CHAPTER 25

Fog Signals

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25–1 DEFINITION

25–1–1 General—

A. *Type and range.*—A fog signal is a sound signal established as an aid to navigation, for the purpose of guiding mariners in periods of reduced visibility. Fog signals may be of several diverse types and have ranges of from one-half mile to several miles, dependent on the source and amount of sound employed and subject, of course, to atmospheric conditions.

B. *Where located.*—Fog signals may be established afloat on buoys and lightships, and ashore on major or minor fixed light structures, pierheads, breakwaters, etc.

C. *Standby apparatus.*—Where standby fog signal apparatus is to be installed at a light station, the equipment in general is to be a duplicate of the regular apparatus. This policy applies not only to new installations but to existing installations when replacements are necessary.

D. *Classification.*—Fog signals are classified herein as minor and major signals.

25–1–5 Minor Fog Signals—

A. *Range.*—A minor fog signal is a sound signal of limited power, generally having an average range of one mile or less.

B. *Types.*—A minor fog signal may be any one of the following:

(1) A small air diaphragm horn (6 inches).
(2) An electric diaphragm horn.
(3) A small electric motor siren.
(4) A large bell.
(5) A bell, gong, or whistle on a buoy.

25–1–10 Major Fog Signals—

A. *Range.*—A major fog signal is a sound signal or normal range of 1½ miles or greater.

B. *Types.*—A major fog signal may be any one of the following:

(1) An air diaphone.
(2) An air diaphragm horn (8 inches or larger).
(3) A siren.
(4) An electric air oscillator.
(5) A reed horn (obsolete).

25–1–15 Chronological Table of Fog Signals—

A. Following is a chronological table of fog signals used in the United States with notes on the current application of each.

Date installed	Device	Present day use	Type
	Bell, hand operated	Obsolete	Minor.
1719	Cannon—guns	do	
1851	Reed horn—trumpet	Obsolescent	Major-Minor.
1855	Bell (bell buoy)	Extensive	Floating.
1857	Whistle	Obsolescent	Major.
1904	Submarine bell, air	Obsolete	
(1)	Siren, air	Decreasing	Do.
(1)	Siren, steam	Obsolete	Do.
(1)	Bell, gravity—clockwork	Extensive	Minor.
1911	Bell, electric	do	Do.
1913	Siren, electric	Current	Do.
1914	Diaphone	Extensive	Major.
1915	Gun, acetylene	Obsolete	
1920	Bell, gas	Current	Minor.
1921	(Radio signals)	Extensive	
1925	Submarine oscillator	Obsolete	
1928	Air oscillator, electric	Current	Major.
1929	Horn, diaphragm (air)	Extensive	Do.
	Horn, diaphragm (steam)	Obsolescent	Do.
1935	Horn, electric (battery operated, diaphragm type)	Current	Minor.
1941	Horn, electric (dynamic cone type)	do	Do.

[1] Prior to 1910.

25–2 CLASSIFICATION OF APPARATUS

25–2–1 General—

A. Present day sound fog signal units are divided into three general classes.

B. *Air-operated units.*

(1) Diaphones.
(2) Sirens.
(3) Horns, diaphragm.
(4) Whistles, wave motion, buoy.

C. *Electrically operated units.*

(1) Electric air oscillators, multiple unit.
(2) Electric air oscillators, single unit.
(3) Horns, diaphragm, electric (vibrator).
(4) Electro-magnetic cones (separately excited).
(5) Motor-driven sirens.

D. *Percussion units.*

(1) Bells (including buoy bells).
(2) Bell strikers (mechanical).
(3) Gongs.

25–3 AIR UNITS, WAVE-ACTION OPERATED

25–3–1 Whistles—

A. *Wave-action operated whistles* are used on lighted and unlighted buoys especially designed with a long counterweighted center tube, through which the air is compressed by the up and down motion of the buoy in a seaway. The air is compressed on the downward motion of the buoy and allowed to escape through a 1/32-inch aperture in the bell casting, blowing the whistle. On the upward motion the partial vacuum created in the whistle tube causes the balls in the whistle valve to lift; air is again drawn into the tube, compressed on the downward movement of the buoy, and the operation is repeated.

B. *The whistle and whistle valve are of two types—four-ball* (fig. 25–1) *and two-ball* (fig. 25–2).—The four-ball whistle valve is used on lighted buoys; the two-ball valve is used on the unlighted standard 7–W buoy, and also on the older nonstandard unlighted whistle buoy.

C. *The four-ball type* whistle body and whistle valve are brass castings. The whistle bell is of bronze, ⅛ inch thick, 10 inches outside diameter by 17 inches long, and is supported by a bronze spindle screwed to the whistle body and bell casting, to which the bell is fastened with ¼-inch brass flathead screws. The whistle body is flanged and is bolted to a whistle valve containing the four cork balls, each of which is 4 inches in diameter and weighs not more than 7¼ ounces. These balls are located between guides to assure proper seating on the machine-surfaced valve seats. A 6-inch pipe flange, centrally located over the whistle tube, is welded to the buoy head. The whistle tube, which is 36 inches in diameter, extends 25 feet below the buoy head.

D. *The two-ball type* whistle body and valve are brass castings. The whistle bell, of 12 gage bronze, 10 inches in diameter by about 18 inches long, is supported by a bronze spindle screwed to a valve casting, to which the whistle bell is riveted and soldered. The whistle valve contains two cork balls of similar size to the ones used in the four-ball valve. These balls are also located between guides to assure proper seating on the machined surfaced valve seats. A standard 4-inch pipe that extends from the valve is welded to the top head of the buoy. The whistle tube is 24 inches inside diameter and extends 12½ feet below the top head.

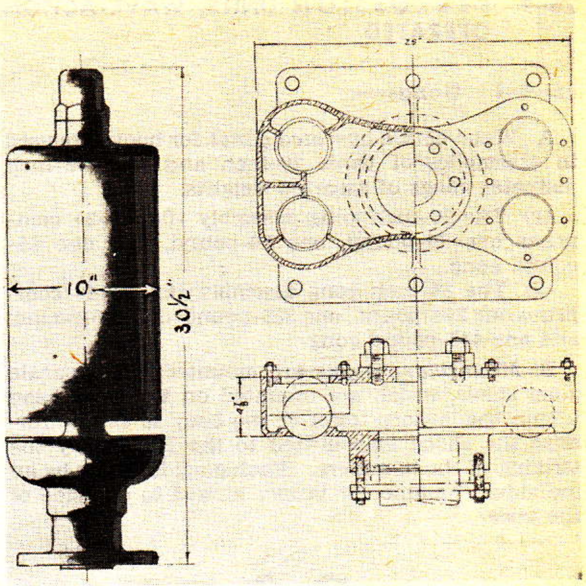


FIGURE 25–1.—Buoy whistle and valve (four ball).

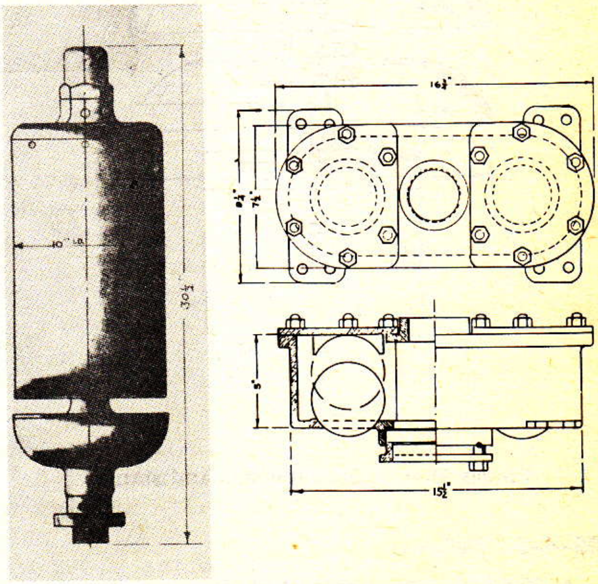


FIGURE 25–2.—Buoy whistle and valve (two ball).

E. *Weights.*—The four-ball valve weights 265 pounds and the whistle body and bell weigh 155 pounds. The two-ball valve weighs about 165 pounds and the body and bell weigh about 125 pounds.

25–4 PERCUSSION UNITS, WAVE-ACTION OPERATED

25–4–1 Gongs—

A. *Wave-action operated gongs* for buoys are used in assemblies of three 20–inch and four 36–inch diameter gongs of assorted weights.

(1) The 20-inch gong assembly (fig. 25–3) comprises one 70-pound, one 80-pound, and one 85-pound gong.

(2) The 36-inch gong assembly (fig. 25–4) comprises one 290-pound, one 356-pound, one 405-pound, and one 445-pound gong.

B. *Mounting.*—Gongs are mounted on separate gong stools, which are mounted on the buoy head within the lantern tower of the buoy so as to minimize the shock transmitted to the lantern by the striking of the hammers. Each gong is struck by an individual hammer or tapper hinged to one side of the tower.

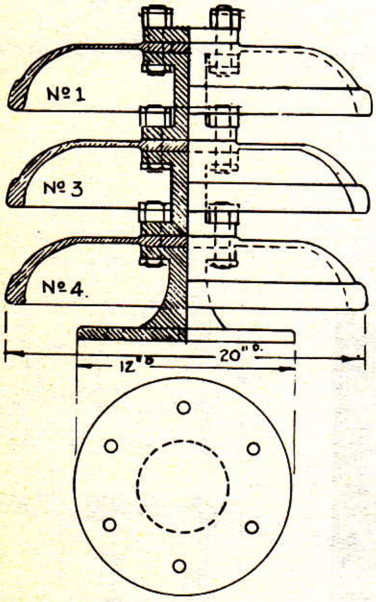


FIGURE 25–3.—20-inch gongs and stand.

25–4–5 Bells—

A. *Wave-action operated bells* for buoys are used in three sizes—85-, 225-, and 1,000-pound. On old buoys the 225- and 1,000-pound bells are suspended from separate bell towers mounted on four legs on the buoy head within the lantern tower. On buoys currently under construction, *all bells* are mounted similarly to the 85-pound bell described in paragraph D below.

B. *The 1,000-pound bell* is 3 feet in diameter by 27 inches overall height and is fastened to the bell tower by four 1-inch and one 2¼-inch diameter bolts. There are four tappers individually suspended from the bell tower.

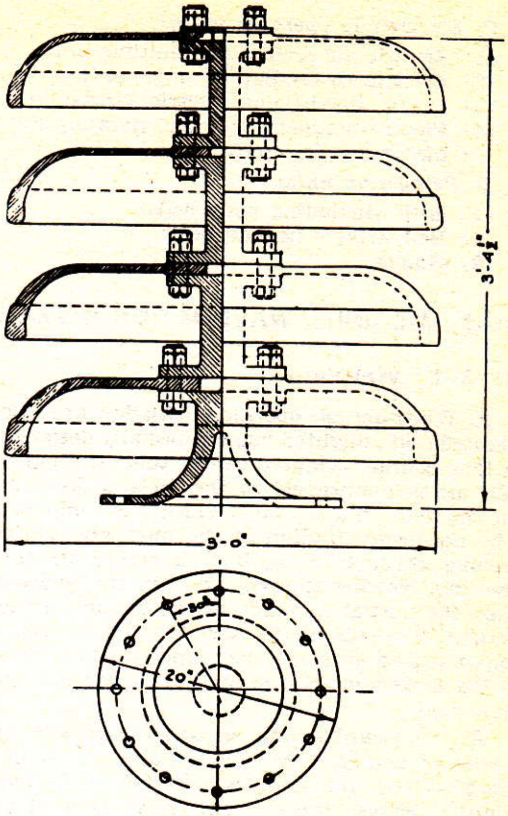


FIGURE 25–4.—36-inch gongs and stand.

C. *The 225-pound bell* is about 20 inches in diameter and 17 inches high. It is secured by three 1⅛-inch bolts.

D. *The 85-pound bell* is 15 inches in diameter and 12¼ inches high. The bell stand, made from 1½-inch steel rod, together with a conical hood, is welded directly to the top of the main buoy body. A shoulder plate, upon which the bell rests is welded to the rod at a height of about 15 inches. The bell is secured to this plate by a brass hexagonal nut that fits the 1½-inch threaded main rod. Four standard type tappers are suspended from a point on the inside of the light tower near the bottom of the daymark.

E. The bells listed above, with the exception of the 85-pound bell, may also be used in connection with mechanical bell strikers.

25–5 PERCUSSION UNITS, MECHANICALLY OPERATED

25–5–1 General—

A. *Type and size.*—Mechanically operated percussion units for fog signal purposes are restricted to bells. These bells may be located on fixed structures and weigh from 225 to 4,000 pounds, or may be located on buoys and weigh 225 or 1,000 pounds.

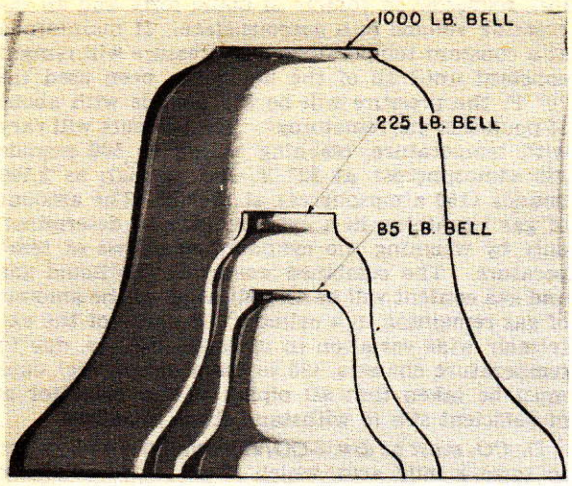


FIGURE 25–5.—Various sizes of bells for buoys.

B. No large bells for navigational purposes appear to have been cast within the last 40 years. Additional establishments will be accomplished by transfer of existing bells.

25–5–5 Types of Mechanical Bell Strikers—

A. Four general types of mechanical bell strikers are in current use. They are as follows:

(1) Hand-wound bell striking machine.
(2) Electric motor-driven striker.
(3) CO_2 bell striker (A. G. A.).
(4) Electric solenoid striker (A. G. A.).

25–5–10 Hand-Wound Bell Striking Machine—

A. Hand-wound strikers were furnished by the Gamewell and Stevens companies. A Service design was also used. The last installations are approximately 30 years old or more. All consisted of a weight-operated drum, connected through a cam, rollers, and linkages to a clapper which struck the bell. A governor controlled the timing, and a control program cam, the characteristic.

B. The apparatus is considered obsolete and with only a few exceptions, hand-wound strikers are applied today to standby bell signals at manned stations.

C. Maintenance is the same as for any mechanical apparatus of similar general type.

25–5–15 Electric Motor-Driven Striker—

A. The motor-driven bell striking mechanism was installed at fixed locations to which electric power could be supplied. It consists of a sealed, oil-filled gear box from which shafts for the clapper arm and motor pinion project through stuffing boxes.

B. *Lubrication and maintenance.*—Gear box lubrication must be suitable for local weather conditions to assure that the motor will successfully start at the lowest probable temperature encountered at the site. Motor maintenance is standard for the class of motor used. The principal difficulty encountered in service has been due to misalignment of the motor and the use of improper lubricants.

C. *Procurement of parts.*—Repair parts not obtainable locally shall be obtained from a Coast Guard Supply Center. Existing units probably will not be replaced in kind. If worn out, submit work authorization request for replacement, recommending more modern striking units or other type of minor fog signal.

25–5–20 CO_2 and Electric Solenoid Bell Strikers—

A. Due to the comprehensiveness of the subjects of CO_2- and electric solenoid-operated bell strikers manufactured by the American Gas Accumulator Co., a separate part of this chapter will be devoted to each.

25–6 CO_2 BELL STRIKER

25–6–1 General—

A. This striker, operated by carbon dioxide gas, is used to strike fog bells in remote unattended locations ashore, and on buoys in sheltered waters where a fog signal is required but where the wave action is insufficient to operate a conventional bell and where a louder signal is desired with a regular characteristic.

B. A typical installation (fig. 25–7) consists of the following items:

(1) A bank of CO_2 cylinders.
(2) Manifold.
(3) Piping.
(4) Apparatus plate.
(5) Striker.
(6) Bell.

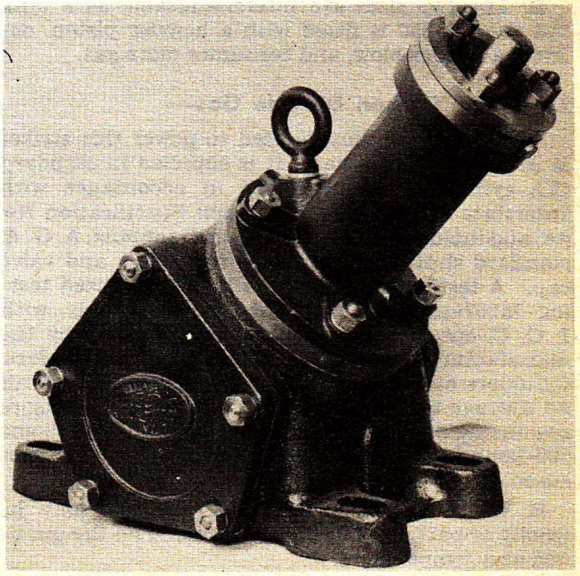


FIGURE 25–6.—Type CS–50 CO_2 bell striker.

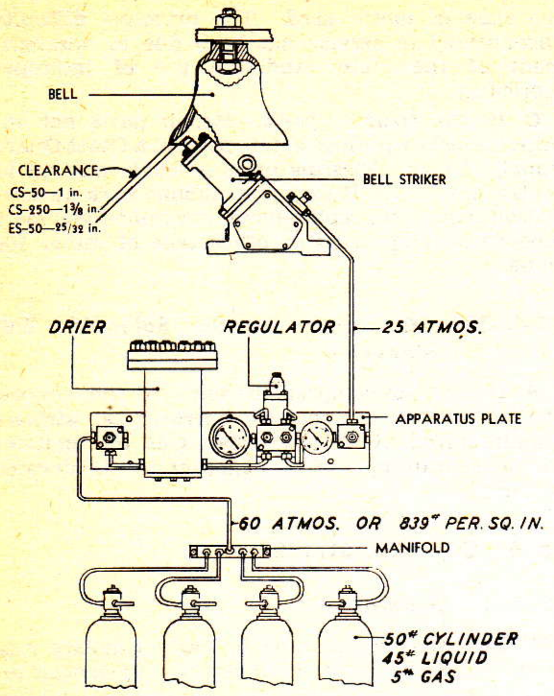


FIGURE 25–7.—Schematic drawing for CO_2 bell striker installation.

25–6–5 Sizes—

A. The CO_2 bell striker is available in two sizes, originally designated as the type CSEP–250 and the type CSEP–50. The designations have been changed to CS–250 and CS–50, respectively. The unit was completely redesigned in 1939, and earlier units should be modified to the later design whenever overhaul or servicing is necessary.

B. The two sizes are interchangeable as a unit, but the CS–250 is fitted with a heavier piston, delivers a harder blow, and consumes more gas.

25–6–10 Carbon Dioxide Gas—

A. The carbon dioxide used to power this striker is in the form of a gas. It is supplied in standard CO_2 cylinders, manufactured in accordance with Interstate Commerce Commission Specification No. 3A, and includes three-quarter-inch tapping, A. G. A. standard shut-off valve, plain neck ring, and valve cap. A test certificate issued by a recognized testing laboratory showing that tanks comply with I. C. C. specification 3A shall be furnished by the manufacturer with each shipment of cylinders. Cylinders are available in 50 pounds capacity with an average tare weight of 120 pounds, and measure 8½ inches in diameter and 65 inches long. Some 100-pound cylinders have been used but are not standard.

B. While stored in cylinders, the gas may be wholly or partially liquefied, depending on the quantity and temperature.

C. *Pressure.*—As the gas is used, the volume in a gaseous state is replaced from the liquid, resulting in a reduction in volume in liquid form and an increasing volume in a gaseous state. If maintained at a constant temperature, the pressure will remain constant until all of the liquid has been used (at 70° F. the pressure will be 839 pounds with about 15 pounds of gas remaining). The pressure will vary with temperature, reaching as low as 500 pounds (35 atmospheres) at 32° F. and as high as 2,100 pounds (150 atmospheres) at 125° F. The amount of gas remaining in a cylinder may be determined only by weighing the cylinder, regardless of temperature. The combined weight of the liquid gas and gas content will be an indication of the amount of gas remaining in a cylinder. Because of the extremely wide variation in pressure possible, due to temperature changes, (35 to 150 atmospheres) care must be taken that all piping to the regulator is of sufficient size to withstand these pressures.

D. *CO_2 must be dry.*—CO_2 gas combines with water to form a mild acid, which is an active oxidizing agent. For that reason, it must be kept absolutely dry. Corrosion of the gas system and striker will occur unless proper precautions to the contrary are taken in the design of the system. Special filters, driers, bronze valve diaphragms, and copper tubing have been incorporated in the design to prevent corrosion.

25–6–15 Characteristics—

A. The CO_2 striker will deliver single recurring strokes at a rate of 2 to 10 strokes per minute.

B. *Gas consumption.*—The CS–50 striker, if properly adjusted, should give approximately 2,500 strokes per pound of gas at 70° F. The CS–250 striker will give approximately 900 strokes under the same conditions. The consumption increases approximately 3 percent for each drop of 10° F.; conversely, it decreases about the same percentage for each 10° F. increase in temperature.

25–6–20 Apparatus Plate—

A. The apparatus plate, see figure 25–8, consists of the following accessories.

(1) Two 3-way shut-off valves.
(2) Drier.
(3) Pressure regulator.
(4) Combination high- and low-pressure gauge valve.
(5) High-pressure gauge.
(6) Mounting plate and piping.

B. If the mounting plate is not used, equipment may be mounted on existing support.

C. *A shut-off valve* (part 4, fig. 25–9) is provided in the line from the cylinders to the assembled accessories, and another is located on the discharge side.

D. *The drier* (part 2, fig. 25–9) being (as will be noted on fig. 25–7) on the high pressure side of the system, is a forged steel cylinder, tested to 3,000 pounds. It has a removable top secured by closely spaced studs and nuts and is made tight by means of an aluminum ring gasket. The drier contains 2 pounds of calcium chloride which serves the purpose of removing any moisture from the gas. The calcium chloride is fused into sticks; it should be renewed not less than twice a year.

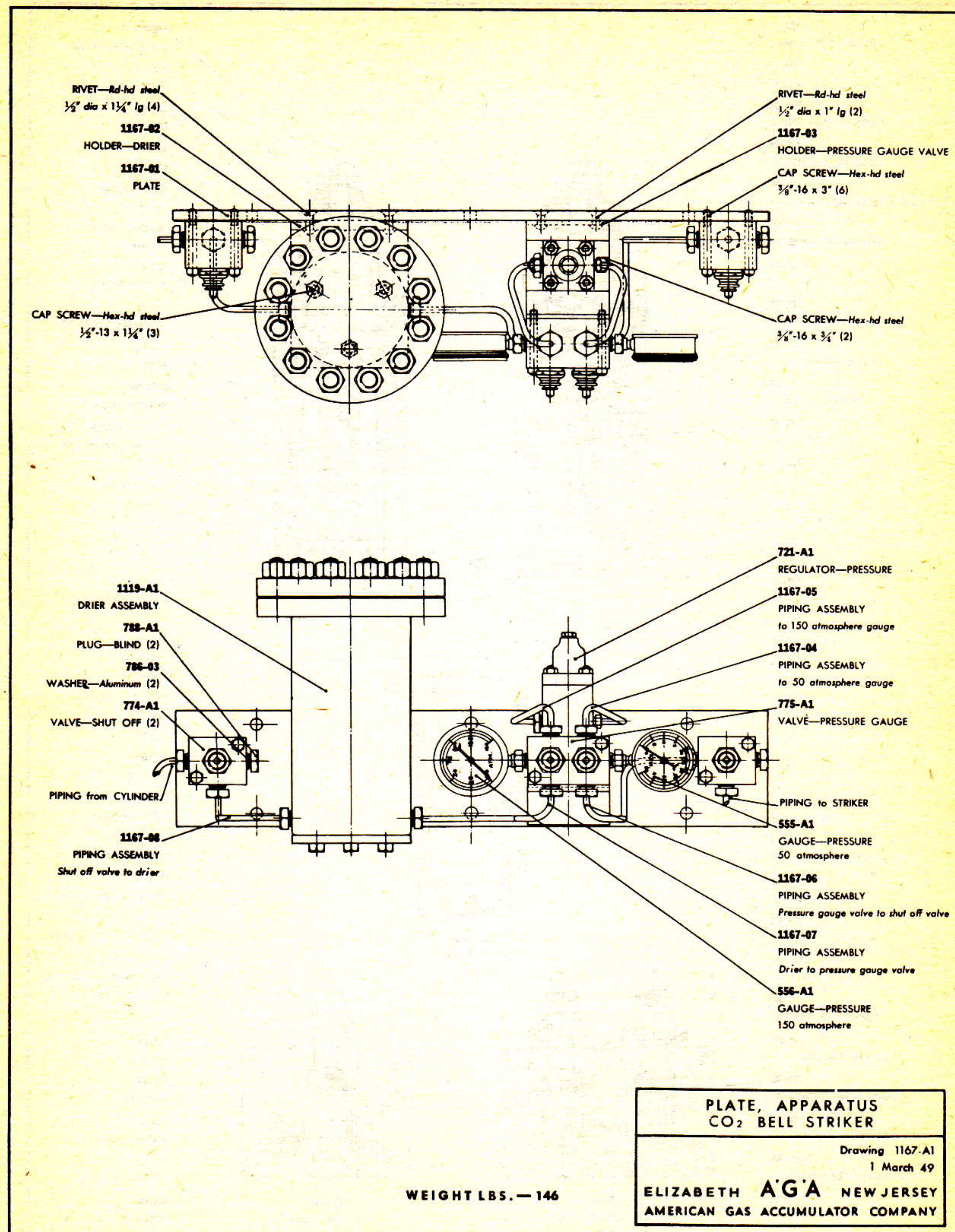


FIGURE 25-8.—Apparatus plate for CO_2 bell striker.

