontal plane. Positive angles are measured clockwise from North.
- DBs Angular bearing rate in slant plane. The angular rate of the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured with respect to the initial position of the line of sight at the instant of firing. The initial position of the line of sight is fixed in the reference frame used by the fire

- control system to measure the angular rate.
- DE Angular elevation rate. The angular rate of the line of sight in the vertical plane through the line of sight, measured with respect to the intersection of the vertical plane through the line of sight and the horizontal plane. (Previously called dE.)
- E Target elevation. Angle between the horizontal plane and the line of sight, measured in the vertical plane through the line of sight. Positive angles are measured upward from the horizontal plane.
- E' Target elevation. Angle between the horizontal plane and the line of sight, measured in the normal plane through the line of sight. Positive angles are measured upward from the horizontal plane.
- Ed Director elevation. Angle between the deck plane and the line of sight, measured in the vertical plane through the line of sight. Positive angles are measured upward from the deck plane.
- Edg . . . Gun elevation order. Angle between the deck plane and the line of fire, measured in the vertical plane through the line of fire. Positive angles are measured upward from the deck plane.
- Edg' . . . Gun elevation order. Angle between the deck plane and the line of fire, measured in the normal plane through the line of fire. Positive angles are measured upward from the deck plane. (Previously called E'g.)
- Eg Gun elevation. Angle between the horizontal plane and the line of fire, measured in the vertical plane through the line of fire. Positive angles are measured upward from the horizontal plane.
- Ei Level angle. Angle between the horizontal plane and the deck plane, measured in the vertical plane through the line of sight. Positive angles are measured downward from the horizontal plane on the target side of own ship. (Previously called L.)
- Eio . . . Pitch. Angle between the horizontal plane and the deck plane, measured in the vertical plane through own ship centerline. Positive angles are measured downward from the horizontal plane.
- E2 Future target elevation. Angle between the horizontal plane and the line to the future target position, measured in the vertical plane through the line to the future target position. Positive angles are measured upward from the horizontal plane.
- L Total lead angle. Angle between the line of sight and the line of fire.
- Ld Dock deflection. Angle between the vertical plane through the line of sight, and the vertical plane through the line of fire, measured in the deck plane from the vertical plane through the line of sight. (Previously called Dd.)
- Lh Horizontal deflection. Angle between the vertical plane through the line of sight and the vertical plane through the line of fire, measured in the horizontal plane from the vertical plane through the line of sight. (Previously called Dh.)
- Ls Sight deflection. Angle between the line of sight and the vertical plane through the line of fire, measured from the line of sight in the slant plane through the line of sight and through the director elevation axis in the horizontal plane. (Previously called Ds.)
- Lz Trunnion tilt correction. Correction to gun train order for the tilting of the gun trunnions due to crosslevel. (Previously called Dz.)
- M Total relative movement. Total linear displacement of the target during the time of flight due to relative motion between own ship and target in the frame used by the fire control system.
- Mh Linear movement in horizontal. The linear displacement during the time of flight in the horizontal plane and in the vertical plane through the relative target speed vector in the frame used by the fire control system. Modifier o is added (Mho) to express the quantity due to own ship motion, and modifier t is added (Mht) to express the quantity due to target motion.

- Mr Linear movement in range. The linear movement during time of flight along the line of sight, due to relative motion between own ship and target in the frame used by the fire control system.
- P Gun parallax base length. Total distance from the reference point to the gun, measured along the gun parallax base line.
- Ps Director parallax base length. The total distance from the reference point to the director, measured along the director parallax base line.
- R Present range. Distance from own ship to target, measured along the line of sight.
- Rh Horizontal range. Projection of present range in the horizontal plane by a vertical plane through the line of sight.
- Rv Target height. Height of target above the horizontal plane, measured in the vertical plane through the line of sight.
- R2 Future range. The distance from own ship to future target position, measured along the line to the future target position.
- R3 Advance range. Distance from own ship to the advance target position. (Previously called R2.)
- R4 Aiming range. The distance from own ship to the aiming position, measured along the line of fire.
- R5 Fuze range. Range used in the computation of fuze setting order. It is equal to advance range plus change in range during dead time.
- S Total angular movement. The total angle between the line of sight and the line to the future target position.
- Sh Horizontal angular movement. Angle between the vertical plane through the line of sight and the vertical plane through the line to future target position, measured in the horizontal plane from the vertical plane through the line of sight.
- T Clock time.
- Tg Dead time. Time between setting the fuze and firing the shell (projectile) or time for which computational quantities must be modified when launching (missiles) is delayed.
- U Initial velocity. The velocity of the projectile with respect to the gun muzzle at the instant the projectile leaves the gun.
- Vs Sight angle. Angle between the line of fire and the slant plane through the line of sight and through the director elevation axis in the horizontal plane, measured from the line of fire in the vertical plane through the line of fire.
- Vz Trunnion tilt correction. The part of gun elevation order accounting for the tilting of the gun trunnions due to crosslevel.
- W True wind speed. The total rate of the true wind measured with respect to the earth.
- Zd Crosslevel. Angle between the vertical plane through the line of sight and the normal plane through the intersection of the vertical plane through the line of sight and the deck plane measured about the axis which is the intersection of the vertical plane through the line of sight and the deck plane.
- Zs Angle between the vertical plane through the line of sight and the normal plane through the line of sight, measured about the line of sight as the axis.

APPENDIX II

BALLISTIC CALCULATIONS

This appendix is divided into two main sections. The first section explains the uses of range tables, and the second section gives instructions for using the air-density nomogram.

This discussion is based on information about a 5"/38 gun and its projectile, contained in OP 551, third revision. Ballistic information on projectiles for other guns may be found in the appropriate OP range table (as this information is called). For example, the range table for certain 5"/54 gun projectiles is found in OP 1182.

USES OF RANGE TABLES

The range table is published by the Naval Ordnance Systems Command for each gun and for each projectile type fired by the gun. It presents, in convenient form, the elements of the trajectories resulting from firing that specified projectile, at a specified initial velocity, at various angles of elevation, under standard conditions. A range table tabulates, for each 100-yard increment of range, such characteristics of the trajectory as angle of elevation, time of flight, angle of fall, and striking velocity.

Preparation of a range table involves experimental firings of a number of the specified projectiles to obtain data used in conjunction with a complex set of equations or formulas to solve the trajectory.

Normal practice at the Naval Ordnance Laboratory is to compute all range table entries directly from equations by means of large mechanical and electronic computing machines. These machines are capable of handling a large number of complex solutions rapidly and accurately.

STANDARD CONDITIONS FOR RANGE TABLES

In the computations upon which range tables are based, certain arbitrary conditions are assumed. These are range-table standard conditions. To use the range table under conditions

other than standard, it is necessary to provide in the table corrections for variations from these conditions.

The standard conditions assumed for range-table values are that:

1. The projectile leaves the gun with the designed velocity.
2. The projectile is of the designed weight.
3. The atmosphere is of an arbitrarily chosen standard density.
4. There is no wind.
5. The gun is motionless.
6. The target is motionless.¹
7. The earth is motionless.
8. The gun and target are in the same horizontal plane, the plane tangent to the earth's surface at the gun.
9. The gun is elevated in the vertical plane; that is, the axis of the gun trunnions is horizontal at the time of firing.

Variations from any one of these conditions may cause a significant error. Therefore, in addition to the tabulation of trajectories under standard conditions, the range table provides necessary corrections for variations from the first six of these standard conditions. Corrections for variations from any of the last three require separate consideration or computation.

Correction for rotation of the earth can be computed from auxiliary tables published with range tables for major-caliber guns, or by fire control instruments. The amount and direction of error vary with the azimuth of the line of fire, the latitude, and the range; but remain small in all cases. The correction is disregarded for guns of 5-inch caliber or smaller. The correction for tilt of the trunnion axis from the

¹Although motion of the target does not affect the trajectory itself, it enters into the problem of determining the trajectory that will reach the target.

horizontal is practical only when using a mechanical solution and is considered in the fire control problem. Use of the columns of the range table to account for nonstandard conditions will be taken up later.

A TYPICAL RANGE TABLE

The discussion which follows is based on the range table (OP551, third Revision) for the 5"/38 gun using a 55.18-pound AA common projectile. The table, excerpts of which are shown in figure A2-1, is based on an I.V. of 2500 ft. per second—an average value for 5"/38 guns.

Columns 1 to 8 inclusive give values of elements of the trajectory under standard conditions corresponding to a given range, in increments of 100 yards.

Columns 10 to 18 inclusive (there is no column 9) list errors caused by the fact that actual firing is seldom, if ever, conducted under actual range table conditions. The heading over each column indicates both cause and direction of error.

COLUMN 10

Column 10 is headed "Change in range for 10 F.S. increase in initial velocity." The two major elements which affect initial velocity are gun erosion and variation in powder temperature. Of these, erosion causes a loss in initial velocity and a decrease in range. The Navy range tables are based on a standard powder temperature of 90° Fahrenheit. Magazine temperature rarely exceeds this figure. The variation in velocity due to temperature variation of one degree from 90°F. is stated in certain range tables and other NavOrdSysCom publications. The loss of initial velocity per degree of change of powder temperature will vary with the caliber, powder index (i.e., manufacturing lot), and erosion.

The loss of velocity caused by erosion is dependent upon the amount of bore enlargement. The range table includes one table which shows the amount of velocity loss for specified amounts of bore enlargement, which can be used following star gaging, and a second table showing bore enlargement versus equivalent service rounds fired, for use in periods between star gaging.

It must be noted that initial velocity for a new 5"/38 gun is 2600 ft. per sec. (often abbreviated also as f.s. or f.p.s.). Since the

average velocity during the life of the gun is 2500 ft. per sec (the range table's assumed value), in a relatively new gun, velocity change due to bore enlargement may have to be computed in relation to the range table as a gain rather than a loss.

COLUMN 11

Column 11 is headed "Change in range for 1 pound decrease in projectile weight." This change of range is due to two causes which are opposite in their effects. The first is the change in I.V. A projectile heavier than standard will be expelled from the gun at lower than designed I.V., causing a decrease in range. However, increase in weight will cause an increase in momentum, which results in an increase in range.

In practice, column 11 is not normally used aboard ship, since only projectiles of standard weight are fired. Projectiles are required to be of designed weight within small tolerances. The effects of these small variations are neglected. This small variation in projectile weight is one reason why all shots of a salvo, fired at the same time and under the same conditions, do not fall at the same point.

COLUMN 12

Column 12 is headed "Change in range for 10 percent decrease in air density." For use under conditions where no aloft observations of air density are possible, a table has been prepared based on the results of many past observations aloft. The entering arguments are the height of the maximum ordinate in feet and the surface density; the result is the ballistic density. Standard surface density has been arbitrarily selected as the density of the atmosphere at a temperature of 59°F., a barometric pressure of 29.53 inches of mercury, and a humidity of 78 percent saturation. This standard surface density is assigned a numerical value of 1.000. To determine variation in the trajectory caused by variation from standard surface density, the temperature and barometric pressure are measured at the surface and the resulting density is expressed as a percentage of the standard. This percentage of standard density at the surface is then used in the table of ballistic density and from it the ballistic density is found.

5-IN. 38-CAL. GUN 1-V. 2500 F.S. 55.18-POUND PROJECTILES

RANGE	ANGLE OF ELEVATION		CHANGE IN		ANGLE OF FALL		TIME OF FLIGHT -	STRIKING VELOCITY	DRIFT	DANGER SPACE FOR A TARGET 20 FT. HIGH	MAXIMUM ORDINATE
			ANGLE OF ELEVATION FOR 100 YDS. INCREASE IN RANGE								
1 YARDS	2 DEG. MIN.	2A MINUTES	2B MINUTES	3 DEG. MIN.	4 SECONDS	5 FT./SEC.	6 YARDS	7 YARDS	8 FEET		
8000	7	11.6	431.6	10.1	13 12	15.83	1040	21.0	29	1033	
8100	7	21.7	441.7	10.3	13 33	16.13	1035	22.0	28	1075	
8200	7	32.0	452.0	10.5	13 54	16.43	1030	22.9	27	1118	
8300	7	42.5	462.5	10.6	14 16	16.73	1026	23.9	26	1162	
8400	7	53.1	473.1	10.7	14 37	17.03	1022	24.9	26	1207	
8500	8	3.8	483.8	10.9	14 59	17.34	1018	26.0	25	1253	
8600	8	14.7	494.7	11.0	15 20	17.64	1014	27.1	24	1301	
8700	8	25.7	505.7	11.2	15 42	17.95	1010	28.2	24	1350	
8800	8	36.9	516.9	11.3	16 4	18.26	1006	29.3	23	1400	
8900	8	48.2	528.2	11.5	16 26	18.58	1002	30.5	23	1452	
9000	8	59.7	539.7	11.6	16 49	18.89	999	31.7	22	1504	
9100	9	11.3	551.3	11.8	17 11	19.21	995	33.0	22	1559	
9200	9	23.1	563.1	11.9	17 34	19.52	992	34.3	21	1614	
9300	9	35.0	575.0	12.0	17 56	19.84	989	35.6	21	1671	
9400	9	47.0	587.0	12.2	18 19	20.17	985	37.0	20	1729	
9500	9	59.2	599.2	12.4	18 42	20.49	982	38.4	20	1788	
9600	10	11.6	611.6	12.4	19 5	20.82	979	39.8	19	1849	
9700	10	24.0	624.0	12.7	19 29	21.15	976	41.3	19	1912	
9800	10	36.7	636.7	12.8	19 52	21.48	973	42.9	18	1975	
9900	10	49.5	649.5	12.9	20 16	21.81	970	44.4	18	2040	
10000	11	2.4	662.4	13.1	20 39	22.14	968	46.0	18	2107	
10100	11	15.5	675.5	13.2	21 3	22.48	965	47.7	17	2175	
10200	11	28.7	688.7	13.4	21 27	22.82	962	49.4	17	2245	
10300	11	42.1	702.1	13.5	21 51	23.16	960	51.1	17	2316	
10400	11	55.6	715.6	13.7	22 15	23.50	958	52.9	16	2388	
10500	12	9.3	729.3	13.8	22 40	23.85	955	54.7	16	2462	
10600	12	23.1	743.1	14.0	23 4	24.19	953	56.6	16	2538	
10700	12	37.1	757.1	14.2	23 29	24.54	951	58.6	15	2615	
10800	12	51.3	771.3	14.3	23 53	24.89	949	60.5	15	2694	
10900	13	5.6	785.6	14.4	24 18	25.25	947	62.6	15	2774	
11000	13	20.0	800.0	14.6	24 43	25.60	945	64.6	14	2857	
11100	13	34.6	814.6	14.8	25 8	25.96	943	66.8	14	2940	
11200	13	49.4	829.4	15.0	25 34	26.32	941	68.9	14	3026	
11300	14	4.4	844.4	15.1	25 59	26.69	939	71.2	14	3113	
11400	14	19.5	859.5	15.3	26 24	27.05	938	73.5	13	3202	

110.168.1

Figure A2-1. — Partial range table (from OP 551, 3rd revision).

