STOKERS' MANUAL
1912

ISSUED TO .....J. Lee..................... RATING .....Sto. II.

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"CERBERUS"

Saml R. Baker
Engineer Lieutenant R.N.

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STOKERS' MANUAL

(FOR ENGINE-ROOM RATINGS NOT ENTITLED TO THE STEAM MANUALS AND SEAMEN UNDER TRAINING IN MECHANICAL AND STOKEHOLD WORK).

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CONTENTS.

Chapters III., VI., XII., and XV., besides the paragraphs between brackets in Chapter II., pages 9, 10, 11, 12, 13, and 14, Chapter VII., pages 57, 58, and 59, and Chapter X., pages 75, 77, 78, 79, 80, 81, and 82, are not included in the Courses of Instruction for Stokers 2nd Class and Seamen.

STOKERS' MANUAL, 1912.

CHAPTER I.

THE BOILER.

When a kettle is boiled over a quick fire steam blows from the spout and, if the lid is loose, moves it up and down, puffing out from under it.

The heat developed by burning coal in the fire passing into the water converts it into steam, whose energy is shown by the force with which it blows out of the kettle. Boilers are formed to communicate the heat given off by the fuel burned in their furnaces to the water inside them, the steam generated is carried through pipes to engines which are driven by its energy.

The steam formed in a kettle where a loose lid and the spout allow free escape to the atmosphere has a pressure only slightly above the atmospheric, but in boilers where the space in which the steam is formed is not connected to the atmosphere much greater pressures are used.

Boilers are made up of steel plates and tubes. The plates are joined by *riveted joints* and the tubes are secured in them by *expanding* or tightly rolling the tube ends into holes in the plates.

The boilers used in the Navy may be divided into two principal classes, *tank boilers* and *water-tube boilers*. The name tank boiler was originally employed with old low-pressure boilers shaped like tanks; these boilers have gone out of use, but the name is still attached to the cylindrical boilers which succeeded them.

Tank boilers are sometimes called *fire-tube boilers* because the flames pass through their tubes.

In water-tube boilers the water passes through the tubes and the flame is outside.

CYLINDRICAL BOILERS have cylindrical shells with vertical flat ends.

The type of circular boiler most commonly found in ships in the Navy is the single-ended return tube boiler (Figs. 1 and 2).

Arrangement of Parts of the Single-ended Return Tube Boiler.—This boiler when at work is filled to about three quarters of its height with water. The interior of the boiler occupied by the water is called the *water space*, and the part above the water level the *steam space*.

The furnaces, combustion chambers, and the tubes are all arranged in the water space.

The crowns or tops of the furnaces, the surfaces of the combustion chambers excepting the bottoms, and the tubes are the surfaces through which the heat passes from the fuel to the water: they are called the *heating surfaces* of the boiler.

The highest part of the heating surface is the top of the combustion chamber, this must always be well covered with water while the boiler is steaming; otherwise the plates will become overheated and there is risk of damage to the boiler, the plates are weaker when red hot than when in contact with water, and if after having been red hot cold feed water reaches them there is a danger of their cracking.

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As will be explained in another chapter, water gauges are fitted on a boiler to show the height of water in it when it is steaming and to enable the necessary amount to be kept.

The furnaces of a modern cylindrical boiler are large cylinders or tubes of corrugated steel plate similarly curved to the thin corrugated plates used for roofing. This curving makes them very stiff to resist the pressure in the boiler.

The combustion chambers are built up of plates which are flat except where they follow the shape of the shell or furnaces.

In the front plate of the combustion chamber (the *back tube plate*) and in the upper part of the front end of the boiler (the *front tube plate*) the ends or most of the tubes are *rolled* or *expanded* into holes drilled in the plates.

Staying.—The circular shell and the furnaces are strong enough to withstand the pressure in the boiler, but the flat ends and the combustion chambers require staying.

In the steam space and below the furnaces the flat ends of the boiler are held together by *long bar stays.* These stays are screwed at the ends and nuts on them are screwed up outside and inside the boiler ends.

The sides, back, and bottom of the combustion chamber are stayed to the plates opposite them (the shell of the boiler or part of an adjacent combustion chamber, as the case may be) by stays known as short screwed stays; these are screwed through the plates they stay and are furnished with nuts on the outside. To stay the front of the combustion chamber to the front of the boiler some of the tubes are threaded and screwed into the plates, thus holding them together. The flat top of the combustion chamber is stayed either to the shell of the boiler above by bar stays, or more commonly by *dog* or *girder stays* running across it resting on it at the front and back, and holding it up by means of bolts screwed through the top of it, which pass through the dog and have nuts on their ends screwed down on it.

Arrangements for burning the Coal.—The end of the furnace in the stokehold is known as its *mouth.* The top half of this is closed by a steel plate or frame called the *furnace front,* this is lined inside with brick to protect it from the heat of the fire and carries the *furnace door.*

At the bottom of the furnace front running across the mouth of the furnace is the *dead plate*, a wide cast-iron plate, which carries the front ends of the *fire bars* of the *grate*, the bars which are separated by air spaces slope slightly downwards along the furnace to the cast-iron *bridge* at the back of the furnace. The furnace grate of a large boiler is 6 feet or more in length, and it is necessary to have the fire bars in *tiers* or lengths, to support the ends not lying on the dead plate and bridge *bearing bars* run from side to side of the furnace barrel.

The cast-iron bridge has a *brick bridge* built up on it. This forms the end of the fire, and is built up some distance into the combustion chamber to protect the plates from the fierce heat of the flames.

The part of the furnace above the brick bridge is known as its *throat.*

At the mouth of the furnace below the dead plate a door or *draught plate* is fitted to the ashpit—as the space below the fire bars is called—this door on the circular boiler is so arranged that it may be kept open

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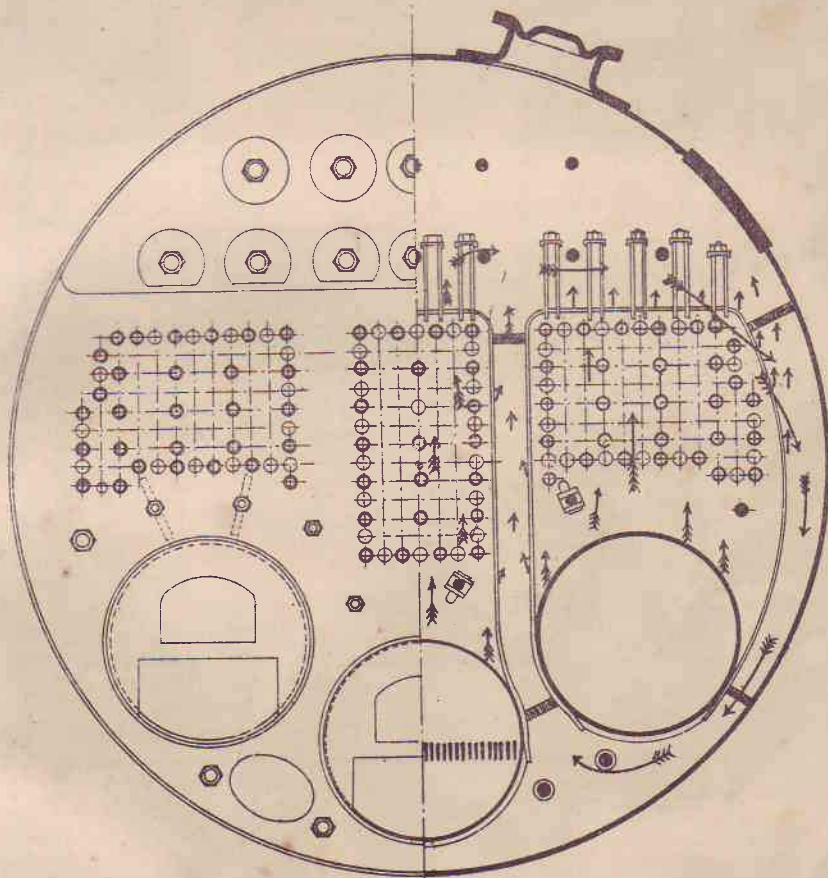

FIG. I. _ CYLINDRICAL RETURN TUBE BOILER.

Arrows show direction of circulation of water

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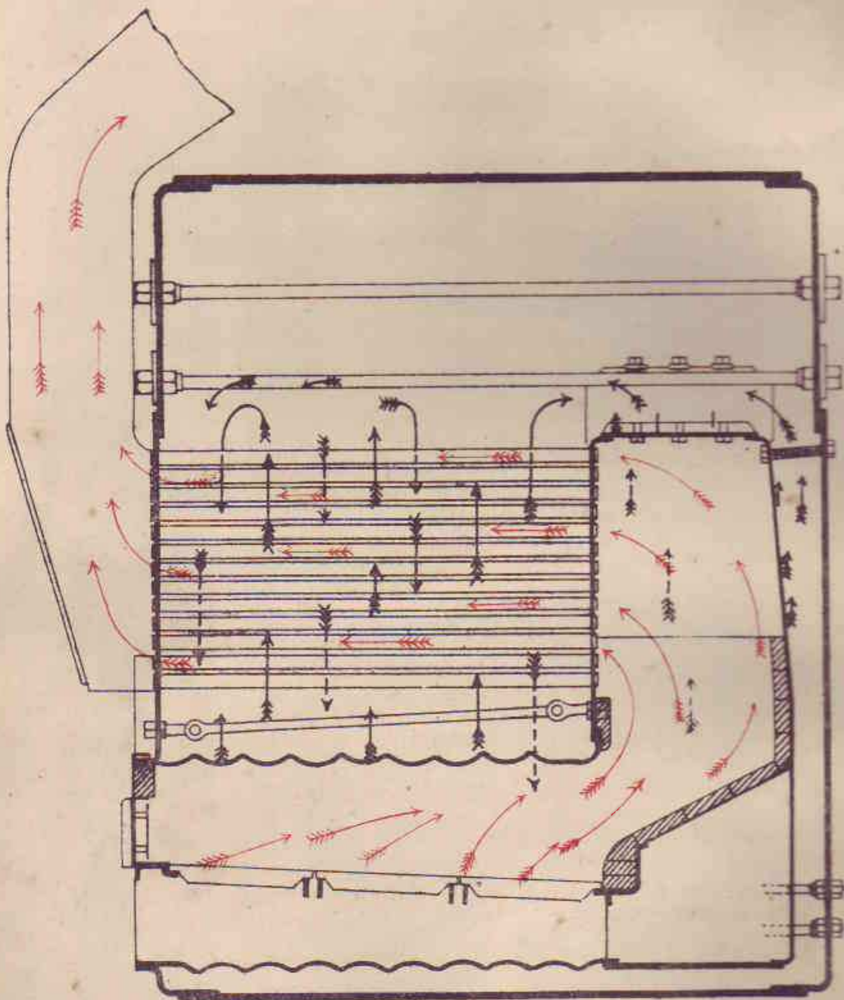

FIG. 2 — CYLINDRICAL RETURN TUBE BOILER.

→ direction of circulation of water
→ " " " " Flames & gases.

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to any extent required or entirely closed, thus regulating the draught or supply of air to the fire on top of the bars. The bars have air spaces between them through which the air from the ashpit reaches the coal on the fire grate; as the coal burns, gas escapes from it into the top of the furnace and mixes with air which has come in through holes in the furnace door; the mixture of air and gas passes to the combustion chamber and after being burned there is led out of the boiler by the tubes.

The tubes discharge smoke and burned gas into the *smoke-box* whence they pass to the *uptake* and are discharged into the atmosphere through the *funnel.*

The smoke-box is a light steel casing carrying doors which allow it to be cleaned of soot and also allow the tubes to be swept.

In modern boilers there is a separate division of the uptake for each furnace and its combustion chamber, a door or *damper* in each division is workable from the outside; by shutting it the communication between the furnace and the funnel is closed. The damper is always closed when a fire is being cleaned or tubes are being swept. When forced draught is used great heat is generated in the combustion chamber, and to prevent the tube ends from being burned or rendered leaky cap ferrules are fitted.

Access to Interior of Boiler when not at work.—It is necessary to get inside boilers when not at work to clean, examine, and repair them. For these purposes *manholes* are provided in the shell of a boiler through which a man can pass, and there are smaller holes called *mud* or *hand holes* through which the boiler can be cleaned by persons outside. When the boiler is at work these holes are closed by doors; the door when in place is inside the boiler, so that the pressure of steam presses it shut, bolts screwed through the door take on a dog or dogs laid across the hole in the end of the boiler, and when the nuts on them are screwed up compress an asbestos ring carried in a recess formed on the flange of the door.

The parts described are common to all circular boilers; the *double-ended* boiler has two fronts and corresponds to two single-ended boilers with the circular part of the shell continuous, placed back to back, with the back end plates omitted.

Circulation of Water.—Water in a kettle or saucepan will be seen to move directly it is put on the fire, and the movement continues till the kettle or saucepan is taken off again.

This circulation takes place because hot water being lighter than cold rises to the surface; it is increased by the presence of air or the formation of steam in the water.

In the circular boiler when steam is being raised the bottom furnaces are always lit first and all the fires are allowed to burn up very gradually to allow all parts of the boiler to heat up together. If fires are lit quickly steam can be obtained and the engines worked very soon, but as little or no heat passes through the bottoms of combustion chambers and furnaces, the water between them and the bottom of the boiler will be cold while the top of the boiler is hot; this is because the circulation of water in the bottom is very slow.

If steam is got up too quickly in a circular boiler, there is danger of damage to it by straining of the riveted seams of the shell and combustion chambers, owing to the top becoming hot while the bottom remains cold.

The heating surfaces of a circular boiler are grouped in the water space in such a way as to allow the water to circulate freely, so that there shall be a supply of water continually reaching the parts through which the heat from the fuel is passing; this is necessary to prevent them from being overheated.

The tubes are arranged in nests above their furnaces with clear water spaces at the sides of them, these water spaces are also carried at the sides of the combustion chambers.

The water above the tubes can pass down these water spaces and reach the tops of the furnaces, from there it rises after being heated through the tubes to the water level. Similar circulation is set up at the sides and back of the combustion chamber, the latter being sloped to facilitate it and to allow the readier escape of any steam formed on it.

Scale.—The various heating surfaces of the boiler communicate heat received from the fire and burning gases to the water inside it. This communication of heat is best when the heating surfaces are clean both on the fire side and the water side.

On the fire side, soot and small particles of ash stick to the surfaces, and these will foul the tubes unless removed by sweeping them.

On the water side any foreign matter contained in the feed water is left in the boiler and forms a scale or deposit on the heating surfaces.

The impurities which enter in the feed are principally due to leakages of salt water into it and greasy matter from the oil used on various internal parts of the main and auxiliary engines and feed pumps.

With boilers worked under modern conditions, with fresh water used as make-up feed, the condensers tight, the amount of oil used inside cylinders, &c., strictly limited, and the grease filters in good condition, little scale or deposit is formed in the boiler.

When boilers are forced comparatively little scale or deposit may cause overheating of the furnaces or the tubes nearest the fire in a water-tube boiler.

Besides taking precautions of using perfectly fresh water for feeding the boilers and limiting the use of internal lubrication as far as possible, boilers are carefully cleaned of all scale whenever they are opened out for examination.

Lagging.—It is necessary that heat should be prevented from escaping from a boiler, both because it makes the stokehold uncomfortable and because it is necessary to burn extra coal to make up the heat which is lost from the boiler.

The escape of heat from boilers and other hot surfaces such as the outsides of steam pipes and cylinders is prevented by lagging them. They are covered with some substance which conducts heat badly, such as asbestos, magnesia compound, or silicate of cotton.

This lagging is kept in place and protected from damage by covering it. In boilers and where rough usage may be expected a light steel plate casing is fitted as a covering.

With steam pipes the covering is usually of prepared canvas.

CHAPTER II.

WATER-TUBE BOILERS.

Water-tube boilers are fitted in all the more modern ships in the Navy.

Compared with tank boilers they possess the following advantages:—

(1) Lighter for the same power;
(2) Better adapted for carrying a high steam pressure;
(3) Not so liable to become strained and leaky if steam is often raised quickly.

In the water-tube boiler the furnace, combustion chamber, &c., are external to the boiler, and casings have to be fitted outside the boiler to confine the fires and gases; these casings are brick-lined to prevent their being burned, and they are lagged where necessary with non-conducting material.

Compared with tank boilers, water-tube boilers contain a small quantity of water, and more attention is required to their feeding; to assist in this an automatic feed regulator is usually fitted.

Water-tube boilers, in which the internal diameter of the generating tubes is $1\frac{1}{2}$ inches, or above, are classed as *large tube water-tube boilers*, those with tubes below that size as *small tube boilers*.

Examples of large tube boilers are Belleville, Babcock and Wilcox, Neclausse and Dürr; and of small tube Thornycroft, White-Forster, Reed, and Normand.

The Yarrow boiler is made with both large and small tubes, and belongs to both classes.

As a rule, large tube boilers are fitted in ships, and small tube boilers in torpedo craft and the smaller cruisers.

THE BELLEVILLE BOILER consists of the boiler proper or *generator* in which the hot feed water is converted into steam, and a feed heater called the *economiser* placed in the uptake above it.

In some of the earlier boilers fitted in the Navy there are no economisers.

The *steam collector* is a large drum lying horizontally across the top of the front of the generator, it is connected to the feed collector, which is a square steel tube running across the front of the boiler just above the furnace doors, by a number of independent *elements*.

Each element is made up of a number of straight steel tubes running from *junction-boxes* at the front to junction-boxes at the back.

These boxes, which are of malleable cast iron, are placed one above another at the front and back, and from each there is a pair of tubes, one going to an opposite box above it and the other to one below; there is a continuous passage from top to bottom of each element as in a flattened coil of tube.

The *front junction-boxes* have hand-holes opposite both the tubes leading to them for use in cleaning or examining the tubes; the hand holes are closed by small doors carrying asbestos rings.

The front junction-box at the top of the element is bolted to the flange of a short pipe, the top end of which projects about 8 inches inside the steam collector; but to allow freedom of movement the bottom front junction-box is secured to the feed collector by a cone and nipple joint.

Coned nipples are screwed into the feed collector, and fit into coned holes in the bottom of the junction-boxes, nickel rings are placed between cone and coned hole, and the junction-box is held down in place by the *anchor bolt*, which holds a flange on the front of the box to an angle iron fastened along the front of the feed collector.

The *bottom back junction-box* rests on a roller carried on a steel chair; it is thus free to move when the tube expands.

At one side of the boiler there is a steel casting containing the automatic feed float, which is supplied with water and steam by connecting it with junction-boxes at bottom and top of the wing element. The float controls the automatic feed valve placed in the pipe leading from the feed pump to the cold water collector of the economiser.

A water gauge is placed on the casting, and another on the other side of the boiler is connected directly to the junction-boxes of the other wing element.

When the boiler is being forced, weights will be ordered to be removed from the regulator levers to cause the automatic gear to maintain a higher level of water in the chamber and in the gauge glasses.

The *economiser*, which is situated above the steam collector, with a space between its tubes and those of the generator, is built up of elements similar to those of the generator.

The upper (*hot water collector*) and the lower collectors (cold water collector) are square steel tubes like the feed collector of the generator. The feed water, after passing through the automatic feed valve, reaches the cold water collector of the economiser, and after passing through the economiser elements, traverses the hot water collector, whence a pipe conveys it to the non-return valve on the steam collector of the generator.

Boiler Casing.—The economiser and generator elements are surrounded by a casing of thin steel plate, the only part of the boiler outside it being the steam collector. This casing below the generator tubes is lined with firebrick, and above it is lagged.

The furnace doors are situated under the feed collector, and below the dead plate there are draught plates and an ashpan kept full of water under each door.

On the front of the generator and economiser casings large doors, called tube box doors, are fitted, through which all the junction-boxes can be reached and the tubes cleaned; sight-holes are fitted in these doors, through which the state of the fires and the condition of the tubes may be observed.

The gas coming off from the coal on the grate is partly burned under the generator tubes; to facilitate this air is blown into the space under the tubes in jets from trunks supplied by the furnace air-pumps; to spread the gases over the tube surface, baffles are placed between the tubes and the casings, and smoke-box doors and back casing are fitted with hooked baffles preventing the gas escaping at the sides of the tubes.

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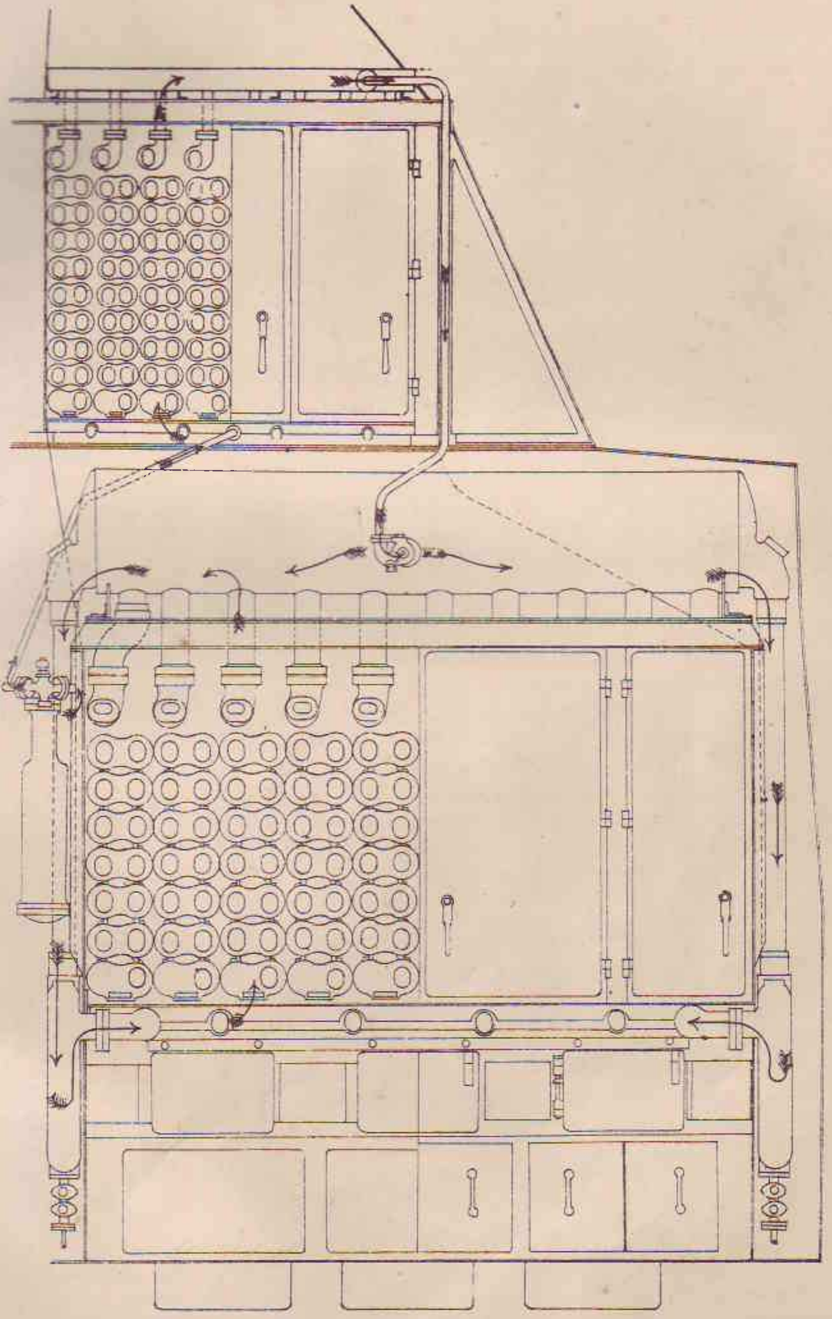

FIG. 3 _ BELLEVILLE BOILER.

⋙——→ direction of circulation of water.

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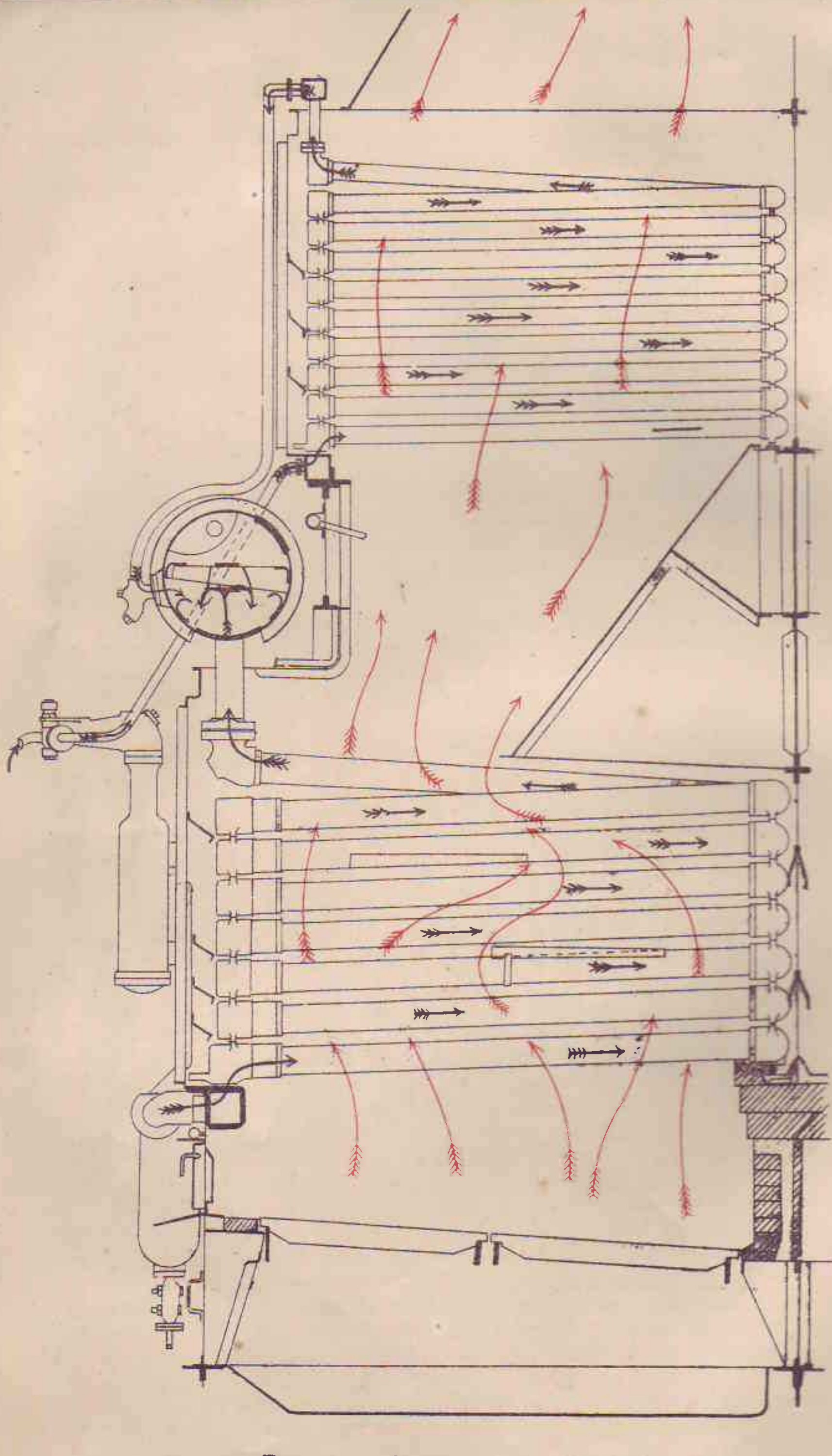

FIG. 4. – BELLEVILLE BOILER

$\ggg$———→ direction of circulation of water

$\ggg$———→ " " " " flames & gases.

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Above the generator tubes there is a space below the economiser where the gases are burned before passing over the economiser tubes.

Baffling arrangements, similar to those in the generator, are placed in the economiser.

Course of Water and Steam.—After leaving the economiser the feed water enters the centre of the steam collector, where it is met by water discharged from the generating tubes, which is separated from the steam issuing from them by baffles.

The feed water passes along the steam collector to either side and descends through downcomer tubes at the sides of the boiler to the mud drums.

The mud drums are fitted with a baffle to facilitate deposit of any foreign matter which may be blown out by the blow-out valves placed on them.

The top of the mud drum on the other side of the baffle is connected to the feed collector by an elbow, and through the holes in the coned nipples in the top of it the water reaches the various elements in which part of it is turned into steam and discharged into the steam collector. It is important that the water in the elements should always move upwards; to ensure this, particularly while steam is being raised when it might otherwise be blown out of the element and the lower tubes burned, a *clack* or non-return valve is fitted at the bottom of the downcomer, where it enters the mud drum.

[*Action of Automatic Feed Apparatus.*—The hand feed check valve should generally be wide open; if, however, the automatic feed regulator is out of order, the feed should be regulated by the hand check valve.

If after steaming some time the water level in a boiler remains sensibly higher than originally with the same number of weights on the lever, this will generally indicate that the automatic float is leaking and getting heavier, or that the automatic valve is worn. This should be rectified at the first opportunity.

Once in each watch the two spindles of the automatic feed apparatus should be carefully wiped with dry cloth to remove any coal dust that may be adhering.

Oil or grease should not be used on these spindles, either when the boilers are at work or at rest; they should always be kept dry and clean.

If after two or three weeks' steaming any lime dries on these spindles tending to make them stiff, they should be removed, cleaned, and polished in the direction of their motion with leather, the glands being afterwards repacked.

The following instructions should be generally followed in packing the two automatic feed spindles:—The gland nut should be clean and of such size that it will screw down easily by hand. The spindle is first put into position and anti-friction packing pressed in hard all round it until the packing can be reached by the gland, then tighten the gland very hard on the anti-friction packing, and move the rod up and down until it works freely. Repeat this operation a second time, sufficient packing being then inserted in the stuffing box to leave the gland half way out of the stuffing box, and move the spindle as before until it works freely. Then take off gland and gland nut and insert a special moulded india-rubber ring on top of the anti-friction packing. Replace gland and nut, and screw up hand tight.]

Two rings, one on top of the other, should not be used, and the single ring should be placed only on the top and not at the bottom of the stuffing box.

When repacking, the old ring should always be replaced by a new one.

If the automatic feed gets stiff at any time, unscrew the nut up to one sixth of a turn from hand tight, but not more than this, otherwise steam may enter under the packing and press it against the gland, which has the same effect as the gland packing being screwed too tightly.

Occasionally examine the automatic feed valve and its seating, to ensure that it does not leak when closed, and is in good condition.

If, while in reserve or for other reasons, the boiler will not be used for three months or more, the automatic feed spindles should be kept without packing in the glands.

Examination and Repair.—When a Belleville boiler is opened for partial examination the doors of top and bottom tubes of economisers and generators should be removed, and the boiler washed out by the fire main hose with a pressure of about 40 lbs. The doors of the three bottom generator tubes of each element should be removed, and the inside of these tubes cleaned with a wire brush. The holes in the coned nipples should be examined to see they are clear.

The feed collectors and mud drums should be opened and cleaned. The non-return valves in mud drums, and upper and lower connections between automatic float box and the element, should be examined to see they are clear and in good condition. Care should be taken that the pins of the non-return valves have not worn so that the valve is much lower than its original position, which may allow the valve to swing into the hole and remain there, thus partially choking the area for downflow of water.

The lower cover of the automatic feed float chamber should be removed and the chamber and connections cleared. The tubes between top of element and steam collector should be examined to see that each is clear, while the upper doors are removed for washing down.

Tube Junction-box Doors.—When closing these doors care should be taken that the spigot of the door is free in the hole and not binding in any place. Before screwing the nut on the bolt the threads of the latter should be covered with mineral grease mixed with finely powdered plumbago. Before placing a new asbestos ring on, the face of the door should be well cleaned by a scraper, and the ring placed dry on the door, the side of the ring, which makes the joint with the box, being coated with mineral grease mixed with finely powdered plumbago. The ring should fit tightly into the angle of the spigot. When doors are removed and the rings are serviceable, the face of the ring should be scraped to remove any roughness due to hardened grease, and coated with grease and plumbago as for new rings.

Nickel Rings on Feed Collector Cones.—The joints should be made with two nickel rings, one on top of the other, both rings being covered with mineral grease mixed with finely powdered plumbago.

The nickel rings should be of the same taper as the hole in the box, and not of the same taper as the nipple itself. To make the joint, raise the front of the element and insert a nickel ring *in the box*, place a small

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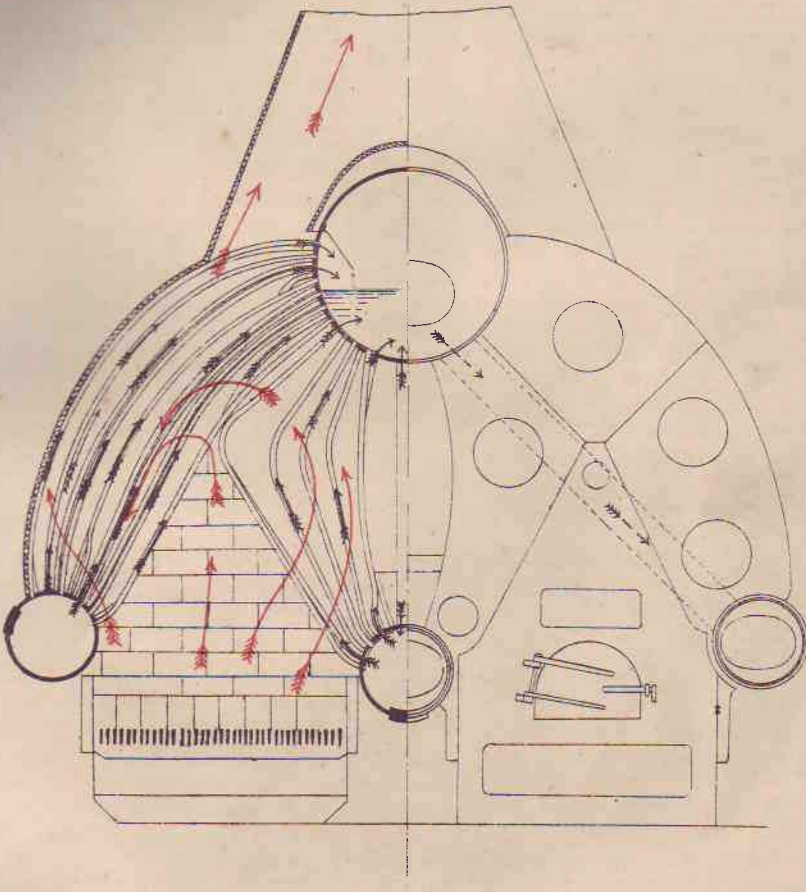

FIG. 11 — THORNYCROFT BOILER

⟶ direction of circulation of water

⟶ " " " " flames & gases.