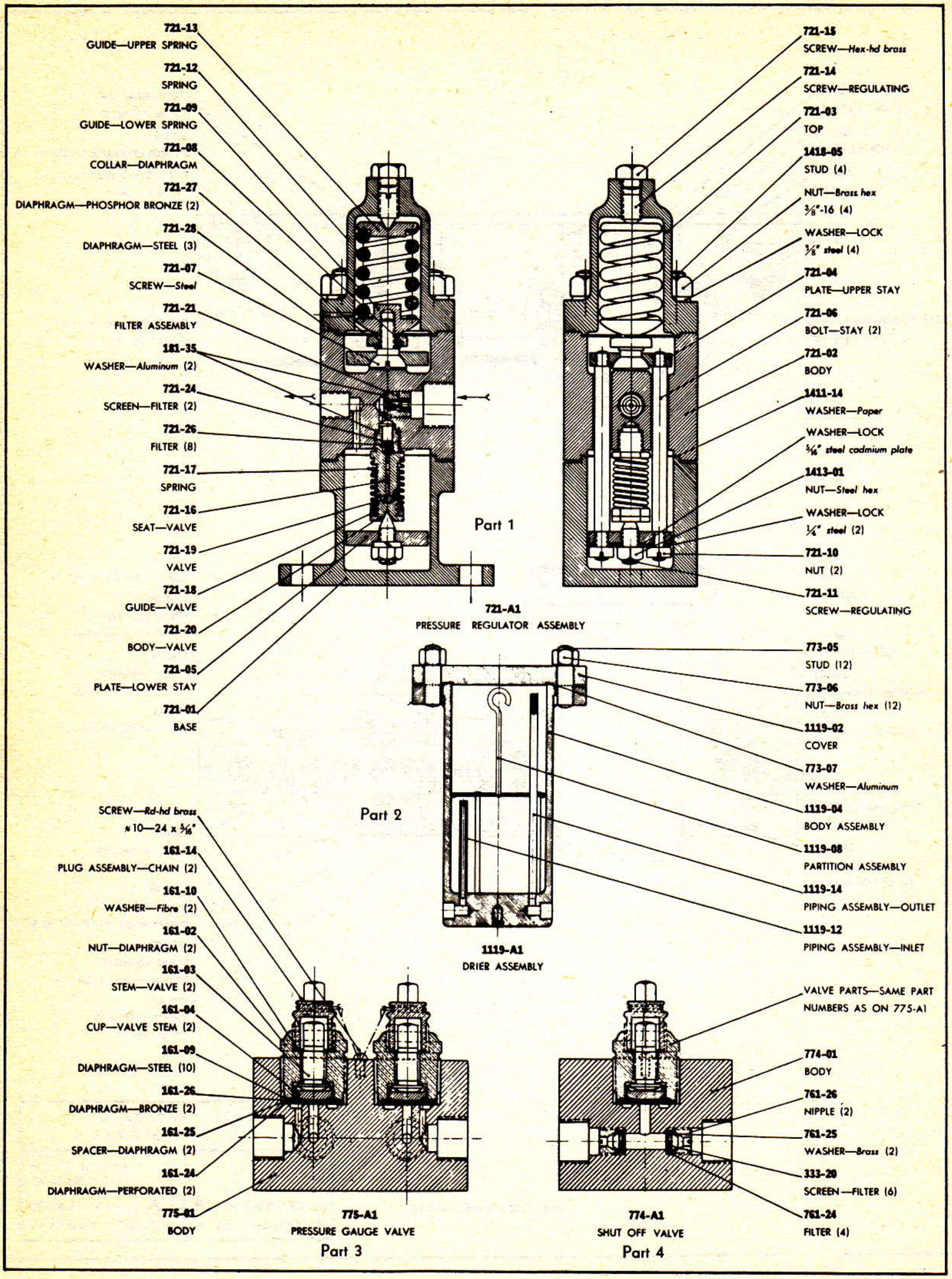


FIGURE 25–9.—Parts assemblies for CO_2 bell striker.

E. *Two pressure gauges* are provided—one in advance of the pressure regulator and one on the outlet side of the regulator. These gauges should not be under pressure except when a reading is in progress. After a reading has been taken, the gauges should be removed and replaced with gasketed blind plugs which should be tested for tightness. If the gauges are left on station they should be checked periodically against standards.

The high-pressure gauge is used for no other purpose than to indicate the tank pressure. It cannot be used to measure the amount of gas in the tanks.

F. *Regulator and low-pressure gauge.*—The function of the pressure regulator is to deliver gas at a constant pressure to the striking mechanism. It is not a mechanism throttle, and no attempt should be made to alter the striking characteristic by altering the regulator pressure.

At normal temperature (70° F.) the operating pressure should be 25 atmospheres.

25–6–25 Piping—

A. Piping for CO_2 gas is made from noncorrosive material, usually copper. Sleeves are generally made of stainless steel and are brazed on the piping. Nuts are made of brass, and their threads are of several sizes and standards, the most common being commercial CO_2 or A. G. A. CO_2. Since there are several possible thread systems (all very similar in appearance) care should be taken not to force the threads.

B. *Do not use acetylene piping.*—Copper-covered steel tubing such as used in acetylene piping should *not* be used in CO_2 systems. CO_2 combines with moisture to form a mild acid, which, should the drier inadvertently be permitted to go too long without servicing, might cause corrosion in the steel tubing.

C. *Different threads.*—CO_2 piping and fittings use a different thread than is used for acetylene gas piping. This is done to prevent the possible misuse of CO_2 copper piping in a high-pressure acetylene system where it might create a serious explosion hazard.

D. *Aluminum washers.*—Pipe connections must be made up tight, using proper aluminum washers. All connections should be tested with soapsuds.

25–6–30 Installation—

A. The striker should be secured to a base underneath the bell. Mounting holes in the striker are elongated to permit correct positioning of the striker relative to the bell.

B. The striking piston should strike the surface of the bell squarely at the point of impact. This point should be at or near the thickest portion of the bell rim. With most bells the striker's 45° inclination will bring the axis of the piston into approximate correct alignment with the bell rim.

(1) *Clearance.*—With the piston in the "down" position, the clearance between face of piston and bell should be as follows:

	Inches
Type CS–50	1
Type CS–250	1⅜

206430 O—52——23

(2) A gauge is available to indicate correct spacing.

(3) *Correct spacing necessary.*—If the distance between the striking piston and the bell is too great, the piston will hit a stop built into the cylinder and will not reach the bell. If less than indicated, the impact on the bell is appreciably lessened and the piston will hit the bell while gas still remains under pressure back of the power piston. It will be held momentarily against the bell, thus muting the sound.

C. The high pressure gage valve, drier, regulator, and low-pressure valve assembly should be mounted in the tank house.

25–6–35 Operation—

A. Carbon dioxide gas from the cylinder enters through the first shut-off valve to the drier, from the drier through the high-pressure side of the gage valve into the pressure regulator, and thence back through the low-pressure side of the gage valve to the second shut-off valve (see fig. 25–8).

B. The first shut-off valve is closed for temporary shut-down while servicing the apparatus plate. The second shut-off valve is closed for temporary shut-down of the striker for servicing. For a complete shut-down of the installation, the cylinder valve must be closed.

C. After passing through the second shut-off valve, the gas goes to the inlet connection of the striker. (See fig. 25–11.) This inlet is on the under side of the manifold located to the rear of the striker on the outside of the lower striker housing. In this manifold is located a throttle valve through which the gas passes into a filling chamber at the bottom of the striking mechanism. In the filling chamber, the pressure builds up gradually to a predetermined adjustable opening pressure. In operation, the time required for the gas to build up to this pressure is the interval between blows.

D. When the opening pressure (approximately 20 atmospheres) in the cylinder is reached, an inlet valve to the power cylinder, directly above, opens against spring pressure and the gas from the filling chamber enters the power cylinder. The tension on the inlet valve spring controls the opening pressure. This tension is adjustable by means of a regulating screw S2, fig. 25–12, located inside the power cylinder.

E. The gas, entering the power cylinder, exerts a pressure on the power piston, pushing it upward with the striking piston. When the power piston leaves its seat, a bypass is opened, allowing gas from the power cylinder to flow back against the inlet valve and close it. As the power piston moves upward, the pressure drops. The pressure at the start is the opening pressure, the pressure at the end of the stroke is the closing pressure.

F. The opening pressure should be 20 plus or minus 2 atmospheres and the closing pressure close to 16½ atmospheres, resulting in pressure drop of 3½, plus or minus two atmospheres. The gas confined in the power cylinder at the closing pressure expands, and the power piston continues to move upward with the striking piston with increasing speed, until the end of the striking piston strikes the bell.

G. Just before the striking piston strikes the bell, an exhaust port is uncovered in the side wall of the power cylinder, releasing the pressure in the power cylinder. Most of the gas escapes through the exhaust port which leads to the striking piston guide and on out through an exhaust pipe.

H. Upon striking the bell, the striking piston rebounds, and both striking piston and power piston return to their original positions by gravity. The exhaust port is closed on the return of the power piston and the gas trapped in the power cylinder escapes through an orifice into the exhaust. The rate of flow through this orifice is adjustable and controls the return velocity of the power piston. The adjustment should be sufficient to allow the pressure back of the inlet valve to reach normal pressure before another blow is delivered.

25–6–40 Routine Maintenance—

A. The information listed below should be considered when effecting routine maintenance of CO_2 bell strikers.

B. The gas content of a CO_2 cylinder must be determined by weight, i. e., the amount of gas in a cylinder is the difference between its actual weight and its stamped tare weight.

It should be ascertained that gas of proper quality and under correct pressure has free access to the inlet throttle.

C. *Cylinder valves* should be checked for tightness. If a leaking valve is found, the cylinder must be replaced and returned for valve repair.

B. *Pressure relief valve.*—Excessive pressure in the housing will cause the striker to stop. It will resume operation as soon as the pressure is relieved, if there are no other faults in the system. Loosen the side plate containing the relief valve. If this was the cause of the trouble and the striker resumes operation, the relief valve should be inspected. This valve consists of a diaphragm held in place by a ring and four screws mounted in one of the side plates.

Disassemble the relief valve, clean all parts, and install a new diaphragm if necessary. Make sure that the hole through the diaphragm matches with the corresponding hole in the retaining ring. *This operation should only be attempted in the field in an emergency since the housing should not be opened.*

E. *The drier* should be filled when necessary (but not less than once a season) with 2 pounds of calcium chloride ($CaCl_2$) fused into sticks. When recharging the drier, do not attempt to lift out the contents of the drier by the partition disk lifting eye before the old calcium chloride is thoroughly loosened. Clean the interior throughly and replace the filters. The cover should be made up tight with a new gasket and checked for leaks, preferably by submergence in water. It will be found that driers can be filled most conveniently at the depot.

F. *Lubrication* is the principal field service item required. Gargoyle Telco AA or equal is a satisfactory lubricant. Use of a lubricant having similar characteristics is necessary.

To lubricate the striker, remove the drain plug and the oil plug and, after the used oil has drained off, replace the drain plug. It should not be necessary to flush out the striker. Refill with approximately 4 fluid ounces of oil and replace the oil plug.

G. *The following instructions, though general in character, are nevertheless important:*

(1) Unless absolutely necessary, the striker housing should not be opened in the field.

(2) The CO_2 system is fitted with filters at numerous points. They should be renewed periodically.

(3) Washers must not be reused.

(4) *Renewing diaphragm.*—Always check the diaphragm in the watertight head. It should be replaced about every 6 months, using the following procedure:

(*a*) Remove three nuts and lift off diaphragm rings.

(*b*) Pull out striking piston assembly and remove old diaphragm.

(*c*) Place new diaphragm over piston and pull down to groove with flap of diaphragm up. Bind twine around flap from groove up to top of flap. Tighten twine, shellac, and dry.

(*d*) Replace piston, diaphragm rings, and three nuts.

(*e*) Fasten striker in place, checking carefully the clearance between piston head and bell. Refer to paragraph 25–6–30 (B).

H. The following tools should be made up into a service kit for use in servicing CO_2 bell strikers.

	Size	Tool	AGA Part No.
1 ea.	13–15 mm	Double open end wrench	311–A1.
1 ea.	27–28 mm	Double open end wrench	1588–A1.
1 ea.	3/4 USS	Open end wrench	
1 ea.	5/8 USS	Open end wrench	
1 ea.	9/16 SAE	Socket wrench	
1 ea.	11/16 SAE	Socket wrench	
1 ea.	3/4 USS	Socket wrench	
1 ea.	(N 130)	T wrench	315–A1.
*1 ea.	TL–2	Special socket wrench and screw driver for PD–PR–PL and opening pressure regulating screw.	1293–A1.
*1 ea.	TL–4	Special socket key wrench for throttle screw packing gland.	1293–B1
*1 ea.		Seat assembly tool for inserting inlet piston disc (seat).	1293–C1
1 ea.	TL–1	0–50 atmosphere CO^2 pressure test gage.	555–A1.
1 ea.	TL–3	0–150 atmosphere CO^2 pressure gage	556–A1.
1 ea.		Test pipe test connections on throttle manifold to gage (5⁄32 o. d. CC. steel tubing will be satisfactory).	
1 ea.		Screw driver, not over 5⁄16″ wide for adjusting reducing valve.	
2 ea.		Gage blocks, 1″ and 1⅜″	

*See fig. 25 10.

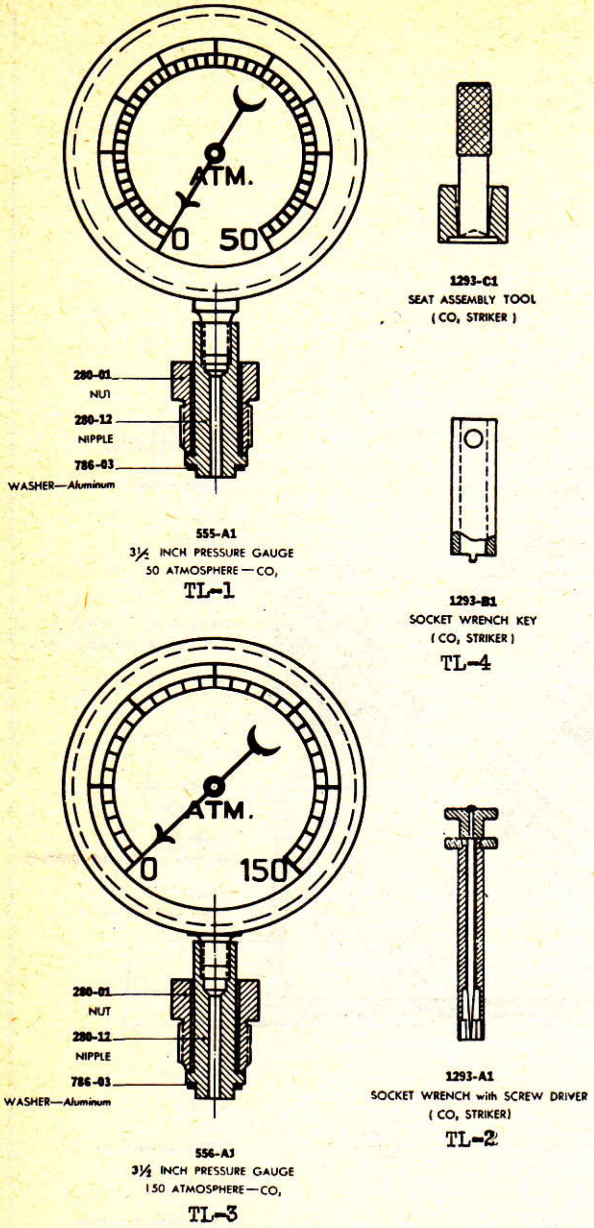


FIGURE 25–10.—Pressure gages and tools for CO_2 bell striker.

25–6–45 Shop Overhaul—

A. *Complete inspection and overhaul of CO_2 striker.*—It should be noted that the adjustments described in the following paragraphs all involve partial disassembly of the striker. Every effort should be made to avoid them in the field unless adequate facilities and trained personnel are available. Should it be desired to inspect the striker thoroughly, or should a striker not respond to the field service adjustments heretofore described, the following shop procedure is outlined.

B. *Adjusting regulator.*—The regulator is set to deliver gas at 25 atmospheres at normal temperature (70° F.) and when functioning properly the low-pressure gage should indicate approximately this pressure. If the pressure is too high, it is due to: (1) maladjustment, or (2) a faulty part, usually a leaking valve. To determine which of the two is causing the excessive pressure, proceed as follows:

(1) Open slightly any connection on the low-pressure side of the system and allow gas to escape until the low-pressure gage indicates about 15 atmospheres. Close the connection and observe the pressure rise. If the pressure rises rapidly to the original value and then remains constant, the valve seat is tight and correction for maladjustment must be made as follows:

(2) Remove cap screw on top of regulator and with a screw driver turn the adjusting screw counterclockwise until the correct pressure is obtained. Replace the cap screws. If the pressure first rises rapidly and then more gradually to the original value, the cause is probably a leaking valve. Under these circumstances the regulator must be replaced and returned for repairs.

(3) If the pressure is too low, it should be corrected by an adjustment opposite to that described above. If the regulator does not respond to this adjustment, it must be replaced and returned for repairs.

C. *The inlet throttle* is the medium through which the number of strokes per minute is determined. On present models (and on old models that have been rebuilt by A. G. A. since 1938) it is located on the top and outside of the striker housing.

(1) To effect an adjustment, remove the plug cap. This is on the outside of the throttle block and is not a standard blind plug. The adjustment screw (S–1) (fig. 25–11) under this plug cap is slotted to receive a screw driver. It is made reasonably gas-tight by a gland packing. This packing is, in turn, tightened by a gland nut, using a special wrench (TL–4). A slight leak through this packing can be tolerated because loss of gas is prevented by the gasketed plug cap which should be carefully tightened and tested after the adjustment is completed.

(2) To increase the number of strokes per minute, turn the adjusting screw counterclockwise; to decrease, turn it clockwise.

D. *Filling chamber pressures.*—It may be observed that the inlet throttle also makes provision for a third connection—a testing connection—located on the top of the throttle block and closed by a blind plug. Remove the blind plug, attach test gage (TL–1), and observe the pressures in the filling chamber. The opening pressure normally is 20 atmospheres (+or−2), the closing pressure, about 16½ atmospheres—a pressure drop of 3½ (+or−2) atmospheres. Any appreciable departure from these values should be noted and corrections made.

(1) If the opening pressure is too high (over 22 atmospheres), it is due to: (1) maladjustment, or (2) a faulty instrument, possibly a sticking valve.

(2) If the opening pressure is too low (less than 18 atmospheres), it is due to: (1) maladjustment, or (2) a faulty instrument, possibly a leaking valve.

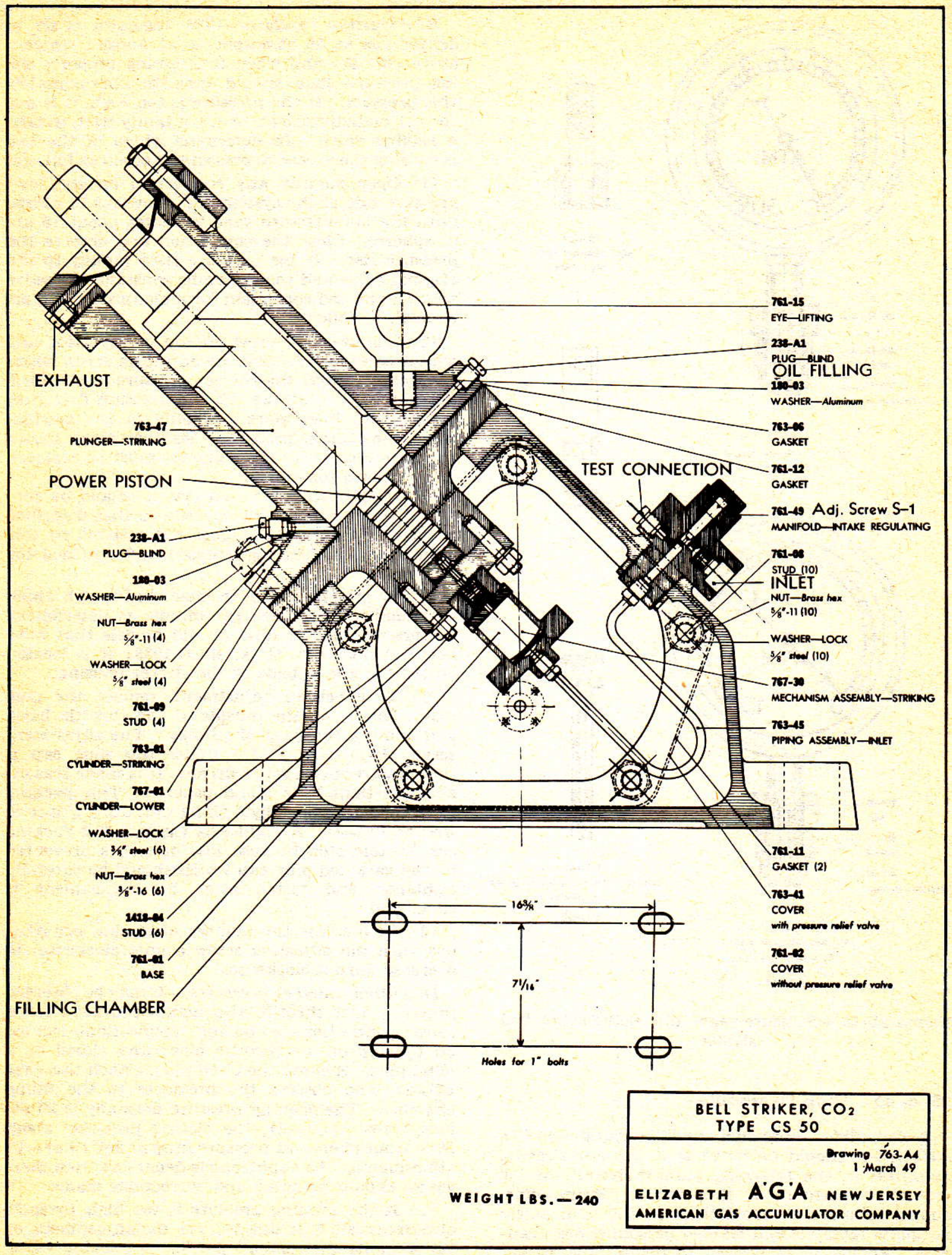
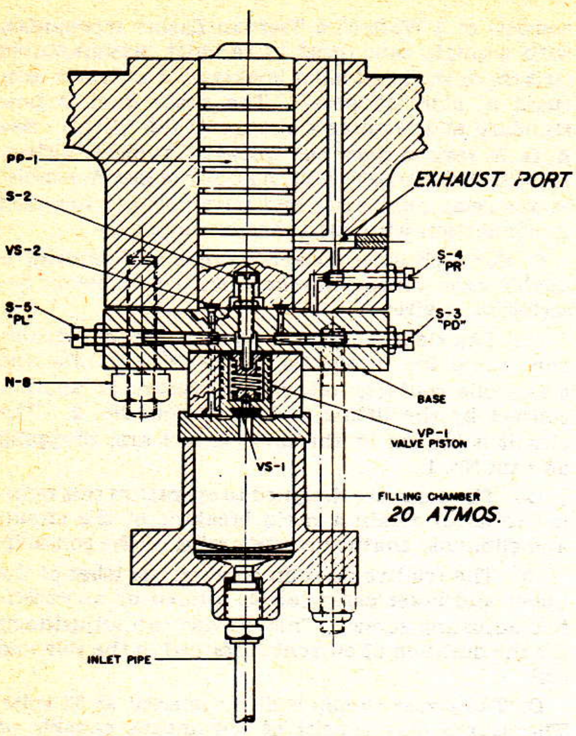


FIGURE 25–11.—Type CS–50 CO_2 bell striker.