5-IN. 38-CAL. GUN 1.4 V. 2500 F.S. 55.18-POUND PROJECTILES											
CHANGE IN RANGE FOR					DEFLECTION FOR						CHANGE IN HEIGHT OF IMPACT FOR 100 YARDS CHANGE IN RANGE
RANGE	10 F.S. INCREASE IN INITIAL VELOCITY	1 LB. DECREASE IN PRO- JECTILE WEIGHT	10 PCT. DECREASE IN AIR DENSITY	10 DEG. F. DECREASE IN AIR TEMPER- ATURE	10 KNOT MOTION IN PLANE OF FIRE			10-KNOT MOTION PERPENDICULAR TO PLANE OF FIRE			
	10 YARDS	11 YARDS	12 YARDS	12A YARDS	WIND 13 YARDS	GUN 14 YARDS	TARGET 15 YARDS	WIND 16 YARDS	GUN 17 YARDS	TARGET 18 YARDS	
8000	42	-11	374	17	48	41	89	34.6	54.5	89.1	70
8100	42	-12	380	17	49	41	91	35.6	55.2	90.8	72
8200	42	-12	386	17	51	42	92	36.6	55.9	92.5	74
8300	43	-13	392	17	52	42	94	37.6	56.6	94.2	76
8400	43	-14	399	16	54	42	96	38.6	57.3	95.9	78
8500	43	-15	405	16	56	42	98	39.6	58.0	97.6	80
8600	43	-16	411	16	57	42	99	40.6	58.7	99.3	82
8700	44	-16	417	16	59	42	101	41.6	59.4	101.1	84
8800	44	-17	423	15	60	42	103	42.7	60.1	102.8	86
8900	44	-18	429	15	62	42	105	43.7	60.8	104.6	89
9000	44	-19	435	15	64	42	106	44.8	61.6	106.3	91
9100	45	-19	441	14	66	43	108	45.9	62.3	108.1	93
9200	45	-20	447	14	67	43	110	46.9	63.0	109.9	95
9300	45	-21	452	14	69	43	112	48.0	63.7	111.7	97
9400	45	-22	458	13	71	43	114	49.1	64.4	113.5	99
9500	45	-22	464	13	73	43	115	50.2	65.2	115.4	102
9600	46	-23	470	13	74	43	117	51.3	65.9	117.2	104
9700	46	-24	476	12	76	43	119	52.4	66.6	119.0	106
9800	46	-25	481	12	78	43	121	53.6	67.4	120.9	108
9900	46	-25	487	11	80	43	123	54.7	68.1	122.8	111
10000	47	-26	493	11	82	43	125	55.8	68.8	124.7	113
10100	47	-27	499	10	84	43	127	57.0	69.6	126.6	115
10200	47	-28	505	10	85	43	128	58.1	70.3	128.5	118
10300	47	-28	510	9	87	43	130	59.3	71.1	130.4	120
10400	47	-29	516	9	89	43	132	60.5	71.8	132.3	123
10500	48	-30	522	8	91	43	134	61.7	72.6	134.2	125
10600	48	-31	527	8	93	43	136	62.9	73.3	136.2	128
10700	48	-31	533	7	95	43	138	64.1	74.1	138.2	130
10800	48	-32	539	7	97	43	140	65.3	74.8	140.1	133
10900	48	-33	545	6	99	43	142	66.5	75.6	142.1	135
11000	49	-34	551	6	101	43	144	67.8	76.4	144.1	138
11100	49	-34	557	5	103	43	146	69.0	77.1	146.2	141
11200	49	-35	562	5	105	43	148	70.3	77.9	148.2	143
11300	49	-36	568	4	107	43	150	71.5	78.7	150.2	146
11400	49	-37	574	4	109	43	152	72.8	79.5	152.3	149

110.168.2

Figure A2-1. — Partial range table (from OP 551, 3rd revision).

USE OF THE NOMOGRAM

The primary means of determining the change of range for variation of air density is by nomogram (fig. A2-6). The nomogram provided with the 5"/38 caliber range table is an example of the type in use in the Fleet today. When aloft aerological observations are not available, it gives a rapid solution of the error in range due to variation in atmospheric density. Instructions for its use are provided with the nomogram.

The use of the nomogram is more accurate than results obtained from using column 12 with surface observations, as it takes into account the ratio between mean measured and standard density for the actual maximum ordinate obtained.² Instructions for using the nomogram are presented later in this appendix.

COLUMNS 15 AND 18

Column 15 is headed "Change in range for 10 knot motion in plane of fire-target" and column 18 is headed "Deflection for -10 knot motion perpendicular to plane of fire-target." Actually, column 15 gives the distance that the target will move in the line of fire, if its speed in the line of fire is 10 knots, during the time of flight of the projectile. Column 18 gives the same information for motion across the line of fire. The values in the columns are derived by multiplying the speed of 10 knots, expressed as 16.89/3 yards per second, by the time of flight of the projectile for the given range, as found in column 4 of the range table.

COLUMNS 13 AND 16

Column 13 is headed "Change in range for 10 knot motion in plane of fire - wind," and column 16 is headed "Deflection for -10 knot motion perpendicular to plane of fire-wind."

A wind, or wind component, in the plane of fire, or line of fire, is spoken of as a range

wind. A lateral wind (wind, or wind component, blowing across the line of fire) is spoken of as a cross wind.

The effect of a positive range wind (blowing in the direction in which the projectile is traveling) is to increase the range. The opposite is true for a negative range wind. A cross wind will carry the projectile in the direction toward which the wind is blowing.

The use of the columns is similar to that described earlier for columns 15 and 18.

COLUMNS 14 AND 17

Column 14 is headed "Change in range for 10-knot motion in plane of fire-gun" and column 17 is headed "Deflection for 10-knot motion perpendicular to plane of fire-gun." By "motion of gun" is meant the "velocity imparted to the projectile due to motion of the firing ship," aside from the velocity imparted by the powder charge. This velocity may be positive or negative. Thus, a ship steaming at 10 knots and firing dead ahead imparts an added velocity of 16.89 ft per sec., in the horizontal plane. The same ship firing dead astern reduces the horizontal component of initial velocity by the same amount. Firing on the beam causes a velocity component across the line of fire in the direction of motion of the ship.

If no wind is blowing, a person standing on deck on a moving ship will feel an apparent wind, equal in force to the speed of the ship. It may therefore be said that a projectile fired from a moving ship, in still air, is opposed by an apparent wind equal in force but opposite in direction to the motion of the ship. The effect of such an opposing wind may be found in column 13 for range wind and in column 16 for cross wind.

The relation of columns 13 through 18 may best be understood from the following expression:

$$\begin{aligned}\text{Column 14} &= \text{column 15} - \text{column 13, and} \\ \text{Column 17} &= \text{column 18} - \text{column 16.}\end{aligned}$$

Examination of any range table for any range shows that this relation is true. (The occasional difference of 2 or 3 yards is due to the fact that columns 14 and 17 actually are computed from formulas, the results plotted, and the curves faired.)

DANGER SPACE AND HITTING SPACE

Column 7 of the range table is composed of values of the danger space (chapter 9) for a target 20 feet high and of zero depth in the line of fire.

² Some recent range tables, including the one in figure A2-1, have an additional column, 12a, which gives the change in range for a variation of temperature of the air of 10°F. from the standard air temperature. The effect given in column 12a is that caused by change in the elasticity of the air and is independent of and additional to the effect of any change in density. Column 12a is used with surface air temperature, the standard being taken as 59°F.

In the 5"/38 range table, range 10,000 yards, the danger space is 18 yards. The value of the danger space at this range for a target 30 feet high is $30/20 \times 18 = 27$ yards. Now if this 30-foot target has a beam of 105 feet (35 yards) it is apparent that its danger space is $27 + 35 = 62$ yards. Column 19 of the range table, headed "Change in height of impact for variation of 100 yards in sight bar," is the column used for determining hitting space (chapter 9). (Sight bar range is the range shown on the sight scale of the gun at the instant of firing.)

To find the hitting space for a 20-foot target at range 10,000 yards, see column 19. The value obtained is 112 feet; i.e., a variation in sight-bar range of 100 yards will move the point of impact 112 feet in the vertical plane of the target. To raise the point of impact 20 feet (to the top of the target) the sight-bar range would have to be increased $\frac{20}{112} \times 100 = 18$ yards.

This value for hitting space is the same as that earlier obtained for danger space. For most battle ranges this relationship holds; for the shorter ranges, however, there may be a considerable difference.

Column 19 is also used in the computation of the correction for trunnion height and curvature of the earth when figuring the initial ballistic correction. (See the following section.)

DEFINITIONS OF VARIOUS BALLISTIC CORRECTIONS

For shipboard firings, it is necessary to determine, or to estimate, the variations from range-table standard conditions as they exist at the time of firing, and to compute corrections for the errors caused by these variations. The individual corrections are summarized and the result is called a ballistic correction.

Most of these ballistic corrections are automatically figured by the fire control computer from the initial inputs. However, there are some initial inputs that must be figured separately and set into the computer prior to firing. They are:

1. Arbitrary ballistic correction
2. Correction for first salvo only
3. Initial ballistic correction

The arbitrary ballistic correction, also called arbitrary correction to hit or ACTH, is designed to correct for errors not otherwise

accounted for. The correction is developed by exhaustive postfiring analysis of accurate data on ranges, target course and speed, and other elements in past gunnery practices. After all errors which can be accounted for (such as errors in rangefinder ranges and in estimates of target course and speed) have been eliminated in these analyses, there usually remains a certain amount of error in the point of fall for which no cause can be definitely assigned. When enough data have been obtained and analyzed to provide an accurate estimate of this quantity, it is used as an arbitrary ballistic correction.

The correction for first salvo only may be necessary if the initial round fired from a gun has a lower I.V., and therefore a shorter range, than succeeding rounds. This effect was at one time thought to be the result of the lower temperature of the bore; thus, the correction has frequently and erroneously been known as "coldgun correction." It is now known that the loss of velocity is caused by oil in the bore; thus, the correction is needed only if the bore has been cleaned and oiled since the last previous shot was fired. The amount of the correction is derived from experience, as is the ACTH, but it must be considered and treated separately, inasmuch as it is applied for the first salvo only and then removed. The first salvo correction should be used only if experience has shown it to be necessary.

Contemporary gun fire control systems develop automatically many of the inputs required for transmission to the gun mounts. However, there are some factors that must be estimated or figured with pencil and paper and introduced manually into the computer. These collectively constitute the initial ballistic correction. Exactly what goes into the initial ballistic correction depends on the particular fire control systems concerned. In most current types of gun fire systems the initial ballistic correction is inserted as three inputs—initial velocity (I.V.), initial range spot, and initial deflection spot. The next section enumerates the factors that go into the initial ballistic correction and explains how they are figured. Figure A2-2 shows a work sheet (filled in with fictitious values) for the computation of the initial ballistic correction. The work sheet shows which factors go respectively into the I.V. computation, the range correction (i.e., range spot) computation, and the deflection correction (spot) computation.

PRINCIPLES OF NAVAL ORDNANCE AND GUNNERY

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WORKSHEET FOR THE COMPUTATION OF THE INITIAL BALLISTIC CORRECTION

BATTERY	5/38	EXERCISE	SAMPLE	DATE FIRED	10 JAN. 1964
PROJECTILE	MK 35-MK 55 WT 39	CHARGE	FULL	RANGE TABLE	OP 551 (3 rd REV.)