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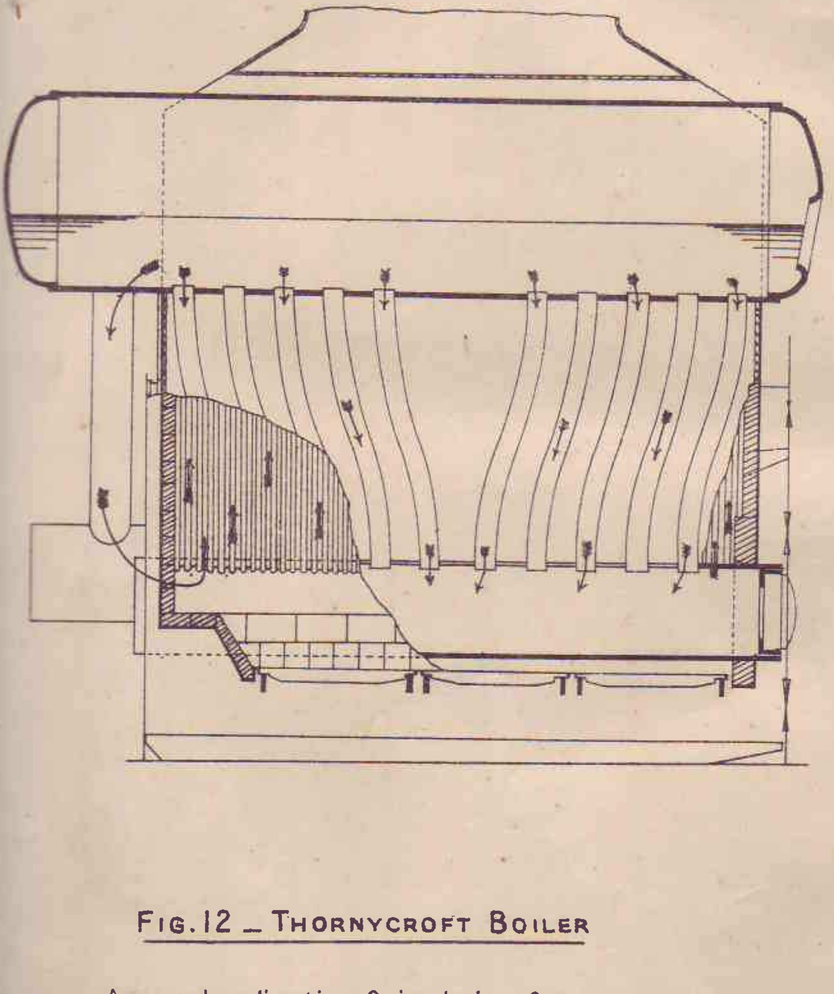

FIG. 12 _ THORNYCROFT BOILER

Arrows show direction of circulation of water.

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To follow Fig. 12.

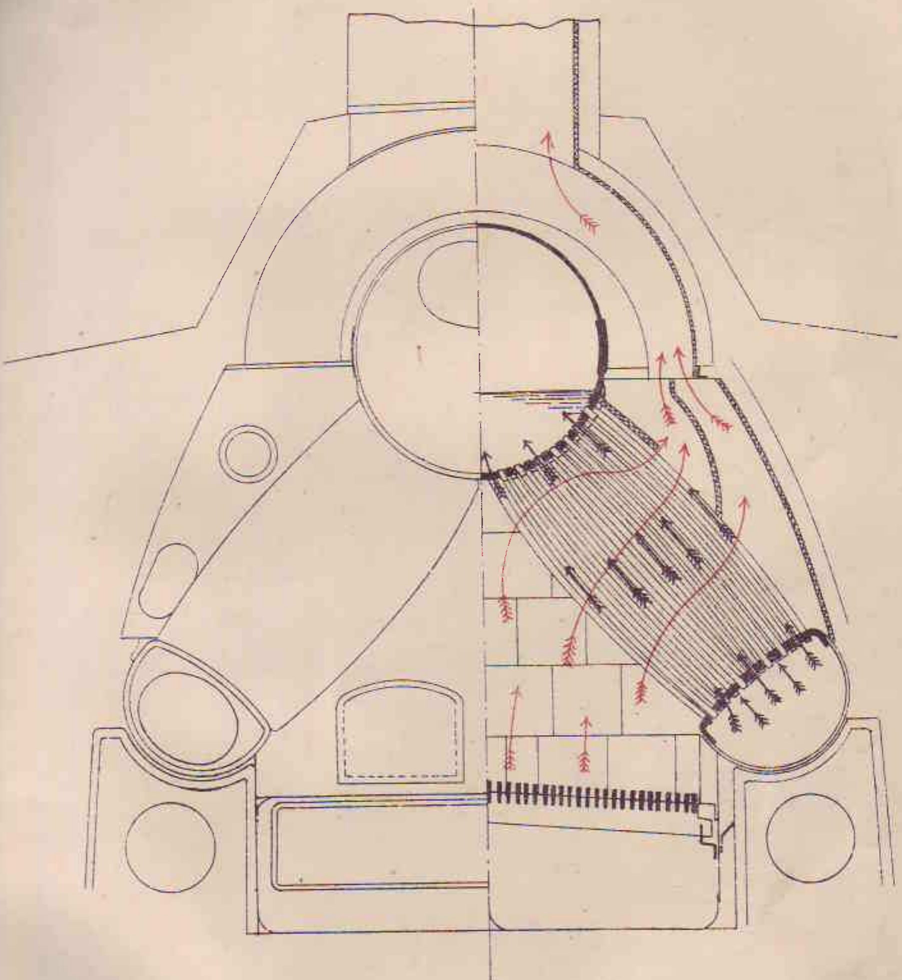

FIG. 13._ WHITE FORSTER BOILER

⟶ direction of circulation of water
⟶ " " " " flames & gases.

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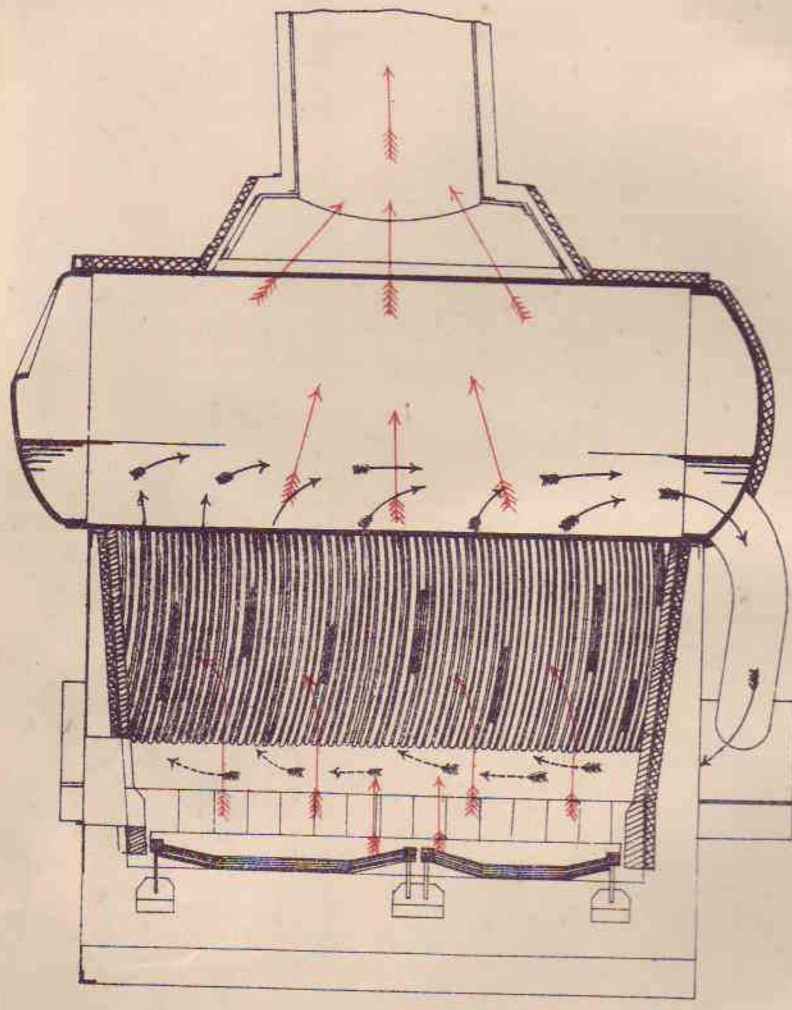

FIG. 14. WHITE FORSTER BOILER.

⟶ direction of circulation of water
⟶ " " " " flames & gases

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piece of plate iron on the top of the nipple in feed collector, lower the element on the plate which will drive the ring home; the element should then be lifted and the same process gone through for the second ring; after removing the plate the element should be lowered carefully on the feed collector cone, keeping the two parts exactly concentric. The anchor bolt is then placed in position and the nut screwed up tightly. It is important that nuts should not fit too tightly on the bolts, as it is sometimes necessary to tighten up the nuts when steam is first raised, especially if they have not been sufficiently screwed up when fitting the nickels.

Before attempting to tighten up an anchor bolt nut in a boiler under steam, a wedge should be driven in between the top junction box and the next below it to prevent any possibility of the element rising off the feed collector nipple, should the anchor bolt break.

The anchor bolts should be frequently examined and tested by hammering to ensure that they are in sound condition.

Zinc Bars in Economisers' Tubes.—Pieces of rolled zinc are to be placed in all the tubes of economisers; these zincs are to be bars of angle form, 4 ft. by $1\frac{1}{4}$ ins. by $1\frac{1}{4}$ ins. by $\frac{3}{16}$ ins. thick, and are to be placed in the tubes angle uppermost. Where supplies of zinc of the above dimensions are not obtainable, any available rolled zinc up to $\frac{1}{2}$ inch in thickness is to be cut up into strips and used as a temporary expedient. The tubes are to be cleaned before the insertion of the zincs. When, in the ordinary course on service, the economisers are open for examination and cleaning, the zincs are to be cleaned from dirt and grease.

Smoke-box and Furnace Doors.—Joints of the smoke-box and furnace doors should be kept in efficient air-tight condition, and it should be constantly observed that the bolts for securing them fit in their sockets and act efficiently.

Smoke Baffles.—It is important that these should be fixed in their proper position. There are two rows, upper and lower, the positions of which are denoted by rings on the tubes. These rings engage in a notch cut in a tongue piece fixed to each baffle, and thus prevent the baffles moving. To insert a baffle in proper position, lift the front box with a lever and wedge up the box until the baffle is in the correct position. The same process should be gone through when baffles are required to be withdrawn. When baffles and boxes are in proper position, it should not be possible to move the baffles except by exerting considerable force. These baffles should be seen to be in proper position before steam is raised and whenever the tubes have been cleaned externally by the brushes supplied.

Fusible Plugs.—Conical plugs of fusible metal are screwed into certain junction-boxes. When a fusible plug melts the noise of the escaping steam will be heard in the stokehold; the draught plates should be immediately shut and the furnace doors kept closed. The condition of the tubes should then be observed through the sight holes in the smoke-box doors, when, if any tubes are red-hot, shut off the feed by the hand feed valve, ease the safety valve and close the stop valve as soon as pressure is lower than in adjacent boilers, keeping the smoke-box, furnace, and ashpit doors closed until the tubes are cooled or there is but little pressure in the boilers. Unless this is done a rupture of a tube may result. If all tubes are black, indicating that they are not overheated, open the smoke-box doors and ascertain whether a jet of steam mixed with water is coming out of the plug hole, in which case a new plug can be inserted and the working of the boiler resumed. If the water does not emerge from the hole and the correct amount of water is in the glass, the cause of the obstruction in the water supply to that element should be ascertained before the boiler is again worked.

Manufacture of Plugs.—The plugs should be formed in the mould 1, Fig. 5, and pure lead only should be used in their manufacture. When removed from the mould, the plug should be trimmed as required, and then driven through the template, Fig. 5, 2, to ensure that it is of uniform and correct dimensions. The driver, Fig. 5, 3, is intended for this purpose.

Fitting Plugs in the first instance.—A hole should be drilled in the box with drill, Fig. 5, 4, which should not exceed $\frac{1}{8}$ inch in diameter. The hole should be rimered with taper rimer, Fig. 5, 5 (which has a taper rather steeper than that of the plug), until the taper gauge, Fig. 6, 6, can be inserted to the scribed mark on it. The hole should then be tapped with the tap, Fig. 6, 7 (which has a taper rather steeper than that of the rimer), until one or two complete threads are formed at the large end of the hole; there will then be partially cut threads, gradually diminishing in depth, in the remaining portion of the hole, up to the small end, where there should be an untapped portion for a distance of about twice the pitch of the thread. The tap should not be screwed in so far that the shoulder touches the box; the resistance offered by the tap will be a guide as to when sufficient threads have been cut. All traces of oil should be removed from the hole by screwing in a piece of soft wood; the hole will then be ready for the insertion of the plug. The plug should be inserted, and it should bear on the small or inner end of the hole only, if the plug and hole have been prepared as described in preceding paragraphs. The plug should then be forced in by light blows with a hammer by means of the tool, Fig. 6, 8, until about $\frac{1}{8}$ inch of the plug is left projecting. This projecting portion should then be riveted over by means of the small snap, Fig. 6, 9, and the point of the plug projecting inside the box should be bent over. If the plug does not project on the inside, a coating of deposit on the inside of the box may prevent the steam emerging from the hole when the plug melts.

Replacing Plugs (Boiler not in Use).—The threads in the hole should be cleaned by means of the tap, and care should be taken that oil is not used, and that additional threads are not cut. The hole should be thoroughly cleaned by screwing in a piece of soft wood.

The plug should be inserted in exactly the same manner, and with the same tools, as described above.

Replacing Plugs (Boiler in Use).—The plug should be inserted by means of the special tool, Fig. 6, 10, provided for use under steam. It will be sufficient if the plug is driven in so far that not more than $\frac{1}{8}$ inch is left projecting outside the box.

General.—If difficulty is experienced through plugs blowing out without apparent cause, after it has been ascertained that there is no obstruction or want of water, the existing holes and plugs should be

Fig. 5.

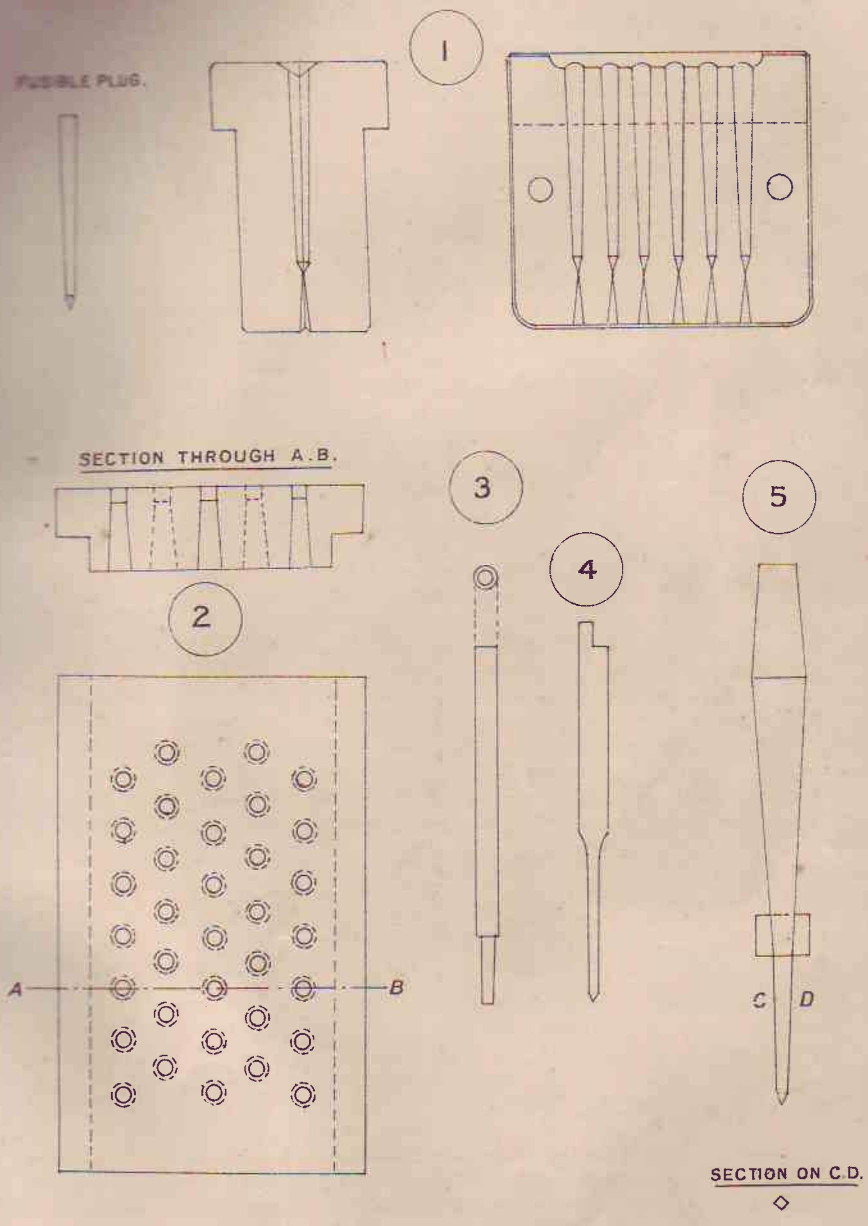

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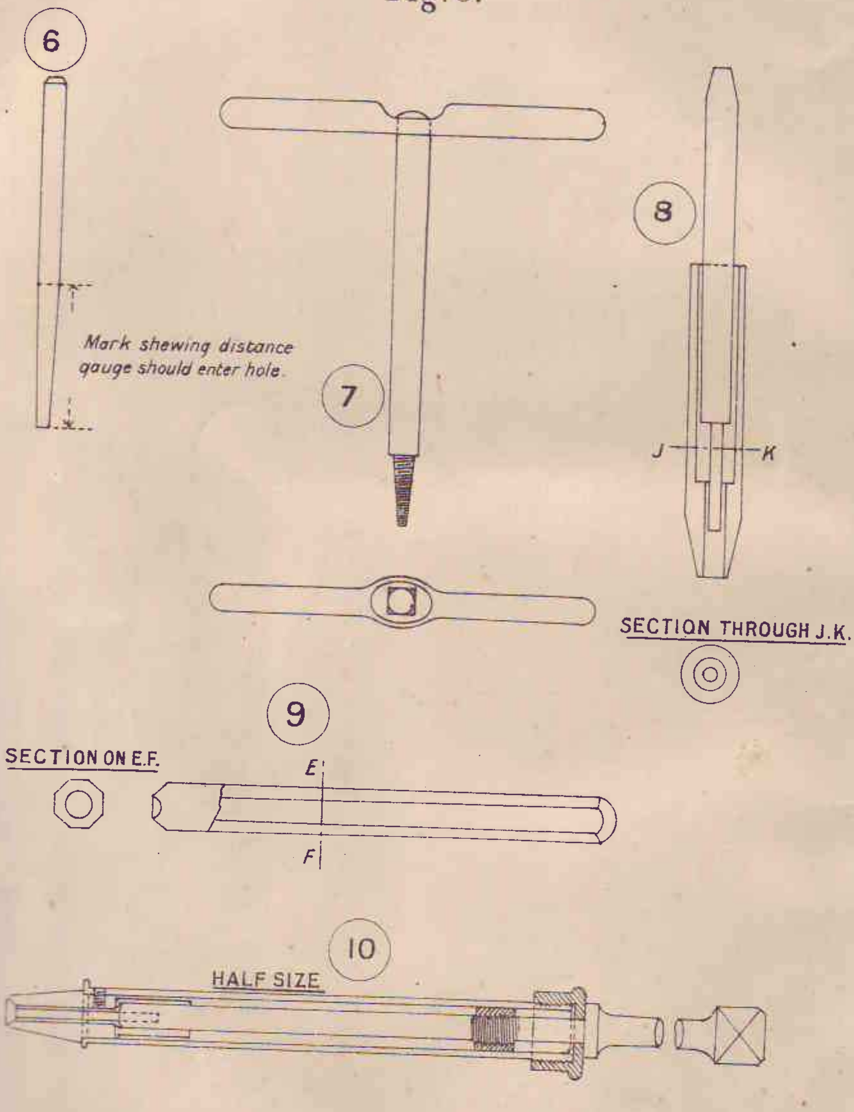
Fig. 6.



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To follow ***Fig. 6.***

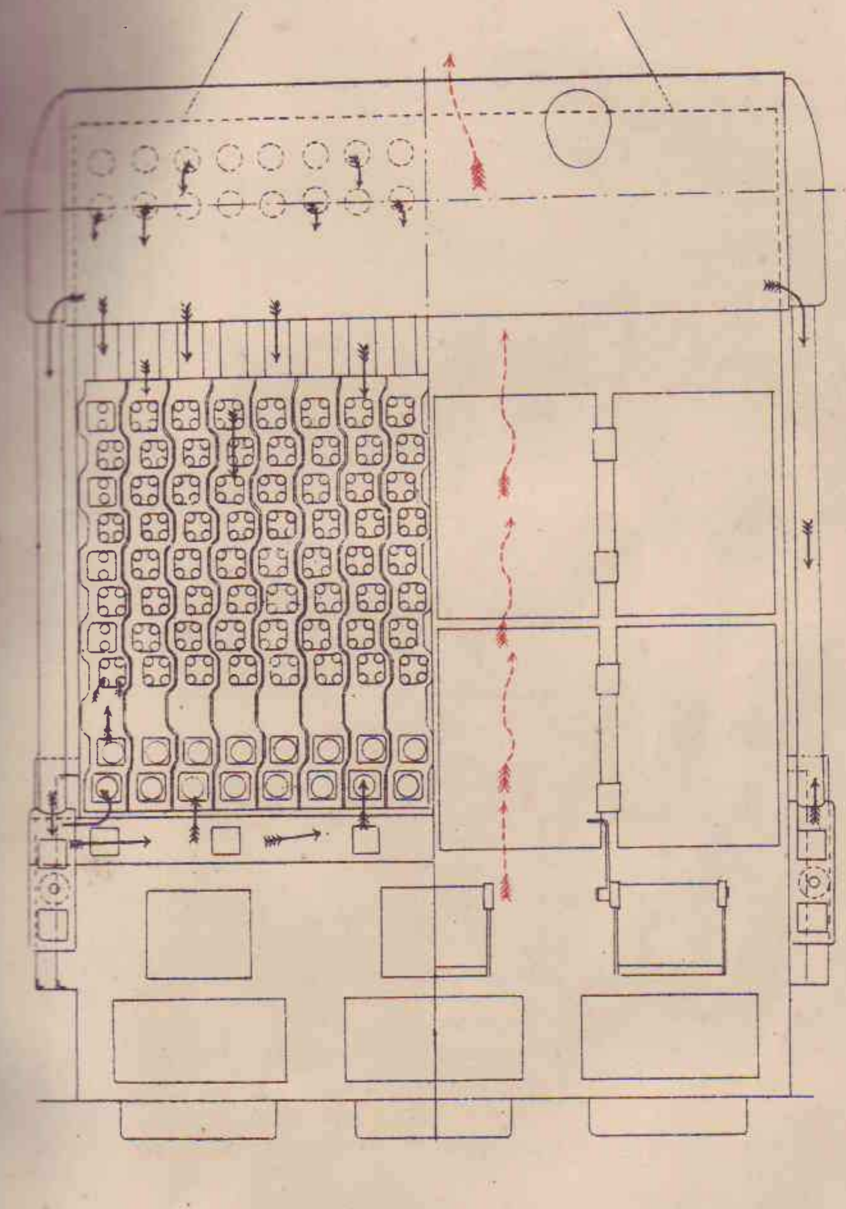

FIG. 7 — BABCOCK AND WILCOX BOILER.

→ direction of circulation of water
→ " " " " flames & gases

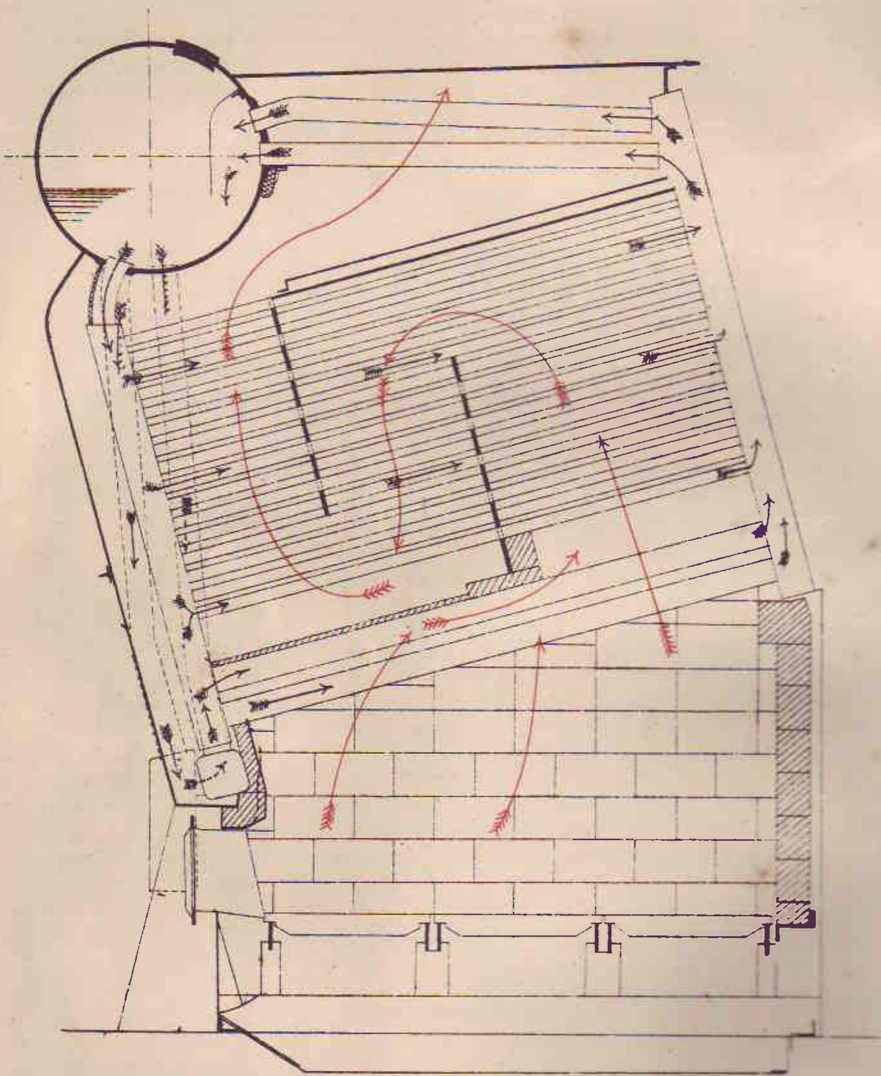

FIG. 8 _ BABCOCK AND WILCOX BOILER.

→ direction of circulation of water
→ " " " " flames & gases.

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[carefully examined and made to conform with the preceding instructions. Any incorrect holes should be screwed completely through and permanently closed by steel screws, and new plug holes made of the correct size.

In all cases where plugs have been replaced in boilers under steam, the holes should be examined and cleared, and new plugs fitted in the manner described above. This work should be done at the earliest subsequent opportunity when the boiler is not required for service.

All the tools and apparatus used should be accurately made to the proper standard sizes.]

Babcock and Wilcox Boiler, Figs. 7 and 8.—In this boiler the tubes forming the heating surface are attached to forged steel boxes or *headers* placed vertically in the boilers. A pair of headers with its connecting tubes form an element.

The front headers carry doors through which the tubes, which are placed in zig-zag rows, may be either cleaned or renewed when necessary.

The rows of tubes just above the fire and connecting the bottoms of the headers are of larger diameter than the others; these tubes are placed one above the other in the headers, the smaller ones above are placed in pairs side by side.

The vertical rows of tubes are staggered to make sure that the gas passes over all the tubes, and the headers are similarly bent.

Each tube communicates directly with the front and back header, and when the elements are in position in the boiler the tubes lie at an angle of about 15° with the horizontal.

Each front header is connected at the bottom with the feed collector, which here, as in the Belleville boiler, is a square tube running across the boiler above the furnace doors and at the top with the bottom of the steam collector.

Each back header is connected at the top with the steam space of the steam collector by two large tubes. The ends of the steam collector, as in the Belleville boiler, communicate with downcomers which lead into mud drums, and the water from these returns to the feed collector before going again to the tubes. The direction of circulation of the water in this boiler somewhat resembles that in the Belleville boiler, but in the Babcock and Wilcox boiler there is a definite water level, which is maintained in the steam collector, and each tube is connected to the headers of its element.

The furnace arrangements are similar to those of the Belleville boiler, and as regards casings it is to be observed that the headers are placed side by side, forming an airtight wall front and back, between which the flames from the furnace are directed by baffles over the whole of the tube surface.

[*Removal of Tubes.*—A bottom tube can be taken out by cutting a groove in each end with a cross-cut chisel and afterwards removing the tube by means of a draw bar, or by cutting completely through each end of the tube by means of a special internal cutter and afterwards removing the two end pieces by cutting through with a cross-cut chisel.

Whenever the chisel is used, care should be taken not to damage the tube seats.

Should it become necessary to remove an upper tube, this can be easily done by closing the ends with a cupping and withdrawing tool] supplied for that purpose, and at the same time driving the tube out. This operation does not necessitate cutting the tube in any way, and can be carried out very quickly.

Handhole and Manhole Doors.—These doors are jointed with wire woven asbestos rings which should be blackleaded on one side only, *i.e.*, the side next the header. The surfaces of the headers should be cleaned before the manhole doors are put on.

Casing Doors.—Special care should be taken that these doors fit well on their framing, and that the catches for securing them act efficiently, also that the asbestos packing between the headers is in good condition, thus preventing any excess of cold air entering the boiler and causing a loss of draught and efficiency.

Yarrow Boiler, Figs. 9 and 10.—The steam drum runs the whole length of the boiler above the centre of the fire-grate and extends beyond it at the front and back; at each side of the fire-grate there is a water drum.

The bottom plate of the steam drum (*top tube plate*) is connected to the top plate of the water drum (*bottom tube plate*) on each side of the boiler by the generating tubes which are straight, except that the rows nearest the fire are bent slightly to it.

At the front end of the drum outside the boiler casing are two large downcomer tubes connecting the steam drums with the water drums.

The feed water in earlier Yarrow boilers is led into the steam drum, and the water circulates down the downcomers to the bottom drums, rising through the generating tubes to the top drum again.

In some recent Yarrow boilers the feed water is led into the outer sides of the bottom drums, which have a space opposite the two rows of tubes furthest away from the fire baffled off from the rest of the drum. The internal feed pipes are in the space so partitioned off.

The whole of the boiler, except the ends of the drums which project, is surrounded by a casing, which is brick-lined and lagged as necessary.

The furnace doors, fire-grates, and ash pans are arranged as usual. The gases from the fire are burned in the space above it, mixing with air admitted through a tube in the back casing, and they pass through the tubes on either side reaching the division of the uptake.

The White-Forster Boiler, Figs. 13 and 14, has the same general arrangement of parts as the Yarrow boiler. Its distinctive feature is that its tubes are curved in the direction of the length of the drum. The curvature given to the tubes is such that any tube may be drawn out of place into the top drum, and a new tube may be put in to replace it without disturbing the others.

The Thornycroft Boiler of the "*Speedy*" type resembles the Yarrow and White-Forster boilers in the arrangement of its steam and water drums and downcomers, but its generating tubes are very much bent, in some instance entering the top of the steam drum after having met below it over the fire.