PP–1 Power piston.
S–2 Opening pressure adjustment.
S–3 "PD" controls pressure drop.
S–4 "PR" controls rate of piston return.
S–5 "PL" releases pressure from back of inlet valve.

FIGURE 25–12.—Striking mechanism assembly—CO_2 bell striker.

(3) If the closing pressure is too high (over 17½ atmospheres), it is due to: (1) excessive opening pressure, (2) maladjustment, or (3) a faulty instrument, possibly a loose valve piston.

(4) If the closing pressure is too low (less than 15½ atmospheres), it is due to: (1) too low opening pressure, (2) maladjustment, or (3) a faulty instrument, possibly a tight valve piston.

(5) Adjustments are provided on the striker, inside the housing, for the control of the filling chamber pressures, and are located as indicated in the description of the striker.

E. *Opening pressure adjustment.*—Referring to figure 25–12, detach the striking mechanism by removing inlet pipe and the 6 retaining nuts (N–8). In removing this unit take care that the power piston (PP–1) does not fall into the base of the housing. The adjustment screw (S–2) can now be reached, and the opening pressure can be increased by turning it clockwise, or decreased by turning it counterclockwise. The combination screw driver and socket wrench (TL–2) should be used. This adjustment should be made in steps of a quarter of a turn, and after each such setting the unit must be put back in the striker and tested. This operation must be repeated until a correct pressure (approximately 20 atmospheres) is obtained.

In reassembling this mechanism, the following should be observed:

(*a*) All parts must be clean and free of dust.
(*b*) The power piston need not be lubricated.
(*c*) The valve seat washer (VS–2) should be inspected but not removed unless it is marred, in which case it should be replaced.

F. *Pressure drop adjustment.*—If the pressure drop prior to adjustment of the opening pressure was correct, and, consequently, an improper closing pressure was due to an improper opening pressure, a correction of the latter corrects the former. If the pressure drop was not correct—3½ atmospheres (+ or − 2)—the closing pressure should be adjusted as follows: Use tool (TL–2) to turn screw (S–3) clockwise to decrease the closing pressure (or counterclockwise to increase the pressure), until proper pressure drop is obtained.

NOTE: This adjustment is marked "PD" on the striking mechanism.

G. *Striking piston return adjustment.*—While making the adjustment of the closing pressure, observe the speed with which the striking piston returns after each stroke. If it appears excessive, turn the adjustment screw (S–4) clockwise, using the same special combination screw driver and socket wrench (TL–2) as is used for the other adjustments. If the return of the piston seems sluggish, the adjustment screw should be loosened. It should be observed that the return of the piston in a CS–50 type striker is faster than in a CS–250 type.

NOTE: This adjustment is marked "PR" on the striking mechanism.

H. *Back pressure relief adjustment.*—Normally this adjustment is 1½ turns open from fully closed. It is made with screw (S–5), using the same special tools mentioned above. Any adjustment of the back pressure relief will affect the pressure drop and should, therefore, if made, be followed by a check of the pressure drop adjustment.

NOTE: This adjustment is marked "PL" on the striking mechanism.

I. *Adjustment locks.*—After "opening pressure," "pressure drop," "piston return," and "pressure relief" adjustments are made, their respective lock nuts should be tightened.

J. *Mechanism failures.*—If a nonoperating condition cannot be corrected by the reestablishment of a gas supply of not less than 25 atmospheres and/or by making the adjustments heretofore described, the trouble is probably mechanical, and due to one of the following causes:

(*a*) Faulty power piston valve seat washer (VS–2)
(*b*) Sticking valve piston (VP–1)
(*c*) Faulty valve piston seat washer (VS–1)

(1) The first condition has already been discussed and can be remedied by removing the filling chamber assembly, taking out the power piston (PP–1) and replacing the valve seat washer (VS–2) with a new seat washer. (See par. (E) above.) This seat is located in a circular groove with undercut edges, and may be removed by using a penknife or other sharp instrument. When the new seat washer has been installed, make sure that it lies flat against the bottom of the groove and that the exposed surface is intact.

(2) To correct a sticking valve piston it is necessary to remove the mechanism from the striker and disassemble it by removing the three nuts on the studs which hold the filling chamber together. Handle all parts carefully; inspect washers and replace them if necessary. After the filling chamber assembly has been dismantled, check the valve piston (VP–1) for fit in its cylinder. The cylinder and the valve piston must be perfectly clean; the piston should slide freely but without noticeable play.

(3) The valve seat washer (VS–1), made from synthetic rubber, is located in a circular depression with undercut edges and can be removed readily with a penknife or other sharp instrument. When replacing this valve disk, make sure that it fits properly against the bottom of the circular depression and that the exposed surface is intact. Inspect for mechanically damaged parts. No other replacements or adjustments are necessary.

(*a*) Reassemble the mechanism in the same order in which it was disassembled, making sure that all parts are perfectly clean and that the gaskets are in good condition.

(*b*) In assembling the four longitudinal holes through the valve piston cylinder, the corresponding holes in the gasket, and the four holes in the base must be in alignment.

(*c*) The three nuts holding the assembly together must be tightened uniformly and the complete assembly tested for tightness.

25–7 ELECTRIC SOLENOID BELL STRIKER

25–7–1 General—

A. This A. G. A. type ES–50 electric solenoid bell striker is used for the same purpose as the CO_2 bell striker described in paragraph 25–6–1 (A), and is suitable for mounting both on electric buoys or fixed structures. The intensity of the signal is approximately the same as the CS–50 CO_2 striker.

25–7–5 Characteristics—

A. The electric solenoid striker may be adjusted (according to the type of flasher) to give single, multiple, or complex characteristics having a total cycle not longer than 60 seconds. The cycle is that period elapsing between any point in the sequence of strokes and recurrence of the same point.

25–7–10 Construction—

A. *The ES–50 striker* consists of the striker proper and the timer-contactor mechanism. The striker is mounted in the same frame as the CS–50 CO_2 bell striker. However, it uses a different piston which is attached to and actuated by the armature of an electric solenoid. The one moving part fits the guides loosely. Little or no wear should be encountered. (A later design pushes the piston which is not attached to the solenoid.)

B. *The timer-contactor* is housed in a weatherproof cabinet known as the control housing. This consists of a Wallace & Tiernan flasher mechanism with a single cam (used in recently manufactured strikers or modified older strikers) or a double cam (used in older strikers). The single cam is now standard and requires a change in the wiring. See A. G. A. revised drawings 1399–125, Typical Wiring; 1399, A3 Bell Striker; 1533, A3 Control Box Assembly. Power relay auxiliaries and terminals are installed in connection with the timer-contactor.

C. For such older strikers as may still be using a *double cam flashing mechanism*, the following description is given:

(1) The timing device is equipped with a double cam contactor. Cam No. 1 (fig. 25–16) lifts and closes one contact, followed by closure of another contact by the lifting motion of cam No. 2. The circuit is broken by the first contact arm dropping off cam No. 1.

(2) The cams are designed to operate in this manner so as to obtain a rapid breaking of the circuit and eliminate chattering and arcing of the contacts.

(3) The relative position between the lobes of the upper and lower cams can be altered by an eccentric adjusting screw. This provides an adjustment for the duration of current sustained in the solenoid coil.

D. *The power supply* is direct current at 32 volts. The source may consist of any means capable of delivering a peak of 40 amperes at that voltage. Primary batteries such as dry cells, copper oxide, and air cells are unsuitable. The striker will deliver approximately 1900 blows per ampere hour. Therefore, if it is adjusted for 4 blows per minute, it will operate for about 165 days on a 500-ampere-hour bank of low discharge cells.

25–7–15 Installation—

A. The electric striker may be applied to all bells up to 1,000 pounds. It is not capable of obtaining full volume from larger bells. The method of mounting is identical to that for the CS–50 CO_2 striker. The clearance between the piston head and bell is $^{25}/_{32}$ inch. Too great a clearance will result in a weakened signal. Too small a clearance will mute the signal and result in arcing at the contacts of the power relay.

B. The timer-contactor cabinet should be mounted on a vertical surface in the battery house.

C. Use not less than No. 8 gage copper wire in the connections to and from battery, timer-contactor, and solenoid. Be sure all connections are tight, as a poor connection will seriously reduce the strength of the signal.

D. For installations on buoys in particular, check for watertightness throughout.

E. Since the bell striker draws a high current for a short duration, the leads in the standard twin conductor buoy cable are paralleled for positive side and the buoy body is used for the negative return (see fig. 25–18).

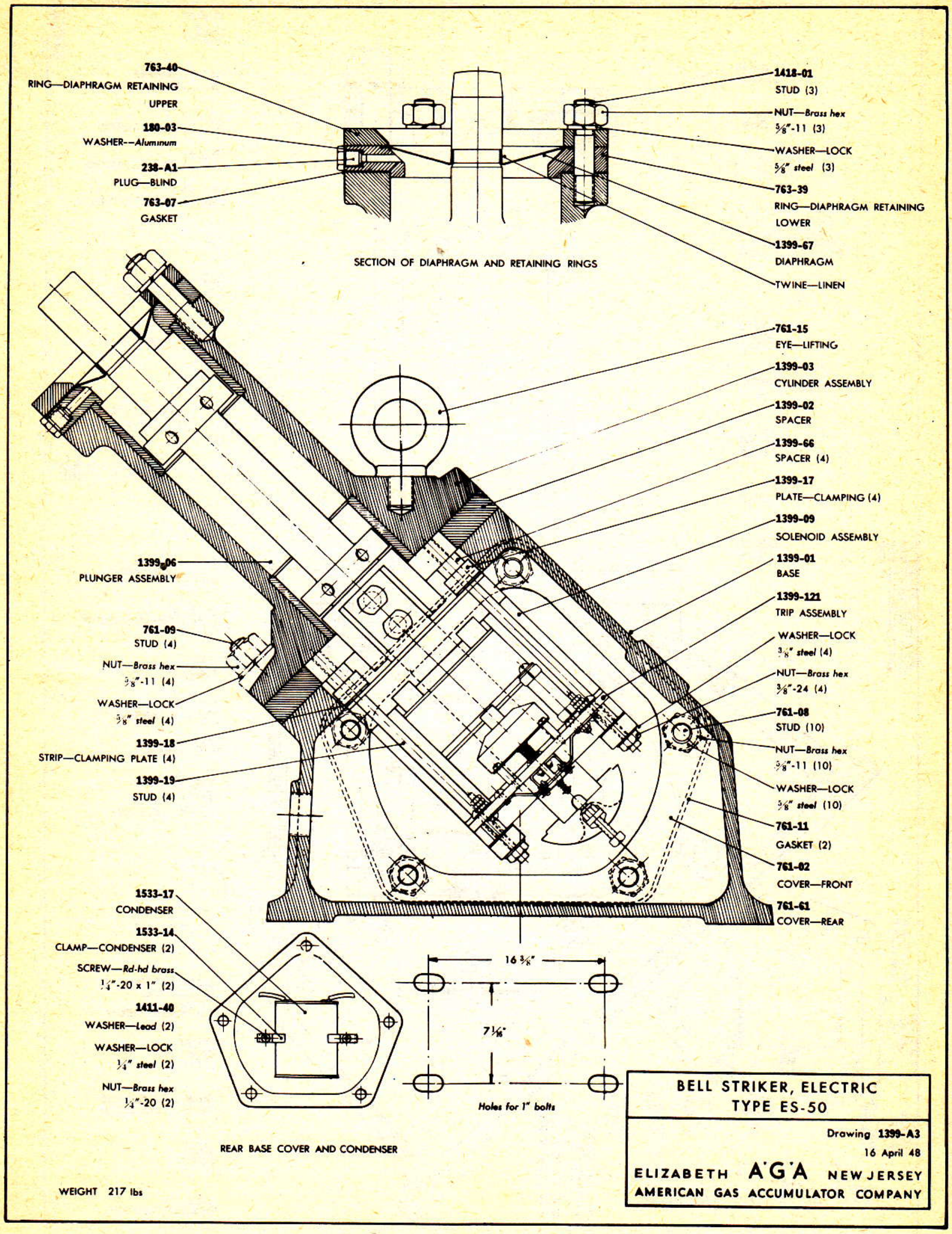


FIGURE 25–13.—Type ES–50 electric bell striker.

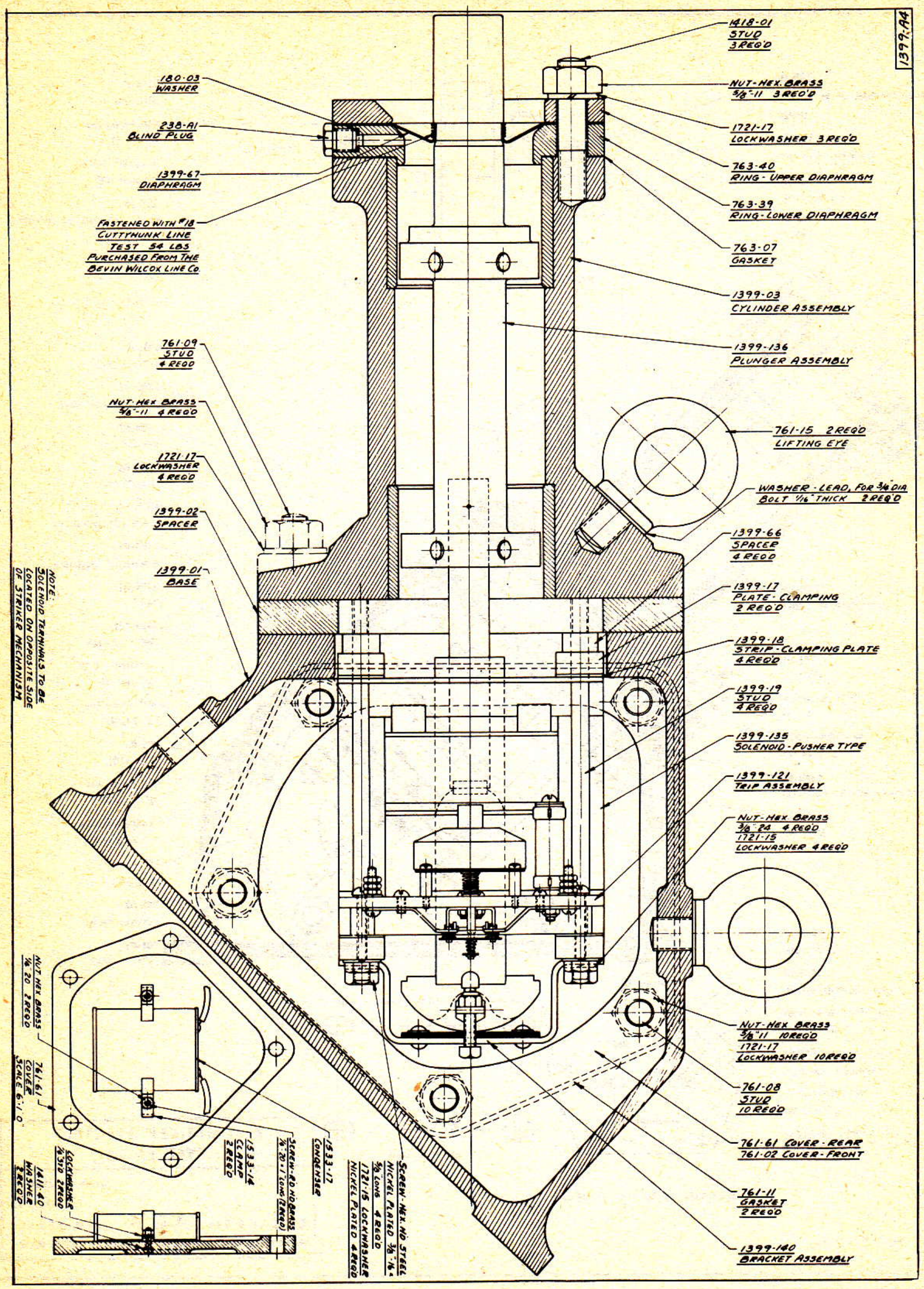


Figure 25–13A.—Modified type ES–50 electric bell striker (pusher-type solenoid).

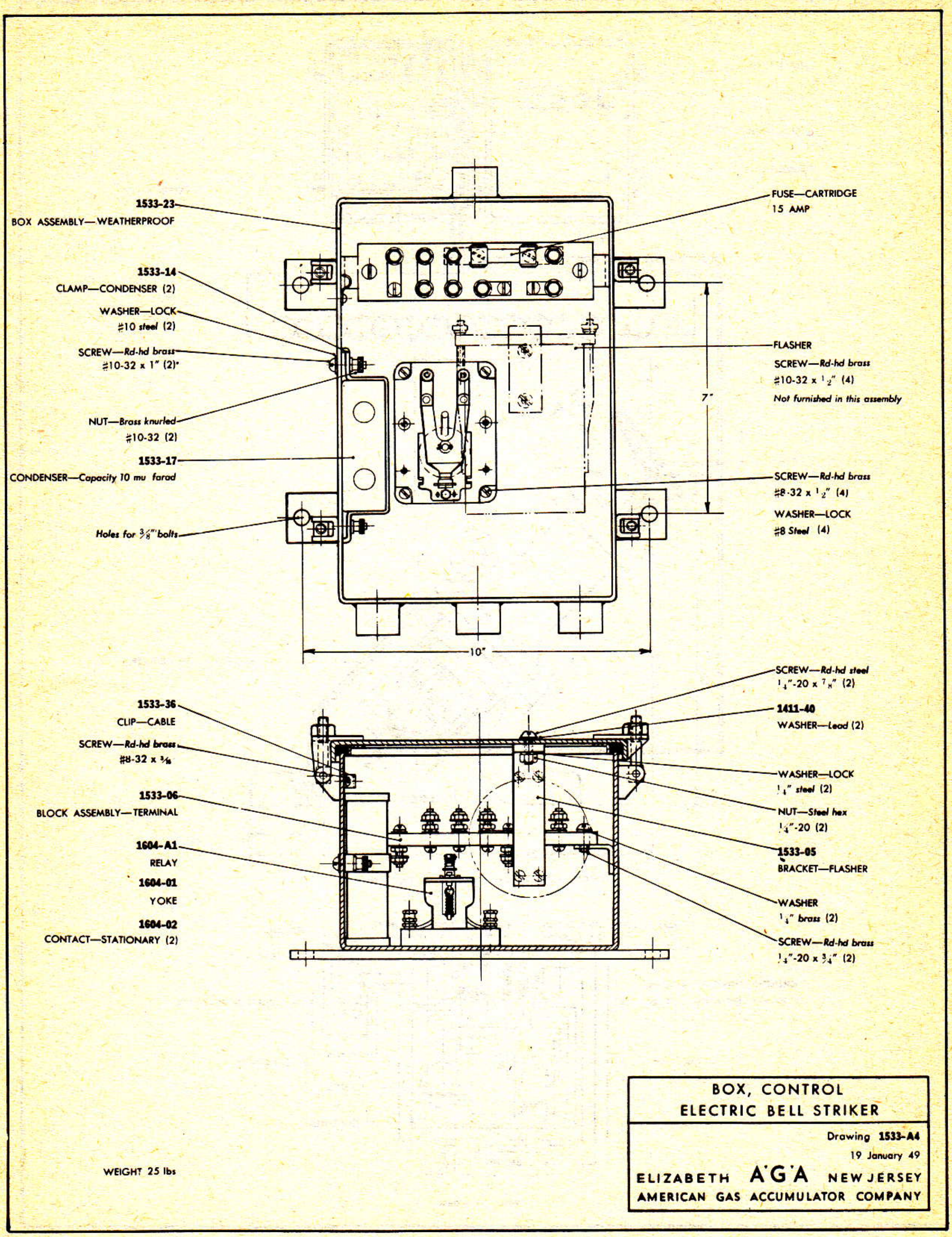


FIGURE 25–14.—Control box for electric bell striker.

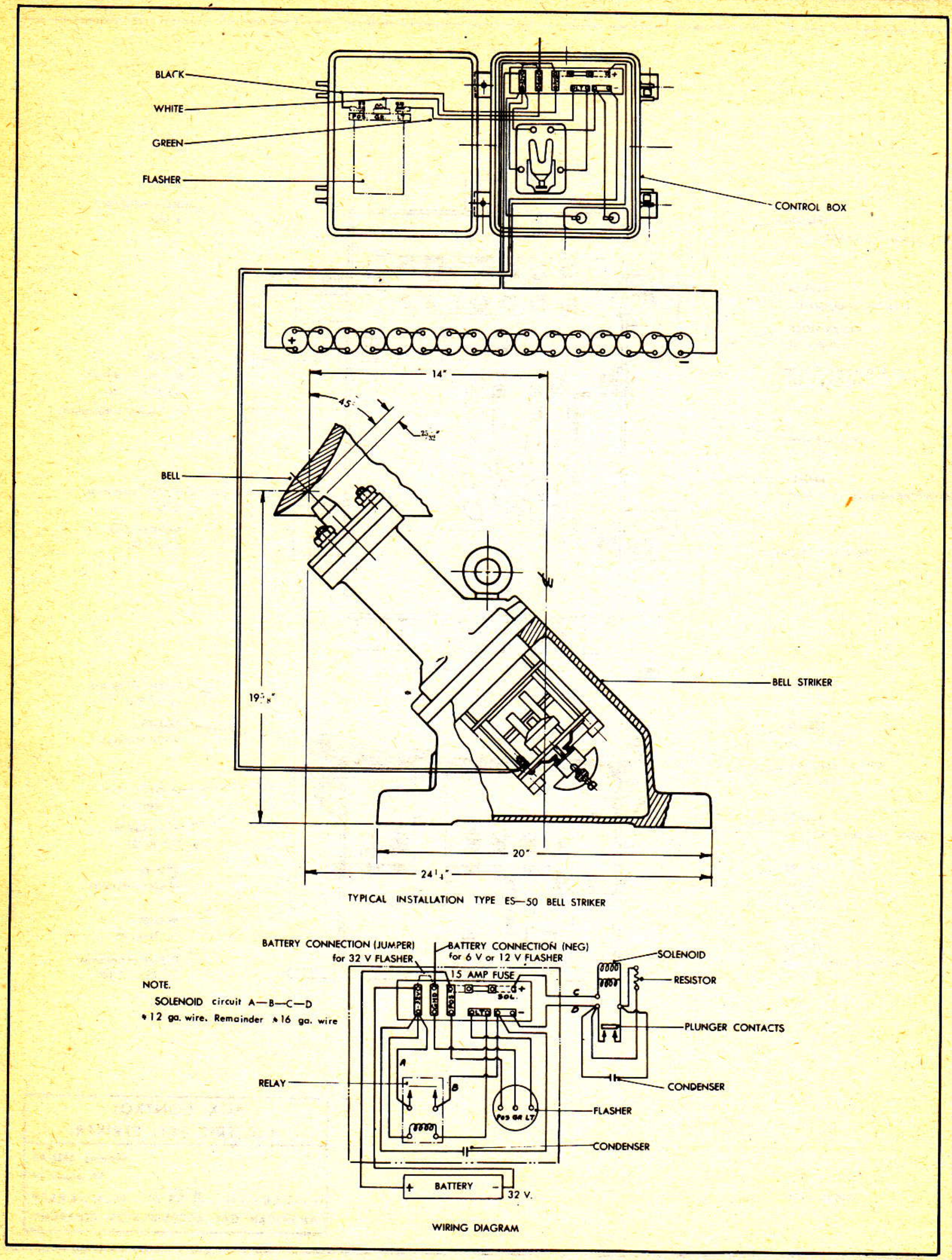


Figure 25–15.—Typical installation of ES–50 bell striker.