POWDER AND EROSION DATA

a	Powder Index	5 PDF	CHARGE WT	16.0 lb	c	Average Powder Temp.	80°F
b	I.V. Erosion Data			2600 F.S.	d	Temperature coefficient	1.2°/°F
e	Cun	PRSR	Bore Enlargement Inches	Gauge	Powder Temp. Corr.	Velocity Loss F.S.	Erosion Corrector Setting Z.S.
	1 R	500	.078	43.4	0	5	NONE
	2 R	520	.081	43.6	0	7	PROVIDED
	3 R	530	.082	43.7	0	8	

ATMOSPHERIC CONDITIONS

ROTATION OF EARTH

f	Barometer	30.4"	l	Latitude	NO CORRECTION
g	Temperature	52°F	m	True Bearing	NEEDED FOR 5°
h	Ballistic Density	NOT OBTAINED	RANGE TABLE DATA		
TRUNNION AND CURVATURE DATA			A	Range	10,000
			B	Column 12	49.3
i	Average Trunnion Height	20.00 FT	C	Column 12a	11
j	Curvature of Earth	21.5	D	Column 19	11.3
k	Sum (i) + (j)	41.5	E	Column 11	-26

COMPUTATION OF INITIAL VELOCITY

F.S.

1	Powder Temp., (d)x(90-c)	12
2	Erosion Lost and Index Correction	7
3	Total Velocity Loss, (1) + (2)	19
4	Item b	2600
5	Expected I.V. (4) - (3)	2581

COMPUTATION OF RANGE CORRECTION

Yards
Over Short

6	Air Density, (100-h)x(8) ÷ 10	210
7	Air Temperature, (59-g) x (C) ÷ 10	7.7
8	Trunnion and Curvature, 100(k) ÷ (D)	37
9	Rotation of Earth for (l), (m), and (A)	
10	Other range errors	21.3
		Drop Add
11	Sum, (6) through (10)	149
12	ACTH from previous practices	75
13	Correction for first salvo only	100
14	Total Correction (11) + (12) + (13)	319

COMPUTATION OF DEFLECTION CORR.

Yards
Right Left

		Right	Left
15	Rotation of Earth for (l), (m), and (A)	x	x
16	Other deflection errors	x	x
		Mils Left	Right
17	(1000) (15+16) ÷ (A)	x	x
18	ACTH from previous practices		5
19	Total Correction (17) + (18)		5

COMPUTATION OF INITIAL
BALLISTIC CORRECTION

In figure A2-2³, the values are representative, but are not taken from an actual firing. The lines across the top of the sheet marked "Battery," "Exercise," etc., are for identification purposes.

POWDER AND EROSION
DATA

In item "a" in figure A2-2 enter the type powder, index number, and charge weight.

In item "b" enter the nominal velocity. Its value is found in the erosion-data section of the range table. It should be noted that this entry is not always the standard velocity used to compute the range table. In some cases, such as the 5"/38 range table, the expected average velocity of the gun's lifetime is used.

In item "c" enter the average residual temperature of the powder to be fired.

In item "d," "Temperature Coefficient," is obtained from the erosion-data section of the range table OP 551 (3rd revision); in this example the temperature coefficient is 1.2.

Space is provided in item "e" for the erosion data of the individual guns. In this example the right gun of three 5-inch twin mounts is used. Entries are made for the gun number, the "pseudo equivalent service rounds (PESR)," and bore enlargement or erosion-gage readings. The velocity loss due to erosion is determined by one of these values. When a gun is fired for the first time after star gage or bore erosion gage readings have been taken, the velocity loss is obtained directly from tables in the erosion data section of the range table. When star gage readings are available use the Velocity Loss vs. Bore Enlargement at Origin And Charge Weight Table (table A2-1) for the type powder to be fired.

When bore erosion gage readings are available, use the velocity loss vs. erosion gage reading and charge weight for the type powder to be fired. This table is similar in construction to table A2-1.

³The forms reproduced in figures A2-2 through A2-5 are marked CONFIDENTIAL when filled in with data pertaining to an actual gunnery practice, and must be so treated. In this case, however, the data used are purely hypothetical.

Suppose, however, the ship has fired several times since any erosion readings were taken on the gun barrel. In this event, the number of equivalent service rounds fired since the last star gage reading is determined. This number is added to the ESR determined with the star gage reading. This will give the best estimate of the present PESR. This value can then be used to obtain bore enlargement at the origin from table A2-2. With bore enlargement, table A2-1 can be entered to obtain velocity loss due to erosion.

If the powder temperatures vary more than 2° Fahrenheit (F) between guns, the powder temperatures are entered under the heading "Powder Temp. Corr." (fig. A2-2). The velocity loss for each gun is thus computed, using the formula in line 1 of the worksheet. If this is done, line 1 of the sheet is left blank. The velocity loss due to powder temperature is combined with the velocity loss due to bore enlargement. This sum is entered in the next column. The 5"/38 gun does not have an erosion corrector in its drive. Therefore, an average powder temperature is used in line 1 of the worksheet, and the average initial velocity loss (7 in this case) is used in line 2 of the worksheet.

ATMOSPHERIC CONDITIONS

Item "f" is the barometer reading in inches, and item "g" is the temperature from the dry bulb thermometer in degrees Fahrenheit. Both are surface readings taken from the ship's instruments located in the ship's bridge. Item "h," "Ballistic Density," is left blank unless this information is available.

TRUNNION AND CURVATURE
DATA

We will assume the exercise to be a surface firing with the stable element controlling elevation. Thus, trunnion height and earth curvature corrections are necessary. Item "i" is the average height of the gun trunnions above the waterline. Item "j" is the earth's curvature for the range listed in table A2-3. Item "k" is the sum of items "i" and "j."

ROTATION OF THE
EARTH

This correction is omitted for guns of 5-inch and below.

Table A2-1. — Velocity loss vs bore enlargement at origin and chart weight.

55.1# 13. PROJECTILE MKS. 35, 47 and 49

5"/38 CALIBER GUNS MK. 12 MOD. 1

SPDN SPDB SPD and SPDW INDEXES

NOMINAL VELOCITY 2600 f/s

	CHARGE WEIGHT								
	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.8	16.0
0	-35	-35	-35	-35	-35	-35	-35	-35	-35
2	-37	-37	-37	-37	-37	-37	-37	-37	-37
4	-39	-39	-39	-39	-40	-40	-40	-40	-40
6	-40	-41	-41	-41	-42	-42	-42	-42	-43
8	-41	-42	-42	-42	-42	-43	-43	-43	-44
10	-41	-42	-42	-42	-42	-43	-43	-43	-44
12	-41	-42	-42	-42	-42	-43	-43	-43	-44
14	-41	-42	-42	-42	-42	-43	-43	-43	-44
16	-41	-42	-42	-42	-42	-43	-43	-43	-44
18	-40	-41	-41	-41	-42	-42	-42	-43	-43
20	-40	-40	-40	-40	-41	-41	-41	-42	-42
22	-39	-39	-39	-39	-40	-40	-40	-40	-40
24	-39	-39	-39	-39	-39	-39	-39	-39	-39
26	-37	-37	-37	-37	-38	-38	-38	-38	-38
28	-37	-37	-37	-37	-37	-37	-37	-37	-37
30	-35	-35	-35	-35	-35	-35	-35	-35	-35
32	-34	-34	-34	-34	-34	-34	-34	-34	-34
34	-33	-33	-32	-32	-32	-32	-32	-32	-32
36	-32	-32	-31	-31	-31	-31	-31	-31	-31
38	-30	-30	-30	-30	-29	-29	-29	-29	-28
40	-29	-28	-28	-28	-27	-27	-27	-27	-26
42	-27	-27	-26	-26	-25	-25	-25	-24	-24
44	-25	-25	-24	-24	-24	-23	-23	-22	-22
46	-24	-23	-23	-23	-22	-21	-20	-19	-19
48	-22	-22	-21	-20	-20	-19	-18	-17	-17
50	-21	-20	-19	-18	-18	-17	-16	-15	-15
52	-19	-18	-17	-17	-16	-15	-14	-13	-13
54	-17	-17	-16	-15	-14	-13	-12	-11	-10
56	-16	-15	-14	-13	-12	-11	-10	-9	-8
58	-14	-13	-12	-11	-10	-9	-8	-7	-6
60	-13	-11	-10	-9	-8	-7	-6	-5	-4
62	-11	-10	-9	-7	-6	-5	-4	-3	-1
64	-9	-8	-7	-6	-5	-4	-3	-2	1
66	-8	-6	-5	-4	-3	-2	-1	0	3
68	-6	-5	-3	-2	0	1	2	4	5
70	-5	-3	-2	0	2	3	5	6	8
72	-3	-1	0	2	3	5	7	8	10
74	-1	0	2	4	5	7	9	10	12
76	0	2	4	6	7	9	11	13	14
78	2	4	6	7	9	11	13	15	17
80	3	5	7	9	11	13	15	17	19
82	5	7	9	11	13	15	17	19	21
84	7	9	11	13	15	17	19	21	23
86	8	10	13	15	17	19	21	23	26
88	10	12	14	17	19	21	23	26	28
90	11	14	16	18	21	23	25	28	30
92	13	15	18	20	23	25	27	30	32
94	15	17	20	22	25	27	30	32	35
96	16	19	21	24	27	29	32	34	37
98	18	21	23	26	28	31	34	36	39
100	20	22	25	28	30	33	36	39	41
102	21	24	27	30	32	35	38	41	44
104	23	26	28	31	34	37	40	43	46
106	24	27	30	33	36	39	42	45	48
108	26	29	32	35	38	41	44	47	50

	CHARGE WEIGHT								
	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.8	16.0
110	28	31	34	37	40	43	46	49	53
112	29	32	36	39	42	45	48	52	55
114	31	34	37	41	44	47	50	54	57
116	32	36	39	42	46	49	53	56	59
118	34	37	41	44	48	51	55	58	62
120	36	39	43	46	50	53	57	60	64
122	37	41	44	48	52	55	59	62	66
124	39	42	46	50	54	57	61	65	68
126	40	44	48	52	55	59	63	67	70
128	42	46	50	54	57	61	65	69	73
130	44	48	51	55	59	63	67	71	75
132	45	49	53	57	61	65	69	73	77
134	47	51	55	59	63	67	71	75	79
136	48	53	57	61	65	69	73	78	82
138	50	54	58	63	67	71	75	80	84
140	52	56	60	65	69	73	78	82	86
142	53	58	62	66	71	75	80	84	88
144	55	59	64	68	73	77	82	86	91
146	56	61	66	70	75	79	84	88	93
148	58	63	67	72	77	81	86	91	95
150	60	64	69	74	79	83	88	93	97
152	61	66	71	76	80	85	90	95	100
154	63	68	73	78	82	87	92	97	102
156	64	69	74	79	84	89	94	99	104
158	66	71	76	81	86	91	96	101	106
160	68	73	78	83	88	93	98	103	109
162	69	74	80	85	90	95	101	106	111
164	71	76	81	87	92	97	103	108	113
166	72	78	83	88	94	99	105	110	115
168	74	80	85	90	96	101	107	112	118
170	76	81	87	92	98	103	109	114	120
172	77	83	88	94	100	105	111	117	122
174	79	85	90	96	102	107	113	119	124
176	80	86	92	98	104	109	115	121	127
178	82	88	94	100	105	111	117	123	129
180	84	90	96	101	107	113	119	125	131
182	85	91	97	103	109	115	121	127	133
184	87	93	99	105	111	117	123	130	136
186	89	95	101	107	113	119	126	132	137
188	90	96	103	109	115	121	128	134	140
190	92	98	104	111	117	123	130	136	142
192	94	101	107	114	120	126	133	139	146
194	97	103	110	116	123	130	136	143	149
196	99	106	113	119	126	133	139	146	153
198	102	109	115	122	129	136	143	150	156
200	104	111	118	125	132	139	146	153	160
202	107	114	121	128	135	142	149	156	163
204	109	117	124	131	138	145	153	160	167
206	112	119	126	134	141	148	156	163	171
208	114	122	129	137	144	152	159	167	174
210	117	124	132	140	147	155	162	170	178

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Appendix II — BALLISTIC CALCULATIONS