The "*Daring*" type fitted in torpedo-boat destroyers has a water drum vertically under the steam drum. Two smaller water drums are arranged at the sides, the fire-grates being between these and the larger central one. Curved tubes of small diameter connect all the lower

To face page 14

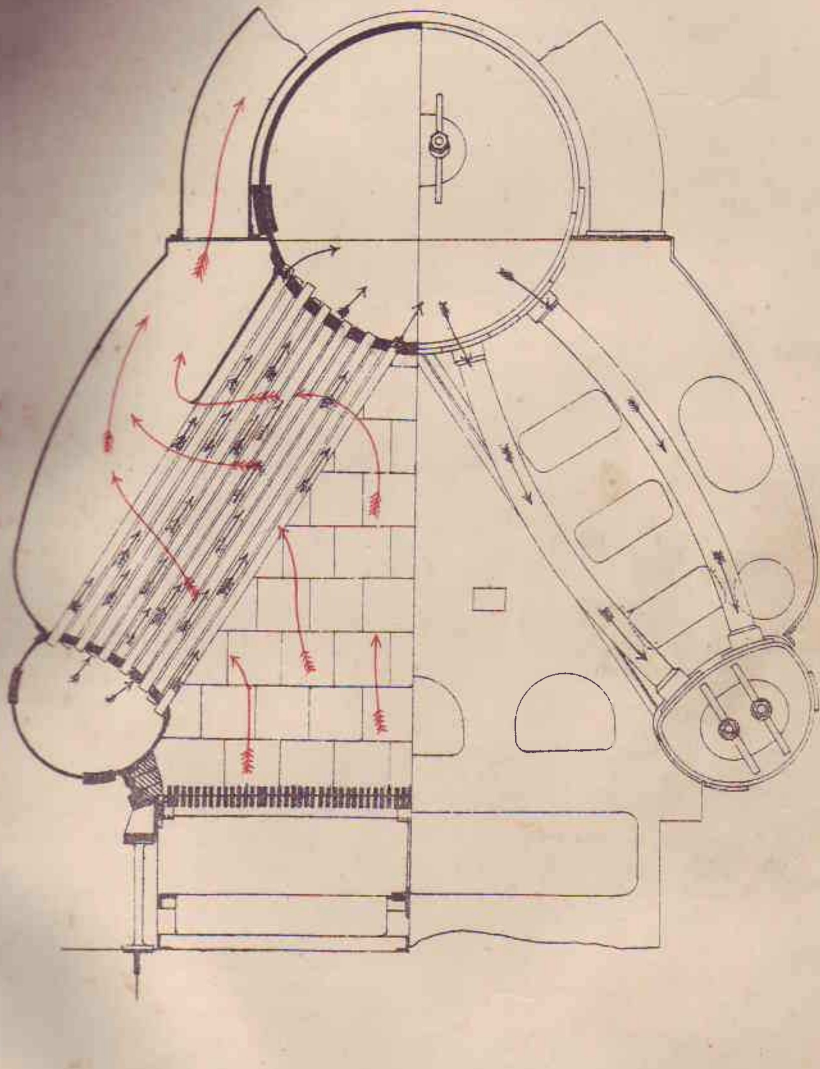

Fig. 9. Yarrow Boiler.


direction of circulation of water

" " " " Flames & gases.

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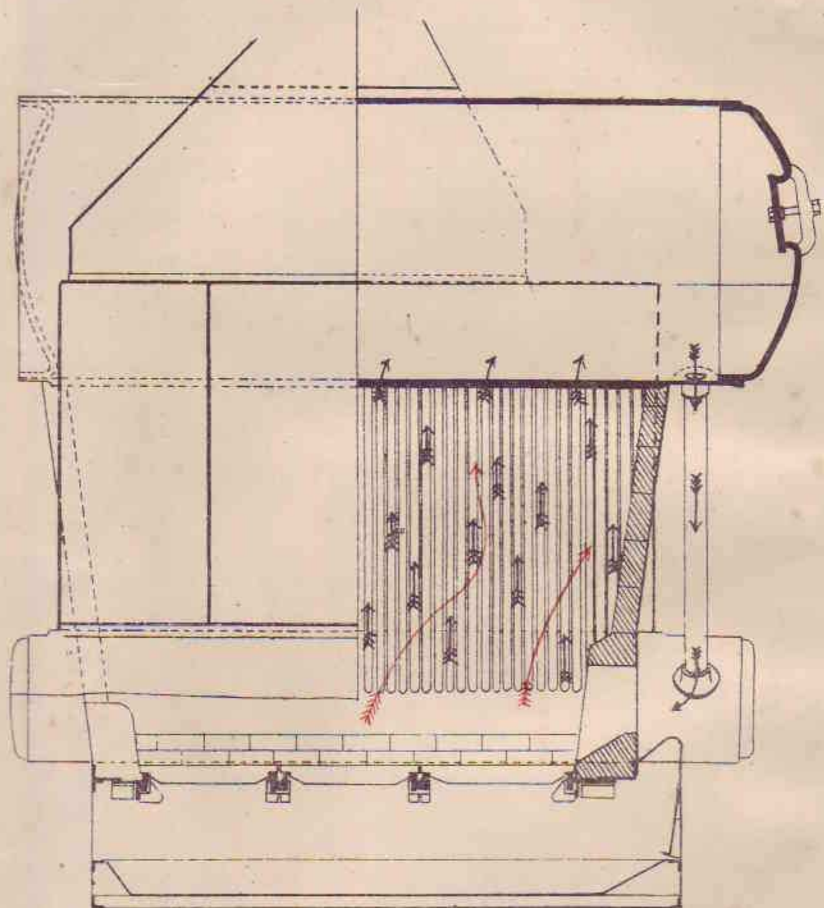

FIG. 10. YARROW BOILER

→ direction of circulation of water

→ " " " " flames & gases

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drums to the steam drum, and the outer water drums are connected to the steam drum by a downcomer at the end similar to that fitted with other types of small tube boiler, while the centre drum is supplied by a series of large tubes. The general arrangement of this type is shown in Figs. 11 and 12, and it will be seen that the small tubes project considerably over the fire-grate, ensuring that the gases from the fire sweep over the whole of the tube surface.

The REED BOILER is somewhat similar in general arrangement to the Thornycroft boiler of the Speedy type, but the tubes enter the drum at the bottom, and they are secured in the tube plates by having their ends reduced in diameter and screwed and tightened up by brass nuts.

The MUMFORD BOILER used in steamboats has the same arrangement of drums, but its tubes curve inwards towards the fire and are withdrawn through doors at the sides of the bottom drums.

One end of the top drum is closed by a large removable door which carries nearly all the boiler mountings.

CHAPTER III.

Fuel and its Stowage.

Coal appears to be solid, but in all kinds of coal combustible gas is present with the solid portions.

The quantity of gas varies in different kinds of coal. In any coal it is greatest when the coal has just been brought from the pit; a part of it escapes from the coal from time to time, some of it being liberated whenever the coal is either broken up or heated.

The process of making gas for lighting illustrates the way in which gás escapes from the solid portion of the coal when it is heated.

Coal used for making gas is placed in a retort closed to air, but communicating by pipes with a gasholder.

The retorts are heated by fires under them; as there is no air in the retort no combustion takes place, and the gas driven off from the coal goes to the gasholder, leaving the solid portion of the coal behind; when all the gas has been driven off, the coke, as the solid part of the coal is called, is drawn from the retort. Both this coke and the gas made may be burned when air is present.

When coal is thrown into the furnace of a boiler the gas is driven off. The solid portion on the fire-bars is burned with air coming up through the air spaces between them, and, as explained in Chapters I. and II., air is admitted above the fire to burn the gas.

To get as much heat as possible out of the coal the gases which result from the burning of both the solid and gaseous parts of the coal must be thoroughly burned before they leave the combustion space.

Besides entailing a loss of heat, their incomplete combustion will either lead to smoke or a tendency to flame at the funnel.

Complete combustion of the solid part on the fire-grate is effected by keeping the fire thin enough for the gas formed by the burning of the coal with the air coming from the ashpit to be thoroughly burned when it escapes from the top of the fire; if the fire is too thick the air will only be sufficient for this part of the way through the fire, and for the rest of the way more coal will be taken up, and the gases when they escape from the top of the fire will need more air to burn them thoroughly.

As regards the complete combustion of the gases given off by the coal; in an ordinary open fire where there is a free supply of air the whole of the gas is not burned as it escapes from the coal and some escapes as smoke, the reason being that the temperature is not high enough for combustion.

The air admitted above the fire in a boiler and the gas escaping from the coal directly after it has been placed on the fire are both cold, and it is to heat these to the proper temperature that the combustion chamber or space above the fire is provided; these cold gases mix there with burned gases which are already hot and rise to the necessary temperature for combustion.

The brickwork in the combustion spaces of all boilers heats gases striking it, and in the circular boiler the brick bridge is arranged with a view of mixing the gases as they pass it; in some of the water-tube boilers the air supplied above the fire is squirted into the combustion space in jets, tending to facilitate the mixing of the gases.

To burn the gases completely we must have sufficient air, but too great an excess leads, as in the case of the open fire, to such a fall in the temperature in the combustion space above the fire that the gases do not burn, and smoke is produced; this happens if the furnace door is kept open too long while firing, and also when the firing is allowed to burn into holes.

These effects are increased with forced draught, and when boilers are being forced the furnace doors should be closed after each shovelful of coal is placed on the fire, and the greatest care should be taken to avoid holes.

The gas contained in the coal is given off most freely directly the coal is thrown on the fire, and if too much coal is put on at a time in one furnace more gas is evolved than can be dealt with there; for this reason, as well as for the sake of not introducing too much cold air at any time, the coal should be put on in small quantities and often.

Different kinds of coal vary very considerably in the quantity of gas they contain.

Bituminous coal contains a great quantity. The cannel coal used for making gas may often be lit with a match.

The other extreme in composition is anthracite coal; some American coal contain little or no gas, and like coke require a fierce draught to burn them.

Neither of these coals is suitable for use in ships' boilers. Such a coal as cannel coal could not be burned without excessive waste and smoke, and anthracite coal would give very little steam when burned in boilers of ordinary size.

The most suitable coal for naval purposes is Welsh, which is a semi-anthracite coal, and in consequence not liable to produce heavy smoke.

North-country coal is sometimes used, being semi-bituminous; there is more trouble in avoiding smoke when burning it.

Stowage of Coal. Ventilation.—When coal is stored precautions must be taken to prevent gas which may escape from it remaining in the storage place with the liability of forming an explosive mixture with air.

For this reason bunkers are fitted with ventilating pipes, and in the few instances where these permanent fittings cannot be fitted it is necessary to remove the bunker lids periodically to allow the necessary ventilation.

If coal becomes damp before it is stored there is an increased tendency for the liberation of gas, and for this reason coaling with wet coal is avoided, and care is taken that no water shall get into the bunkers.

Before coaling commences the coal remaining in the bunkers should be trimmed as far as practicable near the bunker doors to prevent quantities of coal from remaining in the bunkers for an indefinite period.

The ventilating pipes to bunkers are to be kept clear. These pipes will be cleared by the Dockyard by compressed air every year. The louvres fitted to their ends should always be locked open, except when forced draught is being used in the stokeholds.

To clear the bunker ventilation pipes the stokeholds may be put under forced draught immediately before the coaling and the pipes blown through; when coal bunkers are not fitted with permanent ventilating fittings the lids are to be taken off four times a week, and kept off for not less than three hours each time. The bunkers should be thoroughly ventilated before men enter them to work.

For the proper veutilation of a bunker there must be an inlet for fresh air as well as an outlet at or near the top for the foul, and when the permanent fittings do not include these, it will be necessary to remove bunker lids as stated above.

The formation of gas in a bunker is most rapid during and for some days after coaling, because the gas escapes as the coal is broken up by being handled.

Directly after coaling is completed or when it is finished for the night, it should be seen that the bunker ventilation is in good order.

The temperature in coal bunkers and in oil-fuel compartments is to be ascertained every four hours when under steam, and once in every 24 hours when not under steam, except when the temperature is found to be increasing, when it is to be obtained as often as considered necessary.

The coal stowage in the bunkers should be limited to the height of the lower edge of the beams, the preservation of a vacant space for ventilation over the whole surface being thus secured.

The contents of the bunkers are calculated on this basis.

Whenever the door of a coal bunker is opened the air in it should be tested for explosive gas, as described in Chap. XI., by means of a safety lamp before any naked lights are taken into it.

The portable electric lamp, fitted in bunkers, when not in use, is to be hooked up inside the box, switched to "off" and the box closed. Care should be taken that lamp is not left where it can be covered by coal. If, by any accident, the lamps or circuits are buried so that they cannot be cleared, the holders should be disconnected from the socket, the box closed and cut-outs removed from the feeding distribution box.

The good condition of the leads and connections of the portable electric lamps used in or near bunkers should be ascertained. Leads or lamps liable to sparking should not be used.

Scale on Measurement.—Whenever surveys are held on the remains of coal ashore or afloat, the following scale of measurement is to be adopted, viz.:—

One ton of Welsh coal, 40 cubic feet.

One ton of North country coal, 43 cubic feet.

One ton of patent fuel, 36 cubic feet when systematically stacked on shore or in rectangular spaces on board.

One ton of patent fuel, 45 cubic feet when shot into bunkers.

One ton of Westport (New Zealand) coal, $44\frac{1}{2}$ cubic feet.

Quantity in Ship.—This scale is also to be used to measure the weight of coal in bunkers and holds of ships. By making suitable marks for definite quantities on the bunker sides there will be no difficulty in ascertaining, at any time, the approximate quantity of coal in the bunkers, and they are to be frequently examined to verify the amount of charge.

The capacity marked by Dockyard on each bunker is calculated at 43 cubic feet per ton.

Precautions in bunkers when coaling.—In coaling, if it should be desired to keep the cover of the escape scuttle in place, it should be left in the unlocked position, and the grating removed so as to facilitate escape from the bunker in the event of necessity arising.

Oil Fuel.—In spite of the difference in form oil contains the same heat-producing elements as coal, and modern ships are fitted with arrangements for burning oil fuel either by itself or with coal.

The advantages of oil fuel are:—

1. Superior evaporation, one ton of oil fuel being equivalent to 1·4 tons of coal.
2. Much cleaner to burn, there being no coal dust, ash, or clinker.
3. Much less labour required in the stokehold.
4. Much less labour required to fill compartments with oil fuel than to coal ship.

The oil fuel is generally stowed in the double bottoms under the engines and boilers. These compartments are provided with filling pipes leading to the ship's side for taking oil fuel on board; with air pipes leading to the upper deck for ventilation; and with sounding tubes for finding the depth of the oil.

The oil is pumped from these compartments and delivered under pressure through heaters to the burners which discharge it in the form of a fine spray through short steel tubes into the furnace.

These steel tubes are generally called "air cones," they are slightly conical in shape and are fixed in the boiler front so that air can pass through them from the stokehold into the furnace along with the sprayed oil.

Filters are always fitted between the oil pump and the burners to extract any particles of solid matter that may be contained in the oil fuel.

When coal is used as well as oil, the air cones with their burners are placed above the fire-bars and the oil is burnt over the coal.

In this case the coal should not be allowed to pile up in front of the air cones, as this will obstruct the passage of air through the cones and cause them and the furnace fronts to get too hot.

The cones should also be cleared from the deposit which is formed in them by the burning of the oil, and special tools are supplied for this purpose.

Smoke windows are fitted in the uptakes of boilers so that the presence of smoke can be seen from the stokehold. These windows consist of small panes of glass fitted on opposite sides of the uptake, and a light is placed in the stokehold in line with them. Should there be smoke, the light as seen through the opposite window will be obscured. A small mirror is fixed in the stokehold opposite the window farthest from the light and inclined so that smoke observations can be made from the platform. Close attention should be paid to these windows to discover whether undue smoke is being made, this being an indication that something is wrong with the firing or air supply.

In ships fitted with oil-burning arrangements and arrangements for discharging oil fuel through the common filling pipe by means of the oil-fuel pump, the pressure at the pump is to be limited to 40 lbs. per square inch when using this discharge, by adjusting the pump relief valve.

The outputs of the sprayers fitted to the same boilers are in some cases different in different positions with regard to the furnaces. When sprayers of different pattern are fitted to the same boiler, care is to be taken that the correct sprayers are used in their respective air cones.

The steam side of the heaters not in use should be kept dry, the drains left open to the bilge, and any drainage frequently observed in order to detect leakage of oil.

Where oil-fuel pipes are subject to the heat of stokeholds or steam-pipes, valves should be opened as necessary for preventing pressure arising from expansion of the oil.

Pressure gauges fitted in the oil-fuel system should generally be left uncovered to enable any pressure to be observed.

Oil-fuel Compartments.—The oil-fuel compartments are provided with permanent air-pipes, and naked lights are not to be brought into the vicinity of their outlet ends.

Only portable electric lights or safety-lamps are to be used in oil-fuel compartments, and these compartments are only to be opened in the presence of an Engineer officer. It should be ascertained that the electric leads and connections of the portable lamps in use are in good condition, and that no sparking is likely to occur.

Locks or special spanners are provided for securing valves and manhole doors of these compartments. The Engineer officer is to be responsible for the safe custody of the keys and spanners.

It should be noted that a great difference exists in the ventilation of oil-fuel compartments and that of ordinary coal bunkers. In the latter case the gases produced are generally lighter than air, and are consequently dissipated by a supply of fresh air over the top of the coal, with an outlet at the top. The vapours, however, in oil-fuel compartments are heavier than air, and are not displaced by ordinary ventilation.

Before any compartments which have contained oil-fuel are entered, they are to be cleared of oil as far as practicable by the oil-fuel pumps, and are then to be pumped dry by the hand residue pump. To expel any foul air or gases, and to assist in clearing out the residue, the compartments are then to be filled with sea water from the fire-main through the oil-filling pipes. Care is to be taken that the compartments are quite full by observing the head of water at the funnel break in the filling-pipe, water being run in until the level remains constant at the funnel break. The compartments are then to be pumped out as dry as possible, and the operation to be repeated, if considered necessary.

In addition, the instructions as to testing the air before entering contained in Chap. XI. are to be strictly observed.

CHAPTER IV.

BOILER MOUNTINGS.

The following are the mountings fitted on a boiler, with the use of each :—

Main Stop Valve.—This valve is fitted on the top of the boiler, and controls the passage of the steam from the boiler to the main steam pipe and so to the main engines.

Experience has shown that it is necessary to make these valves self-closing or non-return where two or more boilers are connected. If they were not so made, in case of damage to a boiler allowing the steam to escape, the steam from the other boilers in use would pass back through the stop-valve into the damaged boiler.

Fig. 15 shows a section of an automatic self-closing valve. A is the valve box, having a seating for the valve formed at B. The valve C is rigidly attached to the spindle D, which passes through the sleeve E, but is not attached to it. The sleeve E is screwed through the bridge F and has a hand wheel G attached. If this hand wheel is turned in the required direction the sleeve E will be drawn out through the bridge, and this will allow the spindle D to follow it, thus opening the valve. When the hand wheel is screwed in the other direction the sleeve will move inwards, pushing the valve in and closing it. It will be seen that this valve can be closed or the degree of opening regulated, but that working the hand wheel does not actually open the valve, which must be done either by the pressure in the boiler pushing it open or by pulling on the end of the spindle D.

Automatic Action.—Supposing the valve to be open and steam passing through it to the engines. If from any cause a boiler should be so damaged as to allow the water and steam to escape, so as to lower the pressure in the damaged boiler, the steam in the other boilers in use would tend to pass through the valve into the damaged boiler. The rush of steam and fall of pressure below the valve would, however, force the valve down on its seating and prevent any further escape of steam into the damaged boiler.

Since the automatic closing of the valve depends solely on the backward rush of steam through it, it is important that the gland K should be carefully packed so as to allow the spindle to move easily, and the valve should not be opened wider than necessary.

Automatic stop valves are always fitted with the valve spindles horizontal. Care must be taken on opening one of these valves that when the bush E is screwed back the valve spindle follows it, as otherwise the valve may be blown out violently by the pressure in the boiler. A V-shaped piece of brass or steel is often inserted between the wheel and T handle when opening the valve, so that as the wheel is unscrewed the spindle follows. This V-shaped piece must be removed after the valve is open, as otherwise the valve will not be free to close itself on emergency.

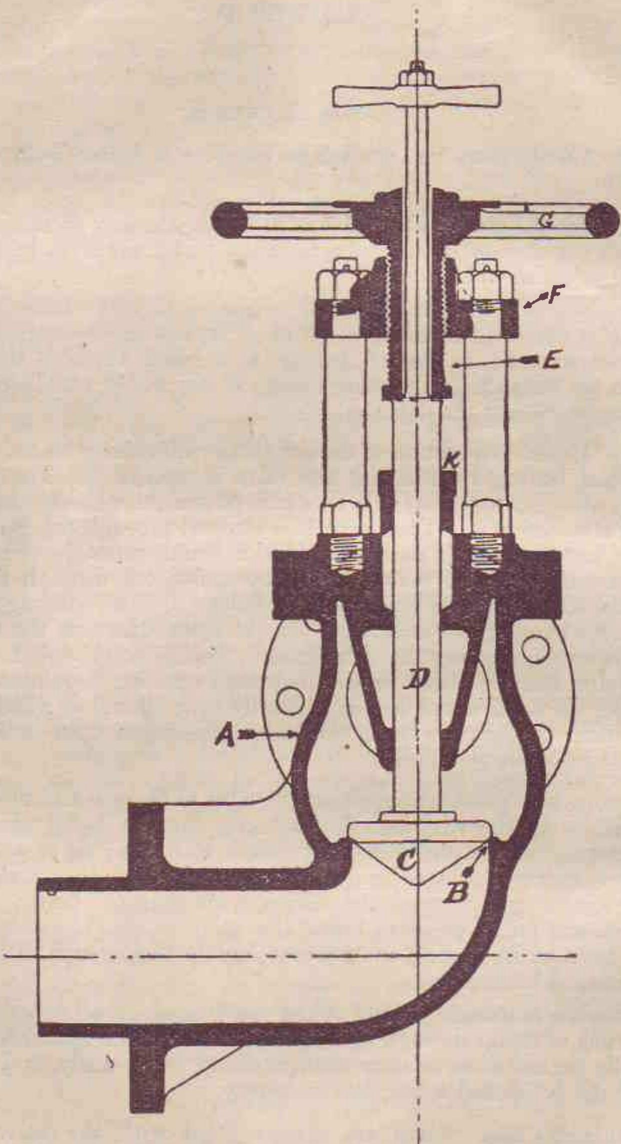


FIG. 15.—SELF-CLOSING STOP VALVE.

In an ordinary stop valve (not self-closing) the spindle D is in one with the bush E, so that on turning the hand wheel in one direction the valve is pulled off its seating, and cannot be shut without revolving the hand wheel in the opposite direction.

Stop valves are fitted in any position where it is desired to control the passage of steam, water, &c.

It is important to remember that stop valves are usually shut with a right-handed motion. By right-handed motion is meant the direction in which the hands of a clock go round, so that if the wheel of a stop valve is turned in this direction the valve is being shut, and if in the opposite direction it is being opened. Fig. 16.

Nearly all valves are shut by moving their wheels in this direction, and all nuts and bolts (except a very few left-handed ones) are screwed up by moving the spanner in the same direction as the hands of a clock move. This direction is often spoken of as "with the sun," because the hands of a watch or clock move in the same direction as the sun appears to.

Recollect that "shut," "screw-up," and "sun," all commence with "S."

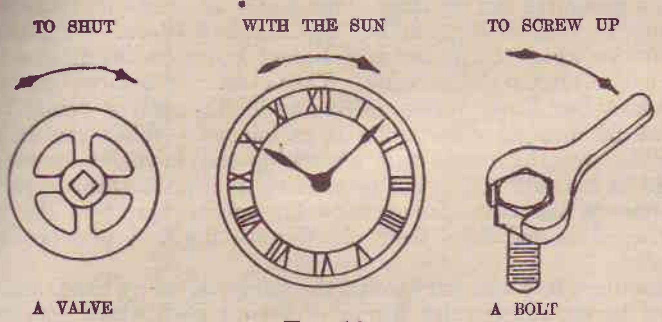


FIG. 16.

Auxiliary Stop Valve.—This is a valve smaller than the main stop valve, but similar in construction and action. Like the main stop valve, it is fitted on the top of the boiler, and its purpose is to control the passage of steam from the boiler to the auxiliary steam pipe and so to the auxiliary engines.

Internal Steam Pipe.—When a boiler is being forced the water inside is in a state of violent agitation, particles of water are carried up with the steam into the steam space, and if precautions are not taken this water may pass out of the boiler with the steam through the stop valve into the steam pipes.

The presence of water with the steam when it reaches the engines is objectionable, and in addition this action may cause the boiler to become short of water.

The passage of water with the steam into the steam pipes is known as priming, and to prevent it an internal steam pipe is fitted. This consists of a pipe with a large number of slots cut in the top and a drain hole in the bottom, closed at one end and at the other end attached to the stop valve.

The steam before leaving the boiler has to pass through these slots into the internal steam pipe, and it is found that this has the effect of causing most of the water contained in the steam to be left behind. In water-tube boilers an arrangement of baffles often takes the place of the internal steam pipe.

Cocks.—These are fitted for various purposes instead of stop valves, when found more convenient.

A cock consists of a casting called the shell, in which is fitted the plug, which has a passage through it and is capable of being turned round as required. The top of the plug in a straight-through cock is marked by a groove across it in exactly the same direction as the passage through the plug. Where the cock has passages at right angles, grooves on top of the plug indicate them, so that it can at once be seen whether the cock is open or shut. Suppose the cock is connected with a pipe, then if the groove on the top of the plug is in the same direction as the run of the pipe it is known that the cock is open, and if the groove stands across the cock is shut. The handles for working cocks are, as a rule, fitted in line with the groove, but in case of handles that can be removed the groove alone should be trusted.

Safety Valves.—Every boiler is designed to stand a certain working or load pressure; for instance, one boiler is made to stand 20 lbs. pressure, another 50 lbs., another 300 lbs., and so on. To prevent the pressure for which the boiler is designed being exceeded, safety valves are fitted on the top of the boiler. They consist of a valve box with two and sometimes three valves fitted inside, the valves being kept in position by springs. The action is as follows:—When the steam rises above the working pressure it pushes up the valves, compressing the springs on top, and the steam escapes up the waste steam pipe; when the pressure has again fallen below the working pressure the springs close the valves and keep them closed until the load pressure is again reached.

Sometimes it is necessary to lift the safety valves by hand, and this is effected by the safety valve lifting or easing gear, which consists of a system of rods and levers fitted to be worked either from the stokehold or deck above. This gear should be worked periodically to make certain everything is free, but care should be taken it should not be moved enough to lift the valves from the seatings unless it is desired to do so.

Main Feed Valve.—As the water by the application of heat is converted into steam and leaves the boiler, more water must be provided to make up the loss, and this is supplied to the boiler through the feed valves by means of the feed pumps. Feed valves are non-return valves and are fitted with screwed spindle and wheel or handle so as to be accurately adjusted to allow the correct amount of water to pass.

Main feed-valves are fitted on the right-hand side looking at the boiler, probably because most men, being right-handed, use things on their right-hand side more readily than those on their left.

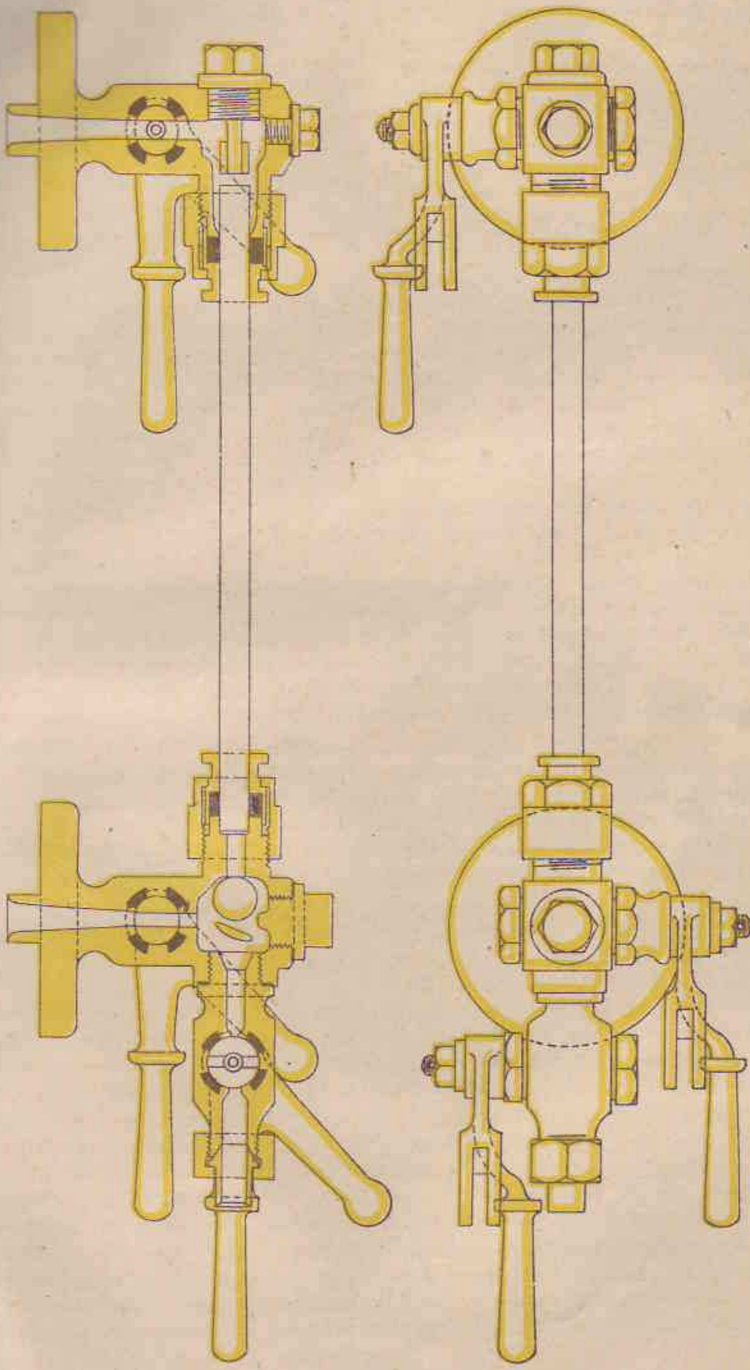
Auxiliary Feed Valve.—This is another valve similar to the main feed valve, but the water is pumped through it into the boiler by the auxiliary feed pump instead of by the main feed pump, and is fitted in case the main feed pump should be not at work or out of order.

Water Gauges are fitted to show the height of water in the boiler. In tank boilers the highest part of the heating surface must be always covered with water, and the position of the water gauge on the boiler is fixed so that when water can just be seen in the bottom of the glass the highest part of the heating surface, when the ship is on an even keel, is covered by three or four inches of water, the usual working level being about six inches above this or about half-way up the gauge glass.

In water-tube boilers the level of the glass is such that half glass is about the desired working level in the boiler. In any water gauge the

To face page 24.

Fig. 17.



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WATER GAUGE.

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disappearance of water from the lower part of the gauge shows that the feeding of the boiler is insufficient, and there is possibility of accident through shortness of water.

The water gauge mounting (Fig. 17) consists of two brass castings. They are connected by a strong tube of glass, sometimes placed directly on the shell of the boilers, one being fitted to the steam and one to the water space, but more usually mounted on a steady pipe, which is a gun-metal cast pipe about two inches in bore communicating with the steam space and the water space of the boiler.

Cocks are fitted in these castings to shut them off from the boiler, the cock in the upper casting being known as the steam cock and that in the lower as the water cock. A second cock, known as the drain cock, is fitted in the lower casting to allow of the glass being drained. In the working position, the steam and water cocks are open and the drain cock closed, the handles in all being up and down, which is contrary to the rule described on page 24 of this chapter. In this case, if the handles were in the usual positions their weight would tend to close the cocks if the glands were slack and there were either considerable vibration or motion of the ship. The height of the water in the glass then shows the height of water in the boiler.

A screwed plug is fitted in front of the steam and water cocks, the removal of which allows of a wire being passed through, in case either cock is choked.

Two water gauges are always fitted to each boiler, one on either side, so that in case one gauge is out of order there is another to work by.

The top and bottom castings of the gauge mountings are always made suitable for glass tubes, but water-level indicators are often used instead in modern boilers. These are gun-metal castings formed at the end into short tubes which fit the gauge mountings. The level of the water inside is seen through glass windows.

Air Cocks.—When it is necessary to empty a boiler, some means must be provided to let in air to take the place of the water, or when filling a boiler with water the air in it must be allowed to escape. This is provided for by the air cock, which is fitted at the highest part of the boiler, thus allowing the boiler to be pumped quite full of water.

Test Cocks.—To provide for the possibility of both water gauges being out of order at the same time, two or sometimes three cocks, known as test cocks, are fitted in tank boilers to test the height of the water. When two are fitted, one is about four inches above the working water level and the other about four inches below the working water level; and when there are three, two are placed in these positions and one at the working water level. Suppose the water at the correct height, then on the bottom test cock being opened water would flow out, from the middle cock steam and water, and from the top cock steam. When using the test cocks always try the bottom cock first; then if only water flows from it, it is known that the heating surfaces are all covered. Owing to the construction of water-tube boilers test cocks are not fitted. In the Belleville boiler fusible plugs are fitted as has been described.

Pressure Gauge Cocks are fitted to control the access of the steam to the *pressure gauges* with which they are connected by means of small pipes, and allow steam to be shut off from a pressure gauge in case of accident to the pipe, or a pressure gauge to be removed whilst there is steam in the boiler.

Scum Cock.—This cock has a pipe leading from it inside to the centre of the boiler, at or slightly below the working water level, with a dish at the end, which is known as the *scum pan.* It is fitted to enable the grease or scum to be removed from the surface of the water. The water, after passing through the scum cock, goes through a pipe to the *sea cock* and *Kingston valve,* through which it is discharged into the sea.

Hydrometer Cock.—This is a cock fitted to the boiler in some convenient position, by which water may be drawn off for testing.

Running-down or Emptying Valves.—By means of these valves the boilers may be emptied either into the bilge or into the reserve feed tanks. To enable the latter to be done the valve is fitted with a hose connection to enable a hose to be connected between it and the reserve tanks.

Blow-down Valves or Cocks.—Should the water in the boiler become dirty when under steam, by opening these cocks a quantity may be blown out, clean feed water being admitted to take its place. These cocks are fitted to the bottom of the boiler, and are connected by a pipe to a sea cock and Kingston valve, through which the water is discharged into the sea.

To prevent leakage these cocks are often fitted in pairs, one directly above the other, and when so fitted the cock next the boiler should be opened first and closed last to reduce the scoring action on this cock to as small an amount as possible.