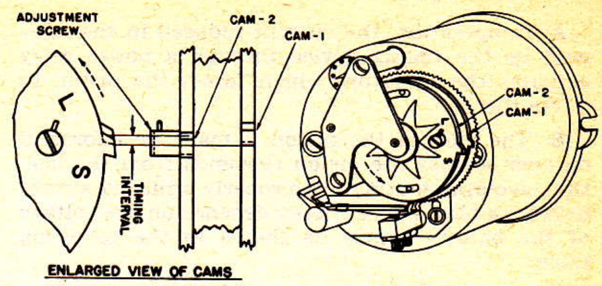


FIGURE 25–16.—Double cam-type timing device (flasher mechanism).

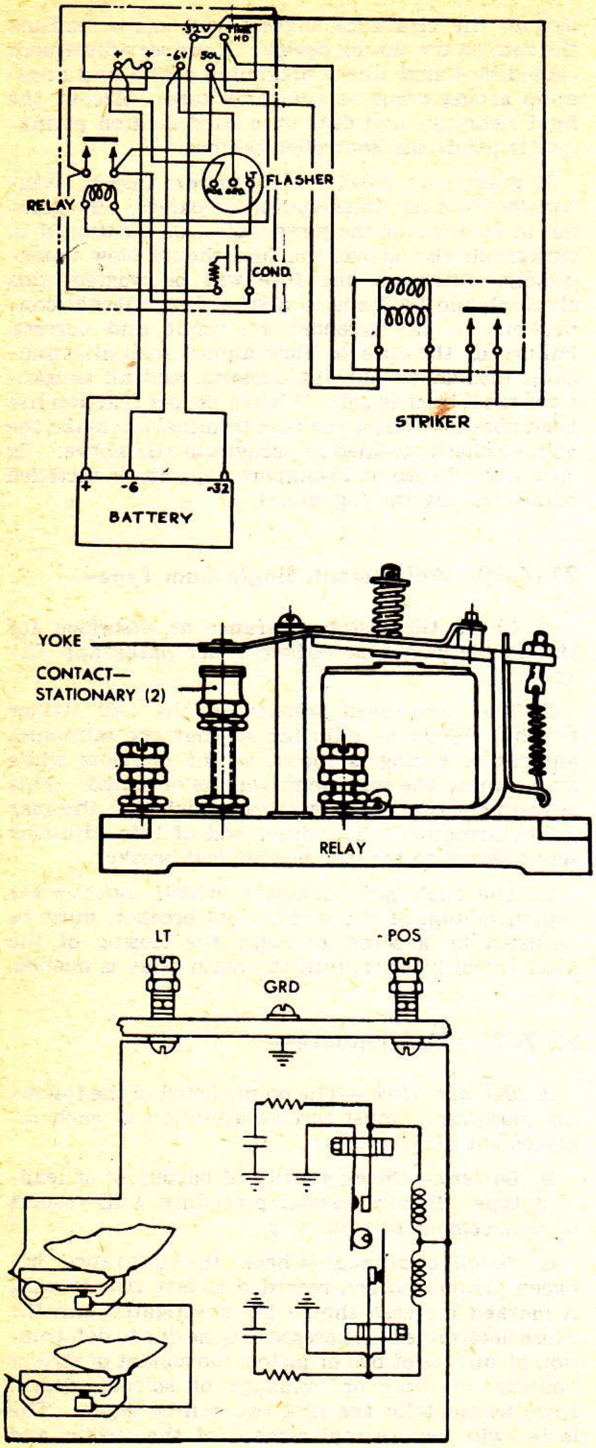


FIGURE 25–17.—Wiring diagram—double cam-type. (The relay shown above has been modified in recent designs.)

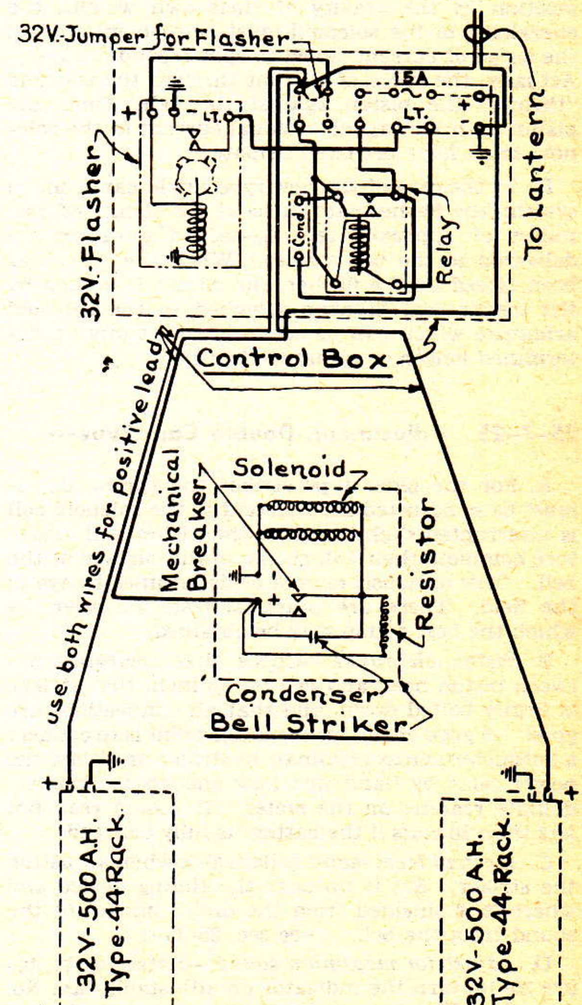


FIGURE 25–18.—Wiring diagram—single cam-type.

25–7–20 Operation—

A. In operation, the current induced in the solenoid by the timing device through a power relay actuates the armature which forces the piston to strike the bell.

B. The blow of the piston is made in a forceful manner so that the piston rebounds from the bell, thus avoiding muting. A properly adjusted striker delivers a blow whose energy depends on the voltage of the battery supply as shown in the following table:

Volts	*Foot-pounds*
24	1.5
28	2.0
32	2.7
36	3.5

C. Since the piston and armature return to rest position by the gravity of their own weight, the energizing of the solenoid must be momentary and the surge of current timed to split second accuracy. Actually, the surge of current through the solenoid "throws" the piston against the bell. Once the piston is on its way, all residual current in the solenoid must have become dissipated.

D. In the case of the new type single cam control system, the flasher cam turns at 1 r. p. m. and impulses of approximately $\frac{2}{10}$-second duration are delivered to the bell striker. When the relay has been closed by the flasher, the circuit is broken by the mechanical breaker attached to the solenoid armature which can be set to break at any predetermined length of armature travel.

25–7–25 Adjustment, Double Cam Type—

A. For the older type striker the timing device must be so adjusted that current to the solenoid coil is interrupted slightly before the piston and armature complete their full stroke to the surface of the bell. This obviously cannot be determined by eye in the field. There are practical tests, however, by which the best action may be obtained.

B. *Piston clearance.*—Check that clearance between piston head and bell is $\frac{25}{32}$ inch, that striker is firmly bolted down, and that all connections are good. A good check for the latter point is to connect a voltmeter across terminals in striker and close the power relay by hand just long enough to obtain a definite reading on the meter. It should read not less than 30 volts if the battery is fully charged.

C. A *sound level meter* is desirable when adjusting the striker. Set it up near the timing device and where it is shielded from the direct impact of the sound from the bell. (See sec. 25–17–1.)

D. *Adjust for maximum sound.*—Referring to figure 25–16, turn the indicator on adjustable cam No. 2 to "S." The power relay may operate quickly, but the stroke of the solenoid will probably be short of actually striking the bell. Gradually increase the length of contact until the sound level meter indicates maximum sound.

E. Also *observe the arc* at the power relay contacts. It should be at a minimum. If it appreciably increases as maximum sound is attained, the clearance between the piston and bell is too great. Reduce the clearance slightly and again readjust the cam on the timing device. A proper adjustment should be found where maximum sound and minimum arcing occur at the same time. Record the final clearance and date on a card secured permanently inside the controller cabinet.

F. *Make fuse check.*—A 15-ampere fuse is specified for existing timer-contactor panels. By holding in contacts of the power relay, as mentioned in paragraph (B) above, the fuse should blow immediately. Although one fuse will be wasted, this check should be made to assure that internal connections in the solenoid are tight and correct. Failure of the fuse to blow almost instantly indicates insufficient current demand, and all connections must be checked. When a proper reaction has been obtained, short the fuse terminals to make the voltage check outlined in paragraph (B) above. Be sure a good fuse of 15-ampere capacity is installed before leaving the fog signal.

25–7–30 Adjustment, Single Cam Type—

A. Check the piston clearance as described for the double cam type striker under paragraph (B) above.

B. The *mechanical breaker* in the bell striker housing should be adjusted so that the minimum amount of arcing is shown at the contacts while maintaining the maximum volume of sound. This adjustment is made by a screw attached to the rear of the armature. The other end of this adjusting screw serves to trip the mechanical breaker.

C. The *dash pot* (Agastat), which controls the return motion of the mechanical breaker, must be adjusted by a screw to delay the closing of the mechanical breaker until the main relay is opened.

25–7–35 Maintenance—

A. *Bell operative.*—The points listed in the following paragraphs must receive attention at each replacement of a battery:

B. *Battery.*—Check gravity of battery if of lead-acid type. Follow normal procedure with respect to replacement of a battery.

C. *Piston clearance.*—Check the clearance between piston and bell recorded at last visit to unit. A marked increase should be investigated and the cause determined. Increase may be due to deformation of surface of bell or piston, movement of striker housing, or wear or breakage of solenoid itself. Readjustment for the first two can be made. The latter will require replacement of the striker and shop overhaul.

D. *Replace the diaphragm* in the watertight head. The striker must be turned out from under the bell to change the diaphragm. To accomplish the replacement, proceed as outlined in paragraph 25–6–40 (G) (4).

E. *Replace striker* under bell, setting clearance to the value previously recorded.

F. *Observe the condition of the contacts* on the power relay (and mechanical breaker, if any) and replace if badly eaten away.

G. *If appreciable sparking* at power relay contacts is noted on double cam-type strikers, adjust the cam on the timing device slightly toward "S" or "L" (fig. 25–16) until the sparking is at a minimum. If sparking is noted at the mechanical breaker contacts on single cam strikers, adjust screw on armature to give a minimum. If heavy sparking occurs irrespective of adjustment, the condenser connected across the contacts of the power-relay may be defective and should be checked. (See section 25–7–40.)

H. *Caution* should be exercised in closing the door to timer-contactor cabinet in order to avoid contact between flasher casing and condenser terminal. It will be noted that the control box door hangs loosely. The door should be aligned with the face of the control box before closing.

I. *Timing device.*—The maintenance of the timing device (a modified type of flasher mechanism) is the same as for all flashers. The condition of the contacts, cam surfaces, and cam shoes on the contact arms should be noted. Any evidence of wear should be carefully examined. The adjustment specified in paragraph (G) above will automatically compensate for wear in the contactor assembly of the timing device. If excessive wear is noted, the timing device should be replaced. In any event, it should be replaced at two-year intervals to permit of routine cleaning, oiling, and adjustment.

25–7–40 Emergency Repairs, Double Cam Type—

A. *Bell inoperative.*—The points covered in section 25–7–35 also generally indicate procedures in event the bell is inoperative. The following outline is for the benefit of tender personnel or light attendant not regularly charged with the maintenance of the solenoid bell striker. It assumes a reasonable familiarity with the mechanical and electrical points involved. As points are disposed of by elimination, reference should be made to section 25–7–35 for procedures.

B. *Voltage at battery; poor connections.*—Check voltage at battery terminals in timer-contactor cabinet. If low or absent, check connections (except on buoy); also check gravity. If bad connections are located, signal should start.

C. *Timing device.*—If battery voltage is correct, note whether the timing device is operating and whether its contactor is apparently all right. Any defective part in the contactor must be replaced.

D. *Power relay.*—If the timing device is functioning properly, the next unit to receive attention is the power relay. If not operating each time the timing device contacts make and break, place a voltmeter across the coil terminals of the power relay.

E. *If a voltage impulse* is noted in step with the operation of the timing device, the power relay coil is defective and must be replaced. If no impulse is noted, the circuit between the timing device and power relay is open. Check and locate the fault.

F. *Power relay contacts.*—If the power relay also is observed to be operating, check the fuse. If not defective, examine contacts on power relay. If they apparently are all right, open striker housing (right side with striker pointing away from observer) and place voltmeter across terminals in striker. If no impulse (quick deflection of indicator on voltmeter) is observed, the fault lies in wiring between timer-contactor cabinet and striker.

G. *Fuse.*—If the fuse was blown and power relay operating, the fault may be in suppressor condenser, wiring, striker, or the fuse may have been inadequate. Replace the fuse. If striker resumes operation, be sure the fuse is tight in its clips and contact is good. Observe arcing at power relay contacts and make slight readjustment of contactor on timing device. (See par. 25–7–35 (G).)

H. *Suppressor condenser.*—If upon replacing the fuse, striker immediately strikes a single blow (without power relay operating) and the fuse again blows, the suppressor condenser connected across the contacts of the power relay is shorted and must be replaced.

I. *Defective solenoid.*—If a heavy arc now occurs at the contacts of the power relay, but the solenoid does not strike the bell, the solenoid is defective and must be repaired.

J. *Defective wiring.*—If the fuse immediately blows when the next contact occurs, the wiring to or in the striker is defective. The fault should be located and, if practicable, be removed.

K. *Spare parts.*—A spare timing device cam assembly, spare power relay contacts, spare condenser assembly, spare piston diaphragm, and two spare fuses should be kept at each fixed installation.

25–7–45 Emergency Repairs, Single Cam Type—

A. Follow the steps outlined under section 25–7–40, and in addition, check the operation of the contacts of the mechanical breaker located in the solenoid housing. If the action of the dash pot in closing the mechanical breaker permits such closure before the power relay has opened the circuit, a rapid action of the armature will result.

25–8 DIAPHONE

25–8–1 General—

A. The diaphone is an instrument using compressed air for producing sound, and is the most widely used type of air horn fog signal in the Service. It is essentially a cylindrical slide valve oscillated at high speed by an efficient self-governing air motor. The slide valve alternately opens and closes ports through which air is discharged in puffs into a resonator to produce a very distinctive sound which is familiar to all mariners. It differs from both the diaphragm horn and the siren, and might be described as an oscillating siren. It is one of the best air-operated fog signals. For identification between stations the use of other signals may be desirable, especially in the smaller sizes and higher frequencies. Diaphragm units may at times be preferable because of their directive propagation.

B. *Procurement.*—The diaphone is available on a term contract. It is ordered through the district Coast Guard office at Cleveland to facilitate inspection of apparatus. Repairs are obtained in the same manner.

C. *Sizes*—The following types of diaphones are currently in use: Types B, CC, F, F2T, and G. The type F2T unit has proven preferable to the type F due to more consistent propagation, and compares favorably with the type G for distance. Therefore, to further standardization, new installations will be confined to the CC and F2T units.

D. The *air consumption* varies with the pressure and condition of the diaphone. The average consumption for various sizes at 35 pounds gauge pressure is as follows:

Type	*Cubic feet per second*
B	2½
CC	4
F	13
F2T	15
G	24

25–8–5 Operation of Standard Diaphone—

A. Figure 25–19 shows the general arrangement of the standard diaphone, its operating valves, resonator, and fittings. The air supply to the magnetic motor and speaking valves is from a common source. The operating pressure should be 35 pounds gage. The air compressor capacity should be of ample size to permit replenishment of the air consumed by one group of blasts and permit the compressor to unload before the next group of blasts occurs. The sizes usually used are compressors having actual deliveries of not less than 18 cubic feet per minute for type B, 40 cubic feet per minute for type CC, 115 cubic feet per minute for type F or F2T, and 225 cubic feet per minute for type G.

B. The magnet valve (1) (fig. 25–19) acts as a pilot valve and is controlled by an electrically-operated code device or signal controller. When the circuit is completed by this device, air is conveyed to the piston chamber at the bottom of the motor valve. There, pressure is exerted against the piston, causing it to rise and force the valve open, allowing air to flow from (2) through (3) and (4) to the motor chamber of the diaphone. At the same time, air is forced to the piston chamber at the bottom of the speaking valve, which in turn causes its piston to lift the speaking valve and permit air to flow from (5) to (6), the speaking air chamber of the diaphone. The reciprocating slotted piston permits the air to escape in puffs through ports in the cylinder to the resonator (7) and produce the distinctive sound by which the diaphone is recognized. The grunt at the end of the blast occurs as the driving air pressure falls in the air motor chamber (4). A critical point in the pressure is reached beyond which the piston is no longer driven smoothly and vigorously by the air motor. The piston then tends to fall into step with the natural frequency of the air wave in the horn, causing the grunt. This effect occurs during the short interval between the closing of the motor valve and the speaking air valve. When the magnet valve is closed, ports are opened which release the pressure in the control pipe between it and the motor valve very rapidly. For that reason the diaphone responds quickly to the impulses given by the electric code device.

25–8–10 Installation—

A. *Clean air supply.*—If a diaphone is properly installed, very little difficulty in maintenance will be encountered. The need for a clean air supply cannot be overemphasized. Every air compressor intake should be equipped with an efficient air filter of liberal size.

B. *Piping.*—All piping used in connection with the air supply should be free from rust, scale, and flux. Any foreign matter of this nature will score the pistons and cylinders and may ruin the instrument. To insure that there is nothing in the bore of the pipes that can become loose and be carried through the system, all pipes should be vigorously hammered their entire length while being turned, and then thoroughly cleaned out with a spiral brush or swab, or be blown out with air pressure before assembly. Use air pressure to clean out all valves and fittings before placing them in the line. After pipe has been cut to length, the ends should be reamed or filed to remove any burrs or fins. After threading, thread should be cleaned with a plater's brush dipped in kerosene. A lubricant consisting of white lead in oil and graphite, in proportions of 10 pounds of lead to 1 pound of flake graphite (applied to the male thread only), will assist in preventing the generation of heat and will allow the pipe and fittings to come apart when required. Drop forge fittings and welded joints are recommended for all permanent installations.

(1) Three-eighths-inch o. d. annealed copper tubing and S. A. E. flared type fittings are recommended for the control valve piping. The length of control piping must be kept to a minimum.

(2) All piping should be arranged to drain to air receivers were condensation can be blown off periodically.

(3) The size of pipe connecting the air receivers with the diaphones should be calculated to keep pressure drop below 2 pounds gage, based on the air consumption shown in the table (sec. 25–18–50). It should be at least the same size as the speaking valve, and if the pipe is long or has several bends or elbows, it should be made one size larger.

C. *Avoid stresses in mounting.*—In mounting the diaphone, it is absolutely necessary that it be supported so that undue stresses will not occur in the casing. The resonator should be placed in position and permanently mounted so the studs on the diaphone will slide into the holes of the resonator flange without forcing when the diaphone is resting on flange of elbow. Instances have been known where it was impossible to remove the piston from the cylinder due to the stresses imposed on the casing because the lugs of the resonator were mounted on a slightly uneven bearing and bolts were drawn up after the diaphone had been permanently installed.

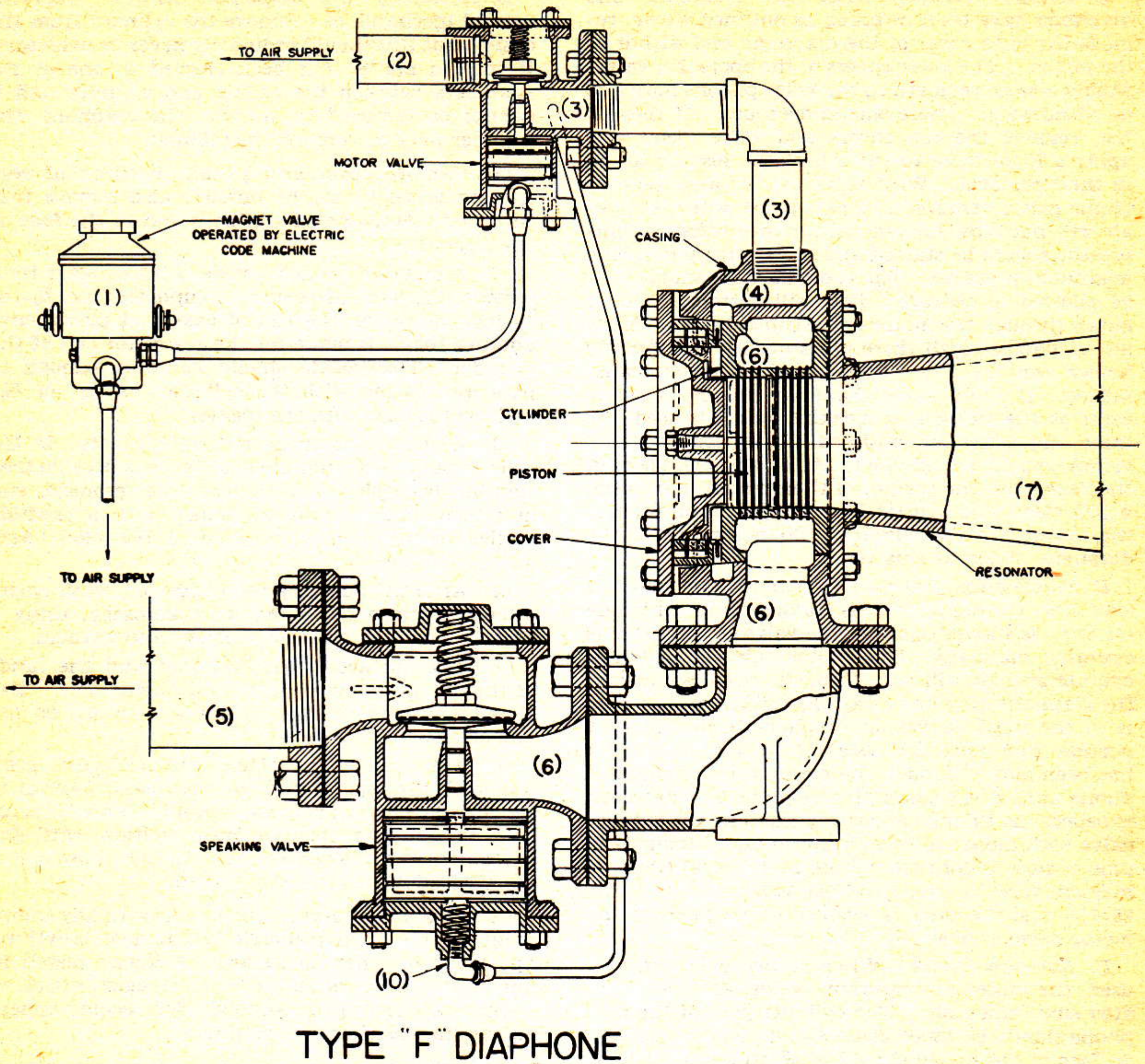


FIGURE 25–19.—Type F diaphone.

D. *Remove pistons.*—After the resonator and diaphone have been installed as outlined above, remove the back cover of the diaphone and withdraw the piston. The lower covers of the operating valves should also be removed so the valve pistons may also be withdrawn. These should drop out. If they do not, remove the top covers and valve stems and apply a little force to the top of the pistons to aid in their removal. With valve pistons and the diaphone piston removed to a safe place, where rush of air will not blow foreign matter into them, a compressor should be started and the system pumped to maximum pressure. The code machine should now be allowed to operate. This will permit air to be blown through the motor-valve control pipes. Allow air to blow through these pipes until it is definitely known that nothing but clean air is being transmitted. If a two-tone diaphone having separate cams on the motor and speaking valves is used, the same procedure as outlined above for speaking valves should be followed. After the cylinders of the valves and the surface of their pistons have been wiped clean and a little light oil has been applied, the valves are reassembled. Do not reinstall the diaphone piston at this time.