Table A2-2. — 5"/38 caliber guns Mk 12 Mod 1

BORE ENLARGEMENT AT ORIGIN vs EQUIVALENT SERVICE ROUNDS										
ESR	0	10	20	30	40	50	60	70	80	90
0	.000	.001	.001	.002	.002	.003	.004	.005	.006	.007
100	.008	.009	.011	.012	.013	.015	.016	.018	.020	.022
200	.024	.027	.029	.032	.035	.037	.040	.042	.044	.046
300	.048	.050	.052	.054	.055	.057	.059	.060	.062	.064
400	.065	.067	.068	.069	.071	.072	.073	.075	.076	.077
500	.078	.079	.081	.082	.083	.084	.085	.086	.087	.088
600	.089	.090	.091	.092	.093	.094	.095	.096	.096	.097
700	.098	.099	.100	.101	.101	.102	.103	.104	.105	.105
800	.106	.107	.108	.108	.109	.110	.110	.111	.112	.112
900	.113	.114	.114	.115	.116	.116	.117	.117	.118	.119
1000	.119	.120	.120	.121	.122	.122	.123	.123	.124	.124
1100	.125	.125	.126	.127	.127	.128	.128	.129	.129	.130
1200	.130	.131	.131	.132	.132	.133	.133	.133	.134	.134
1300	.135	.135	.136	.136	.137	.137	.138	.138	.138	.139
1400	.139	.140	.140	.140	.141	.141	.142	.142	.143	.143
1500	.143	.144	.144	.144	.145	.145	.146	.146	.146	.147
1600	.147	.147	.148	.148	.149	.149	.149	.150	.150	.150
1700	.151	.151	.151	.152	.152	.152	.153	.153	.153	.154
1800	.154	.154	.155	.155	.155	.156	.156	.156	.157	.157
1900	.157	.158	.158	.158	.159	.159	.159	.159	.160	.160
2000	.160	.161	.161	.161	.162	.162	.162	.162	.163	.163
2100	.163	.163	.164	.164	.164	.165	.165	.165	.165	.166
2200	.166	.166	.167	.167	.167	.167	.168	.168	.168	.168
2300	.169	.169	.169	.169	.170	.170	.170	.170	.171	.171
2400	.171	.171	.172	.172	.172	.172	.173	.173	.173	.173
2500	.174	.174	.174	.174	.174	.175	.175	.175	.175	.176
2600	.176	.176	.176	.177	.177	.177	.177	.177	.178	.178
2700	.178	.178	.179	.179	.179	.179	.179	.180	.180	.180
2800	.180	.180	.181	.181	.181	.181	.182	.182	.182	.182
2900	.182	.183	.183	.183	.183	.183	.184	.184	.184	.184
3000	.184	.185	.185	.185	.185	.185	.186	.186	.186	.186
3100	.186	.186	.187	.187	.187	.187	.187	.188	.188	.188
3200	.188	.188	.189	.189	.189	.189	.189	.189	.190	.190
3300	.190	.190	.190	.191	.191	.191	.191	.191	.191	.192
3400	.192	.192	.192	.192	.192	.193	.193	.193	.193	.193
3500	.193	.194	.194	.194	.194	.194	.194	.195	.195	.195
3600	.195	.195	.195	.195	.195	.196	.196	.196	.196	.197
3700	.197	.197	.197	.197	.197	.198	.198	.198	.198	.198
3800	.198	.198	.199	.199	.199	.199	.199	.199	.200	.200
3900	.200	.200	.200	.200	.200	.201	.201	.201	.201	.201
4000	.201	.202	.202	.202	.202	.202	.202	.202	.203	.203
4100	.203	.203	.203	.203	.203	.204	.204	.204	.204	.204
4200	.204	.204	.205	.205	.205	.205	.205	.205	.205	.206
4300	.206	.206	.206	.206	.206	.206	.206	.207	.207	.207
4400	.207	.207	.207	.207	.208	.208	.208	.208	.208	.208
4500	.208	.208	.209	.209	.209	.209	.209	.209	.209	.210
4600	.210	.210	.210	.210	.210	.210	.210	.211	.211	.211
4700	.211	.211	.211	.211	.211	.212	.212	.212	.212	.212
4800	.212	.212	.212	.213	.213	.213	.213	.213	.213	.213
4900	.213	.213	.214	.214	.214	.214	.214	.214	.214	.214
5000	.215	.215	.215	.215	.215	.215	.215	.215	.216	.216
5100	.216	.216	.216	.216	.216	.216	.216	.217	.217	.217
5200	.217	.217	.217	.217	.217	.217	.218	.218	.218	.218
5300	.218	.218	.218	.218	.218	.219	.219	.219	.219	.219
5400	.219	.219	.219	.219	.220	.220	.220	.220	.220	.220
5500	.220	.220	.220	.221	.221	.221	.221	.221	.221	.221
5600	.221	.221	.221	.222	.222	.222	.222	.222	.222	.222
5700	.222	.222	.223	.223	.223	.223	.223	.223	.223	.223
5800	.223	.223	.224	.224	.224	.224	.224	.224	.224	.224
5900	.224	.224	.225	.225	.225	.225	.225	.225	.225	.225

Bore Enlargement at Origin in inches

Table A2-3. — Curvature of earth, feet

R. yds.	0	100	200	300	400	500	600	700	800	900
1,000	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8
2,000	.9	.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8
3,000	1.9	2.1	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.3
4,000	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2
5,000	5.4	5.6	5.8	6.1	6.3	6.5	6.8	7.0	7.2	7.5
6,000	7.8	8.0	8.3	8.5	8.8	9.1	9.4	9.7	10.0	10.3
7,000	10.6	10.9	11.2	11.5	11.8	12.1	12.4	12.8	13.1	13.4
8,000	13.8	14.1	14.5	14.8	15.2	15.6	15.9	16.3	16.7	17.1
9,000	17.4	17.8	18.2	18.6	19.0	19.4	19.9	20.3	20.7	21.1
10,000	21.5	22	22	23	23	24	24	25	25	26
11,000	26	27	27	28	28	29	29	30	30	31
12,000	31	32	32	33	33	34	34	35	35	36
13,000	36	37	38	38	39	39	40	41	41	42
14,000	42	43	44	44	45	46	46	47	47	48
15,000	48	49	50	51	51	52	53	53	54	55
16,000	55	56	57	58	58	59	60	61	61	62
17,000	62	63	64	65	66	66	67	68	69	69
18,000	70	71	72	73	73	74	75	75	76	77
19,000	78	79	80	81	81	82	83	84	85	85
20,000	86	87	88	89	90	91	92	93	94	94
21,000	95	96	97	98	99	100	101	102	103	103
22,000	104	105	106	107	108	109	110	111	112	113
23,000	114	115	116	117	118	119	120	121	122	123
24,000	124	125	126	127	128	129	131	132	133	134
25,000	135	136	137	138	139	141	142	143	144	145
26,000	146	147	148	149	150	152	153	154	155	156
27,000	157	159	160	161	162	163	164	165	167	168
28,000	169	171	172	173	174	175	177	178	179	180
29,000	181	183	184	185	186	188	189	190	192	193
30,000	194	195	197	198	200	201	202	203	205	206
31,000	207	209	210	211	213	214	215	217	218	219
32,000	221	222	224	225	226	228	229	231	232	233
33,000	235	236	238	239	240	242	243	245	246	247
34,000	249	251	252	253	255	257	258	259	261	263
35,000	264	265	267	269	270	272	273	275	276	277
36,000	279	281	282	284	286	287	289	290	292	293
37,000	295	297	298	300	302	303	305	307	308	309
38,000	311	313	315	317	318	319	321	323	325	326
39,000	328	329	331	333	335	336	338	340	342	343
40,000	345									
R. yds.	0	100	200	300	400	500	600	700	800	900

110.125

RANGE TABLE DATA

The best estimate of firing range is entered as item A in figure A2-3. Using this range, take items B, C, D, and E from the range table (fig. A2-1).

COMPUTATION OF INITIAL VELOCITY

Velocity loss should first be computed. Line 1 is the error in I.V. due to a variation in powder temperature from 90° F. It should be noted that

Appendix II — BALLISTIC CALCULATIONS

CONFIDENTIAL
(When filled in)

WORKSHEET FOR PREPARING GUNNERY SHEET 4
(Use separate Worksheet for each Salvo)

Z True Target Bearing At Instant of Firing 165°			RANGE TABLE DATA		
Target			A Range Table I.V.	2500 F.S.	
			B Guns Elevation	675.5 Min.	
			C Gun Range (1)	10100 Yds.	
			D Column 10	47 Yds.	
			E Column 12	499 "	
			F Column 12a	10 "	
			G Column 13	84 "	
			H Column 14	43 "	
			I Column 15	127 "	
			J Column 19	215 Ft.	
AA True Course	265°	K Column 6 (2)	47.7 Yds		
BB Speed	20	L Column 16	57 "		
CC Acute Angle	80°	M Column 17	69.6 "		
DD Cosine	.174	N Column 18	126.6 "		
EE Sine	.985				
Surface, Upper Air Wind			ATMOSPHERIC CONDITIONS		
			O Barometer	30.40 In.	
			P Temperature	52° F	
			Q Ballistic Density	104.3 %	
			POWER AND EROSION DATA		
			R I.V. (Erosion Data)	2600 F.S.	
			S Temperature Coefficient	1.2 F.S.°/F	
			T Average Powder Temperature	80° F	
			U Bore Enlargement - Inches	.080	
				Gauge	
Own Ship			TRUNNION AND CURVATURE DATA		
			V Average Trunnion Height	20 Ft.	
			W Curvature of Earth	21.5 Ft.	
			X Sum (V) + (W)	41.5 Ft.	
			COMPUTATION OF INITIAL VELOCITY		
			1 Powder Temp. Correction (S) x (90-T)	12	
			2 Erosion Loss & Index Correction	7	
			3 Total Velocity Loss (1) + (2)	19	
			4 Item R	2600	
			5 Expected I.V., (4) - (3)	2581	
6 Item A	2500				
7 I.V. Difference (5) - (6)	81				
COMPUTATION IN RANGE			YARDS		
			8 I.V. Difference (7) x (D) + 10	(3)	+381
			9 Own Ship Motion (LL) x (NN) x (H) + 10	(4)	+39
			10 Wind (GG) x (II) x (G) + 10	(5)	-59
			11 Air Density (100-Q) x (E) + 10	(6)	-200
			12 Air Temperature (59-P) x (F) + 10	(7)	+7
			13 Trunnion and Curvature 100(V)+J	(8)	+36
			14 Target Motion (BB) x (DD) x (I) + 10	(9)	-17
			COMPUTATION IN DEFLECTION		
			15 Own Ship Motion (LL) x (OO) x (M) + 10	(10)	+109
16 Wind (GG) x (JJ) x (L) + 10	(11)	+20			
17 Target Motion (100) x (BB) x (EE) x (N) + (P) + (14)	(12)	+25			
(1) Enter in Sheet 4 as item d					
(2) Enter in Sheet 4 as item v					
(3) Enter in Sheet 4 as total for items k, l and m					
(4) Enter in Sheet 4 as item c					
(5) Enter in Sheet 4 as item f					
(6) Enter in Sheet 4 as item g					
(7) Enter in Sheet 4 as item h					
(8) Enter in Sheet 4 as item j					
(9) Enter in Sheet 4 as item q					
(10) Enter in Sheet 4 as item w					
(11) Enter in Sheet 4 as item x					
(12) Enter in Sheet 4 as item bb					

92.4

Figure A2-3. — Worksheet for preparing Gunnery Sheet 4.

if the temperature is greater than 90°F, the sign is negative (-), even though an increase in range results. The reason for this is not obvious, but a study of line 1 in comparison with lines 2 and 3 will clarify it. Line 2 is always a velocity loss (since erosion never increases I.V.). The effect of a powder temperature above 90°F. will reduce this loss, while a powder temperature below 90°F will increase the loss. Line 3, which is the algebraic sum of lines 1 and 2, will therefore be of the correct sign if powder temperature correction is treated as described above. Should line 3 result in a minus sign, it would indicate a velocity gain. Such a case could occur with a new gun when firing powder from a magazine where the powder temperature was above 90°F. This will rarely happen.

Line 4 is the nominal velocity from item "b." Line 5 is the expected I.V. which is found by subtracting the Total Velocity Loss (line 3) from the Nominal Velocity (line 4). This result (line 5) is the expected initial velocity of the projectile, and should be set into the computer.

COMPUTATION OF RANGE CORRECTION

To begin with, the difference between the expected impact point for standard conditions and the expected impact point for existing conditions is dealt with. The entry in line 6 has been determined from the nomogram (appendix 2, part 2) in the range table. When ballistic density (item "h") is used, the formula in line 6 will give the proper value of range correction due to density. If item "h" is greater than 100%, the entry is made in the "Short" column; if less than 100%, the entry is made in the "Over" column. Line 7 is the range change due to variations of the air temperature from standard. If the air temperature is above standard, the entry is made in the Short column; if below standard, the entry is made in the Over column.

The trunnion height and curvature entry in line 8 is always "over." Column 19 of the range table gives the change in height of impact due to a 100-yard change in range. These values assume the gun and target are in the horizontal plane. Trunnion height and earth's curvature are the amounts the problem deviates from the horizontal plane. Since the problem is concerned with total deviation from the horizontal, these factors can be combined. The formula in line 8 results in the number of

yards by which range must be changed to compensate for total deviation.

No compensation is made for earth's rotation in the 5"/38 battery. Therefore, line 9 is left blank. Line 10, "Other Range Errors," is provided for range errors which are normally not encountered. Under this heading in the example is projectile weight. The range table is based on a projectile weight of 55.18 pounds, however the projectile in this example weighs 56 pounds. The formula used to calculate the compensation for the effect of a variation in projectile weight is shown in the table below.

range table		actual weight			
weight		weight	difference	x	column 11 =
55.18		56	+ .82	x	26 = 21.3

Column 11 of the range table gives the effect on range due to a decrease in weight. Since in the example the projectile is heavier, range is increased. Therefore, 26 rather than -26 is used to compute range change. Projectiles heavier than standard will leave the gun at a lower initial velocity, which results in a decrease in range. The heavier projectiles, however, have an increase in ballistic coefficient which results in an increase in range. At short ranges the change in initial velocity has the greater effect, but at long ranges the ballistic coefficient has the greater effect.

Line 11 is the algebraic sum of the range errors. Note that the column headings have been changed from "Over" to "Drop" and from "Short" to "Add." In this manner the errors are converted to corrections. These are reciprocal quantities.

The Arbitrary Correction To Hit (ACTH) in line 12 and the correction for first salvo only in line 13 are obtained from experience within the individual battery. The ACTH remains throughout the firing, but the value of line 13 is removed after the first salvo.

