B.R. 2194

SUBMARINE MACHINERY HANDBOOK

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B.R. 2194 *Submarine Machinery Handbook*, 1960, having been approved by My Lords Commissioners of the Admiralty, is hereby promulgated.

By Command of Their Lordships

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Foreword

This handbook is intended to provide a compact reference containing simple, concise definitions and explanations of the principles behind the design of a submarine and its equipment, and to provide a guide to qualified submariners as to the best methods of operation of machinery and systems. Reference to class differences, materials, sizes, pressures and other details are not made, unless they help in the explanation and understanding of the principles. Details can be obtained from the Class Handbooks, Maker's Handbooks and Ship's Drawings.

Certain features used in the sketches are a departure from usual practice. Each sketch has been built up with the following requirements in mind:—

(a) To be self-explanatory. This necessitates careful illustration of valves, cocks and certain working parts of machines.

(b) To have no arrowed annotations.

(c) To show only the parts mentioned in the sequence notes, all artistic frills being omitted.

(d) To show prominently the parts which achieve the main object, irrespective of their physical size.

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CHAPTER 1

Construction, Tanks, Associated Systems and Machinery

BASIC SUBMARINE CONSTRUCTION (Refer to *Fig. 1*)

Requirement. A vessel which is capable of operating submerged manoeuvring and firing torpedoes under water.

Vessel Submerged

BEST SHAPE. Ideal shape is spherical so that the crushing strain caused by the sea pressure is evenly distributed. Best practical shape is cylindrical with domed ends.

STRENGTH. Depends on pressure hull thickness and "T" section frames spaced about 18 in. apart. Sea pressure (in lb/sq. in.) is approximately half the depth (in feet). Pressure hull designed to withstand 70 per cent more pressure than at normal maximum operating diving depth. Hull is all welded. Holes in the hull, cut to allow for inlet and discharge pipes are always fitted with a hull valve so that continuity of hull can be restored at any time, but particularly on going deep or during depth charge attack.

STABILITY. Maintained by fitting keel with iron or ballast blocks, and arranging as much weight as possible in the lower sections.

MOTION. By propellers, port and starboard, driven by electric motors. Power obtained from large electric batteries. Diesel engines can be used at periscope depth, this is known as "snorting", using an air intake tube.

CONTROL. By a rudder aft for port and starboard movements.

By hydroplanes for up (rise) and down (dive) movements. Set of planes fitted aft and forward to give easier control, each set consisting of a port and starboard pair.

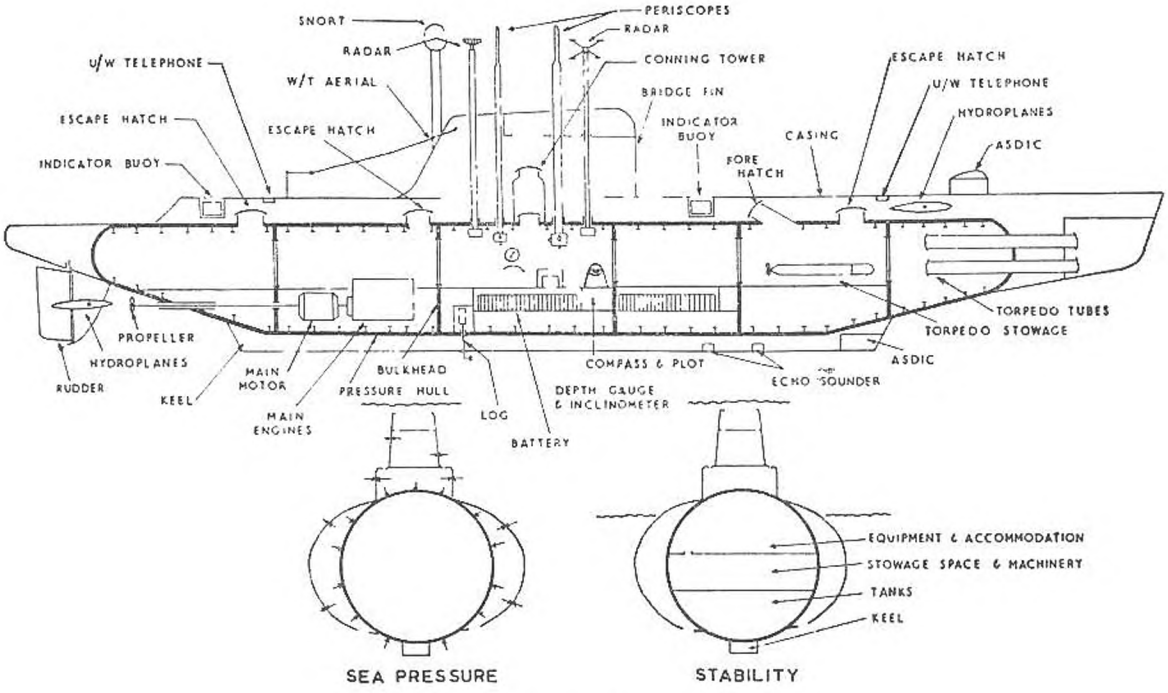


Fig. 1. Basic submarine construction

NAVIGATION. Navigational aids consist of a compass for course, log to measure distance run, plot to show the track, depth gauge to indicate depth in feet of keel below the surface and echo sounder to measure depth of sea bed below the keel. Periscopes, radar, sonar and W/T aids are fitted to assist in navigating the ship and locating the enemy.

WEAPONS. Torpedoes fired from torpedo tubes forward, and sometimes aft. The periscopes are fitted to obtain range and bearing of an enemy target so that the direction in which the submarine must be steered to attack can be worked out. A gun also fitted on a few submarines.

STREAMLINING. A casing covering external fittings and pipes, and a bridge fin covering periscope and radar mast standards, the whole forming a streamline shape for better underwater performance and reduction of "water noise" which gives better asdic listening condition. Holes and projections kept to a minimum. Casing made of light and strong material, usually aluminium.

ESCAPE. Submarine is divided into five or six compartments by fitting main bulkheads. These compartments are known as: tube space, torpedo stowage compartment, accommodation space, control room, engine and motor room, and after ends. Twill trunk escape, by using free ascent and built-in breathing system can be made through hatches in three compartments. Indicator buoys and underwater telephones are provided for getting and keeping contact with surface ships.

BUOYANCY. To enable the submarine to float when surfaced. The total weight of the submarine when dived must be equal to the weight of the volume of water it takes up (or displaces). This is known as "Neutral Buoyancy". If the submarine tends to sink, it is then heavier than the water it is displacing. This is known as negative buoyancy. Any alteration in weight will make the submarine rise or sink and will be indicated on the depth gauge. The deeper the submarine goes, the greater will be the sea pressure on it. The increase in pressure will compress the hull, making its volume smaller. As the total weight of the submarine remains the same, it means that the buoyancy condition gets progressively negative and the submarine will sink faster. Lack of balance will make the submarine angle and will be indicated on an inclinometer placed fore and aft (spirit level). Slight inaccuracies in the weight and balance (trim) can be counteracted by the use of the hydroplanes with varying effect depending on the speed through the water.

Vessel on the Surface

SURFACING. To give the submarine extra buoyancy (positive buoyancy).
Large tanks attached to each side of the pressure hull and like water wings are filled with air. No alteration in total weight is made so that the submerged neutral buoyancy state can be quickly regained by merely letting the surfacing tanks flood up with sea water.

NAVIGATION. Bridge fin fitted with platform with voice pipe and loudspeaker communication to the control room. Conning tower allows access to bridge before the submarine has gained full surface buoyancy, and allows time for the bridge look-out watch to get below when diving quickly. Conning tower hatches are fitted with quick-acting clips with pins for securing positively shut.

ON PASSAGE. Diesel engines used for propelling ahead after being clutched into the main motors. Batteries can be re-charged at the same time by using the motors as generators (running charge), or just enough electricity can be generated to suit submarine's requirements (floating the load).
Porpoise Class are propelled on Diesel/Electric system.

Vessel in Harbour

TROT MOVEMENTS. Manoeuvring for securing alongside when in harbour is effected by using main motors. Main engines are not designed to drive the ship astern. Batteries are re-charged by using the main motor as a generator, the propeller shaft being disconnected (standing charge). (Not applicable to Diesel/Electric propelled vessels.)

CHANGE OF TOTAL WEIGHT. Caused by loading of torpedoes and stores. Before proceeding to sea again, change and distribution of weight must be worked out and compensated for. This process is known as 'putting on a trim".

MAIN BALLAST TANKS—TANK GROUP 1 (Refer to *Fig. 2*).

Object. To surface the submarine quickly and give sufficient positive buoyancy when remaining on the surface.

POSITION. Attached to sides of pressure hull and arranged to give best overall positive buoyancy. Subdivided to reduce effect of free surface. Sometimes additional tanks attached at extreme ends. Tanks numbered from for'd to aft, port and starb. pairs treated as one tank.

CONSTRUCTION. Shape varies according to design requirements. Strength just sufficient to withstand small pressures and for bumping when alongside. Permanent holes are cut into the bottom of the tank (free flood holes). This ensures that sea pressure acts on the inside as well as the outside of the tank.

SURFACING. Water is expelled from the tanks through the free flood holes by admitting compressed air. H.P. air used for initial rapid blowing and L.P. air used to complete blowing when on the surface and conning tower hatch open. Initial rapid blowing necessary to give the submarine a good margin of positive buoyancy so that it does not linger at an unstable condition while surfacing.

DIVING. Each tank is allowed to flood up by venting air from the top through vent valves worked hydraulically from the Control Room. In an emergency the vents can be worked by a lever or handwheel. Vents open inwards so that under normal surface conditions the tank pressure helps to keep the vent valve shut. Surfacing and diving do not alter the overall weight (trim) of the submarine.

SPLIT BLOW TANK. To enable a list to be rapidly corrected especially when surfacing in rough weather. One pair of centrally positioned tanks is fitted so that the H.P. blow (or main vents) can be worked independently.

KINGSTON TANKS. To enable the submarine to remain afloat when in harbour should the main vents be worked accidentally. The free flood holes on a centrally positioned tank are shut off by hand operated flap valves (Kingstons).

BOW BUOYANCY TANK. To keep bows up when on the surface in heavy seas. A small tank situated above the water line right forward, fitted with free flood holes and hydraulically operated vents. A separate hand operated vent is fitted in case the hydraulic pressure fails.

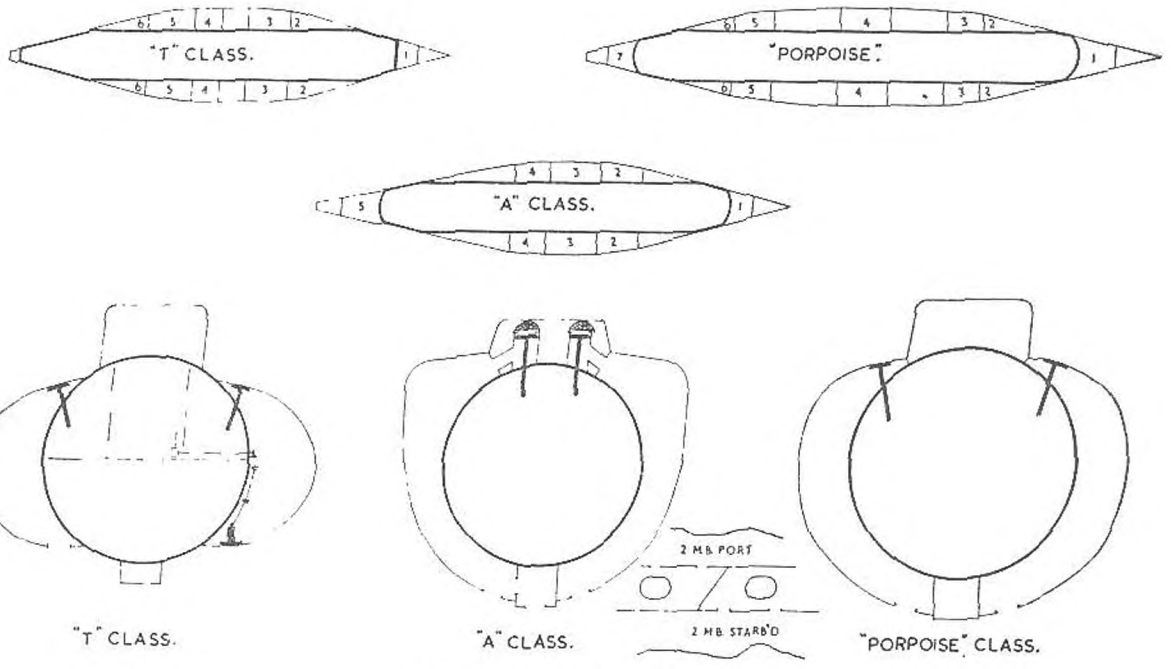


Fig. 2. Main ballast tanks

TYPES OF VALVES AND COCKS (Refer to *Fig. 3*)

SCREW DOWN VALVE (S.D.). Most common valve found on any system and varies considerably in size and design. Gives positive open and shut action. Flow can be regulated by partially opening valve. Fitted so that the source of pressure is on underside of valve.

NON-RETURN VALVE (N.R.). Permits flow in one direction only. A light spring is sometimes fitted to make sure valve reseats especially when fitted in a position where it would normally tend to come off. A *screw-down handle is fitted when a positive shut off is also required.*

SCREW DOWN NON-RETURN VALVE (S.D.N.R.). Fitted where positive shut off is required but flow in one direction only when open.

THREE POSITION VALVE. Gives positive shut and open, but also non-return when the valve handle is only turned half way.

SLUICE VALVE. Fitted where an uninterrupted flow is normally required, but a shut off may be required.

NON-RETURN FLAP VALVE. Permits uninterrupted flow, but in one direction only. A screw down handle is fitted when a positive shut off is required.

HAND OPERATED FLAP VALVE. Fitted when a quick shut off may be required.

SPRING LOADED RELIEF VALVE. Excess pressure will be relieved when the excess pressure overcomes the load of the spring. Sometimes fitted with a screw adjustment to alter tension on the spring for re-setting.

SEA OR DIFFERENTIAL RELIEF VALVE. Permits the relieving of excess pressure which will vary with the depth of the submarine. Excess pressure must overcome spring load plus sea pressure.

STRAIGHT-THROUGH COCK. Suitable for quick and frequent shut/opening. Compact simple design but may tend to become stiff to operate.

"T" AND "L" PORTED COCKS. Suitable for shut off OR change of direction of flow.

OPEN PORTED COCK. Suitable for changing direction of flow with up to four alternative directions. Flow enters centre of cock.

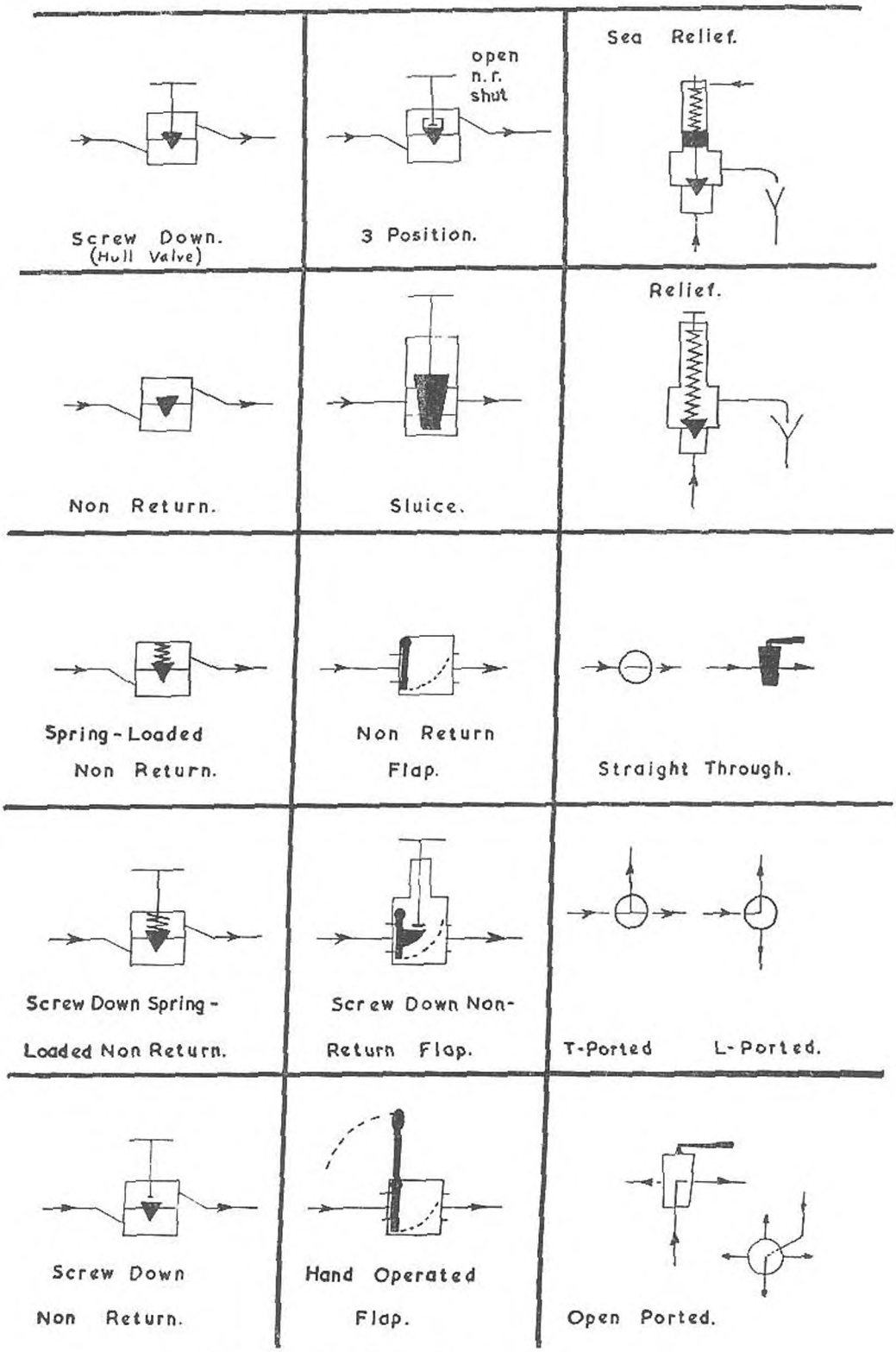


Fig. 3. Types of valves and cocks used in submarines

TANK FITTINGS (Refer to *Fig. 4*)

Object. To fill and empty a tank without damaging it.

(1) FILLING AND EMPTYING. Tank top valve, main line suction or filling valve.

(2) VENTING. Vent cock, either inboard or outboard.

(3) MEASURING. Dip rod (screwed type), gauge glass or contents gauge (Simmonds or Pacitor type).

(4) BLOWING. "T" handled valve for H.P. direct blow or valve with normal handwheel for reduced blow.

(5) CONTROL. Pressure gauge connection.

(6) PROTECTION. Relief valve.

For tanks fitted with reduced blows, pressure gauge and relief valve usually fitted at the blowing station.

Tanks (or systems) that can have direct contact with the sea and can be shut off from the sea are fitted with *differential* pressure gauges and *differential* sea reliefs.

The term "closed" is not to be used; the correct terms are OPEN or SHUT respectively.

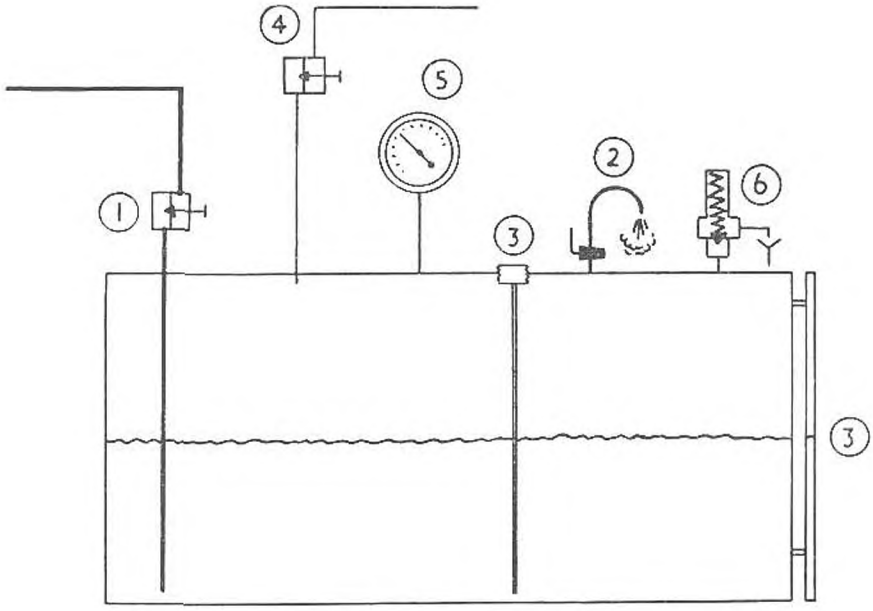


Fig. 4. Tank fittings

TANKS FOR TRIMMING PURPOSES—TANK GROUP 2 (*Refer to Fig. 5*)

Object. (a) In harbour—to provide sufficient tank space to compensate for embarkation of stores, oil, fresh water, personnel, etc. ("Putting on the Trim").

(b) At sea—to provide tank space for making fine adjustments of total weight and distribution of weight so that submarine remains balanced and level when submerged. ("Catching a Trim.")

(a) In harbour

COMPENSATING TANKS. H.M.X.R.W. tanks. Fitted as near as possible to where the changes of weight will occur, i.e. storing ship. When a standby pump is available, reduced blows are not fitted to these tanks.

(b) At sea

CHANGES IN TOTAL WEIGHT

"O" TANKS. Centrally placed, as a pair port and starb. for correcting list. Fitted external to pressure hull either as strengthened portions of a main ballast tank, or separate cylindrical shaped tanks. Adjustment in overall weight is required when entering water of a different density, or when hull is compressed on changing depth ("D" tank Porpoise class). The density of the sea is taken by a hydrometer daily so that buoyancy condition can be anticipated.

CHANGES IN HORIZONTAL BALANCE

"A" AND "Z" TANKS. Situated at each end of the submarine (known as Aux. Ballast tanks). In addition to main line suction and flooding, these tanks can be flooded through a hydraulically operated sea valve (Kingston) and hydraulically operated vent, or blown to sea through the Kingston valve which is designed to act "non-return" as well as "open" or "shut".

TRIM TANKS (submarines not fitted with "A" and "Z" tanks). Positioned near the ends of the submarine inside the pressure hull. A separate trim line is used on these tanks which enables water to be transferred from one to the other.

QUICK CHANGES OF DEPTH

"Q" TANK. Fitted externally in a central position similar to "O" tanks, or slightly for'd in the keel—this tank can be flooded rapidly through a hydraulically operated sea valve (Kingston) and large inboard vent giving the submarine a few tons negative buoyancy. The tank is blown to sea when the required depth is reached. The time taken to dive the submarine from the surface is reduced if "Q" tank is flooded prior to and whilst submerging.

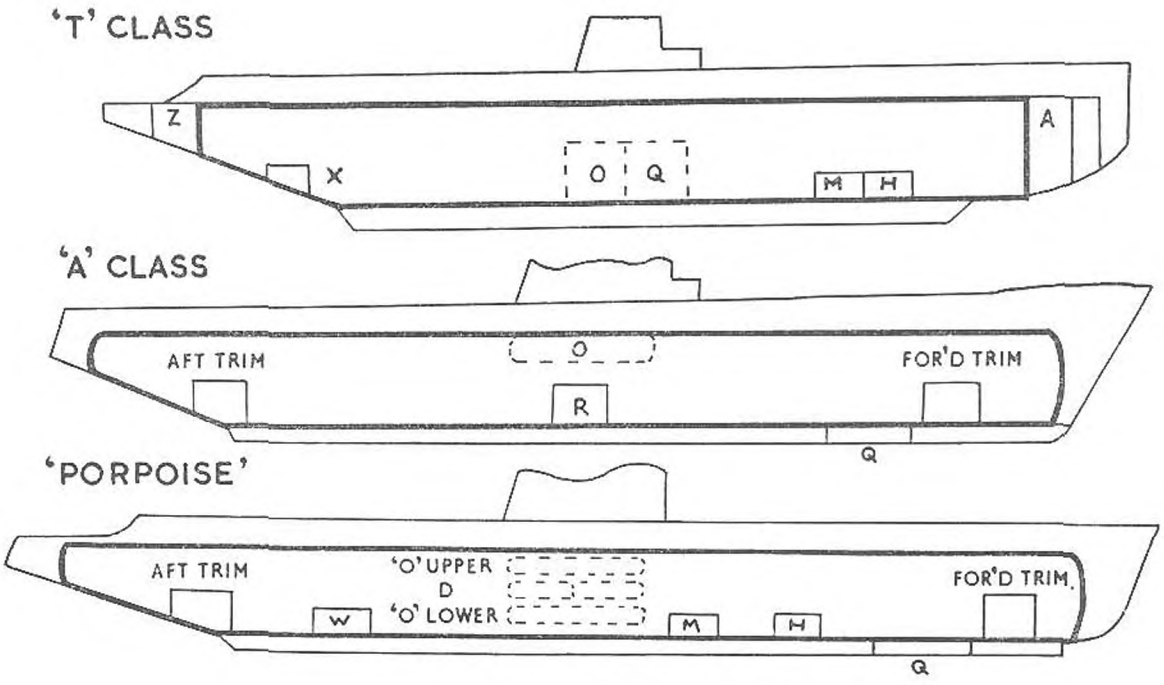


Fig. 5. Tanks used for trimming purposes

TORPEDOES, TORPEDO TUBES AND TANKS—TANK GROUP 3 (Refer to *Fig. 6*)

Object. Main weapon of a submarine to sink enemy surface ships and submarines.

(1) WARHEAD. To contain the explosive charge and detonator.

(2) PROPULSION UNIT. To propel the torpedo. The engine is a small but powerful machine. Contra-rotating propellers and rudders ensure steady motion at the required depth and course.

TORPEDO TUBES (Bow and Stern)

Object. To receive torpedo at inboard end and to enable the torpedo to be discharged out towards the enemy target.

(3) REAR DOOR. To enable torpedo to be loaded into the tube. Hand operated and fitted with safety swing bolt and test cock to prevent door being opened when tube is full of water or open to sea.

(4) BOW CAP. To enable the tube to be shut off from sea. Hydraulically operated and fitted with an indicator. Sometimes interlocked with rear door. Top stop to prevent torpedo sliding out. FIRING GEAR. To discharge the torpedo. A firing lever is pulled which allows H.P. air to enter the rear of the tube, lifting the top stop, and forcing the torpedo forward. The air is shut off automatically. As soon as the torpedo is moving a catch pulls a lever which starts the engine.

TANKS USED WITH TORPEDO TUBES (Refer to *Fig. 6*)

Object. To provide tank space to compensate for weight of torpedoes when embarking, loading and discharging.

(a) **Embarking**

T.O.T. Torpedo operating tank—empty when submarine is loaded with torpedoes and filled as they are expended.

(b) **Loading**

W.R.T. Water round torpedoes—to provide water to fill space round the torpedo. Water is blown up to the tube and all air is vented inboard.

(5) INBOARD VENT PIPE. For venting air inboard when water is blown up to the tube.

(6) HULL VALVE (hot run system). For equalising pressure to enable bow cap to open easily.

(c) **Discharging**

(7) A.I.V. TANK. Automatic inboard vent (open top) to receive the discharge air vented inboard through the A.I.V. COCK before it has a chance to escape to the surface, plus a quantity of water. The tank is open topped. A torpedo plus the water round it in a tube weighs more than that tube full of water only.

(8) H.E.C. HAND EMERGENCY COCK. Fitted in case A.I.V. fails to shut.

(d) **Re-loading**

W.R.T. To receive water from tubes when draining down. Draining can be assisted by a *reduced blow if rapid re-loading is required.*

(9) REDUCED BLOW. Fitted to assist drainage if rapid re-loading is required.

(10) OVERFLOW VALVE. To allow excess water from W.R.T. to overflow into T.O.T.

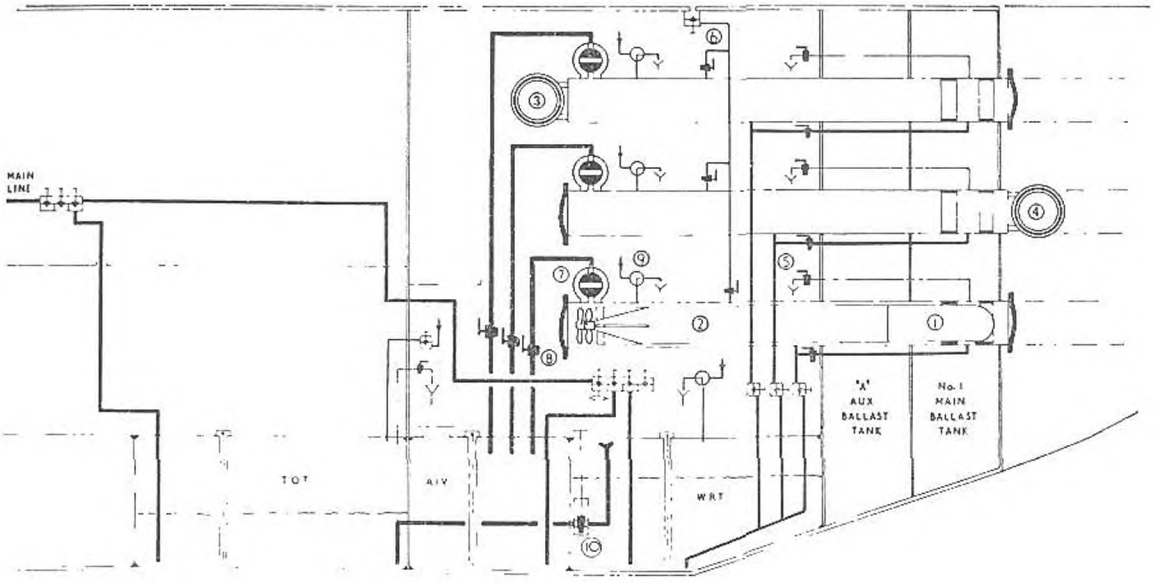


Fig. 6. Torpedo tanks and tubes

TYPICAL MAIN LINE (Refer to *Figs. 7* and *8*)

Objects. (a) To get water, under central control, in and out of tanks used for trimming or compensating purposes.

(b) To get unwanted water out of compartment bilges.

(c) To provide a sea water supply.

(a) Trimming

Refer to *Fig. 7.*

(1) SIX VALVE CHEST. To enable the system to be worked by one man.

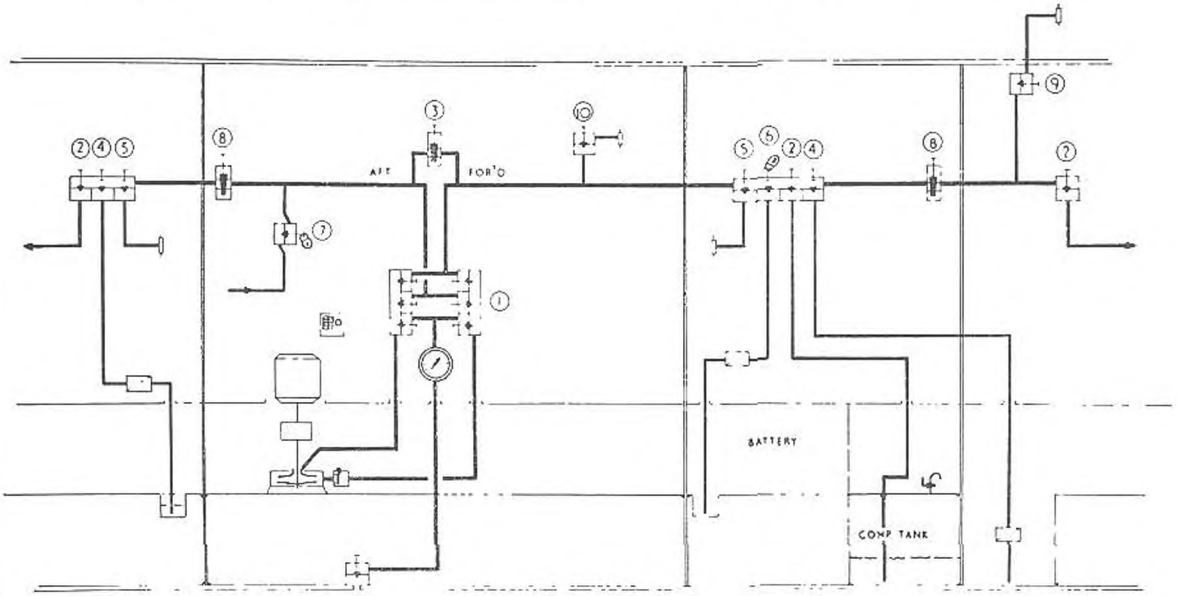


Fig. 7. Typical main line

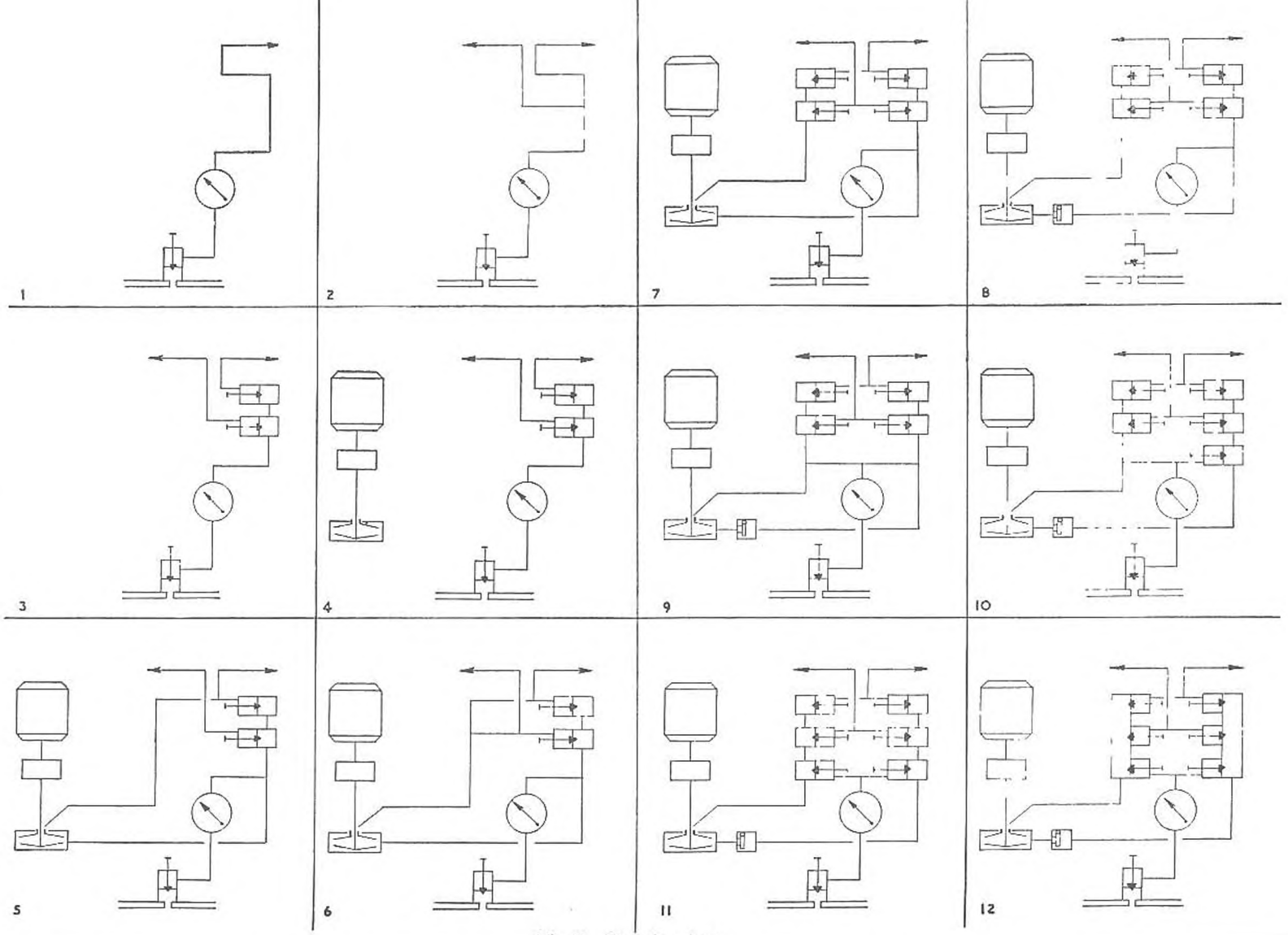


Fig. 8. Six valve chest

Refer to *Fig. 8.*

(1) HULL VALVE, FLOODING LINE FOR'D AND FLOWMETER. To enable the required amount of water to be flooded for'd.

(2) FLOODING LINE AFT. To enable water to be flooded aft.

(3) FLOODING VALVES. To flood for'd, or aft independently.

(4) PUMP (ELECTRICALLY DRIVEN IMPELLER TYPE). To take a suction from inside the submarine and discharge overboard.

(5) SUCTION LINE FOR'D. To take a suction from for'd).

(6) SUCTION LINE AFT. To take a suction from aft and discharge overboard. Flowmeter reversible.

(7) SUCTION VALVES. To take a suction from for'd or aft independently.

(8) NON-RETURN FLAP VALVE. To prevent sea pressure from acting on the pump when flooding.

(9) SEA SUCTION LINE. To take a suction from sea and supply water under pressure to for'd or aft (when cable washing, firefighting or bilge washing, etc.).

(10) PUMP DISCHARGE VALVE. To separate the pump suction from the pump discharge when pumping to the lines.

(11) PUMP SEA SUCTION VALVE. To separate the pump from the sea when taking a suction from the lines.

(12) SIX VALVE CHEST. Valves grouped together to form one box to save space and for quick operation.

Refer to *Fig. 7.*

(2) TANK SUCTIONS (Screw down). To enable each tank to be worked separately. Tank suctions and inboard vents always worked together.

(3) BY-PASS (Sluice). To by-pass the pump (and six valve chest) when another pump is being used. (Ballast pump or trim pump depending on the class of submarine.)

(b) **Suctions**

(4) BILGE SUCTIONS (Screw down non-return)—fitted with strainers. Valves made non-return to prevent flooding back. Suction valves to end compartments situated in the next compartment for emergency pumping out.

(5) HOSE CONNECTIONS (Screw down non-return). To provide in each compartment a convenient connection for a wandering hose for wing bilges, etc.

(6) BATTERY SUCTIONS (Screw down non-return). To remove large quantities of water from battery compartments. Small quantities removed by mopping out the battery tank sump. Valves normally kept *locked* and used only in emergency. *Always* require testing after use to ensure tightness.

(7) OILY BILGE CROSS CONNECTION (Screw down). To enable oily bilge system to be connected to the main line. Valve normally kept *locked* and used only in emergency. (Failure of oily bilge pump.)

(8) STOP VALVES (Sluice). To shut off line in an emergency at each end compartment on the control room side of the bulkhead.

(c) **Sea Water Supply**

(9) CABLE WASH DOWN (Screw down). To provide a water supply for washing down the cable.

(10) ENGINE ROOM HOSE CONNECTION (Screw down). To provide a water supply to wash through engine room bilges.

Valves are being provided for gash ejector flushing and for circulating anti-fouling fluid to aft services and sanitary system.

BALLAST PUMP—2-STAGE (Refer to *Fig. 9*)

Requirement. To enable quantities of water (or oil in emergency) to be discharged to sea from tanks and spaces at any depth, at a rate suitable for trimming.

(1) FIRST IMPELLER. To produce pumping by using centrifugal force. Cannot pump air and will not therefore produce its own initial suction.

(2) MOTOR. To revolve impeller.

(3) SPEED REGULATOR. To vary discharge pressure to suit depth of submarine.

(4) SECOND IMPELLER. To obtain higher discharge pressures without increasing size of pump. Achieved by working in Series with first impeller.

(5) SERIES/PARALLEL BUTTERFLY VALVE. To change the flow of water from Parallel pumping to Series pumping and vice versa.

(6) FLAP VALVES. To enable Parallel pumping (open) and Series pumping (shut). These flap valves work automatically when butterfly valve is operated.