E. *Single-cam timer.*—If a single-cam timer is used, only the motor valve is reassembled. The code machine is started again or the valve of the timer is operated manually. The motor valve should now operate and air will rush from the open cylinder of the diaphone, carrying away any foreign matter that is in the pipes, valves, or diaphone except in that portion supplying the speaking valves. After air has been blown through the motor valve of the diaphone until it is certain all foreign matter has been expelled, the tubing connecting the timer or magnet valve with motor valve is removed and a temporary pipe or hose is connected from mechanical timer or magnet valve to the speaking valve at (10), (fig. 25–19), and the same procedure as outlined for the motor valve is repeated.

F. *Two-cam timer.*—When a two-cam timer is used, the motor and speaking valves may be operated simultaneously. The cylinder bore of the diaphone should be wiped clean and its surface and the surface of the piston should be given a coat of light oil, the piston and cover should be replaced, and all tubing connected as required for the permanent installation.

25–8–15 Maintenance—

A. *Replacing leather disk.*—If the installation for the diaphone was carefully performed, and the filters on the intakes of the compressors are kept in efficient condition, it should not be necessary to dismantle any part of the diaphone installation except for the replacement of a worn leather valve disk.

To replace a leather disk on a valve stem, grip the lower valve stem between fiber or lead jaws in a vise, remove the lock nut, the cap, which is threaded, and the old leather disk. In an emergency any suitable leather may be used, but best results will be obtained by using leather disks made especially for this purpose. Place leather on stem with smooth side down, replace the cap, screwing it down firmly on the leather by hand, and then replace the lock nut.

B. *Removing the diaphone cylinder liner.*—A careful mechanic can remove the cylinder from the casing, but this should ordinarily never be necessary. If foreign matter has been carried to one of the chambers between the casing and cylinder and it cannot be removed by shaking the diaphone, the cylinder may be removed as follows:

(1) Remove cover and piston (position of registering mark should be noted); also remove four threaded dowels which will be found in the face of the diaphone.

(2) A metal or wooden toggle, a little longer than outside diameter of casing, is supported on ⅜- or ½-inch blocks on the rim of casing at piston end; another toggle is made for the resonator end of the cylinder. This toggle should be short enough to pass into casing with the cylinder. A ¾- or ⅝-inch bolt is used with the toggles.

(3) A strain should be put on the bolt. If the cylinder liner does not move after considerable tension has been placed on the bolt, the resonator end of the cylinder should be tapped with a rawhide mallet, or toggle may be struck a few blows with a lead hammer.

(4) After cylinder has been removed, wash entire interior surface of casing with kerosene, using a plater's brush to get into recesses and corners.

(5) The surface of the cylinder and the lands of the casing should be wiped with a chamois. The chamois is used so that no lint will be left on the lapped lands.

(6) The cylinder is replaced, putting it into position with the toggles and the bolt, being careful to set registering marks in line. Apply sufficient pressure to pull the cylinder into position until the threads in the dowel holes are fair, and dowels will start without crossing the threads.

C. *Avoid unnecessary repairs.*—As with any equipment, it is a good principle not to take anything apart except when necessary. A sticky piston in one of the valves is indicated by sluggish action of signal. A worn piston and cylinder become apparent by increased air consumption.

• D. *Installation of spare piston.*—If for any reason it is necessary to use a spare piston, the piston should be allowed to stand near the open diaphone for several minutes to equalize temperatures. Frequently, spare pistons are stored in a warm place and are several degrees warmer than the cylinder. On the other hand, if the spare piston is colder than the cylinder liner, it may be too tight when the temperatures equalize. Use only spare pistons initially purchased with the particular diaphone unit. *If the piston is forced into the cylinder before the temperatures are equalized, both the piston and the cylinder surfaces may be scored.*

E. *Safety valves.*—The safety valves are set to pop at the proper pressure (usually 45 pounds). The unloaders on the compressors are set to operate at 35 to 40 pounds. If the high- and low-pressure receivers are used, the reducing valve is set to the pressure at which it is desired to operate the diaphones (approximately 35 pounds). The safety valve on the low-pressure receiver or receivers is set

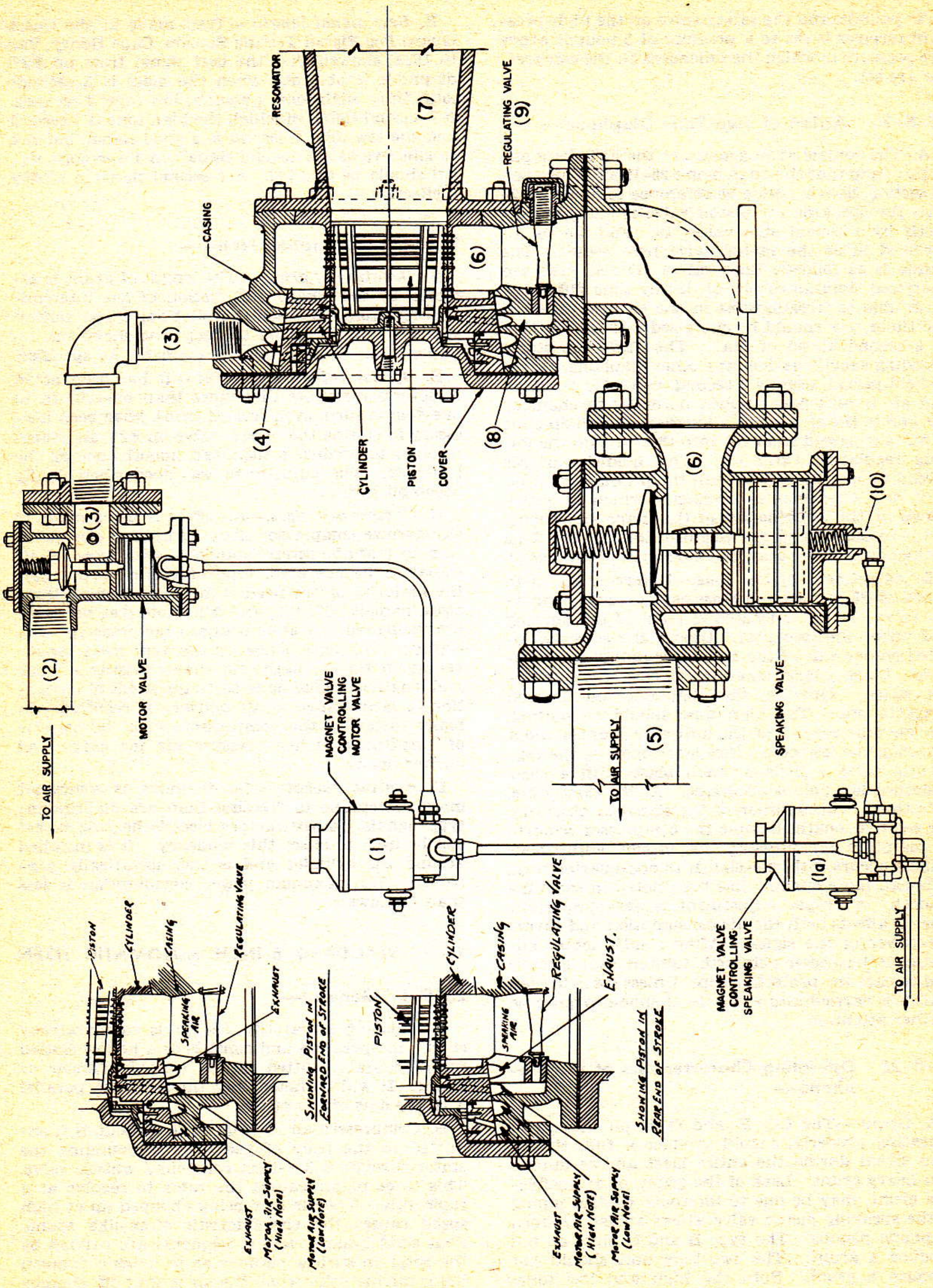


FIGURE 25–20.—Type F2T diaphone.

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to 40 pounds, and the safety valve on the high-pressure receiver is set to a pressure of 5 pounds above the pressure to which the unloaders on the compressor are set.

25–8–20 Action of Two-Tone Diaphone—

A. The control arrangement of the F2T diaphone differs from that shown in figure 25–19 and described in section 25–8–5. Note by reference to figure 25–20 that the speaking air piston valve is energized directly by a second pilot valve (1a), and not by air received after the motor valve has opened. The action is as follows: Both valves (1) and (1a) are energized simultaneously, or, if any time difference exists due to irregularities in the electric cams on the timer, (1) should be energized a small fraction of a second ahead of (1a). The F2T then starts sounding exactly as does any other diaphone. After a short period, usually 1 second, valve (1) is closed and air is no longer applied normally to chamber (4) and to the air motor. However, a small amount of air is bypassed from (6) into (8) through the low tone regulating valve (9). This quantity of air should be just enough to keep the piston oscillating at a new fundamental frequency which is determined by the combination of the shape and length of the resonator and the weight of the piston. This frequency is lower than the normal or "high tone."

B. *Adjustment of low tone.*—Referring again to figure 25–20, remove the brass cap covering regulating valve (9). It is located in front of the housing and under the resonator. Loosen the setscrew located on one side of the boss surrounding the regulator. Using a large screwdriver, close the regulating valve. Operate the diaphone on normal characteristic. The high tone should be normal, the low tone ragged, or the unit may grunt without sounding the low note. Now start opening the regulating valve a little at each blast until a clear sustained low note is occurring. At the same time, note the air consumption of the signal by observing the relative lengths of time the compressor requires to maintain air pressure. A proper adjustment usually occurs with one-eighth to one-quarter turn, although more opening has been noted in some instances. A proper adjustment is very important since it affects both the air consumption and carrying-power of the signal. After a satisfactory adjustment has been obtained, tighten the setscrew and replace the protective cap. Unless some foreign matter is carried into valve (9) it should require no further attention.

25–8–25 Operating Characteristics of the Diaphone—

A. *Grunt.*—The CC, F, and G diaphones, when operating properly, should produce a full, strong, even signal during the entire blast and terminate in a heavy grunt. Lack of the grunt, or an ineffective grunt, may be due to improper control piping to the speaking piston valve, sticky valves, or worn diaphone pistons. The type B and C units do not produce a grunt. The two-tone unit should not produce a grunt. Both the high and low tones should be full and steady.

B. *Best signal length.*—Tests made at the Coast Guard Fog Signal Testing Station, Cape Henry, Va., in 1934, showed that the best signal from an F2T diaphone is obtained when the blast is 3 seconds long, thus: high tone, 1 second; low tone, 2 seconds. A 2-second signal of which the high tone is 1 second and the low tone 1 second is a good signal, but not as effective as a 3-second signal. A 1½-second signal should be avoided. A 1-second signal is wholly ineffective.

25–8–30 Operating Notes—

A. *Duration of grunt.*—The length of grunt is affected by the length and section of the interconnecting tubing between the pilot valve and control valves. It is desirable to keep this short and no larger than ⅜-inch outside diameter as specified.

B. *Bypass valve adjustment.*—It has been noted in several instances that more than one-eighth to one-fourth turn, even several turns, have been necessary in setting the bypass valve on F2T diaphones in order to produce a sustained smooth tone on the low note. The adjustment was good when finally accomplished.

C. *Compressor sizes.*—An effort is being made to standardize compressor sizes. With due consideration to manufacturers, standard sizes, type of air signal to be operated, type of prime mover, etc., the majority of our needs can be satisfied by three sizes, namely; 50, 125, and 210 cubic feet per minute (delivered air) at 40 pounds gage pressure. Exceptions will arise, since by the very need for diversity in the strength and characteristics of tone and length of sounding to serve the needs of navigation, a large range in air delivery is required. In many instances the compressors must be capable of furnishing higher pressure air for cargo and anchor hoists.

D. *Heating jacket.*—The diaphone is somewhat more susceptible to freezing than are diaphragm-type signals. A satisfactory electric heating jacket can be used to offset this tendency. It is installed around the cylinder and is thermostatically controlled. Its maximum power consumption is less than 1 kilowatt.

25–9 STANDARD 6-INCH AUTOMATIC SIREN

25–9–1 General—

A. This fog signal (fig. 25–21) is comparatively simple in operation and consists of a hollow slotted rotor accurately fitted into a slotted cylinder or stator. It will be noted that the slots run parallel with the axis of the piston.

B. Compressed air of from 35 to 60 pounds is admitted to the body of the siren surrounding the stator through a 3½-inch compound whistle valve. This force of air causes the rotor to revolve at a rapid rate. The air flow being chopped up at high speed causes the characteristic siren-like sound. Four solid brass governor segments are carried by the rotor in such a manner as to quickly dampen the revolving rotor when the air is shut off, thereby preventing a lingering tone.

C. The 6-inch siren consumes from 13 to 18 cubic feet of free air per second and has a normal average weather range of 4 miles.

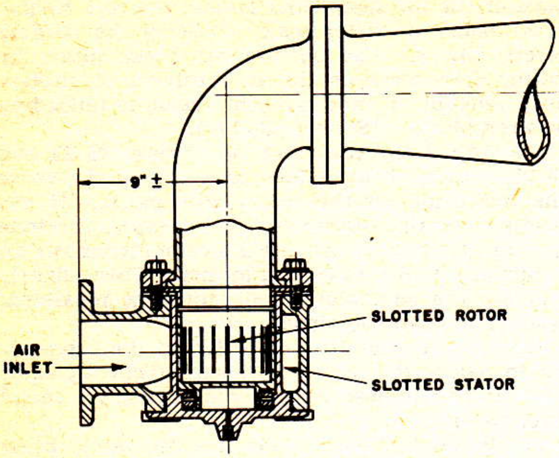


FIGURE 25–21.—Standard 6-inch automatic siren.

25–9–5 Replacement—

A. Existing units will be continued in service until they are worn out or until the needs of navigation can be served more efficiently by other types of signals. Their replacement will also receive consideration if portions of the associated machinery necessary to their operation require replacement. When submitting work authorization requests for replacement of fog signal machinery used with the air siren, develop that fact in the work authorization request.

25–9–10 Installation and Maintenance—

A. No particular instructions are required as to the installation or maintenance of this unit, other than at the time of initial installation, the moving parts of the compound valve, rotor, and stator should be removed from their bodies, the pipes hammered to loosen dirt and scale, and the system thoroughly blown out. The valve, stator, and rotor parts are then installed, care being exercised in bolting up so as to prevent any undue strain or distortion of the unit.

B. Repair parts for existing units may be requisitioned from the Coast Guard Supply Depot, Jersey City.

25–10 DIAPHRAGM HORNS

25–10–1 General—

A. Two general designs of air-operated diaphragm horns are in use in the Coast Guard: Those in which the air is admitted to the center of the vibrating diaphragm (fig. 25–22), and those in which the air is admitted to the periphery of the diaphragm and passes to the horn (resonator) from the center of the diaphragm (fig. 25–23).

25–10–5 Installation—

A. The installation procedure is the same as for the diaphone. (See section 25–8–10.) After the diaphragm fog signal installation is complete, remove the diaphragms from the units and blow out all lines thoroughly. Replace diaphragms and screw down retaining ring or cover. (NOTE.—Tyfon diaphragms are dished. Insert with convex side toward the horn.) Screw down retaining ring until just snug, then slacken back one or two notches, drop retaining pawl, lock into position, and secure with screws or split cotters. The retaining ring must not be drawn tight or it will interfere with free motion of the diaphragms. Whether the retaining ring should be backed off one or two or even three notches from the tight position may be determined by moving it while the unit is sounding. Set the ring as tight as possible without interfering with free motion of the diaphragms.

25–10–10 Design Features Affecting Adjustment—

A. There are a few design features of diaphragm-type fog signals which should be understood to facilitate their proper adjustment.

B. Every air diaphragm horn is equipped with an inlet orifice, either adjustable, as shown at (*a*) in figures 25–22 and 25–23, or fixed. Without this restricting orifice the diaphragm might not oscillate but might stretch open and allow the escape of air from the diaphragm chamber, (*b*), without vibration.

C. The gage pressure in the diaphragm chamber (*b*) for maximum vibration of the diaphragms normally used in fog signal units is about 10 pounds. This is the pressure which should be indicated by a gage attached to the chamber. The indicated pressure is only an average pressure, however, since it is actually varying from a low value at the time when the diaphragm is stretched away from the throat of the resonator to a high value just before the diaphragm leaves the surface of the throat on the next vibration. The actual pressure may vary from 0 to 20 pounds gage. In order for such a

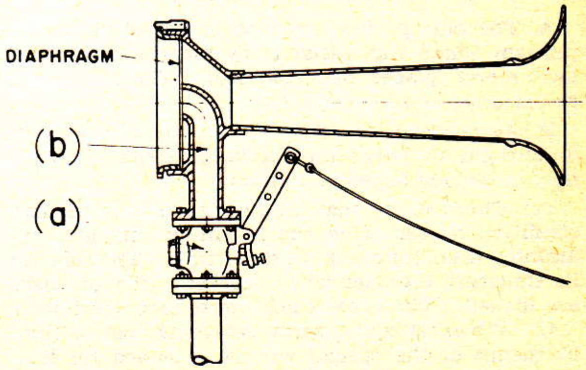


FIGURE 25–22.—Air-operated tyfon.

vibratory condition to exist, air flow to the diaphragm chamber must be restricted. Irrespective of the pressure in the air receivers, the pressure in the diaphragm chamber (*b*), figures 25–22 and 25–23, should be about 10 pounds gage (depending on the number of diaphragm leaves and their tension). Too little air (by closing the needle valve in the orifice or throttling the control valve) results in diminished vibration of the diaphragm and reduced signal strength. Too great a volume of air dampens maximum vibration and results in excess consumption of air and even in loss of quality of signal without any proportionate gain in over-all signal strength.

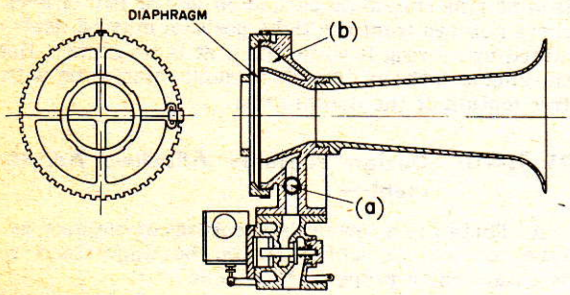


FIGURE 25–23.—Cunningham horn.

D. Diaphragm horns are operated by mechanically-operated valves as shown in figure 25–22 or electrically-operated solenoid valves as shown in figure 25–23.

E. Repeated tests have shown that diaphragm sound fog signals may be operated on receiver pressures ranging from about 25 pounds gage to 40 pounds gage, with full volume of sound, by proper adjustment of the orifice needle valve (*a*). Earlier diaphragm units were furnished to give maximum signal on the pressure specified by the ex-Lighthouse Service. The manufacturer supplied the unit with an orifice which admitted the correct quantity of air at the maximum pressure specified. In such a unit, reduced signal intensity occurs as the pressure is reduced.

25–10–15 Adjustment Procedure—

A. The only positive method of adjusting a diaphragm sound fog signal is by means of a sound level meter, placed near the unit. The meter will be discussed in section 25–17–1.

B. *Adjustment of single horns.*—Adjustment of diaphragm air horns for maximum signal strength may be accomplished as follows:

(1) Check to see that all diaphragms are in good condition by removing the retaining ring and examining them for cracks or distortion. They should lie smoothly together when stacked. (Tyfon disks are dished. The convex side must face the horn.)

(2) When replacing, screw retaining ring up tight by means of the special wrench provided for that purpose (or by hand if no wrench is provided) without exerting undue stress. Then back away until the locking pawl falls into the first or second notch and secure the pawl. (See sec. 25–10–5.)

(3) Start signal on regular schedule.

(4) Place sound level meter in rear of signal at a point where its reading is undisturbed by machinery noises. Carefully obtain a reading during the blast of the fog signal that is near the zero decibel (DB) point on meter scale. Observe the reading several times. Also observe air consumption by noting draw-down on the air receivers, or, preferably, amount of time air compressor is unloading between blasts. (See sec. 25–17–1.)

(5) Adjust throttle valve (*a*), figures 25–22 and 25–23, closing off air a little at a time and observe the indication on the sound level meter. If the reading remains stationary or increases, continue the throttling until the sound level meter shows an unmistakable decrease in intensity. Then slightly increase the admission of air until the maximum reading is again obtained.

(6) Now readjust the unloader on the compressor to reduce the receiver pressure about 5 pounds gage, and again observe the indication on the sound level meter.

(7) When the sound level has decreased, bring the volume of sound back to maximum again by gradually opening throttle valve (*a*) on the horn.

(8) Repeat the procedure outlined in (6) and (7) above until throttle valve (*a*) is open full or until further readjustments result in loss of signal strength.

(9) Adherence to the foregoing should result in either marked improvement of the signal or reduction of pressure on the system, with the same signal strength. Frequently, both improved operation and reduction of pressure occur, accompanied by reduction of load on the motor or engine and improvement in volumetric efficiency of the compressor.

C. *When no sound meter is available.*—In the absence of a sound level meter, careful adjustment by ear for an adequate sound emission, coupled with economic air consumption is all that can be done. Adjust throttle valve (*a*), figures 25–22 and 25–23, until full round tone is had, and at the same time observe air consumption draw-down in the air receiver or the amount of time air compressor is operating between blasts. The draw-down or pressure drop in a proper installation should not exceed 2 pounds gage pressure in the receiver, or the compressor should be unloaded at least 25 percent of the time.

D. *Adjustment of multiple horns.*—The foregoing instructions are applicable to all single units. The adjustment of duplex and triplex units is somewhat more complex but not at all difficult.

(1) Check all diaphragms and start signal as outlined in Paragraph (B) (1), (2), (3), and (4) above.

(2) Next carry out instruction (B) (5) above on each of the units of the multiple signal, one at a time. That is, adjust a wing horn until no improvement is noted, then the other wing horn and, finally, the center horn. There is both air and sound interaction between the separate units. For that reason a final trimming adjustment will be necessary back and forth between the individual units after final downward readjustment of receiver air pressure has been made, as outlined in paragraph (B) (6), (7), and (8) above.

25–11 REED HORNS

25–11–1 General—

A. Reed horns, while still in use in several more or less minor locations, are considered obsolete. They are low pressure devices operating at under 10 pounds pressure. Air is supplied by a blower rather than a compressor. A steel reed averaging 14 inches in length, 4 inches wide, 1 inch thick, tapering to about 3/16 inch, is firmly clamped by three set screws over a distance of about 4 inches at the thick end, the balance of the length, being suspended over a channel, is subjected to air pressure on the thin end. The action is similar to that of a reed musical instrument and the sound produced is of fairly low frequency and of good quality. The reed and hollow channel are housed in a cast iron housing.

B. Whenever existing units no longer serve needs of navigation, or repairs are not practicable, work authorization requests shall be submitted for their replacement.

25–12 AIR SUPPLY

25–12–1 Source—

A. The source of air supply for all air-operated sound fog signals consists of duplicate compressors, air storage, and necessary piping. Suggestions for installation of the piping immediately associated with the signal unit are contained in paragraph 25–8–10 (B).

(1) *Pressure.*—Although air pressures as high as 70 pounds are used on some older fog signals, no such installations have been made recently.

(2) *The standard pressure* for air fog signals is stated under the description of each type.

25–12–5 Air Storage—

A. With the exception of minor fog signal installations in which space is limited, sufficient air receiver capacity shall be installed to limit the pressure drop (draw-down) caused by a 6-second blast to 5 pounds (one-third atmosphere). The specific condition consists of a distance-finding synchronized signal of 1-second blast, 1-second silent period, and a 5-second blast.

B. *Computing capacity.*—For example: What is the required capacity of the air receiver when a fog signal requires 15 cubic feet of free air per second and the compressor has a delivery of 125 cubic feet per minute of free air?

(1) Total air required for the blast: $15 \times 6 = 90$ cubic feet. The compressor pumps $125 \div 60$ or about 2 cubic feet per second. The time interval is 7 seconds. The compressor will supply 2×7 or 14 cubic feet during this interval. Net air required from receiver equals $90 - 14$ or 76 cubic feet. Drop is 5 pounds or one-third atmosphere. The receiver should have a capacity of $76 \div 1/3$ or 228 cubic feet.

(2) This may be supplied by any combination of tanks desired, provided all tanks are piped to supply air simultaneously. The air storage discussed above is based on direct connection to the air signal without the use of high and low pressure receivers and reducing valves. Several such installations are in use. They will not be duplicated by reasons of economy.

C. *Standards.*—All air receivers used with air-operated fog signals shall conform to the standards of the Compressed Air Institute for materials, test, and protective devices.