Line 14 is the algebraic sum of the range corrections. This value is set into the computer as a range spot. In AA fire the range correction is sometimes converted to an initial velocity correction. When this is done the first salvo correction is not included, and the trunnion height and earth curvature corrections are not needed. The formula to convert range correction to initial velocity correction is:

$$\frac{\text{Range correction} \times 10}{\text{Column 10}} = \text{Initial velocity correction}$$

COMPUTATION OF DEFLECTION
CORRECTION

Line 15 indicates the error in deflection due to earth's rotation. As in the computation for range deflection, it is used only in batteries larger than 5-inch. The error's value and sign are obtained from the range table.

Line 16, "Other Deflection Errors," is provided for deflection errors which are normally not encountered.

The formula in line 17 is used to convert yards to mils. Deflection is normally spotted in mils. Note that the column headings have been changed from "Right" to "Left" and from "Left" to "Right." As in range, we are converting from the error to the correction. The ACTH in line 18 is obtained from previous gunnery exercise. Line 19 is the total deflection correction and is applied to the computer as a deflection spot.

POSTFIRING ANALYSIS:
GUNNERY SHEET 4

It has been said, "The best rangefinder is the gun." This implies that the effectiveness of a fire control system is shown by the actual impact point of the projectile. Postfiring analysis concerns itself with a comparison between the observed impact point and the correct theoretical position of the impact point. From this comparison, consistent errors which cannot be accounted for are determined. ACTH in range and deflection is computed from these errors. The most satisfactory results are obtained when error-producing factors (such as relative motion and initial ballistic calculation) are held to a minimum. The ACTH is normally computed from a particular gunnery exercise. This exercise, normally a Z-24-G, should be held under as nearly ideal conditions as possible. The battery should have been accurately aligned, and the fire control system should have been brought to peak performance.

Standard procedure and standard forms are used to determine the ACTH. The standard form is Gunnery Sheet 4, shown in figures A2-4 and A2-5. A worksheet (fig. A2-3) is used in conjunction with the finished smooth Sheet 4. (The worksheet is prepared locally and may vary from the example shown.) Observers record the needed information available aboard ship for each salvo. The location of the impact point or mean point of impact (MPI) is obtained from a

spotting or photographic party. Spotting procedures were covered in chapter 9.

Figures A2-4 and A2-5 show a sample problem of a salvo from the right guns of the twin 5" mounts of a destroyer battery. The values in the figures are representative but are not from an actual exercise.

POSTFIRING ANALYSIS:
PREPARATION OF WORKSHEET

A separate worksheet should be used for each salvo. The worksheet represents a complete picture of the conditions that existed at the instant the salvo was fired.

Range Table Data

In item A (fig. A2-3) enter the initial velocity for which the range table (fig. A2-1) is computed. The 5" range table (OP 551 3rd Revision) is computed for 2500 foot-seconds.

In item B enter the gun's angle of elevation above the horizontal plane at the time of firing. When the stable element controls elevation, this value is obtained from sight angle. Since 2000 minutes represents zero sight angle, we have subtracted 2000 from the value of sight angle in the computer.

When the director controls elevation, sight angle is the angle between the LOS and the LOF. In this case trunnion height and earth curvature corrections are converted to minutes of arc and subtracted from sight angle. This brings the LOS into the horizontal plane. In batteries which have individual erosion correctors, the settings on the corrector affect gun elevation. The velocity loss in foot-seconds is converted to minutes of arc and subtracted from sight angle.

Item C is the range table value corresponding to item B. In the example, a range of 10,100 corresponds to an angle of elevation of 675.5 minutes above the horizontal plane.

Items D through N are taken directly from the range table, using the range in item C. The remainder of the worksheet is used to compute the initial velocity, range, and deflection problems of the exercise.

POSTFIRING ANALYSIS:
COMPUTATION OF ARBITRARY
CORRECTION TO HIT (RANGE)

The first lines on Gunnery Sheet 4 (fig. A2-4) are for identification purposes and in general

GUNNERY SHEET 4
OPNAV FORM 3570-4 (Rev. 1-57) S/N 0107-725-8000

COMPUTATION OF ARBITRARY CORRECTION TO HIT (RANGE)

CONFIDENTIAL
(When filled in)

U.S.S.		EXERCISE SAMPLE		HUN Projectile		DATE	
BATTERY 5"/38		CHARGE (full, reduced) Full		RANGE TABLE, D.P. NO. 551 (3rd rev.)		AND CHANGE NO.	
POWDER INDEX SPDF WT 15.8		EROSION CURVES WFO NO.		AND			

ITEM (Tabulate range and change in range in yards)	SALVO NUMBER							
	NO. 1	NO.	NO.	NO.	NO.	NO.	NO.	NO.
a. NUMBER OF GUNS	3							
b. NUMBER OF COLD GUNS	0							
c. GUNS FIRED	1R, 2R, 3R							
d. GUN RANGE	10100							
e. OWN SHIPS MOTION	+39							
f. TRUE WIND (Upper air/surface)	-59							
g. AIR DENSITY (Upper air/surface)	-200							
h. AIR TEMPERATURE	+7							
i. ROTATION OF EARTH	----							
j. TRUNNION HEIGHT AND EARTH	+36							
k. POWDER INDEX								
l. POWDER TEMPERATURE	+381							
m. EROSION								
n. SUM OF ITEMS (e) THROUGH (m)	+204							
o. EXPECTED RANGE (d + n)	10304							
p. NAVIGATIONAL RANGE AT INSTANT OF FIRING	9950							
q. TARGET MOTION	-44							
r. ERROR OF MPI	+140							
s. ACTUAL RANGE (p + q + r)	10044							
t. ACTH IN RANGE (o - s)	+360							

NOTES:
 c. Identify guns by turret or mount number and gun position, i.e., 1R; 2c; 3 ALL, etc.
 d. Gun range is range table range corresponding to elevation of gun above horizontal plane.
 Items (e) through (n) and (q) compute, using methods explained in range table, erosion curves and NAVPERS 16116, Naval Ordnance and Gunnery, Page 271.
 Items (i) and (g) cross out either upper air or surface as applicable.

THIS SHEET IS REQUIRED FOR CALIBRATION EXERCISE 2-24-G ONLY. SUBMIT COPIES TO UNIT AND TYPE COMMANDERS.

CONFIDENTIAL
(When filled in)

63.4

Figure A2-4. — Gunnery Sheet 4 — ACTH, Range.

CONFIDENTIAL

(When filled in)

COMPUTATION OF ARBITRARY CORRECTION TO HIT (RANGE)

ITEM (Tabulate range and change in range in yards)		SALVO NUMBER						
		NO. 1	NO.	NO.	NO.	NO.	NO.	NO.
u.	DEFLECTION USED IN	+3						
v.	DRIFT (yds.) (right)	+47.7						
w.	OWN SHIP'S MOTION (yds.)	+109						
x.	WIND (yds.)	+40						
y.	ROTATION OF EARTH (yds.)	----						
z.	1,000 [v. + w. + x. + y.] + s. (Mils)	+20						
a	EXPECTED DEFLECTION MPI (u. + z.) (Mils)	+23						
b	TARGET MOTION (Mils)	+25						
c	ERROR OF MPI (Mils)	-2						
d	ACTUAL DEFLECTION MPI (bb. + cc.) (Mils)	+23						
e	ACTH IN DEFLECTION (aa. - dd.) (Mils)	0						

NOTES:

(v) through (y) and (bb), refer to range table, erosion curves and Naval Ordnance and Gunnery, page 271.

(bb) is: deviation for lateral motion of target, (yds.)

(p) + (q)

(cc) is: error of MPI from center of target, (yds.)

(5)

CONFIDENTIAL

E 51870

(When filled in)

are self-explanatory. However, the space labeled "RUN" is normally used to identify the projectile/fuze combination and the weight of the combination.

Item "a," "Number of Guns," refers to the number of guns actually fired. If, for example, a 6-gun salvo was intended, but due to a casualty only five guns fired, the proper entry is 5.

In item "b," "Number of Cold Guns," enter the number of guns firing their initial round since the barrel was last cleaned and oiled. It should be assumed that the guns were fired just previous to this exercise. Therefore the entry is zero.

Item "c," "Guns Fired," identifies guns by turret or mount number and position in the turret or mount. The right guns of mounts 1, 2, and 3 were fired in this hypothetical practice.

Items "d," "e," "f," "g," "h," and "j" are obtained from the worksheet. It is essential that the sign be carried with transferred values. Item "i" is zero in the example. (This correction is always omitted for guns of 5-inch and smaller caliber.)

The total for items "k," "l," and "m" is combined in the computations on the worksheet. Although the computed I.V. of 2581 foot-seconds would cause a decrease in range from the values taken from a 2600 foot-second range table, it does cause an increase in the range values taken from the 2500 foot-second range table which is being used in computing values in the example. Therefore, the sign is PLUS for this entry of 381 yards.

Item "o," the expected range, is the gun range corrected for all known variations from standard range table conditions which affect the projectile in flight, plus trunnion height and earth's curvature. It should be noted that the target motion does not enter into this computation, because the value of expected range applies to the point of fall of the projectiles and is to be used for comparison with the actual range to the point of fall.

Item "p" is the navigational range at the instant of firing. The most accurate and carefully calibrated radar should be used to obtain this figure.

Item "q" is obtained from the worksheet, using care in selecting the proper sign. Since in the example the target is closing, the range will decrease during the time of flight of the projectile.

Item "r," the error of MPI, represents the actual difference between the position of the

target at the instant of the fall of the projectiles and the mean point of impact of the several shots. MPI was discussed in greater detail in chapter 9.

For this use in postfiring analysis, the best available data on the points of fall of individual projectiles should be used. When a camera party is available, the best data is obtained by triangulation of aerial photographs. OVERs carry the plus (+) sign; SHORTs carry the minus (-). An arbitrary value of +140 for error of MPI is used in figure A2-4.

Item "s" represents the actual range to the point of fall of the projectiles fired. Item "t," therefore, represents the otherwise unaccounted-for errors, the average value of which is used as ACTH in range.

POSTFIRING ANALYSIS: COMPUTATION OF ARBITRARY CORRECTION TO HIT (DEFLECTION)

Item "u" (fig. A2-5) is the difference between the midpoint of the deflection scale and the actual scale reading. It is the number of mils between the plane through the LOS and the plane through the LOF at the instant the gun was fired. The sign is + if the scale reading is to the right of the midpoint and - if to the left. In the example the scale reading was 503.

Items "v," "w," and "x"—47.7, 109, and 40 yards, respectively in this example—are taken from the worksheet. The proper sign is important.

Item "y" is similar to item "i" and its value is zero in this example for the reason previously stated.

Item "z," it will be noted, includes a conversion from yards to mils at the actual range.

Item "aa," the expected deflection, consists of the deflection used, corrected for drift and those variations from standard range table conditions which affect the projectile while it is in the air. This item serves the same purpose in deflection as item "o" in range.

Item "bb" is obtained from the worksheet.

Item "cc" is the error of the MPI in mils, obtained by photo triangulation or observation. If the MPI is right of the target, the sign is +, if left -. In the example, the error of the MPI was 2 mils left.

Item "dd" is the actual deflection of the MPI in mils. It is the perpendicular distance (converted to mils) from the vertical plane through the line of sight to the mean point of impact.

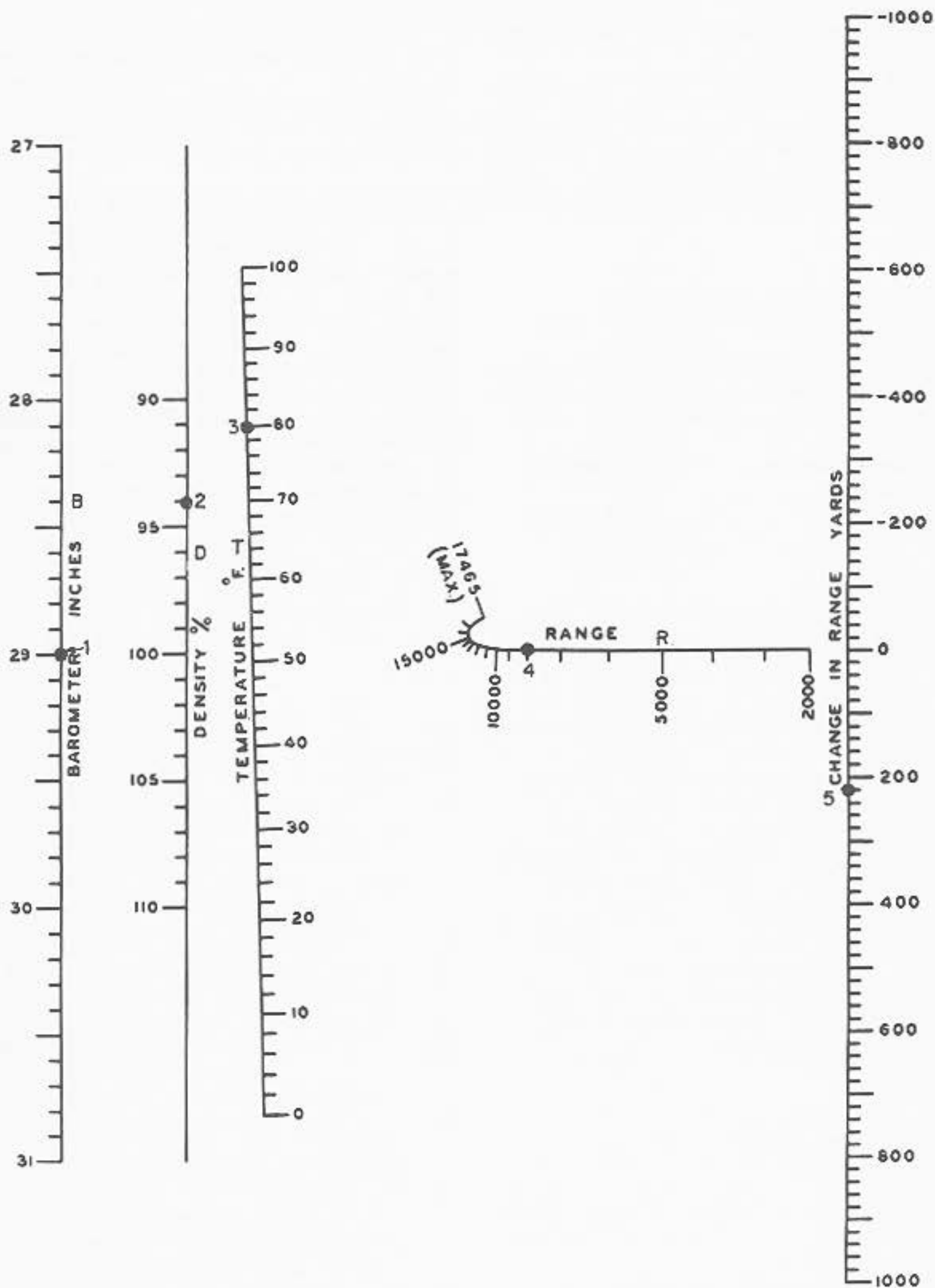


Figure A2-6. — Change in range for variation in density of air.