(7) AIR PUMP. To extract air from the suction piping so that water is drawn along and introduced to the impellers. Driven by the motor.

PRINCIPLE OF THE AIR PUMP

A horizontal paddle wheel when stationary sits in a basin of fresh water. The basin is designed so that it is off centre with the paddle wheel.

When the paddle wheel is spun the paddle makes the water spin round with it, and centrifugal force causes it to build up around the side of the basin. A ring of water is now formed which is off centre to the paddle wheel. The level of water in each paddle space is now reciprocating like a piston. This piston effect is used to pump air.

(8) DIP STICK. To check level of fresh water when pump is stopped.

(9) BALL FLOAT VALVE. To prevent water being drawn over to the air pump.

(10) NON-RETURN VALVE. To prevent air re-entering the suction piping when pump is stopped.

(11) SEPARATION CHAMBER. To cause any air coming over with the water to separate off before it can enter the pump.

(12) VACUUM GAUGE.

(13) PRESSURE GAUGE. To indicate that pumping is taking place. Speed of the pump and Series/Parallel control being worked as necessary (Series at approx. 100 ft.).

(14) ON/OFF COCK. To switch air pump off when running for long periods. Normal position is ON.

(15) SNIFTER COCK. To prevent air pump cavitation noise. To be left in the OPEN position.

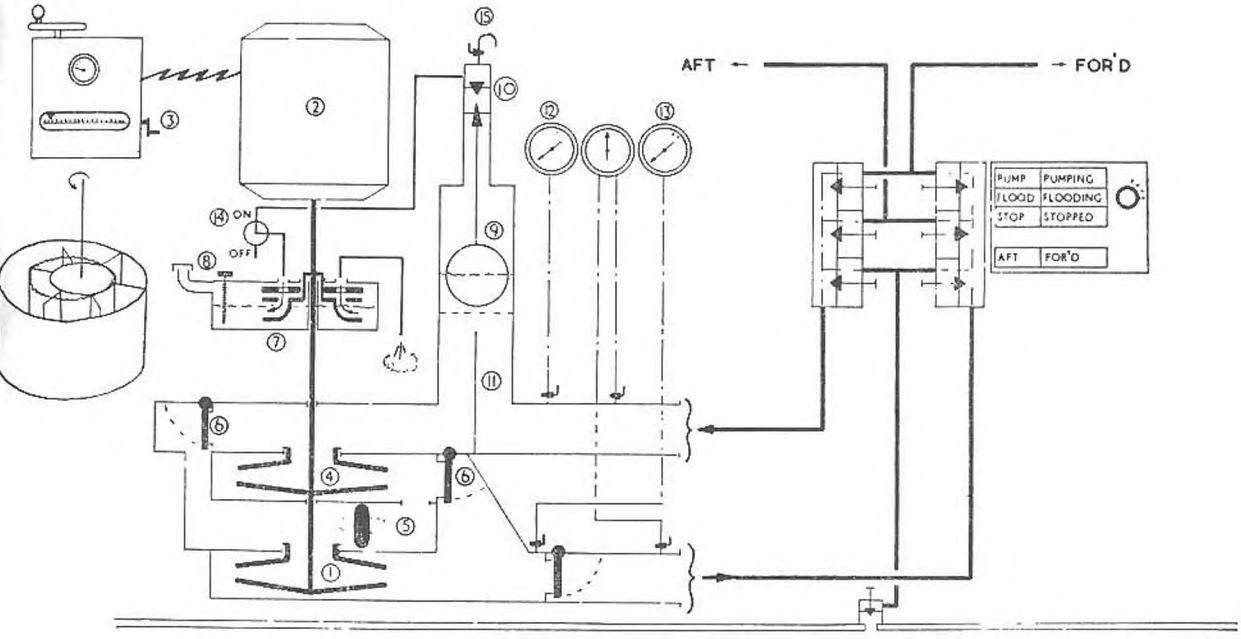


Fig. 9. Ballast pump (2-stage)

BALLAST PUMP—4-STAGE (Refer to *Fig. 10*)

Main Differences in comparison with 2-stage pump

(1) IMPELLERS (four fitted). To obtain greater discharge pressure for later submarines with deeper diving depths.

(2) CHANGE-OVER COCKS. To change the flow of water from parallel pumping to series pumping or vice versa. There are three pumping positions –(a) all parallel, (b) two pairs in parallel, each pair in series, (c) all in series.

(3) GATE CHANGE LEVER. To rotate the change-over cocks, through teleflex leads, for the correct operation of the pump at different depths. Pump is slowed down before changing over.

(4) TACHOMETER. To indicate the speed of the pump in revs. per min.

(5) SERIES/PARALLEL—GAUGE. (a) To indicate depth, (b) to indicate the correct position of the cocks at that depth, (c) to indicate the range of speed at which the pump should be run at that depth to ensure "quiet" running.

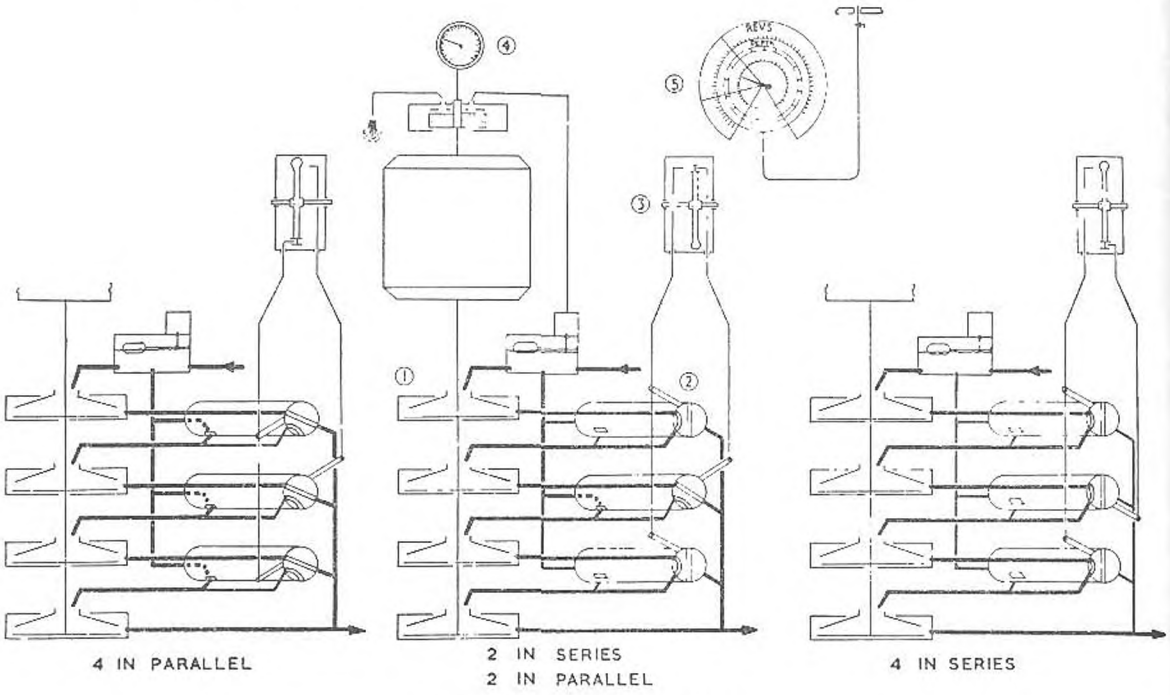


Fig. 10. Ballast pump (4-stage)

TYPICAL OILY BILGE SYSTEM (Refer to *Fig. 11*)

Object. To get unwanted water contaminated with oil out of the submarine.

(1) BILGE SUMPS. To collect oily water at convenient positions in the engine and motor rooms. Gratings fitted over each sump to keep out solid material. An additional sump sometimes fitted in shaft space.

(2) PUMP (centrifugal impeller type). To suck out sumps and discharge overboard. Connected by a line from each sump and thence overboard through a hull valve. Cannot pump below periscope depth.

(3) SHUT OFF VALVES (S.D.N.R.). To enable each sump to be pumped separately. Non-return to prevent flooding back when pump is stopped.

(4) STRAINER. To prevent small solids (matchsticks, paint flakes, paper) passing into the pump. Can be cleaned by removing and clearing perforated plate.

(5) SUCTION HOSE CONNECTION. To enable odd corners to be pumped out by using wandering hose.

(6) DISCHARGE HOSE CONNECTION. To enable oily water to be discharged to a lighter when in harbour.

(7) FLAP VALVE. To prevent sea water flooding into submarine should discharge hose connection be left open.

(8) MAIN LINE CROSS CONNECTION. To enable oily bilges to be pumped out by using the ballast pump. Valve normally kept locked and used only in an emergency.

MOTOR ROOM BILGE ALARM. To indicate when too much water is collecting in the Motor Room bilge. This is necessary to ensure that the main motors do not become flooded. A float switch in the bilge will operate a buzzer and light in the Control Room.

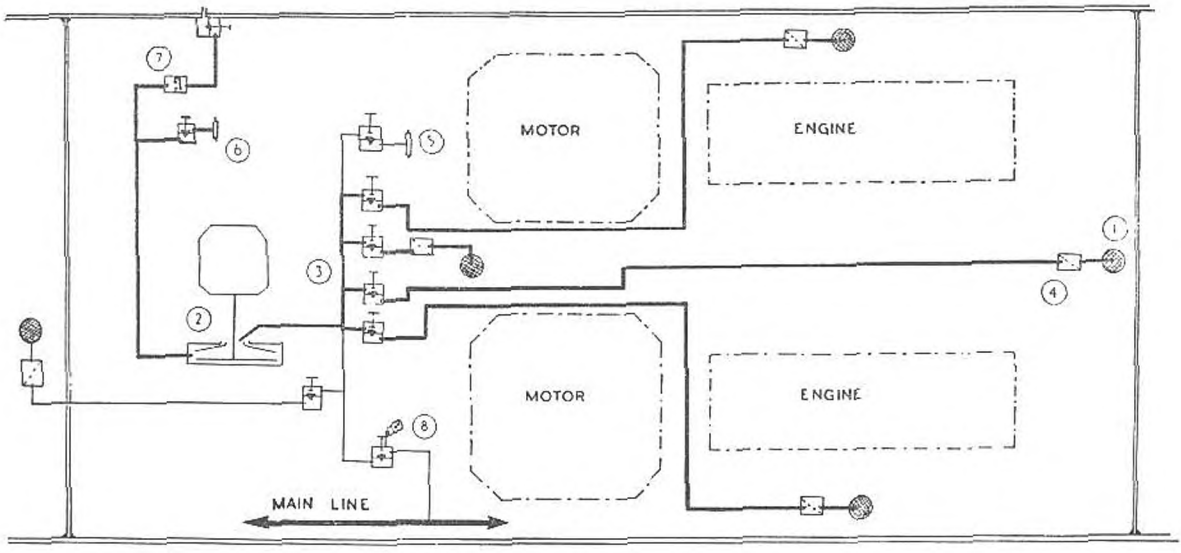


Fig. 11. Typical oily bilge system

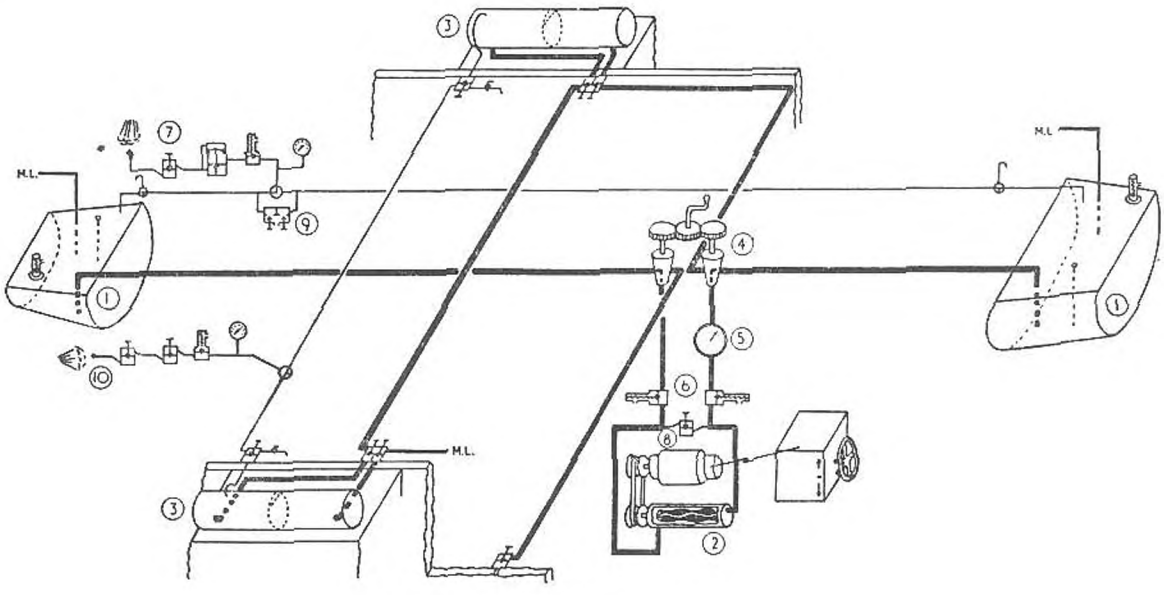


Fig. 12. Trim line

TRIM LINE (Refer to *Fig. 12*)
(applicable only to submarines fitted with trim tanks)

Object. To provide a simple system for adjusting the trim with *central control* and a *silent pump.*

(1) TRIM TANKS. For adjusting fore and aft trim (horizontal balance). Fitted with main line connection (for initial introduction of water), vent and dip rod.

(2) TRIM PUMP (Mono type). To transfer water between the trim tanks in either direction. This pump must never be run dry as rubber stator will be damaged.

(3) "O" TANKS (port and starb.). For adjusting bodily trim (overall weight). Long cylindrical tanks sub-divided to reduce free surface. Fitted with main line connection (for initial introduction of water), contents gauge and inboard vent.

(4) CONTROL COCKS. To provide a means of putting the trim pump *either* on the trim tanks *or* "O" tanks. Cocks are geared together and worked by one handwheel in the control room. Trim tanks cannot be connected to "O" tanks.

(5) FLOWMETER. To measure amount transferred.

(6) RELIEF VALVES. To protect "O" tanks, pump and system against excess pressure. Trim tanks have their own relief valves due to their comparatively light construction.

(7) REDUCED BLOW. To provide an alternative means of transferring water between trim tanks.

(8) PUMP BY-PASS. To facilitate transfer of water when using reduced blows.

(9) VENTS. To enable trim tanks to be vented in the control room. Change over cocks fitted on trim tank local vents.

(10) REDUCED BLOW. To provide an alternative means of emptying "O" tanks. Combined vent and blow fitted.

TRIM PUMP (MONO) (Refer to *Fig. 13*)

Requirements. To enable quantities of water to be pumped in either direction quietly at any depth and at a rate suitable for trimming.

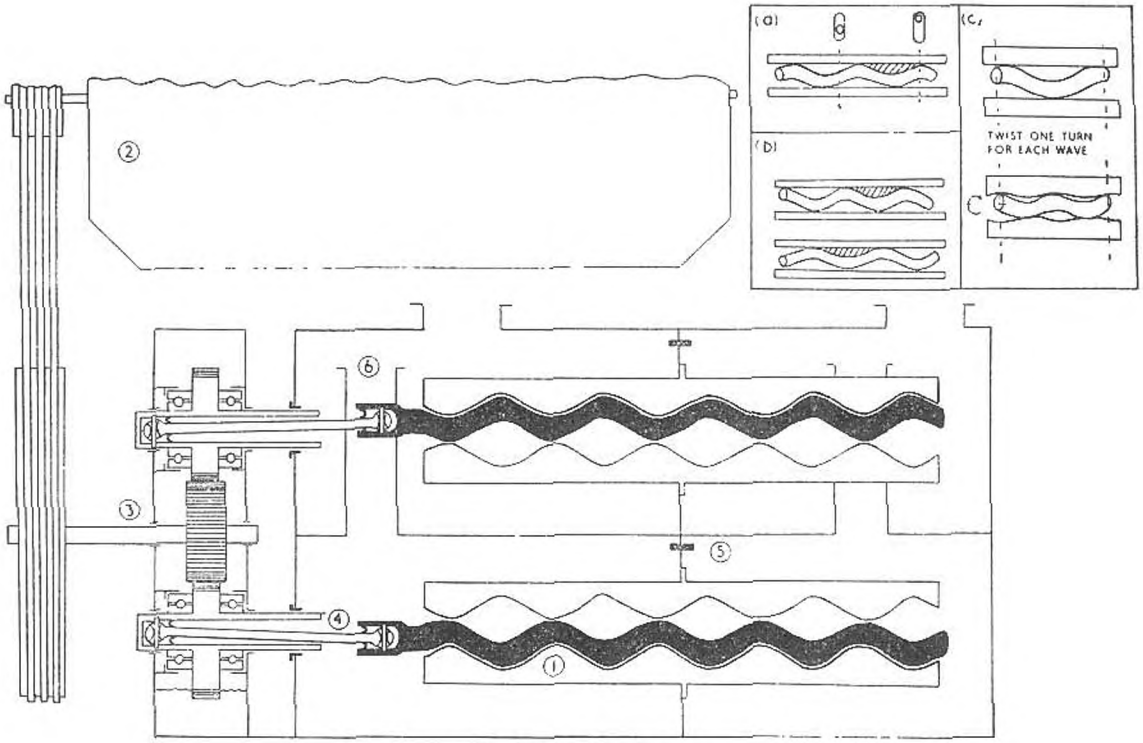


Fig. 13. Trim (Mono) pump

(1) ROTOR AND RUBBER STATOR. To produce the pumping action. Four such units are fitted so that a sufficient pumping rate is obtained. The units are enclosed and each end separated by a division plate. The pump action is silent. Direction of flow depends on the direction of rotation of the rotor.

Principle

(*a*) Consider a flexible length of rod bent in wave form and a sleeve round it shaped so that the sides are flat and the top and bottom curved to fit the rod at the crests of the waves. Each wave of the rod will form an enclosed pocket.

(*b*) Each pocket will move along the sleeve if the rod can be made to writhe in the hole in such a manner that every part of the rod moves in its turn back and forth across the width of the hole. New waves will be continuously formed and follow one another.

This same wave action can be produced by using a rigid rod (rotor) and a rubber sleeve (stator) provided they are re-shaped by twisting.

(*c*) Consider the wavy rod resting in the sleeve. Twist rotor and stator together, one turn for each wave. Now by rotating the rotor, the writhing action will again take place and the pockets move along in the same manner as before except that they will have a spiral, instead of a straight path, because the sleeve is now in spiral form.

(2) MOTOR. To drive the rotors.

(3) GEAR DRIVE. To rotate all four rotors together. The rotors are mounted in a form of a square, each one geared to a central gear wheel which is driven by the motor through a belt drive. To reduce gear noise, the wheels have a rubber sleeve between the teeth and the shaft. All wheels are mounted on ball bearings and lubricated by oil in the sump.

(4) COUPLING ROD. To allow the rotors to carry out a transverse wave-motion as well as rotate. Each end of the rod is fitted with a universal coupling.

(5) BY-PASS NOZZLE. To prevent the pumping units running dry when the pump loses suction. A small amount of water is allowed to re-circulate through a nozzle in the division plate, which is protected from blockage by a small strainer.

(6) WEIR. To keep the top units always immersed in water. It is most important that the units are kept wet in order to prevent seizure or damage to the rubber stators.

INTERNAL AND EXTERNAL FUEL TANKS—TANK GROUP 4 (Refer to *Fig. 14*)

Objects. (a) To provide a stowage for fuel; (b) to compensate for fuel used.

(1) GROUP. Large tank sub-divided for strength and to reduce free surface effect.

(2) FIRST FILLING. To first fill the group with water.

(3) SUBSEQUENT FILLING. To subsequently fill the group with fuel, water being discharged overboard through the first filling pipe.

(4) SYPHON PIPE. To connect adjacent tanks.

(5) RELIEF VALVE. To protect the tanks against excess pressure whilst fuelling.

(6) FUEL SUPPLY TO ENGINES.

(7) COMPENSATING WATER. To replace the fuel with water. Supplied from the engine circulating water system. Only a small pressure (up to 5 lb/sq. in.) required. Pressure gauge fitted on fuel supply to engines.

(8) TEST COCKS. To provide a ready means of estimating the amount of fuel left in the group.

(9) REDUCED BLOW. To provide a means of emptying the group. Normally used in harbour discharging through the first filling pipe.

(10) EMERGENCY HOSE CONNECTION. To enable the groups to be emptied in emergency through the main line. Additional hose connections sometimes fitted on the first filling pipes of internal groups.

(11) SUBSEQUENT FILLING VALVE CHEST and COMPENSATING WATER VALVE CHEST. Situated in the engine room to facilitate a quick changeover of *internal* groups. A shut off valve also fitted for external groups.

EQUALISING SYSTEM

Object. To connect the bottom of the tank with the sea in order to release excess pressure due to changes of depth or changes of temperature.

(12) EQUALISING VALVES. To enable compensating water pressure to be supplied and at the same time release excess differences of pressure. System led to the bottom of the tank where water is always present due to shortening of the first filling pipes. Differential gauge fitted to show difference of pressure each side of the valves.

(13) SEA RELIEF VALVE. An additional safeguard against excess pressure **inside** the tank.

SUB-PRESSURE SYSTEM

Object. To prevent fuel escaping to the surface due to slight damage to the tank (depth charging, bullet holes, etc.).

(14) SUB-PRESSURE PUMP. To take a suction from the bottom of the tank and discharge overboard.

(15) FINE ADJUSTMENT VALVE. To regulate the difference in pressure by giving the pump a secondary suction from the circulating water system. Differential gauge fitted to show difference of pressure between tank and sea.

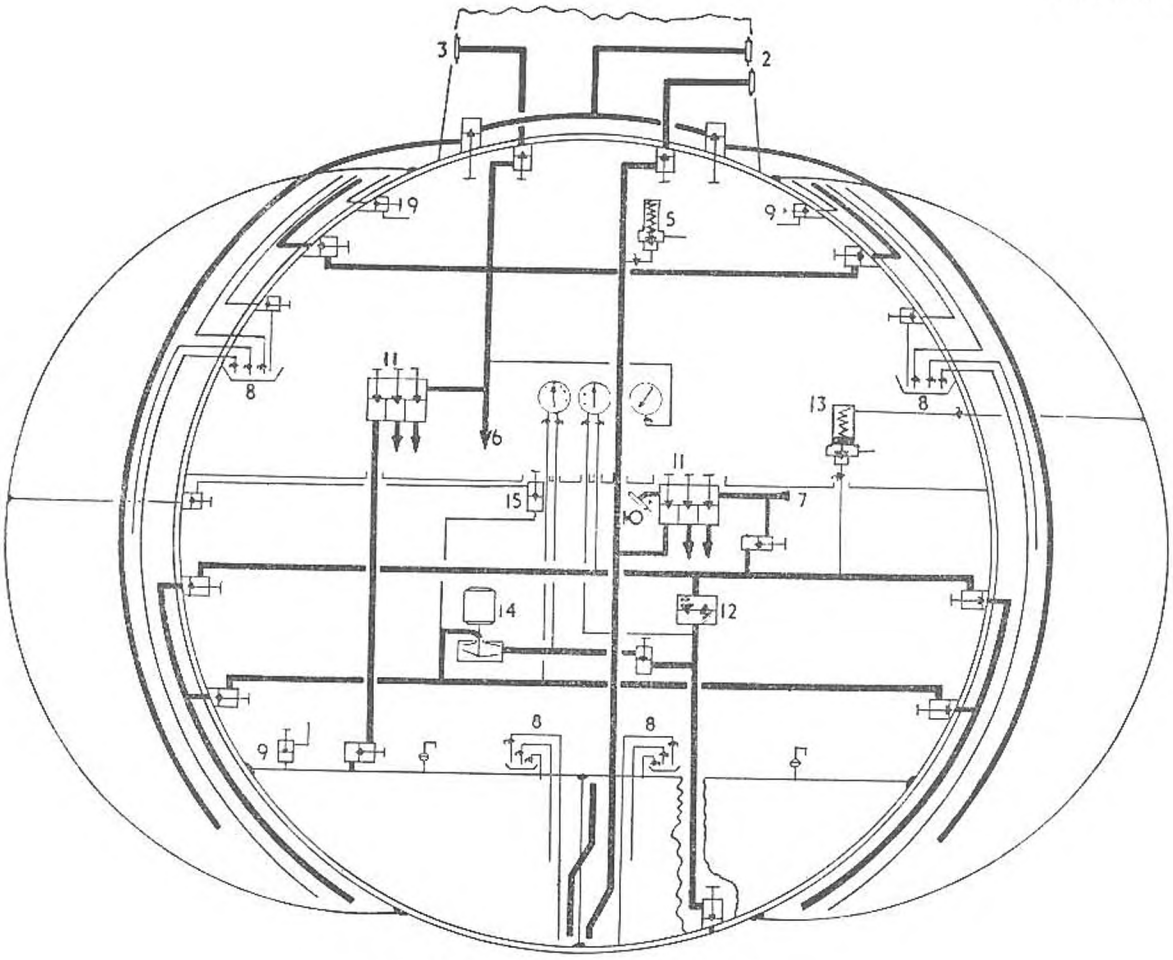


Fig. 14. Internal and external fuel tanks

LUBRICATING OIL TANKS AND SYSTEM—TANK GROUP 4 (Refer to *Fig. 15*)

Objects. (a) To provide a tank to hold sufficient oil for circulating through main engines and to provide a stowage for clean oil to make good oil used by the engines and for topping up other machines and fittings;

(b) To maintain the oil in the tanks in a fit state for use.

(a) **Storage**

(1) DRAIN OIL TANK (D.O.T.). To collect oil being used in the engines for re-circulation. Fitted with a vent and dip rod. Engine sump drain can be isolated from tank by a sluice valve. Extension pipe led below oil surface to reduce fire risk from crankcase explosion.

(2) RESERVE LUBRICATING OIL TANKS (R.O.T.). To contain sufficient oil in reserve to keep D.O.T. topped up, supply other machines and fittings, and enable the oil in the D.O.T. to be completely changed. Usually two or three tanks; fitted with vent, dip rod, reduced blow and handpump.

(3) LUBRICATING OIL FILLING LINE. To fill all tanks. (Hose connection sometimes fitted *inside* the submarine near engine room hatch.)

(b) **Separating**

(4) CENTRIFUGAL SEPARATOR. To extract water, small solids and carbon deposits from the lubricating oil. Run continuously on the D.O.T. when the engines are running. Used on the R.O.T. as required.

(5) HEATER. To heat the oil to obtain the correct viscosity.

(6) HEATER SWITCHES. To control the temperature of the oil entering the separator. All switches ON when starting up, switched off as necessary to maintain the correct temperature (150–160°F.).

(7) DIAL THERMOMETER. To indicate the temperature of the oil entering the separator.

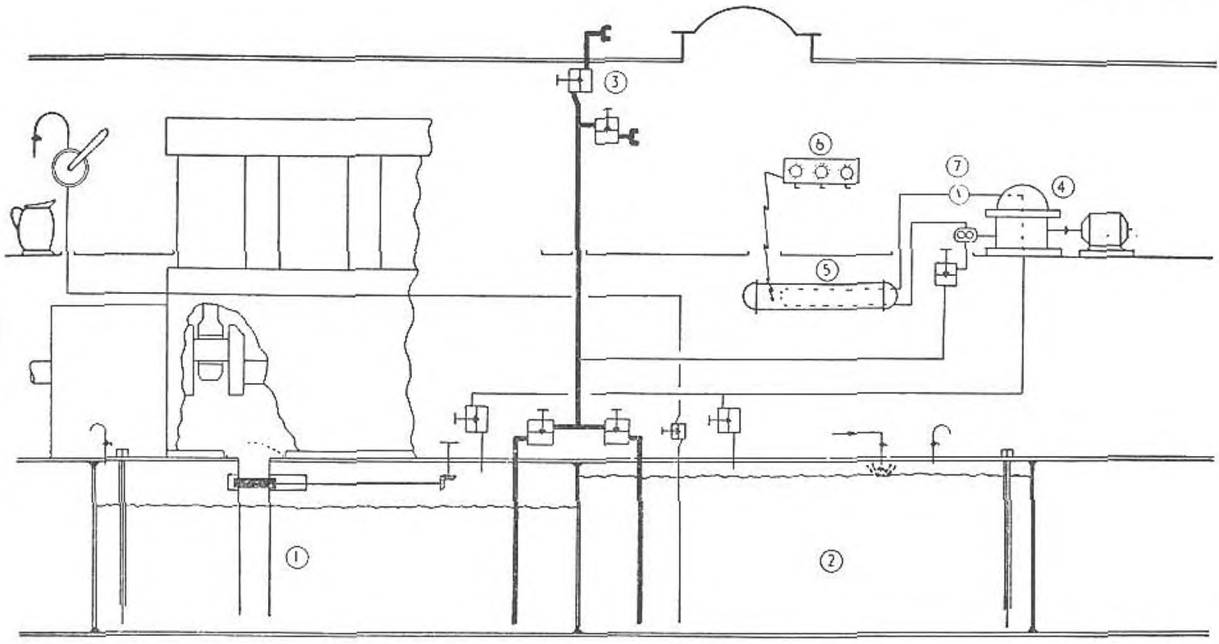


Fig. 15. Lubricating oil tanks

CENTRIFUGAL SEPARATOR (Refer to *Fig. 16*)

Requirement. To receive a continuous flow of dirty oil, separate out unwanted matter and deliver oil fit for use at a rate to suit main engine requirements.

(1) BOWL. To extract water, dirt and carbon from the fuel or lubricating oil.

Principle

(*a*) Consider a settling tank with partition plate. Oil and water levels are at different heights owing to different specific gravities. Solid matter falls to the bottom. To reduce unnecessary disturbance, mixture is introduced at separation level. The mixture is poured in very slowly, the separated liquids will overflow at the different levels.

(*b*) To increase the amount of mixture flowing in without increasing the disturbance, sub-divide the tank into a series of vertical layers by plates. Cut a hole in each plate at separation level to allow mixture to flow along and enter each layer; this is similar to a football crowd queuing along a street and turning in to enter the ground through a set of turnstiles.

(*c*) Flow of mixture is required to be continuous. Complete separation cannot be expected to take place before the liquids enter the layers. Jostling will take place between globules of water trying to travel downwards and oil trying to move upwards. To induce each liquid to flow unhindered in opposite directions within each layer, like "keep left" on the road, plates are inclined. Water tends to fall and takes the lower side, oil rises to take the upper side.

(*d*) Normal gravity pull too slow. Just as a bucket of water can be swung round at arms length without spilling, *tank is whirled round at high speed producing centrifugal force equivalent to* a gravity pull many times greater than normal which speeds up separation considerably.

(*e*) Shape of tank can be converted to a cylindrical or bowl form. To keep the liquid turning with the bowl, the layers, which will now be cone shaped, are fitted with radial strips. Mixture still introduced at separation level and separated liquids will overflow at the same difference of levels as in the settling tank.

(2) DRIVING SPINDLE. To support bowl. Held in two bearings and weight taken on ball thrust bearing.

(3) MOTOR. To drive spindle and bowl at high speed (8,000 rev./min.) through gears. Fitted with centrifugal clutch to allow gradual speeding up of bowl.

(4) TONGUE AND SLOT. To allow bowl to be easily removed for cleaning.

(5) SIGHT GLASS. For observing water discharge.

(6) SIGHT GLASS. For observing oil discharge.

(7) PUMP (Gearwheel type). To supply lubricating oil to separator (or discharge fuel oil to gravity tank). Driven from motor shaft. Regulating valve fitted to adjust flow in order to prevent overflowing of bowl.

(8) SPEED INDICATOR. To check R.P.M. of bowl (1/100 bowl speed).

(9) SUMP SIGHT GLASS. To check level of gearwheel lubricating oil.

(10) SHEARING PINS. To prevent damage to shafts and gears should motor overload or pump seize.

(11) BRAKE. To slow down bowl quickly.

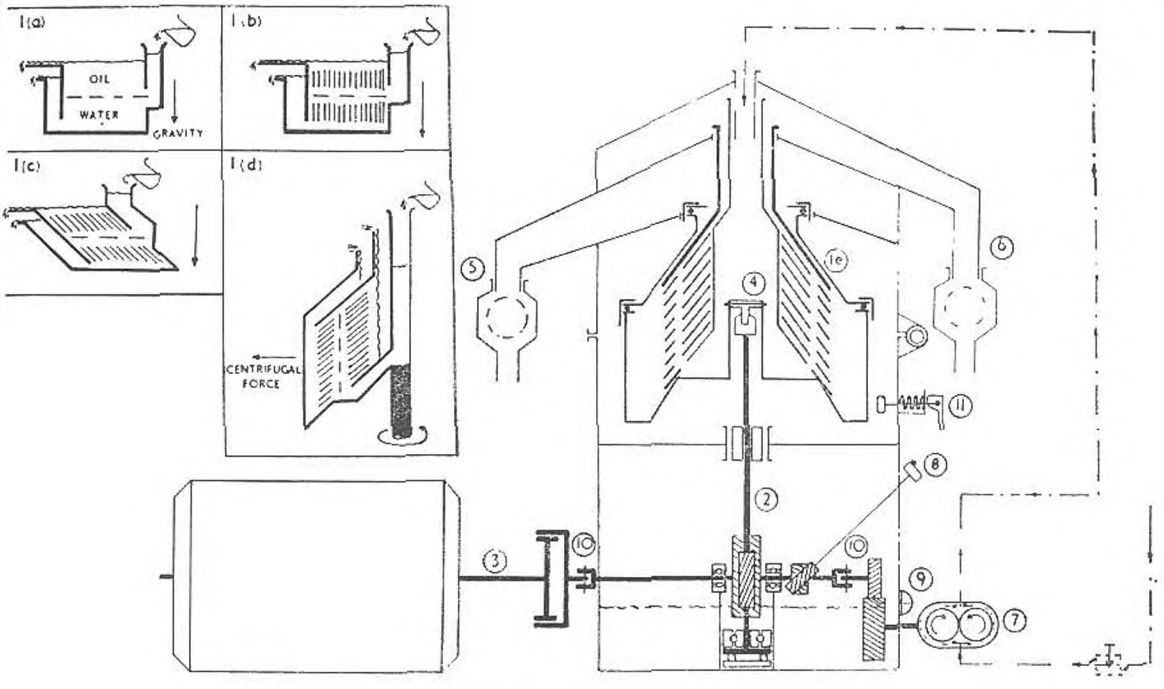


Fig. 16. Centrifugal separator

FRESH WATER, DISTILLED WATER AND SLOP DRAIN TANKS—TANK GROUP 5

Objects. (a) To provide tanks to carry as much fresh water as possible.

(b) To supply hot and cold water to bathrooms, galley and pantry.

FRESH WATER TANKS (Refer to *Fig. 17*)

(a) **Storage**

(1) FRESH WATER TANKS. To contain the fresh water. Tanks are of varying shape and size and fitted where there is room amongst other tanks. Some compensating tanks have been converted to carry fresh water. Coated with Rosbonite to prevent water becoming contaminated by rust or growth.

(2) FILLING LINE. To fill all tanks with fresh water (hose connection on outside of hull).

(3) RELIEF VALVE. To protect tanks and system against excess pressure.

(b) **Supply**

(4) SUPPLY LINE. To supply fresh water to handbasins, sinks and urns.

(5) HEATER. To provide hot water at the handbasins and sinks. Fitted with a thermostat switch and safety valve.

(6) REDUCED BLOWING STATION. To supply a small air pressure to each tank to force water through supply line. Pressure must be released before taking a dip.

(7) STRAINER. To prevent loose Rosbonite entering the supply line.

DISTILLED WATER TANKS

Object. To carry distilled water to make good losses in the battery cell electrolite (through evaporation and hydrogen evolution). To replenish battery cooling system. To replenish main engine cooling system (in submarines using distilled water).

Storage

Similar to fresh water tanks.

Filling

Tanks filled from Depot Ship gravity tank or by handpump. No relief valve necessary.

Supply

Reduced blow feeds water through supply line and flexible topping up hose with bowser valve to the battery cells.

SLOP DRAIN TANKS (applicable also to Sewage Tanks) (Refer to *Fig. 17*)

Objects. (a) To collect waste water (or sewage) in a tank.

(b) To enable waste water (or sewage) to be discharged overboard when operational requirements allow.

(a) **Storage**

(8) SLOP DRAIN TANK. To collect waste water. Situated beneath bathroom.

(9) STRAINER. To prevent solids (lumps of soap, hair, potato peelings) from entering the tank.

(b) **Disposal**

(10) DRAIN VALVE. To shut off handbasins when emptying the tank.

(11) HULL VALVE. To provide an outlet to sea. Sluice type to allow uninterrupted opening.

(12) INTERMEDIATE FLAP VALVE. To prevent the sea from entering the tank when the hull valve is opened.

(13) REDUCED BLOWING STATION. To supply air pressure to the tank for discharging against sea pressure.

(14) OUTBOARD VENT. To vent away most of the blowing air.

(15) INBOARD VENT. To complete venting of the tank. Vent must be left *open*. Smell reduced by de-odouriser.

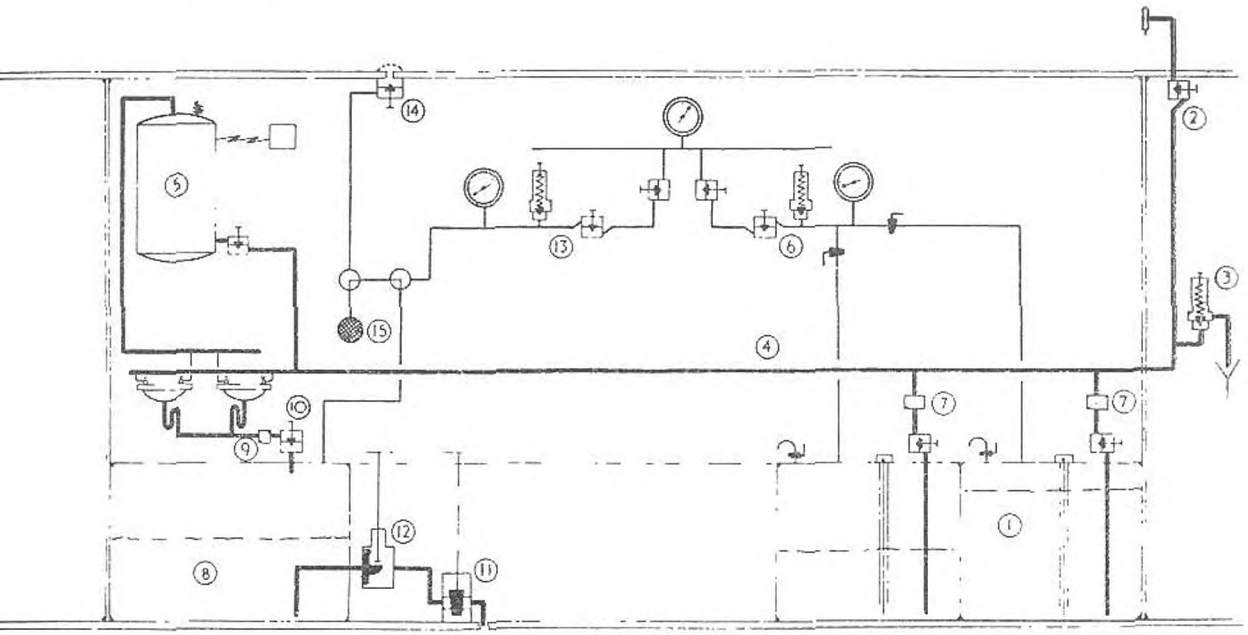


Fig. 17. Typical systems for fresh water and slop drain tanks

TYPICAL SANITARY SYSTEM (Refer to *Fig. 18*)

Object. To enable sewage to be flushed and discharged overboard.

Flushing

(1) LAVATORY PAN.

(2) SEWAGE BOWL. To collect sewage ready for discharge. (In later classes of submarine the sewage is collected in a tank and is blown overboard as convenient as in the slop drain tank.

(3) FLUSHING TANK. To provide a small supply of flushing water with gravity feed. Tank is replenished automatically through a ball float valve from the flushing water supply system.