D. *Connection in tandem.*—Numerous shore air fog signal installations have been made in which the air receivers were connected in tandem, probably for the purpose of cooling the air and removing moisture. This is bad practice, and such installations shall be modified as soon as practicable.

E. *Pressure drop.*—Excessive pressure drop at the signal results in undesirable loss of signal strength and change of tone. It is caused by long lines, excessive use of pipe fittings, and inadequate air storage. Air receivers should be located as near the signal unit as design conditions will permit. Design pressure drop between the signal unit and the receiver should not exceed 2 pounds gage. Pipelines between the compressors and receivers may be of any necessary length since the friction loss is much less than between the signal unit and receivers.

25–12–10 Compressors—

A. *Type.*—Air compressors for fog signals are standard single-stage units operating at 40 pounds gage pressure. Compressor capacity should be such that the compressor will unload at least 25 percent of the time when the fog signal is operating. This practice compensates for wear in compressor and signal unit.

B. Semiportable, single-stage, multicylinder, air-cooled compressors designed for continuous duty service and capable of delivering not less than the number of cubic feet of free air listed in the table below at a maximum piston speed of 725 feet per minute, when operating at not more than 900 revolutions per minute, are furnished in identical duplicates for installation on each station.

C. Horsepower requirements for air compressors are shown in the following table.

Cubic feet per minute free air	Single-stage units (40 pounds gage)	
	Electric motor (horsepower)	Engine (horsepower)
18	3	5
30	5	7.5
45	7.5	10
60	10	15
85	15	20
125	20	30
145	25	30

NOTE.—Variations between motor and engine horsepower ratings are due to continuous duty characteristics of each.

D. *Procurement.*—Consolidated purchases of air compressors will be made during the second quarter of each fiscal year. Submit in letter form not later than September 15 of each year a list of the equipment, giving in each instance the station for which the equipment is intended, the exact performance specifications governing each case, and shipping instructions. Funds will be withdrawn from the district in the second quarter for the consolidated purchase of the equipment.

25–13 CODING DEVICES

25–13–1 General—

A. *Two general types* of coding (characteristic) devices are in use. The first is an electrical system containing a code machine, and the other is a mechanical pneumatic arrangement known as the Crosby Characteristic Regulator. The latter is generally found as a standby coding apparatus, although a few installations may use it as the primary means of coding the fog signal. It is considered obsolete and no new installations will be made.

B. *Two other types* of coding devices are described in sections 25–13–10 and 25–13–15.

25–13–5 Electric Coding Machine—

A. The electric coding machine consists of a motor driven cam device which operates magnetic control valves in the main air line. If not provided in duplicate, manual or mechanical standby arrangements are provided to open and close the magnetic valves in case any part of the electric system should fail.

(1) The code machine may consist of an electrical motor driving a train of reduction gears in a tight housing and running in a bath of light lubricating oil. This train of gears reduces the speed of the motor and drives a shaft, protruding from the other side of the gear housing, on which is a characteristic cam. Contacts make and break as this cam rotates, furnishing the characteristic timing to the magnetic valves, as mentioned above, or to a solenoid valve.

(2) This code machine may also be used for timing main lights.

25–13–10 Control System for Diaphones—

A. The control system for the diaphones differs from other air-operated controllers in that the main air valves must be considered as an integral part of the diaphone assembly. Either a small mechanically- or electrically-operated pilot valve is required. Earlier diaphone control installations consisted of a mechanical cam-operated valve driven through a belt by a small air motor or direct by belt from the air compressor or engine. Since the introduction of distance finding by means of the combination of sound and radio aids, small electric pilot valves have been introduced. These are actuated by cam contacts of the radiobeacon timer.

25–13–15 W. & T. and Other Commercial Flashers—

A. Wallace and Tiernan heavy-duty flashers are frequently used as timing devices on fog signals, the method of operation being basically as described under section 25–13–5.

B. Where commercial power is available, commercial-type sign flashers are frequently used in the same manner.

25–13–20 Crosby Characteristic Regulator—

A. The Crosby Characteristic Regulator (see fig. 25–24) is a mechanical pneumatically-operated control mechanism. It consists fundamentally of a cylinder and air or steam operated piston, a governor-controlled clock mechanism, a characteristic valve, and necessary rods, linkages, and valves. It is connected directly into the main air line. The piston performs two functions; it rewinds a clock escapement, and it actuates a cord or system of rods and linkages, depending on the physical layout of the station, to quickly open and close the main air valve, thus admitting air to the signal.

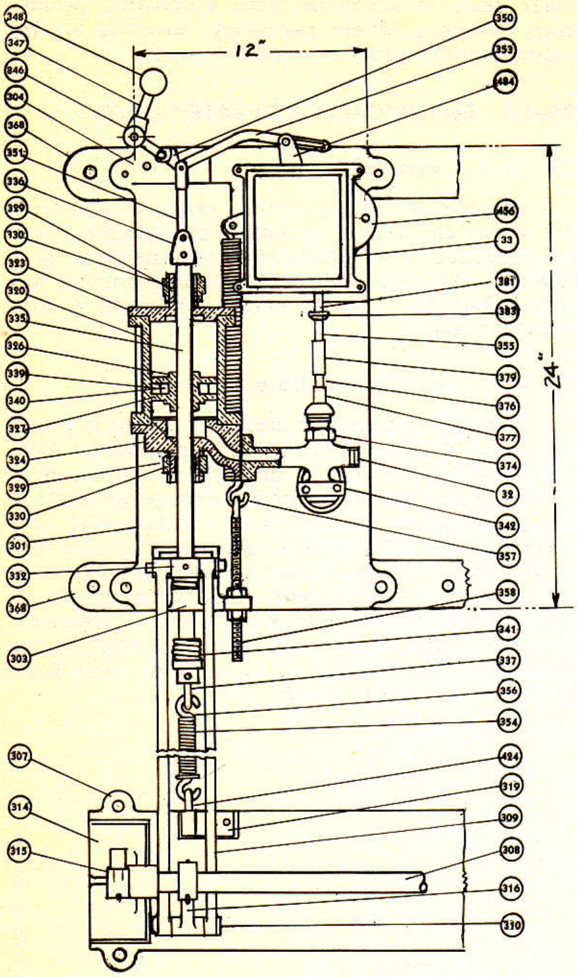
B. The *clock work* consists of a simple spring operated system of gears assembled together to rotate a cam with the least amount of friction and the steadiest driving speed. This constant speed is maintained by the use of a flyball governor and a friction brake. All parts are constructed of a special steel or bronze material to insure long wear.

C. The *characteristic valve* (part No. 32 fig. 25–24) whose opening and closing is regulated by the lobes of the characteristic cam, alternately allows the air to force the operating piston (part No. 326) upward and allows the piston to be returned to its lower position by the tension of the return spring (part No. 354) when the air is released or exhausted from beneath the piston.

D. The *operating piston* (part No. 326) performs two functions. It rewinds the clock mechanism and through the use of a system of cables, rods, or linkages attached to the piston rod, operates to open the main air valve to the fog horn.

E. *Lubrication.*—The clock mechanism should be oiled regularly with clock oil or a good grade of light oil. Apply only enough oil to make the clock operate freely; overoiling may do more harm than good. If excess oil is allowed to remain on the clock work, it will cause an accumulation of dust and dirt, thus increasing the frictional drag on the gearing. The lubricator installed in the air line to the operating piston should be adjusted to admit two or three drops per minute to the air supply. This oil reduces the friction of the piston in operation.

F. *Adjustment.*—The Crosby Characteristic Regulator may be adjusted for characteristic in three ways: first, by regulating the friction brake tension; this regulates the governor speed, second, by adjusting the operating valve rod extension (part No. 379) and third, by changing the characteristic cam. These combined adjustments are made to accurately govern the fog signal characteristic.



Part No.	Name	Part No.	Name
32	Characteristic valve, complete.	337	Piston rod eye.
33	Clock, complete.	339	Piston ring, inside.
301	Bed plate.	340	Piston ring, outside.
303	Piston rod guide.	341	Piston rod spring.
304	Rewind bracket.	342	Valve support.
307	Reducing mot. bed plate.	346	Release lever.
308	Reducing mot. shaft.	347	Release lever stem.
309	Connecting rod.	348	Release lever ball.
310	Connecting rod pin.	350	Release lever knuckle.
314	Shaft bearing.	351	Transmission rod.
315	Valve cord lever.	353	Fulcrum lever.
316	Crank.	354	Piston rod spring.
319	Piston spring attachment.	355	Clock power spring.
320	Cylinder.	356	Piston spring hook.
323	Top cylinder head.	357	Clock spring hook.
324	Bottom cylinder head.	358	Clock spring rod.
326	Piston head.	368	Wall plate.
327	Piston head follower.	374	Valve nut.
329	Stuffing box nut.	376	Valve stem.
330	Stuffing box gland.	377	Valve stem hood.
332	Cross head.	379	Valve stem extension.
335	Piston rod.	381	Valve stem fork.
336	Piston rod fork.	383	Stem thumb nut.
		404	Winding lever.
		424	Piston spring eye.
		456	Case door, curved.

FIGURE 25–24.—Crosby characteristic regulator.

G. *Installation.*—Controls are always installed in duplicate in such a manner that either one or the other may be used to code the horn. Both regulators should not be connected at the same time, for since only the regulator receiving the air is lubricated, the working of the other regulator without lubrication will cause undue wear on the parts concerned.

H. *Operation.*—After the pressure is built up to operating pressure (35 pounds), proceed as follows to put the regulator in operation:

(1) Check rods and linkages, making sure No. 1 regulator is connected so as to operate the No. 1 horn.

(2) Open the air valve to No. 1 horn.

(3) Open and adjust the lubricator; oil all oil holes on the linkage.

(4) Open the intake air valve on No. 1 regulator, making sure this same valve on the No. 2 regulator is closed.

(5) Start clock work in motion by pulling down on release lever ball. Release lever ball is located over, and connected to, the piston by linkage.

(6) Check the signal for correct characteristic, and also periodically during the course of operation.

(7) During operation, occasionally open the lower air drain valve on the regulator to drain moisture out of the pipe lines, especially during a wet, heavy fog.

25–14 STANDARD INSTALLATION PRACTICES, AIR UNITS

25–14–1 General—

A. The following practices are standard for all air-operated fog signal installations.

B. The standard air fog signal layout shall consist of duplicate single fog signal units or one duplex or triplex unit, duplicate characteristic control devices, duplicate compressors, and adequate air storage. If multiple air receivers are provided, they shall be so manifolded together that their capacity is additive.

C. *Accessories and piping.*—Accessories shall include all necessary pressure gauges and valving to permit flexible and positive operation of the signal irrespective of defective units. All schemes for cooling, heating, or drying air are of doubtful utility compared to the complications in installation they entail and will ordinarily not be approved. All necessary safety, relief, and drain valves in accordance with good practice and safety are required.

D. *Running unloaders.*—All existing compressors, unless of obsolete design, shall be equipped with running unloaders.

E. *Starting unloaders.*—Many existing compressors are equipped with starting unloaders. All future units will be so equipped. When not so equipped, compressors may be started by closing line valve and relieve by means of a manually operated bleeder until up to speed.

F. *Continuous bleeding wasteful.*—The practice, now applied to some existing installations, of operating with a constant bleeder is inconsistent with paragraph (D) above. It is wasteful of fuel and causes unnecessary wear on compressors. It shall be eliminated by the installation of running unloaders or starting bleeders on compressors.

G. *Length of fog signal characteristics.*—Due to mechanical lag in valves and in vibrating members of air-operated units, the fog signal blasts for those units should be not less than 1 second long if part of a group characteristic, or 1½ seconds long if sounded singly. The longest blast to be sounded at a station should be limited to a period causing a draw-down of not more than 5 pounds gage in the air storage tanks. For data on best minimum blast for diaphones, see paragraph 25–8–25 (B).

H. *Operating pressures.*—Diaphones will be operated at a pressure of 35 pounds gage at the start of the blast.

(1) All single and multiple diaphragm horns shall be operated at the lowest pressure at which maximum signal strength is obtainable by adjustment with a sound level meter. This will vary from 20 pounds gage to 35 pounds gage, depending on length of air line from air receivers to signal unit.

(2) Existing sirens and reed horns shall be operated as now adjusted. These units are obsolete.

I. *Specifications.*—Fog signal machinery and station design will be specified by the Office of Engineering at Headquarters.

J. *Work authorization requests.*—Structalts (Form 3434) shall be submitted with supporting preliminary sketches, where necessary, covering all fog signal improvements or establishments.

25–15 ELECTRICALLY-OPERATED UNITS

25–15–1 General—

A. Electric sound fog signals range in size from the triplex electric air oscillators composed of three air oscillator units operated simultaneously, to a modified 100-watt loudspeaker unit requiring approximately 55 watts of energy to sound a continuous signal.

25–15–5 Electric Oscillators—

A. *Multple unit electric oscillator.*—This is a unit consisting of three 24-inch double diaphragm electric oscillators driven by one 10 hp. synchronous electric motor through three separate generators. The relationship of the three fundamental frequencies (260, 360, and 495) generated by this unit is such that its signal complies reasonably well with the theoretical requirements for a good signal. It is a powerful signal and may prove to be suitable for locations where space and power are limited at the actual site. Power may be supplied by cable from a distance. (See fig. 25–25.)

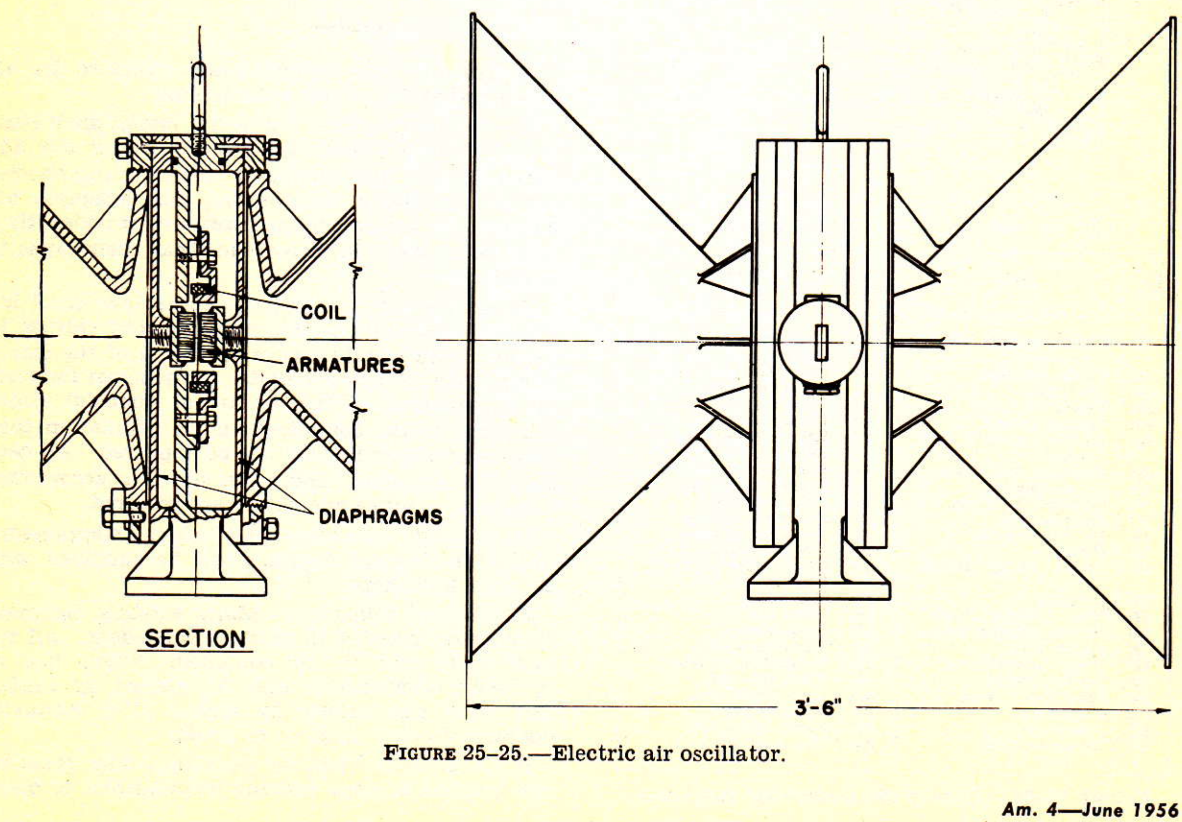


FIGURE 25–25.—Electric air oscillator.

B. *Single frequency units.*—Single unit, single diaphragm, polarized electric air oscillators and a smaller unit known as the *nautophone* are installed at several locations.

25–15–10 W. & T. Diaphragm Horn—

A. Although designed for buoys, the type FA–55 Wallace & Tiernan diaphragm horn may be mounted at light stations, pierheads or breakwaters where a minor fog signal with limited range is suitable. Six months to 1 year is the average service period for buoy installations.

B. The horn operates by means of a vibrator-type of solenoid arranged to directly drive a group of diaphragms. The current supplied to the horn winding creates a powerful magnetic field which attracts the armature to which the diaphragms are attached. When the diaphragms have been flexed through a predetermined distance, the armature also opens a set of rare metal contacts which interrupts the flow of current through the solenoid winding. The energy stored up in the flexed diaphragms now acts to return the armature to and beyond its original position, whereupon the contacts again close, current again flows and the vibratory action is repeated. The weight of the armature and the thickness and heat treatment of its associated diaphragms are carefully maintained within close tolerance so that a desired natural or resonant period of vibration is obtained. Its frequency is approximately 210 cycles. The signal does not have a good harmonic structure.

C. *Coding device.*—A program mechanism is provided with a suitable contactor, or relay, capable of making and breaking the current to the horn motor over extended periods of time and when operated in any position. The contactor is actuated by a standard Wallace & Tiernan flasher mechanism driving a cam which normally provides a 1 second signal every 15 seconds but which is so constructed as to allow the substitution of any characteristic of not less than 1 second in duration or greater than 14 seconds. The program mechanism operates on about 150 watt hours per year and requires no adjustments during that period. It is ordinarily contained within the horn housing.

D. *Current consumption.*—Maximum signal output is obtained with a current drain of 3 to 4 amperes at 14 to 16 volts d. c. Consumption of power occurs only at the time the signal is sounded except for the negligible current consumption of the program device noted above. With a characteristic of 1 second blast—14 seconds silent, the power consumption is 5 to 6 ampere-hours for 24 hours of continuous operation.

E. *Construction.*—The horn operating mechanism housing is constructed of cast bronze throughout and is watertight. Ordinarily the operating mechanism is housed in the mounting casting but as an alternate, the horn may be equipped with a smaller mounting casting which houses only the vibrating horn mechanism. In this case, a separate housing or mounting must be provided for protection of the characteristic controlling mechanism. In either case, heavy lugs are provided for securing the horn to its position. Hinged doors fitted with suitable gaskets provide easy access to the electrical connections and operating parts for adjustment.

F. *Mounting.*—The horns are usually mounted with the trumpet vertically downward and are adjusted for that position. Horizontal mounting can be used if desired, but should be specified, as minor but necessary changes are required to obtain maximum output in the horizontal positions. The controlling mechanism is also affected and should be properly positioned. It may be mounted separately if desired.

G. *External wiring.*—The external wiring diagram for trumpet installations is shown in figure 25–26. If the trumpet is installed on the same structure as battery-operated electric lights, using the same battery for power, then the trumpet installation is as shown in figure 25–27 (No. 1), but special means must be employed to insulate the flasher and lampchanger mechanism from ground. (See fig. 25–27 (No. 2).) This must be done so that the battery will not be shorted during the normal operation of the horn, in which the battery polarity is reversed for each blast.

H. *Internal wiring.*—The internal wiring diagram for the trumpet is shown in figure 25–28. It will be seen from this diagram that the characteristic controlling mechanism also operates to reverse the direction of the current flowing through the horn motor contacts after each blast of the trumpet. This is a special feature which helps to preserve the horn contacts over long periods of operation. Adjustment of these contacts should not be necessary more often than once every 3 months, and in case adjustment at such frequent intervals is impossible, only a slight falling off in volume of sound of the trumpet due to wear on these contacts will be noticed over a period of 6 months. Adjustment of the contacts can be easily and quickly accomplished in the field on any regular inspection trip. Contact adjustments are shown in figure 25–29.

I. *Procurement of parts.*—Replacement parts are available on term contract from Wallace & Tiernan Products, Inc.

25–15–15 R. C. A. Diaphraghm Horn—

A. The basic assembly of the R. C. A. minor electric fog signal consists of one signal generator, type MI–2833, and one or two (preferably two) sound projectors, type MI–6299. (See fig. 25–30.)

B. *Application.*—The R. C. A. minor electric fog signal is suitable for application only at fixed locations.

C. *Signal generator.*—The audio power signal generator consists basically of two vibrators and associated transformers mounted in a weathertight housing, and may be located in a battery house near the projectors. It operates from a source of direct current of 14 to 16 volts and requires 3 to 4 amperes for each projector connected to it.

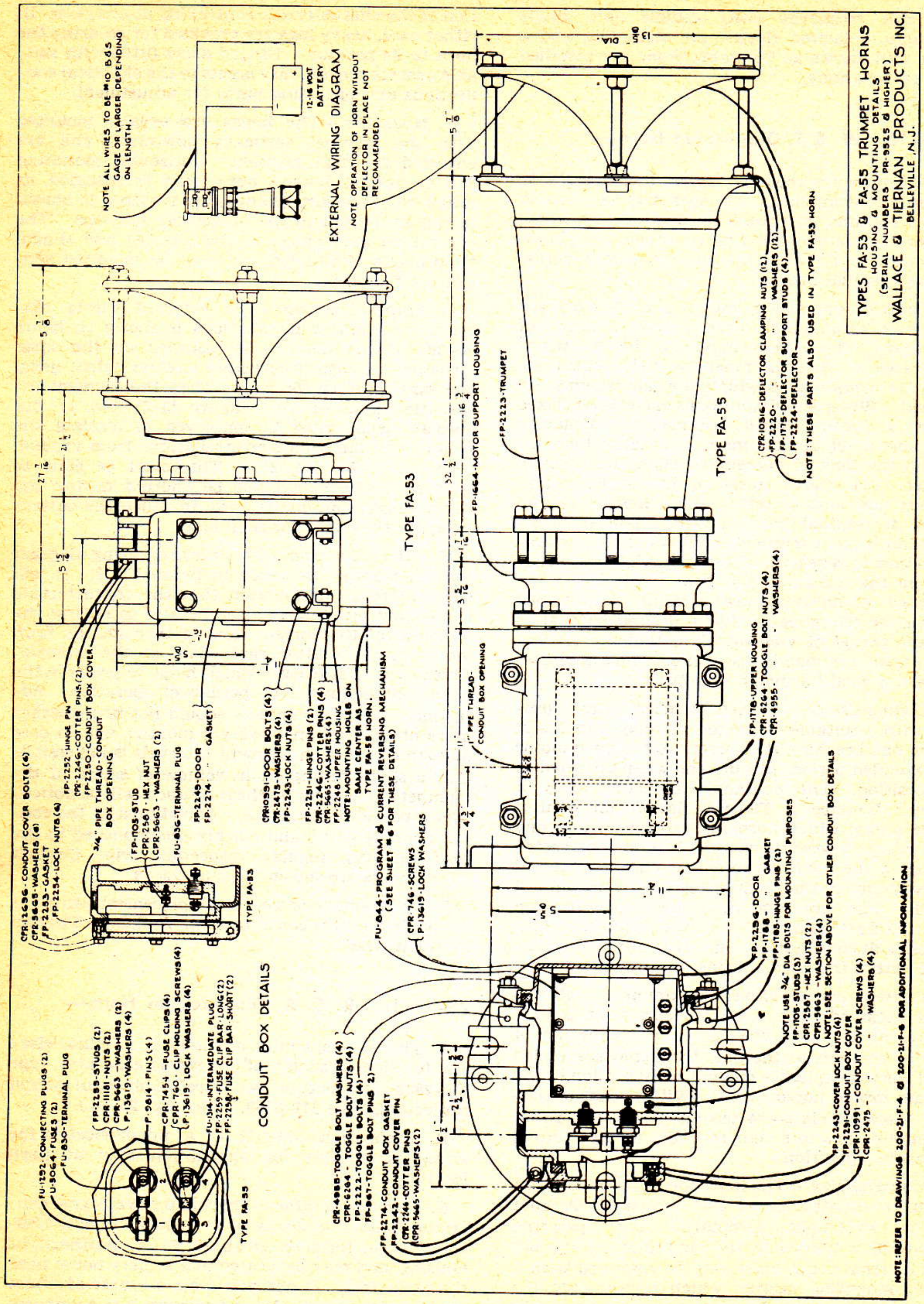
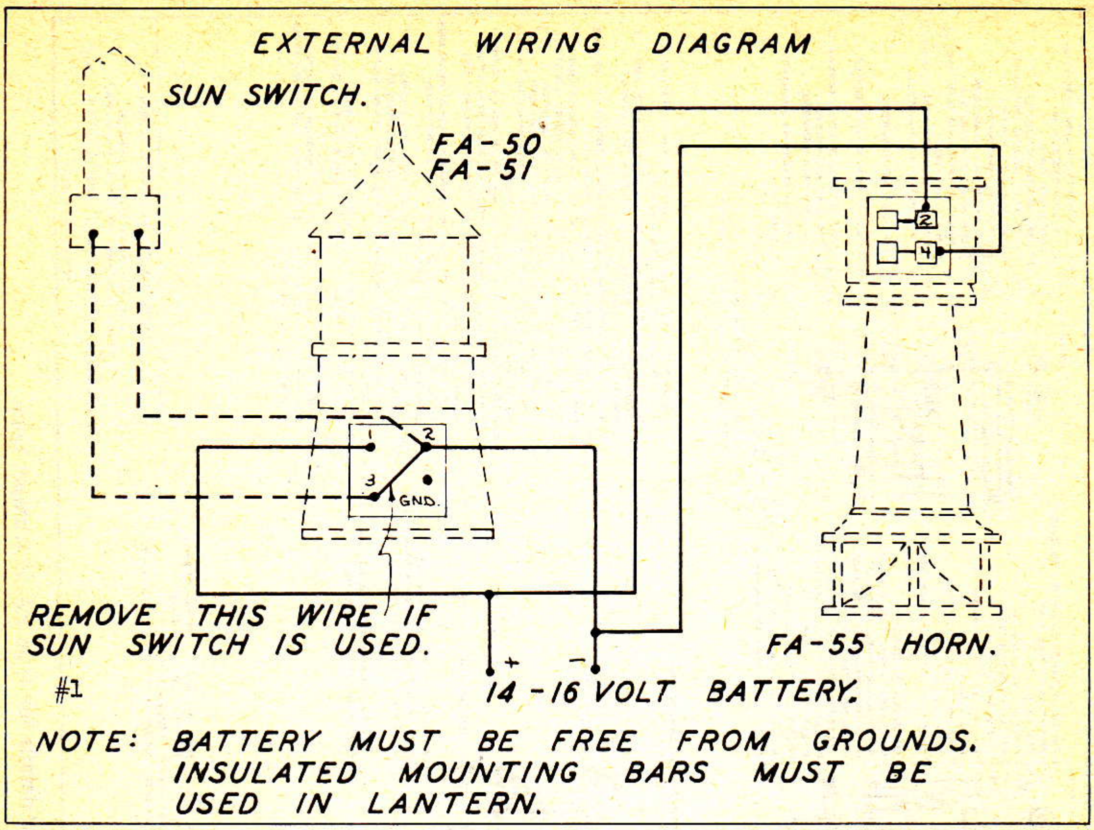


FIGURE 25–26.—Types FA–53 and FA–55 W. & T. trumpet horns.