This item is the deflection equivalent of item "s" above.

Item "ee," the ACTH in deflection, is obtained by subtracting item "aa" from item "dd." Like item "t" in range, it represents the errors otherwise unaccounted for. The ACTH in range and deflection represent the two values which are found through the processes of postfiring analysis.

AIR-DENSITY NOMOGRAM: INSTRUCTIONS FOR USING

To understand how the nomogram is used, refer to figure A2-6 and use the information given in the following example:

Barometric pressure. 29.1 inches
Temperature 80° F.
Range. 8,000 yards

Using a straightedge, connect points 1 and 3 of scales B and T to obtain density (point 2 on scale D).

Similarly, connect points 2 and 4 of scales D and R to obtain change in range (point 5). Change in range is +210 yards in this example.

NOTE. — The best estimate of ballistic density to different altitudes is in very close, but not in exact agreement with standard density when surface conditions are standard. When surface density is not standard the disagreement is usually greater and is a function of surface density and maximum ordinate. Use of this nomogram will not give agreement with results obtained from column 12 of the range table and surface observations only, but it should be a more accurate figure because it takes into account the ratio between mean measured and standard density for the actual maximum ordinate obtained.

APPENDIX III

ORDNANCE SAFETY PRECAUTIONS

The purpose of this appendix is to impress upon you the need and reason for rigid adherence to safety precautions, and to point out the grave consequences that may result from violation of these precautions.

Printed precautions alone cannot prevent accidents. Safe operating procedures must be explained in detail by those who know to those who do not know. Safety is not a one-day-out-of-the-week event, but a daily affair that must be instilled by constant supervision, careful instruction, and adequate training. Safety is both the result and the reflection of good training. The two are inseparable. A well trained crew is necessarily a safety-minded crew.

Safety education is economical. It has been shown beyond any doubt that proper safety training saves untold dollars and lives. The amount of time and money spent for teaching safety totals far less than the hours and dollars lost in a single major accident. Safety can be taught in many ways. Initial training requires instruction in the basic maintenance, operation, and potential danger of any weapon or explosive. Drills must include exercises in safety as well as in mechanical operation. Safety precautions should be explained, and the reason for their existence and the terrible consequences of not following them must be emphasized frequently. Discussions, lessons, practice, and explanations of safety practices must be repeated until every crew member is safety conscious.

The first section of this appendix lists safety precautions especially pertinent to the junior officer. Because officers are particularly responsible for the military safety program, you can expect to be in a position where you will have specific responsibilities for safety.

Another section gives actual case histories that clearly illustrate the safety problem. The cases included are but a few of many that could have been prevented. Although some of these cases are quite old, their value as safety reminders has not diminished. This section

is abridged from OP 1014 (2nd revision), entitled Ordnance Safety Precautions, Their Origin and Necessity. This revision (or a later revision) of the OP should be available at your first duty station. It will be well worth your while to read it, as well as OP 3347, United States Navy Ordnance Safety Precautions.

LIST OF SAFETY PRECAUTIONS

The list of safety precautions in this section is quoted from the appendix of OP 1014 and from OP 3347. It is emphasized that the following is NOT a complete listing of all ordnance safety precautions. A complete listing may be found in OP 1014 and OP 3347. It is important to remember that observance of all safety precautions is imperative. In circumstances which conflict with their requirements, or if for other reasons changes in or additions to them are required, the responsible Navy authority must be informed. If there is any doubt as to the exact meaning of a safety precaution, an interpretation should be requested from NavOrd. Conditions not covered by the safety precautions may arise that, in the opinion of the commanding officer, may render further operation of the equipment unsafe. Under these conditions, nothing in the safety precautions should be construed as authorizing such further operation.

The following list of safety precautions frequently refers to the "Bureau of Naval Weapons." Whenever you see this reference, remember that this refers to what is now the Naval Ordnance Systems Command and the Naval Air Systems Command.

1. SAFETY DEVICES. — Safety devices provided shall always be used as designated to prevent possibility of accident, and shall be kept in good order and operative at all times.

All instructions promulgated by competent authority to insure safe operation or handling of equipment shall be strictly observed.

2. SAFETY WATCH FOR MOVING UNITS. — Whenever any motion of a power-driven unit is capable of inflicting injury on personnel or material not continuously visible to the person controlling such motion, the officer or petty officer who authorizes the unit to be moved by power shall, except at general quarters, insure that a safety watch is maintained in areas where such injury is possible both outside and inside the unit, and shall have telephone or other effective voice communication established and maintained between the station controlling the unit and the safety watch. These precautions are applicable to turrets, gun mounts, guns, directors, rangefinders, searchlights, torpedo tubes, rocket launchers, and similar units. Under the conditions stated above, the station controlling shall obtain a report "all clear" from each safety watch before starting the unit. Each safety watch shall keep his assigned area clear and if unable to do so shall immediately report his unit fouled, and the controlling station shall promptly stop the unit until it is again reported clear.

3. WARNING SIGNALS. — In turrets and enclosed mounts, a warning signal shall be installed outside the turret or mount; and whenever power train is used, except at general quarters, the officer or petty officer in charge of the turret or mount shall cause warning signals to be sounded before using power and at intervals during its use.

4. CHANGES IN MATERIALS. — Changes, modifications in, or additions to ordnance material, or other material used in connection therewith, shall not be made without explicit authority from the bureaus (naval systems commands) concerned.

5. DESIGNATED USE OF EXPLOSIVES. — No ammunition or explosive assembly shall be used in any gun or appliance for which it is not designated.

6. DRILL AMMUNITION. — No other than drill ammunition shall be used for drill.

7. AA FIRING. — Except in action or when specifically authorized, antiaircraft guns shall not be fired at elevations greater than, or fuze settings less than, those prescribed in the current orders for Gunnery Exercises. When firing antiaircraft guns as such, all personnel not required to be exposed shall be kept under cover.

8. SUPERVISION. — As familiarity with any work, no matter how dangerous, is apt to lead to carelessness, all persons who may supervise or perform work in connection with the inspection, care, preparation, use, or handling of ammunition, or explosives —

(a) Shall exercise the utmost care that all regulations and instructions are rigidly observed.

(b) Shall carefully supervise those under them and frequently warn them of the necessity of using the utmost precaution in the performance of their work.

No relaxation of vigilance shall ever be permitted.

9. AMMUNITION TRANSFER. — Except in case of emergency, ammunition shall not be transferred during fueling operations.

10. HIGH TEMPERATURE. — All ammunition, explosives, and powder shall be protected from abnormally high temperature. If so exposed, they shall be handled in accordance with current instructions of the Bureau of Naval Weapons. Permissible maximum storage temperatures shall be prescribed by the Bureau of Naval Weapons.

11. SMOKELESS POWDER. — Smokeless powder which shows unmistakable signs of advanced decomposition shall be disposed of in accordance with current instructions of the Bureau of Naval Weapons.

12. HANDLING. — To minimize the risk of fire, explosion, and damage to ammunition and its containers from accidental causes, ammunition shall be handled as little as practicable. As the action of denting thin-cased high-explosive ammunition is known to have caused detonation of the explosive in some instances, special care shall be exercised to insure that such ammunition is never struck, dropped, or bumped.

13. DEFECTIVE AMMUNITION. — Defective bomb type and thin-case ammunition shall be disposed of in accordance with current instructions of the Bureau of Naval Weapons.

14. DROPPING FUZED PROJECTILE. — A fuzed projectile, whether in a container or not, if dropped from a height exceeding 5 feet shall be dumped overboard in a manner conforming with regulations for dumping ammunition at sea except when practicable to turn the projectile in to a Naval Ammunition Depot. Such ammunition shall be handled with the greatest care.

15. STRIKING FUZED PROJECTILE. — Care must be used to avoid tapping or otherwise striking fuzed projectiles. This precaution is particularly applicable to attempts to loosen

such a projectile in the cartridge case by repeated light blows of a mallet, unloading such a projectile wedged in the bore of a gun, and the striking of a projectile by the recoil of a gun or an ejected case.

16. **SWITCHES.** — The covers of switches, circuit breakers, etc., shall be kept securely closed while powder is exposed in the vicinity.

17. **MAGAZINES.** — Magazines shall be kept scrupulously clean and dry at all times. Nothing shall be stored in magazines except explosives, containers, and authorized magazine equipment. Particular attention shall be paid that no oily rags, waste, or other foreign combustibles are stored in them.

18. **NAKED LIGHTS.** — Naked lights, matches, or other flame-producing apparatus shall never be taken into magazines or other spaces used primarily as magazines while these compartments contain explosives.

19. **EXCESSIVE HEAT.** — Before performing any work which may cause either an abnormally high temperature or an intense local heat in a magazine or other compartment used primarily as a magazine, all explosives shall be removed to safe storage until normal conditions have been restored.

20. **BLACK POWDER.** — Black powder is one of the most dangerous of explosives and shall always be kept by itself. Only such quantities as will meet immediate needs shall be taken from the magazines. A container of black powder shall never be opened in a magazine nor in the vicinity of a container in which there is any explosive.

21. **ALTERING AMMUNITION.** — Ammunition shall not be altered, nor shall fuzes or any other parts be removed or disassembled without explicit instructions from the Bureau of Naval Weapons.

22. **TRIAL LOADING.** — Live ammunition shall be loaded into guns for firing purposes only. Test or inspection of ammunition by fitting it into guns is prohibited, except when authorized by specific instructions of the Bureau of Naval Weapons.

23. **EXCESS AMMUNITION.** — During firing no other ammunition than that immediately required shall be permitted to remain outside of the magazine.

24. **ASSEMBLING CHARGES.** — During gunnery exercises, charges in excess of the amount required to be available for one run shall not be assembled in the vicinity of guns mounted outside of turrets. No charge for a bag gun shall be removed from its tank, nor shall the tops

of tanks be removed or so loosened that the bags may be exposed to flame until immediately before the charge is required for loading.

25. **FLAME-PROOF COMPARTMENTS.** — When either cartridges or bag charges are outside the magazines, each flame-proof compartment or space which forms a stage of the ammunition train, including the magazine and gun compartments (in or out of turrets), shall, wherever practicable, be kept closed from all other compartments or spaces except when the actual passage of ammunition requires it to be open. Where practicable, no flame-proof stage of the ammunition train shall be open to both the preceding and the following stages at the same time.

26. **POSITION OF BREECH.** — The limiting position of the breech of the gun on recoil shall be indicated and the gun crew shall be instructed to keep clear.

27. **UNLOADING GUN.** — While a gun is being unloaded, all personnel not required for the unloading operation shall be kept at a safe distance from the gun.

28. **RAMMING DEVICES.** — Only approved ramming devices and methods shall be used in loading live cartridges. Any cartridge which does not freely and fully enter the chamber of the gun shall be carefully extracted and put aside, and no further attempt shall be made to fire such a cartridge.

29. **OPENING OF BREECH.** — Effective measures shall be taken to guard against prematurely opening the breech of a loaded gun, whether or not the gun is fitted with a salvo latch.

30. **LOADED GUN.** — If a gun is loaded at the order "cease-firing"—

(a) The gun shall be kept pointed and trained in a safe direction.

(b) The breech mechanism shall be kept fully closed.

(c) The gun shall normally be cleared by firing as soon as practicable.

31. **FUZED PROJECTILE IN HOT GUN.** — A loaded and fuze projectile, seated in the bore of a gun that is hot from previous firing, presents a hazard, since detonation of the projectile is possible as a result of being heated. Whenever practicable, such projectile should be disposed of promptly by firing the round. Whether a gun is hot or cold, the risks attendant upon removing a loaded and fuze projectile seated in the bore by backing out are considered unwarranted except in the case of guns for which existing instructions specifically prescribe this procedure.