(4) FLUSHING VALVE. To control the amount of flushing.

Discharging

(5) HULL VALVE. To provide a sea connection for the sewage bowl. Sluice type to allow uninterrupted opening.

(6) INTERMEDIATE VALVE (Screw down flap). To prevent sea flooding back into sewage bowl.

(7) FLAP VALVE. To shut off sewage bowl from the pan so that a discharge pressure can be applied.

(8) AIR BOTTLE. To hold sufficient compressed air to discharge sewage overboard.

(9) REDUCED BLOW. To top up air bottle. Differential gauge fitted between bottle and sea. Usual pressure used is 15 lb/sq. in. above sea pressure. Relief valve fitted to relieve excess pressures.

(10) BLOW VALVE. To control the application of discharge pressure to sewage bowl.

(11) VENT VALVE. To vent air pressure in bowl after discharging, or before attempting to flush.

(12) HAND LEVER. To work flush, flap valve, blow and vent in the proper sequence.

Back halfway	—vent open.
Back fully	—flap opens, flush valve opens.
Central	—flush valve shuts, flap shuts.
Forward fully	—blow valve opens.
Forward halfway	—blow valve shuts, vent opens.
Central	—ready for use.

Flushing Water Supply

(13) FLUSHING SUPPLY LINE. To keep flushing tanks topped up with sea water through hull valve. Fitted with hose connection to provide a means of introducing anti-fouling solution from the main line.

(14) AUTOMATIC REDUCING VALVE. To reduce sea pressure to 15 lb/sq. in.

(15) PUMP (very small vane type). To provide pressure when sea pressure is less than 15 lb/sq. in., i.e. when on the surface.

(16) PRESSURE SWITCH. To start and stop the pump; cuts in at 10 lb/sq. in. and cuts out at 15 lb/sq. in.

(17) N.R. VALVE. To prevent loss of pressure back to suction when pumping.

(18) N.R. VALVE. To prevent loss of pressure back to sea when pump is stopped.

(19) BOTTLE RESERVOIR. To provide a reserve of pressure so that pump is not stopping and starting too frequently.

(20) RELIEF VALVE. To protect pump against excess pressures.

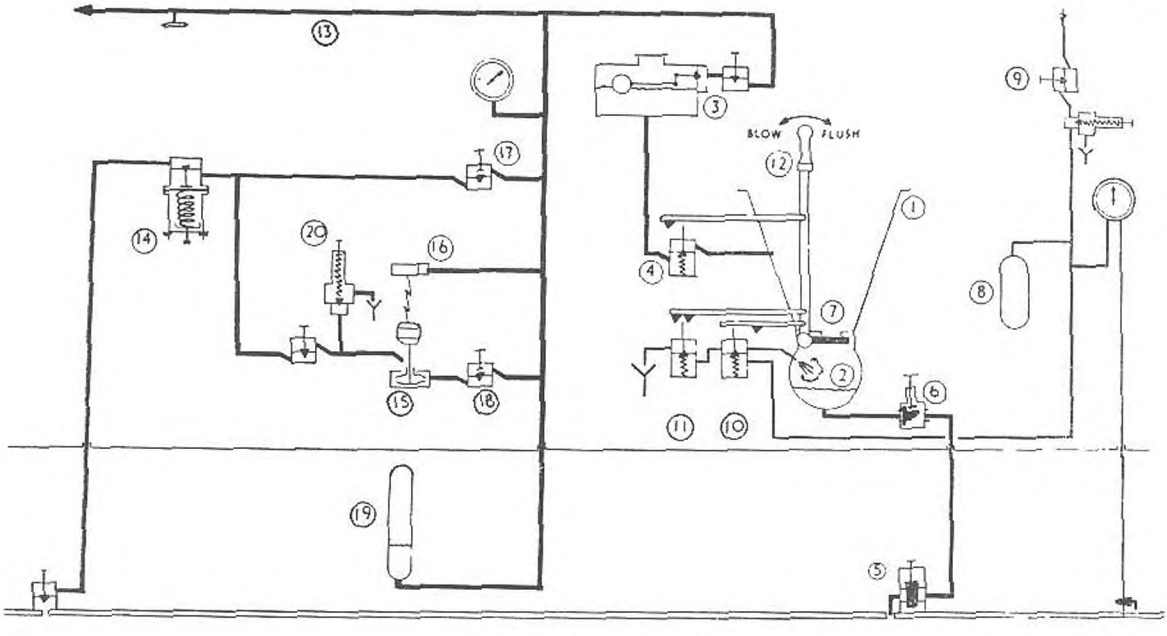


Fig. 18. Typical sanitary system

CHAPTER 2

Air and Hydraulic Systems and Machinery

TYPICAL H.P. AIR SYSTEM (Refer to *Fig. 19*)

Objects. (a) To connect H.P. air bottle groups to the main ballast tanks for surfacing the submarine.

(b) To connect H.P. air compressors to the bottle groups for topping up.

(c) To supply air operated fittings and services with H.P. or reduced air pressure.

(a) **Blowing Main Ballast Tanks**

(1) BOTTLE GROUP. To store air at high pressure (up to 4,000 lb/sq. in.). Each bottle fitted with a shut off valve, pressure gauge and drain valve. Connected by a line to Main Ballast Tanks.

(2) H.P. TANKSIDE VALVE (spring loaded screw down non-return). To shut off air line at the hull, and, as a N.R. valve, to prevent water from entering the line when M.B. Tanks are flooded. Spring loaded to make sure valve re-seats after blowing the tank.

(3) DIRECT BLOWING PANEL. To enable M.B. Tanks, NOT FITTED WITH KINGSTONS, to be blown from a central position (control room). Screw down valves fitted with "T" handles for quick operation. Each valve admits air to a M.B. Tank, port and starboard together where applicable. An amidships tank can be blown separately port and starboard (Split Blow). Fitted with panel shut off valve, pressure gauge and drain. There are four (or five) bottle groups fitted and each group can be connected individually to the panel. Direct blows are also fitted to "A", "Z", "Q" and "D" tanks. To protect these tanks against excess pressure, sea relief valves are fitted.

(4) H.P. TO L.P. (emergency blowing station). To blow M.B. tanks with H.P. air in an emergency should the direct blowing panel be out of action. Fitted with master valve, working valve with a spoked handle and differential pressure gauge so that blowing can be limited to 15 lb/sq. in. above sea pressure.

(b) **Topping up Bottle Groups**

(5) COMPRESSOR. To compress the air to be stored in the bottle groups. Takes air from inside the submarine, but conning tower hatches must be open or snort induction opened up. Connected by a line to the bottle groups.

(6) SEPARATOR COLUMN. To collect any water or oil passed over by the compressor. Fitted with drain valve and pressure gauge.

(7) COMPRESSOR SHUT OFF VALVE (screw down non-return). To prevent pressure coming back and acting on the compressor when it is being stopped.

(8) SHORE CHARGING CONNECTION (screw down non-return). To enable bottle groups to be topped up from depot ship compressors. Hose connection situated outside the pressure hull. Valve non-return to prevent loss of air should hose break or become disconnected. Small drain valve fitted, which is left open, to keep air pressure off hull valve.

(c) **Supply to fittings and Services**

(9) RING MAINS. To supply H.P. throughout the submarine for air operated fittings and services. In the event of damage, sections can be isolated using shut off valves on the control room side of each bulkhead. Sometimes cross connections fitted in each compartment to enable air to be supplied from undamaged section of the main.

(10) REDUCED BLOW PANEL (10 to 200 lb/sq. in.). To supply air at a reduced pressure to fittings and services not operated by H.P. air. Consists of master valve, relief valve, pressure gauge and shut off valve or cock for each fitting or service.

(11) COMPARTMENT BLOWS (salvage blows). To enable holed compartments to be blown out. A direct blow to each compartment with the valve on the control room side of the bulkhead and an open end on the other side.

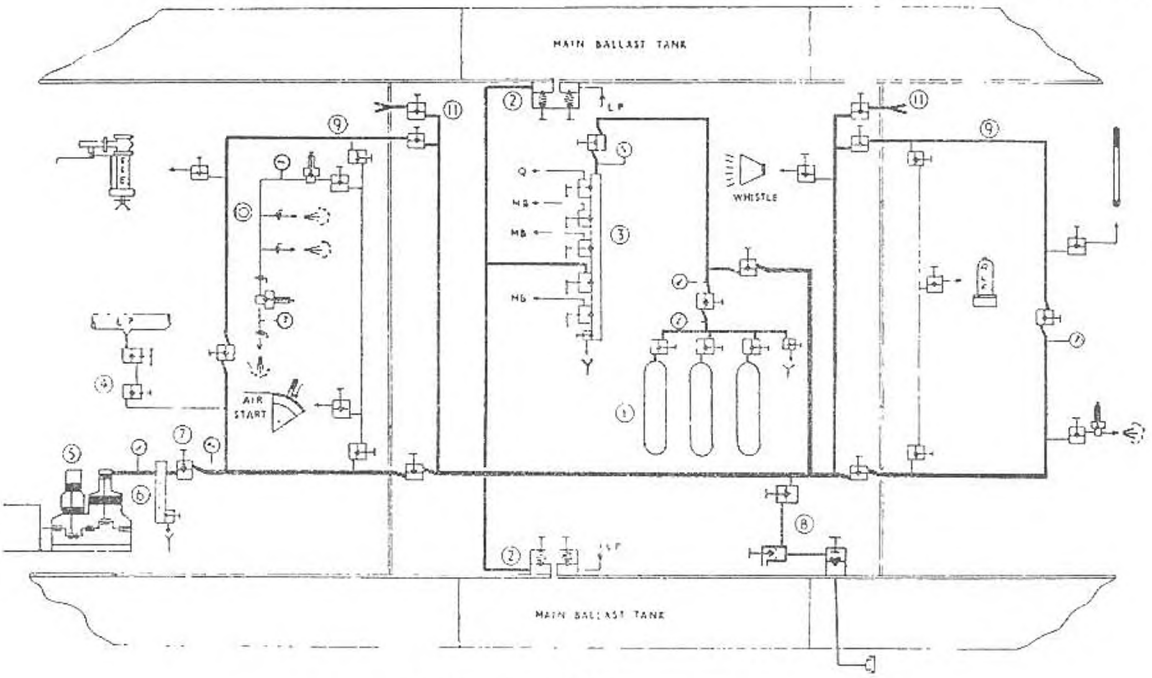


Fig. 19. Typical H.P. air system

LIST OF FITTINGS AND SERVICES USING AIR

FITTINGS

"Q", "A" and "Z" tanks.
Torpedo firing gear.
Torpedoes.
Air loaded accumulator.
Whistle.
Main engine starting.
Snort exhaust.
Heads (not later classes).
Submerged signal ejector.
CO_2 absorption units.

SERVICES (REDUCED BLOWS)

Compensating and trim tanks.
Fuel tanks, internal and external.
Lub. oil tanks.
Fresh and distilled water tanks.
Slop drain and sewage tanks.
Telemotor replenishing tank boost.
Periscope desiccator.

H.P. AIR COMPRESSOR (REAVELL TYPE) (Refer to *Fig. 20*)

Requirements. (a) To compress air (at atmospheric pressure) to 4,000 lb/sq. in. and deliver it to the H.P. air storage bottles.

(b) To keep air temperature constant throughout to obtain better compressor performance and no drop in pressure in the bottles through cooling.

(c) To lubricate all moving parts.

(a) **Air Circuit**

(1) PISTONS. To compress air taken from the atmosphere to 4,000 lb./sq. in. in four stages. Pistons worked by crankshaft driven by electric motor.

(2) SUCTION AND DISCHARGE VALVES. To enable pumping action to take place in each cylinder. First and second stages are plate valves—third and fourth stages are thimble valves.

(3) RELIEF VALVES. To protect each stage from excess pressure in the event of valve failure of the following stage.

(4) PRESSURE GAUGES. To indicate stage pressures.

(b) **Water Circuit**

(5) COOLERS. To cool air after it has been compressed in each stage. First and second stages are tube type—third and fourth stages are coil type.

(6) PUMP (impeller type). To circulate water through coolers and around jackets. Driven off crankshaft. Pump takes suction from sea—discharges to combined third stage, fourth stage and oil cooler, through to bottom of the jackets which also house first and second stage coolers and then on from top of jackets overboard.

(7) DRAIN BOTTLES AND COCKS. To collect and drain off water vapour that is condensed during cooling.

(8) RELIEF VALVE. To protect system from excess sea pressure.

(9) BURSTING DISC. To protect jackets against sudden rise in pressure due to burst cooler tube or coil.

(c) **Oil Circuit**

(10) SUMP. To hold lubricating oil. Fitted with dip stick, thermometer and breather valve. Cock fitted to bottom of sump to test for water or sludge.

(11) PUMP (eccentric type). To supply oil under pressure to bearings. Driven by crankshaft. Takes suction from sump through gauze strainer.

(12) FILTER (Autokleen). To prevent solid matter from going to the bearings. Cleared by rotating the handle.

(13) ADJUSTABLE RELIEF VALVE. To keep correct pressure at bearings.

(14) COOLER. To prevent oil overheating.

(15) MECHANICAL LUBRICATOR. To supply small quantities of oil for third and fourth stage piston rings. Driven off crankshaft. First and second stage pistons lubricated by splash.

Waller type compressors work on the same principles. The pistons are, however, reciprocated by a "swash" or inclined plate instead of a crankshaft.

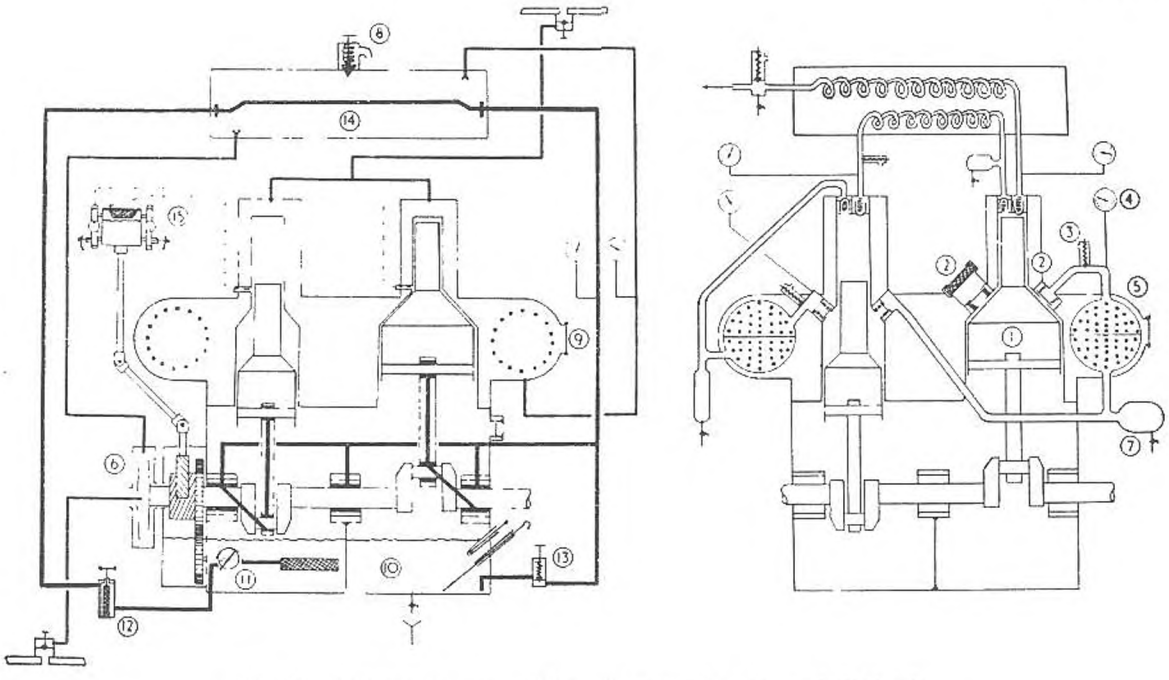


Fig. 20. H.P. air compressor (Reavell type)—air, water and oil circuits

TYPICAL L.P. BLOWING SYSTEM (L.P. LINE) (Refer to *Fig. 21*)

Objects. (a) To connect low pressure blower (compressor) to all main ballast tanks for obtaining and maintaining full buoyancy on surfacing.

(b) To provide a means of testing the pressure hull for leaks (vacuum test) or testing compartment bulkheads for leaks (pressure test).

(a) **Emptying Main Ballast Tanks**

(1) L.P. BLOWER. To supply air at lower pressure to all M.B. Tanks when the conning tower hatches are open.

(2) L.P. TANKSIDE VALVES (spring loaded screw down non-return). To shut off air line at the hull, and, as a non-return valve, to prevent water from entering the line when M.B. Tanks are flooded. Spring loaded to make sure valve reseats after blowing the tanks.

(3) L.P. MASTER BLOWS (screw down). To provide a ready means of shutting off each M.B. Tank, port and starboard together where applicable. Positioned overhead in the passageway.

(4) BLOWER SHUT OFF VALVE (screw down non-return). To shut off blower from L.P. line. Non-return to prevent flooding of blower should a tankside valve stick open.

(5) DRAIN COCK. To drain the line before starting blower. ALWAYS KEPT IN THE SHUT POSITION so that line is always ready for emergency blowing.

(6) DIFFERENTIAL RELIEF VALVE (emergency blowing station). To protect M.B. Tanks from excess difference of pressures when blowing H.P. to L.P. line tested to full diving pressure so that M.B. Tanks can be blown at any depth.

(b) **Pressure Hull and Compartment Tests**

VACUUM TEST. To ensure that all pressure hull fittings above water line are watertight before diving the ubmarine. Usually carried out after maintenance period in harbour. All hatches are shut and the blower un on M.B. Tanks. A slight vacuum is created in the submarine, any leaks being heard or detected by ighted wax taper.

Any drop in vacuum is registered on the barometer. Vacuum is broken by opening voice pipe cocks.

(7) COMPARTMENT TESTING BLANKS. To enable a small pressure to be raised in a compartment to test that bulkhead fittings are watertight. A blank on the L.P. line in the compartment is removed and the blower run until a pressure is raised (up to 15 lb/sq. in.).

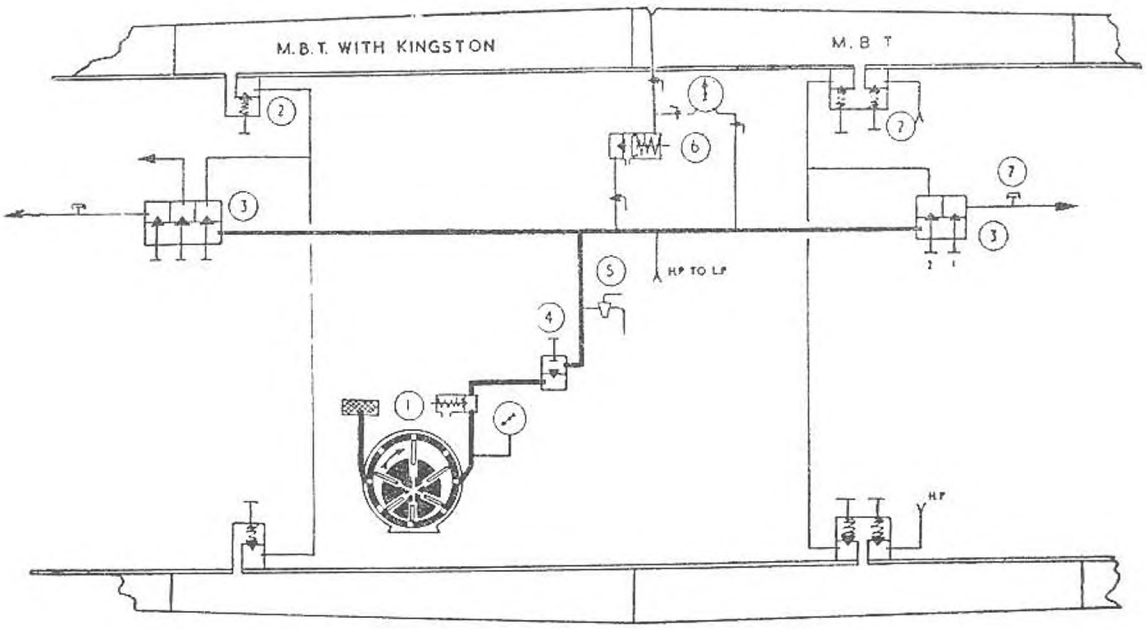


Fig. 21. Typical L.P. blowing system

L.P. BLOWER (Refer to *Fig. 22*)

Requirement. To compress large quantities of air to low pressure (up to 15 lb/sq. in.).

Air Flow

(1) VANES. To paddle air from inlet to discharge. Enough blades must be fitted to achieve continuous flow.

(2) ROTOR. To carry vanes round and enable them to move in and out radially. Driven by electric motor. Rotor mounted eccentrically to casing so that air can be paddled over but not back again to inlet side.

(3) PERFORATED DRUM. To prevent vanes wearing away the casing. Drum is free to rotate and will get carried round as rotor is set in motion and centrifugal force keeps blades against it.

(4) RELIEF VALVE. To protect blower against excess pressure.

(5) FILTER. To prevent dirt entering and damaging rotating parts.

Lubrication

(6) MECHANICAL LUBRICATOR. To feed small quantities of oil to each vane through axial and radial holes in rotor.

(7) GREASE LUBRICATOR. To lubricate roller bearing on motor end. Other ball bearings lubricated from oil mist created inside blower.

Cooling

As no special cooling arrangements are fitted, the blower must not be run for more than twenty minutes at one time.

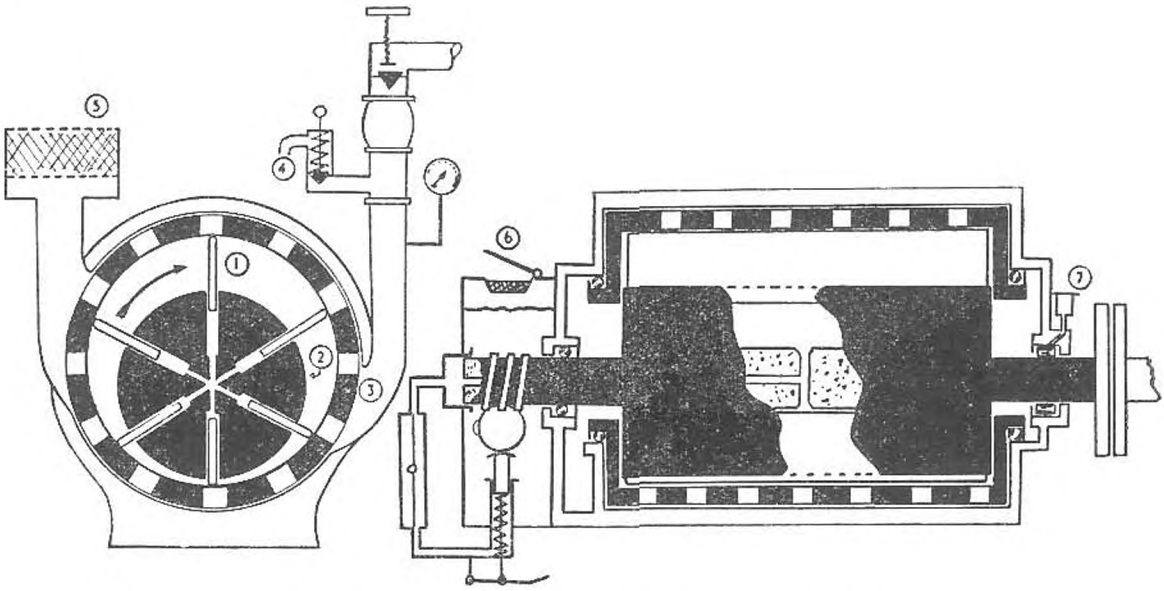


Fig. 22. L.P. blower—method of air blowing and lubrication

TELEMOTOR (HYDRAULIC) POWER UNITS AND CONTROL VALVES

(Refer to *Fig. 23*)

Requirements. (a) To operate main vents and Kingston valves from a central position (control room).

(b) To raise or move heavy equipment where hand operation is too slow or beyond human effort.

(c) To have a supply of hydraulic pressure (P) and a means of returning used hydraulic fluid (R).

(a) Main vents and Kingston valves

(1) MAIN VENT

DOUBLE RAM. Suitable for small movement. Design of leverage to the main vent easily adapted for hand operation; a portable lever can be shipped onto squared portion of shaft. A cotter is inserted to keep the main vent positively shut when hydraulic power is shut off. In the event of pressure failure, both rams will be pushed clear of leverage when working in hand.

"D" VALVE. Suitable to give full pressure to either rams, and therefore positive shut or open action. Pressure keeps "D" valve on its face. In the event of pressure failure, valve will no longer be kept tight on its face so that any pressure on the rams will be released to "return", whateve position the open/shut lever may be in. When practising "main vents in hand", with pressurer still on, the "D" valve can be placed in the central or by-pass position which will connect both rams to "return".

(2) KINGSTON

TRIPLE RAM. Fitted on "Q" tanks, suitable for small movement, and compact design for positions where space is limited. When pressure supply is shut off, a spring loaded accumulator (small reservoir of pressure) will keep Kingston shut tight provided the lever is left in the shut position. Cannot be worked in hand, but in the event of pressure failure sea pressure will keep Kingston on its seat.

"D" VALVE. Similar to (1).

THREE POSITION KINGSTON. Fitted on "A" and "Z" tanks in older classes, the triple ram and "D" valve are slightly different design to give the additional non-return (or blow) position.

(b) Raising or moving Heavy Equipment

(3) BOW CAP

PISTON. Suitable where fairly large movement and equal power in both directions is required. When pressure supply is shut off, a spring loaded accumulator will keep bow cap shut tight provided the lever is left in the shut position.

CONTROL COCK. Suitable for giving full pressure or fine control to either side of piston. Simple design but inclined to be rather stiff to operate.

(4) PERISCOPE

PRESS. Suitable where large raising movement is required in one direction only. Comparatively small movement at press is multiplied by a system of pulleys and wires. Lowering cylinder is of small diameter because little or no power is needed for lowering. Relief valve fitted on lowering lead because, if this lead was shut off or blocked, application of pressure to the raising side would create a very high pressure on the lowering side owing to the difference in area of the two cylinders.

PISTON CONTROL VALVE. Suitable for giving full pressure and very fine control. Easy to work and will centralise itself by spring loaded action.

(5) EXTERNAL FITTING

OLEO CONVERSION CYLINDER. Suitable for transferring hydraulic pressure to another fluid for fittings outside the pressure hull.

POPPET VALVES. Suitable to give full pressure in each direction and where a double system is controlled by one lever. No fine control is possible.

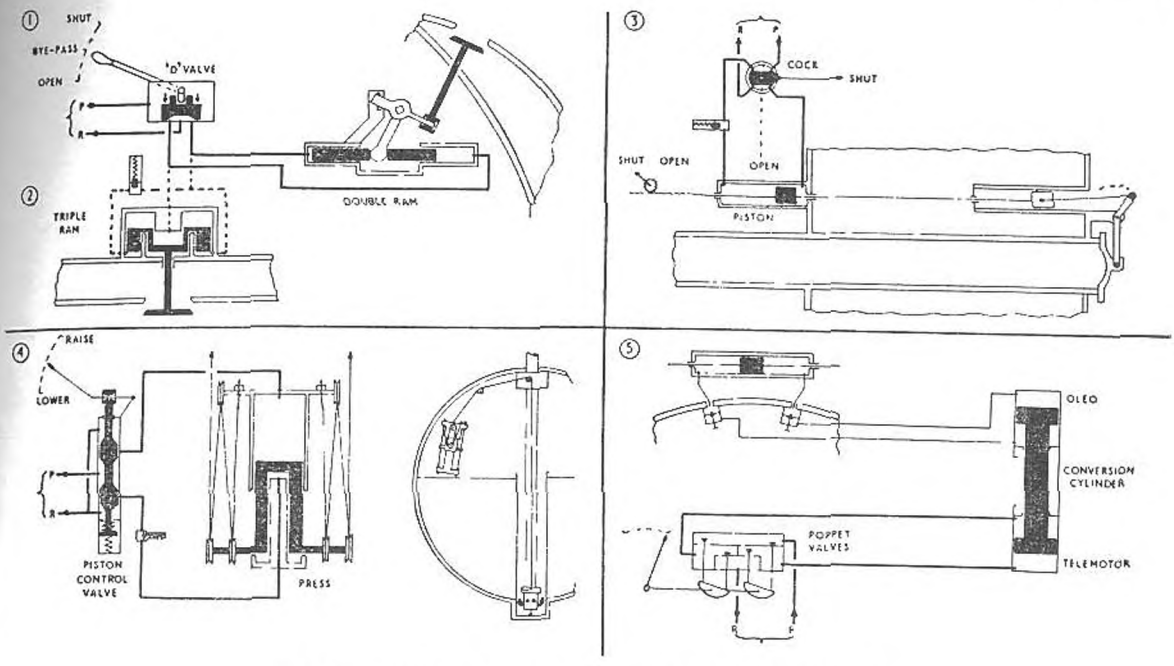


Fig. 23. Examples of hydraulic power units and control valves

FITTINGS WORKED BY TELEMOTOR (HYDRAULIC) PRESSURE

Fitting	Power Unit	Control	Remarks
MAIN VENTS AND AUXILIARY VENTS	Double ram	"D" valve on main panel	Cottered in harbour worked by hand lever on failure of pressure.
KINGSTON ON "Q" TANK	Triple ram	"D" valve on main panel	S/L accumulator on shutting side.
KINGSTONS ON "A" AND "Z" TANKS	Special triple ram	Special "D" valve on main panel	S/L accumulator on shutting side.
H.E.C's. (deep discharge gear)	Single ram	Cock	
BOW CAP	Piston	Cock	Hand pump on failure of pressure. S/L accumulator on shutting side.
SNORT MAST RAISING	Piston	Piston control valve	Interlocked with snort mast locking pin.
ENGINE CLUTCHES	Piston	Piston control or poppet valves	Handpump used on failure of pressure.
PERISCOPES	Press	Piston control valve	Relief valve on lowering side.
SEA GUARD MAST A.N.F.	Press	Piston control valve	Relief valve on lowering side.
TORPEDO LIFTING	Press	Cock	Relief valve on lowering side.
SNORT INDUCTION HULL VALVE	Small press	Cock, at engine control position	Cottered when shut S-L accumulator on shutting side. Worked by hand on failure of pressure.
AIR GUARD MAST A.P.T.	Oleo piston	Poppet valves	
BOW BUOYANCY TANK VENTS	Oleo piston	Poppet valves	
CAPSTAN	"V.S.G." "B" end	Piston control valve	"T" Class has "V.S.G." "A" end supply of pressure.

MAIN TELEMOTOR SYSTEM (HYDRAULIC) (Refer to *Fig. 24*)

Objects. (a) To supply hydraulic pressure to all telemotor operated fittings.

(b) To return all used hydraulic fluid to a supply tank for re-use.

(c) To have pressure always available and maintained automatically.

(a) **Pressure Supply**

(1) PRESSURE LINE. To lead pressure (up to 1,500 lb/sq. in.) to all telemotor operated fittings. Pressure gauge fitted in control room. Lubricating oil used as hydraulic fluid.

(2) PUMP (IMO type). To provide hydraulic pressure. Driven by an electric motor. Fitted with relief valve to prevent damage through excess pressures, and a N.R. valve to prevent pressure "motoring" pump when it is stopped. Strainer (Lolos type) in the sump to prevent dirt or grit damaging moving parts.

(3) REPLENISHING (SUPPLY) TANK. To provide oil for the pump suction. Fitted with a vent and drain. A hand pump for topping up from a storage tank is fitted.

(4) FILTER (Vokes type). To remove fine particles of dirt. This was found necessary as IMO pumps are fitted to very fine limits.

(5) BOOST PRESSURE CONNECTION. To assist the pump suction when large angles are on the submarine. Air pressure (up to 10 lb/sq. in.) kept inside the replenishing tank using the air space in the engine room as a large reservoir. Tank fitted with pressure gauge and relief valve.

(b) **Fluid Return**

(6) RETURN LINE. To collect all oil after it has been used in the power units, and return it to the replenishing tank.

(7) STRAINER (Lolos type). To prevent dirt entering the replenishing tank. After refits filters are also fitted between pressure and return lines and oil pumped round in order to get rid of as much dirt as possible. As pumps, control valves and power units have very fine finishes, it is most important to have the whole system dirt free.

(8) BY-PASS VALVE. To provide an easy means of releasing the pressure for maintenance purposes.

(c) **Automatic pressure control**

(9) AIR LOADED ACCUMULATOR. To provide a reserve of pressure for period of heavy demand and to allow the pump to be stopped during idle periods. Air being compressible acts as a cushion and will maintain a pressure on the system although the level of oil in the accumulator varies.

(10) AIR BOTTLES. To provide a larger air cushion to reduce the overall drop in pressure over the full range of the oil level. Ram (or piston) is fitted in the accumulator to stop oil entering the bottles or, as is much more dangerous, to stop air entering the pressure line. When the ram is at the top the pressure should be at the working maximum (1,500 lb/sq. in.). Pressure will be approximately 1,100 lb/sq. in. when ram is at the bottom.

(11) ACCUMULATOR AIR PANEL. To enable accumulator bottles to be topped up or drained down.

(12) "RAM AT TOP" INDICATOR. To indicate when ram is at the top of its stroke so that correct air pressure can be put in the bottles. When button is pushed on the small indicator box in the control room, an amber light burns continuously if the ram is at the top. This indicator works by using a 230V ac. supply on an induction coil. The soft iron rod on the ram must be inside the coil before the light will burn continuously.

(13) PRESSURE CONTROL GAUGES. Pump gauge to stop (at 1,515 lb/sq. in.) and start (at 1,250 lb/sq. in.) the pump. Indicator gauge to give warning if the pump fails to start (at 1,200 lb/sq. in.) or fails to stop at 1,500 lb/sq. in.). Both gauges are connected to the accumulator where there is the least fluctuation of pressure when the power units are being used.

(14) CONTROL BOX. To house switches and indicator lights. Pumps can be switched to "Automatic", "Off" or "Hand". AMBER light burns when pump is running. GREEN light (pressure available) burns provided the pressure is above 1,200 lb/sq. in. If pump fails to cut in at 1,200 lb/sq. in. or below, a buzzer is started and the green light flashes. Buzzer can be switched off when submarine is in a Quiet State but the green light will continue to flash. RED light will burn just before pump is automatically stopped but will go out as soon as the starter contacts are broken. If the red light continues to burn, it means that the starter is still on, the pump running, and relief valve lifting.

(15) LINE RELIEF VALVE. To protect the pressure line against excess pressures should the pump fail to stop. Oil is relieved into the return line. This relief is designed for quiet operation and to lift before the pump relief.

All submarines have at least two pumps and two accumulators, and they work together in parallel. An additional pump is being fitted in later classes owing to an increase of power units using hydraulic pressure. As rubber pipe lengths are fitted on the pump discharge line, an additional N.R. valve is fitted to prevent loss of pressure in the system should the rubber pipe lengths fail.

Oil used: OM 65 80°F. and below.
OMD 110 110°F. and above.
Either between 80°F. and 100°F.

Later classes use working pressure of 2,500 lb/sq. in.

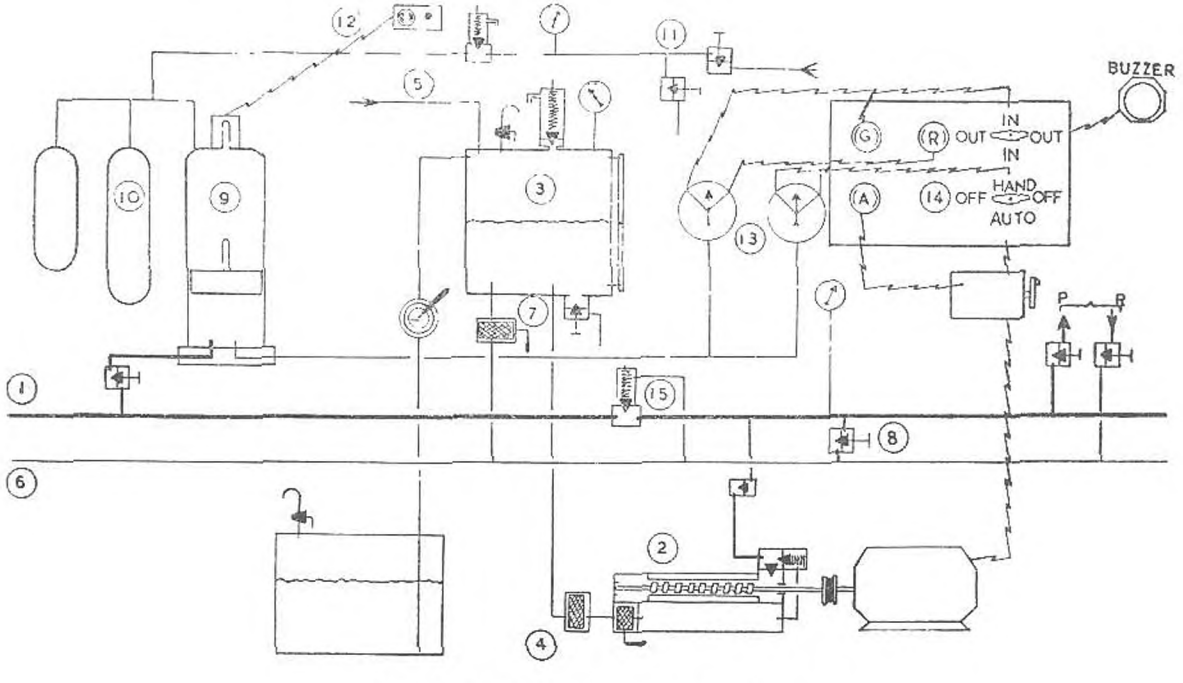


Fig. 24. Main telemotor (hydraulic) system

TELEMOTOR (IMO) PUMP (Refer to *Fig. 25*)

Requirement. To pump hydraulic pressure to 1,500 lb/sq. in. and to have a quiet pumping action.

(1) ROTOR AND IDLERS. To produce the pumping action. Rotor is made in one piece, but the idlers are sub-divided into three pieces to minimise the binding effect due to twisting strain when pumping.

(2) SLEEVE. To house the rotor and idlers. The rotor and idlers are lap finished in the sleeve and are not interchangeable with other pumps. When worn the whole unit (sleeve, rotor and idlers) must be changed.

Principle. The rotor, which is a screw, is rotated in a sleeve, and the fluid is carried from one end to the other by the screw action (like a mincing machine). However, when a pressure is built up on the outlet side, the screw will find it difficult to carry the fluid along, the flow decreasing as the pressure goes up. By mating another screw (idler) alongside the rotor, the fluid will now be positively carried along the rotor, thus a flow with a high pressure can be obtained. Two idlers one each side of the rotor, are fitted for balance. The outside diameter of the idlers is made equal to the inside diameter of the rotor so that a rolling and not a rubbing takes place between them. As there are no reciprocating parts, the pumping action is smooth and quiet. The efficiency of the pump is, however, dependent on the lap finish of the screws which can be ruined very quickly by dirt in the fluid.

(3) MOTOR. To drive the rotor.

(4) BEARING BUSH. To steady the rotor at the driving end.

(5) PRESSURE BALANCING COVER. To steady the rotor and idlers at the free end and balance the thrust. The thrust is caused by the difference in pressure between suction and discharge acting on the screws tending to push them toward the suction side. This thrust is balanced by having pressure acting on the ends of the screws at the free end pushing them toward the discharge side.

(6) BALL BEARING. To locate the rotor and take the thrust which may result from uneven balancing.

(7) LEAK OFF PIPE. To lead any oil leaking through the bearing bush to the suction. Oil seal prevents the oil going through into ball bearing housing.

(8) GREASE CAP. To lubricate the ball bearing. A seal is fitted so that grease is retained in the housing.

(9) PRIMING FUNNEL. To prime the unit with clean oil when first starting up.