Circulating Valves.—In some cylindrical boilers a valve connected to the suction side of the feed pump is fitted to the bottom of the boiler. This valve is called a circulating valve, and, when raising steam, cold water is withdrawn from the bottom of the boiler and returned through the feed valves, the resulting circulation allowing steam to be raised rapidly without straining the boiler, the bottom being thoroughly heated by the hot water which replaces the cold pumped from it.

The following fittings, not boiler mountings, are connected to the boiler, and are necessary for the proper working of the boiler:—

Pressure Gauges.—The pressure in a boiler is indicated by a pointer, which, as the pressure varies, points to different figures on the face of this gauge, the figures indicating the pressure. Thus, if the pointer stood at 10, it would mean there was a pressure of 10 lbs. per square inch inside the boiler, no matter at what part, if it stood at 60 there would be 60 lbs. pressure, and so on. Two pressure gauges are always connected to each boiler, one of which is marked up to at least the working pressure and the other to double that pressure. They are not fitted directly on the boiler itself, but are usually secured to the bulkhead, being connected to the boiler by a copper pipe of small size.

Kingston Valve.—This is a valve which is secured to the bottom of the ship, communicating directly with the sea, for the purpose of admitting or letting out water. It would be a matter of very great difficulty to refit this valve, in case of accident or leakage, unless the ship were placed in dry dock, so immediately inside it there is another cock or valve known as the *Sea Cock.*

Waste Steam Pipe.—This is a pipe from the safety valve box, led up by the side of the funnel, through which the steam escaping from the safety valves finds a passage to the atmosphere.

CHAPTER V.

The Steam Engine.

The steam generated in the boiler passes into the main steam pipe, by which it is conveyed to the engines. A steam engine is any contrivance by means of which work can be got out of the steam. Steam engines used in the Navy are of two classes:—

(1) Reciprocating engines.
(2) Turbine engines.

Reciprocating engines as now fitted in the Navy for propelling ships are of the vertical type, that is with the *cylinder* at the top and the *crank shaft* underneath, the *piston* working in a vertical or up and down line; originally they were placed in the horizontal position, in which case the cylinder was on its side and the piston and rod moved horizontally.

Cylinder.—This is an iron casting which is secured so as to be unable to move, its inside being bored out in a lathe so as to form a true cylindrical surface on which the piston works; in shape the inside resembles the inside of a large but short pipe, and it is closed at either end by a cover. In large engines the surface on which the piston works is formed by a separate barrel or tube of cast iron or steel secured inside the cylinder. It is called the cylinder liner. The cover at the end next the crank shaft is usually part of the casting itself, whilst the cover at the other end is made to take off to allow the piston to be removed, and in large cylinders a *manhole* with plug is fitted in the cover and bottom of the cylinder by which access can be gained to each side of the piston.

Piston.—This is a forging or casting made to fit the cylinder accurately, but capable of moving from one end of the cylinder to the other. The piston is made steam tight in the cylinder by means of piston *spring rings* which press against the cylinder sufficiently to prevent passage of steam past the piston, but not to such an extent as to cause too much friction when piston is in motion.

Piston Rod.—This is a steel rod with one end secured to the piston, the other end projecting through the cylinder cover next the crank shaft, so that as the piston moves the piston rod moves up and down with it.

Gland.—The hole in the cylinder bottom through which the piston rod passes has to be made steam tight, to prevent a constant leakage of steam. This is accomplished by fitting a gland and stuffing box to the piston rod, the stuffing box being a deep recess in the bottom in which the gland fits. The stuffing box is filled round the piston rod with packing, which is kept in place by the gland.

Ports.—In the cylinder face on which the *slide valve* works are passages leading to each end of the cylinder, called steam ports, with a larger port between them called the exhaust port, leading to the eduction pipe. Through the steam ports, steam is admitted to the ends of the cylinder, and after having done its work it escapes through the steam port again and by way of the exhaust port into the eduction pipe.

Slide Valve.—The steam enters and leaves the cylinder by the steam ports: the admission and exhaust of the steam through them are affected by a slide valve. Slide valves are of two kinds—flat slide valves and piston slide valves.

A *flat slide valve* consists of a box-shaped casting which works on a flat face of the cylinder. The cylinder face and the slide valve are enclosed in a casing secured to the cylinder known as the slide casing. Steam is admitted from the main pipe to the slide casing and surrounds the slide valve, whilst the inside of the slide valve is in connection with the exhaust through the eduction pipe. The flat slide valve is pressed against the cylinder face by the steam pressure in the slide casing, and with high-pressure steam the friction between the valve and cylinder face becomes very great, causing excessive wear. A slide valve of different construction known as a *piston slide valve* has been adopted when high steam pressures are used. This consists of two pistons connected by a smaller hollow trunk, the cylinder slide face in this case being circular instead of flat.

With this type of valve the space between the two pistons forming the valve is connected either to steam or to exhaust.

With this type of valve the steam pressure has no effect in pressing the valve against the cylinder face, and the excessive wear is avoided.

Eduction Pipe.—This is a large pipe connected with the exhaust port of a cylinder through which the exhaust steam passes after it has done its work.

Eccentrics.—The slide valve moves up and down a certain amount each stroke of the engine, and it is moved as required by the eccentric which is fixed on the crank shaft. If the engine is only to revolve in one direction the eccentric and slide valves are connected by two rods jointed together, one of which, the eccentric rod, is connected to the strap which encircles the eccentric, and the other, the slide rod, is secured to the slide valve.

Link.—As it is necessary that the Main Engines should work in both directions, so as to drive the ship either ahead or astern, two eccentrics are fitted to work each slide valve, one of which is known as the *ahead eccentric* and imparts motion to the slide valve so as to drive the engine to move the ship ahead, whilst the other, called the *astern eccentric*, moves the slide valve so that the engine drives the ship astern. By means of the link, to the ends of which the tops of the eccentric rods are jointed, either of them may be brought opposite the end of the slide rod which is geared in it. If the end of the ahead eccentric rod is brought opposite the end of the slide rod the engine runs ahead, if the end of the astern eccentric rod the engine runs astern, and if the middle of the link the engine is stopped.

The action of the steam in the cylinder is as follows :—

Suppose in a vertical engine the piston is at the top of its stroke, the slide valve will have just uncovered the top port, allowing the steam to enter the top of the cylinder, while it also allows steam to escape from below this piston by placing the bottom of the cylinder in connection with exhaust; thus pushing the piston down to the bottom of the cylinder. During the time the piston is travelling down, the slide valve has been so actuated by the valve motion that when the piston has reached the bottom the slide valve has travelled up so as to just uncover the bottom port, which then admits steam to the cylinder beneath the piston to drive it up again.

We now have the cylinder above the piston full of the steam which has pushed it down. At the same time that the slide valve travelled upwards and opened the bottom port to steam it also connected the top port with exhaust through the hollow part of the slide valve: and while the steam in the bottom of the cylinder pushes the piston up, the steam above the piston, which has done its work, is free to escape by the exhaust port. This action is similar for every stroke of the piston.

The action of the steam in driving the piston up and down the cylinder is regulated by a slide valve in all engines. In the main engines the slide valve is always worked by a slide rod gearing with a link connected to the ends of eccentric rods worked by eccentrics placed on the crank shaft, but in some of the auxiliary engines there is no crank shaft and another sort of gear has to be used to work the slide valve.

In order that the engine may be the means of turning the propeller, a crank and connecting rod are used to turn a shaft in the same way as a bicycle wheel is made to turn round by moving one's legs up and down on the pedals.

Connecting Rod and Crank Shaft.—The propeller is connected to steel shafting which is led inside the ship and attached to the crank shaft. The cranks of this shaft are connected to the piston rod by means of a connecting rod which has bearings at each end.

The bearing at the piston rod end, known as the *cross head bearing*, works up and down in a straight line, and is kept so working by a slipper attached to the cross head working in a guide fixed to the cylinder; whilst the bearing at the other end, known as the *crank head bearing*, revolves with the crank, which it drives.

Bearings.—The bearings carrying the crank shaft are known as *main bearings*, and those supporting the propeller shaft inside the ship are known as plummer block bearings. The main bearings are carried in the engine bed plate and the plummer block bearings in the plummer blocks, both bed plate and plummer blocks being rigidly secured to the hull of the ship.

The shafting is carried through the hull of the ship by being passed through a stern tube. It is supported by bearings at the ends of this tube. The inboard end of the stern tube has a stuffing box and gland called the stern gland, the packing in which prevents the sea water passing into the ship.

Outside the ship the propeller shaft is supported in a bearing carried in a bracket known as the A frame, which is secured to the side of the ship.

The bearings in each end of the connecting rod and those in which the crank and propeller shafts work are made of gunmetal, the actual bearing surface being formed by white metal cast into the brass and secured to the brass by dovetailing.

In the stern tube and A frame in ships, strips of lignum vitæ wood are used instead of white metal, as this is more suitable for working in water; but in torpedo vessels and steamboats white metal is used. In new ships a grease lubricant from a special lubricator is forced into the stern tube bearings to lubricate them.

The Thrust Block is a casting rigidly secured to the framework of the ship and having a number of horseshoe-shaped rings or collars attached to it.

The length of shaft next to the crank shaft has a number of collars, or rings formed on it, and these shaft rings fit between the thrust collars.

The thrust of the propeller tends to drive the shaft forward into the ship or draw it out of the ship according to the direction in which the engine is working, and this is prevented by the thrust collars, which transmit the thrust or pull of the propeller to the hull, and thus move the ship ahead or astern.

Propeller.—Consists of a gunmetal boss secured to the shaft and carrying three or four blades, which form part of a screw thread of large pitch. The effect of these blades revolving in the water is the same as that of a screwed spindle revolving in a nut which is held, that is, the propeller moves through the water driving the ship ahead or astern.

Compound and Triple Expansion Engine.—Steam has the property of expanding, that is, of filling a larger volume than it originally filled, but at a less pressure, and this property is made use of in the steam engine. For example, if steam at 60 lbs. pressure per square inch is admitted to a cylinder and the supply is stopped when the piston has moved halfway, the steam then behind the piston will continue to move it, and the piston, without any fresh supply of steam from the boiler, will move to the end of its stroke, but it will be found at the end of the stroke that the pressure is about 30 lbs. per square inch.

To get as much work as possible out of the steam, high-pressure steam is used and expanded to as low a pressure as practicable.

It is neither economical nor convenient to use a single cylinder for a high expansion, and the steam is therefore passed through two or more cylinders, a stage of the expansion being carried out in each cylinder.

When the expansion is carried out in two stages, the engine is known as a compound engine, and when three stages are used as a triple expansion engine.

In a triple expansion engine the steam from the boiler is first admitted to the smallest cylinder, called the high-pressure cylinder, in which it drives a piston. After it has done its work in it, it passes at a lower pressure into a second and larger cylinder, called the intermediate or medium-pressure cylinder, in which it drives another piston; afterwards passing at a still lower pressure into a still larger cylinder, called the low-pressure cylinder, in which it drives a third piston. Having done its work there the steam passes away through the eduction pipe to the condenser. Thus it will be seen that a triple expansion engine must necessarily have at least three cylinders (as the steam is expanded in three stages), a crank shaft with generally three cranks, three slide valves and six eccentrics, each cylinder and its gear forming actually a separate complete engine. All the different parts are usually distinguished by the name of the cylinder to which they belong, for example, the H.P. crank, the M.P. eccentric, the L.P. slide, &c.

Sometimes the low-pressure cylinder would be of such large dimensions if only one cylinder was used that there would not be room for it in the space allotted to the engines, in which case two smaller cylinders are fitted. When this is done, the steam, after it has performed its work in the intermediate cylinders, passes into the two L.P. cylinders, one half into each.

The fitting of two or three cylinders is necessary for the proper driving of the propellers and ship, besides being desirable with high-pressure steam from the point of view of economical working.

When the piston in any cylinder is at the end of its stroke, pressure on it has no effect in turning the crank shaft, and the engine must be dragged round till the next stroke is begun. In some engines with one cylinder this is done by fitting a heavy fly wheel, but in engines fitted for driving ships and boats it is effected by placing another cylinder or cylinders on the same shaft with their cranks out of line, so that only one piston at a time has no effect.

TURBINE ENGINES.—In this type of engine, the pressure of the steam is employed in a somewhat different manner to revolve the shaft. It consists essentially of the rotor and the rotor casing. The rotor consists of a hollow cylinder secured to the shaft and having attached to its exterior a large number of blades arranged in a series of rings. Between these rings of rotor blades, which revolve with the rotor and shaft, corresponding rings of fixed blades are secured to the casing.

The steam enters at one end of the rotor casing, strikes the first row of the fixed or casing blades, and is deflected on to the first row of the rotor blades. It then passes to the second row of fixed blades, from which it is deflected on to the second row of rotor blades, and so on to the end of the casing, the force with which the steam strikes the rotor blades causing the rotor and shaft to revolve at a high speed and thus rotate the propeller. As in the reciprocating engine, but for reasons of convenience only in turbines, the work of the steam is carried out in stages, the steam on leaving the H.P. turbine being led at a lower pressure to a second turbine and sometimes to a third before passing to the condenser.

Owing to its construction the steam turbine used in the Navy can only be driven by the steam in one direction, and for the purpose of driving the ship astern separate turbines are fitted on the same shafts as the ahead turbines.

In the Parsons turbine thrust blocks are fitted at the forward end of the turbine castings; on account of the fineness of the clearances between the revolving parts of the turbine and the fixed parts, and the damage which would be done if they fouled while the turbine was running, wear in the thrust blocks and shaft journals is of more moment than in the case of a reciprocating engine.

Forced lubrication is always fitted to the bearings.

Pipes from the discharge of a lubricating oil pump deliver continuously into the various bearings; the oil, after having passed through a bearing, falls into an oil well under it, which drains to the settling tank from which the pump sucks. There are two settling tanks in the system, either of which can be put in use, the other allowing the oil in it to deposit any water or sediment. There are also an oil cooler and a filter, the former to cool the oil and the latter to take out any dirt in it.

Course of Steam and Water.—The steam goes from the boiler through the engines to the condenser and back again to the boiler in the shape of water, and the following is the order of the parts through which it passes:—From the boiler through the internal steam pipe and the main stop valve to the main steam pipe, separator, bulkhead stop valve, intermediate stop valve, regulating valve and manœuvring valve, high-pressure cylinder, intermediate cylinder, and low-pressure cylinder, eduction pipe, condenser, air pump, hot well, hot well pump, grease filter, and feed tank, from which it is pumped by the feed pump through the feed pipe and feed valve back to the boiler.

Bulkhead Stop Valve.—This is a stop valve of the self-closing type, like the main stop valve on the boiler, and is fitted on the engine-room bulkhead. In ships having more than one boiler-room the steam from each boiler-room is usually carried independently to the engine-room bulkhead, and at the end of each pipe a bulkhead stop valve is fitted so that in the event of a big leakage of steam or a fall of pressure on the boiler side of this valve due to accident or other cause, only the boilers in connection with the steam pipe would be put out of action.

Separator.—This is fitted in some ships for extracting the water from the steam immediately before it goes to the engines, and is a large vessel connected with the main steam pipe, so that all the steam going to the main engines has to pass through it. Inside the separator is fitted a vertical baffle or diaphragm plate which reaches from the top about three-quarters of the way to the bottom.

Steam from the main steam pipe on entering the separator on one side strikes against and passes down under the baffle plate, then rises to the top on the other side to the outlet: during this the moisture or water contained in the steam falls to the bottom of the separator, from which it can be blown out from time to time into the condenser.

Regulating Valve.—This is a valve fitted direct on the high-pressure slide casing, through which the steam passes to the engines, and by means of it the amount is controlled so as to regulate the revolutions to the speed required.

Manœuvring Valve.—On the shell of the regulating valve a small valve is fitted by means of which steam can be passed to the engines around the regulating valve. This valve is known as the manœuvring valve, and is fitted to allow the amount of steam passing to the engines to be increased or decreased by a small amount. This is necessary when the speed of the engines requires to be altered a few revolutions only.

Intermediate Stop Valve.—Is fitted to the main steam pipe and controls the passage of steam to the regulating valve. It is usually worked from the engine room and also from a position outside the engine room. The object of the latter is to allow the valve to be shut in case of an accident in the engine room when it might be found impossible to work the valve from the engine room.

This valve is usually fitted with the steam pressure acting on the top, so that when closed the pressure of steam assists in keeping the valve tight.

To assist in opening this valve, a small bye-pass valve is fitted on its shell. By means of it the pressure on the top of the large valve is balanced by admitting the pressure to the underside.

Silent Blow-off Valve.—This valve is fitted to allow steam to be passed direct from the main steam pipe into the condenser. Its object is to allow the pressure in the steam pipe to be relieved when it becomes excessive, due to the sudden stoppage of the engines or other reason.

Condenser.—At the end of every stroke of the low-pressure engine the exhaust steam is led through the eduction pipe to a surface condenser, a large vessel in which it is condensed into water by coming into contact with the cooling surfaces.

These cooling surfaces consist of a number of small tubes. The exhaust steam passes either inside or outside them and the other side is swept over by sea water pumped by the circulating pump. The tubes are closely placed in the condenser; they are straight and their ends are kept tight where they pass through the tube plates by cotton tape packing tightened up by glands in screwed stuffing boxes formed in the tube plate.

The greatest care is taken to make the condenser tight, that is, to prevent the salt circulating water leaking to the steam side and mixing with the fresh condensed water which falls from the tubes to the bottom of the condenser. The tubes and tube plates are of brass. The shell is sometimes of brass and sometimes of steel plates.

Vacuum.—A total vacuum exists in a space in which there is a total absence of pressure. As generally used the term vacuum is applied to any pressure less than that of the atmosphere, that is, to a partial vacuum. In the condenser a vacuum is formed by the condensation of the steam and the action of the air pump.

As the low-pressure slide valve opens up a passage between the back of the piston in the low-pressure cylinder and the condenser at the end of every stroke, it can be seen that if there is a vacuum in the condenser the exhaust steam will pass rapidly from the cylinder to the condenser. If there were no vacuum in the condenser the exhaust steam would have to be forced out of the cylinder, thus decreasing the power of the engine.

Circulating Pump.—The circulating pump is continuously at work whilst steam is up pumping water through the condenser to condense the steam. The water is drawn by this pump through a valve secured to the bottom of the ship known as the ***main inlet valve***, forced through the condenser and overboard again through another valve called the *main discharge valve.* For a purpose explained later these pumps are also provided with a suction from the engine-room bilges.

Air Pump (*see also Chap. VI.*).—The water which is formed from the condensed steam and any air present is pumped by this pump from the bottom of the condenser into the hot well, from which the water is pumped into the feed tank and thence back again to the boiler.

The name "air pump" is given to this pump because it has to pump out a certain a mount of air in addition to the water condensed from the steam. This air leaks. in through slack glands, defective joints, leaky covers, &c., and passes with the exhaust steam to the condenser.

Formerly the air pump was worked from the main engines, but in all recent ships it is worked by an auxiliary engine.

CHAPTER VI.

AUXILIARY MACHINERY.

The engines used to propel the ship are called the main engines, all others, whether necessary for the main engines or not, are known as auxiliary engines.

Auxiliary Machinery used in connection with Main Engines :—

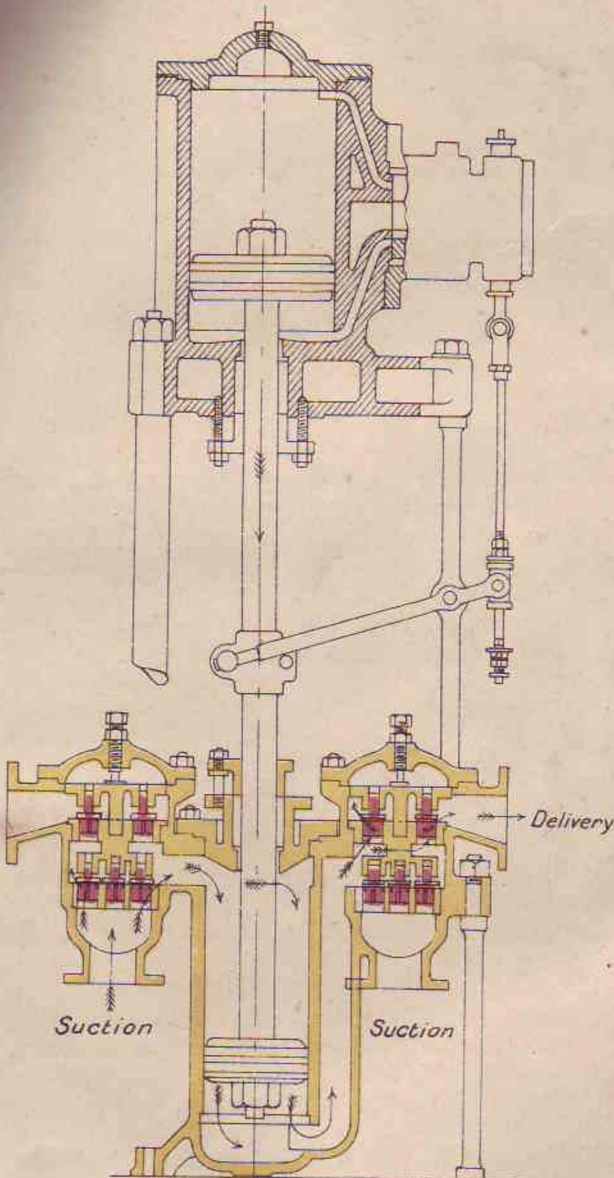
- MAIN AND AUXILIARY FEED PUMPS to pump water into the boilers.
- MAIN AIR PUMPS to pump air and water from the main condensers and keep a vacuum in them.
- MAIN CIRCULATING PUMPS for circulating the cooling water in the main condensers.
- FORCED LUBRICATION PUMPS for pumping oil through the forced lubrication system to the bearings.
- FORCED DRAUGHT FANS for supplying air to the boiler rooms.
- OIL FUEL PUMPS for supplying oil fuel where boilers are fitted to burn it.
- REVERSING ENGINES for working the reversing gear on large reciprocating engines.
- TURNING ENGINES for turning the main engines when the ship is in harbour.
- ASH HOISTING ENGINES for hoisting ashes from the stokeholds, and in some cases engines for use with the ash ejectors.
- EVAPORATORS AND DISTILLERS for making extra feed water for the boilers and for drinking.

Auxiliary Machinery for other purposes :—

- AUXILIARY CIRCULATING AND AIR PUMPS for the auxiliary condenser.
- CAPSTAN ENGINES for working anchors and cables.
- STEERING ENGINES for working the rudder.
- FIRE AND BILGE ENGINES for pumping water through the fire mains and pumping out the bilges, &c.
- ELECTRIC LIGHT ENGINES for driving the dynamos.
- BOAT HOISTING ENGINES for hoisting the heavy boats.
- AIR COMPRESSING ENGINES for compressing air for torpedoes.
- HYDRAULIC PUMPING ENGINES for pumping water into the hydraulic mains which supply the hydraulic machinery working the heavy guns.
- REFRIGERATING ENGINES for cooling the refrigerator rooms and for making ice.
- VENTILATING ENGINES for pumping air into or exhausting air from various parts of the ship.
- WORKSHOP ENGINES for running workshop machinery.

To face page 34.

Fig. 18.



BOILER FEED PUMP.

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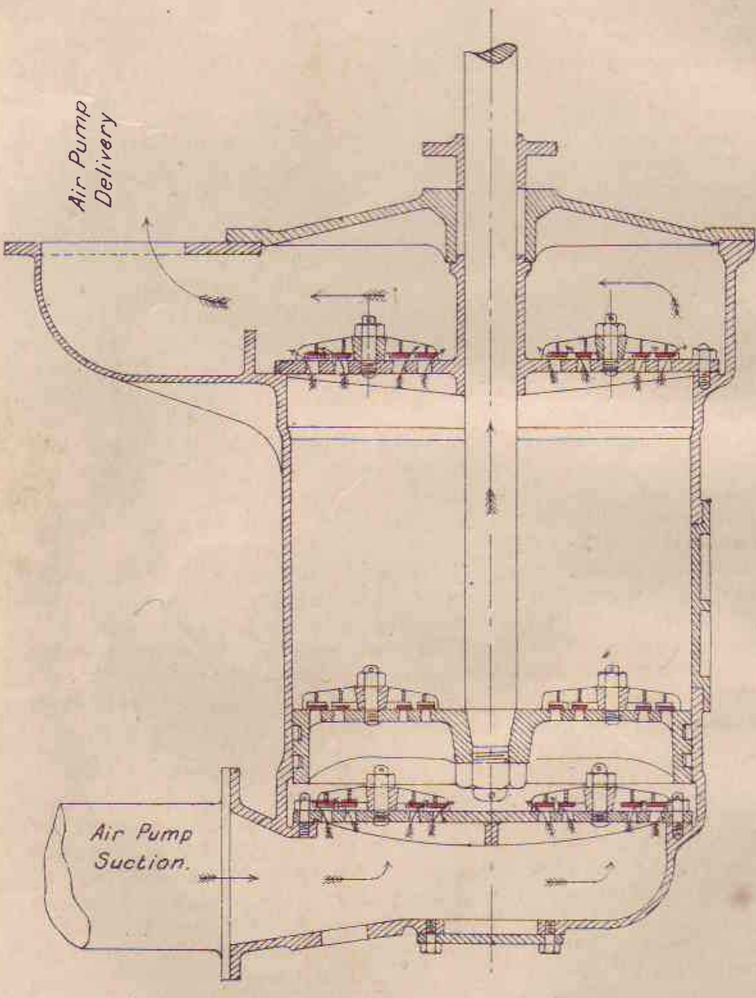
Fig. 19.



AIR PUMP.

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In recent ships electric motors have been employed instead of steam engines to drive refrigerating machinery, ventilating and fan engines, and for running the workshop machinery, &c.

The type of engine used for auxiliary purposes varies with the work it is required to perform.

The pumping engines in connection with the machinery (feed, fire and bilge, air, oil fuel, &c.) are usually slow-running engines, single-cylindered and without crank shafts.

Engines working continuously and driving revolving parts such as fan, circulating, and electric light engines, are usually fast-running crank shaft engines fitted with forced lubrication. Such engines as the capstan, steering, boat hoisting, and reversing engines, which have to run fast or slow as required and to start readily from any position in which they happen to have stopped, are always two-cylindered engines with cranks placed at right angles, and are of the open type fitted with ordinary external lubrication.

Turbine engines are sometimes fitted to drive the dynamos.

PUMPING ENGINES.—The engines used for pumping services, which have no crank shaft, have as shown in Fig. 18 the steam cylinder vertically above the pump barrel, with piston and pump rods joined end to end by a sleeve coupling.

The slide chest usually lies horizontally across the cylinder and contains a main and an auxiliary slide valve, the latter worked by the slide rod and a system of levers moved by the piston rod. There is often a bye-pass arrangement on the slide casing for use in starting the pump and to make it work smoothly.

The pump is double-acting, that is to say, during each stroke water is sucked into one end of the pump and discharged from the other.

Each end of the pump barrel is connected by a passage with a space between its own suction and delivery valves; the suction valves, which are at the bottom of this space, when open allow water to pass into the pump from the suction pipe, the discharge valves at the top when open allowing water to pass out of the pump to the discharge pipe.

On the downstroke water is drawn into the top of the barrel through the suction valves and the pressure in the discharge pipe keeps the discharge valves from this end of the pump closed, at the bottom of the plunger the water is forced through the delivery valves into the discharge pipe. In Fig. 18 arrows show the water being sucked and delivered on the downstroke of the pump. For clearness sake the suction and delivery valves for the top end of the pump barrel have been shown on one side, and those for the bottom on the other, and suction and discharge branches are shown on each box. Actually the two valve boxes would be placed side by side and would communicate below the valves with a common suction pipe, and above with a common delivery.

On the upstroke of the plunger the water which had been sucked into the top of the pump is discharged and water is sucked in below the plunger.

The pump plungers are packed with rings.

Near the pump an air vessel is fitted on the discharge pipe to steady the flow of water.

Engines of the type described are fitted as main and auxiliary feed engines, fire and bilge engines, oil-fuel pumps, &c. Stop valves are fitted between the suction and discharge valves on the pump and the suction and discharge pipes.

In the case of the fire and bilge engines, besides the pump stop valve there is a nest of suction valves which allow the pump to suck either from the sea or from any of the pipes led to it from the various compartments which it is fitted to pump out.

In all engines of this type which have main and auxiliary slide valves, it is necessary to ensure that the slide valve which is not moved by the slide rod should be kept from rusting when in harbour. After running the engine, if it is not required to steam again, the valve should be taken out, cleaned, and coated with heavy filtered mineral oil before it is put back again.

The Air Pump (Fig. 19) is a single-acting pump. The delivery and suction valves, which in the air pump are called the head and foot valves, are placed at the top and bottom of the barrel, and the plunger or bucket also carries valves; all these valves are non-return and only allow air and water to pass from suction to delivery.

When the bucket is at the top of its stroke, the space below is charged with the air and water sucked in on the upstroke; on the downstroke the head and foot valves are both kept shut, as the downward motion of the bucket tends to suck through the head valves and deliver through the foot valves, for which the valves are non-return, and the air and water below the bucket pass to the top. On the upstroke, both head and foot valves open, the air and water on top of the bucket being discharged through the head valves and more being sucked in from the bottom of the condenser through the foot valves.

The valves in air pumps were formerly made of india-rubber, but they are now made of thin sheet brass.

It is necessary to clean air-pump valves frequently as the amount of vacuum which can be kept in the condensers depends on their tightness and freedom from dirt.

The air-pump bucket is kept airtight as it moves up and down the barrel by small packing or spring rings.

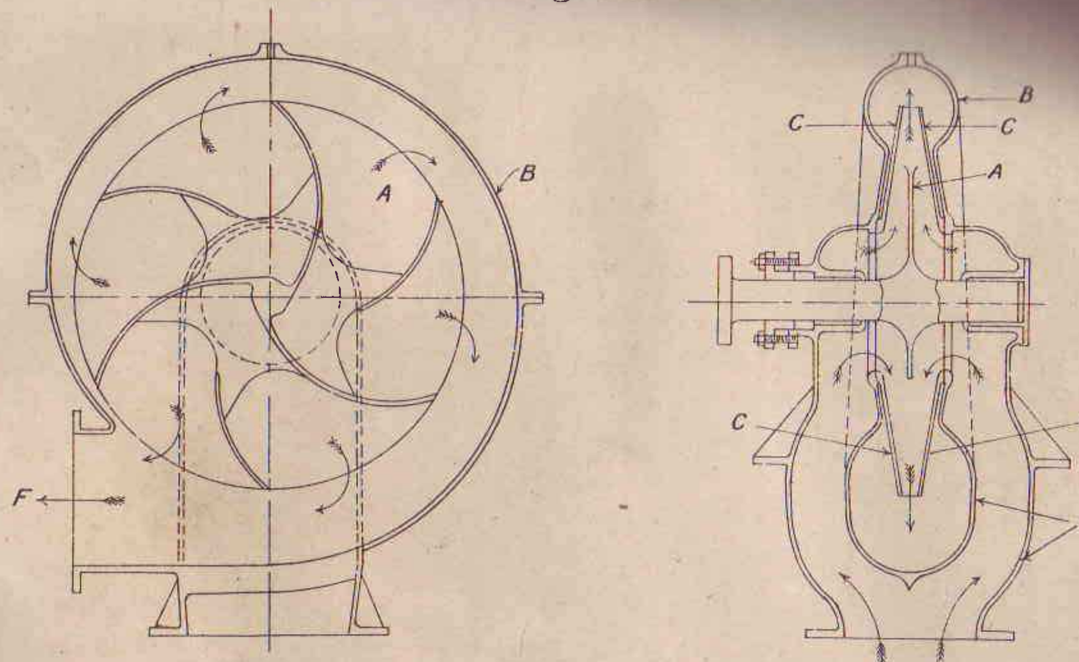
A door is fitted in the side of the air-pump barrel to give access to the bucket and foot valves.

In the latest type of independent (not worked by the main engines) air pump there are two separate pump barrels, one of which—the wet pump—deals with the water and discharges it to the feed tank and the other—the dry pump—maintains the vacuum. They are situated side by side, one being directly under the steam cylinder, the plunger rod of the other being driven by a rocking beam from the piston rod.

Circulating Fan and Ventilating Engines.—In modern ships single-cylindered crank-shaft engines fitted with forced lubrication are usually fitted to drive centrifugal pumps and air fans. They are vertical engines

To face page 36.

Fig. 20.



CENTRIFUGAL CIRCULATING PUMP.

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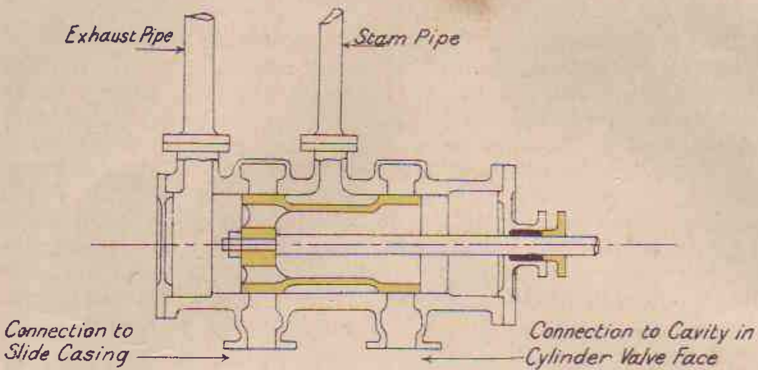
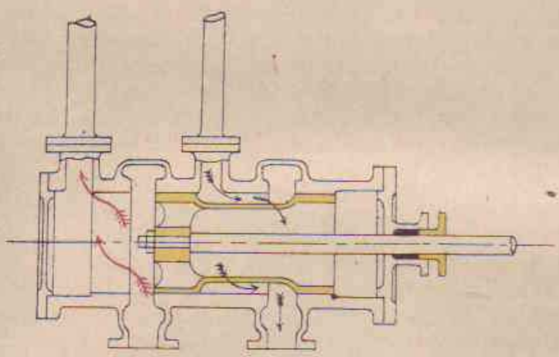
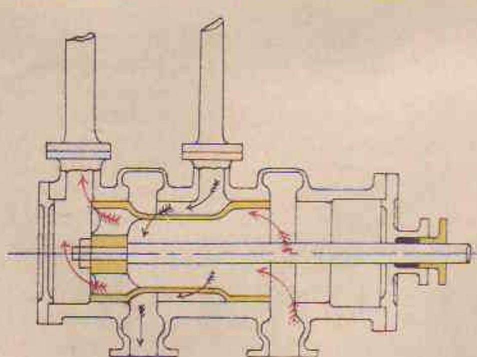
Fig. 21.