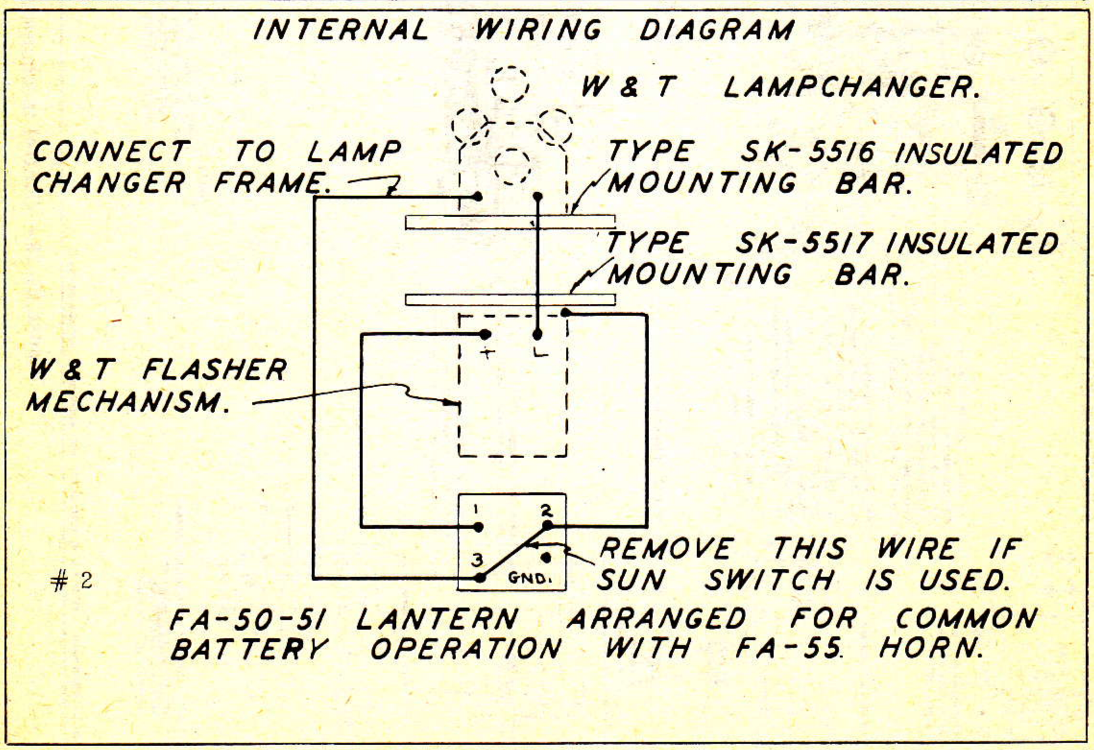


FIGURE 25–27.—Wiring diagram for W. & T. trumpet horns.

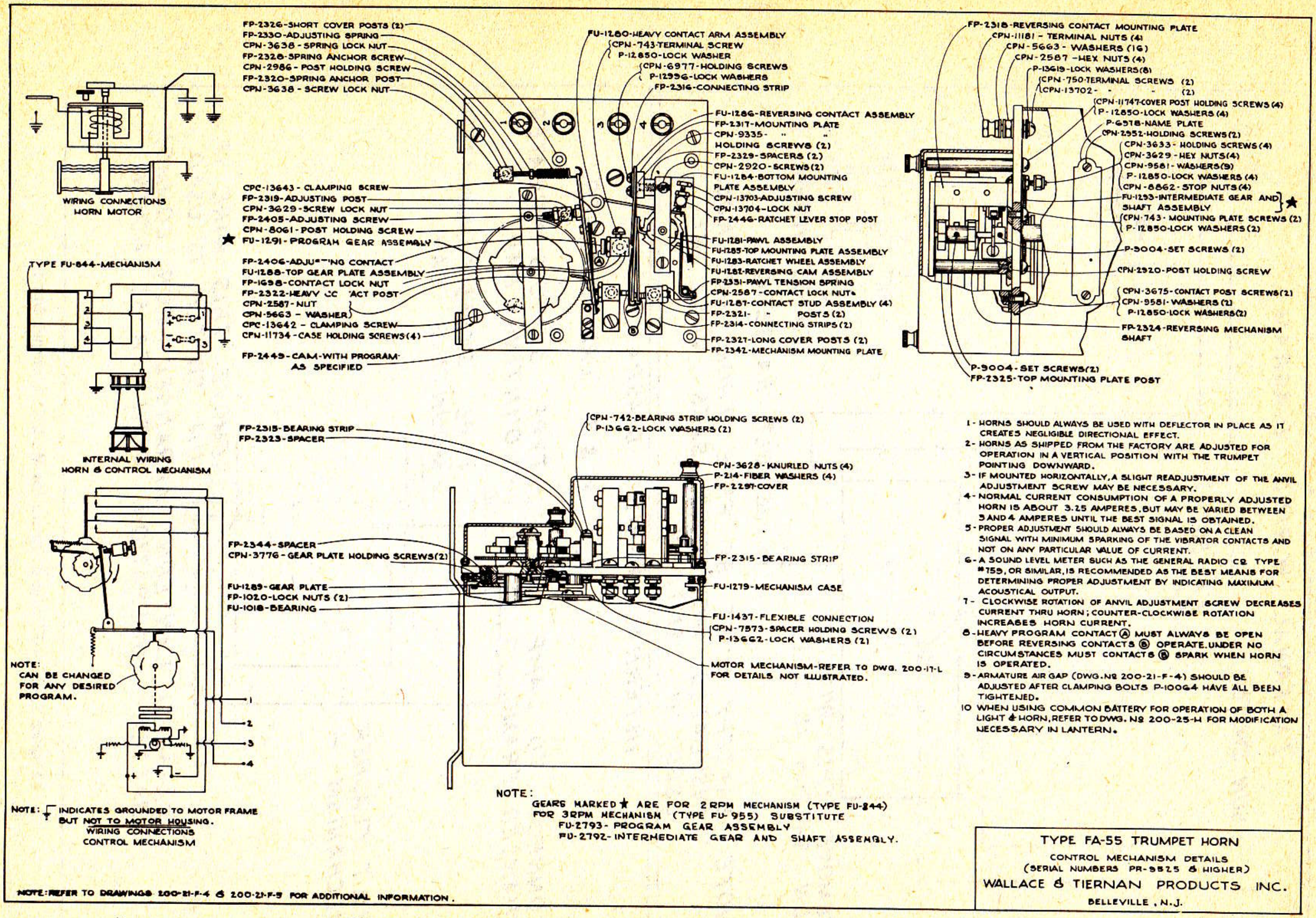


FIGURE 25–28.—Control mechanism details for type FA–55 trumpet horn.

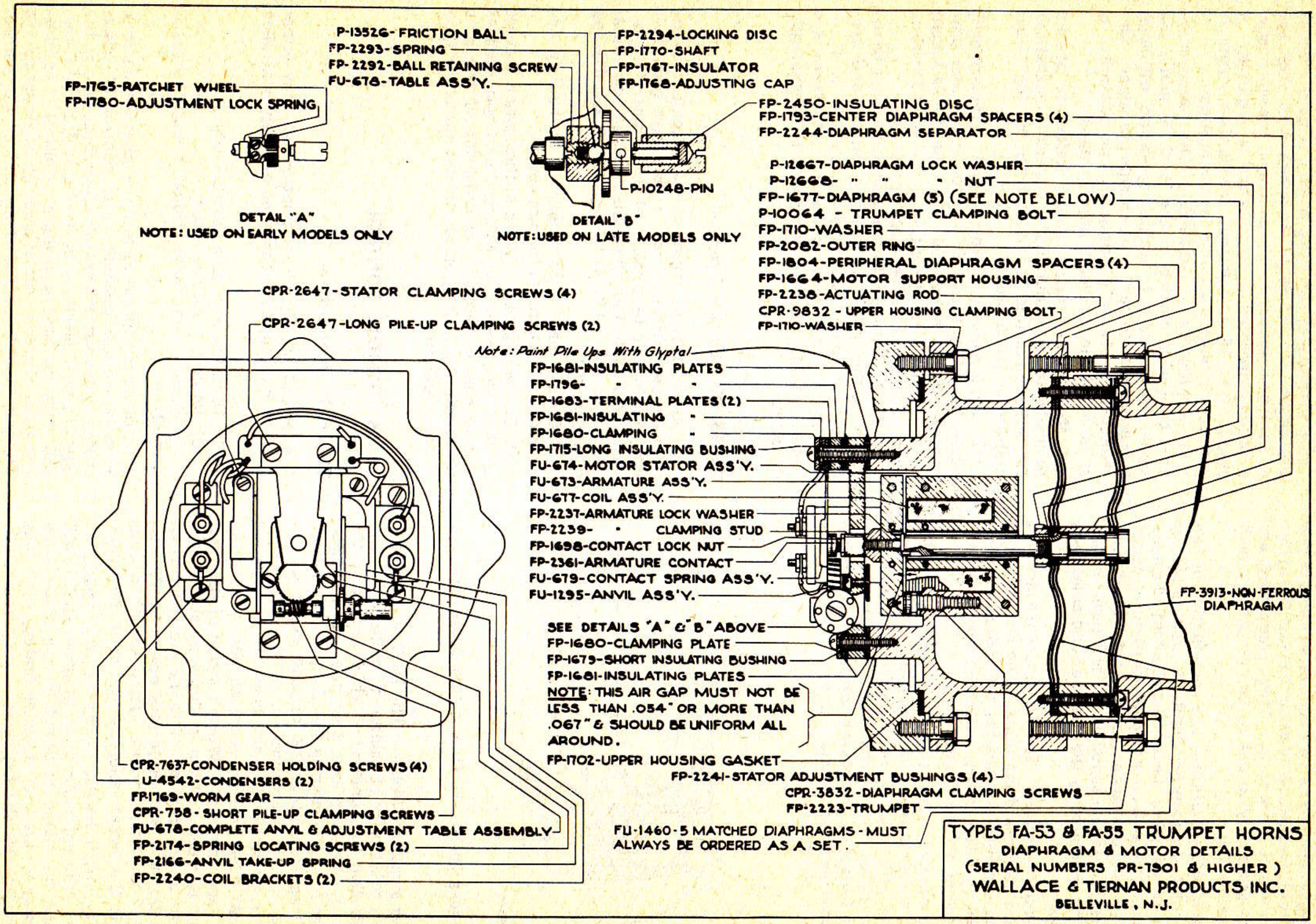


FIGURE 25–29.—Diaphragm and motor details for types FA–53 and FA–55 trumpet horns.

D. *Frequencies.*—The two vibrators generate two fundamental frequencies of about 240 and 270 cycles having a square wave form. These frequencies are delivered separately to one or two projectors each (total two to four).

E. *Harmonic structure.*—The combination of two fundamental frequencies emitted simultaneously provides an arresting "beat" note of about 30 cycles. The signal has a good harmonic structure, which adds to its effectiveness as a minor aid. Good harmonic content of the signal-in-air is a result of the wave form generated by the vibrators and associated apparatus.

F. *Sound projectors.*—The projectors are modified shipboard public address units. The design of the vibrating member accentuates the frequency band from 250 to 1,000 cycles. Consequently they are unsuitable as voice reproducers.

G. *Resonators.*—The projectors are fitted with aluminum resonators, completely protected against effects of salt spray. The manufacturer will furnish cast metal resonators if required, although experience to date has not shown them to be necessary. At exposed locations it may be desirable to maintain spare resonators.

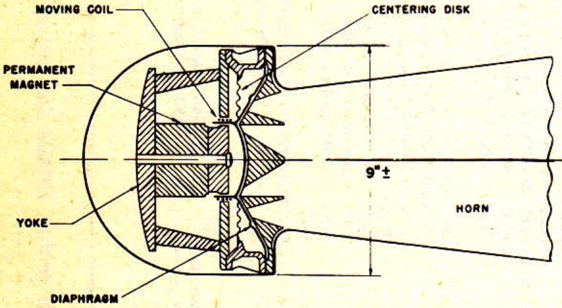


FIGURE 25–30.—R. C. A. sound projector.

H. *Fog signal controller.*—The R. C. A. unit may include a third piece of equipment called a fog signal controller, the function of which is to keep the fog signal shut down except when a ship's navigation whistle in the vicinity sounds a sustained blast in the frequency range 200 to 1,000 cycles with a loudness level of 50 decibels or more. The signal controller, electronic in design, is normally connected to the MI–6299 projectors, which act as listening devices (microphones). When a signal of sufficient intensity is received from a ship's whistle by the projectors and is transmitted to the controller as an electric impulse, the projectors are instantly disconnected as microphones. They are then connected to the signal generator and emit the signal.

(1) *Operation limited to period ship atually in vicinity.*—The controller is so designed that it will cause the fog signal to sound back a single blast which may be used for distance finding, or it may be set to operate the fog signal for approximately seven minutes, when it shuts the signal down until again actuated by a ship's whistle.

(2) *Coding.*—If the R. C. A. unit is used without the controller (MI–2834) or, when used with the controller, is sounded on a published characteristic, a battery-operated coding device is required. A standard 12–16 volt flasher mechanism complete with power relay is suitable for the purpose.

(3) *Application of controller.*—The sound-operated controller portion of the R. C. A. minor fog signal apparatus is in regular operation, although it is considered to be in the experimental stage. Development is being continued. The controller is suitable for the control of any fog signal.

I. *Maintenance instructions.*—Reference should be made to the manufacturer's special instructions for adjustment and repair of both the fog signal and the signal controller.

(1) *Replacements.*—Orders for replacement parts, including those for the fog signal and projectors, should be placed with the Replacement Parts Division Department, R. C. A. Victor Division, Radio Corp. of America, Camden, N. J.

(2) The following information must always be included in the order: (1) drawing number and item number, (2) description of item, and (3) R. C. A. catalog ordering serial number. All three are shown on bill of material block or engineering drawings.

25–15–20 Electric Sirens—

A. *Application of minor sirens.*—Small, conventional, motor-driven electric sirens have been, and may continue to be, applied where commercial current is available and where the needs of navigation are not so important as to require full standby fog signal facilities.

B. *Coding* may be accomplished by built-in devices or by a separate program device.

C. *Design approval.*—Work authorization request shall be accompanied by sufficient descriptive material to enable complete identification of the unit proposed. No restriction to particular make or type exists at this time.

25–16 REMOTE CONTROL

25–16–1 Methods—

A. Sound fog signals, if unattended, may either operate continuously or may be remotely controlled by:

(1) Land line and/or submarine cable.
(2) Radio control (ANRAC).
(3) Sound from navigational whistle (experimental).

B. Relative application is in the order listed above. Remote control assumes relay control of power switches, or starting controls on engines, that is, the flow of power, electrical or mechanical, is not transmitted by the control medium. Control of an electric siren over one mile of cable by interrupting the 440-volt circuits at the shore end of the control circuit is not classed as remote control as outlined herein.

25–16–5 Possible Control Arrangements—

A. A variety of possible control arrangements exist. The exact needs in each instance must be considered. A few major premises should always be kept in mind when laying out a remote control scheme. In order of importance these premises are:

(1) The control must be reliable.

(2) The control must function negatively.

(3) The control must be simple.

(4) The control should be economical of power.

B. The second point is amplified by explaining that the control should hold the fog signal inoperative. Hence failure of any functional portion of the control scheme places the fog signal in operation.

C. If manual supervision is involved, the control function stops the control and the signal starts. This principle of operation also will be worked into the functional layout between main fog signals and stand-by units. Failure of the main unit should act to start the stand-by unit.

D. The fourth point though last is by no means unimportant. Controls which consume as much or more power than the device they control may in some instances defeat their primary purpose of reducing demands on manpower and equipment.

25–16–10 Modifying Existing Stations—

A. When preparing plans for modifications to existing stations or for new installations, the foregoing points must receive full consideration.

B. *Wired control.*—Full use of modern superposed circuit arrangements shall be made when providing fog signal control over wire facilities. Full latitude in circuit equipment arrangement is given within the limitations of paragraph 25–16–5 (A).

C. *Radio control.*—Various radio control systems have been in use for several years. All engineering of radio control systems will be done by the Office of Engineering, Headquarters.

D. *Sound control.*—This method of control is now in the experimental stage.

25–17 SOUND MEASURING DEVICE

25–17–1 Sound Level Meter—

A. The General Radio Co.'s type 759a sound level meter is suitable for the fog signal adjustments mentioned in this chapter. A sound level meter should be included in the technical apparatus of every district engineering office. Engineering officers concerned with the adjustment and maintenance of air diaphragm fog signals and minor fog signals should familiarize themselves with the contents of General Radio Co.'s technical bulletin No. 20, The Technique of Noise Measurement.

25–18 THEORY OF FOG SIGNALS

25–18–1 General—

A. Before a discussion of the design and operation of sound fog signals is undertaken, the engineer should have a brief but clear understanding of the relation existing between their design and other less tangible factors affecting their usefulness. Providing good sound fog signals depends on: the design and operation of the units; behavior of sound in the transmission medium; and the receiving unit (the ear or special amplifying aids). The first two involve purely mechanical and physical actions; the third involves mechanical, physiological, and psychological reactions affecting hearing. Intelligent engineering of sound fog signals is not possible without due consideration of all aspects of the problem. Consideration of the first factor can only be made after reference to the others. All are interdependent.

(1) Although fog is popularly associated with the design and performance of sound aids to navigation, it has only an indirect effect on their performance. Fog is only one of several conditions which obscures the atmosphere. Other conditions are dust, rain, snow, smoke, and "arctic steam." When the navigator can no longer see far enough to assure safe navigation, and believes he is in the vicinity of hazards to navigation, he is aided by sound signals.

(2) The degree of that aid is dependent on the characteristics of the fog signal and whether he (the navigator) is able to form a positive conclusion as to its direction and distance and thus indirectly determine his own location.

(3) Although not directly affected by fog, rain, or the other obscuring media, the propagation of the sound wave and character and volume of received sound are profoundly affected by physical and meteorological conditions. Thus, vertical and horizontal temperature gradients, wind, background, and elevation affect the transmission. Likewise, the quality of the note of the fog signal is affected by the length of the transmission path.

25–18–5 Fundamental Behavior of Sound—

A. *Review of physical aspects of sound transmission.*—For the benefit of the engineer, a brief review of some of the fundamentals of the behavior of sound may be helpful. Sound is vibrational energy. It is generated by a vibrating body. It is propagated by longitudinal compression and rarefaction of the transmitting medium. It is diffracted, reflected, refracted, and absorbed much in the same way as light. Its speed of transmission is dependent on the elasticity and density of the medium and may be expressed by the formula:

$$V=\sqrt{\frac{E}{d}}$$

where V=velocity
E=elasticity
d=density of medium

B. *Velocity.*—The velocity of sound in air is approximately 1,100 ft. per second at 0° C. Sound travels a statute mile in 5 seconds and a nautical mile in 5½ seconds.

C. *Distance finding.*—The above values are used for distance determinations in connection with simultaneous radiobeacon signals transmitted from the same general location as that of the fog signal. By starting both the radiobeacon and sound signals away at the same instant, and assuming the radio signals are received without measurable time lag, the speed of sound may be used for the measurement of distance-off with a good degree of accuracy.

D. *Directive propagation.*—The initial propagation from a source at the surface of the earth is essentially hemispherical, although the shape of the vibrating body and connected resonator affect the field pattern. Increasing the ratio of the diameter of the opening of the resonator (horn) to the wave length of the sound causes the propagation to be increased along the axis of the horn and decreased normal to the axis. This is due to interference phenomena occurring in an increasing degree as the angle with the axis is increased. By application of the foregoing principles, in using either several small projectors operating with phased sound waves or a single large-mouthed resonator, directive propagation of a sound wave is possible. The practical application of this phenomenon has been limited by available apparatus. This will be discussed further in paragraph 25–18–45.

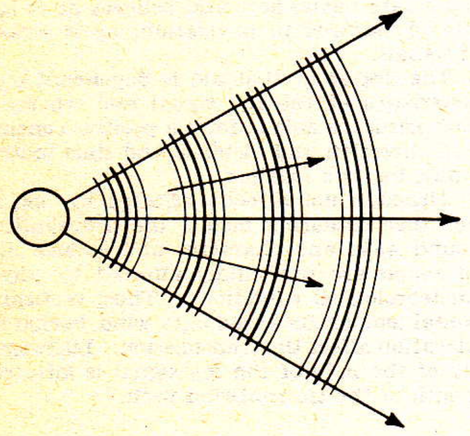


FIGURE 25–31.—Directive propagation of sound.

E. *Reflection.*—Reflection occurs from "cold fronts," cloud banks, hills, waves, and man-made structures. Use is customarily made by the practical navigator of this effect to determine distance-off by checking the time and dividing by two. The roll of thunder is a recurring series of reflections from "fronts" and cloud banks.

F. *Refraction* occurs when a sound wave moves obliquely from one area into another having a different density or elasticity. The waves move more rapidly in warm air. This causes a sound wave to turn downward when the air on the surface of the water is cooler than the layers above. Since wind moves more rapidly as the distance above the earth or water increases, the effect is to turn sound upward against the wind, and downward to the water if the sound moves with the wind. It is this effect and not the velocity of the wind which causes the familiar loss of sound against the wind.