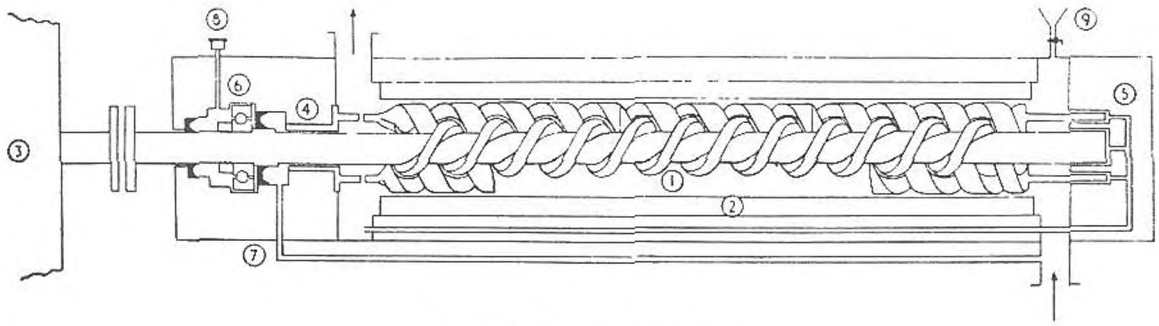


Fig. 25. Telemotor (Imo) pump

TELEMOTOR HAND PUMPS (Refer to *Fig. 26*)

(10) 2-POWER PUMP. Worked by hand lever either:—

(*a*) on large piston double acting for low pressures (800 lb/sq. in.)
or
(*b*) on small piston single acting for high pressure 1,500 lb/sq. in.).

(11) 4-POWER PUMP. One large piston (a) and two small pistons (b and c) worked by a hand lever, all with double acting action. The four powers are obtained by using the three pistons in different combinations.

Position 1—all pistons working—(340 lb/sq. in.)
Position 2—pistons a and c —(450 lb/sq. in.)
Position 3—pistons b and c —(830 lb/sq. in.)
Position 4—piston c —(2,100 lb/sq. in.)

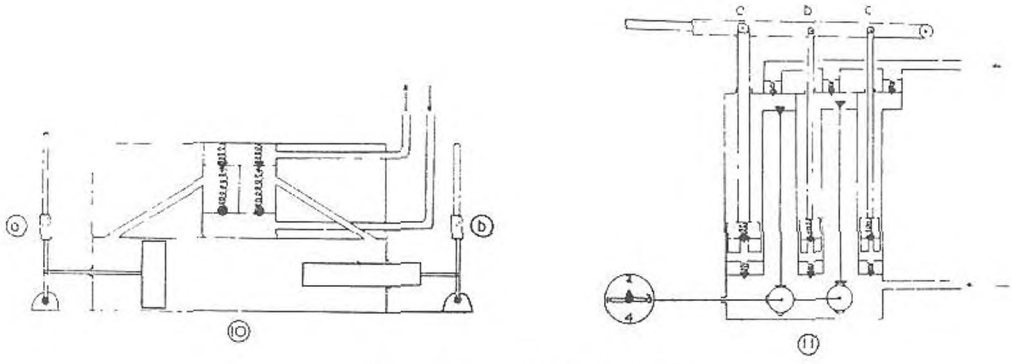


Fig. 26. Telemotor hand pumps

TYPICAL OLEO SYSTEM (Refer to *Fig. 27*)

Object. To work a hydraulic power unit external to the pressure hull using a fluid which is non-freezing and will not leave a surface trail.

External Fitting

(1) POWER UNIT. To work an external fitting (foreplanes housing, airguard mast raising, bow buoyancy vents).

(2) OLEO CONVERSION CYLINDER. To convert main telemotor pressure into Oleo pressure. Oleo consists of 50—50 mixture of glycerine and water. An indicator shows the normal limits through which the pistons work.

Telemotor Side

(3) POPPET VALVES. To control the telemotor side of the conversion cylinder.

(4) RELIEF VALVE. To relieve excess pressures that could be built up on the small area side of the telemotor piston if the return is shut off or blocked.

(5) SPRING LOADED ACCUMULATORS. To provide a small reserve of pressure on each side of the telemotor piston when the telemotor pressure is shut off so that the external fitting does not move.

Oleo Side

(6) OLEO REPLENISHING TANK. To provide a small reserve of Oleo mixture for a gravity feed to the system and a make up for small leaks.

(7) HAND PUMP. To top up replenishing tank.

(8) POPPET VALVES. To connect idle side of Oleo piston to the replenishing tank. *Relief valve* and *replenishing valve* allows Oleo to be released or fed into the idle side of the Oleo piston. This allows for the difference in volumes each side of the piston, and for leaks. All the poppet valves are worked by one hand-lever.

(9) BY-PASS VALVE. To marry both sides of the Oleo piston. Should the external power unit get *out of step* with the Oleo cylinder, due to leaks, the normal condition can be restored by moving the Oleo piston (with by-pass open) without moving the power unit.

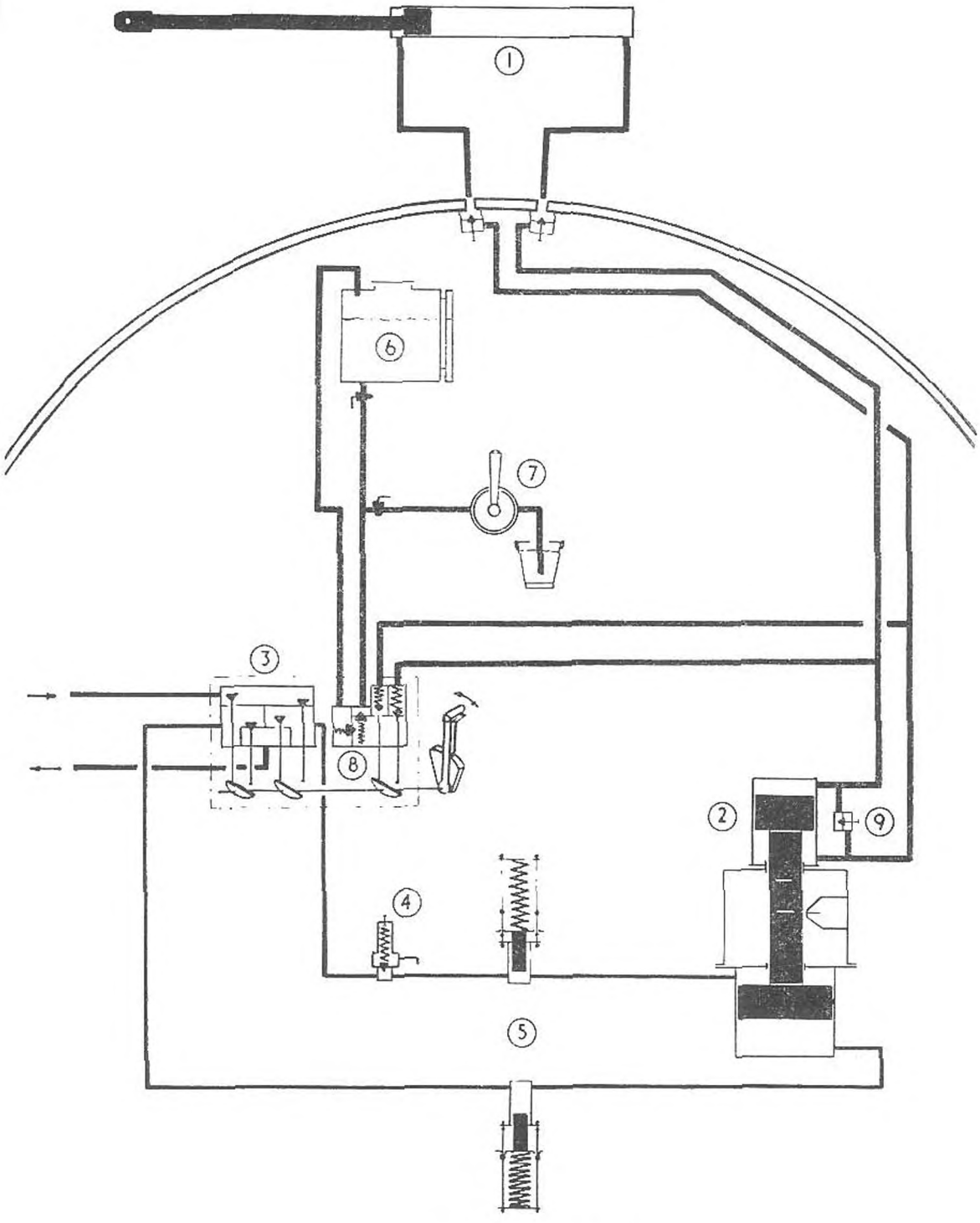


Fig. 27. Typical Oleo system

CAPSTAN LAYOUT (Refer to *Fig. 28*)

Requirement. To turn the warping barrel and cable holder by power at varying speeds and powers.

(1) V.S.G. "B" END (variable speed gear). To drive the warping barrel and cable holder at varying speeds and powers, according to the amount of hydraulic pressure admitted. The unit is sometimes fitted outside the pressure hull housed in a pressure tight dome.

(2) V.S.G. "A" END. To provide hydraulic pressure to the "B" end. It is driven by an electric motor. The main parts are as follows :—

(*a*) *Pistons*, which produce the pressure.

(*b*) *Cylinder barrel*, which provides cylinders for a set of pistons arranged in a circle.

(*c*) *Valve plate*, which provides a butting surface for the cylinder barrel. The barrel slides on the valve plate under the pressure of a spring, and the surfaces are oil tight.

(*d*) *Tilt plate*, which produces a reciprocating motion on the pistons.

(*e*) *Universal joint* and

(*f*) *Spline*, which rotate the tilt plate and cylinder barrel together.

Later classes do not have a V.S.G. "A" end, but use hydraulic pressure from the main telemotor system through a piston control valve.

(3) CONTROL HANDLE. To regulate the hydraulic pressure to the "B" end. The handle angles the tilt plate. The rate of oil supply and pressure depends on how much angle is put on, which will determine the speed and power on the capstan. The direction of rotation of the "B" end depends on the direction of pressure supply, which, in turn, depends on what side of the central position the tilt plate is angled.

(4) AUTO-CONTROL. To automatically bring back the tilt plate to the central non-pumping position when maximum loading is reached on the "B" end.

(5) REPLENISHING TANK. To keep the V.S.G. unit completely topped up with oil, and prevent entry of air.

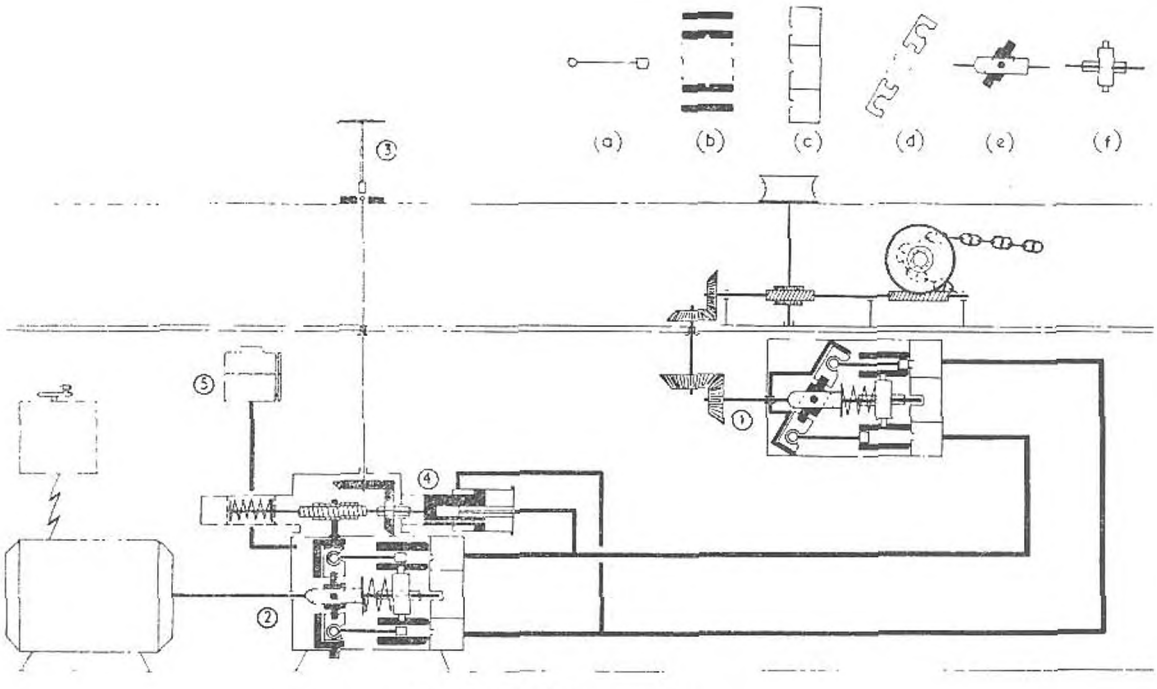


Fig. 28. Typical capstan layout

STEERING GEAR (Refer to *Fig. 29*)

Objects. (a) To steer the submarine port and starboard

(b) To provide an alternative means of steering the submarine in an emergency.

(c) To provide a means of operating the steering gear quietly.

(a) **Primary (first) Control**

(1) RUDDER. To turn the submarine to port or starboard. Mounted on the after fin abaft the propellers.

(2) STEERING POSITION. To control the rudder. Situated in the control room.

(3) STEERING RAM OR PISTON. To provide a powerful means of turning the rudder. Connected to the rudder through a crosshead, guide, connecting rod and crank lever.

(4) STEERING PUMP (V.S.G. unit). To provide hydraulic pressure either side of the steering ram. Pump revolves continuously with the tilt plate normally central in the non-pumping position. Pumping commences when the tilt plate is angled from the central position, the direction of pressure supply being dependent on what side of the central position the tilt plate is angled.

(5) BROWN'S RECEIVER and

(6) BROWN'S TRANSMITTER. To transmit, hydraulically, movement of the steering wheel to the tilt plate.

(7) HUNTING GEAR LEVER. To automatically centralise the tilt plate when the required degree of rudder has been reached.

(8) LEVER AND RODS. To give maximum movement of tilt plate for small changes of helm.

(9) BUFFER SPRING. To prevent damage to lever and rods when making large changes of helm.

(10) "EVERSHED". To relay the angle of the rudder to the helmsman.

(b) **Emergency Control**

(11) SHIP'S TELEMOTOR SYSTEM. To provide an alternative source of hydraulic power. Pressure and return valves fitted where lines are taken off the system.

(12) PISTON CONTROL VALVE. To control the movement of the steering ram.

(13) EMERGENCY HANDWHEEL. To work the piston control valve.

(14) CHANGE-OVER VALVE BOX. To provide a quick means of changing over the pressure supply lines of the V.S.G. unit and ship's telemotor.

(15) "EVERSHED". To relay the angle of rudder required to the emergency handwheel position.

(16) BY-PASS VALVE. To enable the steering wheel to work the Evershed without working the Brown's system.

(c) **Quiet Routine**

(17) ADDITIONAL ROD. To enable the piston control valve to be worked by the Brown's system and hunting gear.

(18) PIN. To connect *either* the rod *or* the handwheel to the piston control valve. Handwheel has a drop link, the rod has a sliding sleeve. Pin may be left in either position.

On later classes of submarines, the steering gear has been much simplified since the introduction of the automatic pressure control telemotor system. The V.S.G. unit and Brown's system are not used. In primary control, pressure from the telemotor system is used, and is controlled by a piston control valve worked by the helmsman who, sitting facing forward, pushes down on a lever to the left for port and to the right for starboard. Hunting gear is not necessary. This method is referred to as "Direct control" or "Tapper gear". The hydraulic "hammer" or "tapping" produced by each movement is made by the sudden introduction of pressure in the pipes, but has now been eliminated by a re-design of the piston control valve to allow for a gradual build up of pressure in the pipe leads at each movement. For emergency control, a similar piston control valve is situated in the after ends, and a hand pump is used as a source of pressure. No quiet routine is necessary as primary control is, in fact, a quiet method.

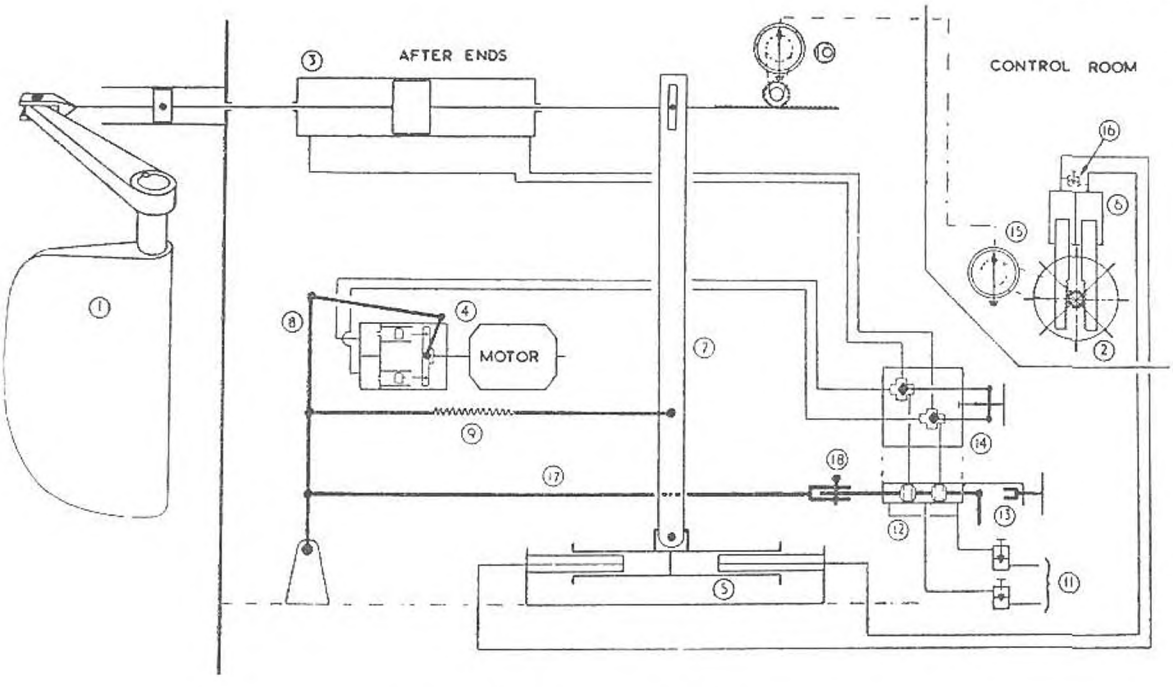


Fig. 29. Arrangement of steering gear

HYDROPLANES TILTING (Refer to *Figs. 30 and 31*)

Objects. (a) To control the submarine to rise and dive in order to assist submerging from the surface and assist surfacing; incline the submarine for change of depth; and counteract slight changes of trim (trim error, change of sea density, movement of crew, rough weather).

(b) To provide an alternative means of control in an emergency.

On early classes hydroplanes are operated in the same way to steering gear using V.S.G. units and Brown's system, and with the same alternative methods of control.

Later classes have direct control.

The following numbered annotations refer to both *Figs* 30 and 31.

(a) **Primary control (and Quiet Routine).**

(1) PLANES. To provide an upward and downward thrust each end of the submarine. Hinged athwartships in pairs acting as horizontal rudders. Fore planes keep depth and after planes control inclination. Planes are only effective when they have motion through the water.

(2) RAM (or piston). To tilt the planes by using pressure from the telemotor system. Ram connected to the planes through cranks and rods.

(3) CONTROL LEVER. To control the amount of tilt on the planes through a piston control valve. When not in use the lever is secured in the central position. This type of control is sometimes referred to as "tapper gear" due to the hydraulic "hammer" produced each time the planes are tilted. Re-designed control valves now fitted have eliminated this noise.

(b) ***Hand Control***

(4) HANDGEAR. To tilt the planes by hand through a worm, wormwheel, rack and pinion connected to the ram.

(5) RAM BY-PASS VALVE. To hydraulically by-pass the ram when in hand.

(6) CLUTCH. To enable the handgear to be disconnected when tilting by power.

(7) INTERLOCK (C). To prevent power tilting when in hand.

(8) EVERSHEDS. (a) To relay the angle on the planes to the planesman.

(b) To relay the angle required on the planes to the watchkeeper when in hand control.

AFTER PLANES LOCKING ("A" CLASS ONLY) (Refer to *Fig. 30*)

Object. To lock the after planes at a few degrees to rise to obtain maximum effectiveness from the propellers when on passage.

(9) LOCKING WEDGES. To lock the planes at 5° to rise. The wedges are strong enough to withstand telemotor pressure on the tilting ram. Two wedges are fitted, one each side of the rack are kept in by springs.

(10) RAM. To disengage wedges by power.

(11) CONTROL VALVES (poppet type). To work the rams. Fitted alongside after planes tilting control position in the control room.

(12) TOMMY BAR. To disengage wedges by hand on failure of pressure. The wedges are then kept out by engaging a detent.

On the other classes, the after planes are kept between 5° to 7° to rise by normal operation.

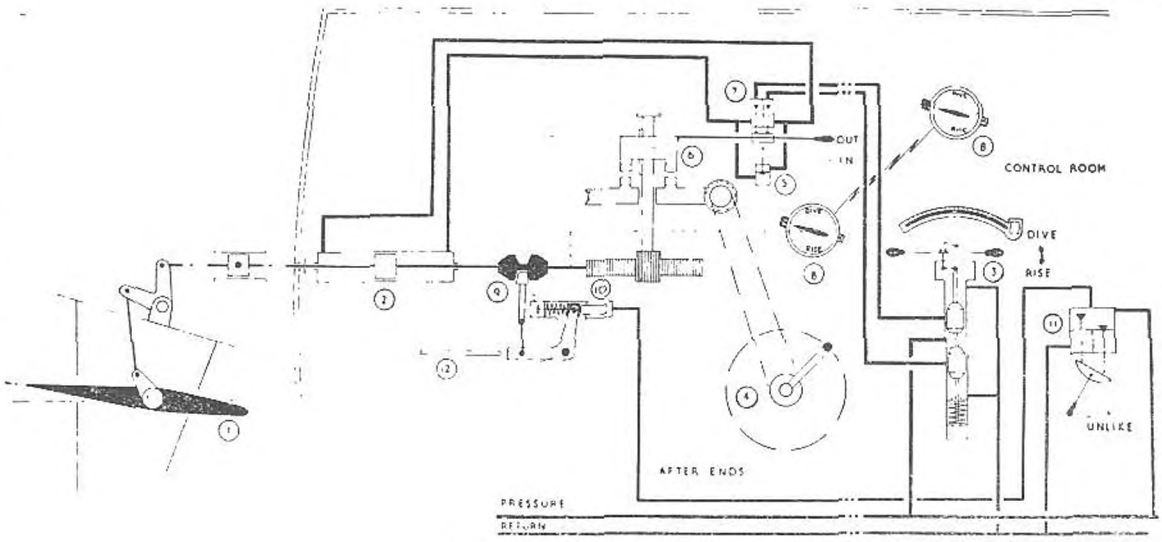


Fig. 30. Aft hydroplanes

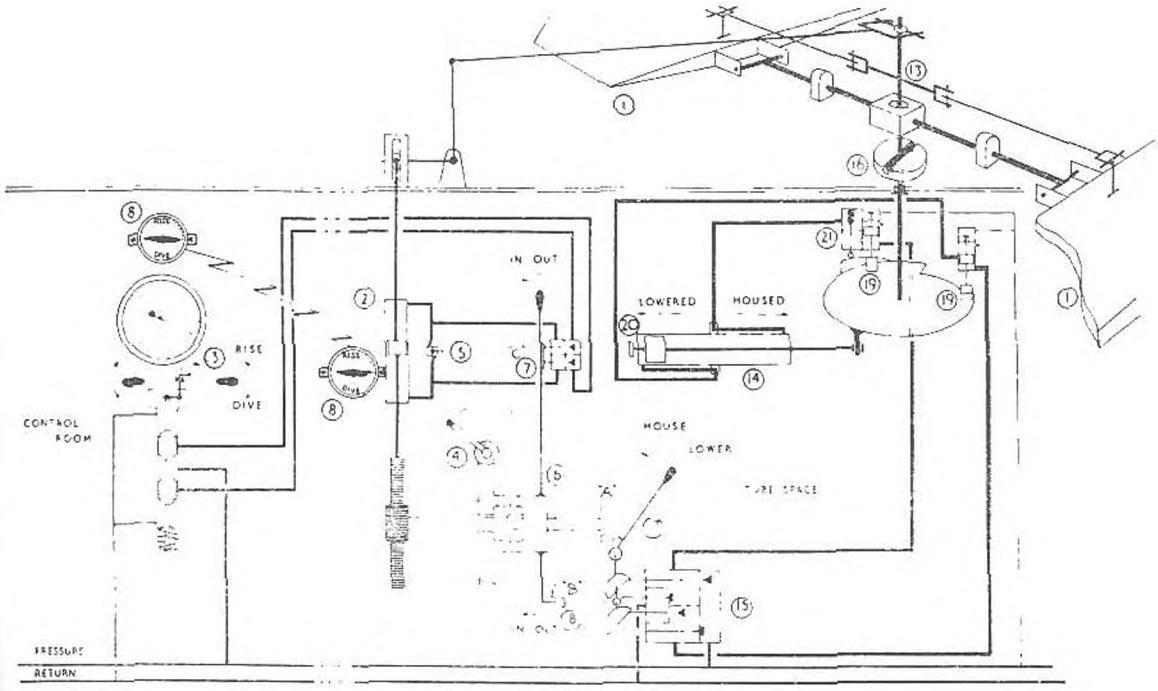


Fig. 31. Toggle type forward hydroplanes

FORE PLANES HOUSING (Refer to *Fig. 30*)

Object. To prevent damage from rough seas or when in harbour.

Earlier classes having housing arrangements to allow the planes to hinge upwards and house against the side of the casing. Each plane is drawn up by a hydraulic ram mounted on the tilting gear external to the pressure hull. An Oleo system is therefore used. Flexible pipes allow for tilting. The disadvantage of using an Oleo system is its tendency to get "out of step" due to leaks or fractured flexible pipes.

Later classes have the "toggle" type housing, arrangement which is entirely mechanical external to the pressure hull.

(13) TOGGLE (*Fig.* 31). To draw the planes up to the side of the casing. When rotated the toggle acts as a double crank.

(14) HOUSING CYLINDER (oscillating). To rotate the toggle.

(15) CONTROL VALVES *(poppet type). To work the housing cylinder.*

(16) TONGUE AND GROOVE. To enable the planes to be tilted *after* the toggle has been rotated to the lowered position, that is, with the tongue and groove fore and aft.

(17) INTERLOCK (A). To prevent housing when planes are tilted. Lever cannot be put to house until the planes are amidships.

(18) INTERLOCK (B). To prevent power tilting when planes are housed. Hydraulic pressure is shut *off from the tilting cylinder (handgear clutch in) before the lever can be put to house.*

(19) STOPS (housed and lowered). To secure the planes in either the fully housed or fully lowered position. In the event of failure of telemotor pressure, the planes will remain fully housed or fully lowered.

(20) STOP (housing cylinder). To prevent toggle revolving past the fully lowered position should the "lowered stop" fail to engage.

(21) GAG VALVE. To slow down the housing of the planes as the toggle approaches the fully housed position. The toggle will tend to speed up when it is in the fore and aft position owing to a progressive decrease in pull on the connecting rods and full leverage on the toggle arms.

STEERING AND HYDROPLANES—METHODS OF CONTROL

Fitting		Porpoise	A	T. Con.	T. Mod.	T	S
STEERING IN PRIMARY	*P*	Tele pressure	V.S.G.	Tele pressure	Tele pressure	V.S.G.	V.S.G.
	C	*P.C.V.*	Browns	*P.C.V.*	*P.C.V.*	Browns	Browns
STEERING IN EMERGENCY	*P*	Hand pump	Tele pressure (non-Hunting)	Hand pump	Hand pump	Tele pressure (non-Hunting)	Tele pressure (non-Hunting)
	C	Local *P.C.V.*	Local *P.C.V.*	Local *P.C.V.*	Local *P.C.V.*	Local *P.C.V.*	Local *P.C.V.*
FORE PLANES IN PRIMARY	*P*	Tele pressure	Tele pressure	Tele pressure	Tele pressure	V.S.G.	Tele pressure
	C	*P.C.V.*	*P.C.V.*	*P.C.V.*	*P.C.V.*	Browns	*P.C.V.*
FORE PLANES IN EMERGENCY	*P*	Hand pump	Hand gear	Hand gear	Hand pump	Tele pressure	Hand pump
	C	Local *P.C.V.*	—	--	Local *P.C.V.*	Local *P.C.V.*	Local *P.C.V.*
AFT PLANES IN PRIMARY	*P*	Tele pressure	Tele pressure	Tele pressure	Tele pressure	V.S.G.	Tele pressure
	C	*P.C.V.*	*P.C.V.*	*P.C.V.*	*P.C.V.*	Browns	*P.C.V.*
AFT PLANES IN EMERGENCY	*P*	Electric motor	Hand gear	Hand gear	Hand pump	Tele pressure	Hand gear
	C	Switch on starter	—	—	Local *P.C.V.*	Local *P.C.V.*	—
FORE PLANE HOUSING	*P*	Osc. piston	Osc. piston	Osc. piston	Oleo piston	Oleo piston	Oleo piston
	C	Tilting *P.C.V.* with changeover box	Poppet	Poppet	Poppet	Poppet	Poppet
			Single rams		Quiet *P*	Tele pressure	Tele pressure
			Poppet		Routine *C*	Browns	Browns

P —Power After Planes P
C —Control
P.C.V. —Piston locking control valve

CHAPTER 3

Shafting and Main Engines

SHAFT FITTINGS—TYPICAL LAYOUT AND LUBRICATION (Refer to *Fig. 32*)

Object. (a) To enable main engine or main motor to drive the propeller.

(b) To enable main motors, driven by the main engine, to be used as generators for charging batteries, either with the propeller disconnected (standing charge), or with the propeller driven at the same time (running charge).

Main Motor Drive

(1) PROPELLER AND TAIL SHAFT. To give the submarine ahead or astern motion. Driven by main motor.

(2) MAIN MOTOR BEARINGS. To support armatures. Self lubricated from sump of oil by disc and diffuser. One dip stick measures level in sump and another dip stick measures level in bath when armatures are revolving. After bearing fitted with thrust pads to keep armatures correctly positioned, particularly when submarine is inclined.

(3) "A" BRACKET. To position and support the weight of propeller and shaft outside the pressure hull. Fitted with whitemetal bush lubricated by grease fed through a hull valve from a grease gun positioned in the after ends. (These bearings are being replaced by "Lignum Vitae" bearings which do not require grease lubrication.)

(4) STERN TUBE. To enable shaft to go through the pressure hull. Fitted with whitemetal inner and outer bushes lubricated with grease fed through hull valves from a grease gun in the shaft space.

(5) STERN GLAND. To make the stern tube water-tight. Lantern ring fitted central with the turns of packing is kept full of grease by a small spring loaded greaser to provide lubrication which helps to reduce wear on the shaft. If heating occurs, cooling water can be applied from aft services.

(6) THRUST BLOCK. To transmit thrust of propellers to the hull and support weight of the shaft. Michell thrust pads and bearings self lubricated from sump of oil using diffuser on thrust collar. Dip stick to measure oil level when shaft is stationary.

(7) BULKHEAD GLAND. To make bulkhead watertight where shaft goes through. Lubricated by oil from a drip feeder.

Main Engine Drive—Running Charge

(8) ENGINE CLUTCH (Dog or Radial type hydraulically operated). To connect the main engine to the main motor enabling engine to drive the propeller. Main motor can be used as a generator at the same time for re-charging batteries. Dog clutch must be lined up before putting it in, but radial clutch can be put in with shafts in any position. Shafts must always be stationary before working clutches. Lubricated with oil from the engine forced lubrication system led from crankshaft bearing through holes in the shaft.

(9) TURNING GEAR. To line up engine so that clutch can be put in.

Standing Charge

(10) TAIL CLUTCH (Dog type hand operated). To disconnect tail shaft so that the main motor when it is clutched to engine, can be used to re-charge batteries. Lubricated by oil from a drip feeder.

(11) TAIL BRAKE. To stop tail shaft revolving when there is way on the submarine so that tail clutch can be put in. Clutch is lined up by using engine turning gear with engine clutch in.

(12) PLUMMER BLOCK. To provide support for the shaft near tail clutch. Self lubricated from sump of oil by disc and diffuser. Dip stick to measure oil level when stationary.

It is most important that the temperatures of main motor bearings, thrust blocks and plummer blocks, all of which are self lubricated, are checked frequently by thermometer. The temperature must not exceed 140°F. When checking the lubrication for tail clutches and bulkhead glands the drip feed must be sighted.

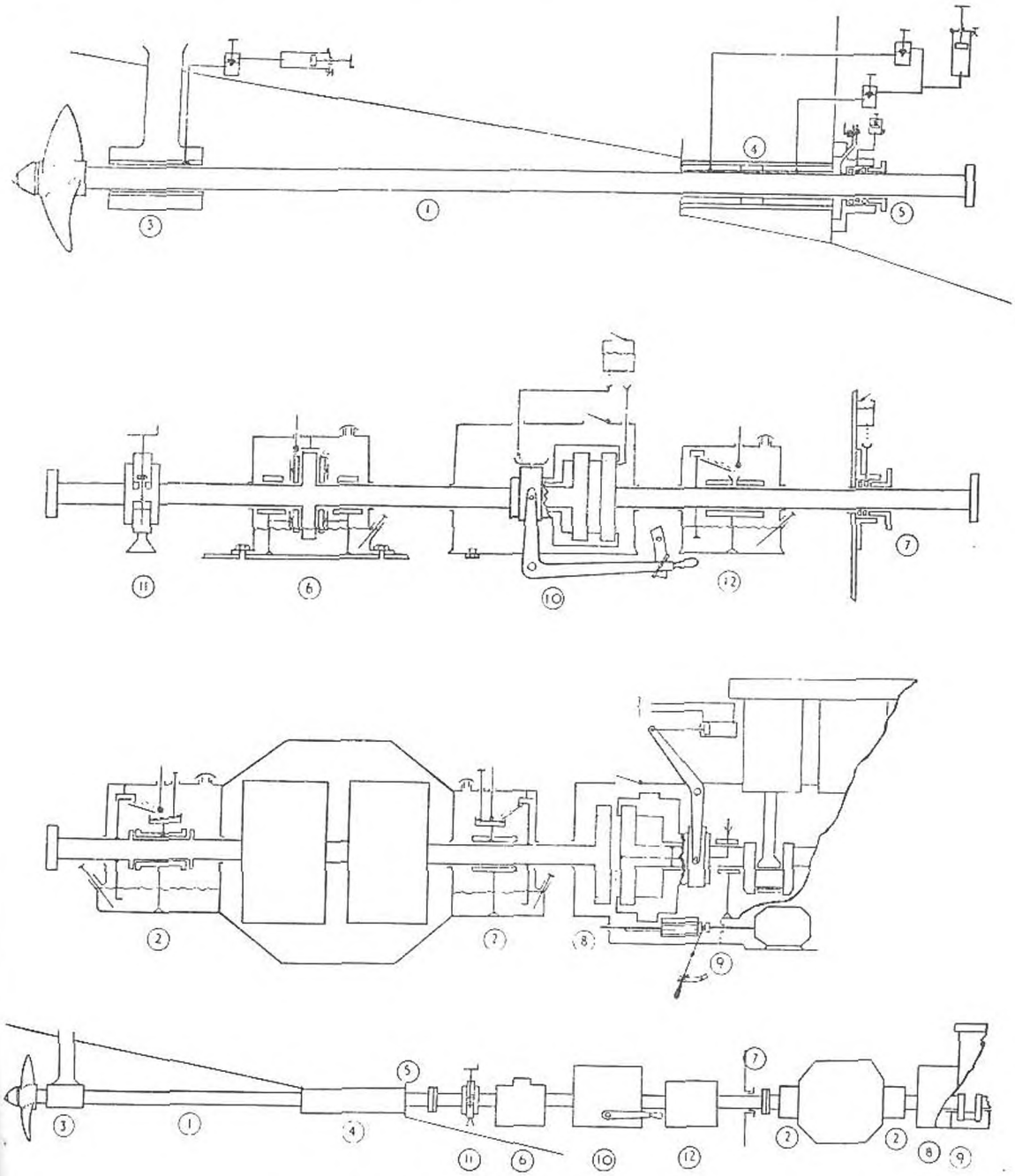


Fig. 32. Shaft fittings—typical layout and lubrication

CIRCULATING WATER, TYPICAL SYSTEM—AFT SERVICES (Refer to *Fig. 33*)

Object. (a) To prevent overheating of the lubricating oil in the shaft bearings.

(b) To provide cooling water for main motor coolers and forward services.

(a) **Shaft Bearing Coolers**

(1) SUPPLY LINE. To supply sea water to shaft bearing cooling coils. Bearing temperatures should not exceed 140°F. Line is tested so that it can be used at full diving depth. Individual shut off cocks are fitted at each bearing.

(2) AUXILIARY PUMP (centrifugal type). To feed supply line with water pressure. A differential gauge is fitted between the discharge and sea to indicate that the pump is circulating.

(3) DISCHARGE LINE. To collect all discharge water from fittings. Individual shut off and vent cocks are fitted.

(4) OVERHEAD (hull valve). To allow discharge of water to the exhaust tank sprays.

(5) HOSE CONNECTION. To provide a means of introducing anti-fouling solution into the system from the main line.

(b) **Main Motor Coolers and Forward Services**

(6) MAIN MOTOR COOLERS. To reduce the temperature of the main motor cooling air before it is discharged into the motor room. Fitted with isolating valves and vent cocks.

(7) FORWARD SERVICES SUPPLY. To provide a water supply to air conditioning plant condensers (discharged overboard locally) and distillers; and alternative supply for refrigerator condenser and heads flushing.

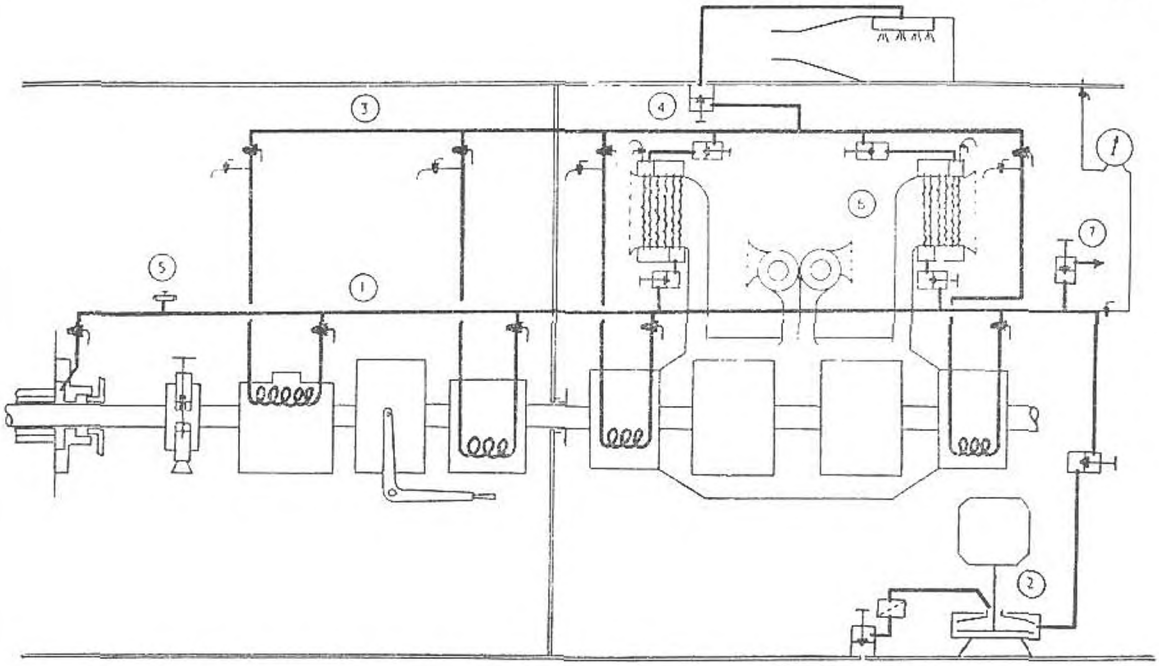


Fig. 33. Circulating water system—aft services

MAIN ENGINES—4-STROKE CYCLE (Refer to *Fig. 34*)

Object. To convert heat (produced by the combustion of diesel oil) into useful work (rotary motion on crankshaft).