CONTROL VALVE CENTRAL-ENGINE STOPPED



CONTROL VALVE TO RIGHT-ENGINE RUNNING IN ONE DIRECTION



CONTROL VALVE TO LEFT-ENGINE REVERSED

→ Steam to Engine
→ Exhaust Steam from Engine

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with the usual arrangement of a piston connecting rod and slide rod and eccentric. To provide the forced lubrication chamber a casing generally of cast iron fitted with suitable doors encloses the whole of the working parts. It is carried just above the crosshead at the highest part in its stroke, and packing glands or some other device are fitted where the piston and slide rods pass through the casing to prevent forced lubrication oil being carried into the cylinder, and so finding its way to the boilers. This casing with the bed plate of the engine form a well holding the lubricating oil. A small pump driven by the engine forces oil through pipes and holes in the crank shaft and rods to the various bearings, pins, and guide surfaces. A pressure gauge is placed on the oil discharge from the pump, and a means is fitted of regulating the pressure kept in the system.

The centrifugal pump, Fig. 20, consists of an impeller or fan A revolving inside a casing B. The impeller has a central web guiding the incoming water and two side plates CC gradually approaching each other as they near its circumference. Between the side plates run a number of vanes curved away from the direction of turning of the impeller. The water enters the impeller at the centre, it is caught by the vanes, and driven out at the circumferences of the impeller into the space communicating with the discharge pipe F.

The fans for forced draught and ventilation are constructed on a similar principle, but are made of light steel sheeting instead of gun-metal, as in the centrifugal pumps.

Electric Light Engine.—The electric light engines fitted to modern ships are forced lubrication engines similar to the circulating and fan engines, but they are two crank engines, the cranks being at right angles. They are fitted with governors to prevent the engines from running away and damaging themselves in case of the failure of a circuit.

Capstan Engine.—The capstan engine is a two-cylindered open engine (*i.e.*, not cased in for forced lubrication of the working parts) with cranks at right angles.

It is placed low down in the ship to be under protection. The capstan, and at the forward end of the ship the cable holders, port and starboard, driven by the capstan engine, are on the upper deck, with spindles led down through the various decks to the gearing in the capstan engine flat.

This gearing is so arranged that the capstan or either of the windlasses may be stopped or revolved in either direction independently of the others.

Worm gearing is frequently fitted to the spindles, a bronze worm wheel, keyed to the bottom of the spindle, gearing with a worm driven by the engine, the shaft carrying the worm is fitted with a thrust bearing to take the thrust due to driving the wheel.

There is considerable friction between a worm and its wheel, and the worm is generally arranged to dip in an oil bath, being thus constantly lubricated.

A worm is a screw with the thread of proper shape to work with the worm wheel, which may be regarded as a nut. Just as pressing on the end of a nut without turning it does not screw it up on the bolt, so no force exerted on the wheel will move the worm; thus a capstan or cable holder driven by worm gear cannot be moved by the pull of the cable when the engine is stopped.

Each cylinder of the engine has its slide valve driven by an eccentric on the crank shaft, with an eccentric rod attached directly to the slide rod.

To reverse the engine a controlling valve is fitted between the steam and exhaust pipes and the slide casings and exhaust ports of the engine.

In steam engines steam is usually led into the casing round the slide valve, and exhaust is effected through the exhaust port in the slide face and the eduction pipe, but in engines like the capstan engine and the steering engine this controlling valve may place either the steam or the exhaust pipe in communication with the slide casing, while it places the other in communication with the eduction pipe.

When steam is admitted by the valve into the slide casing the crank shaft will turn in one direction, and when it is admitted into the eduction pipe, in the other direction, and when the controlling valve is placed in its central position it cuts off communication from the engine with both steam and exhaust and stops it. Fig. 21.

In the capstan engine the gear of working the valve is led to the deck.

The arrangement of reversing gear described which is commonly used in capstan, steering, and boat hoist engines, can only be used where handiness is the first consideration, as it entails a large expenditure of steam.

STEERING ENGINE.—The steering engine, like the capstan engine, is a two-cylindered open engine, with cranks at right angles, and has a similar reversing gear.

The positions from which the ship is steered are remote from the steering engines, which are situated in or near the engine rooms, and are out of sight of the rudder.

The gear of the controlling valve of the engine is so arranged that the engine stops when it has moved the rudder into a position corresponding to that shown on an indicator fitted at the steering position.

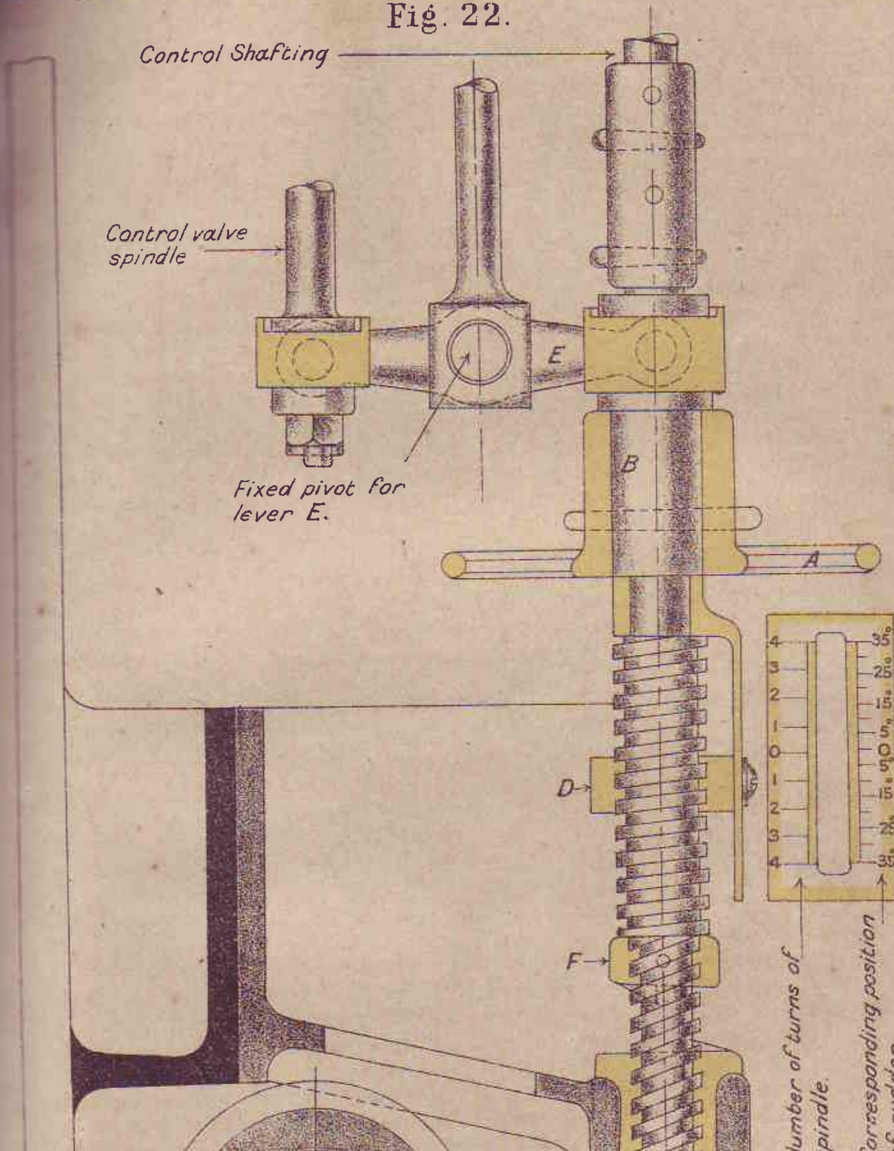
Steam steering wheels carried on suitable pedestals containing the gear are placed at each steering position; they are arranged so that the upper part of the wheel moves in the same direction as the head of the ship, and positive stops are placed on the gear inside the pedestal to prevent the wheel being turned more than four revolutions in either direction, and the whole of the steering gear is so arranged that in moving the rudder from hard-over at 35° S. to hard-over at 35° P. the steering wheel makes eight revolutions between these stops,

Either controlling gear of light shafting and bevel wheels or telemotor gear with hydraulic cylinders connected by piping and placed in the pedestal and near the engine are employed to communicate the movement of the steam steering wheel to the gear on the controlling valve of the engine.

On the pedestal there is a pointer moving 35° in either direction operated by the hand wheel and moving in the same direction, which shows the position into which the rudder is to be moved. Glass, under which a lamp is fitted, is placed below the pointer, and the sector is so marked as to be visible by day or night. A helm indicator usually worked

To face page 38.

Fig. 22.



DIFFERENTIAL VALVE GEAR WITH CONTROLLING SHAFTING.

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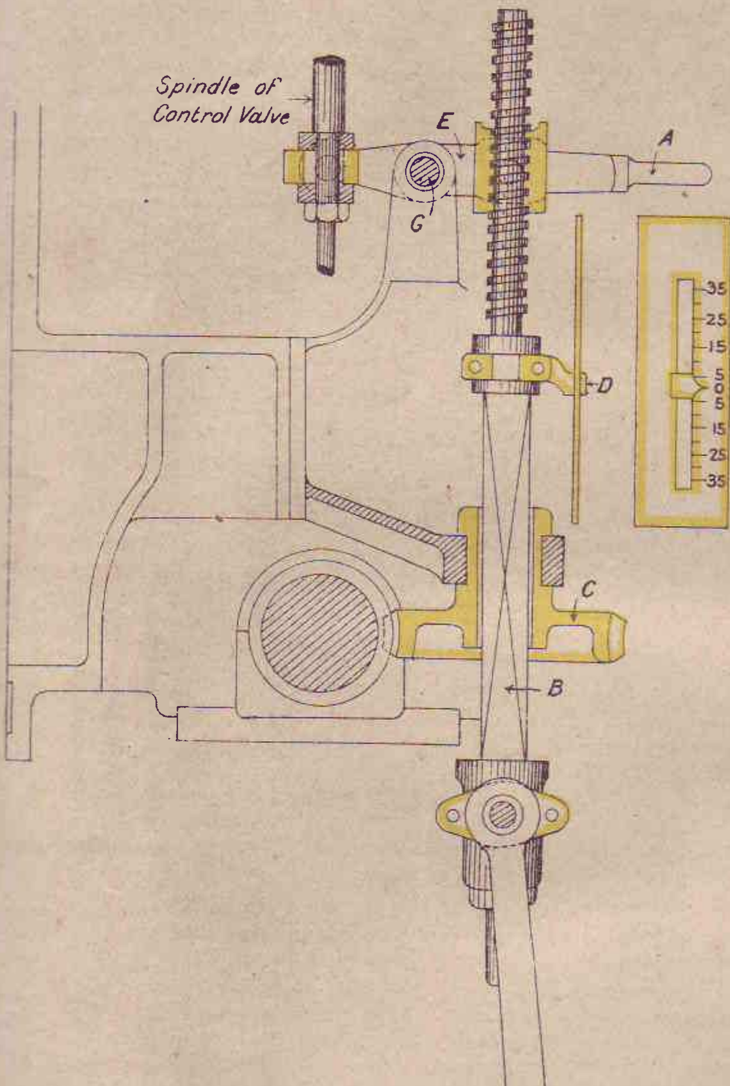
Fig. 23.



DIFFERENTIAL VALVE GEAR,

WITH TELEMOTORS.

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electrically from the rudder head is fitted near each pedestal to show the actual position of the rudder, and helm signals also worked direct from the rudder head, and generally operated by telemotors, show whether the helm is to port or starboard.

Fig. 22 shows the gear at the controlling valve of the engine when controlling gear is fitted. A is a wheel used in trying the engine before it is connected up to one of the deck positions; it is keyed on the spindle B, which is threaded at the end and is engaged by the worm wheel C, geared with worm on the shafting from the engine G; C is held in a bracket, and can only turn round. Another thread on B works an index D, which shows the position of the rudder.

When the spindle B is revolved, either by using the wheel A, or if connected up by one of the steam steering wheels, it moves up or down in the wheel C, and by means of the lever E moves the controlling valve from its central position and starts the engine; as the engine moves its crank shaft revolves the worm wheel C, and the wheel turning on B moves it up or down in the opposite direction to that in which it was moved by turning the wheel A or the steam steering wheel, this centres the controlling valve and stops the engine when B has returned to its original position. If the spindle B is given two revolutions by the wheel A it will move two threads up or down, and the engine will have to run twice as far to return it to the central position as if it had been given one revolution, and so on; and it will be seen that the position of the rudder, which depends on the distance it is moved by the engine, will be represented by the index D, which is moved up and down when the spindle is turned. The nuts FF, with lugs projecting on them corresponding with similar lugs on the top and bottom faces of the boss of the wheel C, are fixed by pinning them on the spindle B, and they prevent it from being turned more than four revolutions in either direction, corresponding to a movement of 35° in the rudder.

This arrangement is similar to that of the positive stops fitted in the pedestal, but in that case the threaded shafting does not move up and down, but a nut on it corresponding to the wheel C is prevented from revolving, and its travel up and down is limited by stops similar to FF.

Fig. 23 shows the corresponding gear fitted with telemotors; in this case stops are fitted outside the motor cylinder, as the telemotor cylinder working the valve is called, to limit the travel of the shaft H.

A lever H, on a shaft worked by the motor cylinder, moves the spindle B up and down by means of a connecting rod. The spindle B, which is so attached to the connecting rod that it is free to revolve, is squared, running through a square hole in the worm wheel C geared to a worm on the engine shaft. The end of B is screwed, and works in a nut moving the end of the lever E which is pivoted at G and works the controlling valve; the nut is so guided that it can only move up and down and E is free to slide along its attachment to it.

An index D shows the amount the spindle B has been lifted from the central position, and hence the amount the rudder is moved. When the telemotor moves B up or down it moves the control valve from its central position and starts the engine revolving the worm wheel C and the spindle B, which is held fast in a vertical direction by the telemotor gear; and by means of the nut in the end of E moves the valve towards the central position and eventually closes it and stops the engine.

For working the gear at the engine the lever E is prolonged as shown at A.

With telemotor gear it may happen, owing to leakage of the leathers in the pistons or for some other reason, that the movement of the telemotor mechanism in the pedestal may not be exactly reproduced by the rudder, *i.e.*, it may be central when the rudder is not; fittings are placed on the telemotor to enable this to be corrected, and stops on the gear on the motor cylinder prevent the rudder being thrown over too far either way.

In a large vessel there are two steering engines each capable of working the rudder when the ship is at full speed; these are placed in different engine rooms.

By means of clutches either of them may be connected with a shaft between them which carries the worm driving the bronze worm wheel keyed on the forward end of the steering shafting; the gear for working these clutches is usually so arranged that it is impossible to connect both engines to the worm shaft.

The steering shaft runs aft from the engine to the gear working the rudder; it is usually connected to this by spur wheels, and there are clutches on the shafting to the rudder gear allowing the steam gear to be disconnected and the hand steering wheel connected, so that in case of total breakdown of the steering engines or accident to the steering shaft the rudder may be worked by hand.

In modern ships screw gear is usually employed to operate rudder, which is balanced.

Fig. 24 shows the gear. The crosshead A on the rudder is connected by two connecting rods BB with two cast steel sleeves CC, guided in a

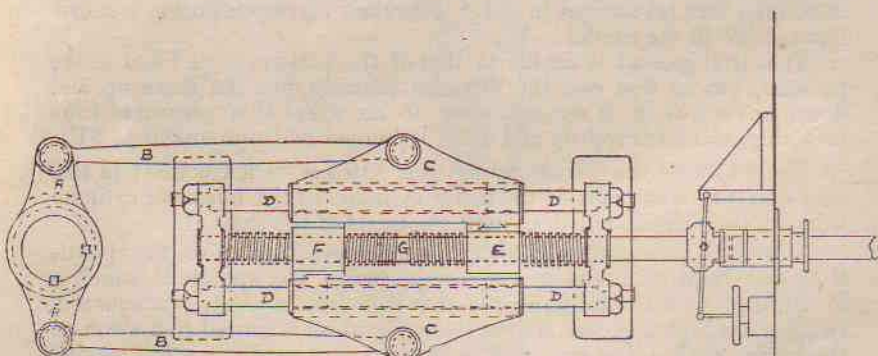


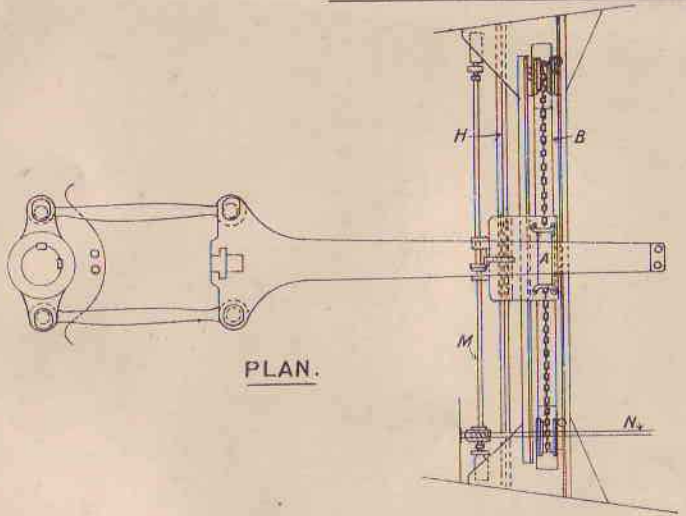
FIG. 24.

fore and aft direction and prevented from turning by the guide bars DD, along which they slide. Nuts EF are carried in the ends of CC, and these work on threads cut on the shaft G, which runs forward and aft along the centre line of the ship.

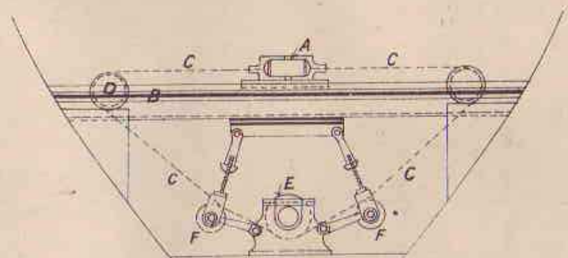
To face page 40.

Fig. 25.

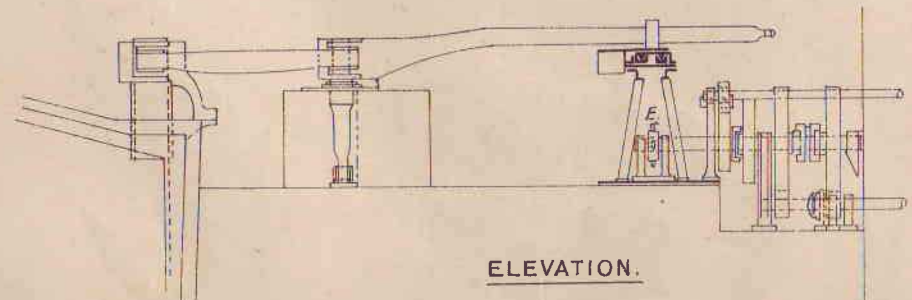
RAPSON'S SLIDE. STEERING GEAR.



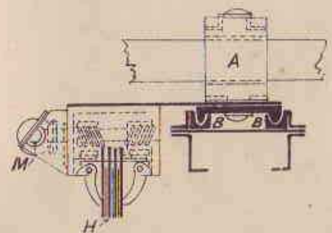
PLAN.



SECTION THRO' SLIDE.



ELEVATION.



SECTION SHEWING CARRIAGE GUIDE & FRICTION PLATES.

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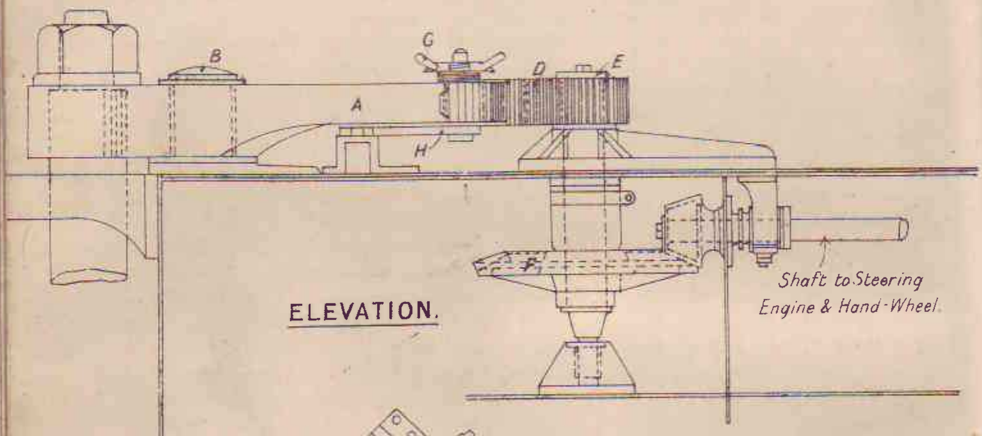
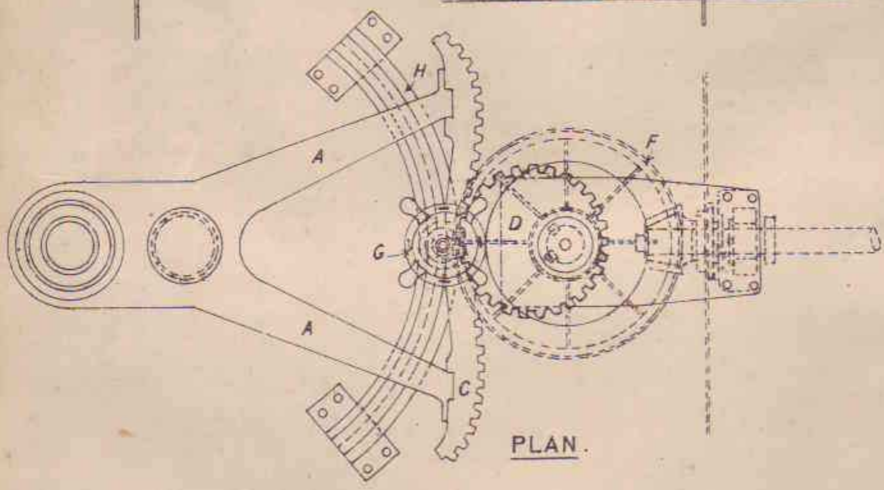
Fig. 26.

HARFIELD'S COMPENSATING STEERING GEAR.



ELEVATION.



PLAN.

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E the nut working the port side is right-handed, and F the nut working the starboard side left-handed; as shown, with the rudder central, E and F are at the middle of their respective screws.

By turning the shaft G the nuts E and F move in the opposite direction and thus turn the rudder.

This gear takes up little room, is light compared to other gears, and it will not walk back. To move the rudder the shaft G must be moved either by engine or by the hand steering wheel, and when these are stopped no force such as a sea striking the rudder will move the gear; but it is not compensated, that is to say, the force which the engine exerts to move the rudder is the same when the rudder is over as when it is central, and consequently this type of gear can only be used where the rudders are balanced.

In older ships, where unbalanced rudders were common, Rapson's slide was commonly used.

Fig. 25 shows the gear. A carriage A slides transversely across the ship on a guide B. An endless chain C connected to the sides of A passes over rollers D at the ends of the guide, thence under a sprocket wheel E fitted at the central line of the ships directly under B. Tightening arms FF are provided for taking up any slack due to the stretching of the chain. The carriage A holds a block, which can turn round in it and slide along the tiller at the same time. The sprocket wheel E, which is moved either by the steering engine or the hand steering wheel, moves the carriage A along the guide B by means of the chain C, the tiller sliding in or out of A as it moves with it. The shortest distance from A to the point at which the tiller is pivoted is when the rudder is central, and this distance increases as the rudder is moved over, and consequently owing to increase of leverage the effect of force exerted by the engine pulling C is increased in moving the rudder.

This gear, however, is reversible, and it is necessary to secure it when changing over from steam gear to hand steering, or *vice versâ*. For this purpose a brake is fitted; three fixed vertical plates H run across the ship at the after side of B, and four short plates fixed to the carriage A can be made to press on them by two jaws actuated by right and left hand threads driven by a shaft M running across the ship and geared with a fore and aft shaft N, fitted with a hand wheel in the steering engine compartment.

In some of the older cruisers and in some recent torpedo craft Harfield's compensating gear is fitted.

A V-shaped tiller A (Fig. 26) pivoted about a vertical spindle B carries the toothed rack C shaped as shown. The rack is formed to gear with a circular pinion D mounted eccentrically on the shaft E, which is driven through bevel wheels by the steering shaft. Owing to the spur wheel D being placed eccentrically on the shaft driven by the engine and to the shape of the rack C a great increase of leverage may be obtained, and in some cases with this gear the leverage at the extreme position is three times as much as in the central. The gear will walk back, and it is necessary to fit a brake for use when changing from steam to hand or *vice versâ*; in ships this is sometimes fitted on the rudder spindle, but in torpedo craft a fixed guide H is usually fitted to which the gear may be clamped by the hand wheel G. It will be noticed in the figure which shows the gear arranged for a torpedo boat destroyer that, unlike other rudders which move round the axis of the stock, the rudder moves round the axis of the spindle B, the stock moving bodily from side to side.

When a ship is at anchor the rudder is kept in place by locking bolts; the first thing to be done in preparing to steer by steam is to take out the locking bolts and stow them in their proper stowing positions.

The engine should be warmed up while disconnected from the rudder and the controlling valve should not be connected to a deck position while this is being done, but the engine should be worked by the wheel or lever fitted on it to operate the valve gear; the person working the valve will then be able to see what is happening at the engine.

After the engine has been thoroughly warmed up it should be left in the central position, and after the clutch to the hand wheel has been seen out all clutches between engine and tiller should be put in. After this the gear should be worked by steam, the engine being worked as before by the wheel on it. It should first of all be made to put the rudder over to small angles, someone being stationed to report the actual position of the rudder, so that it may be seen that this corresponds with that shown on the index at the engine. After this has been seen correct in both directions the angles should be increased, and finally it should be seen that when the valve gear is put hard over the tiller or gear does not foul the stops fitted to prevent the rudder going over too far.

After this the controlling gear or telemotor gear should be connected up, it being seen that the indexes correspond before the connection is made.

After the controlling gear has been connected the whole steering gear should be tried again, first to small angles and then hard over in each direction; someone being stationed at the rudder to report the actual amount moved, so that it may be compared with the reading of the index at the steering position.

Distilling Machinery.—Evaporators and distilling condensers are used to make fresh water for drinking and for the boilers. The evaporator is a boiler in which sea water is converted into steam; its heating surfaces are furnished by brass or copper coils inside it.

Steam from the auxiliary exhaust system or the boilers passes through the inside of these coils and boils the sea water on the outside, the steam inside the coils becomes condensed and is blown away to the condenser, from which it is returned to the feed tank for the boilers again. This steam is called the primary steam of the evaporator. The secondary steam which is formed by boiling the sea water is led from the evaporator, either to the distilling condensers, as the condensers belonging to the evaporator plant are called, or else to the main or auxiliary condensers of the machinery.

When the salt water is boiled away its salts remain behind in the evaporator casing and are added to those in the fresh sea water pumped in, which in turn leaves its own behind as well. The water thus tends to become more and more salt and would soon reach a density at which it would rapidly coat the heating coils with scale and prevent the heat in the primary steam inside them from boiling the sea water in the casing. To prevent this density from being reached a brine pump is fitted which is continually drawing the dense water from the evaporator, and the amount of water withdrawn is replaced by pumping in more sea water than is required to supply that turned into steam.

A blow-down valve is also fitted for the same purpose.

It has been found by experience that the density of water in the evaporator should not be allowed to exceed 30°, and it is necessary to draw off water and test it by a hydrometer to see that this density is not being exceeded.

Evaporators are often worked with a vacuum, that is, a pressure below the atmospheric in the shell, and then the blow-down can only be used by allowing a small pressure to accumulate in the casing, but the brine pump will still keep the density down. Evaporators usually need blowing out at intervals of about six to eight hours.

The distilling condensers to which the secondary steam from the evaporator is led are surface condensers like the main and auxiliary condensers. They have circulating pumps for pumping the cooling water through them, and a pump for pumping away the gained fresh water to the tanks.

Two engines are usually provided for the distilling machinery. In working an evaporator great care must be taken to prevent it from priming, and the gained water, whether for the ship's tanks or for the boilers, must be tasted and tested with nitrate of silver solution from time to time to see that it is quite fresh.

Should any density be observed the drain cock on the distiller should be kept open until the water is pure again.

The evaporator must be worked carefully, the speed of the pumps and opening of the various valves being set to ensure a steady water level, the steam inlet and coil drain valves should be adjusted to maintain the required pressure in the coils, and the latter kept sufficiently closed to prevent the primary steam blowing through to the condenser before it is condensed, and where the evaporator is connected to the main or auxiliary condenser, the vacuum control valve should be set to maintain the desired vacuum or pressure in the evaporator shell steady independently of the varying vacuum in the condenser. The density of the water should be watched, and it may be necessary (*e.g.*, when the brine pump plunger or the valves of the pump are out of order) to keep a small pressure in the evaporator for brining.

Besides the detailed instructions issued by the makers of distilling machinery, each evaporator has a plate fixed on it on which are engraved the adjustments of the various valves and pressures maintained, &c., when the trial of the plant was made on board.

The automatic feed details must be kept clean and in good order and the feed box must be opened out occasionally for this purpose.

All pipes in connection with the plant must be well jointed to prevent leakage and loss of water, and when evaporators are being cleaned the brine pipes and valves must be cleared of salt to allow the brine pumps to suck properly from the evaporator.

The coils require constant examination to see that they are free from scale; when cleaning coils the greatest care should be taken to protect the connections at their ends from damage, and after rejointing them before the cleaning door is closed they must be tested to see that no leakage of primary steam will take place when the evaporator is working. This can be done at once by turning on the steam where the coils are not attached to the door, but where they are special arrangements must be made for the necessary test.

The distilling plant in a ship of any size is in two independent sets. Each set consists of a distilling condenser and one or more evaporators and the necessary pumps.

Fig. 27 shows a distilling plant with one evaporator and its pipe connections.

A.—The valve admitted steam for the coils from the auxiliary exhaust system. This valve is made non-return to ensure that boiler steam shall not pass back into the exhaust system if it is left open by accident while boiler steam is being used.

B.—Valve supplying boiler steam.

C.—Coil steam sentinel valve to call attention to the fact that the working pressure in the coils is being exceeded.

D.—Coil drain valve. The setting of this valve principally controls the supply of primary steam to the evaporator. With boiler steam, which contains little or no water when admitted to the coils, less drainage is required than with exhaust steam, which contains water before it begins to condense in the coils. In some cases, to render the necessary regulation of the opening easier, a supplementary coil drain is fitted.

E.—Pressure gauges; one connected to the coils to show the pressure of primary steam and the other to the steam space of the evaporator to show the pressure or vacuum of the secondary steam.

F.—Vapour valve to main or auxiliary condenser.

G.—Vacuum control valve fitted to keep a steady vacuum in the evaporator shell while that in the condenser varies. If the evaporator were connected directly to the condenser, sudden increases of vacuum would tend to cause priming.

H.—Vapour valve to distilling condenser.

In some plants the evaporators are connected only to the distilling condenser.

J.—Feed check valve.

K.—Automatic feed valve chest.

L.—Safety valves fitted to prevent over-pressure on the evaporator shell in such a case as one of the coils bursting or steam being admitted when no coils are in place.

M.—Brine valve allowing communication with brine pump.

N.—Blow down to sea or to bilge.

A running-down valve (not shown in figure) is sometimes placed on the bottom of the evaporator to drain it completely to the bilge; any drain pipe led from this to the bilge is broken above the floor plates to prevent bilge water being sucked by a vacuum in the evaporator shell if the valve is either leaky or left open by accident.

O.—Water gauge and brine test receiver. With a vacuum in the evaporator any cock opened on the shell will draw in air. A brine receiver is fitted communicating with the shell by cocks. When these are closed brine can be drained through another cock in the bottom into the hydrometer port.

P.—Besides the large door for removing the coils a smaller door is sometimes fitted at the bottom of the evaporator, through which scale which falls off the tubes may be raked out. If water is suddenly admitted to the evaporator after it has been empty, the coils having been first thoroughly warmed up by steam, a great deal of scale will be cracked off.