32. **OBSTRUCTED LINE OF FIRE.**—Ships shall cease the firing of any gun whose line of fire is endangering any objects other than the designated target. These objects include friendly ships and aircraft and own ship's structure together with the mounts and launchers and their barrels, fixed or moving. This stipulation applies to objects in the vicinity of the firing point, throughout the trajectory and in the vicinity of the target. Turrets, mounts, guns, and launchers which are not firing, while others are firing, shall be trained and elevated if manned, or secured if unmanned, in a manner that will provide the greatest amount of safety from the firing. This position of greatest amount of safety of the unmanned mounts will generally be that position which the firing cut-out mechanism cams of the firing mounts were cut to clear.

33. **ARMED AMMUNITION.**—Since it is not always possible to ascertain readily whether mines, depth charges, rockets, projector charges, and aircraft bombs have been inadvertently armed in storage or handling, all of these types, when fuzeed or assembled with firing mechanisms, shall at all times be handled and treated as if armed, in strict conformity with the instructions for safeguarding against the inadvertent arming, firing, or launching of such ammunition.

34. **REMOVING FUZES.**—Fuzes, firing mechanisms, or primer mechanisms for bombs, depth charges, rockets, projector charges, demolition outfits, or mines shall not, except as covered by special orders or current instructions of the Bureau of Naval Weapons, be removed, disassembled, repaired, or in any way altered.

35. **STORING FUZED ORDNANCE.**—Bombs, rocket heads, and projector charges, for which fuzes are issued separately, shall not be stowed with those fuzes installed in or near magazines containing explosives.

36. **STORING FUZES.**—Fuzes issued separately for bombs, rockets, and projector charges, which contain integral detonators or other explosive components, shall be stored only in specially designated fuze magazines which shall not be located adjacent to magazines containing high explosives.

37. **STORING DETONATORS.**—Detonators which are not assembled integrally with fuzes shall be stored only in standard type detonator lockers located in approved places.

38. **REMOVING FUZE ARMING.**—Fuze-arming wires or devices shall not be removed

from the unarmed position until just before releasing or firing. Safety pins or other devices requiring removal before flight, or firing, shall not be removed until the ammunition has been loaded in racks, projectors, or launchers and not until after the arming wire or device has been put in place. Bombs, mines, depth charges, rockets, or projector charges not expended shall be made "safe" at the first opportunity in accordance with current instructions for the respective assemblies. When handling or unarming an accidentally armed fuze, the prescribed procedure shall be carefully followed.

39. **ELECTRONIC COMPONENTS.**—Electric igniters, primers, or detonators, electrically fired rocket and guided missile motors, electric or electronic ordnance fuzes, including VT fuzes, shall not be stowed in the same compartment with, to be exposed within five feet of, any exposed electronic transmitting apparatus or exposed antenna or antenna lead, except where such electronic apparatus or antenna is a part of authorized test equipment of a weapon or is integral with a weapon containing such components, in which event special instructions pertinent thereto shall apply.

40. **RECOVERING TORPEDO.**—In recovering a torpedo in the water the propeller lock shall be put on at the first opportunity and kept on until the torpedo is safely landed.

41. **TORPEDO TORCH POTS.**—Because the filling material used in torpedo torch pots ignites spontaneously or forms poisonous gas when combined with water, or subjected to moisture, extreme care must be taken to follow existing Bureau of Naval Weapons instructions concerning the handling of torch pots.

42. **ELECTRIC TORPEDOES.**—The use of electric torpedoes involves hazards of mechanical injuries, electrical shock or burn, acid burns, and hydrogen explosion or combustion. Bureau of Naval Weapons instructions prescribe effective measures to prevent accidents and shall be rigidly adhered to at all times.

43. **PYROTECHNIC MATERIAL.**—Pyrotechnic material shall always be kept by itself in regular pyrotechnic storage spaces, if such are provided, or in pyrotechnic lockers on upper decks. In using it, only a minimum amount shall be exposed.

44. **PATH OF EXHAUST.**—All personnel shall keep clear of the possible exhaust path of rockets at all times.

45. **ROCKET MISFIRES.**—In case of rocket misfire, personnel shall not approach the rocket for at least 10 minutes, nor until firing circuits

are known to be open. This, at the discretion of the commanding officer, is not obligatory in time of action.

46. **BLOWBACK.**—In firing small arms, machine guns, and submarine guns, whenever a blow-back occurs, the bore shall be examined for foul bore before firing another round.

47. **SMALL ARMS.**—Safety precautions in Army Regulations AR-385-63, Safety Regulations for firing ammunition, training, target, and combat shall apply to all small arms firing by Navy or Marine Corps personnel.

48. **HAZARDOUS PROCEDURES.**—Officers or supervisors must be alert to detect any hazardous procedures or practices and symptoms of a deteriorating mental attitude, and take timely corrective action.

49. **INOPERATIVE SAFETY DEVICES.**—Safety devices must not be bypassed nor made inoperative except in accordance with approved instructions. If they are inoperative for any reason, warning signs should be used to inform everyone of the increased hazard.

50. **SMOKING.**—Smoking is not permitted in magazines, nor in the immediate vicinity of handling or loading operations involving explosives or ammunition.

51. **PERSONNEL INSTRUCTION.**—All personnel required to handle ammunition shall be carefully and frequently instructed in the safety precautions, methods of handling, storage and the uses of all kinds of ammunition and explosive ordnance with which the vessel, aircraft unit, or station may be supplied. No one shall be permitted to inspect, prepare, or adjust live ammunition and explosives until he thoroughly understands his duties, the precautions and the hazards involved.

Personnel assigned to operate any ordnance equipment shall receive, prior to commencing operation, a thorough indoctrination in general safety precautions applicable to ordnance and in the specific precautions applicable to the equipment they operate. Periodic drills shall be conducted to provide realistic training for operation of ordnance equipment, and to note and eliminate any unsafe practices. New or inexperienced personnel must not be permitted to work independently on explosive ordnance of any kind, but shall be under the direct and continued supervision of skilled and experienced personnel, until adequate experience is acquired.

CASES OF ORDNANCE CASUALTIES

As stated earlier, some of the cases of ordnance casualties are quite old. More recent examples (in most cases) cannot be used because of security classification.

1. Aboard a destroyer in May 1949, a gunner's mate was cleaning and chipping paint off a 40-millimeter gun mount. For some reason, and in violation of existing orders, he removed the cover plate from the train motor control switch box. Perhaps he meant to clean it.

Minutes later he was found on the deck, dead. He had been electrocuted by a circuit of 440 volts. Artificial respiration was of no help. Actually, the switch box was part of the fire control circuit and the gunner's mate was not authorized to open it. Even if he thought he was, he certainly should not have forgotten this precaution issued to the ship:

When work is done on any circuit, the switch controlling that circuit should be opened and a danger sign secured to it.

The danger sign should contain sufficient instructions to prevent anyone but the proper individual from reenergizing the circuit. (Note precautions 1 and 8.)

2. In September 1963, a DD was moored in a nest with five DDs and one AD, third ship outboard, at Newport, R. I. During the morning, extensive system alignment checks were being conducted on the torpedo fire control system in preparation for a test firing of dummy torpedoes the following day. The crew, which was being directed by a Torpedoman's Mate 2, had been working long hours the previous week attempting to get the system in proper working condition for the forthcoming exercises. They had had trouble clearing electrical grounds from the firing circuits of numbers 2 and 4 tubes. While conducting tests during the previous week and that day, it had been necessary for them to remove the torpedo from each tube before firing an air slug electrically, then to reinsert it after firing. One of the torpedoes (the one that had been in number 2 tube) was left on the rack behind the tube. The crew had difficulty clearing the ground from number 2 tube so they decided to switch their efforts to number 4. They corrected the ground in number 4 tube but failed to remove the torpedo. Meanwhile, the ship experienced a shore power failure. This

failure did not stop the work on number 4 tube but did add somewhat to the existing confusion. Finally, after the tube was charged with air, it was electrically test fired by the TM 2 (who forgot number 4 was loaded). Result—the #4 torpedo, which was a warshot, was fired against the superstructure, frame 81, of the DD alongside. Damage to the DD was minor. The torpedo, however, had to be removed from service.

The findings of the Board of Investigation were that:

1. The firing of the torpedo from tube number 4 occurred as a result of personnel error.

2. The temporary loss of ship's power for a period of one hour and ten minutes prior to the incident, coupled with numerous pulling and reinserting of torpedoes from their tubes in the days preceding the incident, were distracting influences which might have "dulled" the attention to detail which a transmission check demands. (Note precaution 8.)

The TM 2 was wrong in what he did, but it appears he could have used some backup supervision. If his leading division petty officer or his division officer had been on deck during this crucial test of the tube, chances are that the accident would not have happened. They should make it a point to be at the places where work is going on, at the right time. That way they have a much better chance of catching possible trouble sources before it is too late.

MATERIAL DAMAGE: Loss of one torpedo.

3. In 1964, a grenade fuze detonation occurred in an aircraft carrier's fuze magazine, which contained stored fuzes. (Note precautions 12 and 21.)

Two military personnel entered a fuze magazine, whereupon the topic of conversation turned to grenade throwing. One of the men picked up a grenade fuze and proceeded to demonstrate the hand launching method. While going through the motions of hand launching, the grenade fuze activated. Realizing what had happened, an attempt was made to kick the fuze under a storage bin. Detonation occurred, causing multiple wounds, punctures, and lacerations to the two military personnel. Fortunately the blast was not of sufficient magnitude to activate the stored material.

INJURED:
Two

MATERIAL DAMAGE:
None

4. In April of 1963, at a Naval Auxiliary Air Station, a fixed-fin air-launched rocket was inadvertently fired after checkout and arming. An aircrewman, upon completing a stray voltage check of launcher control circuits, placed the selector switch on station number one. Rockets were then installed and the rocket motors armed.

Without warning, the number six position rocket inadvertently fired. Fortunately, a malfunction occurred and the rocket motor exploded after only traveling about 200 yards. The only damage sustained was to the rocket itself plus a slight injury to the left forefinger of the aircrewman.

INJURED:
One

MATERIAL DAMAGE:
None

5. Hand grenade fuzes were being stowed away in a small arms magazine aboard a Navy vessel on March 29, 1963, when one accidentally exploded.

The hand grenade fuzes were received in ammo container consisting of various broken lots. Two ordnance men were in the process of stowing the shipment when an explosion occurred.

One ordnance man suffered severe powder burns of the right hand and chest, and amputation of one digit on second finger of the right hand. The other man sustained minor powder burns to his right hand, arm and chest.

The probable cause of the accident, after checking the ammunition container and the detail report from the two personnel, can only be theorized. The accident probably occurred because the pin end of the remaining fuzes was not completely spread and resulted in improper packaging. The improperly packaged fuze ring may have caught on a projection of the storage rack during storing procedures.

INJURED:
Two

MATERIAL DAMAGE:
None

6. During a scheduled night training exercise (in December, 1964) a large multi-engined aircraft was scheduled to drop aircraft parachute flares every eight (8) seconds to properly illuminate the target area. Flares Mk 5 which would normally be employed were not available and flares Mk 24 were substituted; although they were similar, no formal publication had been received by the operating activity concerning their use.

On the flare dropping run the aircraft personnel radioed they had difficulty meeting the

rate of drop and had experienced one or two instances of flare hang up in the sonobuoy launch chute, and instructions were requested. However, the operation was continued. Shortly after, observers saw a brilliant light and burning in the after lower section of the aircraft's fuselage. The aircraft crashed into the sea killing all thirteen (13) persons aboard. The crashed aircraft sank in deep water. Investigation showed the planned training exercise called for an unusually short interval between drops, and no deflector was provided to lessen the ship air stream pressure at the sonobuoy chute outlet. It is believed that a flare jammed in the chute and was inadvertently ignited before it could be cleared from the aircraft.

KILLED:
Thirteen

LOSS:
One airplane

7. After supper, a marine who was out in the field on training maneuvers (March, 1964), took a stroll near his bivouac, and found an unexploded item of dud ordnance. Instead of marking its location and reporting the find to his Commanding Officer in accordance with specific instructions, he picked it up and carried it into a nearby gun emplacement. None of his marine associates in the field maneuvers could readily determine what it was. Soon there was a small group around the ordnance curiosity. When disassembly operations were started, the resulting explosion killed three and seriously injured two.

This incident was determined to be the result of a violation of instructions.

INJURED:
Two

KILLED:
Three

MATERIAL
DAMAGE:
None

8. In December 1964, the missile racks of an aircraft were being prepared for loading. The port and starboard missile stations were each checked and the port station was found to be unsatisfactory. The starboard station was found to be operative however, and was thus loaded.

During a continuity check of the port station, the starboard missile fired setting fire to the aircraft. The ensuing fire resulted in serious burns to two personnel and completely destroyed the aircraft.

Since the aircraft was destroyed, one can only assume the cause of the accident. However, it can be said that had both launchers been

clear for checkout, this accident would not have happened.

INJURED:
Two

MATERIAL DAMAGE:
One aircraft lost

9. In November 1964, a functional firing test was being performed on a nonrotating variable time fuze. In preparing the fuze for test, two ordnance men had overlooked a booster which should have been removed. The fuze thus ignited during the test and the two men were injured although not seriously. (Note precaution 8.)

INJURED:
Two

MATERIAL DAMAGE:
Slight

10. In April of 1964, a range clearance operation was underway at a Marine Corp. base. A master sergeant assigned to the operation came upon a torching igniter of an impacted dud. He attempted to extinguish the flame with dirt and had apparently succeeded when the igniter exploded. The master sergeant was killed.