	COMBUSTION			USEFUL WORK
FUEL (Diesel)	+ OXYGEN (Air)	+ IGNITION (Heat of Compression)	=	HOT GASES + PRESSURE (Expansion moves Piston)

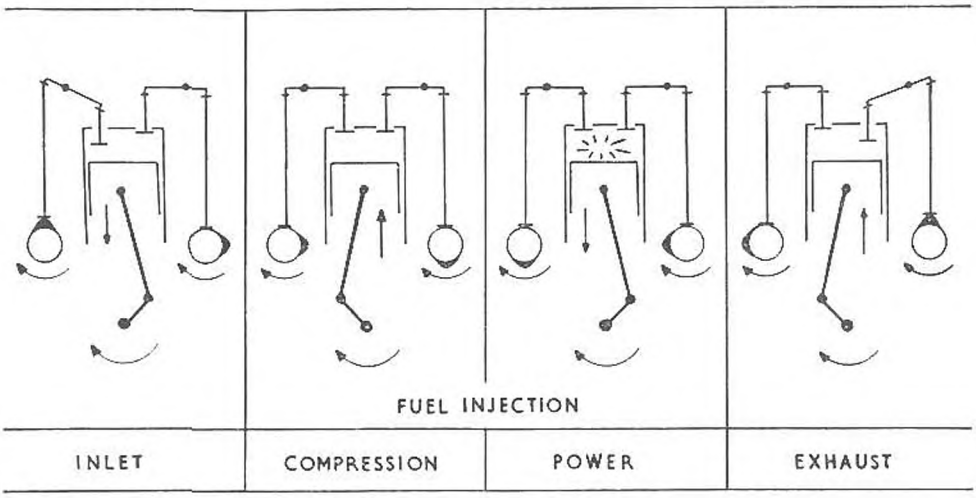


Fig. 34. Main engine—four-stroke cycle

PARTS OF A MAIN ENGINE (Refer to *Fig. 35*)

Main Moving Parts

PISTON. To enable the heat of combustion to be converted into motion. Fitted with PISTON RINGS to ensure a flexible gas tight joint in the cylinder. The piston is open at one end and a GUDGEON PIN is fitted diametrically across inside.

CONNECTING ROD. To connect the piston to the crankshaft. The smaller end of the rod is fitted on to the gudgeon pin with a SMALL END BEARING, and the larger end is bolted on to the crank by a LARGE END BEARING.

CRANKSHAFT. To convert the reciprocating motion of piston to rotary motion.

Cylinder Unit

CYLINDER LINER. To surround the piston. Open at both ends.

CYLINDER HEAD. To enclose the top of cylinder and hold valves and fuel injector. A joint ring or explosion joint of copper or steel is fitted between head and liner.

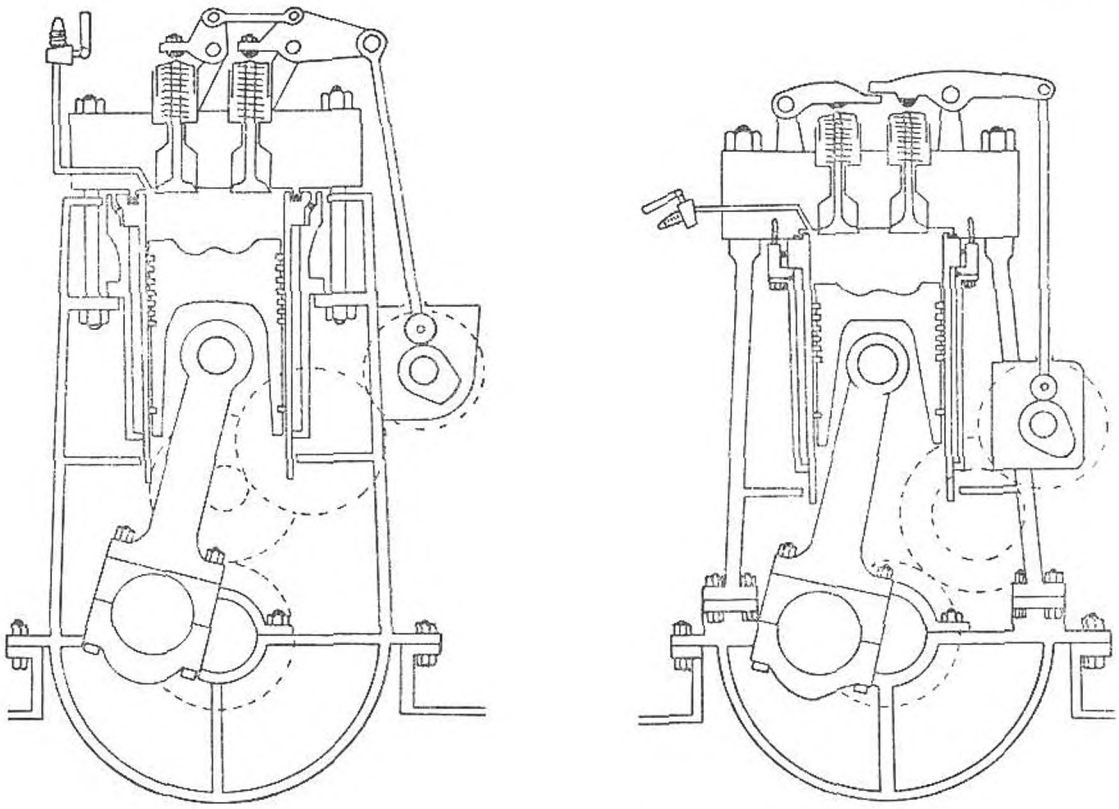
WATER JACKET. To enable cooling water to be circulated around the liner to prevent overheating. The water is also led to the cylinder head.

Crankcase

FRAME. To make a rigid connection between the cylinder unit and the crankshaft. There are two methods of securing the head to the frame; Admiralty design has an all welded frame with the heads bolted down onto it, squeezing the lips of the liners and jackets between them; Vickers design has a frame built up by a series of columns with the heads bolted on to them, the liner and jacket being secured to the head separately.

MAIN BEARINGS. To support and hold the crankshaft in position.

HOLDING DOWN BOLTS. To hold the whole engine rigidly to the submarine.



ADMIRALTY VICKERS

Fig. 35. Engine construction—Admiralty and Vickers

Valve Gear

INLET AND EXHAUST VALVES. To allow air into, and exhaust gases out of, the cylinder. Valves are fitted in pairs so that the engine can "breathe" more easily. Valves are kept on their seats by strong VALVE SPRINGS.

ROCKER ARMS AND PUSH RODS. To enable the valves to be opened by a camshaft. An adjustable TAPPET is fitted at the point where rocker arm meets the end of the valve stem. A small clearance is deliberately left between the tappet and valve stem so that the valve always positively shuts even when it expands due to the heat.

CAMSHAFT. To open the valves at the appropriate periods to achieve the four-stroke cycle. A shaft held in bearings is fitted with a set of cams, one for each pair of valves and is driven from the crankshaft by a set of gear wheels (or bevel wheel vertical drive), it is designed to run at half the speed of the crankshaft.

Other Fittings

SUPERCHARGER. To increase the power that can be obtained from an engine. Air is pumped up to a small pressure so that when the induction valve opens a greater weight of air can enter the cylinder. This provides more oxygen for burning more fuel, and therefore, getting more power.

VIBRATION DAMPER. To help smooth out the sudden strain on the crankshaft as each piston comes on the power stroke. It is either fitted on the forward end of the engine (Vickers-Sandner hydraulic damper), or incorporated in the engine clutch (Bibby coupling).

INDICATOR COCK. To provide a means of fitting a Dobbie McInnes Indicator for measuring cylinder pressures. The cock is also used when turning the engine to make sure water is not present in the cylinder.

"S" class	8 cylinders	950 H.P.
"T" class	6 cylinders	1250 H.P.
"A" class	8 cylinders	2150 H.P. Supercharged
"ASR 1"	V16 cylinders	1840 H.P. Supercharged

FUEL INJECTION—JERK AND COMMON RAIL (Refer to *Fig. 36*)

Requirement. To introduce fuel as a fine spray into the cylinder at the correct moment; and in varying quantities to suit engine power required.

Jerk Type (Injector)

(1) NOZZLE. To break up the fuel into fine particles to spread it evenly throughout the space above the piston, and mix it with the air.

(2) PLUNGER. To force fuel through small holes in the nozzle.

(3) CAM. To operate plunger in step with the piston on every other top dead centre (four-stroke cycle). Cam rotates at half crankshaft speed.

(4) SPRING LOADED VALVE (needle valve). To ensure that fuel arrives at the nozzle holes at high pressure.

(5) SPRING. To keep the plunger following the cam when on the suction stroke.

(6) START OF INJECTION. When plunger covers the suction port. Injection is designed to start when the piston is at or near the top of the compression stroke.

(7) END OF INJECTION (Refer to *Fig* 36)

(*a*) To stop the engine the pumping action of the plunger is stopped. This is done by by-passing the space above the plunger with the suction port by cutting a groove in the plunger.

(*b*) To get the plunger to pump again, the groove must be moved round away from the suction port, and the space below the groove sealed by extending the plunger. This, however, will give injection over the full stroke of the plunger and therefore full power only.

(*c*) For half-power, only half the stroke is needed for pumping; the other half of the stroke is by-passed by cutting the groove wider on the lower half of the plunger. For more variations of power, the groove is cut wider at various heights.

(*d*) For all powers from zero to full, the grooves are joined into the form of a slope. The power on the engine is then determined by rotating the plunger so that the slope will uncover the suction port and by-pass the pressure at different lengths of the stroke.

(8) ROTATING SLEEVE. To rotate the plunger for varying engine powers. An arm fixed to the plunger engages with a slot in the sleeve to allow for the up and down movement. The sleeve is turned by the control lever at the forward end of the engine.

(9) NON-RETURN VALVE. To keep a pressure in the supply pipe when plunger is on the suction stroke. This pressure tends to balance the pressure of the spring in the injector which tends to cause dribbling at the nozzle.

(10) ANTI-DRIBBLE DEVICE. To allow the spring loaded valve (Injector) to shut tight. A plunger on the non-return valve takes up space in the supply pipe when valve is open, but, when the valve shuts, this space will be taken up by the fuel in the pipe thus causing a drop in pressure.

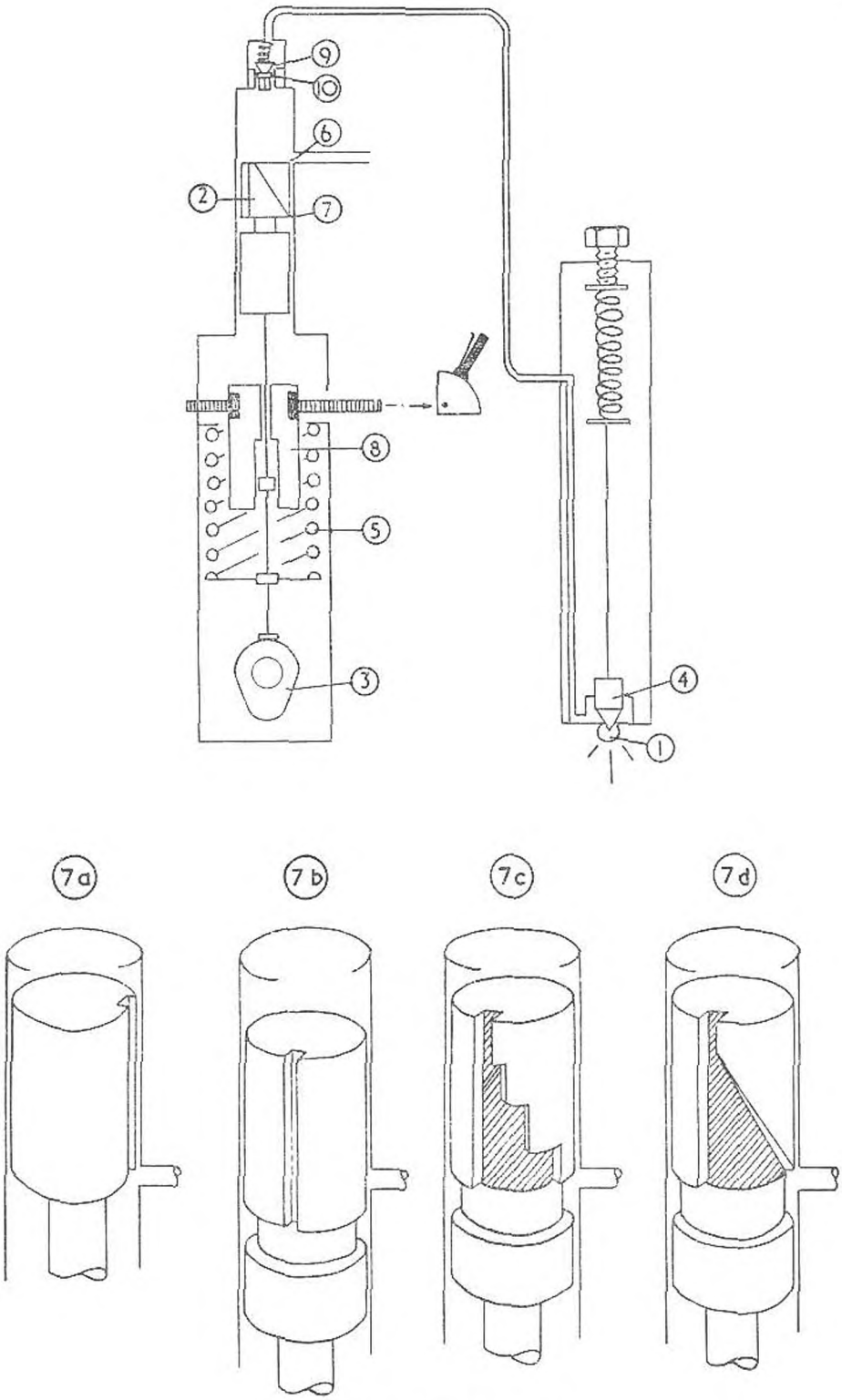


Fig. 36. Fuel injection—Jerk type

COMMON RAIL TYPE (SPRAY VALVE) (Refer to *Fig. 37*)

(1) NOZZLE. To break up fuel into fine particles to spread evenly throughout the space above the piston, and mix it with the air.

(2) COMMON SUPPLY RAIL. To supply fuel at a high pressure (up to 12,000 lb/sq. in.) to all spray valves.

(3) CAM OPERATED VALVE. To allow fuel to pass through the nozzle when the piston is on every other top dead centre (four-stroke cycle). The rods and levers between the cam and valve are in two parts.

(4) SPRING. To keep valve on its seat because the fuel pressure tends to open it.

(5) BALANCE PLUNGER. To equalise the fuel pressure acting on the valve. This enables a much smaller spring to be fitted.

(6) START OF INJECTION. When cam opens valve.

(7) END OF INJECTION. When cam allows spring to shut the valve.

(8) SPRAY VALVE LEVER. To vary the amount of fuel injected. This lever (fitted at the forward end of the engine) alters the gap between the two parts of the leverage system, and will alter the time the valve is open and how much it lifts, which determines the amount of fuel being injected.

(9) PLUNGER. To provide pressure to the common rail.

(10) ECCENTRIC. To operate plunger.

(11) SUCTION AND DISCHARGE VALVES. To enable the plunger to pump.

(12) FUEL PUMP LEVER. To vary the output of the plunger and, therefore, the pressure in the common rail. Higher pressures are required for high engine speeds to get efficient mixing of fuel and air in the shorter time available. The effective pumping stroke of the plunger can be varied by keeping the suction valve open for part of the stroke.

In order to ascertain that each piston is doing its fair share of work, the temperature and pressure inside each cylinder must be checked. To do this a thermometer (or pyrometer) is fitted close to the exhaust valve outlet to measure the temperature of the gases as they leave the cylinder (exhaust temperature), and a Dobbie McInnes Indicator is fitted on the indicator cock to measure the pressure (maximum pressure). By comparing the exhaust temperatures and the maximum pressures on each cylinder, alterations necessary in the amount of fuel injected and the time of injection can be estimated.

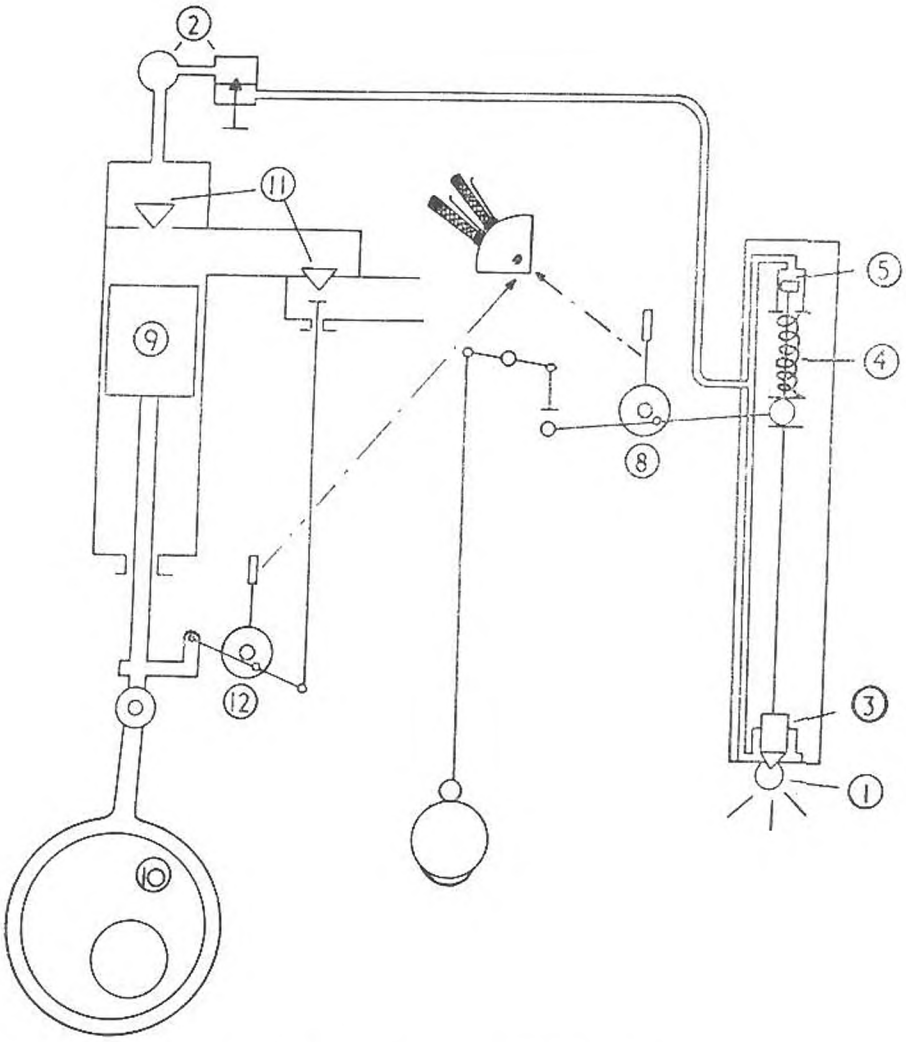


Fig. 37. Fuel injection—Common rail type

TYPICAL SYSTEM FOR FUEL SUPPLY TO ENGINES (Refer to *Fig. 38*)

Objects. (a) To supply fuel from the fuel group to the engine fuel pump in a clean, water free state.

(b) To measure fuel consumed (to 1/10 gallon), and to have a quick accurate method of measuring fuel consumption for checking engine performance.

(c) To collect fuel leak-off for re-use.

(a) **Fuel Supply**

(1) SUPPLY LINE. To connect fuel group subsequent filling lines to the engine system. Fuel is pushed out of the group by compensating water pressure from the engine circulating water system regulated from the engine room. Pressure gauge is fitted to the supply line to indicate that fuel is in fact reaching the engine room.

(2) FUEL PUMP. To pump fuel to injector or spray valve at a very high pressure.

(3) GRAVITY TANK. To provide a reserve supply of fuel when groups are being changed over, and to provide a gravity (small pressure) feed when the engines are stopped to prevent air locks forming in the fuel supply line to pump. Fitted with vent and gauge glass. Any water coming over with the fuel can be drained off from the sump in the tank bottom.

(4) FLOAT VALVE. To regulate the flow of fuel so that the level in the gravity tank is automatically maintained.

(5A) CHANGEOVER COCK. To by-pass float valve in the event of the float valve failing to open.

(6) CENTRIFUGAL SEPARATOR. To extract water and small solid matter from the fuel before it enters the gravity tank. Comp pressure feeds fuel to the separator, and separator pump discharges it to the gravity tank. A spare bowl is carried so that the separator need only be out of action for short periods.

(7) STRAINER (Lolos type). To extract small solid matter from the fuel when separator is being cleaned or out of action.

(5B) and **(5D)** CHANGEOVER COCKS. To direct flow of fuel either through the separator or through the strainer.

(8) *FILTERS (Vokes type). To extract fine particles of dirt from the fuel. It is most important* that the fuel injection equipment is not ruined by scores or wear caused by dirt particles and rust on the polished finish of the working parts.

(b) **Fuel Consumption**

(9) FLOWMETER. To measure the total fuel consumption to the nearest 1/10 gallon. Flowmeter and filter can be by-passed for repair or cleaning.

(10) SNAP TANK. To measure the rate at which the engine is using fuel (e.g. gallons per hour). A separate compartment in the gravity tank, approximately one gallon, can be put on the engine, and the time taken to use this amount is measured by a stop watch.

(11) VALVE CHEST. (a) To enable the snap tank to be individually connected to the engine, or (b) to enable the gravity tank to be by-passed.

(c) **Fuel Leak-off**

(12) DRAIN TANK. To collect the leak-off from the fuel injection equipment, vents and drains.

(13) HAND PUMP. To empty the drain tank.

(5C) CHANGEOVER COCK. To direct the drained fuel either to the separator inlet, or for ready use purposes.

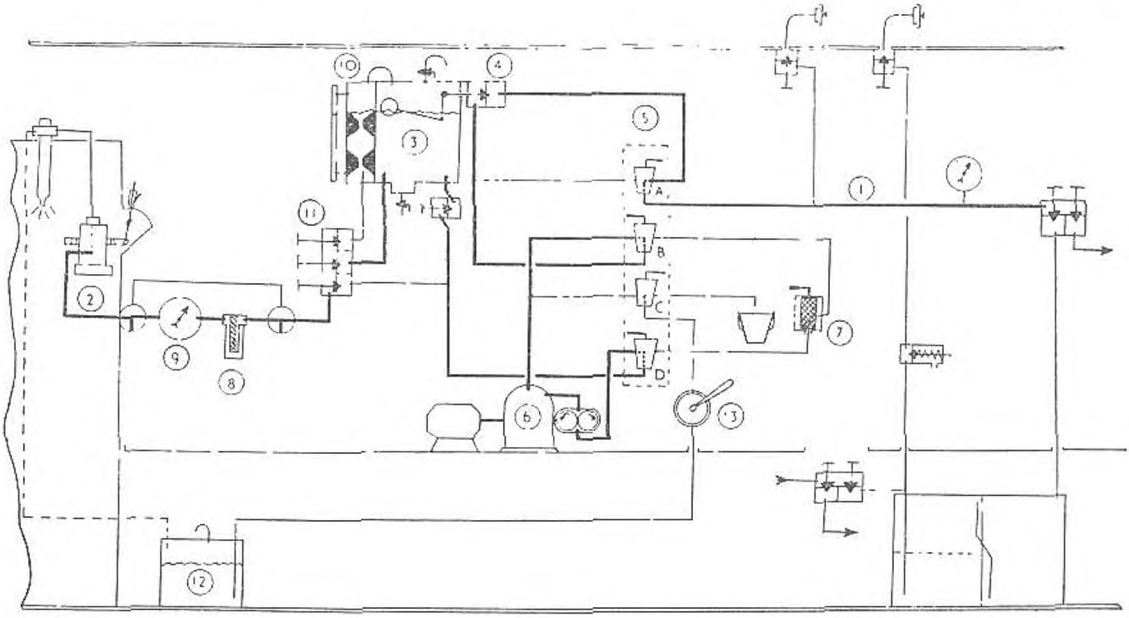


Fig. 38. Typical system for fuel supply to engines

TYPICAL SYSTEM FOR LUBRICATING OIL SUPPLY TO ENGINES (Refer to *Fig. 39*)

Object. To carry oil, cool and free from solid matter, under pressure to the bearing surfaces of the moving parts to reduce friction and carry away the heat.

(1) CRANKSHAFT IN MAIN BEARING. Supplied with oil under pressure. Oil is led through a hole in the crankshaft to the *Crankpin in the Large End Bearing*, and thence through a hole in the connecting rod to the *Gudgeon pin in the Small End Bearing*.

(2) CLUTCH SLIDING SLEEVE. Supplied through crankshaft.

(3) CAMSHAFT BEARINGS. Lead off main supply at a lower pressure.

(4) GEARING. Lead off main supply to an oil spray onto the teeth of the gears.

(5) PISTON RINGS IN PISTON. Has separate supply using a mechanical lubricator.

(6) ENGINE DRIVEN PUMP (gear wheel type). To supply oil under pressure while the engine is running. Suction taken from the D.O.T. through an S.D.N.R. valve so that the pump is kept primed. Fitted with a relief valve on the suction side to prevent damage should the engine "kick back" or be turned astern.

(7) ENGINE SUMP. To collect hot oil coming out of the bearings and gears. Oil drains down into the D.O.T.

(8) ADJUSTABLE RELIEF VALVE. To enable pump discharge to be adjusted to designed working pressure. Pressure gauge fitted on supply to main bearings.

(9) COOLER. To prevent oil overheating. Fitted with thermometers to show the temperature drop, and gauges to show the pressure drop through the cooler. Can be by-passed for maintenance purposes.

(10) STRAINER (Lolos type). To prevent solid matter passing round and scoring bearing surfaces. The cartridge will tend to clog but it can be cleared by rotating.

(11) PRIMING PUMP (gear wheel or Imo type, motor driven). To provide oil pressure before starting and when stopping the engine. It normally takes suction from the D.O.T. through an S.D.N.R. valve. It takes suction from the reserve tanks for topping up the D.O.T.

(12) HAND PUMP (semi-rotary type). To provide oil pressure for starting and stopping if the priming pump fails.

(13) PRIMING AND VENT COCKS. To initially prime the engine driven pump suction line using either the priming pump or the hand pump.

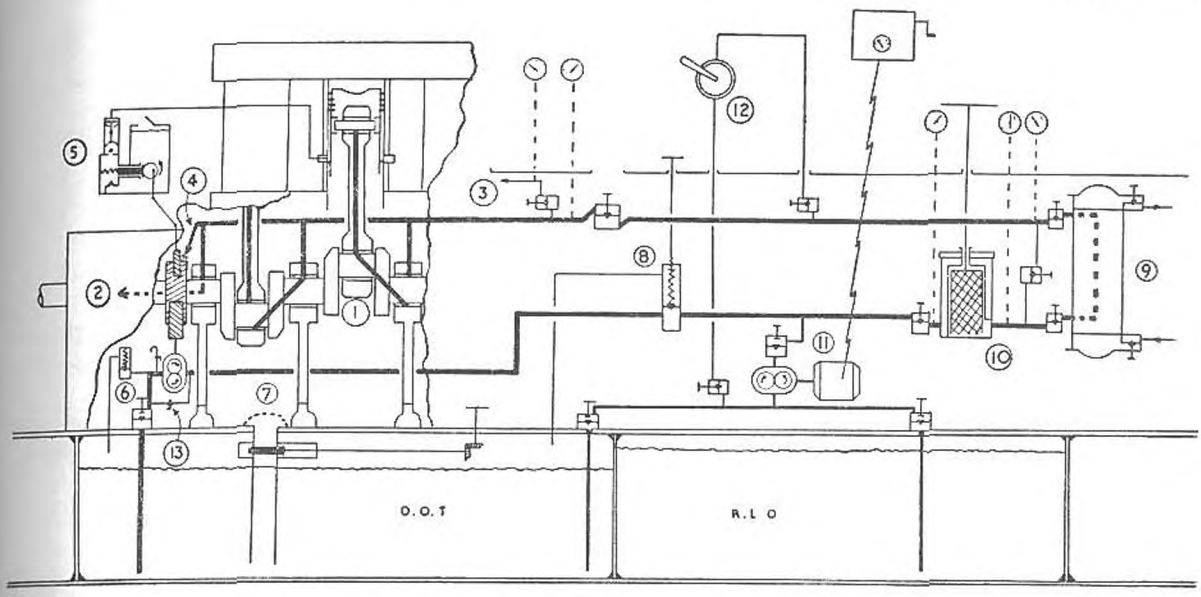


Fig. 39. Typical system for lubricating oil supply to engines

CIRCULATING WATER SYSTEM—MAIN ENGINES (Refer to *Fig. 40*)

Objects. To prevent overheating of the engine parts.

(b) To have a means of, (i) regulating the water temperature for maximum engine efficiency, and (ii) cooling the engine gradually after stopping to prevent strain on the engine parts due to uneven cooling.

(c) to provide comp water pressure for the fuel groups.

(a) **Engine Cooling**

(1) SUPPLY LINE. *To supply water to each cylinder water jacket. Water enters bottom of cylinder* jacket, passes around the cylinder and up through holes or tubes to the hollow cylinder head. Discharge pipes from each cylinder head are led into the exhaust manifold jacket.

(2) MAIN CIRCULATOR (centrifugal pump). To feed supply line with water pressure. Pressure gauge is fitted to indicate that the circulator is working. Relief valve fitted to relieve excess pressures.

(3) DISCHARGE LINE. To collect all discharge water from the exhaust manifold.

(4) OVERHEAD (hull valve). To allow discharge of water to exhaust tank sprays.

(5) EXHAUST JACKET SUPPLY. To supply water to exhaust system jacketing.

(6) LUBRICATING OIL COOLER. To prevent lubricating oil overheating. Fitted with a pressure gauge to measure the drop of pressure through the cooler on the water side, and a by-pass valve in case of blockage.

(7) VENT. To vent the system, which ensures that no air locks or pockets are formed. Fitted at the highest point in the system.

(8) REDUCED BLOW. To clear the water from the cylinder jackets and heads for maintenance purposes by blowing down to sea.

(9) HOSE CONNECTION. To feed water pressure into the system from the main line in an emergency.

(b) (i) TEMPERATURE CONTROL

(10) LOOP VALVE. To enable some hot water to be led back to the circulator suction for recirculation. Valve is opened up to maintain a temperature of approximately 120°F. at the discharge line.

(11) THERMOMETER (dial type). To indicate temperatures in the discharge and supply lines.

(b) (ii) GRADUAL COOLING

When the submarine is dived, the circulator inlet and overhead discharge valves are shut because the engine system will not stand pressures below 120 feet. In order to cool the engine gradually and evenly, the loop valve is opened fully and the water recirculated for about five minutes until the discharge and inlet temperatures are the same. Pressure in the system will rise if the hull valves are leaking, but this pressure can be released through the hose connection or vents. A relief valve is fitted to protect against excess pressures.

(c) **Comp Water Supply**

(12) COMP MASTER VALVE. To provide water pressure for fuel group compensating.

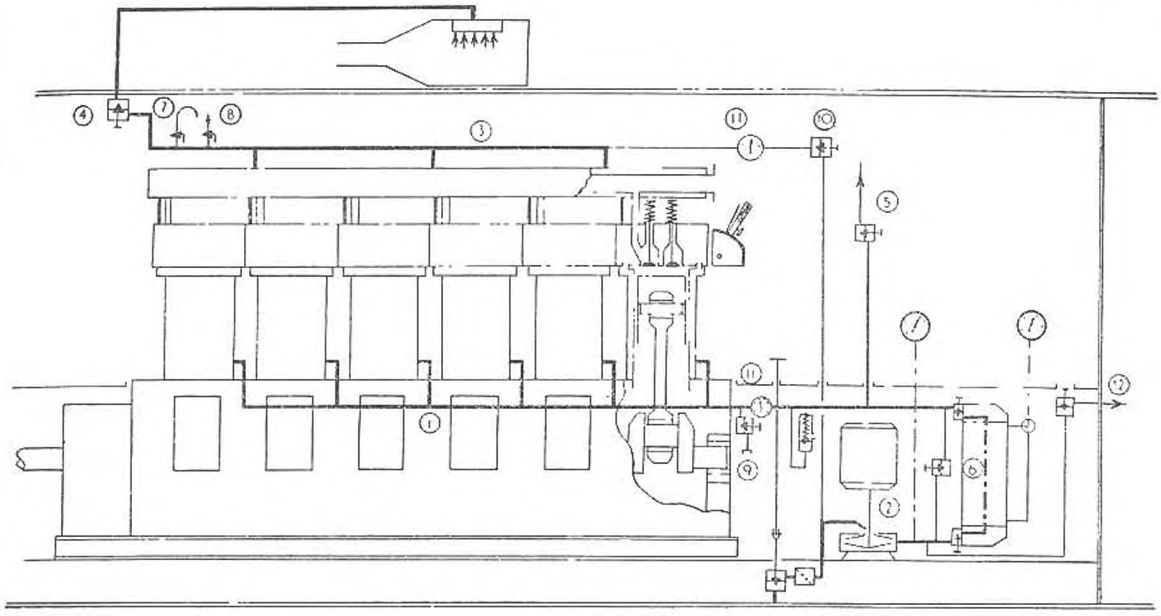


Fig. 40. Circulating water system—main engines

TYPICAL EXHAUST SYSTEM (Refer to *Fig. 41*)

Object. To lead the engine exhaust gases outside the pressure hull when either (a) on the surface, or (b) at periscope depth.

(a) **On the Surface**

(1) EXHAUST MANIFOLD. To group individual cylinder exhaust pipes into one pipe. Cooled from engine circulating water system.

(2) GROUP EXHAUST (hull valve). To enable exhaust gases to pass through the pressure hull.

(3) EXPANSION GLAND. To allow for expansion of piping.

(4) SURFACE MUFFLER. To shut off exhaust pipe. This valve is designed to shut easily and quickly, and it has a "dexine" seat which helps to reduce the chance of leakage due to carbon *deposits.*

(5) EXHAUST TANK. To cool the gases and muffle the noise. Discharge from aft services and engine circulating water provide the water for the sprays.

(6) VENT PIPE. To enable the exhaust tank to flood when the submarine dives.

(b) **At Periscope Depth**

(7) SNORT EXHAUST PIPE. To enable the exhaust gases to be discharged at periscope depth. Designed so that outlet is 3 to 4 feet under the water in order to reduce vapour trail. The pipe is usually secured inside the bridge fin (hinged with induction pipe on earlier classes).

(8) SNORT MUFFLER. To shut off snort exhaust pipe. This valve has a metal seat and is therefore fitted with grinding gear to remove carbon deposits. The grinding gear is normally locked by a pin. For grinding, this pin is re-positioned to lock the shutting gear with the grinding gear so that they revolve together.

(9) SNORT EXHAUST DRAINS (inboard and outboard). To drain down snort exhaust pipe after surfacing.

(10) SNORT EXHAUST BLOW. To expel water from the snort exhaust pipe just prior to starting the engines to reduce back pressure.

(11) MUFFLER LOCK. To ensure that the surface muffler is held on its seat when snorting.

(12) EXHAUST COOLING WATER. To cool all piping subject to heat from the exhaust gases. Water is discharged as a spray above the surface muffler seat for extra cooling.

(13) GROUP DRAIN. To drain off any water that may leak through either the surface muffler valve or the snort muffler valve. This drain is normally left open when the engines are stopped so that a leak is detected immediately.

The exhaust mast on later classes is telescopic instead of being a fixed pipe secured to the fin, as in he earlier types. Raising and lowering is carried out by means of a telemotor operated press or hydraulic notor situated inside the hull.

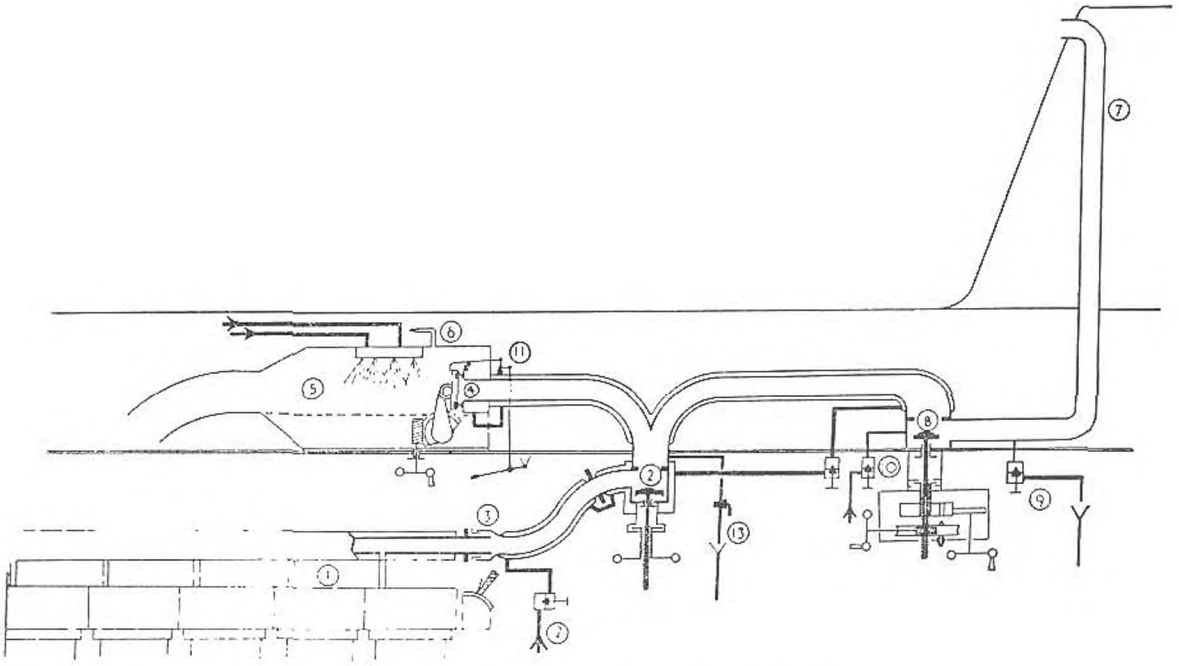


Fig. 41. Typical layout of exhaust system

HINGED SNORT INDUCTION SYSTEM (Refer to *Fig. 42*)

Object. To enable the main engines to get an air supply when the submarine is at periscope depth.

Induction

(1) SNORT MAST. To enable air to be drawn into the submarine when the engine(s) are running.

(2) HEAD VALVE (ring float type). To prevent water entering the mast. The float shuts the valve when the head is dipped by a wave or by loss of depth. When the head is dipped the submarine acts as a large reservoir to enable the engines to continue running until the head valve re-opens.

(3) SNORT INDUCTION HULL VALVE. To shut off mast when not in use. ALWAYS SHUT AND COTTERED WHEN THE MAST IS NOT ACTUALLY BEING USED, that is, when the engines are stopped.

(4) HYDRAULIC POWER UNIT (small press type). To open and shut the hull valve. Valve can be shut by hand should telemotor pressure fail. The by-pass to be opened when working in hand.

(5) CONTROL COCK. To control shutting and opening of induction hull valve. Situated at the engine control position readily accessible. Shutting line fitted with a spring loaded accumulator.

(6) DUAL CONTROL COCK. To enable the induction hull valve to be SHUT (only) from the control room. Cock introduces pressure to a small ram which turns the main control cock in the engine room to the shut position.

(7) SNORT EMERGENCY FLAP VALVE. A quick means of shutting off induction. Always shut when engines are stopped. Can be shut from the engine control position by an extension wire, and will shut automatically on a heavy inrush of water.

(8) VENTILATION CROSS CONNECTION. To enable fresh air to be drawn through the ventilation trunking. All or part of the induction air can be fed to the ventilation by adjustment of the flap valves.

Lowering and Raising Mast

(9) HINGE (trumnion bearing). To enable the mast to be lowered level with the casing.

(10) PISTON. To lower and raise the mast by power. Connected to the snort mast by connecting rod and slipper. Totally enclosed so that telemotor pressure can be used. Drain valve fitted to enclosure to indicate any leakage.