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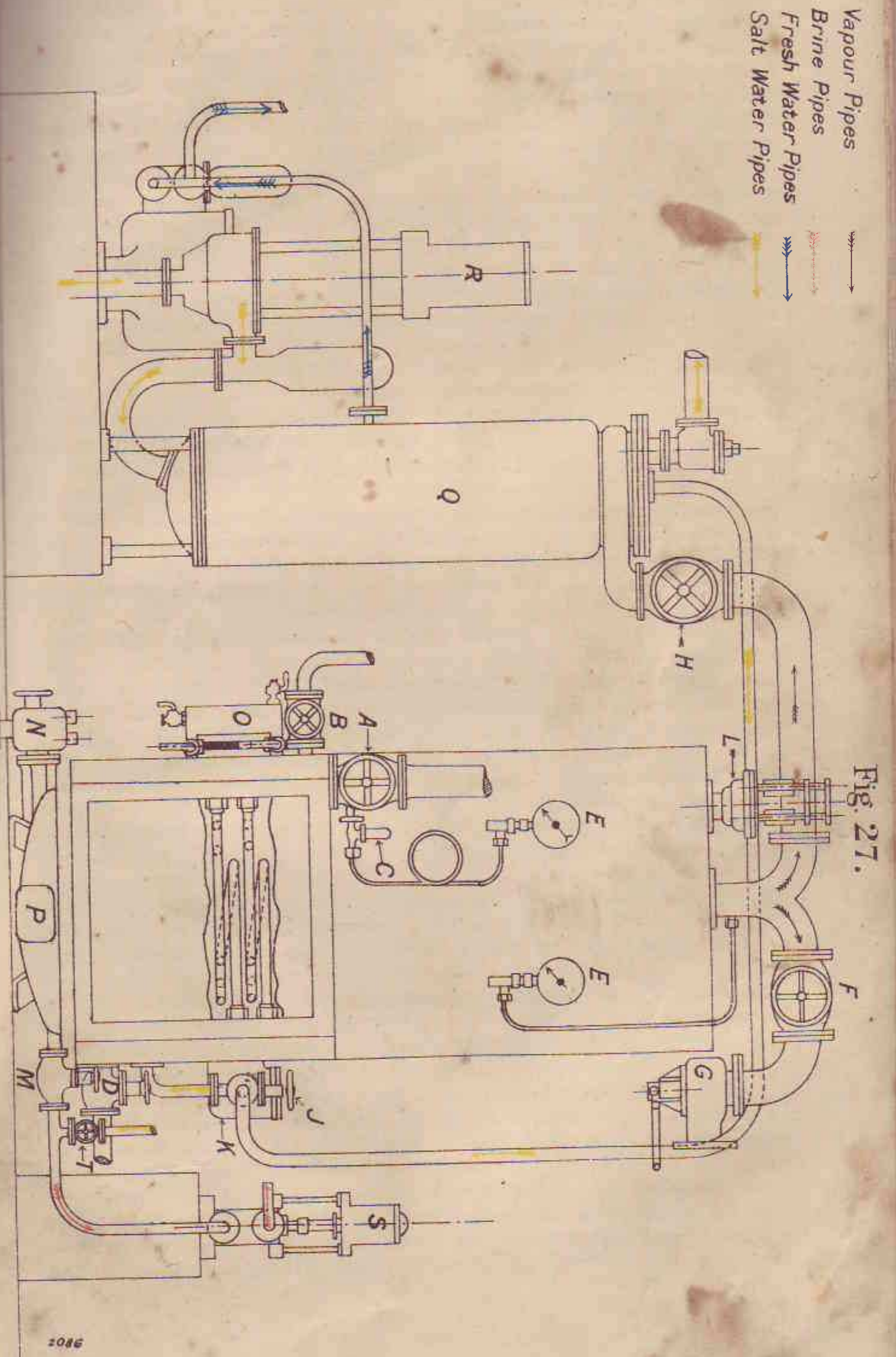

Fig. 27.

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Q.—Distilling condenser.

R.—Distiller pump circulating sea water through the distiller tubes and pumping gained fresh water to the test or feed tanks.

S.—Evaporator pump or brine pump for pumping away brine and keeping down density in evaporator. Sea water admitted through the valve T is mixed with the brine before it reaches the pump, cooling it and rendering it less salt. This tends to keep the pump barrel, plunger, and valves in good order.

Where it is necessary to fit a feed pump on account of the pressure in the evaporator shell it is combined with the brine pump.

The feed water is often taken from the circulating discharge of the distilling condenser, and in some cases it passes through a feed heater warmed by coil drainage, which is led through it before going to the feed tank or condensers. This is not fitted in the newest ships.

Air Compressing Machinery.—Air compressors are used to compress the air which is used in Whitehead torpedoes.

The pressure to which air is compressed may be as much as 2,500 lbs. per square inch.

The arrangement of air compressors made by different makers varies, but in all the compression is carried out in three or four stages, the cylinders and spaces into which the air is admitted becoming smaller and smaller with each stage.

As the air is compressed and its pressure increases it gets hot, and to prevent the fibre washers which are used to pack the plungers from being burned, and to save unnecessary work from being done by the engine, it is cooled as it passes through the compressor. For this purpose a water jacket is formed round the compressor through which a pump worked by the engine circulates sea water, and the air after leaving each stage passes through copper coils placed in this water jacket and is there cooled nearly to its original temperature. In addition a spray of water and about a drop of light oil a second are allowed to enter each compressor with the air.

To prevent the water and oil admitted with the air from passing to the torpedo with it, the air is passed through a separator column after it leaves the compressor.

The separator column is a steel tube closed at the ends by bronze caps; it is placed vertically, and the water and oil which fall to the bottom are blown out either by an automatic drain worked by a float or by the hand drain valve.

The proper working of the compressor depends in great degree on the efficiency of the fibres used for packing.

The fibres are supplied ready cut and before fitting in place they should be softened by soaking in water.

The valves must be kept clean and in good condition. When the compressor is at work care must be taken that the cooling water in the jacket is circulating efficiently and the discharge must be felt to see that it does not get too hot.

Neatsfoot oil must be used inside the pump; or, if not supplied, some animal oil. The water used inside the compressor must be free from dirt and should if possible be distilled, and a special condenser is fitted on all modern air compressors which makes the fresh water used.

In electrically driven pumps the lubricating oil in the crank chamber should be kept at as low a level as possible to prevent the splashing on the cylinder walls and passing over of crank chamber oil to the air system.

The valve on the pressure gauge of the separator column is always to be left open, so that any pressure left in the pump or the separator may be indicated and accidents in disconnecting the pumps, &c., avoided.

All parts of the compressor and separator column should be blown out and drained of water after use.

Compressed air is stored in capped tubes similar to the separator column but placed horizontally; these tubes are arranged in nests and connected up by branches with valves for admitting air from the compressor, discharging it to the air service and draining water away.

In recent ships these tubes have been replaced by air bottles of larger capacity.

Where it is desired to level the pressure in different parts of the air system and one of the parts is of small volume, care must be taken to open the valves very gradually indeed and not to allow the pressure to rise too quickly, as there is a risk of explosion of any oil which may have collected if too sudden a generation of heat occurs.

REFRIGERATING MACHINERY.—Refrigerating engines are used in a warship to cool refrigerating chambers for the storage of fresh meat and vegetables, to make ice, and to cool the air in magazines.

Three types of machine are in use in the Navy, viz.:—

Cold-air.
Carbonic anhydride, or CO_2.
Ammonia anhydride, or NH_3.

Cold-Air System.—We have seen in considering the air compressor used for supplying air to the torpedoes that when air is compressed it becomes hot, conversely if air expands it becomes cold.

In the cold-air machine air is sucked into the *compressor cylinder* at atmospheric pressure and compressed to about 60 lbs. per square inch or so, it becomes heated and is partly cooled by sea water circulated round the compressor, and finally by passing through the *cooler*, a vessel similar to a surface condensor and furnished with a supply of cooling water; the air thus cooled to nearly the temperature of the sea water but still carrying a considerable pressure is led to the *expansion cylinder*, where it expands and losing further heat reaches a very low temperature. The expansion given in the expansion cylinder is regulated by slide valves, rods, and eccentrics similar to those employed in the steam engine. The cold air exhausted from the expansion cylinder passes through the *snow box* and any moisture in it is deposited as snow and may be cleared away.

In cold-air machines as little lubricant as possible should be used in the compression and expansion cylinders, and it is most important that wooden *air trunks* and *ice boxes* should be kept perfectly airtight; they should be smoke tested immediately on the machine showing any falling off in efficiency and any leakage detected should be made good.

Leaks can generally be detected by a lighted taper and may be stopped temporarily by a little putty

In working cold-air machines it is of importance that an ample supply of cooling water should be maintained. The circulating pump on the machine and its valves must be kept in order to ensure this, and if necessary the branch supply from the fire main must be used.

It should be remembered that with an increase of temperature in the circulating water a lower pressure in the discharge from the compression cylinder may be required, this can be obtained by adjusting the expansion valve on the expansion cylinder.

CO_2 Machinery.—In carbonic anhydride machines the gas is compressed to a high pressure in the compressor A, which is single-acting, and discharged through the separator H; any oil carried by the gas may be blown out through the valve J.

Passing to the condenser B, a coil of pipe in a tank through which sea water is circulated, the gas becomes liquefied and escapes through the regulating valve G to the evaporator coil D, where it evaporates into CO_2 gas, cooling the brine in the surrounding tank.

The gas on leaving the evaporator returns through the suction stop valve K and the gauze strainer V to the compressor.

When the machine is running heat is being continuously withdrawn from the gas in the condenser, and the gas itself in the evaporator is continuously taking heat from the brine. In an ice machine the moulds containing the water to be frozen are placed in the brine in the evaporator tank; but if the machine is for magazine cooling or cooling a storage room the brine is pumped away as shown in Fig. 28, where the pump E circulates it through cooling coils.

Besides the parts already mentioned—

There is a stop valve L in the discharge from the compressor. When it is required to rid the circuit of air before charging with CO_2 this valve is shut, and a plug N on the compressor side of it is unscrewed and the pump started to pump out the air through it, leaving a vacuum in the system.

M is a plug on the compressor side of suction stop valve for use in drawing air when it is required to pump the system full of air for testing purposes with the suction valve K closed.

O, situated at the top of the condenser coil, is the foul gas valve for ridding the circuit of air or gas which is not CO_2 when the machine is running.

P is the condenser gauge showing pressure and corresponding temperature of CO_2 gas before it enters the condenser.

Q is the evaporator gauge showing pressure and temperature after the gas has left the evaporator.

R, situated on the evaporator side of the regulating valve, is the charging valve for admitting gas from a CO_2 flask to charge the machine.

S is the lubricator which is fitted with filling plug and a valve to admit the oil to the compressor, to fill, close the valve and fill through plug on top. To start the lubricator working, open valve slightly.

C is the pump circulating sea water round the condenser coil.

Before charging the machine with CO_2, examine, clean, and replace the gauze strainer V.

Place the compressor piston at the bottom of its stroke, and lubricate it by emptying the lubricator S into the cylinder.

Open all the valves in the circuit and remove the plug M, keeping the valves O, J, R, closed, run the engine and pump air round the circuit for some time.

Now shut the suction valve K and run the machine till the condenser gauge shows a pressure of 70 atmospheres, and having painted all glands and joints with a lather of soap and water, examine for leakage, and go over all the joints till everything is tight at that pressure.

After this pump the air out of the machine by replacing M, taking out N, shutting L, and opening K. When all the air has been pumped out replace N, and the machine will be ready for charging through the valve R.

Directions are issued with each machine detailing the best conditions of working, and the steps to be taken to remedy any causes of failure.

As a rule when the machine is working the discharge from the compressor should be warmer than the hand can bear, and its suction and the bottom of the compressor cold.

Assuming that the machine is running properly, and charged with the right amount of gas, this will be controlled by the regulating valve G.

A very high pressure is maintained in the compressor, and it is important that its valves and its piston rod should be perfectly tight, and to ensure this the utmost care must be taken to keep them in good condition.

The gauze strainer V is fitted to prevent dirt or any scale from the inside of the coils from getting to the compressor.

If the engine is stopped for any time the compressor rod must be taken out and well greased; it must not be left in the packing.

The compressor rod is packed by cup leathers between which mineral oil is forced at a pressure exceeding the compression pressure.

Cocks are placed on top of the condenser and refrigerator casings to deal with accumulation of gas; these should be left open when the machine is not at work, and opened for a short period once in each watch when it is at work.

As hydrogen gas is liable to be generated in the condensers and refrigerators, naked lights should not be brought near the ends of the escape valves from the casings.

The ventilation of the compartment in which CO_2 machines are placed should be kept as efficient as possible, and whenever machines of this type are in use, a lighted candle should always be placed on the deck near the machine, as a precautionary measure, to indicate the presence of any serious leakage of CO_2 gas. The CO_2 gas being heavier than air will accumulate in the bottom of the compartment, whence it can be discharged by a fan fitted for the purpose.

In the case of a large leak in a CO_2 machine, such as due to the safety disc bursting, it will usually be impossible to close the valve to the condenser sufficiently quickly to save any portion of the charge, and where the machine is situated in a small compartment no attempt should be made to do so, but the compartment should be temporarily left.

NH_3 Machinery.—The action of ammonia anhydride machines is similar to that described for CO_2 machines, but a very much smaller pressure is necessary in the compressor and condenser. They have the

To face page 48.

Fig. 28.

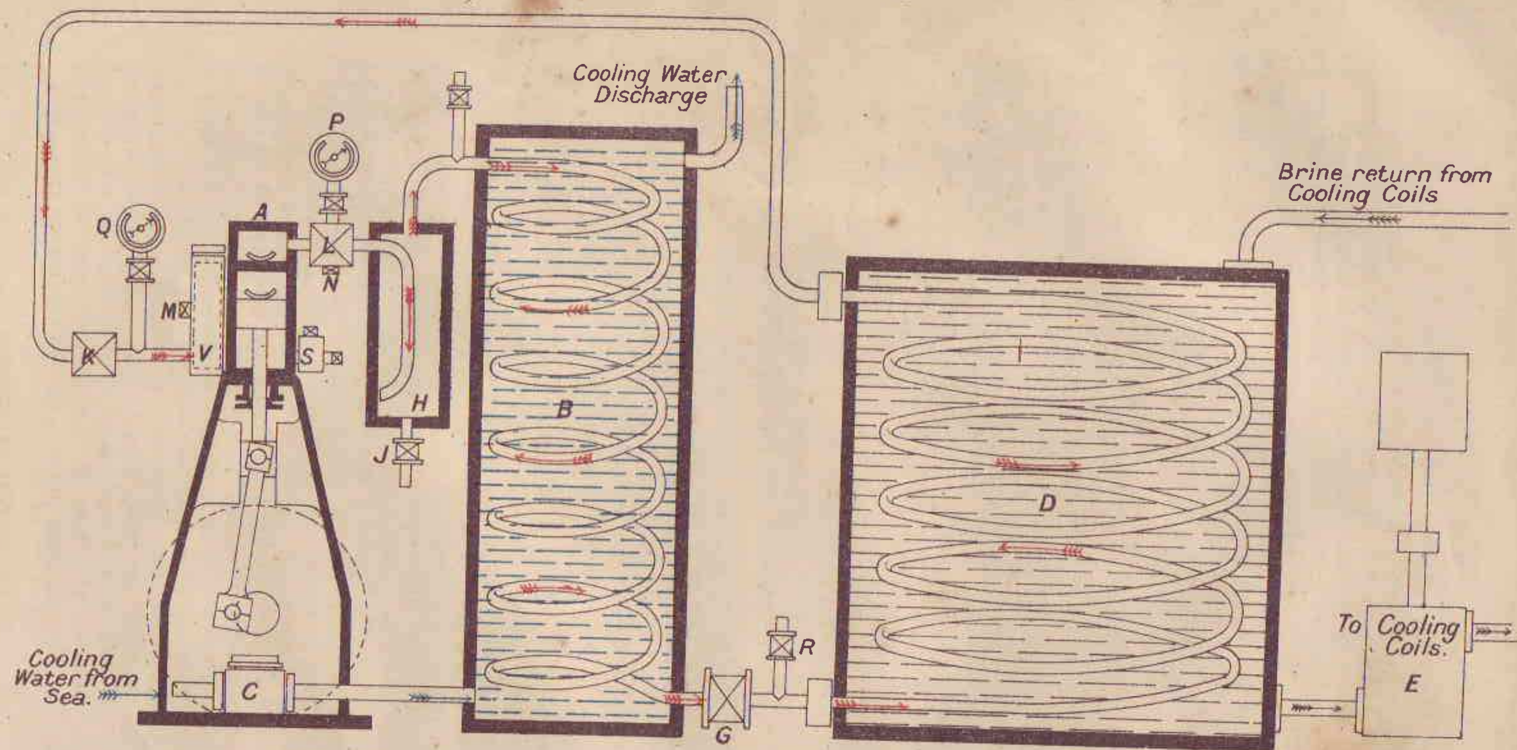

DIAGRAM OF CARBONIC ANDHYDRIDE REFRIGERATING MACHINE.

Carbonic Acid circuit
Cooling Water from Sea
Brine

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same parts as shown for that machine in Fig. 28, except that it is not necessary to fit a wire gauze strainer in the suction to the compressor.

As with the CO_2 machines, mineral oil only is to be used on the compressor glands, and the same precautions are to be taken to prevent accumulation of gas in their condensers and refrigerators and to keep naked lights away from the end of escape pipes from them.

On account of the corrosive nature of ammonia gas it is necessary to guard against leakages.

Ammonia gas is exceedingly soluble in water, and a water service is fitted to enable the ammonia connections to be drenched in the event of a sudden leakage; it should always be tested on starting the machine.

Usually the machine can be approached if the leakage is slight if a piece of wet rag or waste is held over the mouth or nostrils, but in the event of a bad leakage of ammonia, or if the shut-off valves are defective when repacking the compressor gland, the whole charge should be blown out through the emptying pipe, which should always be kept in position with a bucket of water handy to receive the ammonia.

Water of a temperature greater than that of the atmosphere should never be put into the ice pails as it is dangerous to do so.

Lead washers are supplied for making joints on the ammonia circuits of machines.

Brass and copper must on no account be used.

Care is to be taken when handling or transporting filled flasks of ammonia and CO_2 gas; they should be enclosed in wooden cases and must not be dropped nor subjected to rough usage.

The brine for use with refrigerating machinery should never be made with salt water; it is made by dissolving calcium chloride in fresh water.

For provision room cooling and ice making it should have a density of 1·25, that is to say, a gallon should weigh 12½ lbs. For magazine cooling the density may be 1·12.

AUXILIARY EXHAUST PIPES.—The exhaust steam from most of the auxiliary engines passes into the auxiliary exhaust pipes which lead to the auxiliary condensers; these have circulating and air pumps similar to those fitted to the main condensers. The auxiliary exhaust pipes are also so arranged that the exhaust steam from most of the auxiliary engines may be led either to the evaporators or to one of the receivers of the main engines; when so used a pressure is maintained in the exhaust pipes.

INTERNAL COMBUSTION ENGINES.—The fuel for these engines is burned inside the cylinders as implied by their name.

In dealing with coal and oil, precautions are necessary in confined spaces to prevent naked lights or sparks from electric terminals from exploding mixtures of gas which escape from the fuel with air.

In the internal combustion engine the force obtained from similar explosions is usually employed in driving the pistons, the engines being arranged to control the mixing of vapour and air, and to regulate the explosions.

In the Navy internal combustion engines of different types are fitted to propel submarines and boats, and they are also used to drive dynamo engines. In all these the vapour of petrol or oil is mixed with air by the action of the engine, and this mixture is ignited either by the flame of a lamp or by an electric spark, the force of the explosion driving the piston. The greatest care must be taken with these engines, especially where situated in a confined space, that the inflammable mixture is not formed outside the engine due to leakages in pipes, &c.

Vaporisers.—The vaporisers should be cleaned at regular intervals, the frequency of which will depend on the quality of the oil used.

Internal Chambers.—Special arrangements for lubricating the cylinders of these engines have generally been found unnecessary. Where necessary special mineral oil is to be used, but if unprocurable ordinary service mineral oil may be used, in which case the pistons and cylinders are to be more frequently examined for deposits of carbon.

Crank Chambers.—The level of oil in the crank chambers is to be kept as low as is found just sufficient for the lubrication of the bearings. Any excess of lubricating oil is found to pass the pistons into the combustion space, where it burns, fouling the cylinders, and increasing the expenditure of oil for combustion.

The crank chambers should be cleaned out at intervals and filled with clean oil.

Cylinders, Jackets, and Covers are to be examined regularly, and any deposits from the circulating water removed from the surfaces. In the event of the cylinders heating internally the jacketed surfaces in contact with the cooling water should be cleaned at the earliest opportunity.

Pistons and Valves.—The pistons and valves of internal combustion engine must be kept clean and in good condition, in order that the work of the engines may not be impaired by leakage during compression. Leakages of oil in the oil supply pipes should be stopped at once. In petrol engines these are very dangerous.

When opening out internal combustion engines electric lamps, the connections of which are in good order and not liable to sparking, should be used if possible. No naked light is to be brought into the vicinity of the vaporisers or crank chambers until all inflammable gas has been expelled.

The inflammable vapour which may be formed being heavier than air, its dispersion from tanks and closed spaces by ordinary means of ventilation is very difficult. The use of bellows or windsails will assist in expelling the vapour. In motor boats especial care is necessary.

Matches or lamps are on no account to be brought into the vicinity of fuel tanks or lockers.

Cans for containing inflammable oil, whether empty or not, must be securely closed and stowed in the locker provided. When not required to be open, the locker is to be properly closed; it is not to be used for any other purpose than storing the cans.

If fire extinguishers are supplied for motor boats they are always to be carried in the boat, and the crew are to know how to use them.

Hoisting in Motor Boat.—The oil supply is always to be shut off before the boat is hoisted on board.

CHAPTER VII.

RAISING STEAM AND MANAGEMENT UNDER WAY.

Although boilers are generally prepared for steaming beforehand, it must always be ascertained immediately before lighting fires that the amount of water ordered is showing in the gauge glasses. About three inches in the glass is usually carried with tank boilers and water-tube boilers of the large tube type. With small tube water-tube boilers this quantity will generally be sufficient except in Thornycroft boilers, in which the ends of the generating tubes are above the water level, where, while raising steam or waiting for orders (that is to say, where the upper bends of the tubes will not have water forced through them by the circulation in the boiler), the level of the water in the steam drum should cover the mouths of two or three of the lowest rows of generating tubes. In this type of Thornycroft boiler no attempt should be made to get up steam quickly by burning wood, oily waste, or any other substance which would expose the dry part of the tube to the action of flames.

Raising Steam.—Lay and wood fires and light fires up when ordered.

See that the dampers are open, the draught plates shut and furnace doors open.

See nothing inflammable is on top or at the sides of the boiler.

In cylindrical boilers where the furnaces are not on the same level, light the lower furnaces first so as to gradually heat the boiler.

Steam should always be raised slowly in cylindrical boilers and also in water-tube boilers where the brickwork is new or recently repaired, if the service allows, but at other times, when urgently required, steam may be raised in water-tube boilers more rapidly.

Time should always be allowed, however, to properly warm the engines.

When the front of the fire is thoroughly burnt through push it back with the rake over the unlighted part of the coal, and lightly sprinkle coal over the furnace. Shut the furnace door and open the draught plates.

The fire should be kept as thin as possible and without holes while raising steam and until the engines are under way; this will guard gainst blowing off and will also prevent the fire-bars from becoming warped or bent.

If valves are shut when the water is cold they will be very hard to open when hot, so they should be eased off their seats when fires are lighted.

If the steam pipes between the boilers and engines are not in use, directly fires are lighted the boiler stop valves and all valves between boilers and engines should be opened enough to allow hot air and steam as it rises to circulate through pipes and engines and warm them up gradually. All drain cocks and valves should be opened to clear the various parts of water.

Cylinder and slide chests, drains on both main and auxiliary engines should be kept on the bilge till it is certain there is no oil or grease in the drainage water.

Care must be taken that the water level in the boilers is not unduly lowered before there is steam enough to work the feed pump.

The turning gear must be taken out before there is steam enough to turn the engines. This will generally be ordered to be done either before or directly fires are lighted.

If a boiler is to be connected to other boilers in use the stop valve must not be opened until its steam pressure is slightly greater than that in the steam pipe which connects it to the other boilers, but the air cock and drain cocks on the pressure gauge pipes should be opened as soon as fires are lighted to allow the air to escape and kept open until steam blows through.

It is most important that air should be allowed to escape from a boiler while steam is being raised. If this is not done a pressure which increases very quickly is shown by the pressure gauges before steam begins to form.

The effect of this pressure is to check the formation of steam and to hinder the circulation of the water in the boiler, and, if it is not detected that the pressure is due to the presence of air, the boiler may be connected before steam is being formed in it.

Before the stop valve is opened the valve box and branch to the main run of steam pipes must be thoroughly drained of water. The stop valve at first should only be opened sufficiently to just allow steam to pass from the boiler, and it should not be opened wide till it is evident that the branch pipe and valve box are thoroughly heated and drained. On any sign of water hammering in the pipe the stop valve should be closed and the necessary steps taken to ensure the stop valve box and pipe being again drained before a fresh attempt is made to open out. When opening out a stop valve it should be ascertained by watching the spindle that the valve actually opens as the wheel revolves. The same precautions should always be taken in opening a valve to admit steam from one steam pipe to another, and it should always be borne in mind that steam will condense in the ends of runs of pipe at which no engines are at work.

In the Dürr boiler the superheater must be drained before connecting.

Stop valves should be opened gradually both when admitting the steam to the engines and when admitting steam into any fresh system of steam pipes.

As soon as steam appears attention should be given to all boiler fittings and feed arrangements to see that they are in good working order.

The gauge glass is to be blown through as follows to make sure that it is in working order:—

1. *Close the water cock and open the drain cock*, steam should pass through the steam cock down the gauge glass, drain cock, and drain pipe into the bilges, and can be heard showing that the steam cock is not choked.
2. *Close the steam cock and open the water cock;* if water is heard blowing in the bilge it shows the water cock is clear.

3. *Close the drain cock and open the steam cock.* The gauge will then indicate the level of water in the boiler; the water should come up smartly in the glass. If the water rises slowly the water cocks or water passage are probably choked.

Whilst steam is being raised special care should be exercised in tightening up any handhole door which may have been taken off for examination or cleaning in Belleville, Babcock and Wilcox, or Dürr boilers.

In the Dürr boilers, if the door still leaks after being tightened up, the nut should be slackened back slightly and the door tapped and allowed to reseat itself, retightening to the same extent as before. As the joint is a metal to metal one it should be remembered that undue force would only strip the thread.

No joint should ever be tightened up under any circumstances in a Niclausse boiler under steam, and smoke-box doors should always be kept closed while the boiler is working.

The safety valve easing gear should be worked to see that all is clear, but *where the machinery is in charge of an Engineer Officer*, it should not be moved so far as to lift the valves off their seatings until ordered.

Where the machinery is not in charge of an Engineer Officer the safety valves are to be lifted occasionally while the steam is rising, and after it is raised, to see that they are free in their seats and that the springs continue in proper working order. The safety valves should also be lifted occasionally when the vessel is under way for the same reason.

Great care should be exercised in lifting the safety valves to avoid injury to the valves and seats by dirt and scale being blown through them.

Safety valves should never be opened suddenly to their full extent.

The feed pumps should be warmed through and as soon as the steam pressure is high enough the pumps should be started slowly and a small quantity of water discharged into the boiler to make sure everything is clear.

As soon as the boiler is connected the draught plates should be adjusted as required and careful attention paid to the condition of the fires, the water level as indicated in the water gauges, and the steam pressure as shown by the pressure gauge.

Steps are to be taken to ensure that under all conditions of working the steam stop valve to main feed pumps is open sufficiently to ensure an adequate supply of feed water when the height of water in boilers is regulated by an automatic feed apparatus.

When steaming, about a half glass of water will usually be ordered to be kept, but with the boilers of the Thornycroft type referred to in which the ends of the generating tubes are above the water level, the water in the glasses should be kept as high as possible without causing the boiler to prime.

In order to guard against water passing over from the boilers to the engines the boiler stop valve should only be opened wide enough to pass the required quantity of steam, and care should be taken to start the engines slowly and gradually work up to the required speed.

In all boilers the working level of the water should be constantly maintained at the height which is ordered, and both gauge glasses should be worked by in order that any considerable difference of their indications may be investigated and put right.

The gauge glass should be blown through occasionally as previously described to ensure that the connections are clear. Where an automatic feed regulator is fitted the apparatus should be moved by hand at intervals so as to make certain that everything is free.

All persons attending boilers under steam should be repeatedly cautioned against the tendency to rely solely upon the automatic feeding arrangements for keeping the correct water level without attention to the water-gauge glasses. The water-gauge glasses should always be carefully observed.

Attention is directed to the grave risk attached to the practice of closing feed check valves of boilers fitted with automatic feed apparatus to prevent the gauge glasses filling when cleaning fires or lighting up, particularly when these operations are carried out shortly before changing watches. It has been found in some cases that the feed checks have been left closed when subsequently raising steam, thus preventing action of the automatic feed apparatus in maintaining a proper water level. The result has been that the rapid fall of water level has been unobserved, and the boiler or boilers have been damaged.

In relieving watches, the Chief Petty Officer or Stoker Petty Officer acting as water tender of the oncoming watch is always to satisfy himself that the feed check valves are fully open.

Should any difficulty be found in keeping the proper water level with the feed pumps, the fires should be checked by closing the ash-pit doors or reducing the number of oil fuel sprayers in use and steps taken to find out the cause. If the water disappears below the bottom of the gauge glass and the cause cannot be discovered at once, the oil fuel supply to the boiler should be shut off, the boiler stop valve must be closed, safety valves lifted, and the fires put out.

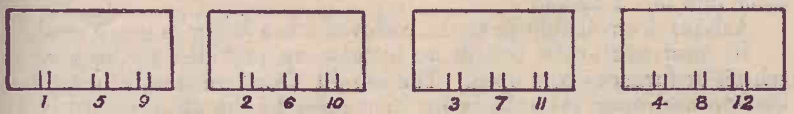
A report of steps taken should be made at once to the Engineer Officer of the watch in the Engine Room.

All ratings in stokeholds are authorised to shut the draught plates on a boiler and shut off oil fuel should they see no water showing in the gauge glasses. The occurrence should be at once reported to the person responsible for feeding the boilers.

Forced Draught.—With natural draught, that is, draught due to the height of the funnel only, the power of a boiler is limited, and it is therefore necessary that other methods should be adopted to increase the draught and thus the power of the boilers. For this purpose centrifugal fans are fitted to draw air through the cowls on the upper deck and discharge it into the stokeholds, and so past the draught plates into the ash-pits and through the fires.

Management of Boilers under Way.—To maintain a steady steam pressure and to ensure economical working it is necessary to keep the fires even at the proper thickness and to fire regularly. The best results for natural draught are generally obtained with a thickness of 4 inches to 6 inches.

To assist the stoker to fire regularly the furnace doors in each stokehold are numbered in a similar manner to that shown in the sketch and should be fired in numerical order.



When all the furnaces have been fired, the time the stoker will wait before again commencing firing will depend on how much the boilers are being forced.

In modern ships an electrical instrument is provided which rings a bell in each stokehold when the firing is to commence, the time at which the bell rings being adjusted from the engine room.

The furnace doors should not be kept open longer than is necessary. Two men should work together when possible, one to put the coal on and the other to open and shut the door.

When a furnace door is open for firing the stoker should see at a glance where the coal is required. The flame caused by the first shovelful if placed at the front of the furnace prevents the stoker from seeing the exact condition of the fire afterwards, and for this reason the grate should be fired commencing towards the back and working to the front. Care should be taken to prevent the fires becoming thin at the sides of the grate and between the furnace doors. The coal must be well broken up and thrown on the fires quickly, the largest lump being not greater than a man's fist.

In water-tube boilers of the small tube type care should be taken that coal is not thrown over the brickwork at the lower ends of the tubes, where it might cause overheating of the tubes and choking of the air passages betweeen them.

The small coal that falls through the bars and all partially burned coal should be reburned, and the fires should not be unnecessarily forced or disturbed.

All ships with water-tube boilers, except torpedo boats and torpedo boat destroyers, are fitted with fenders to their ash-pits in order to prevent coal from being pushed into the ash-pits by accident and to make shovelling easier.

Looking into the ash-pit will show the spots at which a fire is not burning bright, and at which it may be necessary to use fire-irons to break up coal which has caked or to stir clinker from the top of the fire-bars.

Smoke may be considered as fine particles of coal carried up by the draught before it has time to burn, and indicates that the coal is not being burnt as economically as possible. If the firing is carried out as described, and careful attention paid to the fittings for regulating the air supply to the fires the production of smoke will be largely prevented.

The fires should be kept clear of the dead plate so that the furnace door baffles will not be burned away.

When draught plates are adjustable they are so balanced that in case of an escape of steam into the furnace and ash-pit the rush of steam past the ash-pit door will cause it to close.

The amount of opening of the ash-pit doors when adjustable should be kept as small as possible to obtain the best results. They should never be opened wide except to remove the ashes, as it has been found that self-closing doors are liable to stick when in a horizontal position in the case of a tube giving out, thus failing to check the rush of steam and flame into the stokehold.

Ash-pit doors should never be removed when boiler is being used.

In most small-tube boilers no fittings are provided for keeping the ash-pit or furnace doors open. The ash-pit doors are simply hung from the top and open inwards, being kept open by the air pressure in the stokehold.

If it is absolutely necessary to open an ash-pit door so wide as to interfere with its automatic closing in the case of cleaning fires or for any other purpose, it is to be replaced in its automatic position directly the operation is completed.

The furnace doors are generally so hung that unless held open they close by their own weight, and in some cases a spring is fitted to ensure the door closing when released. They are so constructed that in the event of a tube bursting, the furnace door, if open, on being let go will immediately close, as will also the ash-pit door from the pressure of steam in the ash-pit; thus preventing the steam and flame from escaping into the stokehold.

It is most important to keep these fittings clear of obstructions so that they may immediately close in case of necessity.

The ashes should be removed as often as convenient, as they interfere with the draught and damage the fire-bars.