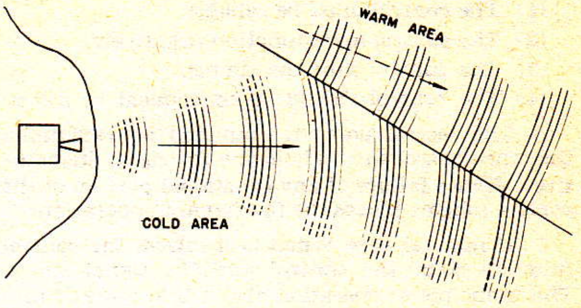


FIGURE 25–32.—Horizontal refraction.

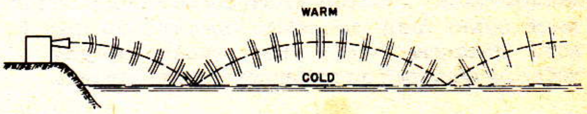


FIGURE 25–33.—Vertical refraction.

G. *Absorption.*—Sound is lost by friction at the surface of the water. Sound travels more readily in those layers of air above the immediate surface of the water. Hence, a fog signal may be heard from the masthead when inaudible from the deck of the vessel.

25–18–10 Tests for Location—

A. The foreground, background, and height of the sound source all affect the field pattern. Much testing has been carried out on all of our coasts and on the Great Lakes for a period of at least 75 years, to determine the reasons for irregular behavior of the sound wave from a sound fog signal. Silent zones exist both close to, and at moderate distances from, fog signals. This is as true of signals from lightships as from shore signals. If observed irregularities in the field pattern of the sound have been inconsistent; that is, silent zones did not recur at the same locations, the answer has been sought in the phenomena previously mentioned—horizontal and vertical temperature gradients in the atmosphere, and in direction and intensity of the wind. When such phenomena have been consistent over periods of time and in varying weather conditions, the answer has been sought in the physiography of the area, the background and height of the signal, and the consistency and prevalence of cold or hot currents of water contiguous to the signal.

B. *Relocation of fog signals.*—If irregularities in the field pattern of the sound from a station have been shown by consistent records to be relatively unaffected by meteorological conditions, the proper conclusion has been that a relocation might be productive of beneficial results. A review of many records of tests indicates that results were inconclusive or that it was impractical to continue the tests until positive conclusions could be reached. However, there are instances where fog signals have been relocated because tests have shown location to affect the transmission of the signal. Before expensive construction of a fog signal station is attempted, portable apparatus should be operated from all suitable points at the location to determine whether irregularities due to location will cause unsatisfactory results.

C. *Proper location of sound signal.*—Conclusions are drawn with caution from the history of tests. However, it may be safe to conclude for the benefit of the engineer, that increasing the height above, say, 50 feet, does not result in an increase in the range or reliability of transmission. The signal should not be located on the front of a precipitous coast where the cliff or bluff projects for some distance to one or both sides of the signal at angles less than 135° with the axis of the signal. The shore, if precipitous, should recede abruptly from the location of the signal. The signal should not be located where opposite headlands may cause reflections or destructive interference in the wave pattern. It should be located as close to the water as possible unless the foreground is flat and practically at water level. The presence of dunes, hillocks, or precipitous cliffs in the foreground probably will contribute to the formation of "silent zones" in the useful field of the signal.

D. *Signals cannot be classified by range.*—Except for minor passing signals, there can be no relative classification of signals based solely on the relative generated intensity of sound on the axis of the signal unit. There is no reliable yardstick by which to measure the range of sound fog signals, as is the case with radio signals. The determination must be a relative one, based on a study of the probable benefits accruing from the signal as compared to its first cost and maintenance; also, a thorough knowledge of all the factors affecting the ultimate usefulness of the signal must be brought to bear on the problem before the decision is made. A brief outline of some of these factors will follow.

25–18–15 Theoretical Propagation—

A. The classical theory of physics shows that sound generated by a small source has spherical propagation and should attenuate as the square of the distance. However, it has been shown that sound attenuates more rapidly with increase of frequency. Thus Rayleigh developed the formula

$$X=8800\ \lambda^2\ \text{cm.},$$

where X is that distance in which the sound has diminished in the ratio e/1 and λ is wave length of the sound. The relative humidity and density have also been shown to cause selective attenuation with frequency, the maximum effect occurring somewhere between 10 and 20 percent humidity. This effect is negligible below 1,000 cycles. It is obvious that the relative humidity is much greater than 20 percent when navigational fog signals are required.

25–18–20 Physiological and Psychological Factors—

A. Before the instrinsic frequency and frequency structure of the sound signal and the sound generators can be discussed, a brief reference must be made to the characteristics of the ear, viz, to the physiological and psychological aspects of the sound signaling problem, after which, discussion of the signaling units may be continued. The subject is discussed objectively, that is, with respect to those characteristics of a fog signal which produce special effects on the brain of the navigator.

B. *Orientability.*—By *orientability* is meant that quality of the sound structure of the signal which facilitates a correct conclusion as to its azimuth.

(1) *Factors affecting orientation.*—It has been determined that the direction from which sounds appear to come, and to a certain extent their distance-off, are determined by combined action of the two ears. Rayleigh suggested that the location of high-pitched sounds, for which the head is large enough to cast a sound "shadow," is determined by relative intensity at the two ears. For low-pitched sounds the sound shadow is not pronounced; the only determination of direction possible must depend on difference of phase at the two ears. Stewart experimentally verified that difference in phase between the ears is the important factor in the frequency range from 100 to 1200 cycles and that above that frequency range, relative intensity is also a factor.

(2) With the foregoing in mind it is helpful to consider further the actual mechanics of the hearing system. There are many sound channels leading to the brain from the ear. Each tone and harmonic of a sound is assumed to proceed on a separate channel. A signal containing a "rich harmonic structure" reaches the brain over more channels (nerves) than does a single pure tone. The ability to determine relative characteristics by the two ears, and hence direction of the sound, is facilitated by the multiple frequency responses reaching the brain due to harmonic structure of the signal. It is assumed that the foregoing may account for the fact that a signal containing a multiple-tone structure can be more readily oriented than can a pure note. Each channel to the brain can be loaded by a single tone. Further increase in intensity of that tone is of little further value in the interpretation of direction. The individual frequencies are superimposed on the intervening medium, and while they do not contribute to the over-all sound intensity of the signal in the air in proportion to their individual intensities, they do contribute in an additive fashion to the impression of the signal created in the brain. This is probably due to the ability of the brain to select and identify individual tones even though they are of lower intensity than other frequencies being heard at the same time. This will be discussed further in paragraph 25–18–35 (A).

B. *Perception of relative change of distance.*—The foregoing discussion of characteristics of the ear is given to impress the engineer that the design and performance of sound fog signals must be considered in the full light of the physiological aspects of hearing. Determination of distance-off, or more particularly, of a change in distance-off, is a fundamental requirement in navigation by means of sound fog signals. Here again qualities of the sound structure facilitate a conclusion to be drawn by the navigator. This is especially important when signals are passed close-to. The bell and gong are in this class of signals. The clue to special effectiveness of these signals was found when a selective study of their frequency structure was made. If a change in distance could be detected, especially when drawing near, then a change in the quality of the signal must have occurred. It is known that attenuation of sound is proportional to frequency (above approximately 200 to 400 cycles—below this value there is evidence to indicate that attenuation may not be proportional to frequency). The frequency structure of the sound generated by a good bell, shocked into oscillation by the stroke of a hammer, has been studied by the Service. It contains one, two, or three strong frequencies in the range 200 to 500 cycles and many higher harmonics. The timbre of the sound from the bell changes perceptibly as the distance is changed, due to proportional attenuation of the higher harmonics. Thus, change of distance can be determined. At a distance all bells sound mellow; the higher harsh harmonics disappear. The same observation is true of all sound fog signals. At great distances they are more distinguishable by the characteristic than by the quality of the signal. They tend to sound alike. One minor fog signal, classified as an electric diaphragm horn, emits a relatively pure tone of about 210 cycles and, with relatively low amplitude, a series of high frequency harsh "tinny" tones. Change of distance cannot be accurately noted when approaching this signal until the tinny frequencies are perceived. This may not occur until the mariner is too close to the signal for safety.

25–18–25 Selective Attenuation by Frequency Bands—

A. In connection with mention of frequency structure, another factor not so likely to be associated with minor signals is selective attenuation of bands of frequencies due, possibly, to selective reflection and refraction by critically oblique temperature fronts in the service area of the sound signal. In this case, a unit emitting a sound signal having rich harmonic frequency structure may be heard with greater consistency than a pure tone unit. An observation frequently reported is that of hearing only the high or low tone of a duplex or triplex diaphragm horn, or, in the case of the diaphone, hearing at one time the high tone and at others only the low tone.

NOTE.—The low tone contains a greater range of harmonics than does the high tone.

25–18–30 Correlation Between Frequency Structure and Hearing—

A. If the present theory with respect to the mechanism of hearing is tenable, it may be assumed, first, that a good minor fog signal unit should generate a note containing a rich frequency structure and, second, that a good major signal should contain several powerful tones in the frequency range, say, 300 to 800 cycles, and a reasonably rich structure of overtones. A study of signals has been made to determine why certain signals have been accepted as good signals, others less so, and some as not generally suitable. Close correlation has been found to exist between the frequency structure of the good signals and their effectiveness. Thus the steam whistle, siren, diaphone, and multiple-unit air-diaphragm horns are rated as good high-power units. The bell has always been an effective minor signal. Hence, further research to build better signals should start with the premise that a suitable frequency structure is an essential. Various models of one type of signal still used in the Coast Guard generates a single pure note in the range 250 to 520 cycles. Although frequently heard at long distances, they have generally failed to qualify as good signals for the reasons outlined above. By combining three such units in a single sound fog signal having fundamental frequencies of 260, 360, and 495 cycles, a "synthetic" fog signal was designed which has promising characteristics and is in regular operation.

B. The frequency response of the ear is approximately as shown in figure 25–34, curve A. The relative propagation of sound waves in the atmosphere is indicated by curve B. Curve C represents the relative effectiveness of sound signals when their propagation is weighted by the relative sensitivity of hearing over the same frequency range. It shows that signals having the majority of their sound energy in the range 300 to 800 cycles should be good signals.

25–18–35 Masking Noise—

A. Ability to hear a signal depends not only on the loudness of the signal and its frequency but also on the interfering noises over or through which the sound must be heard. Interfering noises are divided into two types: (1) machinery noise and reverberation, and (2) wind and wave noises. The frequency range of the interfering noise affects its masking effect, if in the same range as that of the fog signal, its interference is greater than otherwise. The significance of this common observation becomes more apparent if the reference to the manner in which sound proceeds from the ear to the brain is recalled. (See par. 25–18–20 (B) (1).) Machinery noise varies widely, depending on the listening point on the ship. Wind noises are of two kinds—noise due to the action of the wind around the head and ears, and noise occasioned by eddies around the superstructure of the ship and over the water. Wave noises are in a frequency range where they interfere with reception of faint signals. Wind noise is generally conceded to lie both in the range below 200 cycles and above 1000 cycles. Unless of considerable amplitude, the ear is able to identify a fog signal through wind noise even though the intensity of the wind noise is greater than that of the fog signal. Note particularly that wind noise frequencies are not predominant in the same range in which the most effective propagation of sound signals occurs.

25–18–40 Theoretical Relationship of Size to Frequency—

A. As the physical dimensions of the fog signal unit increase, the fundamental frequency of its signal decreases. Having discussed both the characteristics of propagation of sound and of hearing, and having drawn the conclusion that strong signals in the frequency range 300 to 800 cycles should be the most effective signals (par. 25–18–30 (B)), it should be apparent that there is a physical size which should not be exceeded in the design of fog signal units. Extensive fog signal tests have generally confirmed that fact. A résumé of all reports indicates that the type F and F2T diaphones are in general as good fog signals as the larger type G and K units.

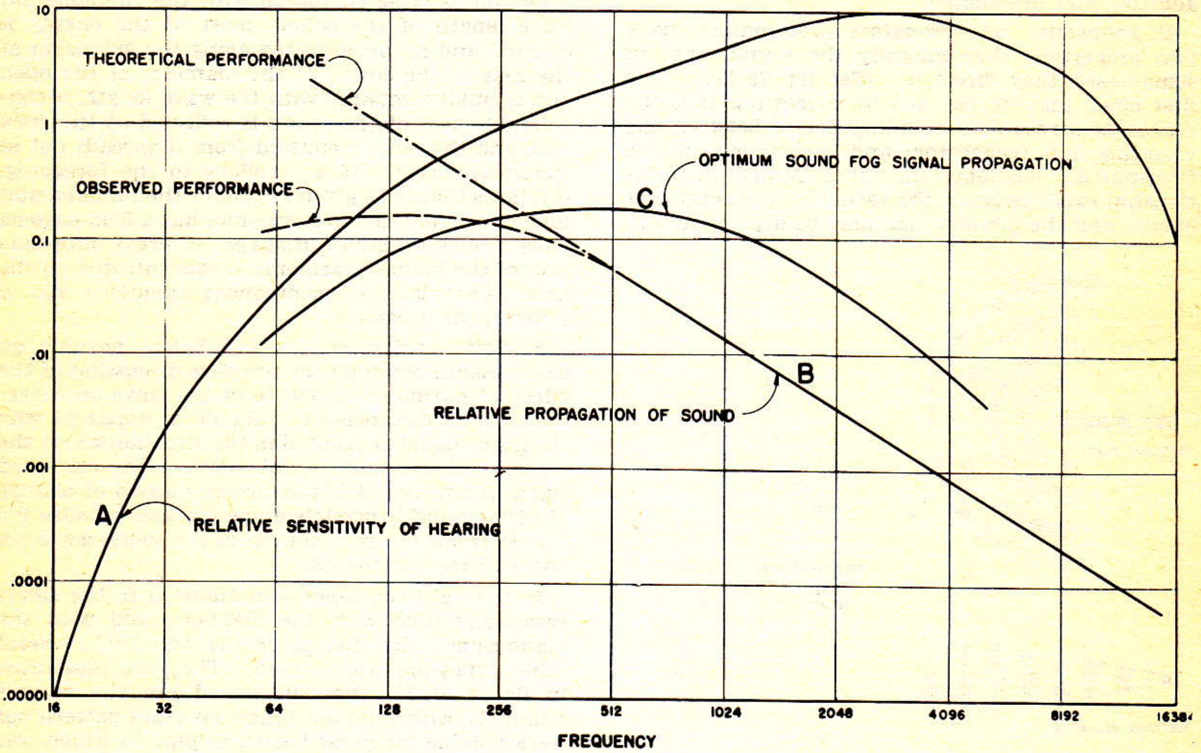


FIGURE 25–34.—Graph of relative sensitivity of hearing and relative propagation of sound for equivalent initial intensity.

B. A typical type F unit was found to have a frequency structure as follows:

Sustained tone

	f1	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*	*f9*	*f10*
Frequency, cycles per second	220	440	660	880	1100	1320	1540	1760	1980	2200
Relative intensity, percent	55	100	50	35	28	18	15	9	6.5	3

Grunt

	f1	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*
Frequency, cycles per second	93	186	279	372	465	558	651	744
Relative intensity, percent	12	50	100	25	45	18	12	8

Note that the maximum signal intensities lie in the frequency range between 200 and about 700 cycles.

C. For purposes of comparison the frequency distribution of a typical diaphragm fog signal is shown as follows:

	f1	*f2*	*f3*	*f4*	*f5*	*f6*	*f7*	*f8*
Frequency, cycles per second	186	372	558	744	930	1116	1302	1488
Relative intensity, percent	100	15	38	29	2	9	5	3

Note that the fundamental frequency has predominantly more intensity than all but the third harmonic.

25–18–45 Resonator—

A. The resonator affects the performance of the fog signal. If the signal is a diaphragm unit, its signal strength lies principally in the fundamental tone. For that reason it is possible to design the resonator to accentuate (amplify) that frequency and its odd harmonics. Note especially in this connection the frequency distribution of a typical diaphragm horn shown in the table above. The resonator must have an acoustic length of odd quarter wave lengths. All commercial diaphragm units are purchased complete with accurately adjusted resonator. The action of the mouth (bell) of a resonator depends on diffraction and interference, both additive and destructive.

B. *Properties of resonators.*—Resonators have two properties; they magnify the sound, and, in some cases, they direct it. (See fig. 25–35.) The first effect may be restated by suggesting that the resonator serves as a coupling device between the vibrating unit (generator) and the particles of the transmitting medium (the air). A definite relationship exists between the rating of a generator of energy and the power which may be drawn from it.

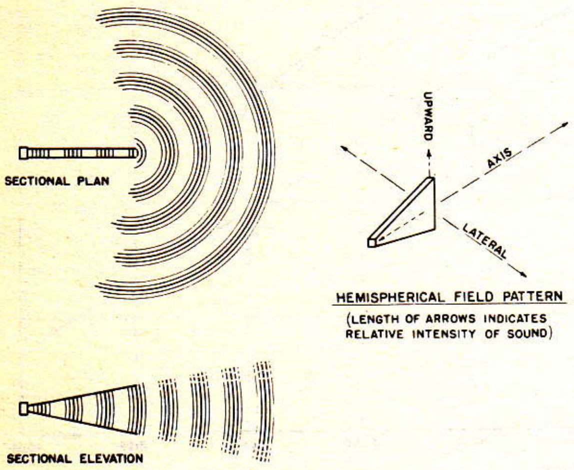


FIGURE 25–35.—Sound field patterns.

C. *Resonator couples vibrator to air mass.*—Too large a resonator might result in a weakened signal because it might "load" the vibrating member until it no longer operates at maximum efficiency. The best length for the resonator has been found to be three-fourth wave length, and the best shape, some modification of the exponential form. A cone is the most rudimentary exponential form. (See fig. 25–36 (a).) Exponential shapes do not strongly accentuate particular frequencies. The resonators used with diaphragm horns more nearly approach a cylindrical form with a flare at the mouth, to provide the "coupling" previously mentioned. They exhibit resonant properties at exact frequencies. (See fig. 25–36 (b).)

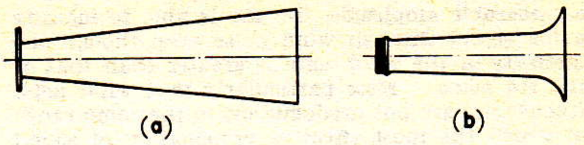


FIGURE 25–36.—Resonator types.

D. *Diameter of mouth affects directivity and loading.*—If the diameter of the mouth of a conical resonator is large compared with the fundamental wave length of the sound, most of the energy is emitted and is concentrated along the extension of the axis of the cone. If the diameter of the open end is small compared with the wave length, a considerable part of the sound is reflected at the open end, and the energy emitted from it spreads out in spherical waves. As a corollary to the foregoing, it follows that for a given resonator the fundamental tone of a signal rich in harmonics has a field pattern more nearly spherical in shape; whereas, propagation of the highest harmonic is concentrated on the axis. That is, each component frequency has a different field pattern.

E. *Better determination of change possible on axis.*—Again recalling the previous discussion of the effect of harmonic structure of the wave on determination of distance-off, it should be apparent why the horn should be pointed in the direction where the signal will be most useful, aside from increased signal intensity. A better determination of change of distance-off is possible along the axis because the higher frequency components of the sound wave are concentrated on the axis.

F. *Special horn types.*—In addition to the single resonators used with the diaphone and with the diaphragm units (fig. 25–36 (a) and (b)), several other types are widely used. They are illustrated in figure 25–37. Not illustrated are the various trumpets, which did not follow an exact pattern but were notable for great length of pipe to which was attached a curved bell or resonator.

G. *Conclusions and discussion as to utility of horn types.*—Based on theoretical considerations verified by extensive tests, the following conclusions have been drawn concerning resonators for air operated sound fog signals. They will affect future planning.

(1) *The standard horn* for the diaphone, illustrated in figure 25–36 (a), is suitable where definite orientation is desired. While the propagation of the strongest frequencies from the diaphone is essentially circular at the surface of the water, a pronounced difference in "quality" of signal is detectable as the listener moves along the axis. This change is not as pronounced at large angles to the axis. Reasons for this are discussed in paragraph (E) above.

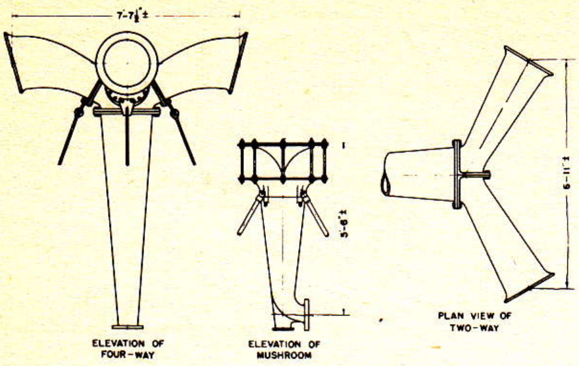


FIGURE 25-37.—Special horns (horns operate in positions shown).

(2) *The mushroom horn* is probably the most effective form for use aboard a lightship. The propagation is essentially circular at all frequencies, and the sound pattern will be good except for interference caused by the ship's superstructure. This unit is suitable at lighthouses located on submarine sites where the signal is useful to navigation throughout a large arc of the horizon.

(3) *The four-way horn* is much heavier than the mushroom horn. It has not been demonstrated as possessing sufficient other advantages to justify its continued use.

(4) *The two-way horn* is used at several installations, especially with the siren. The siren generates a rich harmonic structure similar to that of the diaphone. Further use of the two-way horn is subject to demonstrated desirability for special applications.

(5) *Sound direction vs. resonator length.*—Long resonators direct the sound along the axis not because of their length but because of the favorable ratio of diameter of mouth to wave length of the sound. They are objectionable for two reasons: structurally, their physical size is unwieldy, and, standing waves occur in the resonator.

(6) *Efficient utilization of energy.*—By the foregoing means, better utilization of available sound energy will be had. New fog signaling apparatus will be more efficient due to better conversion from electricity to sound and to better control of field pattern, although it may not generate greater total sound energy. The over-all efficiency of air-operated signals, including the diaphone, siren, and diaphragm horn, is poor. All of them are less than 8 percent efficient. The electric air* oscillator is approximately 20 percent efficient. The minor electric horns manufactured by Wallace and Tiernan Products, Inc., and R. C. A. Victor Corporation are at least 40 percent efficient. Electric motor-driven sirens are more efficient than air-operated sirens.

*In name only, since no air is used.

25–18–50 Table of Fog Signal Data—

A. Following is a table of data for the fog signals in general use at the present time:

Unit	Consumption of free air in cubic feet per second at pressures of—								Distance heard (miles)	
	20 pounds per square inch	25 pounds per square inch	30 pounds per square inch	35 pounds per square inch	40 pounds per square inch	60 pounds per square inch	Power for continuous blast [1] (horsepower)	Class of signal	Average weather	Maximum reported
Diaphone, A				1.0			10	Major	1.5	11
Diaphone, B				2.5			25	do		
Diaphone, CC				4	5		40	do	2	18
Diaphone, F			11	13	15		130	do	4	28
Diaphone, F2T			13	15	17		150	do	5	
Diaphone, G				24			240	do	6	
Diaphone, K				36			360	do		
Diaphragm, 6 inches	0.75	1.0	1.0	1.3	1.3		12.5	Minor	1	
Diaphragm, 8 inches	1	1.25	1.5	2.0	2.3		20	Major	1.5	
Diaphragm, 12 inches	2	2.5	3.0	3.5	4.5		35	do	3	
Diaphragm, 17 inches	4	4.5	5.5	6	7	13	60	do	4	
Triplex diaphragm			9	10	10		100	do	4	15
Siren, 6 inches				13	15	18	130–150	Major	4	
Electric air oscillator							2.5 kw.[2]	Major	3	
Triplex air oscillator							8.0 kw.[2]	do	5	
Nautophone							1.25 kw.[2]	do	.5	
W. and T. horn	3.5 amperes at 15–16 volts						55 watts	Minor	.5	3
R. C. A. horn	3.5 amperes at 15–16 volts						55 watts	do	.5	
Bell	Mechanical striker						0.5 kw	do	.25	
Bell	Solenoid striker at 4 blows per minute						90 watt-hrs per day.	do	.25	

[1] Air-operated signals at 35 lbs.
[2] Blast limited to 20 percent of the time.

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