(11) PISTON CONTROL VALVE. To control the lowering and raising of the mast from the control room.

(12) MAST INDICATOR. To show movement of the mast. Situated close to the control position.

(13) LOCKING PIN. To secure the mast to the bridge fin when in the raised position.

(14) HANDWHEEL (locking pin). To work the locking pin. Interlocked with the raising control lever to prevent mast being worked when the pin is in. Control valve lever cannot be moved until pin is fully out.

Flooding

(15) HEAD VALVE GUIDE. To open the head valve when the mast is in the lowered position. Mast is not tested to full diving pressure so it is made free flooding when lowered.

(16) VENT. To allow mast and induction to flood up completely as far as the induction hull valve. Vent fitted at highest point and automatically shuts and opens when the mast is raised and lowered.

Draining Down

(17) SNORT DRAIN ONE and

(18) SNORT DRAIN TWO. To drain the mast and induction as far as the induction hull valve to a compensating tank ("O" or "R").

(19) TUNDISH. To enable draining down to be sighted in the control room.

(20) SNORT DRAIN TWO INTERMEDIATE. To provide a shut off at the engine room bulkhead. Valve is normally pinned open.

(21) DRAIN PLUG. To test for water before opening emergency flap valve.

(22) WATER TRAP. To collect water that may splash down the mast during choppy weather. Snort drain one is left open while snorting in order to keep the water trap drained.

(23) SNORT DRAIN TANK. To collect water or spray which gets carried over with the air.

(24) INDICATOR PIPE. To show when large quantities of water are flowing down the mast.

NOTE. The drill for starting and stopping snorting varies with the hinged and periscopic induction systems and general guidance for the operations is laid down in *Submarine General Memoranda*, No. 207.

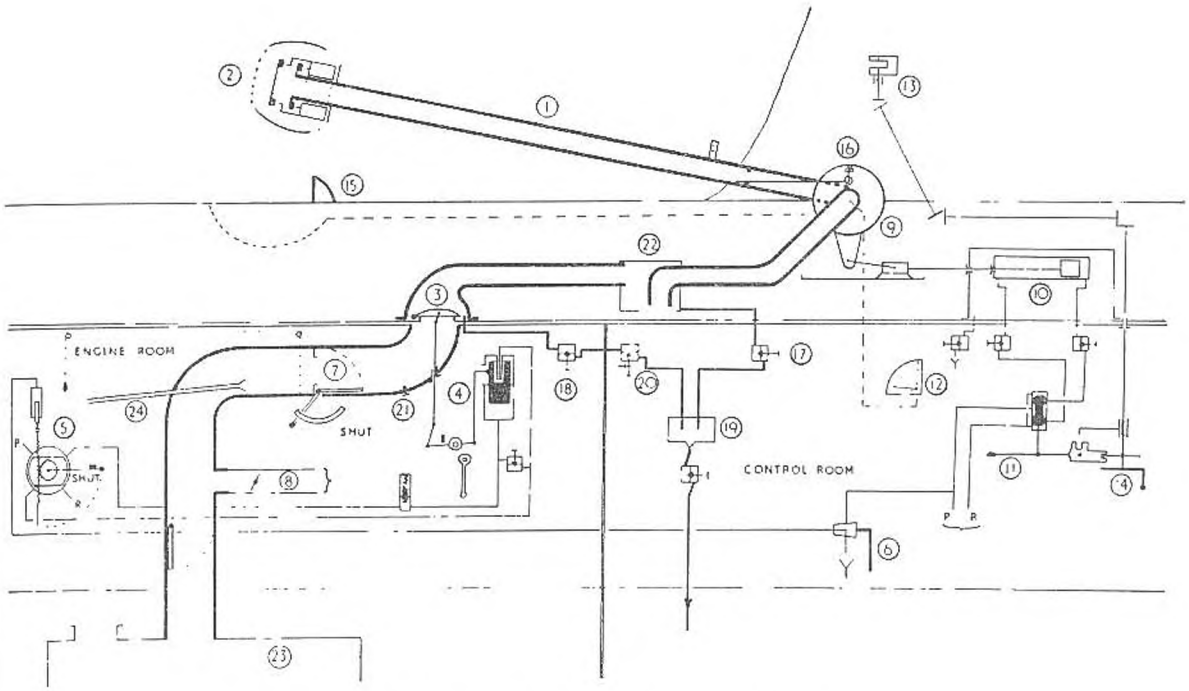


Fig. 42. Layout of hinged snort induction system

PERISCOPIC SNORT INDUCTION SYSTEM (Refer to *Fig. 43*)

Induction

Items (1)—(8) listed on the hinged type snort induction system are fitted on the periscopic system.

Lowering and Raising Mast

(9) OUTER TUBE. To allow free passage of air from the mast to the induction piping when the mast is raised. A pressure tight gland is fitted at top and bottom. The bottom three feet of the outer tube forms the water trap.

(10) CROSSHEAD. To enable the mast to be raised by a conventional wire rove periscope press.

Flooding

(11) MASTER FLOOD AND DRAIN VALVE. Fitted for use in the event of (12) leaking. Located outside the hull but operated from inside. Normally lashed open.

(12) FLOOD AND DRAIN VALVE. To allow induction piping, outer tube and upper part of the mast to fill with water when not snorting as none of these parts of the system are tested to full diving pressure. Located outside the hull but operated from inside. It also allows the system to be drained down in harbour.

(13) A AND B VENTS. A. Outer tube vent to allow outer tube to flood. Fitted to the highest point of the outer tube and operated by the hull cock inside the hull.

B. Upper mast and head valve vent to allow the upper section of the mast to flood. Fitted to the highest point of the head valve and, by means of rod gearing, can be operated when the mast is in its well.

Draining Down

(14) SNORT DRAIN ONE. To drain the outer tube and upper part of the mast into a compensating tank. Fitted to the bottom of the outer tube (water trap).

(15) SNORT DRAIN TWO. To drain induction piping from the outer tube to the hull valve.

(16) TUNDISH. To enable draining down to be sighted in the Control Room.

(17) HELICAL DRIER. To remove moisture from the air by imparting a swirling effect, centrifugal force then throwing out the heavier water. Water is drained into snort drain two line so it too must be left open when snorting.

(18) DRAIN PLUG. To test for water before opening the emergency flap valve.

(19) SNORT DRAIN TANK. To collect any water which passes the helical drier.

(20) INDICATOR PIPE. To show when large quantities of water are flowing down the mast.

Main Hazards

(a) Water entering induction hull valve so rapidly that it may sink the submarine.

(b) Going too deep with engine running so that water floods back through the exhaust damaging the engine beyond repair.

(c) Air pressure below 25¾ inches produces ill effects in the crew through lack of oxygen.

Stopping Engines without Orders

(a) Continual heavy inflow of water coming down the mast.

(b) Pressure persists steadily below 25¾ inches for more than 2 or 3 minutes, or falls below 22 inches.

(c) At a certain depth (T and S 60 feet, T Conversion 62 feet, A 68 feet).

(d) Back pressure across the engine reaches 12 lb/sq. in.

(e) A bow down angle persists more than 6 degrees for more than 2 minutes.

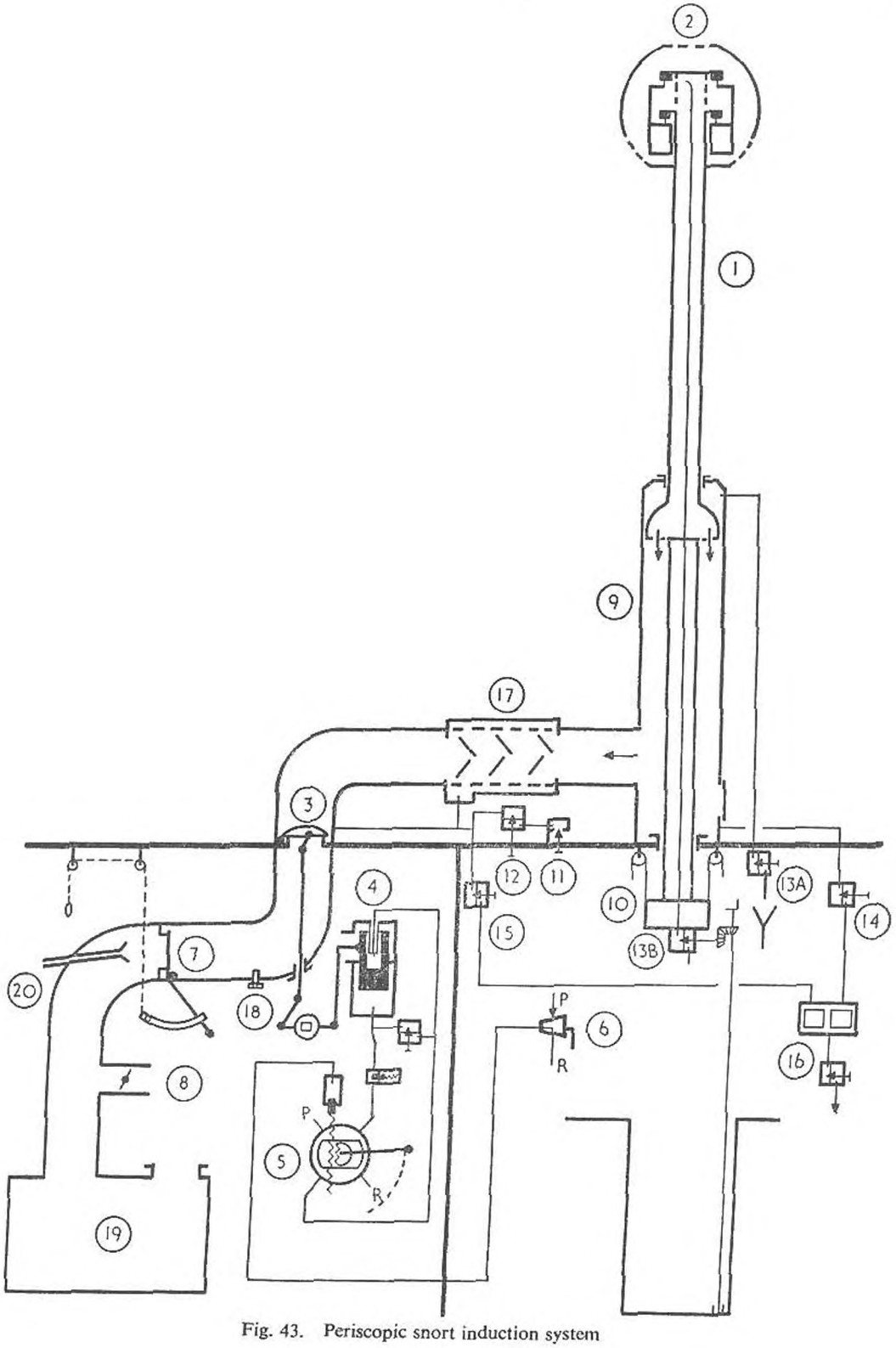


Fig. 43. Periscopic snort induction system

AIR START SYSTEM

Objects. (a) To get the engine turning at a sufficient speed so that compression ignition can take place.

(b) To turn the engine before starting to ensure that each cylinder is free of water.

AIR START BOTTLE. To hold sufficient compressed air to start the engine. Air is admitted from the H.P. air system to give bottle pressure up to 1,000 lb/sq. in.

DISTRIBUTION BOX. To admit air to the cylinder which is on the power stroke, that is, the cylinder which has inlet and exhaust valves shut. This will force the piston down. Thereafter, air will be admitted to the other cylinders when they are on the power stroke. This will go on until the engine speed is enough to create sufficient heat of compression to ignite the injected fuel in a cylinder which is on the compression stroke. As soon as one cylinder fires, the others will quickly follow suit, and the air can be shut off. A non-return valve on the cylinder head prevents firing pressure entering the system.

CONTROL VALVE. To admit air from the bottle to the distribution box when starting is desired.

INTERLOCK. To prevent damage to the turning gear when it is "IN". Engine starting air cannot be admitted to the distribution box until a cock or valve on the system is opened when the turning gear is taken "OUT".

CHAPTER 4

Auxiliary Machinery and Miscellaneous Equipment

TYPICAL REFRIGERATOR SYSTEM (Refer to *Fig. 44*)

Object. To preserve foodstuffs by freezing in a closed cupboard.

Principle

(*a*) Refrigeration is brought about by the cooling effect of the evaporation of a liquid gas. Approximate temperature required is 10°F.

(*b*) Maximum evaporation takes place as liquid "boils".

(*c*) Each liquid has its own boiling temperature (at normal pressure).

(*d*) A liquid with a low boiling temperature (below 10°F.) is required. Freon 12 is used.

(*e*) This liquid is known as a refrigerant.

(1) COLD CUPBOARD. To hold the foodstuffs to be cooled.

(2) EVAPORATOR COIL. To provide a large cooling surface.

(3) LIQUID CONTAINER (condenser). To hold the liquid refrigerant under pressure.

(4) REGULATING VALVE. To control the flow of liquid refrigerant. A pressure drop occurs through this valve. Fitted with strainer and sight glass.

(5) COMPRESSOR. To extract refrigerant vapour from the evaporator coils at the same rate as it is being admitted, and to compress the vapour and return it to the liquid container.

(6) COOLING WATER SUPPLY. To cool the compressed (hot) vapour. The vapour will then condense. Cooling water circulated by a small pump driven from the compressor motor.

(7) AUTOMATIC TEMPERATURE CONTROL. To maintain the cold cupboard at the desired temperature. A small bulb, filled with refrigerant, fitted in the cold cupboard and connected by a small bore pipe to a bellows piece working an electrical switch. As the temperature in the cold cupboard falls to the required temperature, refrigerant in the bulb contracts, bellows contract, switch is broken and the compressor is stopped.

(8) AUTOMATIC LIQUID CONTROL. To pass the correct amount of liquid to the evaporator coils. A bulb on the evaporator discharge pipe connected to a bellows piece under the regulating valve. Too much liquid passing the valve will cause evaporation to take place in the discharge pipe. The bulb cools, bellows contract and valve shuts.

(9) HIGH PRESSURE CUT-OUT. To stop the compressor if excessive pressures are reached in the condenser.

(10) GAUGES. To register working pressures in the system. Compressor discharge pressure/temperature should be approximately 10°–15°F. above condenser water outlet temperature; compressor suction should be approximately 10°- -15°F. below cupboard temperature.

(11) THERMOMETERS. To register inlet and outlet temperatures of cooling water at the condenser.

(12) SERVICE VALVES. (a) To isolate parts of the system to repair leaking joints, refit compressor, refit shaft bellows gland, clean regulating valve and recharge drier, and (b) to enable the system to be filled with refrigerant.

(13) DRIER. To extract moisture from the refrigerant, particularly when charging the system.

(14) HEAT EXHANGER. To increase the efficiency of the plant by pre-cooling the refrigerant before it passes through the regulating valve.

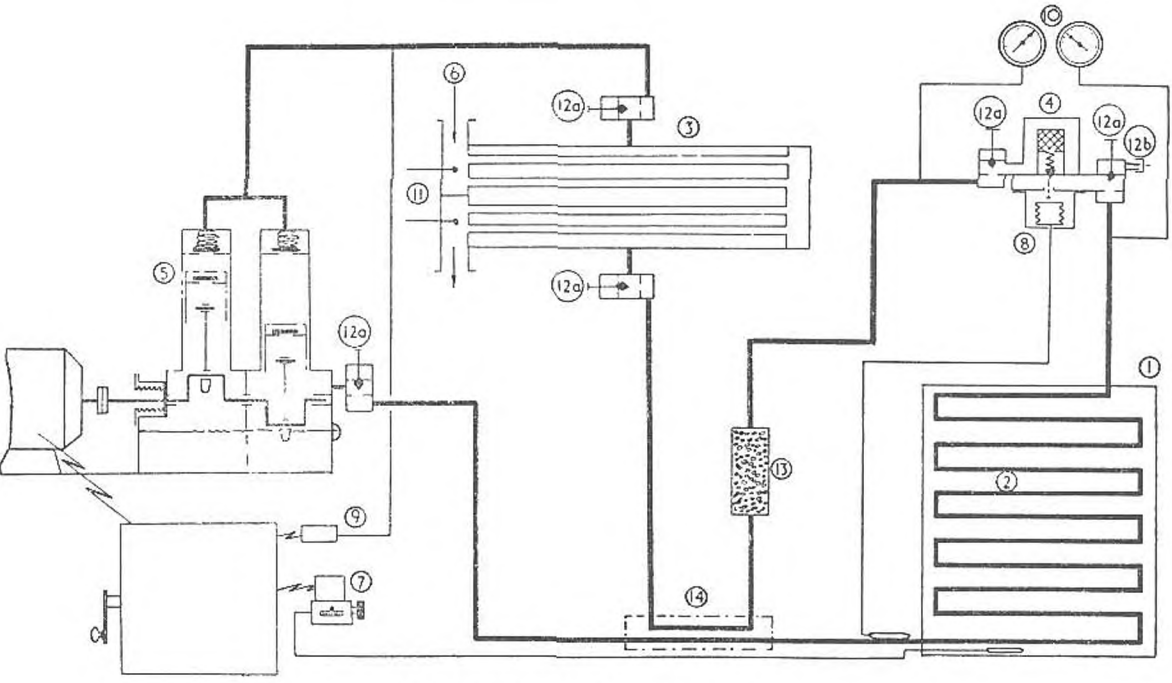


Fig. 44. Typical refrigerator system

AIR CONDITIONING PLANT (Refer to *Fig. 44*)

Object. To reduce the moisture content (humidity) of the air by cooling.

The plant uses the refrigeration cycle to cool the air. The main differences are :—

(1) FAN TRUNKING. Evaporator coils are placed inside the fan trunking on the suction side of the fan. The air is cooled and the moisture in the air condenses. The condensate drips to the bottom of the fan trunking, and is led away to a compensating tank. It is essential that the evaporator coils are kept clear of dust and fluff.

(5) COMPRESSOR—4 pistons. Starter has a speed regulator so that the plant can be run to suit humidity conditions.

(6) COOLING WATER SUPPLY. From forward services, but with a local discharge hull valve.

(7) AUTOMATIC TEMPERATURE CONTROL. Not required. The plant is started when humidity conditions make it uncomfortable for the crew, the plant is run continuously, as sweating and bilge evaporation tends to constantly raise the humidity again. Very little advantage is gained by running the plant in harbour with the hatches open or the battery ventilation discharging outboard.

DISTILLER (Refer to *Fig. 45*)

Requirement. To get fresh water (pure enough for drinking and topping up batteries) from the sea.

Boiling and Condensing

(1) SHELL. To hold sea water (water, salts and dissolved air) for boiling. Water heated by electrical immersion heaters.

(2) HEATER SWITCHES. To regulate the rate of boiling. All heaters are switched on for starting. Once the water is boiling the number of heaters can be reduced so that the foam level is just up to sight glass level.

(3) CONDENSER. To condense the steam. Condenser should be kept as near as possible to the temperature of the boiling water.

(4) VAPOUR COMPRESSOR. To draw off steam (and liberated air) from the shell (shell vacuum) and compress it (condenser pressure). Fitted with by-pass to enable gradual work-up of pressure.

Principle

(*a*) Boiling temperature of water at sea level (15 lb/sq. in.) is 212°F. On top of a mountain where the atmospheric pressure is less (say 13 lb/sq. in.) the boiling temperature is lower (207°F.). Down a mine where the pressure is more (say 17 lb/sq. in.) it will be higher (215°F.).

(*b*) Steam produced on the mountain at 207°F. would not remain steam if taken down the mine unless it is at the same time heated up to 215°F. If the temperature is kept at 207°F., the steam would condense back to water because of the increase of pressure.

(*c*) The vapour compressor produces corresponding conditions. Sea water is boiled in a shell at reduced pressure (mountain top) and the steam is condensed in the condenser at increased pressure (down a mine), the temperature remaining the same.

(5) BAFFLE. To prevent salty spray passing over with the steam.

(6) RELIEF VALVE. To protect the shell against excess pressure. This valve can be lifted by hand for venting purposes during the starting procedure.

Distilled Water Discharge

(7) CONTROL VESSEL. To retain a water seal in the distilled water discharge pipe. Funnel and changeover cock for priming seal before starting up.

(8) PUMP. To draw off the distilled water from the control vessel and discharge to ship's tanks.

(9) SNIFTER VALVE. To limit suction of the pump so that a level is maintained in the control vessel. Should the level become too low, air from the control vessel is sucked over with the distilled water. This induces more air to disolve in the water than would do under normal conditions, and the extra CO_2 dissolved will cause a higher reading on the salinometer.

(10) TEST COCK. To draw off samples for testing with silver nitrate.

(11) ELECTRIC SALINOMETER. To give a continuous reading of salinity (salt content in grains/gallon) by using a conductive cell and a special thermometer. Red light gives warning of readings above 0·3 grains/gallon. White light indicates salinometer switched on. By-pass cock is fitted.

(12) CHANGEOVER COCK. To permit discharge to bilge when starting up.

Venting

(13) CONDENSER VENT. To allow liberated air to vent from the top of the lower half on the condenser to the control vessel.

(14) VENT PIPE. To vent air from the control vessel to the submarine. Venting restricted to help to maintain stable conditions.

Brine Discharge

(15) PUMP. To draw off concentrated salt solution (brine) from the bottom of the shell and discharge it to bilge. The density should be kept at 20.

(16) STRAINER. To prevent scale fouling line and pump.

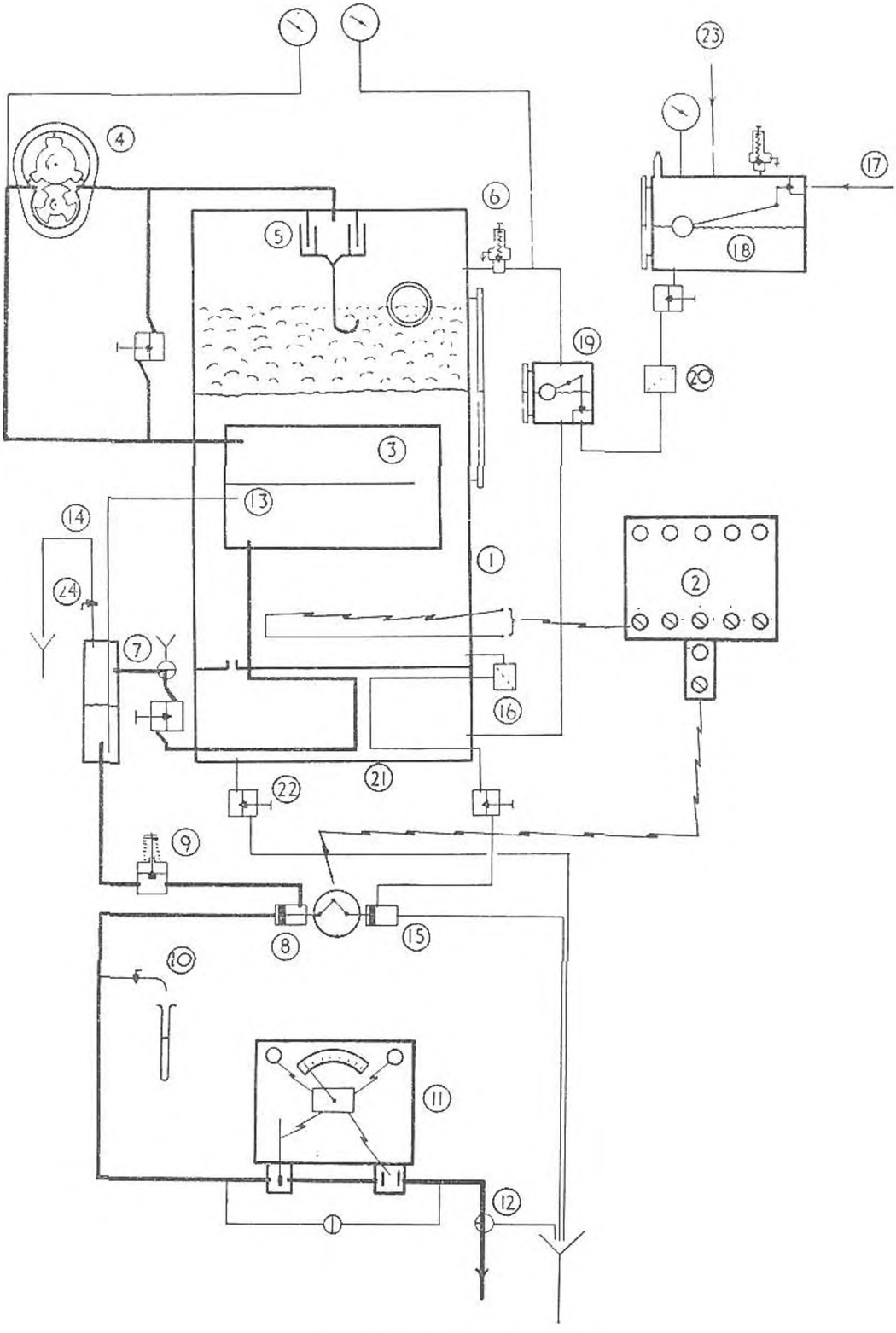


Fig. 45. Arrangement of distiller

Feed Water

(17) SEA WATER SUPPLY. From forward or aft services.

(18) FEED TANK. To provide a constant head of water so that the rate of feed is kept constant. Float valve controls the level in the tank.

(19) FEED REGULATOR. To make up water that has boiled, or has been drawn off with the brine, keeping a constant level in the shell.

(20) STRAINER. To prevent fouling of the feed regulator.

(21) HEATER UNIT. To pre-heat the feed water by using the heat from the distilled water and brine.

(22) DRAIN VALVE. To drain down the shell to bilge. Small door is fitted in front of the shell for access to remove scale.

Effects of Snorting

Stability of the plant depends on constant difference in pressure between the shell and the condenser, and steady boiling of water, which, in turn, depends on the feed head and submarine pressure.

(23) REDUCED BLOW. To introduce a small pressure in the feed tank. Reduced air is fed very slowly into the tank and bled off through a restricted vent. Alteration in submarine pressure due to snorting will have a reduced effect. Tank protected by a relief valve.

(24) VENT COCK. To control the venting of the control vessel. The cock is turned to a smaller sized hole so that alterations in the submarine pressure while snorting will reduce the pressure change effect in the condenser.

PYROTECHNICS

Object. To provide a means of indicating to surface ships the submarine's position when submerged.

Smoke Candles

WHITE—gives off white smoke and flame (10 to 15 minutes) for night use. Used when exercising with surface ships.

YELLOW—gives off yellow smoke (2 to 5 minutes). Used instead of white to show up better during bad weather and is always used for exercises with aircraft.

Float Signal Submerged (F.S.S.)

RED—for emergency surfacing or "subsunk". Four F.S.S. are always kept loaded with red grenades and stowed close to the ejector.

GREEN—used during an exercise attack to indicate when "dummy" torpedoes have crossed target track.

YELLOW—for special exercises.

When the container reaches the surface, a grenade is fired upwards between 50 to 100 feet, and shows as a star for 3 to 5 seconds in the air, and a further 2 seconds on the water.

Deep White Smoke Candle

Used as a message carrier. A small water tight steel container for a message is attached to the top of the candle. A green dye marker is screwed to the bottom before attaching the base plate.

BASEPLATES. The yellow candle and F.S.S. have base plates attached, held only by two lead pins. If these pins are sheared and the baseplate comes loose, the fuse is started and the candle or F.S.S. becomes highly dangerous. Two steel removable safety pins positively secure the baseplate until required for use. The safety pins are withdrawn when the candle or F.S.S. is required for use, but then only when it is nearly fully loaded in the ejector. When the candle or F.S.S. is fired, the base plate is left behind.

White smoke candles are comparatively safe. A baseplate must be attached before loading.

BUBBLE DECOY. This is a neutral buoyant container which gives off a large number of small bubbles. This gives a false sonar echo which confuses the enemy sonar operators.

SUBMERGED SIGNAL EJECTOR (S.S.E.)—Mk. I AND Mk. II (Refer to *Figs. 46 and 47*)

Requirements. (a) To provide a safe means of loading and ejecting smoke candles and float signal submerged (F.S.S.) containers from the submarine using air discharge.

(b) To provide a means of pushing out bubble decoys without using air discharge.

(a) Air Discharge

LOADING SMOKE CANDLES AND F.S.S.

(1) BARREL (MK. I) OR SLEEVE (MK. II). To receive the container. A rubber ring on the container makes a seal with the bore of the barrel or sleeve.

(2) SLUICE VALVE (MK. I) or FLAP VALVE (bow cap type) (MK. II). To shut off barrel from the sea. Mk. 1—a sluice valve worked by hand lever, gear wheel and rack on Mk. 2—flap valve worked by T handle, bevel wheels and levers.

(2A) SPRING LOADED CATCH. To keep the flap valve positively shut or open. The catch must be withdrawn by pulling down before the handle valve can be turned.

(3) BREECH. To shut off inboard end of barrel. The breech is swung on a hinge and pushed into position by hand. The rubber seating is screwed up tight or slackened off by a handwheel.

(4) BREECH INTERLOCK. To prevent both sluice valve (or flap valve) and breech being opened at the same time.

(5) EQUALISING VALVE. To enable the pressure in the barrel to be equalised with the sea pressure so that the sluice valve (or flap valve) can be opened easily.

EJECTING SMOKE CANDLES AND F.S.S.

(6) AIR BOTTLE. To hold sufficient compressed air to eject once and give the container plenty of initial movement.

(7) REDUCING VALVE. To enable the correct pressure to be put in the bottle. Pressure gauge and relief valve fitted on the reduced side. Mk. I—reducer is hand operated giving pressures up to 400 lb/sq. in. Mk. II—reducer is automatic and is differential so that the bottle pressure will always be charged to 200 lb/sq. in. above sea pressure. Air filters are also fitted.

(8) FIRING VALVE. To allow air in bottle to enter the ejector beneath the container when the order to fire is given. Ejector side of firing valve is to vent through the spindle when the valve is shut.

(9) FIRING INTERLOCK. To prevent firing when sluice valve (or flap valve) is shut. Mk. I—firing lever is positioned close to the sluice valve quadrant. Mk. II—valve on air lead remains shut until opened by a cam when flap valve is fully open. If there is a leakage of air into the barrel, the resultant pressure, when it overcomes sea pressure, will push the flap valve open slightly. The spring loaded catch is designed with a 45° incline so that the bevel wheel shaft can rotate when the flap valve moves. When the pressure has been released, the sea pressure will shut the flap valve again, and the spring catch will return to its normal position.

(10) NON-RETURN VALVE. To prevent sea water flooding back into the firing air system.

(11) DRAIN VALVE. To enable the ejector to be drained of water after the sluice valve (or flap valve) is shut.

(12) VENT VALVE. To assist in draining down. On Mk. II—the valve automatically opens when drain valve or equalising valve levers are worked. The levers are designed so that the vent always shuts first.

(b) Pushing Out Bubble Decoys

(13) RAMMER DISCHARGE GEAR. To push out the container. Mk. I—the container is pushed out by hand using rods which are screwed onto the ram rod mounted in the centre of the breech handwheel. Mk. II—container is pushed out by a ram rod operated by air pressure which acts on the underside of a small piston fitted on the rod.

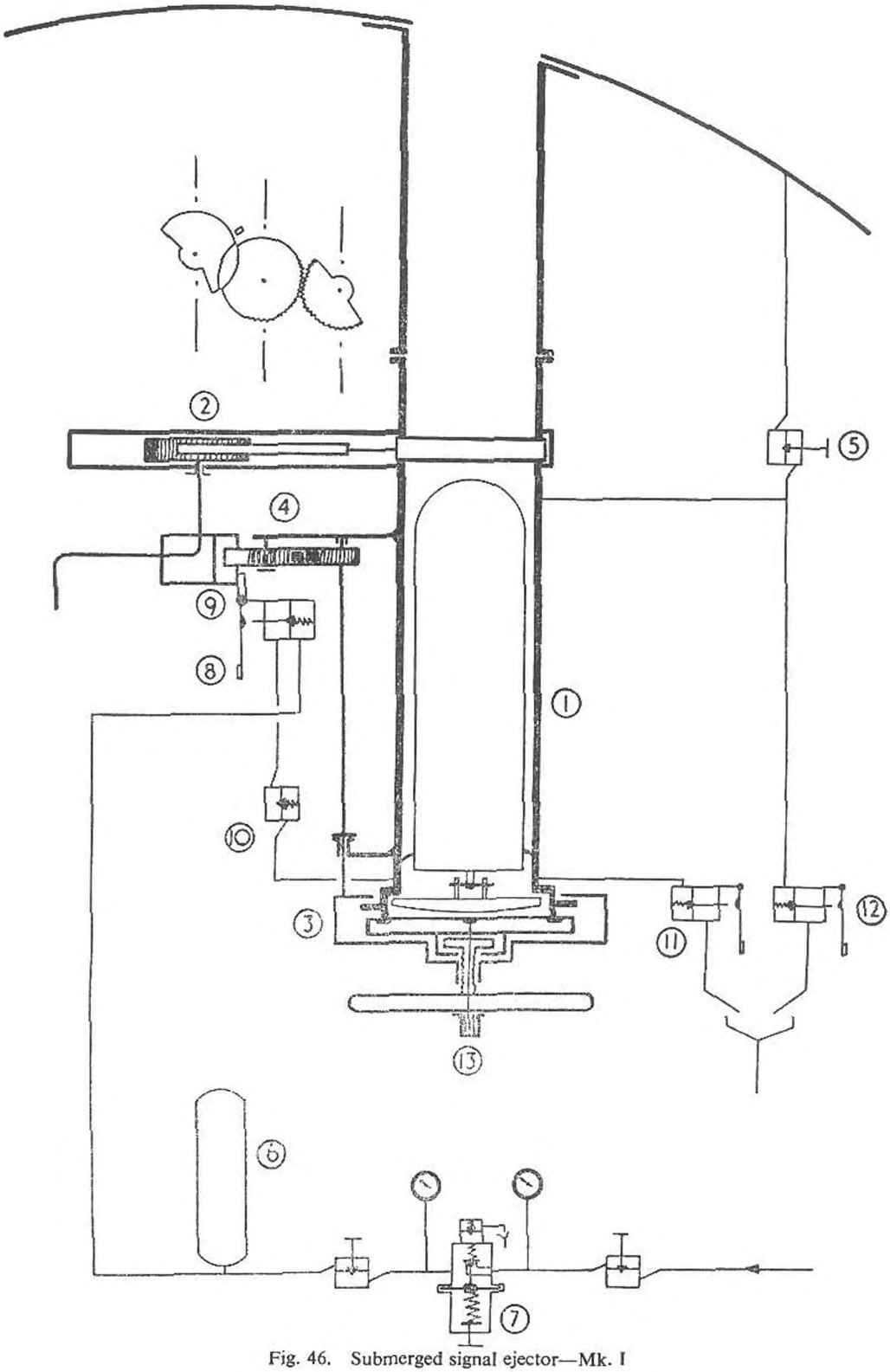


Fig. 46. Submerged signal ejector—Mk. I

(13A) BREECH LOCK. To ensure that the breech is pushed fully home so that the ram rod is beneath the centre of the container.

(13B) SELECTOR VALVE. To shut off air lead to barrel and to open up air lead to underside of ram rod piston. When the selector valve is worked, the sleeve is lifted up at the same time so that its bottom face is clear of the barrel. This enables water to flow down the outer side of the sleeve to the bottom as the container is being pushed out.

(13C) AIR LOADED PISTON. To buffer the ram rod as it gets to its upper limit. The piston is air loaded at the same time as air is put on the ram rod piston.

(13D) RE-COCKING VALVE. To admit air to the upper side of the ram rod, piston to return the rod to its normal position. This valve is worked by the firing interlock cam so that the rod is re-cocked as the flap valve is being shut. Re-cocking side of ram rod piston is normally open to vent through the valve spindle of the re-cocking valve.

(14) INDICATOR. To prove that the container has left the ejector after firing. The indicator lever must not be worked while the sleeve is being moved, because the indicator plungers will be bent.

(15) EMERGENCY FLAP VALVE RELEASE. To release the T handle catch so that the flap valve can shut. Should the breech be opened while the flap valve is open, due to a fault in the interlock, the resultant in-rush of water will draw the released flap valve down to the shut position. The emergency lever for releasing the catch is positioned at the bulkhead door of the compartment.

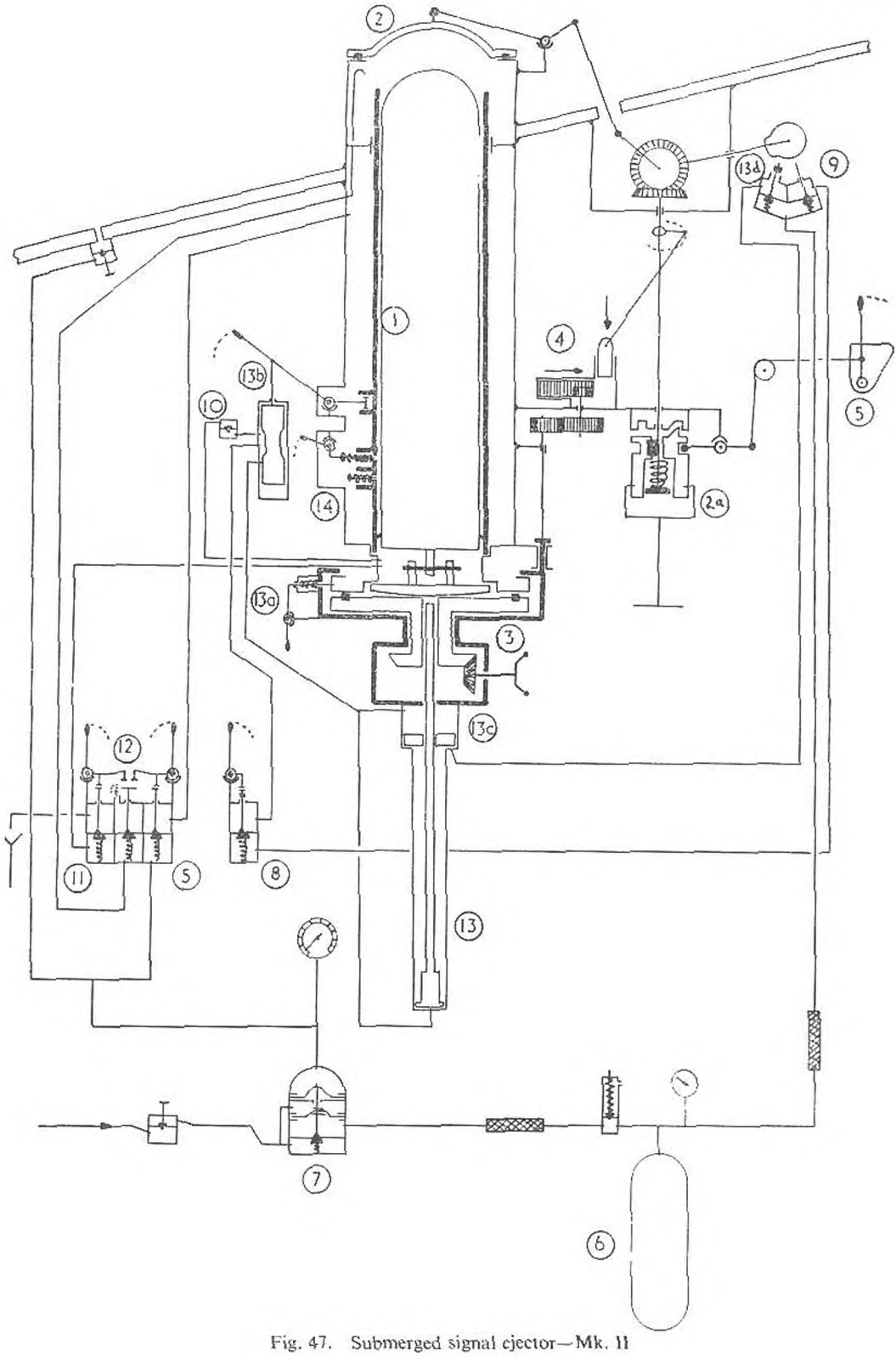


Fig. 47. Submerged signal ejector—Mk. II

AIR PURIFICATION EQUIPMENT

CO_2 (CARBON DIOXIDE) ABSORPTION UNIT (Refer to *Fig. 48*)

Object. To reduce the CO_2 content of the air in the submarine during prolonged periods dived.