Water should only be used in the ash-pits to a limited extent as too much water causes a deposit to form on the tubes nearest the fire.

The coal trimmers should be trained to fill the coal buckets and to be careful in tallying them, and Chief Stokers, Stoker Petty Officers, and leading stokers should consider it an important part of their duty that the coal is properly charged.

If the engines are suddenly stopped, steam should not be allowed to blow-off through the safety valves, but should be checked by closing the ash-pit doors, and if necessary by gradually opening the silent blow-off, which must be used with great caution and never opened suddenly.

With water-tube boilers of the small tube type ease the fans; if burning coal, open the hatches; if burning oil, regulate the burners as necessary.

With Belleville boilers open the tube-box doors and ease the furnace blast. With tank boilers, the safety valves and smoke-box doors should only be opened when absolutely necessary, and then but gradually.

The fire-extinguishers fitted to water-tube boilers should only be used in cases of emergency, as their use injures the tubes by causing them to become pitted on the outside. They should, however, be tried cautiously once a week.

Care should be taken at all times to prevent the steam pressure becoming high enough to lift the safety valves. In addition to the loss of water caused, it is often found that when the pressure falls and the valves shut, a slight leakage continues due to the scoring of the valve or to grit on the seating.

Cleaning Fires.—After steaming for some time the fires become clogged by clinker and dirt, and it is necessary to remove this to allow the fires to burn freely. This is done by burning down the fire and detaching the clinker from the fire-bars by means of a long slice and pulling out the clinker and dirt into the stokehold with a rake. Burning coal from the adjacent part of the furnace is drawn over and spread over the clean bars and fresh coal thrown on the top. As soon as the fire is properly burnt through routine firing should again be commenced.

The fire on the grate opposite one furnace door only should be cleaned out at a time, as if a number of fires are cleaned out at the same time difficulty will be found in keeping up the steam pressure.

A good plan to adopt in cleaning fires is as follows:—

The section of grate opposite Nos. 1, 2, 3, and 4 furnace doors should be cleaned in one watch, the section opposite Nos. 5, 6, 7, and 8 furnace doors, in the next watch, and so on, with regular intervals between the fires cleaned in each watch, so as to divide the work equally throughout the watch.

The fire-bars should be kept free from clinker in the intervals between the cleaning of the fires by running the slice along the bars at intervals, and removing the clinker with a rake.

Cleaning the Fire Side of Tubes.—Soot is formed by the gases given off by the coal and lies in the tubes of cylindrical boilers and on the tubes of W.T. boilers, it also collects in the smoke-boxes, uptakes, and funnel. The soot deposited on or in the tubes obstructs the passage of heat and reduces the power of the boiler, and should be removed at intervals. With W.T. boilers this should be done just before cleaning fires, one boiler at a time, so as to spread the work over all the watch, and also to prevent the clean fires from being choked by the soot and dirt displaced.

How often the tubes will require cleaning will depend on the quality of the coal and the amount the fires are forced. The tubes of large tube W.T. boilers are cleaned by a jet of steam or air discharged from a lance which is directed amongst the tubes.

Where possible the lance should be passed across the boiler from side to side commencing at the top and working down to the bottom. Care should be taken to well blow through the lance before using, otherwise the soot on the tubes will be wetted and cake on.

Steam tube cleaning apparatus fitted with small-tube boilers is only for use in cases of emergency.

Deposit which accumulates on the bottom rows of tubes should be removed by scrapers when the fires are being cleaned.

OIL FUEL.—After using oil fuel, and before again lighting up, care is to be taken that ash-pits and furnaces are well ventilated, and when lighting or relighting a sprayer the operator should stand clear of the sight-holes.

The whole of the oil system between the pumps and the sprayer spindles should, on all occasions after overhaul, before the oil is heated, and before lighting up, be put under the maximum working oil pressure by means of the pumps, in order that any leakage may be detected.

When a sprayer is lighted the oil supply should always be turned on gradually. A sprayer should never be left in place disconnected, and, if it is removed for any length of time, a screwed plug should be inserted in the union at the end of the supply pipe.

Should a leakage of oil occur at any time, immediate action is to be taken to shut off the oil supply by means of the stop valves provided and to stop the oil pump.

In working oil fuel installations attention must be paid to—

Pressure of Oil in discharge from Pump.—This to a great measure controls the amount of oil supplied.

It should never exceed 150 lbs. per square inch where ships have been designed for a greater pressure; in these the pressure used on the contractors' trials is not to be exceeded without special orders. Oil pressure should be kept steady; this is aided by keeping a low oil level in the air vessel, but the oil should always be kept in sight in the glass.

The oil level in the air vessel will rise when the pressure in the pump discharge is increased, and will fall when it is lowered. If additional air is required in the air vessel it may be let in through the air valves on the pump, and air may be discharged from it through the air cock on top of it.

An increase or decrease of the amount of oil required to be burned should be made by increasing or decreasing the oil pressure as required rather than by altering the position of the burner spindles. If necessary, sprayers should be shut off.

Temperature of Oil.—The oil is heated to make it thin enough to spray properly. If the temperature is raised too high the oil will decompose and particles of carbon will choke sprayers, filters, heaters, and pipes. On the other hand, with too low a temperature the output of the sprayers is increased and oil may drip from the cones, besides which there is risk of damage to the fireclay plugs over the bolts securing the brickwork and to the brickwork itself.

The temperature to be kept will depend on the thickness of the oil used, ordinarily it will be about 200° F., but with thinner oils lower temperature is required, if there are undue pulsations at 200° F. These pulsations may be reduced by fixing the sprayer nearer the air cone.

Air Supply.—The amount of air supplied should be such as to produce smoke which is just visible at the funnel, at the same time the doors to each cone should be kept as wide open as is consistent with obtaining a proper flame from each sprayer.

If the air pressure is increased above that necessary to produce smoke which is just visible, the smoke will disappear but the efficiency of the boiler will be decreased.

The air supply should be increased or decreased as necessary to keep smoke just showing by regulating the speed of the fans whenever the oil supply is altered.

On easing down or stopping the oil supply should be reduced before the air supply, so that any inflammable gas may be blown out.

The flame in the air cone should be frequently observed to see that it is efficient, and the air cone should be inspected frequently for deposit; generally the cones require cleaning at intervals of 20 to 30 minutes.

The rate at which deposit lodges will be increased if the air supply is sufficient.

When burning coal and oil if the fires are clean the draught plates should generally be more or less closed, and their opening should be gradually increased as the fires become dirty.

The fire-bars should be kept well covered and the fires should be even and of moderate thickness, there should be no holes. Coal should be put on in small quantities.

Fires should be kept off the dead plates to prevent blocking the cones and overheating of furnace fronts and cones. Fire doors should be kept open as small a time as possible.

When burning oil fuel it is very necessary to take precautions that the boilers are not worked above the power intended, and the oil pressure, temperature, the number of sprayers in use, the amount of opening of their spindles, and in addition the quantity of coal allowed for each boiler, if oil and coal are being burned together, should be as ordered.

Precautions against Fires.—No oil should be allowed to accumulate in the air boxes, bottoms of furnaces, bilges, or on the floor plates, and a careful watch is to be kept on the bilges to detect the presence of oil. No lighted material is to be allowed access to the bilges.

Should any material quantity of oil accumulate in the bilges, the oil supply to the boilers should be shut off, and if coal fires are alight they should be extinguished by water. If the oil in the bilge shows any signs of overheating water should be directed into the bilge to cool the oil, and the bilge pumps used as necessary to clear the bilge.

With reasonable care there should be no danger of an oil fire in the stokehold.

Should a small fire occur such as an ignited pool of oil on the floor plates, it may be smothered with fireclay or a damped piece of canvas; such materials should be kept at hand for the purpose.

If the fire occurs where it cannot be got at to treat it in this manner, water should be directed on it. If the fire cannot be readily extinguished by the above means, the oil supply to the boilers should be shut off; coal fires, if any, extinguished by water, fans stopped, and all air doors on the boilers closed. Should the fire increase all hands should be sent out of the compartment, which should then be closed and its funnels and ventilators covered and every possible means taken to prevent air passing into it.

Leakage of Oil in Heater.—Every care is to be taken to prevent leakage of oil through the tube ends of the oil heaters. If leakage does occur, the oil is liable to mix with the feed water and cause damage to the boilers. The oil pressure should be, whenever possible, lower than that of the steam supply to the heaters, and the water collectors are to be occasionally drained in order to test the absence of oil in the water.

Use of Lime in Feed Water.—Whenever water-tube boilers are under steam lime should be dissolved in the feed water and introduced into the boilers to assist in their preservation; besides facilitating the deposit of grease in the mud drums, it keeps the feed water in an alkaline condition.

It should be dissolved as far as possible in buckets, and the chalky liquid poured into the lime tanks, or into the feed tanks where lime tanks are not fitted.

A portion of the lime will be found to be insoluble in water, and this heavy residue should be thrown away.

The amount of lime introduced should, as far as practicable, be regulated according to the amount of feed water delivered.

Where a continuous addition of lime cannot be arranged, small amounts at frequent intervals should be introduced and the addition of large quantities at a time avoided.

It is very desirable that the lime be thoroughly mixed with the feed water before the latter passes through the feed filters.

Grease filters require to be frequently cleaned and filtering material renewed as necessary. With the type now fitted this is necessary after about three days' ordinary steaming.

Care should be taken in replacing the grids or filtering material that no space is left through which greasy water can pass without being filtered.

Blowing down.—Besides being used to keep down the density of the boilers in case of leakage of salt water in the condenser, the blow-downs are used to get rid of the lime and grease. In water-tube boilers of the large tube type this should be done as follows:—

The blow-down valve should be opened wide quickly for about two seconds and then closed quickly. After waiting about one minute this operation should be repeated. This removes the deposits from the mud drum.

Where double valves are fitted in the blow-down system the valve next the boiler should be opened before and closed after the second valve in order to reduce the scoring action on the inner valve.

The blow-down valves should never be opened a small amount for a long time in order to blow out, as this may choke up the valve or cut the faces and make it leak.

Tank boilers and locomotive boilers are never to be emptied by blowing them out, except in cases of extreme urgency, as such a practice causes leaky tubes and joints, but the water is to be allowed to remain until it has become cool before the boilers are emptied; and cold water is not to be pumped in for the purpose of reducing the pressure of steam or of cooling the water preparatory to running it out.

Scumming.—If the gauge glasses show that oil or dirt is present the scum cocks on the steam drum where so fitted should be used as follows:—

The water level should be increased to about $2\frac{1}{2}$ inches above the usual level, and the scum cock should then be opened and kept open until steam blows through.

When a water-tube boiler is to be shut off the blow-down and scum cocks should be used to remove accumulations of dirt, and the fires should be allowed to burn down slowly so that dirt remaining in the water will not settle in the tubes.

To replace a broken Gauge Glass.—Shut off the water and steam cocks, unscrew the top and bottom nuts and remove the top cap plug. Remove the broken glass and the old packing. Pass the new glass through the top cap plug hole and place the new packing rings on the glass in their proper relative positions.

Replace the top cap plug and see that the glass cannot be lifted out of the bottom recess.

Tighten the nuts by hand while the glass is lifted about one-sixteenth of an inch. Now warm the glass through by opening the drain cock wide and the steam cock slightly so as to allow steam to blow through. When the glass is heated the drain cock should be closed, the water cock opened slowly, and the steam cock opened wide. If there is any leakage the nuts may now be tightened up by a spanner, but this should be done carefully. If india-rubber rings are used for packing they should have an asbestos washer on each side of them.

Every Petty Officer and Stoker in whose care a boiler is placed is to fully understand the correct method of renewing and testing water-gauge glasses. If it is necessary to replace a glass when no officer is present, a report is to be made as soon as possible in order that the gauge and its fittings may be inspected by one.

Fresh Water Supply.—To prevent the deposit of salt or scale, except in cases of emergency, fresh water only is now used for feeding the boilers. Fresh water is lost by leakage of steam from joints and glands, and also by leakage from glands and joints of pumps, feed pipes, &c.

To make up this loss a large quantity of fresh water is carried in reserve tanks in the double bottoms, but this by itself would not be sufficient to make up the loss when steaming at a high rate of speed for a considerable period, and for this reason distilling plant is fitted for making fresh water from sea water, both for boilers and for drinking purposes.

There is a connection on the feed tank in the engine room for admitting salt water to it. This is used only in great emergency and by order of the officer on watch.

Where the feed water is not fresh the density should be kept down to between 30 and 35 degrees by using the blow-down as necessary.

To avoid saline deposits as much as possible a good circulation should be kept up in large tube boilers where the condensers are leaking by working them fairly hard, the deposit will then be carried to the mud drums and may be blown out.

If fires are pushed back or banked or the boilers are steaming easily a good circulation should be produced every four hours by making the fires active.

The water in the boilers in use and in the feed tanks should be tested for density every four hours.

Where fresh water is available for make up feed a rise of density of more than two degrees in three days is considered excessive in tank boilers. In water-tube boilers of the small tube type, as a rise of density is liable to cause priming, a rise of $\frac{1}{10}^{\circ}$ per day and an eventual density of $\frac{5}{10}^{\circ}$ is considered excessive. (The density of sea water being 10°.) The water in boilers should be tested with litmus paper once a day while the boilers are being steamed to see that it will turn red litmus paper blue. This shows that the water is in an alkaline condition. If on the other hand the water is found to turn blue litmus paper red it is in an acid condition and more lime must be added to the feed water to render it alkaline. When any water-tube boiler is suspected to be injured to such an extent that fires should be drawn, the fire doors are not to be opened to do so until the safety valves have been lifted, stop valves closed, and the steam pressure reduced to 50 lbs.; while the steam pressure is dropping, the fire and ashpit doors should be kept closed, and the extinguisher if fitted should be used.

To guard against Fire.—The spaces at the backs and sides of the boilers are at all times to be kept clear, and on no account is anything combustible to be placed on the top of the boilers or in contact with them; and the air space between the uptake and the casings of the boilers is to be frequently examined, in order that accumulations of soot or coal dust may be prevented.

Engine-room Duties under Way.—It should be remembered that the cleanliness and orderliness of the engine room both in harbour and at sea are essential to the proper working and management of the machinery.

Every precaution should be taken to prevent damage to machinery, particularly when in motion, from anything falling on it.

It should be seen that auxiliary engines do their work efficiently when running at the proper speed for it. Engines should not be allowed to run faster than is necessary.

Auxiliary engines should always be turned by hand with the cylinder drains open, before any attempt is made to start them by steam.

Steam should only be put on auxiliary engines slowly, and care should be taken to drain the branch pipes leading to them. The exhaust valve should always be opened before the steam valve and cylinder, and slide chest drains should not be shut till the engine is well under way and steam is coming from them. All engine-room watchkeepers should be fully acquainted with the means of lubrication provided for each part of the machinery, and as to the kind and amount of oil to be used for each part according to the speed of the engine.

Internal Lubrication.—Oil used for internal lubrication will be carried along by the water or steam, and will find its way to the boiler unless removed by the grease filter.

Any grease entering a boiler is quickly deposed and forms a scale on the heating surfaces which is very dangerous in causing overheating.

Oil for the internal lubrication of both main and auxiliary machinery should be limited in quantity as far as practicable.

It should only be used as ordered.

Mineral oil only should be used for parts which come in contact with steam and feed water such as piston and slide rods, feed pump rods, and air pump rods.

With machinery where the boilers carry a pressure of 155 lbs. and over, heavy filtered mineral oil is to be used exclusively for this purpose.

Oils used for external Lubrication.—When the main engines of a ship are reciprocating and not fitted with forced lubrication, *olive oil* is used for their lubrication at the highest powers only.

At slightly lower powers, *olive oil* mixed with ordinary service *mineral oil* is used ; at lower powers again *special mineral oil* and at cruising speeds ordinary service *mineral oil* alone.

Main engines fitted with forced lubrication use *special mineral oil.*

Auxiliary engines, whether fitted with forced lubrication or not, use ordinary service *mineral oil.*

But with both main and auxiliary machinery a little *heavy filtered mineral oil* may be added to the oil used for lubrication of the crosshead pins.

In ships fitted with forced lubrication any oil drawn off from the system on account of deterioration should be filtered and used for open auxiliary engines.

In engines fitted with forced lubrication, the oil supplied to the bearings is used over and over again, and it is only necessary from time to time to supply that lost by leakage and occasionally to renew oil which may have deteriorated ; in consequence it can be arranged, with a comparatively small expenditure of oil, to have ample lubrication at all times.

In the case, however, of engines where the lubrication of the bearings is effected by lubricator boxes and worsteds, all the oil used in the bearings is lost for lubricating purposes, and it is necessary to carefully regulate its supply, using only enough for the power the engine is developing.

The amount of oil supplied to a bearing, neglecting the temperature of the oil, depends mainly on the number of strands and length of worsted in use, and the height of oil in the lubrication box in which the worsteds dip. The level of oil in the oil box must be determined to give the required supply for the rate at which the engine is steaming, and this level must be maintained by constantly filling up the box to it, as even a slight variation in the oil level has a considerable effect on the quantity of oil supplied by the worsteds to the bearings.

It should be seen that the lids of lubricator boxes do not shut air-tightly while in use, as this stops the syphon action of the worsteds.

It will be found that the worsteds supply different quantities of different oils. Olive oil will be found to syphon over to the bearing faster than mineral oil, and in consequence it will be necessary at any given power to keep a higher level if mineral oil is used than with olive. It must also be remembered that oil thickens and runs slowly when it becomes cold.

Overheating of Bearings.—Should any bearing or rod, &c., become warm, the lubricating arrangements should be examined to see that everything is clear, additional oil supplied, and the condition reported.

Water is never to be used on a hot bearing without orders.

Where bearings with ordinary lubrication show a tendency to overheat with mineral oil, it may be necessary to mix olive with it, or to employ olive oil alone till they can be readjusted.

When it is necessary to use water on a bearing, and the water is liable to mix with the oil, olive oil should be used till the water can be shut off. Water washes away mineral oil, and a mixture of water and mineral oil is not a good lubricant.

Whenever water is used care is to be taken at the end of a passage, before the engines are stopped, that its use is discontinued in time to admit of the surfaces of the journals being thoroughly coated with oil. Neglect of this precaution is likely to entail serious injury to any bearings on which water has been used.

The fact of a bearing having been warm should never be concealed, for although this may be done successfully for a time, what has occurred will be discovered when the machinery is examined, and the machinery may have been injured through the omission to report that the bearing warmed.

Where serious overheating is suspected in the bearings of a closed engine fitted with forced lubrication, it should be eased at once and naked lights—if present—should be removed from the vicinity of the chamber.

Lubricators to be kept clear of Water.—If water finds its way into an oil box, the oil will float on the top of the water, giving the impression that the box is full of oil, although it may be nearly full of water. Because of this, all oil boxes should be emptied occasionally and refilled with fresh oil, this being done in all cases when water has been used near an oil box.

In forced lubrication systems for turbine machinery the oil after passing through the bearings drains to one of two tanks which are provided, and the oil pump takes it from this tank again and delivers it to the bearings. The idle tank allows its oil to separate from any water which may have gained access to it, and this may be pumped out by a hand pump sucking from the bottom of the tank.

Savealls with means of draining them are fitted to prevent oil falling into the bilges. The oil so collected should be used for some purpose connected with the preservation of the machinery.

Tallow and mineral grease are never to be used for internal lubrication, they are supplied for use in preserving machinery and for those cases in external lubrication (such as plummer block) where more effective than oil.

Leakages of Water or Steam.—Such losses of water have to be made up by distilling, and cause waste of coal; if reported it may be possible to take steps to prevent leakages from increasing.

Bilges.—Constant attention is necessary to see that the bilges are kept properly free from water. The height of water in the bilges is to be measured once an hour, and the height of water during the watch is to be reported at the end of it; the strainers and mud boxes on the bilge suction pipes should be cleared periodically, and dirt or small coal which may either choke them, or if it gets through them prevent the bilge pump from acting properly by getting under the valves, should be prevented as far as possible from falling into the bilge.

Especial care is necessary in the stokeholds, floor plates should always be put back in their proper positions so that there is no space at the sides through which coal can fall into the bilges.

The stokehold bilges should always be kept well pumped out so that in the event of the ship rolling the water shall not rise above the floor plates in the wings and wash the coal on them into the bilges.

Dress of E.R. Staff.—When under steam it is essential to the health and comfort of the engine-room staff that they should be properly clothed, and the dress for either closed or open stokeholds is to consist of fearnought or woollen trousers, flannel vests, cloth cap, and boots.

At the end of each watch the stokers as soon as they are relieved are to wash themselves and put on dry and clean clothes before returning to their messes or turning in to their hammocks. They will be mustered by the senior Chief Stoker of the watch.

Responsibility.—The Chief Petty Officer or Petty Officer in charge of the machinery and boilers in each watertight compartment is directly responsible for the efficient working and proper management of the machinery and boilers in that compartment when no Officer or Chief Petty Officer senior to him is present. Should an accident of any kind occur, or should anything which he thinks likely to cause injury to the machinery and boilers be observed, he is immediately to acquaint the Engineer Officer of the watch, and his responsibility only ceases with the presence of an Officer or a senior Chief Petty Officer.

He is on no account to leave the compartment of which he is in charge unless properly relieved, and all communications with the Engineer Officer of the watch should be made by the voice-pipes and telephones fitted; if, however, circumstances prevent this, a trustworthy person is to be sent with the message.

Means of Communication.

Engine-room Telegraphs.—Consists of two dials, one in the engine-room and one on deck, their pointers being connected by light shafting. The dials are divided into sections, in which are printed the orders: full speed ahead, half speed ahead, slow ahead, stop, slow astern, half speed astern, and full speed astern.

When the pointer on deck is moved by means of a handle provided for the purpose to either of these orders, by means of the connecting shafting, the pointer in the engine-room is caused to point to the same order, and at the same time a gong is rung which draws attention to the fact that an order is being transmitted. An electric bell is fitted which when rung from the engine room indicates to the bridge that the order has been received.

Revolution Telegraphs.—This is similar to the above telegraph, except that in place of orders the dials are marked with numbers, and is used for indicating to the engine room the number of revolutions required.

Tell-Tale Telegraphs.—This is a dial fixed on the upper deck with a pointer, which is connected by shafting to the shaft of the main engines. When the engines are in motion the pointer travels in the same direction as the engine and enables the officer of the watch on deck to see exactly what the engines are doing.

Telephones and voice pipes and electric bells are fitted, where necessary, to allow communication to be established between the different compartments of the ship.

When an order is received through a voice pipe or telephone it should be repeated to prevent mistakes being made.

Instruments used in Engine and Boiler Room.

Hydrometer.—This is an instrument for testing the density of any liquid, and is chiefly used on board ship for testing the density of the boiler water or feed water. It is made of glass or metal, and consists of a large bulb to which is joined the stem on which is marked the various degrees of density, and it is so constructed that it floats with the degree of density on the scale, level with the surface of the liquid of that density. As all hydrometers are graduated at a particular temperature, it is important when using them to see that the water being tested is of this temperature.

The ordinary service hydrometer is usually graduated to show the density of the water at 200 degrees temperature, because when water is drawn off from a boiler for testing it will be about this temperature, and a thermometer should be used to verify the temperature.

The scale is graduated in degrees, each degree representing one tenth the density of sea water.

Suppose a hydrometer was placed in a pot of absolutely pure water at 200 degrees temperature, then it would float so that the degree on the scale, marked 0 degree, would be exactly level with the surface of the water, but suppose the density of the water was such that the hydrometer floated in it with the mark 10 degrees on the scale level with the surface, it would be said that the density of the water was 10 degrees, which would be the case with ordinary sea water.

In addition to the above scale, service hydrometers have a second scale graduated for 100 degrees temperature for use when testing feed water.

Hydrometer Pot.—Is a pot of brass or copper of suitable shape for use with the hydrometer.

Thermometer.—This is an instrument which is used for measuring the degree of heat. It consists generally of a glass tube partially filled with mercury, a graduated scale marked in degrees being attached. According to the temperature, the level of the mercury takes up a certain position in the tube, and the number on the graduated scale corresponding to this position indicates the temperature. Thus, if a thermometer is placed in water, and the mercury rises in the tube until the top of it is on a level with the mark 200 degrees on the scale, the temperature of the water is said to be 200 degrees.

Air-Pressure Gauge.—This is an instrument which is used for measuring the air pressure in the boiler rooms when using forced draught. It consists of a U-shaped tube of glass and a scale divided in inches fitted in a box secured to the bulkhead. One end of the tube is open to the boiler room and the other end communicates with the atmosphere. The glass contains a quantity of coloured water, and when there is an air-pressure in the boiler room, the level in the arm of the tube connected to the boiler room will be lowered and the level in the other arm raised. The distance between the two levels indicates the amount of air pressure in the boiler room, and by means of the scale it can be read off in inches.

CHAPTER VIII.

MANAGEMENT IN HARBOUR.

On arrival in harbour, when the engines are done with, after the stop and regulating valves have been closed and after *it has been definitely ascertained that there is no steam present and that the vacuum is destroyed*, the turning gear should be shipped and the engines should be wiped down while warm, the bilges pumped out and cleaned, and the engine room generally put in order; gear being got ready for any examination of machinery which may be required.

In order to prevent corrosion of the journals when turbine and other engines fitted with independent oil pumps are not in use, oil which has been ascertained to be free from water should be circulated through the bearings and the engines turned by the turning gear sufficiently to ensure the bearings being filled with oil free from water.

In harbour the main engines and all auxiliary engines not in use are to be turned partly round every day, and the slide valves of the main engines are to be moved by the hand reversing gear. Drain cocks are to be opened while engines are being turned.

Engines without crank shafts must be moved with the gear provided.

Slide valves which are not moved when the engine is turned, such as the shuttle valves on the steam cylinders of a Weir's feed pump, should be taken out and oiled whenever the engine is stopped for some days.

When not under steam, mineral oil for preserving the machinery is to be used sparingly; syringing oil through sight holes on to the working surfaces, or supplying oil by oil cups, is only to be resorted to when time does not allow of the removal of the manhole covers. As a general rule the manhole covers of the machinery are to be removed and the internal working surfaces carefully cleaned as soon as possible after the engines are done with. Before closing up the machinery for raising steam, any mineral oil that has collected in the internal parts should, as far as possible, be removed and the working surfaces cleaned.

When machinery is opened out and when closing up, every precaution is to be taken to prevent anything remaining inside or upon any part of the main or auxiliary machinery which would be likely to lead to obstruction or injury when the machinery is running.

Protectors fitted to surface condensers, distillers, or evaporators should be regularly inspected and renewed, care being taken when securing the connections that good contact is made.

Care is to be taken when applying cement wash to the tube plates, &c., of the condensers to coat the inner surfaces of the ferrules and the internal portions of the tube ends as far inwards as possible by using a small brush so as to leave a slight protective coating of cement in the tubes without restricting the inlet area to any serious extent.

Naked Lights.—When opening out the crank chambers of forced lubrication engines, no naked light is to be taken near the engine till the oil chamber has been thoroughly ventilated.

Feed Tank.—To prevent the passage of oil to the boilers the feed tank must be cleaned from grease. Except where cylindrical boilers alone or Belleville boilers of the economiser type are fitted, this will need to be done after about 14 days' ordinary steaming.

Boiler Room.—Before a ship comes into harbour as much of the dirt and ashes in the stokehold should be got up as is possible.

When engines are done with, dampers and ash-pit draught plates are shut to allow fires to die out and boilers to cool down gradually.

Sweeping Tubes, Cleaning Furnaces, &c.—After the boilers have cooled down, furnaces, uptakes, and combustion chambers must be cleaned out and tubes swept.

This cleaning should be thorough and no dirt should be left.

Dirt which is left is not only present when the boiler is next steamed, but it collects moisture and sets up corrosion, which attacks such parts as nipples in feed collectors of Belleville boilers, outer part of the tubes near tube plates on small tube boilers, &c.

After furnaces have been cleaned out they should be examined.

In tank boilers the condition of the seams at the throat of the furnace should be noted; in water-tube boilers, whether tubes have distorted.

Fire-bars, ferrules, and baffles which have worn excessively should be renewed, and brickwork should be repaired, special care being taken in boilers using oil fuel to examine and renew as necessary the bolts holding it up.

Where the zinc coating has worn off the outside of boiler tubes, they should be protected by coating them with black lead moistened with a little water; this not only protects them from corrosion, but prevents clinker and soot from sticking to them.

Examination and Cleaning of Boilers internally.—It is necessary to examine the interior of boilers frequently both to remove deposit from the heating surfaces and other parts and to observe the condition of all parts of the boiler and take the steps necessary to stop any corrosion which may be taking place.

Precautions before opening Boilers.—Before taking off the doors of a boiler which may contain steam, the safety valves, air cock on top of the boiler, and the test or water-gauge cocks in the steam space should be opened to ensure no steam is left.

Foul Air in Boilers.—Care should be taken that whenever boilers are opened sufficient time is given to allow foul air to escape before any one is allowed to enter the boiler.

Explosive Mixture in Boilers, Evaporators, &c.—The possibility of an explosive mixture of hydrogen and air being present when boilers, condensers, evaporators, &c., are opened should be borne in mind, and before using a naked light in them they should be thoroughly ventilated.

Precautions against Accidents to Men.—Whenever men are employed in one boiler whilst steam is up in another, the main and auxiliary stop-valves, safety-valves, feed-valves, brine, and blow-out valves, and any others through which steam or hot water could enter the boiler on which the men are employed, are to be shut and secured against being accidentally opened. Similar precautions are to be taken where men are employed near a boiler or steam pipe, where they are liable to injury from escaping steam from inadvertent opening of a valve.

When stop-valves, &c., are secured in the shut position for this purpose, great care is to be taken to guard against accident arising from accumulation of hot water on the pipe system owing to the valves leaking slightly. To ensure proper drainage pipe-joints near the secured valves should be broken, if necessary.

Cleaning.—When the deposit in a boiler is soft, it is often advantageous to remove it by washing out with a hose. Whether this is done or not a boiler should be thoroughly dried out as soon as possible after it has been opened. If necessary bogie fires should be used to warm it. As a rule the deposit left in a modern boiler is easily removable by light scraping or brushing after the boiler has been dried; but if it cannot be removed by these means it must be chipped away where it can be got at; but if there is any doubt or difficulty as to the complete removal of scale or deposit from the interior of the tubes of water-tube boilers by ordinary means, the boiling of a solution of caustic soda in the boiler for several hours will facilitate it. In this case as soon as the soda has been removed the boiler should be again boiled out, and finally washed out with clean fresh water, in order to remove any traces of the soda solution.

After the scale has been removed wire brushes should be used till the surfaces of the boiler are bright. Where corrosion is found it should be coated as ordered, but no coating or wash of any description is to be used on the heating surfaces, or on parts of a boiler in contact with flame.

Zinc slabs are fitted in a boiler to protect it from corrosion. They are effective when the zinc wastes away; this only occurs when there is good metallic contact between the zinc and the metal of the boiler shell.

Slabs which are reduced to half their original thickness, or which are bent or distorted, should be replaced by new ones.

When zinc slabs are replaced in a boiler, all surfaces of slab, the hangers, washers, and nuts, and where the hanger takes on stay or shell, the boiler should be brightened by using a scraper or file, and the nuts should be screwed up tightly.

After a boiler has been cleaned and before it is closed up it should be closely examined to see that nothing has been left in it.

It should be seen that the slots in the internal steam-pipe and the pressure gauge-cocks are clear; also that there is no obstacle in the steady pipe or the water-gauge mountings. The down-comer tubes should be examined, and any foreign substance removed.

After all these parts have been seen in proper order a brush or searcher should be passed through each tube of a water-tube boiler.

Directly a boiler has been searched the doors should be put on and no one should be allowed to enter the boiler.

Men working in a water-tube boiler should not be allowed to take in with them anything which may fall into the tubes, and all tools, articles, &c., passed into the boiler for any purpose should be mustered out or accounted for.

When doors or covers on boilers are of the flanged type, and secured by bolts or studs and nuts, the thickness of the asbestos jointing ring or ring of similar material should not exceed $\frac{1}{8}$ of an inch. Especial care should be taken where bolt holes require to be punched in fitting the same, and in all cases the joint must be examined and found fair before making. If these joints are not properly made there is danger of serious and even fatal accident.

Boilers not in use or being cleaned should always be kept full of water. No boiler should be allowed to lie with fires out and water at working height.

The boilers must also be kept quite full. After steaming the contraction due to cooling of the water in them must be made up day by day until they are quite cold, and water escapes from the air cock on the first stroke of the pump. After that the loss of water may be made up weekly.

The water in boilers not in use should be tested once a week with litmus paper to see that it is not acid. Acid water turns blue litmus paper red. Alkaline water turns red litmus paper blue.

If the water is found to be acid a little soda or lime should be added.

Fires are never to be kept laid in an empty boiler.

Empty boilers are to be kept closed as much as possible, and are to be warmed to dry them when necessary.

In a water-tube boiler corrosion of the tube ends where they are bell-mouthed should be reported if discovered. This is of especial importance in the case of Thornycroft boilers of the type in which pressure in the boiler tends to pull the tubes out of the plate.

Whitewash is not to be used on the funnels, casings, bunkers, or on any of the exterior steelwork of boilers.

Before painting steelwork care is to be taken that all rust and dirt are thoroughly removed, so that the paint may be applied to the clean surface of the steel, and thus preserve it from corrosion.

Precautions in Cold Weather.—In cold weather all necessary precautions to prevent injury are to be taken by keeping the engines and pipes thoroughly drained, or where this is impracticable, by warming the engine and boiler rooms.

CHAPTER IX.

Machinery of Steamboats. Boiler Tube Leak Drill. Instructions.*

1.   inches of water must be in the gauge glasses before fires are lit or when waiting for orders. Raise steam slowly. Lift safety valves occasionally while raising steam and whilst under way.