DEAD:
One

INJURED:
None

MATERIAL
DAMAGE:
None

11. In April of 1963, two ship's personnel were clipping small arms ammunition in the magazine of a ship. As they proceeded about their duties, one of the men removed a hand grenade from a near by container. Without further regard, he pulled the pin and the grenade detonated in his hand causing injury to him and his companion.

INJURED:
Two

MATERIAL DAMAGE:
None

12. A destroyer had just completed firing a pattern of four Hedgehogs on the morning of 19 January 1950. In his hurry to reload the projector, a gunner's mate apparently neglected to remove the safety plugs from the firing circuit.

An assembly error in the firing circuit caused spigot contacts to be 180° out of phase. At the end of the ripple switch cycle, the circuit for spigot No. 12 was energized continuously. When the gunner's mate placed a charge on this spigot, the charge fired. It blasted the man's hand off up to about one-third of his forearm.

INJURED: 1.

13. In 1952, on the hangar deck of an aircraft carrier, an aviation ordnance man was ordered to overhaul the 20-millimeter guns of a plane. He did not check thoroughly to see that the guns were empty before he started working. One of the guns accidentally fired. Five people were injured, and the belly tank of an F47 was badly damaged.

INJURED: 5.

14. In September 1949, an amphibious landing demonstration was scheduled at a large eastern Atlantic port. Thousands of spectators attended. One part of the program called for a demonstration of demolition techniques. Live explosives were to be used against dummy obstacles. In order to simulate the burst of an anti-aircraft projectile, the Ordnance Officer of one demolition team modified Emergency Identification Signals. Their pyrotechnic contents were removed, and a charge of one-half pound of TNT was substituted. A hand grenade detonator was tied or taped to the TNT. The alterations were made without any authorization from the Bureau of Naval Weapons. (Note precautions 4 and 5.)

Only 5 minutes prior to the demonstration, the Commanding Officer and the Executive Officer were told of the substitution. The Ordnance Officer, an experienced man, assured them that the signals had been test fired and were safe for firing. He was given permission to fire the modified signals.

Two signals fired satisfactorily. The third misfired and was removed from the projector. The fourth detonated within the projector, causing it to explode violently. A newspaper photographer was struck by a flying fragment and killed instantly. The Ordnance Officer, fatally injured, died 6 days later. Three others were hurt.

DEAD: 2.

INJURED: 3.

15. 9 August 1950. During a primer test of a 3-inch mount in a destroyer, a gunner's mate second class inserted a short shell case containing the primer and ordered the loader motor energized. The gun switch was on BOTH, and the other gun had previously cycled. In this condition, the loader mechanism of the gun on which the gunner's mate was working also would cycle.

Either the gunner's mate was not aware of this fact, or he forgot it. When the loader mechanism cycled, the flexible end of the pivoted

chute liner struck him a flat, jolting blow on the head, dislocating and fracturing a cervical vertebra. As a result, the gunner's mate died.

DEAD: 1.

16. 1 July 1952. During a practice run of a destroyer, a member of the gun crew of a 5-inch 38-caliber mount, was seated on the right gun captain's platform. The right gun was not to be fired. The man's left leg was placed beneath the right gun slide. At command, the mount elevated, the breech of the right gun descended and crushed the man's leg. It had to be amputated.

INJURED: 1.

17. On 21 April 1952, a heavy cruiser was engaged in a bombardment of enemy land troops on Korea. No enemy return fire was experienced during the time involved in this casualty. During the forenoon watch, turret one fired 42 rounds, 14 from the left gun. Guns and breech mechanisms were serviced after this firing was completed.

No firing occurred during the afternoon watch. After this watch was relieved, shortly before 1600, the left and center guns of turret one were loaded, ready to resume fire. Control of the 8-inch 55-caliber turret was in PLOT with spotting by a shore fire control party. At 1557, the firing circuit for the first salvo was closed by PLOT. The center gun fired; the left gun did not.

Apparently, no one in the fire control organization, either inside or outside the turret, knew that only the center gun had fired. The commanding officer knew, but he had no reason to think that anything was wrong. An open firing key, a slow load, or several other safe reasons for the left gun not firing could have existed.

No report was received from the turret that the left gun had not fired. Later actions indicate that the gun crew of the left gun apparently believed the gun had fired. The noise, added to the heavy vibrations of an adjacent gun firing, can fool even the most experienced. It is difficult for the crew member charged with observing the recoil-counterrecoil marks to keep from involuntarily closing his eyes as the salvo is fired.

This would not be the first instance in which a gun crew did not realize that its gun had not fired. Salvo latches were first installed many years ago because of the difficulty in knowing whether a particular gun had fired in salvo.

After the spot had been received from the shore party and applied to the range-keeper, the

control officer ordered turret one to reload the left and center guns. The order was acknowledged over the fire control telephone. Further indication that turret personnel believed the left gun had fired, no comment was made by the turret captain when he received orders to "reload" the left gun. This evidence presented to the Court of Inquiry indicates that the casualty had not yet occurred; the turret captain was still alive.

Immediately thereafter, the commanding officer saw "white and some yellowish smoke issuing forth from turret one" and sounded the general alarm. From within the turret, someone shouted to the safety watch outside to open the latches. In a few seconds, a second "explosion" was heard.

When rescue teams finally succeeded in opening the hatches, a thick, choking smoke poured out. Bodies were found piled against the hatches. At the port hatch, for example:

"... there were these people all wedged in the hatch at once and we pushed them up. We tried to pull them out first. We couldn't get them out that way so we pushed them with our feet and they came back down and we pushed them up again and we finally got one man out."

When the turret at last was cleared, 28 men were found dead of suffocation. Several minutes later, the two men still alive when pulled out, died—without saying a word.

The first fire consumed two full charge smokeless powder bags in the chamber of the left gun. The second fire consumed one full charge bag in each of the two upper hoists.

No one ever will know exactly what happened at the left gun just before the first fire, or from then on. All the witnesses died. But from the conditions found within the gun room and the hoists, it seems most probable that the breech of the gun was opened while a hangfire was in progress.

(The possibility of a serious accident due to opening the breech of a gun too soon in the case of a hangfire demands the constant exercise of the utmost prudence and caution. . . . Keep the breech mechanism fully closed.)

These were the conditions found:

1. The breech plug was opened and latched.

2. The gas ejector control valve was closed.
3. A projectile was seated in the gun.
4. The tray was spanned.
5. A second projectile was on the tray, its point-detonating fuse blackened by flame or heat.
6. There was an accumulation of burned powder residuc in the left gun chamber.
7. Both upper end covers of the upper powder hoists were open; the left cover was broken.
8. The gun captain's ready switch was at SAFE.
9. The salvo latch was in an operating condition.

To determine just how the accident could have happened, several tests were made. It was found that the firing circuit to the primer could be closed when the breech operating lever was within less than 2 inches from its latched position. The rotary motion of the long breech operating lever closed the firing circuit before actually engaging the salvo latch. This in itself did not create a dangerous condition except as it affected later actions; if the gun had fired immediately, no casualty would have occurred. However, a current OrdAlt changes the arrangement so the lever cannot remain in this position.

At the order to reload, the gun captain apparently opened the breech. (Note precaution 29.) In doing so, apparently the gun captain did not notice that he did not have to release the operating lever catch. He did not realize that anything was wrong until the breech plug had swung down and clear of the breech. If a hangfire was in progress, as seems likely, the gas ejector air—which normally clears the bore of unburned gases—was fanning the flame.

The gun captain must have tripped the lever to cut off the gas ejector. Then, either the intense heat of the burning powder or an instinctive reaction caused him to turn away from the breech—at least momentarily. He may have been calling for the sprinkling system to be turned on.

Somehow, this or some other inadvertent action of the gun captain must have been misunderstood by the trayman as a "bore clear" signal. The tray was spanned; the situation became hopeless. With the tray spanned, it was impossible for the gun captain to close the breech quickly enough to avert disaster. The partly confined powder in the gun chamber became fully ignited and belched flame into the gun room.

Apparently a crew member actuated the foot-pedal system following the "bore clear" signal to open or partly open the upper end covers of the upper powder hoists. With the cars at the upper end of the hoist, two bags of powder were exposed to burning powder grains from the first two charges. Both bags were consumed entirely. Whatever oxygen was left after the first charges burned must have been exhausted by the second two. The men who died suffocated; they were not burned to death.

Several safety precautions, general and specific, were involved in this tragic series of incidents. So far as is known, none of these precautions were violated intentionally. But error built upon error. If the same precautions are not observed on a similar gun, the same results can be expected. Only training and strict observance of every precaution can prevent such accidents.

DEAD: 30.

18. During an advanced battle practice, another foul bore casualty was narrowly averted because of the action of an alert rammerman. The rammerman, stationed in turret four of a battleship, had been thoroughly indoctrinated with the importance of continued observance of the powder chamber and the screwbox as the load was being made.

He detected a burning fragment in the powder chamber as he was ramming the projectile home. The gun captain had not seen the fragment, and he started to open the powder door. The rammerman immediately threw his body across the loading tray and pushed the incoming powder bags back into the upper handling room. The powder door was then closed, and the fragment was put out by the auxiliary gas ejector air jet.

CASUALTIES: None.

19. On 1 October 1951, one 5-inch 38-caliber gun aboard a destroyer fired into another. As a result, 6 men were killed and 15 wounded.

In the investigation that followed, the Commanding Officer and the Gunnery Officer stated that they were unaware that such an accident was possible. If they had known that one gun could fire into the barrel of another, they would

have—as prescribed by the general safety precaution A-1—issued additional precautions intended to prevent such an accident. As it was, no warnings or precautions dealing with this hazard had been posted.

The mount captain had not complied adequately with safety requirements, for he did not use his sight port to observe the line of fire to insure that it was safe. The gun of mount two, the mount hit, was trained and elevated to a "ready" position. In this position, the gun barrel could be in the line of fire of mount one. Mount two was not firing; it was not to fire until after mount one had completed its firing. For safety, therefore, mount two should have been held "ready" at its normally secured position "ready," degrees train. If it had been held "ready," no accident would have occurred.

The cut-out cam is designed to prevent firing into fixed objects of the ship's structure. These include turrets, mounts, launchers, torpedo tubes, and cranes in their stowed position only. Personnel must see that such items do not endanger the line of fire. In this case, any one of several responsible individuals—the Commanding Officer, the Gunnery Officer, the Control Officer, the mount captain, or a safety observer—could have prevented the accident. No mechanical defect existed. The failure was human.

At the time of this casualty, safety precaution A-52 (precaution 32 in this appendix) read:

When using director train while firing at gunnery exercises, an observer from the firing vessel for each gun or turret shall cause the firing circuit to be broken whenever the gun or turret is trained dangerously near any object other than the designated target.

This precaution has been revised to its present form, to remove any possible doubt as to its meaning. The change was made partly as a result of this accident.

DEAD: 6. INJURED: 15.

20. In September 1944 a violent blast wiped out a naval ammunition depot. The Chief of the Bureau of Ordnance stated that the explosion resulted from "accidentally dropping or otherwise roughly handling a depth bomb."

According to eyewitnesses, a depth bomb was being transported on a standard two-wheeled

stevedore truck. Apparently, because of carelessness, the bomb fell from the truck and exploded. One end of the depot became enveloped in flames. It spread to loaded charges in the building, but enough time elapsed to allow most personnel to escape. A huge blast then took place, blowing up the depot and its adjacent facilities. (Note precautions 8 and 12.)

DEAD: 10. INJURED: Over 60. MATERIAL DAMAGE: Destruction of depot.

21. On 12 June 1952, drill projectiles were being sent up the hoist of a transport during a supply drill for 5-inch 38-caliber guns. The projectile hoist suddenly failed. It would not hoist from the handling room to the mount. The mount captain opened the hoist and placed his right hand on the butt end of the projectile and his left hand on the ejector lever. He proceeded to twist the projectile in order to see if the fuze setting lugs were correctly engaged in the fuze pot.

The hoist operator then said that the hoist manual lever was stuck, at the same time placing his hand on that lever. The hoist cycled. The index and middle finger of the mount captain's right hand were shorn off.

A notice plate just above the door read DO NOT PLACE HAND IN HOIST. Instruction specified that power must be secured before any adjustments are attempted. (Note precaution 1.)

INJURED: 1.

SUMMARY

The following report of a Navy board clearly expresses the lesson this appendix strives to emphasize:

"It is unquestionable that any intelligent action in prevention of casualties must be based on a thorough knowledge and understanding of safety precautions. All personnel concerned must thoroughly understand how and why (safety precautions) actually apply in practice, as well as have a knowledge of what (safety precautions) are. Constant vigilance must be exercised to assure that they are at all times carried out in every detail; any violations or tendency to veer from this vigilant attitude must be abruptly checked at the time it occurs.

Inasmuch as the safety precautions are generally understood by all hands to be one of the primary laws of self-preservation, cases of willful violation of them are rare. It is, rather, ignorance of their existence and application, or a slacking off of their meticulous observation bred from an overconfidence in nonoccurrence of casualties, that causes violation of them.

There can be no law against casualties nor can they be ordered out of existence. This can obviously not be done under conditions where the human element is involved. However, a large percentage of casualties can be very definitely and positively eliminated by a proper overhaul, inspection, and test of material and by proper and sufficient drill of personnel in handling their gear."

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