(1) CO_2 CANISTERS. To hold soda lime (protosorb). Canisters are sealed. When required for use the top and bottom are opened by a special tin cutter. Canisters sit on rubber seats, and are held in position by spring clips. Partly used containers can be temporarily sealed by fitting a special blank which clips onto the rim of the canister.

(2) FAN. To draw air through the CO_2 canisters. Electrically driven and designed for quiet running.

(3) FLEXIBLE HOSE. To connect the unit to ship's ventilation system.

(4) VACUUM GAUGE. To indicate that the fan is drawing air through the canisters at the correct rate. Gauge is connected to the space beneath the canisters, and will register the reduction in pressure (vacuum). The dial has a small green section where the needle must point for correct air flow.

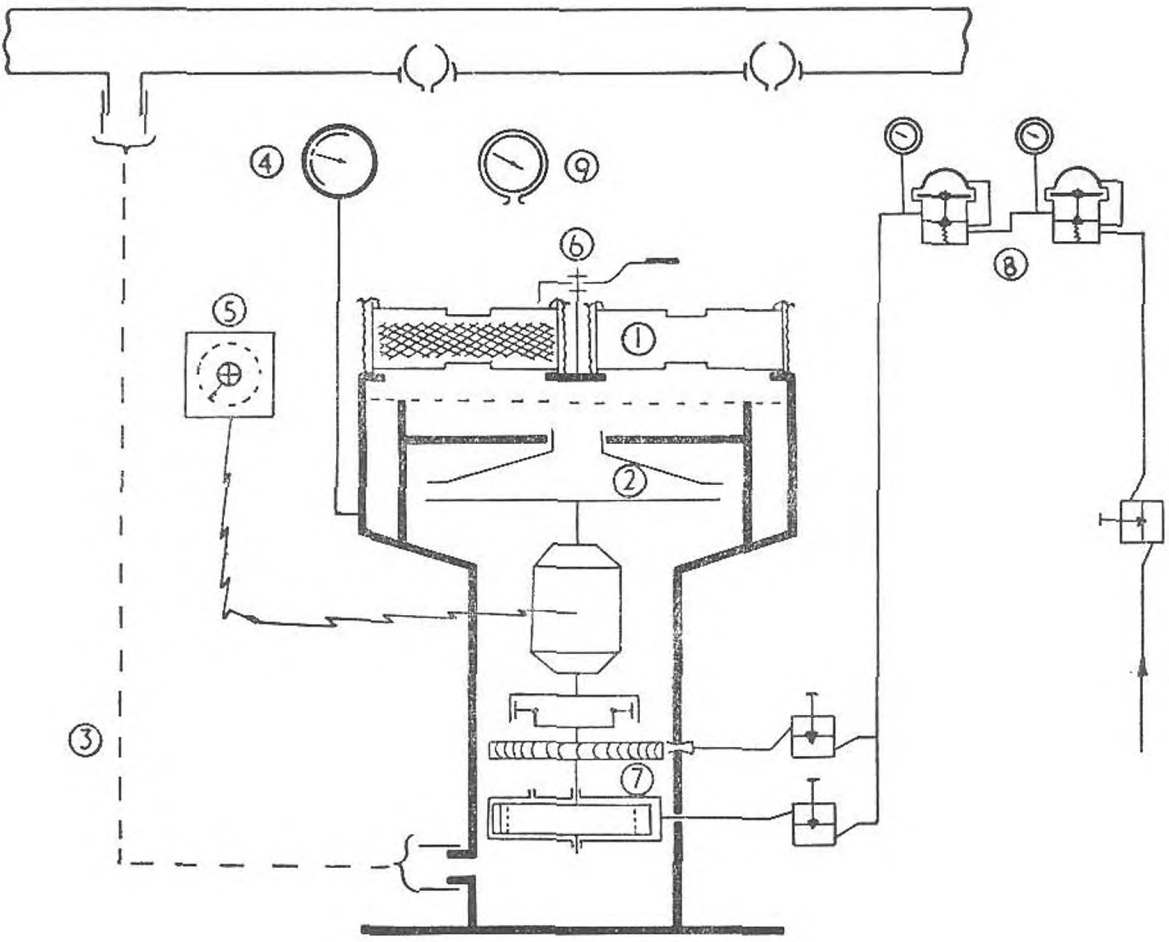


Fig. 48. CO_2 absorption unit

(5) FAN REGULATOR. To adjust speed of fan.

(6) ROTATING HEAD. To ensure that each canister is used and replaced in rotation.

(7) AIR MOTOR AND TURBINE. To rotate fan should electric power fail. Air motor (eccentric vane type) gives sufficient power. If the air motor is at dead centre, the turbine is used for initial start and then shut off.

(8) REDUCING VALVES. To reduce the H.P. air which is fed direct from the bottles groups (4,000 lb/sq. in.). Reduced in two stages (500 lb/sq. in. and 70 lb/sq. in.).

(9) CO_2 GAUGE. To indicate the pressure of air in the submarine and the maximum allowable proportion (per cent) of CO_2 content. The CO_2 content is measured on the Dwyer or Ringrose CO_2 Indicator.

OXYGEN GENERATOR (Refer to *Fig. 49*)

Object. To replenish the oxygen content of the air in the submarine during prolonged periods dived.

(1) OXYGEN CANDLE. To produce oxygen by self-burning action (sodium chlorate and iron filings). Kept in airtight container until required for use.

(2) BURNING CHAMBER. To contain candle while burning. Air cooling assisted by air space formed by outer cylinder.

(3) DROPPING COVER. To shut the end of the burning chamber and provide a convenient platform for loading the candle when in the lowered position. Cover, with copper asbestos joint, shut tight by screwed handle.

(4) HEATER ELEMENT (electric). To start burning action on the candle. Glows red hot.

(5) SWITCH. To switch on heater.

(6) COOLING FINS. To cool the hot oxygen as it leaves the burning chamber.

(7) FILTER. To extract traces of salt given off by the burning candle. Safety disc fitted on inlet side in case of blockage.

(8) FLOW INDICATOR. To indicate that the candle is generating. Worked by a plunger which rotates the indicator to show a green portion. The green portion will not show until plunger has moved enough to allow escape of oxygen into the submarine (after about five minutes). Movement of the plunger also switches off the heater.

OTE. The Routine to be followed in Air Purification drills in "T" and "A" class submarines is given in *. 51.*

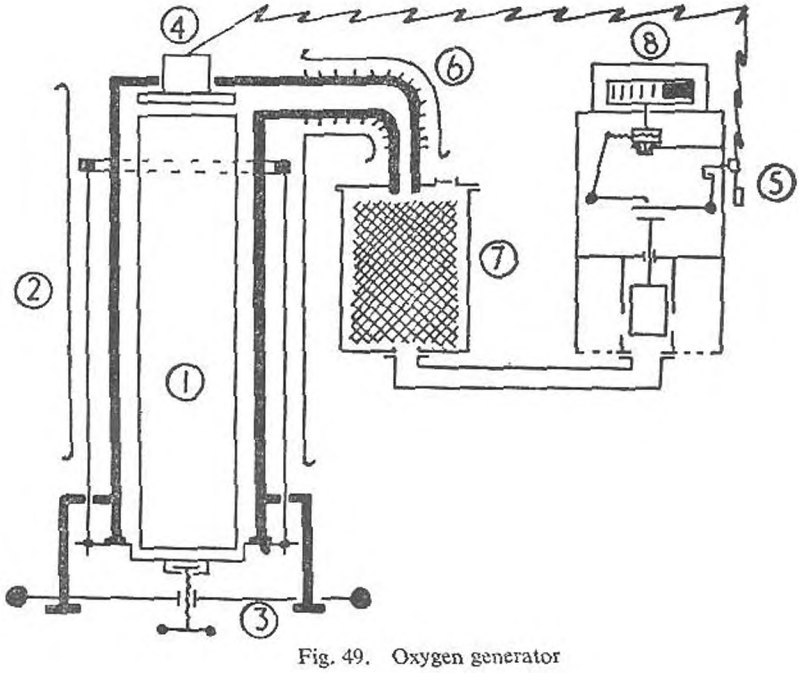
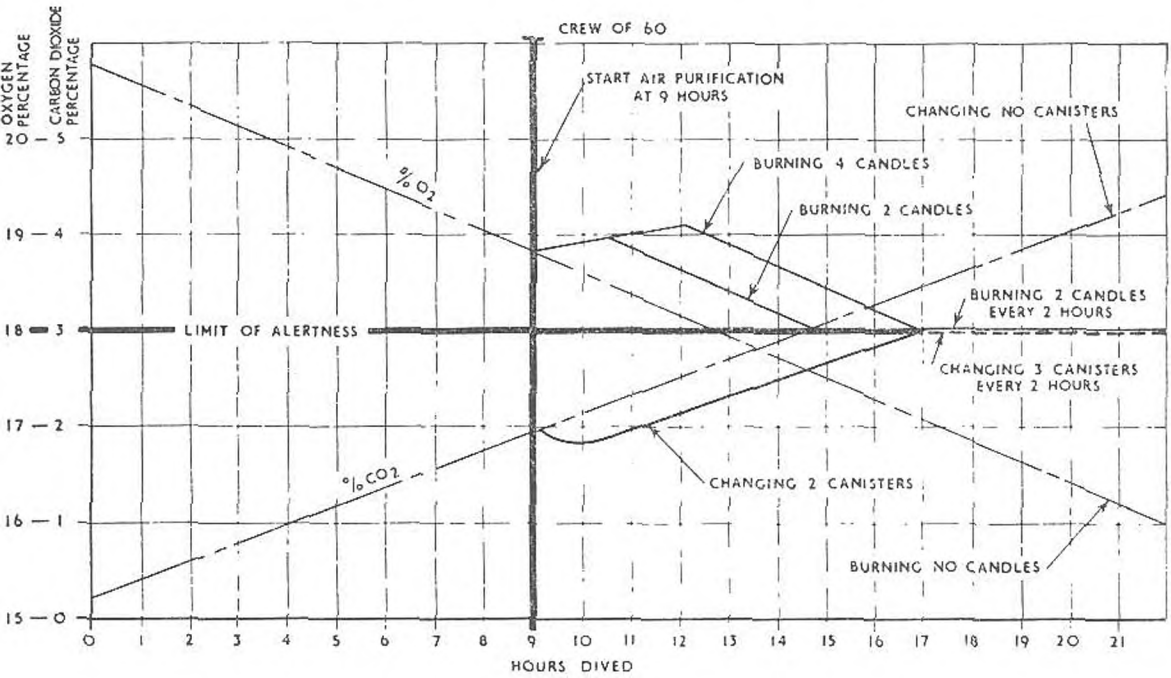


Fig. 49. Oxygen generator

AIR PURIFICATION DRILLS (Refer to *Fig. 50*)



DRILL	HRS. DIVED	PROCEDURE	DRILL	HRS DIVED	PROCEDURE
A	0-15 HRS.	AT 9 HOURS BURN ONE OXYGEN CANDLE IN EACH GENERATOR. CO_2 ABSORPTION UNITS NOT REQUIRED	C	OVER 17 HRS	AT 9 HOURS CARRY OUT DRILL 'B', THEN AT 17 HOURS CHANGE 3 CO_2 CANISTERS EVERY 2 HOURS AND BURN ONE OXYGEN CANDLE IN EACH GENERATOR EVERY 2 HOURS
	17 HRS.	AT 9 HOURS RUN CO_2 ABSORPTION UNITS AND CHANGE ONE CANISTER ON EACH — ALSO BURN 2 CANDLES IN EACH O_2 GENERATOR	D	FOR RAPID REDUCTION OF CO_2	CHARGE EACH ABSORPTION UNIT WITH 4 NEW CANISTERS AND RENEW THEM EVERY 2 HOURS — ALSO BURN ONE OXYGEN CANDLE IN EACH GENERATOR EVERY 2 HOURS

Fig. 50. Air purification drill

BUILT IN BREATHING SYSTEM (B.I.B.S.) (Refer to *Fig. 51*)

Object. To provide an unpolluted supply of air to escapers during the flooding up period and immediately prior to ascent.

(1) BOTTLE GROUP. To hold the air under pressure. Bottles stowed outside pressure hull.

(2) HULL VALVE. Enables bottles to be isolated whilst charging hoses are being disconnected or in the event of damage. Valve is wired OPEN.

(3) H.P. PRESSURE GAUGE. Shows pressure in storage bottles.

(4) CHARGING CONNECTION. For charging or topping up bottles with air.

(5) DIAPHRAGM VALVE. Seals H.P. air in system and is only opened when required for escape. Fitted with safety collar which prevents the valve being inadvertently screwed down thus piercing the diaphragm (the OPEN position).

(6) AIR TEST CONNECTION. For routine testing of reducers and L.P. system.

(7) REDUCER SHUT OFF VALVES. Fitted in duplicate to isolate reducers.

(8) REDUCERS. To reduce the bottle pressure to 100 lb/sq. in. above compartment pressure. Fitted in duplicate in case one is defective.

(9) DIFFERENTIAL RELIEF VALVE. Protects L.P. side of system.

(10) DIFFERENTIAL L.P. PRESSURE GAUGE. Shows pressure in L.P. side.

(11) QUICK RELEASE SOCKETS. To accommodate the male adaptors of the breathing units.

(12) BULKHEAD STOP VALVE. Fitted where B.I.B.S. manifold is extended into a Supplementary Escape Compartment. Kept SHUT when not in use.

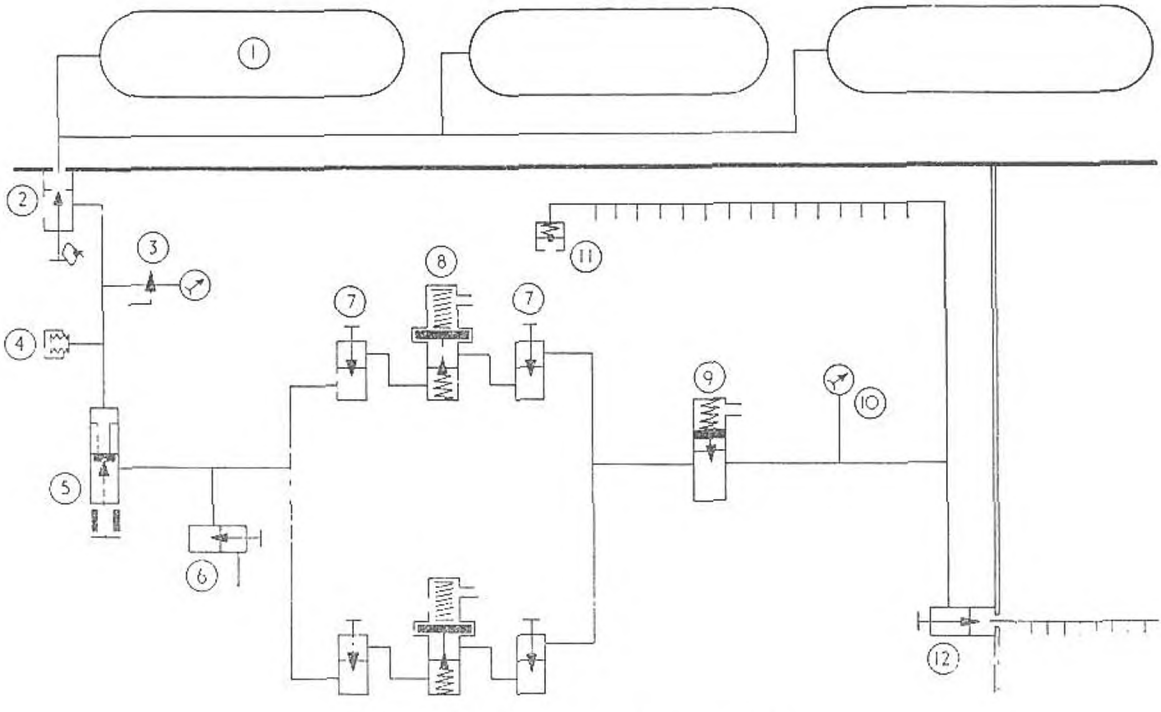


Fig. 51. Built in breathing system (B.I.B.S.)

UPPER DECK GEAR (Refer to *Fig. 52*)

Object. To enable the submarine to be:
(a) secured alongside;
(b) anchored;
(c) secured to a buoy, and
(d) taken in tow.

NOTE. Not all the numbered items listed below are shown in *Fig. 52.*

(a) **Alongside**

(1) FORE AND AFT BREASTS (Rope). To secure the submarine alongside.

(2) BULLRINGS. To provide a fairlead for the breasts over the bow and stern.

(3) DISAPPEARING BOLLARDS. To provide securing fore and aft for breasts and other wires. All wires and ropes secured and seizings put on. Breasts and springs doubled up.

(4) FORE AND AFT SPRINGS (Wires). To prevent fore and aft movement when alongside. Secured to bollards.

(5) BOLLARD STROPS. To provide a convenient means of securing other vessels when alongside. A short strop and hock is kept over the bollard to receive the eye of the other vessel's wire.

(6) COMPOSITE HAWSER (4½ in. manilla with two lengths of 3½ in. wire each end). To secure bows and stern in rough weather.

(7) GANGPLANK. For access ashore. Must have guard rails.

PPING

reasts and springs are slipped, stowed and secured inside the casing. Bollards are housed flush with the ng. Gangplank clamped to the top of the casing.

ING ALONGSIDE

(8) HEAVING LINES (four required). To enable breasts and springs to be passed.

(9) CAPSTAN WARPING BARREL. To enable the bow to be warped (heaved) in.

(10) ROLLER (disappearing). To give breast a fair lead to the warping barrel. Normally housed flush with the casing.

(11) PROPELLERS. To bring in the stern after the fore breast is passed. After breast is not passed until bridge have stopped the propellers, and it is kept clear of the water to prevent fouling propellers.

At Anchor

12) ANCHOR (12 cwt). To provide a grip on the sea bed.

13) CABLE (7 shackles, that is 15 fathoms or 90 feet, of chain). To connect anchor to submarine.

4) CABLE HOLDER. To hold the cable to the submarine. When riding at anchor, the weight is taken on the cable holder.

5) COMPRESSOR. To provide a secondary means of holding the cable.

6) MEDITERRANEAN LADDER. To provide a convenient gangway for boats coming alongside.

ING

7) CAPSTAN. To revolve the cable holder for heaving in by power. Heaving in by hand is done by using two tackles.

8) CABLE LOCKER. To provide stowage for the cable. A small compartment usually in a main ballast tank. Cable washdown is provided from the main line.

9) HAWSE PIPE. To provide secure stowage for the anchor.

) SCREW SLIP. To pull anchor right home in the hawse pipe. Consists of a small length of chain, bottle screw and slip which is secured over a convenient link in the cable.

LETTING GO

(21) BLAKE SLIP. To provide a quick method of releasing the anchor. Consists of a small length of chain with a Blake slip and secured over a convenient link in the cable. Anchor is first veered clear of the hawse pipe.

(22) CLUTCH. To disconnect the cable holder from the capstan. This will leave the cable holder free to revolve. Blake slip will hold the anchor until knocked off. The anchor will then plunge down pulling the cable with it.

(23) BRAKE (attached to cable holder). To control the length of cable released. Cable holder clutch is engaged if heaving in and is required for adjustment of length of cable used when anchoring.

(24) CABLE LOCKER CLENCH. To prevent losing the end of the cable. While riding at anchor, the weight is taken on the cable holder although the compressor and slips are left on. With the anchor housed, the weight is taken by the screw slip, the Blake slip, compressor and brake are also put on.

(c) **At a Buoy**

(25) "SHIP TO BUOY" SHACKLE. To connect cable to buoy. The cable is disconnected from the anchor at a lugless joining shackle just aft of the screw slip, and is reeved through the bull ring. When the stern is also secured to a buoy, a wire is used.

SLIPPING

(26) SLIP ROPE (soft eye one end, spring hook and loop the other end). To provide a temporary securing to the buoy. Soft eye is reaved through the bull ring and connected to the Blake slip. Free end of cable is disconnected and re-secured to the anchor.
When ready to slip, Blake slip is knocked off and rope heaved in.

COMING TO BUOY

(27) PICKING UP ROPE (combined with slip rope). To get initial securing to the buoy. One of the Casing Party (Buoy Jumper) secures hook and loop to the buoy ring and free end on the warping barrel. Bows are brought close to the buoy. The cable can now be connected by using the "ship to buoy" shackle. The picking up rope is then removed and the cable veered as required and secured as for anchoring (except screw slip).

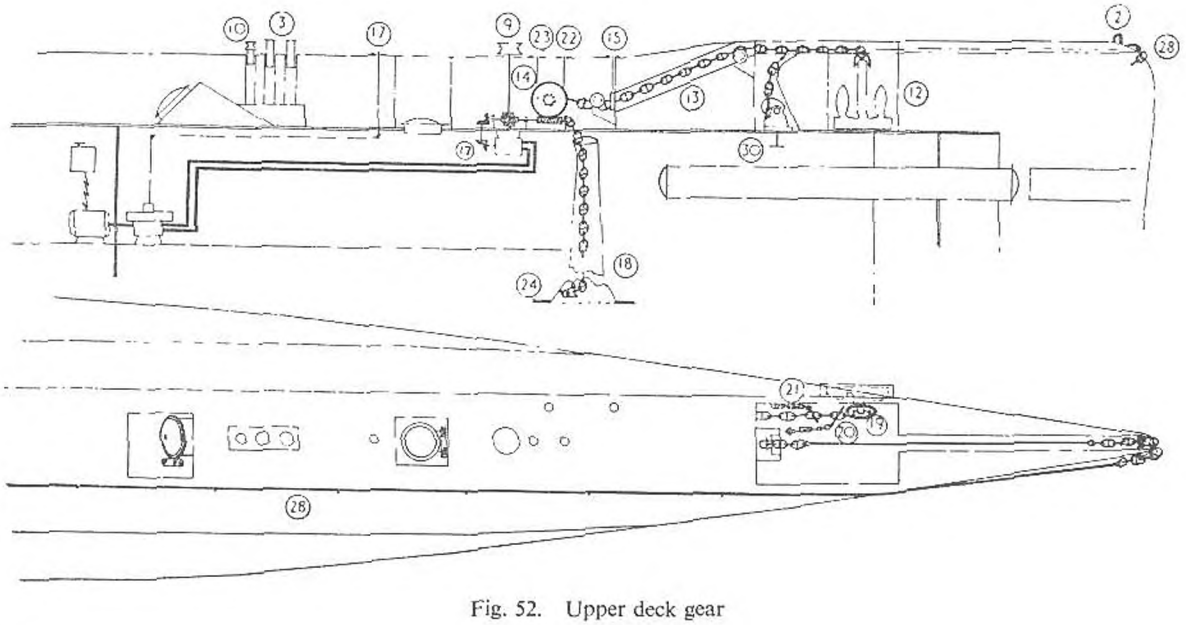


Fig. 52. Upper deck gear

(d) **On Tow**

(28) TOWING PENDANT. $3\frac{1}{2}$ in. F.S.W.R. with chain cable inserted where chafing occurs. Normally stowed alongside the casing and bridge with lightly tack welded clips. In streamlined submarines it is set in a cement filled trough.

TAKING THE TOW

(29) SNATCH BLOCKS. To enable the towing ship's tow to be heaved across by the crew. One snatch block is secured to the periscope standards and another to the periscope well. This enables a heaving rope to be led below. The towing ship's tow is connected to the eye of the towing pendant. Towing ship takes the strain and towing pendant is then pulled clear of the welded clips or trough.

RELEASING THE TOW

(30) TOWING SLIP. To release inboard end of pendant. Slip is operated from the tube space.

REDUCTION OF NOISE

Objects. (a) Avoid detection by enemy surface ship or submarine listening on their sonar sets.

(b) avoid being hit by enemy acoustic under water weapons.

(c) avoid interference with own sonar.

Travel of noise. Noise travels through water to greater distances and more rapidly than the same noise would through air.

Air noise inside the submarine is reduced as much as possible for comfort and greater efficiency of the crew, particularly during an attack or hunt.

Water noise, not necessarily heard by the ear, can radiate from the submarine, and can be detected by the enemy. (Noisy propellers can be detected many miles away.)

Sources of Noise

(a) MAN MADE. Hammering, wheel spanners, movement, intercom system. Quiet states clearly laid down in ship's orders, and the crew are trained to be noise conscious.

(b) WATER. Casing holes, projections, hull valve openings, tube orifices. Reduced by streamlining such as bridge fin, fairing plates and bow shutters.

(c) PROPELLERS. Cavitation, "singing", vibration. Reduced by dressing up damaged blade tips, renewal of "A" bracket bushes and fitting reduced noise propellers.

(d) RATTLES. Casing flaps, pipes, loose gear. Provide rigid securings with rubber inserts where possible.

(e) MACHINERY VIBRATION. Insulate by rubber mountings. (*Fig. 53*).

(1) RUBBER MOUNTINGS. Machine secured to bedplate and mounted on "L" Type rubber mountings. MOUNTINGS MUST NOT BE PAINTED OR OILED.

(2) PIPES. Fitted with short rubber lengths.

(3) ELECTRIC CHANNEL PLATES (left with a gap). Loops in the wires to allow for machine movement.

(4) SPARE GEAR. Kept secured and clear of machine.

(5) LIMIT STOPS. Machines that are fitted with rubber mountings are likely to move excessively under shock of depth charging. To limit the movement under shock, limit stops (rubber pads) are fitted. Under normal conditions there is sufficient clearance to allow for machine vibration.

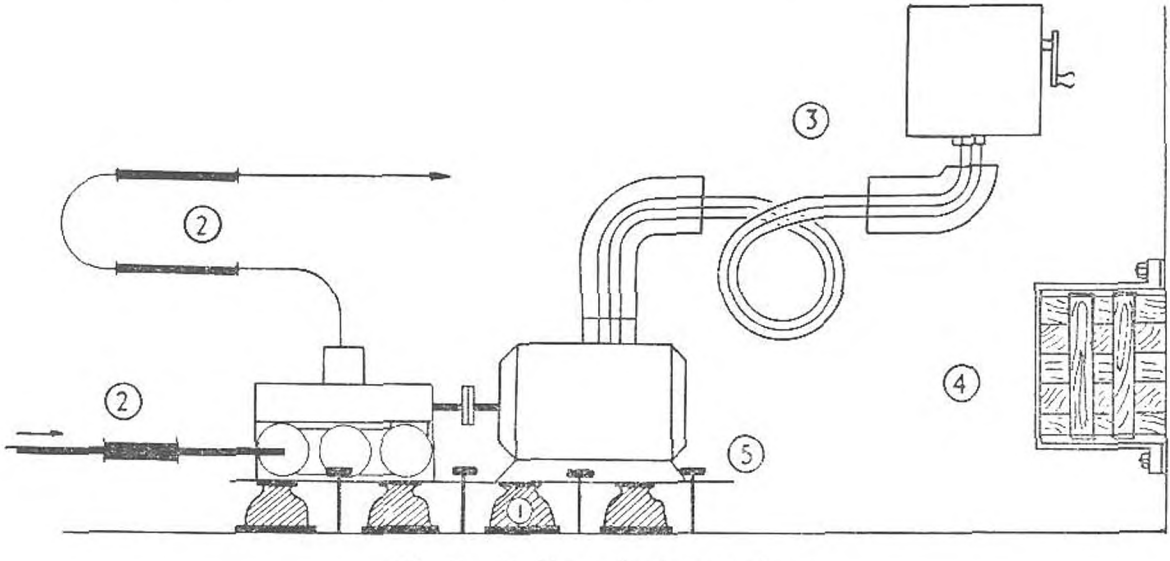


Fig. 53. Machinery vibration mountings

ELECTRICS

BATTERIES. To provide power for the main motors and other electrical equipment. There are two, three or four batteries in a submarine, giving an electrical pressure or voltage of approximately 220 or 440V. Each battery contains 112/224 cells, each cell giving approximately 2V. The cells are therefore connected one after the other (in series) thus giving just over 220V.

LEAD ACID CELL. This is an electric cell used for storing electricity by chemical action. If two dissimilar materials (plates) are immersed in a certain chemical solution (electrolyte), an electrical pressure (volt) will exist. If the ends of the plates (terminals), which are above electrolyte level, are connected by a wire (circuit) a flow of electricity will take plate (electrical current or amps).

The submarine cell consists of a container (2 ft × 1 ft × 3½ ft high), several plates, which are alternately "spongy" lead and lead peroxide, separators, which keep the plates apart but firmly held, and the electrolyte, which is dilute sulphuric acid. The whole weighs about ½ ton.

The greater the surface area of the plates in contact with the electrolyte, the greater the amount of electricity (amps/hours) that can be stored.

When the battery is being charged, electricity from the generator (or main motor used as a generator) passes through each cell and a chemical action takes place. During this chemical action, the electrolyte changes its composition, and, as a result, changes its density. This change of density can be utilised to indicate how much each cell is charged. The density varies between 1.100 when the cell is run down, and 1280 when it is fully charged.

During the chemical action, hydrogen and oxygen gases are also given off, and any dangerous accumulation of hydrogen will produce an explosive mixture. To prevent any accumulation, the air above the cells is thoroughly ventilated.

The gases are formed by the decomposition of water in the electrolyte, and it is necessary to top up the level in the cell at regular intervals by using distilled water.

BATTERY TANK AND COMPARTMENTS. Each battery is stowed securely in a tank or compartment which is coated with "Rosbonite" or rubber to prevent corrosion from spilt electrolyte. Any spillage collects in a small sump and this is inspected and mopped out dry frequently.

A battery tank is fitted with portable screw down water tight boards so that each cell can be tested and topped up, but for normal daily check on the state of the battery, access ports to two cells (pilot cells) are provided. When checking the density (taking a dip) electrolyte is sucked out of the cell by a rubber bulb and tube, and transferred to a density pot. A hydrometer is immersed, a reading taken and the electrolyte transferred back to the cell.

A battery compartment has only one access hatch as it is possible to get to all of the cells when in the compartment.

MAIN MOTORS. Each motor consists of a pair of armatures, mounted end to end, rotating in a magnetic field. This arrangement gives a good range for speed and charging rates. By using the electricity stored in the batteries, the armatures, and therefore the propeller is revolved. By driving the armature by the engine, electricity is generated which is stored in the batteries.

MAIN SWITCHBOARD. To control the electric power available, large switches are required. These switches are mounted in the vicinity of the motors, and are connected to the batteries by large armoured cables. A typical switchboard consists of the following:—

Starting switches - -to start the main motors and allow them to pick up gradually. Otherwise too great a current would flow and blow the fuses.

Field regulator—to vary the strength of the magnetic field in order to vary the speed of (or charge on) the armatures.

Reverse switch—to enable the armatures to be revolved astern as well as ahead.

Grouper switch—to connect the pair of armatures either in parallel, or in series. The port and starboard pairs can also be connected in series to give a slower speed range.

Interlocks—to prevent the switches being worked at the wrong time or in the wrong sequence, which would damage the equipment and be dangerous to personnel.

CONSTANT AND VARIABLE VOLTAGE. When the batteries are being charged the voltage varies between 192 and 315V. The rise in voltage is too great for electric light bulbs, heaters, some W/T. machinery, and galley range, so the voltage is reduced by a special motor generator. There are therefore two or more electrical supply mains for the submarines electrical equipment, the V.P. ring main (variable pressure or voltage), the C.P. ring main (constant voltage), and a.c. ring main in Porpoise Class.

LIGHTING. Normal lights off the C.P. or a.c. ring main. Police lights off the C.P. ring main and also direct from the battery for emergency purposes. Navigation lights are port bow, starboard bow, steaming light, shaded stern light, N.U.C. lights and anchor lights.

EMERGENCY LIGHTING. Oldham's lanterns and pressure tight torches are used in emergencies.

LOW POWER SUPPLIES. A 24V. system used for instruments and indicators. The supply is obtained from a motor generator or a battery during emergency.

A.C. SUPPLIES. Necessary for domestic services, W/T., radar and other electronic equipment. The supply is obtained from motor generators.

MISCELLANEOUS FITTINGS

GYRO COMPASS. To give the officer of the watch and helmsman sense of direction for steering and navigation. Electric repeaters at the wheel and bridge, and also on the P.P.I., asdic training unit, Torpedo Control Equipment and periscopes.

PROJECTOR COMPASS (magnetic). A standby compass using the earth's magnetic field to give sense of direction. Fitted in the bridge and enclosed by a tube. A system of prisms and mirrors gives an image at the helm position.

"FAITHFUL FREDDIE". A portable magnetic compass used on the bridge to take bearings in the case of gyro failure. Normally stowed in the conning tower.

LOG. To measure the speed of the submarine *through the water*. A small impeller on a tube is streamed (put out) through the hull so that the flow of water makes it turn. As the impeller rotates it makes and breaks a pair of contacts, and through an electrical circuit gives readings on the speed and distance recorder.

A.R.L. PLOT. To trace the directional movements (track) of the submarine. A spot of light is projected from the plot upwards through a glass pane onto a plotting sheet. The spot is moved by the combined influence of the gyro compass and the log.

RADAR. This is used both as a navigational aid and as a source of information for an attack. The radar aerials are periscopic and may be lowered when not in use to cut down chances of detection.

P.P.I. (plan position indicator). To give a radar map of the area surrounding the submarine. All land and other ships and objects give a radio wave reflection back to the rotating radar mast. These reflections show up as bright spots on a television (cathode ray) tube screen.

TORPEDO CONTROL EQUIPMENT. T.C.S.S. (Torpedo Control System Submarines) 123 or 5 a computer system designed to work out the course required to be set on torpedoes to ensure their hitting the target. In the more advanced systems this is set on torpedoes automatically before firing.

SOUND ROOM EQUIPMENT

(a) Either to enable noises made by other ships or submarines to be picked up. The noises are received by a transducer (underwater microphone) fitted in the keel or on the casing, conveyed electrically to the sound room "sonar sets", and heard on a pair of earphones or loudspeaker. It is possible for the sonar operator to train (rotate) the transducer so that the direction from which the noise is coming can be ascertained. He may also distinguish certain noises, e.g. the thrashing of propellers, or types of propulsion machinery, or

b) To locate ships, submarines or mines. The sonar operator can send out a sound wave which, on striking a solid object, will be echoed back. The echo is picked up and is heard by the operator on the phones.

UNDERWATER TELEPHONE. To provide voice communication between the submarine and surface ships or other submarines. Sound waves are transmitted through the water, and are picked up by a similar set at the receiving ship. Two battery operated sets for escape purposes and one mains set with a range of up to 12 miles are fitted.

ECHO SOUNDER. To measure the depth of water beneath the keel. Transmitter send a sound wave downwards, and the reflected wave is picked up. The time taken is used by an electrical recorder to indicate the depth.

BATHYTHERMOGRAPH (depth-temperature-graph). To record the change of temperature and salinity with depth. Useful in two ways, temperature layers cause reflection of the enemy sonar beam and affects their performance. Change of temperature indicates a change of sea water density necessitating adjustment of trim.

INDICATOR BUOYS. To indicate the position of the submarine if unable to surface. One forward and one aft. Released from inside the submarine, and connected to 600 feet of wire. Fitted with: "cats eyes", a flashing light and a W/T. transmitter.

TELEGRAPHS. To transmit engine and motor orders from the control room. The normal telegraph orders are used: stop, slow, half and full ahead as astern. "In engine clutch" and "Standing charge" are also used. In addition, a "grouper" telegraph is used for main motors.

DESICCATOR. To dry the air (reduce moisture) inside the periscopes and projector compass to prevent fogging up of lens and mirrors. Radar guide tubes are also desiccated to increase the efficiency of the set. H.P. air, which has been partially dried when passing through the compressors, is allowed to reduce to a low pressure, and is led to the highest point of the fitting. The moist air, which is heavier, is pushed out at the lowest point. The amount of humidity (dampness) is measured on a hygrometer.

CHAPTER 5

Submarine Organisation and Routines

DUTIES OF KEY RATINGS AND WATCH STATES

(*See* Chart—*Fig. 54*)

Seaman Department (First Lieutenant)

COXSWAIN. The Coxswain is considered the Master-at-Arms of the submarine, and is responsible for seeing that the ship's orders and routines are adhered to, and that the good order and discipline of the ship's company is maintained. He is also responsible for: the demanding, stowage, preservation and issue of victualling stores, medical stores, first aid equipment, submarine escape equipment, loan clothing and rum; and the internal cleanliness of the submarine up to the Engine Room. He assists the First Lieutenant in keeping the books and records. He mans the wheel at harbour stations and the after hydroplanes at diving stations.

SECOND COXSWAIN. The Second Coxswain is responsible for the outside appearance of the submarine; care and maintenance of cable gear, breasts, springs, periscope wires and upper deck fittings. He is usually given one rating to assist him. He mans the forward hydroplanes at diving stations.

Electrical Department (Electrical Officer or First Lieutenant)

ELECTRICAL ARTIFICER. The E.A. is responsible for seeing that the care and maintenance is carried out on all electrical machinery and circuits. His diving station is in the control room, and he assists the working of the T.C.S.S. at action stations.

ELECTRICIAN. The Electrician (Petty Officer) is responsible for carrying out the care and maintenance of H.P. electrics, including main batteries and battery ventilation, and for the cleanliness of the Motor Room. He keeps the battery and insulation logs. His harbour and diving station is in the Motor Room.

RADIO ELECTRICIAN. The Radio Electrician is responsible for carrying out the care and maintenance of W/T., radar and asdic electronic equipment. His diving station is in the Radar Office.

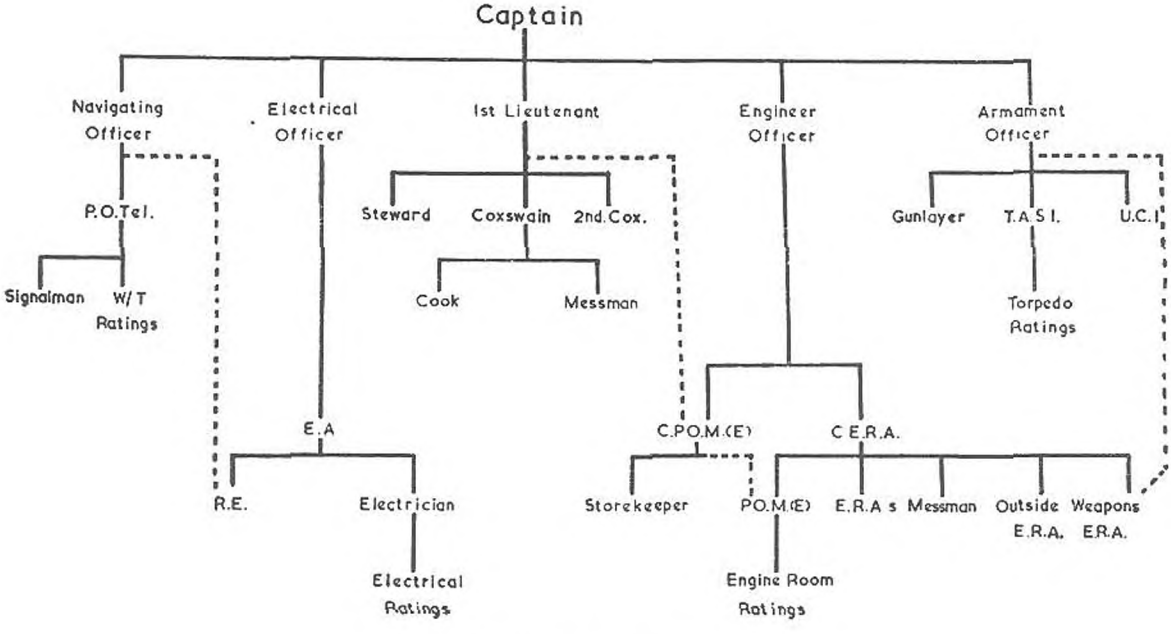


Fig. 54. Submarine crew

Engineering Department (Engineer Officer)

CHIEF ENGINE ROOM ARTIFICER. The C.E.R.A. is the Senior Engineer of the submarine. He is responsible for the care and maintenance of all mechanical machinery and systems; that all the Engine Room ratings are usefully employed and encouraged to increase their technical knowledge; and for co-operating with other departments. He organises the Engine Room staff and available facilities to achieve the highest standard of maintenance efficiency. He assists the Engineer Officer in keeping books and records.

OUTSIDE ENGINE ROOM ARTIFICER. The Outside E.R.A. is responsible for carrying out the maintenance of machinery and systems normally considered as "outside" the Engine Room, including periscopes, and for seeing that they are kept in an efficient state. He is usually given an experienced L.M.(E.) and an M.(E.) greaser to assist him. He mans the panel in the Control Room at diving stations.

WEAPONS ARTIFICER. The Weapons E.R.A./O.A. is responsible for carrying out the maintenance of the torpedo tube machinery including exactor gear, and other mechanical T.A.S. equipment (hull outfits and submerged signal ejectors), and for seeing that the routines in B.R.772 are carried out. He is usually given a U.W. rating to assist him. He keeps Part 2 of the T.A.S. Equipment Progress Book. His diving station is the fore ends.

CHIEF ENGINEERING MECHANIC. The Chief M.(E.) is responsible for: the correct measurement of tank dips and the proper use of the main line (the First Lieutenant giving orders for any tank adjustments in a "trim book"), the embarkation, working and recording of fuel, lubricating oil and fresh water, and the observance of the safety precautions as indicated in the Engineering Manual (Articles 379 to 380): the demanding, stowage, preservation and issue of spare gear and stores (S.155); care of fire fighting equipment; the divisional duties and watchbill of the M.(E.) branch. His diving station is the Control Room. He operates the snort mast and draining arrangements when required.

PETTY OFFICER ENGINEERING MECHANIC. The P.O.M.(E.) is responsible for: the cleanliness of the submarine from the Engine Room bulkhead aft (except Motor Room), including bilges; cleaning filters and separators in accordance with the routines and as ordered by the C.E.R.A.; care and stowage of engine tools and appliances; supervising the M.(E.)'s under the direction of the C.E.R.A. His diving station is in the Engine Room.

Weapons Department (Armament Officer)

T.A.S.I. The T.A.S.I. (or U.W.1) is responsible for: the loading, working and routines of torpedoes and mines; training the torpedo team; providing assistance for the Weapons E.R.A. for tube maintenance. He keeps Part 1 of the T.A.S. Equipment Progress Book. His diving station is in the tube space.

GUNLAYER. The Gunlayer is responsible for: carrying out the care and maintenance of the gun and the small arms; stowage and preservation of ammunition and pyrotechnics.

Navigation Department (Navigating Officer)

PETTY OFFICER TELEGRAPHIST. The P.O. Telegraphist is responsible for: care of equipment associated with the W/T Office (except electronics) and the communications department generally. His diving station is in the W/T Office.

SIGNALMAN. The Signalman is responsible for the care and stowage of the visual signalling equipment, navigational instruments and binoculars. He keeps the harbour signal log up to date. His diving station is in the Control Room.

U.C.1/U.C.2. The U.C.1/U.C.2 is responsible for the care of the sound room equipment and echo sounder (except electronics). His diving station is in the Sound Room.

WATCH STATES

Harbour Stations. All the crew closed up in the submarine which is made ready for sea.

Passage Routine. One watch closed up with the submarine on the surface shut off from diving and making surfaced passage in peace time.

Patrol Routine. One watch closed up with the submarine on the surface opened up for diving. The submarine is ready to dive at any time.

Diving Stations. All the crew closed up at their stations for diving, surfacing, attacking, being hunted.

Watch Diving. One watch closed up with the submarine dived and in trim propelling on the motors, and watching and/or listening for the enemy.

Watch Snorting. One watch closed up with the submarine dived and in trim propelling or charging main batteries on engines at periscope depth.

QUIET STATES

There are two states as follows:—

(1) "Patrol quiet"—which is all normal activities permitted according tactical requirements.

(2) "Ultra quiet"—which is essential machinery compatible with operational requirements running. Otherwise quietest possible conditions to enable best use to be made of Sonar equipment and to prevent detection by enemy hydrophones.

DIVING AND SURFACING

Diving

The order for diving the submarine is given by the Captain, or the Officer of the Watch, and is done by giving TWO blasts on the klaxon. The crew proceed to their diving station at the rush. The panel watchkeeper opens main vents on the second blast. Telegraphs are put to Half Ahead Group two Up, the fore ends watchkeeper turns out the foreplanes, the planesmen man the planes and put them to dive, voice pipe cocks are shut, main engines are stopped and shut off from sea and the upper conning tower lid is shut and clipped. Main vents are checked open and reported either verbally or by electric indicator. The Electrician shuts down battery ventilation, leaving the outboard drains open.

Catching a Trim

When the submarine is submerged, the First Lieutenant will slow down the main motors and "catch a trim" using the main line and/or the trim line. The planesmen will keep depth as ordered by the Captain. Tank suctions and inboard vents are kept shut until an alteration in trim is required. As alterations become necessary, the order will be given to open the appropriate valve and vent, the valve being named in the order. Example: "Open "O" suction and inboard vent". When the trim has been obtained, the main vents are shut.

The ballast pump watchkeeper carries out orders given to him over an electric indicator box. When ordered to "pump": he opens fore/aft suction and pump discharge valve on the six valve chest, starts the pump, speeding it up until a suction of at least 20 in. vacuum registers, then he puts reply indicator to "pumping". When ordered to "stop": he shuts pump discharge valve on six valve chest (if the pump is stopped first, the non-return flap valve will slam shut), stops the pump and puts the reply indicator to "stopped", he then shuts fore/aft suction. When ordered to "flood", the valves on the discharge side of the six valve chest must be used. If the suction valves are used, the ball float inside the pump is liable to be crushed.

It is dangerous to pump into a tank as high pressure may burst a weak tank.

Failure of Telemotor Pressure

Should telemotor pressure fail, the telemotor alarm buzzer will sound and the green "available" light will flash. Main vents can be worked in hand, steering and planes in emergency control and other fittings worked either by using the hand pumps or in hand. If the hand pumps are put onto the line for raising periscopes, the air loaded accumulators should be shut off so that all the pressure goes into the line.

Changing Depth

Hydroplanes are normally used to change depth.

Changing depth can be speeded up by flooding "Q" tank. At the order "flood Q", the panel watchkeeper opens "Q" Kingston and "Q" inboard vent. If the vent is not worked from the panel, a watchkeeper near the vent will open it. The vent is shut when the tank is full, that is, when water comes out of the vent. By this time "Q full" light would have come on. The Kingston is left open.

At the order "blow Q", the panel watchkeeper checks the Kingston open and opens "Q blow", putting 15 lb/sq. in. differential pressure in the tank. When the "full" light goes out (or the mark is reached on the contents gauge) the watchkeeper shuts the Kingston, stops blowing, and reports, "Q tank blown, Q Kingston shut".

The Officer of the Watch will ask the Captain for permission to "vent Q inboard". When the order is given, a watchkeeper opens the vent until all pressure is released from the tank into the submarine. Venting is done soon after blowing so that the tank is always left ready for flooding again.

Shutting Off for Going Deep

The object is to shut off systems and fittings that are not tested to full diving pressure, such as, shallow depth gauges, heads (older classes) and engine circulating water system.

Aft services, refrigerator and air conditioning plant need not be shut off. Sea relief valves and differential gauges, which are for protection and guidance during blowing operations, should not be shut off.

Shutting Off for Depth Charging

The object is to shut off all hull fittings. A control room depth gauge must be left open. If external fuel is carried, the equalising and sub-pressure systems will have to be left open. Portable gear must be secured and spare lamps made available for replacement of damaged ones.

Shutting Off Bulkheads

The object is to reduce the risk of completely flooding the submarine if damage is likely. The following are shut: quick-acting bulkhead doors, ventilation bulkhead flap valves, voice pipe cocks and isolating valves on the systems which pass through the bulkhead.

Surfacing

Main vents are checked shut. L.P. master blows are opened. Lower lid is opened.

When the Captain is satisfied that it is safe to surface, the order "surface" is given. After checking main vents are in shut "position" the Officer of the Watch gives orders to blow each main ballast tank. When working the direct blowing panel, the panel watchkeeper must open the valves fully. The Officer of the Watch will order "stop blowing" on each tank when he reckons that the submarine has sufficient buoyancy.

When the conning tower is above the surface, the upper lid is opened and the order given to "start the blower". The watchkeeper starts the blower and reports.

If the weather is rough, it is essential to give the submarine plenty of buoyancy on first blowing, and to counteract any tendency for heavy list on the split blow.

If the main blowing panel is out of action, the submarine is surfaced by using the emergency blowing station (H.P. to L.P.). When the order "stand to surface H.P. to L.P." is given, the L.P. master blows are opened and the H.P. to L.P. master valve on the H.P. air line is opened.

When the order "surface" is given, the blowing valve is opened (identified by the four spokes) until a differential pressure of 15 lb/sq. in. registers on the gauge. Surfacing by this method is much slower than by the direct blows.

After surfacing, the pressure in the air group on the panel is checked, and, if it is below 1,500 lb/sq. in. it is shut off and the stand-by group put on.

Opportunity is taken to pump out bilges after permission has been obtained from the Captain.

PREPARATION FOR SEA

Putting on the Trim

The First Lieutenant works out the amount to be put in the compensating and trim tanks. The Chief M.(E.), using the main line and ballast pump, "puts on the trim", that is, gets the correct amount of water in each tank either by flooding in or pumping out.

Testing the Ballast Pump

The ballast pump is tested as follows:

VACUUM TEST. Run the pump in parallel with forward and aft suction valves open on the six valve chest, and sea discharge open. Snifter cock should be open. Speed the pump up until a vacuum of at least 26 in. registers. Stop the pump. The vacuum should be retained. This proves that the air pump is working, and valve glands and pipe jointings on the main line are not leaking.

PRESSURE TEST. Run the pump in series with the sea suction and discharge valves on the six valve chest open. Shut the discharge valve and speed up the pump until at least 270 lb/sq. in. (4 stage), or 150 lb/sq. in. (2 stage) registers. This test proves that the pump is capable of discharging at full diving pressure.

FLOW TEST. Run the pump in series taking a suction from a tank and discharging overboard. With a discharge pressure of 20 lb/sq. in. the flow through the flowmeter should be at least 20 gallons in 7 seconds. This test proves that there are no obstructions in the pump impellers.

Checking the Telemotor System

Run the telemotor pump in "hand" until the line relief valves lift.

Check that the ram in each accumulator is at the top (ram at top indicator). Adjust air pressure to ,515 lb/sq. in. Too little or too much air pressure will prevent the ram in the accumulator from working p and down over a sufficient range which causes the pumps to cut in and out too frequently.

Release the pressure in the telemotor system by opening the main by-pass. This will get the rams in the ccumulators at the bottom. Test, at the plugs, for presence of an oil seal at the top and absence of air nderneath. Leakage of air past the ram and into the system will cause damage to the fittings owing to heir erratic behaviour, and damage to the replenishing tank due to sudden expansion of the air as it nters the return line.

Put pumps to "auto" and check that they start and stop automatically.

Topping up Air Groups

Before starting the compressor, the First Lieutenant must be informed as the compressor motors take a rge electric current. It is usual to arrange the running of the compressors when a charge is put on. ll groups should be topped up to 4,000 lb/sq. in.

Check that all bottle groups are free of water by opening the group drains. Open up the bottle groups the ring main (or valve chest in the control room). Any full groups can be left shut off or married up the other groups.

Starting and Stopping the Compressors

Check the oil sump free of water and for oil level, and mechanical lubricators topped up and primed. pen circulating water inlet and outlet hull valves. Open the four stage drains and the separator column ain. Turn the machine at least two revolutions by using the hand lever.

Start the compressor. Adjust the lubricating oil pressure to between 25 and 30 lb/sq. in. and check ater pressure at least 5 lb/sq. in. Shut stage and column drains.

When the column pressure gauge registers slightly above ring main pressure gauge, open the discharge D.N.R. valve. Check the stage pressures. Any abnormal reading indicates that a stage has a faulty lve.

While the compressors are running, the drains are to be opened every 10 minutes. The temperature of e lubricating oil should be watched.

When stopping, open stage and column drains, stop compressor, shut discharge S.D.N.R. valve and ut circulating water inlet and discharge hull valves.

uel Tanks

Put comp pressure on all internal and external groups, and vent each tank. Check that equalising stem is correctly opened up. On completion, shut off comp system, open subsequent filling tank top lve of the group to be used. The stand-by group is noted in the Engine Room Register.

eering Gear and Hydroplanes

Steering and planes are tested hard over each way. Those that have Brown's control system are given a hour creep test.

esting Telegraphs

Telegraphs and relay gongs must be tried and proved correct before any movements are made on the otors or engines.

acuum Test

The object is to reduce the pressure in the submarine so that leaks can be detected on the hull fittings ther by hearing air hissing in or by a lighted taper.

All hatches are shut, except the lower lids in the conning tower and gun tower. The bridge voice pipe ck is left open, but the hull voice pipe cock is shut. L.P. master blows are opened and the blower run til about 26 in. registers on the barometer. The blower is then stopped and L.P. master blows shut.

When all hull fittings have been proved, the vacuum is released by opening voice pipe cocks.

Starting the Blower

Before starting, check oil in mechanical lubricator, and give a few jerks on the hand lever. See that the intake is free from obstruction. Open the drain. When clear, open the discharge S.D.N.R. valve.

After starting, shut the drain and check mechanical lubricator by observing the oil drops. To avoid overheating, the blower is not run for more than 20 minutes.

After stopping, shut discharge S.D.N.R. valve. See that the drain is shut, so that the line is always ready for blowing H.P. to L.P.

Trying Main Vents

Main vents are worked weekly during long spells in harbour. All hatches are shut except the conning tower, hand operated Kingstons are opened, and the main panel opened up and main vents uncottered.

An Officer on the bridge will then give orders for the L.P. master blows to be opened and the blower to be started.

While the blower is running, each main vent is worked two or three times.

At Harbour Stations

The following is carried out at harbour stations 15 minutes before proceeding to sea:—

Steering gear tried hard over each way.
Hydroplanes turned out and tilted hard over each way.
Telegraphs tested.
Air group pressures checked and air opened up to the panel master valve.
Air on the whistle and whistle tried.
Telemotor system checked and pressure opened up to the panel master valve.
Raise and lower periscopes and radar masts.
Clean periscope top windows.
Main ballast tank Kingstons opened.
Snort mast raised and lowered.
Fire air shots from the S.S.E's.
Fuel groups vented.
Engineroom staff prepare main engines.
Casing party closed up. Pressure on the capstan.
All hatches (except conning tower) shut and clipped. Fore and aft torpedo hatch frame strongbacks shipped.
Tube space doors shut.
Main motors ready, grouped up. (Tail clutches IN, engine clutches OUT).
Klaxons, night alarms and navigation lights tested.
Indicators and alarms tested.
Radar warmed up and tested.
Sonar sets lined up and echo sounder tested.
Battery ventilation master outboard shut and battery ventilation shut down.
Battery reading.
All hands and stores checked on board.
Gyro running and repeaters lined up.
Indicator buoys secured.

Opening Up for Diving

When the submarine is opened up for diving, the crew go to diving stations. H.P. air and telemotor pressure panel master valves are opened, and the panel opened up. Main and auxiliary vents are uncottered. Periscope well covers are removed and stowed.

The First Lieutenant and the Outside E.R.A. then proceed through the submarine and check the following:—

Pressure on main vent and blowing panels, and correctly opened up.
Main and auxiliary vents uncottered.
Gauge glass on A and Z tanks open.
Sea relief valve and differential gauge sea cocks open.
Depth gauge cocks and hull cocks open.
Main line stops open and all other main line valves shut.
Hand operated Kingstons open.
H.P. and L.P. tanksides open. L.P. master blows shut.
Trim tank local vents open to the control room and local suction valve open.

"Q" tank vented and vent hull valve open. If a telemotor operated vent is fitted, check uncottered.
Snort drains shut.
Snort induction hull valve and emergency flap valve shut.
External pressure tight dome vents open.
Hatches properly clipped and vents shut.
Conning tower and gun tower flood valves shut, upper lid operating mechanism idle and inboard vents shut.
Conning tower light on (red at night).
Escape flood valves shut and seals intact. Emergency flap valves open.
Indicator buoys checked secured.
Battery ventilation system shut down
Bow caps shut, tubes vented and dry. Overflow valve to T.O.T. shut.

MAIN ENGINES, PREPARATION, STARTING AND STOPPING

Preparing for Sea

MAIN ENGINE. Examine tops of the engines and camshaft sumps for loose gear.

SHAFTING. Check for the possibility of loose gear fouling when under way. Sight tail clutch "IN", engine clutch "OUT", and tail brake "OFF" if applicable. Check all shaft bearing sumps for oil. Top up drip feeds to tail clutches and bulkhead glands, making sure that they are on, and the drips sighted. Open up the aft services, start the circulator and vent the system.

SYSTEMS

Exhaust. Check exhaust cocks and drains open. Open group exhaust valve and try muffler valve.

Oil. Dip the D.O.T. and start the lubricating oil separator and check for the presence of water. When it has been ascertained that the D.O.T. is fit for use, start the lubricating oil priming pump and vent the system. Top up the mechanical lubricators.

Water. Open up circulating water inlets and overheads, start the circulator and vent the system.

Fuel. Open up fuel group to gravity tank, start the separator and open up comp water supply. Vent the system and prime the injectors.

Air. Drain the air start bottle of water and top up from the H.P. air system.

The above five systems can be remembered by using the initial letters of: "Engineer Officer Wants Five Answers".

TURNING UP. After the lubricating oil pump has been started, put the turning gear in and turn up. Sight the cocks and drains clear.

BLOWING ROUND. When all the systems are opened up, stop turning the engine, OUT turning gear. Blow round at least two revolutions, sighting cocks and drains. IN turning gear ready for lining up the engine clutch. The engine is now ready for obeying telegraphs.

Starting

"OBEY TELEGRAPHS". When the telegraph goes to "In engine clutch", the tail brake is put on to stop the shaft moving, and the engine turned to line up the clutch. When lined up, OUT turning gear, put the clutch IN, and OFF tail brake. Report to the control room. The next order on the telegraph will be "Slow ahead". After confirming the order on the reply gong, blow round again sighting cocks and drains clear. Shut cocks and drains, start the engines, opening the muffler valve after the engine has fired.

Checks after Starting

When the engine has been set at the correct revolutions, and the engine driven lubricating oil pump is proved to be working by observing the increase in pressure, stop the priming pump and adjust the lubricating oil pressure. Listen for unusual or uneven firing, and sight exhaust temperatures in order to check that the injectors are working correctly. Adjust circulating water inlet and outlet temperatures by the loop valve as the engine warms up.

Preparing for a Standing Charge

The procedure is carried out as for preparing for sea except that the tail clutch is taken OUT and the engine clutch is put IN.

When the motor room watchkeeper is ready, the engine is started at approximately 400 revs. on a load. When the engine room watchkeeper is satisfied that the engine is running correctly, the field switch is put in, and the electrical load gradually worked up. At the same time the engine setting is adjusted to keep the revs. at 400.

Stopping and Shutting Down

STOPPING. The engines are stopped either by telegraph, or two blasts on the klaxon. As the engine is stopping, shut the muffler valve. When the engine is stopped, take the engine clutch out and report to the control room.

COOLING DOWN. Start the priming pump. Open cocks and drains. IN turning gear and start turning up. Shut circulating water inlet and overhead.

Continue to re-circulate water round the engine through the loop valve until the inlet and outlet temperatures are the same, and the exhaust temperatures have dropped to 200°F.) after about 5 minutes). Stop priming pump, stop circulator, stop turning and out turning gear.

SHUTTING DOWN. Stop lubricating oil and fuel separators. Shut off comp water supply. Shut off fuel subsequent filling valve, but leave gravity tank opened up to the engine system. Shut group exhaust.

CENTRIFUGAL SEPARATOR

To Clean

Switch off heaters, shut off oil supply, stop motor and apply the brake. When stopped, take off brake.

Raise the hood, lock the bowl with the two locking screws, and unscrew the bowl (L.H. thread). Remove the bowl and strip it down.

Clean the inside of the bowl, the disc carrier and each conical disc with a wooden scraper and oil fuel. Assemble the discs on the carrier in the correct order of numbers, and re-assemble the bowl making sure that the dexine joint ring is in good condition and in one piece.

Put the bowl back in the separator, tighten the bowl ring and take off the securing screws. Replace the hood and secure.

To Start

Check oil in sump at the working level. Start the motor. Remove the plug at the top of the hood and pour in hot water until it discharges. This gives the water seal in the bowl. Replace the plug.

DOMESTIC FACILITIES AND BATTERY VENTILATION

Fresh Water (Refer to *Fig. 17*)

Fresh water is supplied to the basins and sinks by applying air pressure to the tank. This is done by opening the master valve on the H.P. air line, check that the switch cock is on the tank to be used, crack open the reducing valve, observe the gauge and build up a small pressure in the tank (5 lb/sq. in.), shut off the reducing valve and the master valve. The pressure in the tank is sufficient to supply water for some time.

Slop Drain

When slop drain tanks require emptying, permission must be obtained from the Officer of the Watch as the dirty water could leave a trail and its discharge will effect the trim. When permission has been obtained, shut the tank drain valve, put vent and blow cock to blow, and open hull valve and intermediate flap valve. Apply reduced blow and build up a pressure of about 35 to 40 lb/sq. in.

When the pressure drops sharply, the tank is empty. Stop blowing, shut hull and intermediate valves.

To release the pressure left in the tank, open the outboard vent if on the surface, or inboard vent if dived. If venting outboard, when complete, change over to the inboard vent. Open the tank drain valve.

Distiller

PREPARATION. Check all valves shut, put distilled water discharge to bilge, check oil level in vapour pump and grease the bearings.

Prime the distilled water cooler with fresh water using the funnel. Top up the chemical injection tank.

Open up water supply to the feed tank. Open feed valve from tank to the regulator and let the level line in the shell until the condenser is covered. Shut the feed valves.

Prime the distilled water and brine pumps through the valve caps.

STARTING. Switch on all the heaters. Open vapour pump by-pass.

When the water is boiling and shell pressure reaches ½ lb./sq. in., start the vapour pump. Gradually shut the by-pass valve, making sure that the foam level does not rise above the observation glass. Open feed valve. Switch down to 2½ heaters.

Open the distilled water valve and start the combined pump, switch on the salinometer.

When the salinity is sufficiently low, put the distilled water discharge to a fresh water tank.

Open brine valve about ½ turn.

WHILE RUNNING. The vacuum should be between 3 to 4 inches in the shell. Regulate the brine to maintain a density of 20. The vapour pump discharge temperature must not exceed 300°F. The normal temperature is betweeen 250° to 280°F. *A rise in temperature is counteracted by switching more heaters ON.*

TO STOP. Put distilled water to bilge, shut off feed water and switch off the heaters. Open by-pass and stop vapour pump. Stop combined pump and shut all valves. Open drain and empty the shell.

BATTERY VENTILATION

Object. To prevent accumulation of hydrogen so that the possibility of an explosion is eliminated.

Ventilation System

Air is allowed to enter one end of the battery tank through two inlet trunks, the openings being about head level and fitted with gratings to prevent objects falling down. Two fans, fitted on the other end of the tank, draws air across the tops of the cells and discharges it through a hull valve. The air is led along an external pressure tight trunking, either to the engine room through another hull valve, or, when in harbour, to an outlet valve (master outboard) or door on the side of the bridge.

Each battery has its own fans and discharge hull valve with an additional hand operated flap valve for emergencies. Drain cocks, outboard and inboard, are fitted each side of the hull valve.

Clearing Fans

When the battery ventilation is shut down, the intakes are left open, although they can be shut in cases of fire or testing the tank by swinging down and screwing up a flap.

The discharge hull and flap valves are however always shut.

To prevent accumulation of hydrogen in the trunking between the tank and the flap valve, a small hydrogen clearing fan is fitted as near the flap valve as possible, so that the air from the compartment is circulated back to the inlet and out into the compartment again.

Clearing fans are always run when the main battery ventilation is stopped. The fans must be stopped before the main battery ventilation is started up.

Starting Ventilation

Check master outboard shut by checking the indicator in the control room in the case of a valve fitting. In the engine room, check outboard drain and crack open hull valve. If the drain remains clear, shut the drain, open hull valve fully and open flap valve.

Carry out similar procedure at each battery hull valve.

Start the fans and check that air is actually circulating by testing with a handkerchief at the intakes.

For ventilating outboard, instead of opening the hull valve in the engine room, the master outboard valve (or flap) is opened.

Hydrogen Eliminators

To prevent the build up of hydrogen in the submarine when dived ~~or charging for long periods~~.

MAINTENANCE AND REPLENISHMENT

Fittings External to the Pressure Hull that require Greasing

Bow caps and shutters.
Towing slip.
Forward hydroplanes.
Capstan gear and rollers.
Cable compressor.
Forward escape hatch, springs and shaft.
Torpedo loading hatch, springs and shaft.
Forward indicator buoy drum and shafts.
Garbage ejector.
Battery ventilation hull and master valves.
Hand operated Kingstons.
Gun tower, springs and shaft.
Gun tower escape gear operating shafts.
Voice pipe cocks.
Conning tower hatch, springs and shafts.
A.P.T. mast sheaves.
Periscope and A.N.F. mast bearings.
Snort raising operating ram and slide or snort mast and snort exhaust mast bearings.
Snort mast indicator operating rods.
Snort head float valve.
Engine room hatch, springs and shaft.
After indicator buoy drum and shaft.
Aft escape hatch, springs and shaft.
External tube door operating rods.
Disappearing bollards.
No. 5 main ballast tank vent link gear (A class only).
Aft hydroplanes.
Rudder bearings.
"A" brackets and stern tubes.

Jointings and Packings

Lubricating oil pipe joints	"Gaskoid".
Lubricating oil hose joints	Leather.
Oil fuel pipe joints	"Gaskoid", or face to face, fibre or cork insert.
Oil fuel hose joints	Leather.
H.P. air pipe joints	Diamond copper washers.
H.P. air valve box cover joints	Square copper washer.
H.P. air valve packings	Lampwick and tallow, or plaited cotton and vaseline, or rubber cored greased cotton packing.
Circulating water pipe joints	Rubber insertion, or permanite or dexine.
Circulating water valve gland packing	Rubber core water packing.
Telemotor pipe joints	Diamond copper washer.
Telemotor valve packing	"Lomoto" or "Plasco".
Manhole covers	"Oakencork", or rubber insertion, or liquored leather.
Manhole covers—main ballast	*Rubber insertion or dexine.*
Manhole covers—oil fuel	Leather, or "Gaskoid".
Manhole covers—lubricating oil	Leather, or "Gaskoid".
Main line pipe joints	Rubber insertion.
Brown's system glands	"Lomoto" and S.E.A. rings.
Crankcase disc joint	Oil paper, or "Gaskoid".
Hatch joints	Dexine.
Water tight doors	Dexine.
Exhaust tank cover	Wire woven asbestos cloth.
Exhaust joints	Permanite or copper asbestos.
Induction joints	Permanite or copper asbestos.
Cylinder head joint ring	Mild steel or copper.
Fresh water joints	Rubber insertion.
Main vent hull glands	S.E.A. rings.
Hull joints	Face to face with red lead and copal varnish.
Sonar hull joints	Permanite 1/64 in. Faces to be prepared as for face to face.
Stern glands	Black hemp or Masco.
Periscope tube joints	N.B.O. jointings.
Radar glands	"Plasco" blockhouse gland.
Periscope gland	Blockhouse gland, grease packed.
S.S.E. reducing valve diaphragm	Dexine.

FUELLING

First Filling (group completely empty)

Remove first and subsequent filling caps, open first and subsequent filling hull valves, and the subsequent filling tank top valve.

Open vents on the group.

Connect water hose from the main line, or hydrant on the jetty, to the first filling hose connection. Turn on the water supply. As each tank becomes full of water, shut the vents. When the group is full, water will pour out of the subsequent filling.

Shut off water supply, shut valves and replace caps.

Filling with fuel

Before starting, take precautions in accordance with B.R.16(50), article 379.

Remove first and subsequent filling caps, open first and subsequent filling hull valves, and subsequent filling tank top valve.

Connect hose from the fuelling lighter to the subsequent filling hose connection. A goose neck may be needed on certain submarines. Dip the lighter's tanks.

Commence pumping slowly, venting air from the hose at a cock on the goose neck or filling pipe. Speed up fuelling but not above 35 lb/sq. in. tank pressure. Observe the water discharge from the first filling.

When the first filling discharge becomes discoloured, stop pumping. Wait 15 minutes to allow fuel and water to settle down, and then start pumping again until the water discharge again discolours. Stop pumping.

Shut subsequent filling valve. Get the lighter to suck back to empty the hose. Disconnect hose. Shut subsequent filling tank top valve and the first filling hull valve. Replace the caps.

Open up comp water supply so that each tank can be vented and proved completely full. Dip the ighter's tanks again to cross check amount received.

External Tanks

Carry out the same procedure as for internal tanks except for the following:—

Before filling external tanks, open up equalising system except for equalising hull valve.

While fuelling the pressure in the tank must not exceed 10 lb/sq. in. The sea relief valve will protect the anks during this operation.

On completion open equalising hull valve.

Before fuelling emergency tanks (Kingston main ballast tanks), shut and lash the L.P. master blows nd L.P. tank sides, shut the hand operated Kingstons, and stow the Kingston levers in the store, and it harbour cotters to the main vents.

De-fuelling

Remove the first filling cap and open the first filling hull valve. Check the subsequent filling tank top alve shut.

Open the reduced blow to the group. Pressure must not exceed 35 lb/sq. in. Water will start flowing rom the first filling.

When the water discolours, shut off the blow. Shut the first filling hull valve. Connect hose from fuel ighter to the first filling hose connection. Dip the lighter's tanks.

Open the first filling hull valve and carry on blowing. When the group is empty, shut off the blow. When tank has finished venting through the first filling, shut off first filling hull valve, disconnect hose and replace the cap. Dip the lighter's tanks again to cross check the amount discharged.

PERISCOPES—CARE AND MAINTENANCE

N HARBOUR. Keep the bottom end dry and clear of damp well. Keep in lowered position to reduce ibration when charging, and damage from cranes when alongside. Caps placed on tops of periscope tandards.

TOP WINDOWS. Keep canvas bag on as a protection against paint, seagulls dirt. At sea, wash off with resh water, wiping carefully with a non-fluffy cloth. Use spirit to remove grease.

PERISCOPE MAIN TUBE. If dry after a spell in harbour, wipe clean with fuel and lightly oil. Protect against elding splashes. The section between the hull and the bottom of the standard is particularly vulnerable, even when protected by perforated guard plate.

BEARING SCALE. Check in dock with torpedo tube bores, theodolite and graduated board across the end of the dock. Check frequently with a mark on the casing for skysearch periscope and with the other periscope. Both should give same bearing on a distant object. Scale is mounted on elongated holes, so beware of any accidental alteration after work on main gland or even scale lighting.

CROSSHEAD BEARING. This bearing carries the weight of the periscope on a ball thrust bearing and needs greasing.

DESICCATION. "Inlet" marked on the main tube leads dry air to the top of the tube. The practice of connecting the desiccator to the outlet to prevent dust going to the top and settling on the graticule is incorrect. Filters are fitted to the desiccator pipes. All connections are covered by a screw cap with spring loaded ball valve inside, which is pushed open by the pipe ends. The ocular box desiccator connections are not marked as it does not matter which is in or out. Take care face plate joint is cut away at the top to avoid blanking ocular box air circuit. Desiccation can only remove damp. If persistent fogging occurs, suspect water in the ocular box. Test by removing bottom desiccator cap and pushing open the ball valve. Beads of water indicate the necessity of removing ocular box for complete drying out and desiccation after replacement. Main tube fogging is rare, and can be identified by inspection of the main tube lenses after removing the face plate. If this has occurred, venting the main tube top vent and persistent desiccation is the only remedy other than top overhaul.

PERISCOPE HOIST WIRES. Lang's lay. Keep lubricated. A spare wire for each periscope is kept with one eye-bolt already spliced on. Ease clamps on the crosshead occasionally to even the stress in the wire. Check adjusting eye-bolts at ends and see that lock-nut is in place.

PERISCOPE WELL. Keep clean and dried out. Use heater moderately if periscope is down, otherwise it has the effect of a Turkish bath or oven. The periscope must be on the pins if a man is in the well for cleaning.

CHANGING PERISCOPES. Clamps are carried by each submarine. Blank the hole in the pressure hull when the periscope is out.

NAVAL STORES PROCEDURE AS APPLIED TO SUBMARINES

Classification

Stores are dealt with in two sections. Permanent and Consumable.

Permanent Stores

These are valuable articles that can be returned or re-used. Initial supply is made by the Superintending Naval Stores Officer (S.N.S.O.) of the storing yard to the scale laid down in the Establishment of Sea Stores for Submarines B.R.363, in conjunction with the List of Particulars raised during the building or conversion period.

Increases of specific quantities allowed are not permitted without approval. After the initial supply has been completed subsequent issues will only be made in the following circumstances:

(a) To complete to allowance shown in B.R.363.

(b) In lieu of similar items returned.

(c) In lieu of losses accounted for on form S.126.

(d) Additions for which approval has been given.

All permanent naval stores are accounted for in the submarine's Naval Store Account S.151. This account is a loose leaf ledger providing a separate page for each item held on board. The account is divided into two sections, A and B. Section A comprises all valuable and appreciable items and are to be mustered every six months by the Commanding Officer (or other responsible officer delegated by him) and on change of Commanding Officer. Section B comprises the remainder of the stores on charge and is to be mustered at indefinite periods, and on change of Commanding Officer.

The items in both sections of the account are grouped and indiced as shown in the front of the section. Each group is compiled in numerical order of pattern numbers. Items having no pattern numbers are arranged in alphabetical order. This arrangement allows for the charge of any items held on board to be readily found in the ledger.

S.1099 is used for mustering stores. It contains all items listed in the S.151 pages. It is usually split up departmentally.

TRANSACTIONS WITH THE DEPOT SHIP. Demands are made on S.156 in triplicate. Returns are made on S.1091 in triplicate. Copies 1 and 2 are extracted by the depot ship. Copy 3 is held on board. The Naval Stores Account is actioned by this copy.

TRANSACTIONS WITH S.N.S.O. Demands are made on S.134, 5 copies. Returns are made on S.331, 5 copies. Copies 1, 2, 3 and 4 are forwarded to S.N.S.O. on completion of the transactions. 1 and 2 copies are retained by S.N.S.O., 3 copy is forwarded to the Supply Officer of the depot ship, 4 copy is forwarded to the submarine.

The submarine's account should be actioned by the 4 copy. Receipt of the stores on board is to acknowledge on this copy.

All 3 and 4 copies of S.134 and S.331 received on board are to be forwarded to the Supply Officer of the depot ship as soon as possible after accounting action has been taken. It is essential that these forms should be passed on to the depot ship as soon as possible in order that S.N.S.O's. records may be cleared.

LOSSES. Losses by accident or neglect are to be dealt with on Form S.126. B.R.4, article 74, shows the value of stores lost for which the Commanding Officer can authorise removal from charge.

Losses above this value must be submitted for higher approval. Charges for losses by neglect are normally approved by Captain S/M.

Consumable Stores

These are drawn as required providing that the quantities are reasonable in proportion to the work for which they are required. Certain items, however, are subject to a Valuation Allowance, and demands for these items should be reviewed with care to avoid excess expenditure. Item subject to valuation are: paint and painting materials, cleaning gear, timber, cotton waste and rags, electric bulbs.

MACHINERY SPARE GEAR, SPECIAL STORES AND DRAWINGS

Spare Gear

Machinery parts which become worn out or defective must be replaced. Two lists of items are made out, one list for the submarine, which consists of items that may be required when the submarine is at sea (carried on board spares), and the other list for the depot ship, which consists of the items of the submarine's carried on board spares together with items that are used for major maintenance (depot ship spares). The two lists are kept in one book (D.787). Submarines therefore can replenish with spares and obtain other items when alongside the depot ship. In order that the submarine and the depot ship can

account for spare gear usage transactions, demand forms S.134 and ledgers S.151 are used, a similar procedure to storekeeping being followed.

Special Stores

Machinery parts, such as gland packings and joints, which are not included in the spare gear lists but can be supplied through the naval stores department, are known as special stores. A list of items for each machine, with the description and method of replenishment is contained in a book S.122a. Replenishments can be made from the depot ship on demand notes S.156.

Drawings and Handbooks

To assist the ship's staff in maintenance and during refits, detailed drawings and maker's handbooks are carried on board the submarine. A list of these drawings and handbooks is kept in the D.787.

Although the above applies mainly to the Engineer's organisation, a similar system is used by other departments.

ARMAMENT AND T.A.S. EQUIPMENT

SUBMARINE GUNNERY

Objects. (a) To provide a secondary weapon (4 in. gun) for sinking small targets when torpedoes are unsuitable or unnecessary.

(b) To provide sufficient small arms for boarding parties.

(a) Equipment

GUN. 4 in. Q.F. Mk. 12 or Mk. 22 (1 in. sub-calibre mounted on a platform on the casing).

GUN TOWER. To provide access to the gun from the control room. Similar to the conning tower but sometimes fitted with two upper lids.

AMMUNITION. Kept in the magazine or the torpedo stowage compartment, and supplied by hand through the gun tower. Facilities for flooding the magazine in an emergency consists of either a direct sea connection or hose connection from the main line.

T.C.S.S. PERISCOPE AND RADAR. To find the initial range and deflection before surfacing.

GUN'S CREW

ON THE GUN. No. 1 Gunlayer (G.A.2), No. 2 Breechworker, No. 3 Loader, No. 4 Trainer (G.A.3), No. 5 Sightsetter.

AMMUNITION SUPPLY. No. 6 and No. 7 supply at the gun, Nos. 8 to 14 supply between the magazine and top of the guntower. Telegraphists and U.C. ratings are not used for gun's crew due to the possibility of "gun deafness".

IN CHARGE. An officer (Armament Officer) who is stationed on the bridge or at the rear of the gun platform.

GUN ACTION

PREPARATION. Gun's crew in the control room, open magazine and supply equipment. Initial range and deflection from the Command Lower Lids of both towers opened. First Lieutenant stands by with whistle. Armament Officer mans the conning tower, and the gunlayer the gun tower, remove pins from the upper lids.

SURFACING. Must be done as quickly as possible. When the submarine starts to rise remove one clip from the upper lids. At approximately 25 feet, the First Lieutenant gives long blasts on the whistle. Upper lids are opened, crew man the gun and open fire.

SPOTTING CORRECTIONS. Adjustments of range and deflection made according to the judgment of the armament officer. The gunlayer takes over if the armament officer becomes casualty.

"SECURE THE GUN". Crew make their way quickly below. Gunlayer checks the gun secured, shuts and secures upper and lower lids and reports.

"DOWN BELOW". This is an emergency order. Gun is abandoned, crew proceed below at full speed, lids secured and reported.

(b) **Small Arms—6 Sten carbines**

Other items of gunnery equipment are two 2½ in. grenade pistols, one line throwing rifle and hand grenades.

SUBMERGED SIGNAL EJECTOR

Preparation

The order is given from the control room to load a candle or a grenade. The order will state the particular type and colour.

The watchkeeper will check sluice and equalising valves shut, open drain, open breech and sight it clear with a torch.

The candle or grenade is loaded, making sure that the safety pins are not withdrawn until the container is nearly loaded. The breech is then swung into position and screwed up tightly.

The air bottle reservoir is now charged by opening the H.P. air valve on the H.P. air line. The reducing valve is screwed up until the correct firing pressure registers on the gauge. The valve to the reservoir is opened until the reservoir is charged, and then shut.

The watchkeeper will then report that the S.S.E. is loaded.

Firing

The control room then gives the order to fire.

The watchkeeper will open the sluice valve, opening the equalising valve if necessary, press the firing lever and report that the S.S.E. has been fired.

After three minutes he will shut the sluice valve, drain down, open breech, recover the base plate and sight the bore with a torch. He will then report that the S.S.E. is drained down and the bore sighted clear.

Four Float Signals Submerged are stowed near the S.S.E. for emergencies. When a red grenade is ordered to be fired, the watchkeeper will load and fire as quickly as possible.

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