As soon as the fire is lit open stop-valves a little to warm up the engines gradually. Open the drains. Always thoroughly drain engines immediately before moving. Greasy water to be drained to bilge.

2. As steam rises try auxiliaries and boiler mountings. All feed arrangements to be tried against full pressure. Clean the donkey if dirty by pumping from sea to sea before trying with fresh water on boiler. Start circulating engine as soon as possible and keep running. Try fire extinguishers cautiously.

3. See oil in crank-chamber free from water and at proper level before engines are tried. When engines move watch pressure gauge. If oil heats unduly when under way remove naked lights from near crank chamber and ease engines if possible.

Lubricate internal parts and rods sparingly, using heavy filtered mineral oil.

4. Under way keep as much water in the boiler as possible without priming. If the boiler primes, ease the engines if possible. Keep a light fire to avoid flaming. Prick it from underneath the bars to keep it bright. Draught plates are to swing freely unless pricking or drawing ashes. Use water in the ashpans and keep ashes drawn.

The air pressure is not to exceed   inches of water. Work fan to keep steam and ease it while cleaning fires. The furnace door is not to be held open to check steam. Extinguishers are only to be used in emergency; but if a serious leakage occurs observe "Boiler Tube Leak Drill" as far as possible.

5. Use the main feed pumps. Fresh water tanks are to be filled whenever possible. Unless taking in fresh water, only use the ejectors on the bilge in case of emergency. Do not let safety valves blow-off. In using silent blow-off valve open it gently. Test water in boiler and tanks occasionally for density and alkalinity. Strain lime water before adding it. If salt water has to be used, blow-out to keep the density below 40°.

6. Renew broken gauge glasses as soon as possible, and on return to the ship report the renewal to an Engineer Officer. When engines are finished with, close cocks and valves and let fires die out unless otherwise ordered.

7. Do not empty the boiler by blowing out. Never lay fires in an empty boiler.

8. If the boat is ordered to take an extended trip, orders should be obtained as to the extra tools, stores, and spare gear to be taken.

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* The blank spaces in these instructions are filled up to suit each boat, and clauses which do not apply are struck out.

The machinery and boilers of torpedo craft and steamboats are designed and managed on the same general principles as the machinery and boilers of ships.

At present the use of turbine machinery has extended only to torpedo boat destroyers and torpedo boats, while steamboats still have reciprocating engines. Forced lubrication is fitted except in the case of steam cutters, where the engine is open, and works by a circular boiler with fan draught in the ashpit, while all other steamboats have small tube water-tube boilers in closed stokeholds.

A novel feature at the present time in steamboats is the lubrication of the stern tube; previously water was relied on to lubricate the stern tube bearings, but in the latest steamboats a lubricator is fitted which continuously pumps a small quantity of grease into the tube bearing.

In managing a steamboat great care is necessary with the boiler. In Chapter VII. the necessity of maintaining a very high water level when raising steam or waiting for orders with Thornycroft boilers, where the upper ends of the generating tubes deliver into the steam space, has been pointed out. With such boilers in a steamboat the same care is necessary; although when the boiler is actually steaming the circulation carries water continuously with the steam right through the tubes. When no steam is being formed the parts of the tubes above the water level in the top drum are dry and there is a danger of the tubes becoming overheated at that part.

Care is also very necessary in taking in water for the boilers, as the length of time the boiler can continue running without cleaning depends to a very great extent on the water used.

For the same reason the oil used for internal lubrication must be reduced to a minimum, and great care must be taken that oil from the crank chamber of a forced lubrication engine does not pass on the rods into the cylinders.

The boilers in steamboats are cleaned at least once a quarter, and in case of heavy work once a month.

Steamboats' boilers and the boilers in torpedo vessels are water-tested every six months. On account of their exposed situations it is sometimes necessary to keep the boilers in steamboats empty; in which case they are closed up and preserved with charcoal or lime.

If preserved with charcoal the boiler, after being thoroughly dried with ordinary airing stores, has small trays containing burning charcoal or coke inserted in the drums before it is made airtight, the object being to consume all the air inside the boiler.

If preserved with lime, quicklime in trays is placed in the drums and burning charcoal as well in other trays, the removal of the air by the charcoal increasing the preserving effect of the quicklime.

After either of these methods has been employed, in spite of the fact that the lime and charcoal have been placed in the boiler in trays, the tubes must be searched to make sure that nothing has dropped into them.

Boiler Tube Leak Drill.

(A copy of the drill form will be posted in each engine room and stokehold and embodied in the Station Bill.)

(It will be practised weekly if convenient and in the case of instructional boats at least twice with each class under instruction.)

The following drill for use in torpedo boat destroyers and torpedo boats has been formulated to meet the emergency of a sudden leaking of a tube in the boilers, and to ensure the prompt and intelligent handling of the safety appliances on such occasions.

Stokehold.

When the order is given, "Leak in the furnace of No.   Boiler," the stoker petty officer or leading stoker of the stokehold is to—

(1) See that the fire and ashpit doors, whether automatic or otherwise, are closed and secured.
(2) Increase the speed of the fan engines.
(3) Open the safety-valves on the injured boiler.
(4) Cautiously open the fire-extinguisher on the injured boiler, or, if fitted for oil-burning, quickly shut off the supply of oil to the burners.

To ensure the greater safety of the men in the stokehold, he will be responsible that the stokehold hatch is not opened from below, and that the furnace doors of the injured boiler are not opened till the pressure in that boiler is below 50 lbs. If there is more than one boiler in the stokehold he is to take special care that the water level in the other boilers in use in that stokehold is kept at the correct height, the tendency being for all the feed water to go into the injured boiler.

The stoker in the stokehold is to—

(5) Increase the speed of the feed pump.
(6) Start the auxiliary feed pump.
(7) Open the auxiliary feed valve on the injured boiler, and if other boilers in the same compartment are alight, close the main feed valve on the injured boiler.
(8) Shut the stop valves on the injured boiler.

In the absence or any inability of the stoker petty officer or leading stoker to perform his duties, the stoker firing defective boiler is to take his place, and the remaining stoker is to carry out the duties detailed for the stoker in the stokehold. In the case of one stoker only being available, he is to carry out the whole of the above duties as expeditiously as possible.

A report of the steps taken is to be made at once to the Engineer Officer of the watch in the engine room.

Where ashpit doors have to be entirely removed for drawing ashes, great care should be taken to replace them as soon as possible.

Engine Room.

The engine-room artificer in the engine room, on hearing the safety-valves lifted, and seeing at the same time a rise of air-pressure or a sudden fall of steam pressure, or receiving a report from the stokehold, is to—

(*a*) Station a man to prevent the stokehold hatches from being opened from deck, and to shut off, if necessary, the oil supply to the burners when fitted for oil fuel.
(*b*) Increase the supply of feed by using reserve tanks.

(*c*) Increase the speed of the feed pump if fitted in the engine room.
(*d*) Cautiously open the silent blow-off to the condenser.
(*e*) Work the engines as fast as circumstances will permit.
(*f*) Inform the stoker petty officers of any other stokeholds in which boilers are in use that an accident has occurred, so that particular attention may be paid to the water in these boilers.

When an order is given "leak stopped," the ratings in the stokehold are to revert to the conditions before the drill, by reducing the speed of the fan engine, shutting the safety-valves, fire-extinguisher, &c., &c., and the engine-room artificer is to pursue a similar course in the engine room.

NOTE.—The steps laid down in this drill are only to be put into actual practice when the leak is serious, *i.e.*, likely to endanger persons in the stokehold when the fire-doors are opened. In the case of a lesser leakage the fact should be immediately reported to the engine room for the engineer officer to decide whether the boiler is to be shut off.

If the drill be practised when engines are not under way, the engine-room artificer will modify his instruments as requisite.

CHAPTER X.

Double Bottoms, Pumping, Flooding, and Draining, &c.

To minimise risk from projectiles, torpedoes, and mines, or by collision or grounding, a warship is divided into a number of water-tight spaces, so that in the event of the hull being pierced below the water-line, water can only enter and fill the space which is pierced.

To effect this (1) all warships, excepting the smallest and torpedo craft, have a water-tight inner bottom which is fitted some 3 feet or so inside the outer bottom; the space between the two bottoms is divided into numerous water-tight compartments; (2) all decks and flats are made water-tight; (3) numerous water-tight bulkheads are fitted.

The bulkheads which are fitted across the ship are called transverse bulkheads. The main transverse bulkheads which run across the ship from outer bottom to outer bottom, and from keel to upper or main deck, divide the ship into main compartments.

The ship is further subdivided by minor transverse bulkheads which form the boundaries of separate water-tight spaces, and by longitudinal bulkheads.

The transverse bulkheads were formerly known by letters A, B, &c., and longitudinal bulkheads by the transverse bulkheads they join; but in modern ships, transverse bulkheads are indicated by the numbers of the stations at which they are situated.

Water-tight Doors.—To allow for communication doors are cut where necessary in the bulkheads and decks dividing the various water-tight spaces.

Water-tight doors are of two kinds, viz., sliding and hinged.

Sliding water-tight doors are fitted in the main transverse and longitudinal bulkheads below the water line.

The doors from the coal bunkers into the stokeholds are vertical doors, but in most of the other positions horizontal doors are fitted.

The doors are slightly tapered where they slide into the guides, and as they close are made water-tight in the door frame.

Horizontal doors are moved by a rack and pinion, and vertical doors by a screwed spindle working in a screwed bracket or brush fitted to the door.

The spindles of the pinions of the horizontal doors are arranged to be worked at the door or from the deck by means of shafting. Those on vertical doors are worked either from the deck or by means of chain gear at the door, the latter being so arranged that the door may be lowered very quickly.

Hinged water-tight doors are closed by engaging clips carried in the door frame with wedge-shaped strips on the door; india-rubber strips are secured to the door frame, and the door is pressed on them by the action of the clips.

Water-tight hatches are also fitted in all decks; those fitted in protective decks are armoured and require gear for opening them.

Water-tight hinged doors are fitted to the double-bottom manholes, but these are fastened by nuts on bolts hinged on the door frame instead of by clips.

[Directly the anchor is off the ground all water-tight doors and valves below the protective deck, whether automatic or not, should be closed by hand, and not opened again until the ship reaches harbour, except as required for purposes of ventilation.

Where men are sleeping it may be necessary to leave some open continuously, but the others will only be left open where ordered for as short a time as is absolutely necessary.

Men will be told off to close by hand the whole of the doors and valves, whether automatic or otherwise, when ordered.

Water-tight doors and scuttles are divided into three classes, A, B, and C, the letter being painted on them.

Those marked A are to be closed at the order "close water-tight doors."

B doors and scuttles are kept closed when manœuvring, entering or leaving harbour, at night and in fogs.

C doors are those always kept closed at sea.

All bunker doors, armoured shutters, &c., are to be kept closed, except when actually required for use. Whenever doors or shutters between upper and lower bunkers, or any other bunker doors, are about to be closed, the jointing surfaces of the doors or shutters and their framing should be thoroughly cleaned, under the superintendence of a trustworthy petty officer or higher rating; in the case of hinged doors, he is to see that the india-rubber of the door and the seating upon which it closes are in good condition and the clips properly set up, and where covers are fitted in the floor of the upper bunkers, he is to see that they are well jointed with red lead or other jointing material.]

Pumping and Drainage.—Through even a small hole in pipe low down in the vessel, water runs very quickly into the bilge compared to the rate at which it can be pumped out.

With the main circulating engines pumping on the engine-room bilges as well as the fire and bilge engines and Downton pumps in use, the water flowing through a moderate-sized hole low down in the bilges could flood the ship if it were free to do so. We have seen, however, that the ship is subdivided into water-tight compartments and spaces to provide against injury to the hull in action, collision, or grounding.

The large pumping power provided is for removing water which may leak from the compartment whose side is pierced into neighbouring compartments through damaged bulkheads and fittings.

In the case of a compartment damaged by collision or otherwise, so as to admit water, the sluice valves on the bulkhead are not to be opened until the ingress of water has been entirely stopped.

The pumping arrangements are also designed to remove water from all parts of the ship which may enter it by accidental causes, such as the shipping of a sea, leakages, drainage of torpedo tubes, &c.

The arrangements in the majority of large vessels afloat at the present time are generally as follows :—

Circulating Engines and Main Drain.—The main circulating engines which are capable of discharging large quantities of water take their suction either from the engine-room bilges or the sea, and can be employed in cases of emergency to pump large quantities of water from the bilges.

A main drain (Fig. 29), a pipe of about 15 inches in diameter, running from the after end of the forward boiler room to the forward end of the engine rooms, where it is branched to allow communication to either engine room, allows water to be brought from any boiler-room bilge to either or both of the engine-room bilges. There is a sluice valve, with a non-return valve behind it, admitting water from each boiler-room bilge,

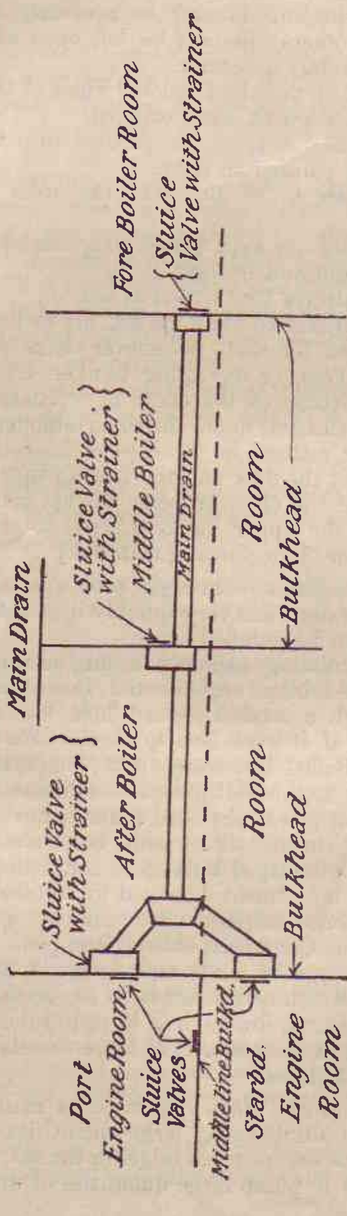


Fig. 29.

but not allowing it to flow back, and a sluice valve (not on the drain) is fitted on the bulkhead between the engine rooms.

[In some of the older battleships the main drain is continued to the ends of the ship, or branch main drain pipes of about 8 inches diameter are fitted on either side of the ship, into which submerged torpedo tubes, flats, &c., drain. In this case small quantities of drainage water are not admitted to the engine-room bilge, but are pumped overboard by the fire and bilge engines, which draw from a tank on the main drain through a branch fitted on the main suction.

In other cases drainage water from the forward part of the ship is led to the forward boiler-room bilge.

There is a sea connection to the main drain for pumping it through and cleaning it.]

Main Suction, &c.—For dealing with small quantities of water in the engine and boiler rooms and screw alleys, suction pipes are led directly from the fire and bilge engines to wells formed in the lowest parts of each of the bilges.

The fire and bilge pumps and the Downton pumps have suctions connected with the *main suction pipe* of about 6 inches diameter running fore and aft the ship, and tapering to about 4 inches at the ends. This pipe has branches led to each compartment in the hold and double bottom. Stop valves are fitted on it at each bulkhead, and at the end of each branch there is a valve which is non-return, screw-down, and flooding. *See* Fig. 31.

[The magazines have no branch from the main suction, and in case one is flooded a suction hose must be led to it from the nearest Downton

Fig. 30 shows the suctions and deliveries of the Downton, suctions to sea, main suction, and hose connection and deliveries to fire main or overboard.]

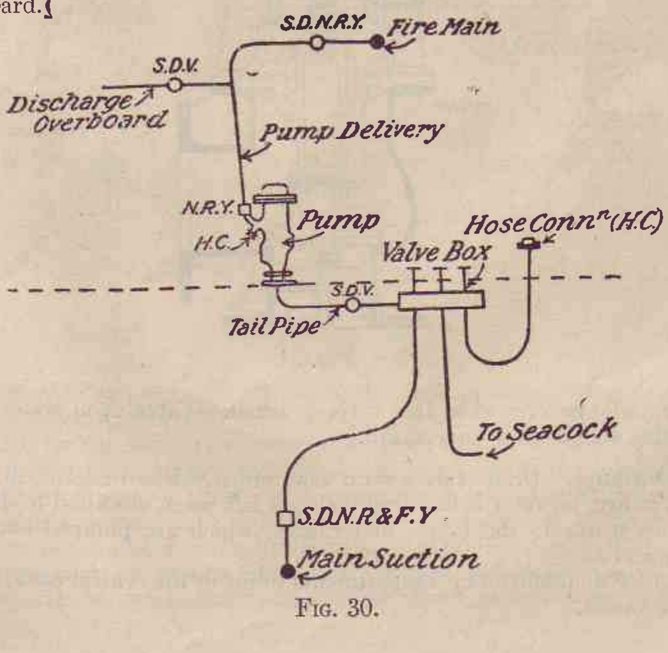


FIG. 30.

]The reserve feed tanks and oil fuel tanks are not permanently connected to the main suction in order to avoid accidental flooding from it, which would be serious. In each of them a branch is fitted to the bottom furnished with a screw-down non-return valve; but to use it must be coupled to the main suction by a hose.

Fig. 31 shows a section of this valve. The ordinary screw-down non-return valve which is not used for flooding, like the boiler stop-valve, can only be screwed down, and cannot be held open. In a great many screw-down non-return valves the spindle is not in any way attached to the valve, and merely presses on the back of it.

In the valve shown the button at the end of the spindle, when it is screwed back far enough, holds the valve open, and will not allow it to close.

An index at the top end of the spindle shows the position of the spindle with relation to the valve seating, and the way in which the valve will act.

Spindle screwed down.—Valve closed.

Spindle unscrewed, but before button on end has lifted valve.—Valve allowing water to pass from under it, but closing if water attempts to pass back.

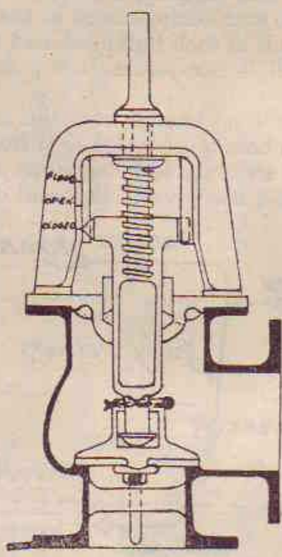


Fig. 31

Spindle unscrewed so that valve is lifted.—Valve open water on top of valve able to pass underneath.[

Drainage.—Drain valves with non-return valves underneath, to prevent return of water if the drain valve is left open, are fitted to drain the various spaces to the bilges underneath, which are pumped out by the main suction.

Outer double-bottom compartments drain to the central ones through sluice valves.

[In the most modern ships the main drain has been entirely omitted, and the circulating pumps can only pump from the engine-room bilge. The main fire and bilge engines too can only pump out the engine rooms or double bottoms directly under them. Each boiler room and the spaces under it are pumped out by a separate engine situated in it, the spaces being flooded, if necessary, from the sea suction of the pump.

Outside the engine and boiler rooms instead of Downton's pumps there are motor-driven centrifugal pumps in each main compartment (*i.e.*, in each compartment bounded by two main transverse bulkheads), which can pump out only the spaces in the compartment. Fig. 32 shows the connections of one of these pumps.

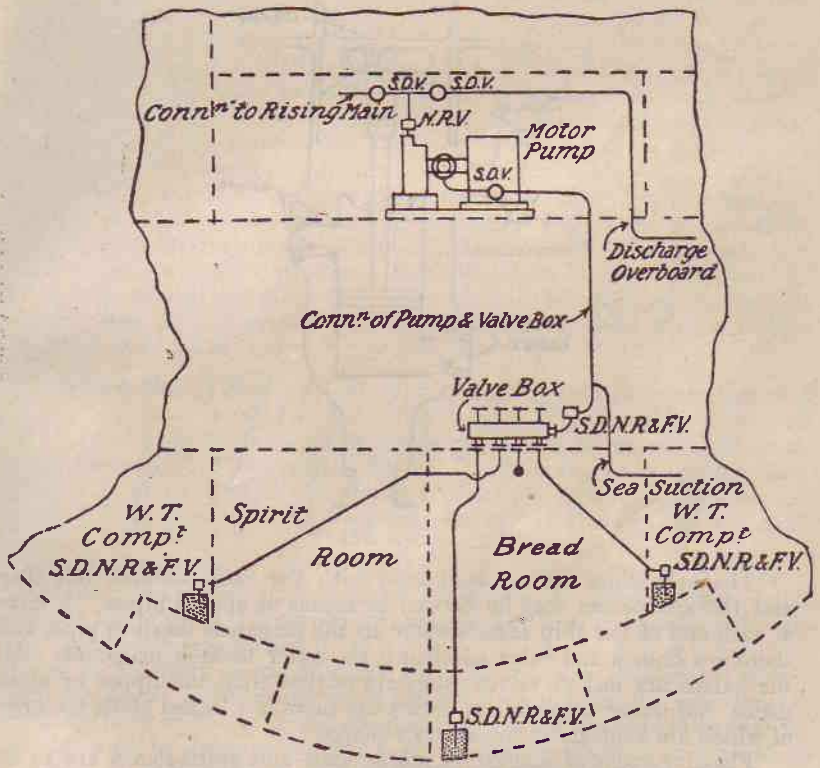


FIG. 32.

Downton's Pumps.—Fig. 32A shows the general arrangement of these pumps as fitted in the older battleships. As a rule four 9-inch pumps were fitted for the ordinary service of the ship, besides two for fresh water pumping only. The pumps are operated by hand; as shown in the figure the crank works in a slide. The pump is an ordinary double-acting pump, with a suction and a delivery valve for each end of the barrel. The space on top of the pump forms an air vessel.

The sea-cock of pumps should be opened and closed daily. The water-tight doors, except those permanently closed, sluice-valves between] compartments, Kingston, flooding, and other sea cocks and valves, are to be opened and shut once a week to ensure their being in good working order; but on no occasion is any one of them to be opened or shut except under the superintendence of one of the Engineer Officers, a competent Engine-room Artificer, or a Chief Stoker, who is held responsible for their being closed when not in use.

Flooding.—By opening the sea-valves to the Downton pumps the main suction may be flooded, and through it any of the compartments with which it connects.

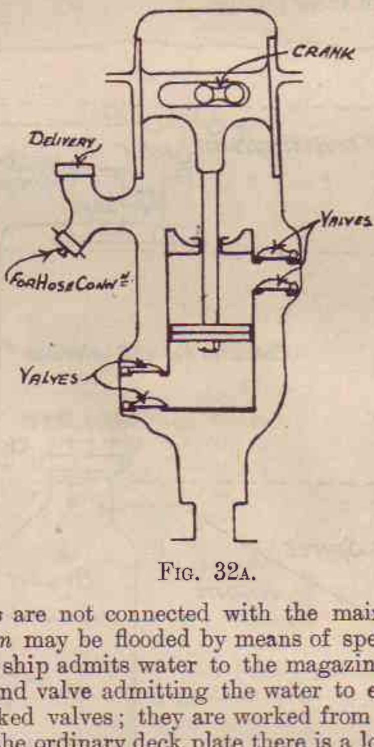


FIG. 32A.

The *magazines* are not connected with the main suction, but they and the *spirit-room* may be flooded by means of special pipes. A valve at each end of the ship admits water to the magazine flooding pipe, and there is a branch and valve admitting the water to each magazine. All the valves are locked valves; they are worked from the upper or main decks, and under the ordinary deck plate there is a locked plate, the keys of which are kept under the sentry's charge.

Flooding-cocks of magazines, store-rooms, and spirit-rooms are to be worked weekly under the direction of an Engineer Officer.

In vessels where the number of flooding-valves is greater than can be conveniently and efficiently worked once a week in accordance with the above directions, the valves, including the locked valves, are to be divided into two, three, or four groups. Each group to be worked in rotation, and every valve to be worked, and the working gear cleaned and examined during the course of a month.

Cases have occurred in which magazines have been accidentally flooded, apparently through an erroneous impression that the flooding-valve is of necessity hard down on its seat when the indicator stands at "shut" on the deck plate, and also through insufficient observation of the flooding inlet to the magazine after the flooding-valve has been screwed down, locked, and covered.

The valve must always be screwed hard down on its seating without reference to the mark on the indicator being exactly opposite the "shut" marked on the deck plate.

Although when first fitted the mark comes opposite the "shut" when the valve is hard down, after some wear it will be necessary to move the mark past this position to shut the valve.

The fact that the valve is closed should be judged by screwing it hard down, and it should always be ascertained that the valve is actually closed by inspecting the flooding inlet in the magazine. If anything is done to the valve, deck plate, or its gearing after this the flooding inlet should again be inspected.

In all cases the various parts of the valve gearing, thickness of valve, &c., are to be kept in such adjustment as to admit of the valve rod being locked when the valve is hard down on its seating. In such cases as valves for flooding wing bunkers where the inlets from the flooding-valves are usually inaccessible, the valves should only be worked when the bunkers are empty or the inlets otherwise accessible.

Every person in the engine-room staff must know his post and the duties he has to perform in closing water-tight doors and sluice-valves, and opening flooding-cocks and sluice-valves, so that in emergency this may be done without confusion. Members of the engine-room staff not definitely detailed for other duty in action will be exercised in possible emergencies during general quarters to familiarise them with the steps required to be taken.

Preservation of Hull.—In all but the most modern ships the inside of the plating and riveting of the outer bottom of a steel ship is covered with cement up to the turn of the bilge; this ensures good drainage. The other parts of the plating in the double bottom are covered with paint. In ships in which the plating of the outer bottom is not cemented it should be seen that the drainage holes cut in frames, &c., are kept clear.

In composite ships also the flanges of the outer angle-irons of frame keels, &c., are coated with cement to cover up all fastenings up to the turn of the bilge, and the wood planking is coated to the same height, all the other parts being painted.

It is necessary to examine the whole of the painted surfaces of the hull frequently and to make good any defects which may be discovered.

Care is to be taken in all cases to remove rust from the steel plating of the hull by hammering, scraping, and thoroughly cleaning before paint or other material is applied to it. In ships sheathed with wood care must be taken not to break off the points of the sheathing bolts by heavy blows of the chipping hammer.

To prevent excessive wear of the inner bottom plating under the engines and boilers, more especially in the upper surface, due to the action of rust and hot water, the plating is to be frequently examined and whenever rust is found to be forming, or where the paint is abraded, the surface is to be thoroughly scaled, cleaned, and dried to ensure the paint sticking to it, and then coated with three coats of red lead.

In dealing with torpedo boat destroyers and torpedo boats the thinness of the plating should always be kept in view. No portion of the hull should be allowed to become devoid of paint or other anti-corrosive [composition, and the whole of the paint should be kept in good order. Should any of the inside of the vessel become bare pieces of zinc are to be placed on the inside, about five or six feet apart, as low down on the bilge as possible, and in metallic contact with the frames or other parts of the structure.

The double bottoms of a ship require continuous attention and a party of engine-room ratings is employed on them whenever the ship is in harbour.

The precautions to be taken in entering these spaces after they have been closed are dealt with in the next chapter, but it is also necessary to pay attention to the following matters to avoid injury to health.

Red Lead.—In view of the injurious effect of read lead on men employed in confined spaces, this paint is not used in them to any great extent. Oxide of iron paint (unless other approved material be supplied) is used in double bottoms, wing passage and other confined places on board ship, but red lead is used for painting the portions of frames, girders, &c., where its use will not be injurious to the men.

Instructions for use of Red Lead.—Where red lead has been used in confined spaces the following precautions should be adopted by men working there.

Cleanliness.—To prevent the introduction of lead paint through the skin, minute attention to cleanliness is necessary. The face and hands should be washed, the mouth rinsed, the hair combed several times in the day, and the whole body frequently bathed. The working clothes should be made of canvas, and washed once a week at least; they should be worn as little as possible after coming out, and a light and impervious cap should be worn to protect the head.

Food.—Care should be taken that none of the poison is admitted into the system with the food. Meals, therefore, should not be taken when scaling has been going on, and the hands and lips should be washed before eating.

Plenty of fat or oily food, like bacon, should be eaten.

Breathing.—The entrance of the poison into the air passages during respiration should be guarded against. A mask of muslin or bunting is useful where it can be worn.

All men employed on red-leading should appear before the medical officer at least once a week.

Precautions against galvanic action in Bilge Pipes.—If unprotected copper pipes are immersed in bilge water in contact with the hull of the ship galvanic action is set up and the pipes corrode.

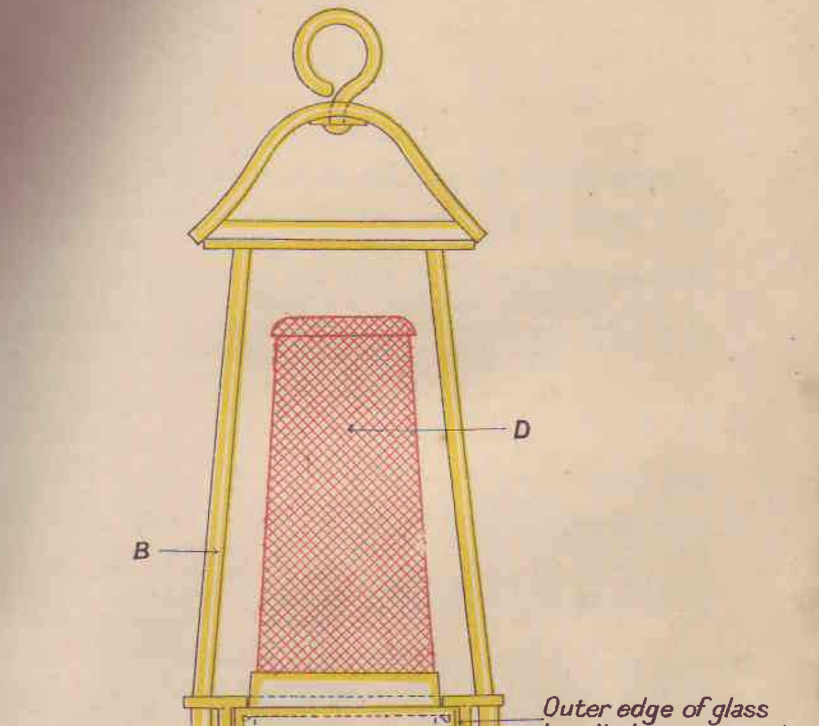
To prevent this the lower ends of bilge suction pipes are made of galvanised iron with galvanised iron strainers fitted to them to prevent choking.

Where pipes in connection with the engines and boilers, which are necessarily of copper or brass, run through the bilge and may be immersed in bilge water they are well painted or varnished and then covered with new canvas, painted over with oxide paint so as to be waterproof.

No copper or brass pipes are allowed to rest on the hull of the ship.

Iron or steel bolts are not used in gunmetal flanges where they are liable to be exposed to the action of moisture.]

Fig. 33.



SAFETY LAMP.

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CHAPTER XI.

Testing the Air in Confined Spaces for Foul and Explosive Gas.

When a space is insufficiently ventilated there may be danger to life either—

(1) Owing to the presence of gas which forms an explosive mixture with air which will ignite if a naked light is brought into it;
(2) By the absence of the air necessary to support life owing to its having been used up or excluded by another gas.

In buildings on shore these conditions do not often arise owing to the sufficiency of the ventilation afforded by windows, doors, and through the chimneys; but accidents occasionally happen due to—

(1) Lights being brought into a room where coal gas has leaked from the gas pipes or fittings and causing an explosion;
(2) Charcoal or other fires being left alight in sleeping-rooms, whose windows, doors, and chimneys are closed, resulting in the suffocation of persons sleeping in the rooms because the fires use up all the air. Lamps or candles alight in the room go out at the same time.

Before men enter such spaces as coal bunkers, double bottoms, wing compartments, boilers, &c., it is necessary to open doors on them to drive away any explosive gas which may be present and to allow air enough to support life to enter.

It is necessary to keep all naked lights at least 20 feet away before the doors are opened, and if boilers are alight within 20 feet their furnace-doors and draught-plates should be kept closed to prevent the explosion of any gas which may escape.

These precautions are also necessary when the doors on oil fuel tanks are opened.

Explosive gas occurs most commonly in coal bunkers and oil fuel tanks, but accidents have happened due to its presence in double bottoms, wing spaces, boilers, evaporators, the crank chambers of closed engines, and the evaporator and distiller casings of refrigerating machinery, which latter are furnished with pipes and cocks for discharging the gas.

Before any confined space is entered with a naked light, it is necessary to test the air to see that it does not contain explosive gas.

This is done by a safety lamp.

This safety lamp (Fig. 33) consists of—

(1) An oil reservoir A fitted with wick holder, &c.;
(2) Brass wire frame B protecting glass and gauze shades;
(3) Cylindrical glass shape C at top of reservoir;
(5) Copper wire gauze shade D.

The oil reservoir is fitted with a wick holder with a screw gland.

The wick is adjusted by a spindle passing outside the reservoir through a stuffing-box and gland which prevent leakage of oil.

An air supply tube through the reservoir has a screened inlet and projects above the reservoir preventing trimmings from the wick getting down and choking the air supply. It is necessary this should be kept clear.

The glass shade is opposite the lower part of the flame, and the copper wire gauze shade surrounds the upper.

The brass wire frame which is screwed on to the top of the reservoir has at its upper end a bracket and hook for suspending the lamp, it carries an intermediate ring which fits over the top of the glass shade, and the ring on the bottom of the copper wire gauze shade fixing both in position when it is screwed down.

When the brass wire frame is screwed down hard and all the parts of the lamp are fixed a hinged catch on the frame falls over an eyelet on the reservoir and is padlocked.

To allow for any variation in length in the glass shades, a cupped ring is fitted to take their ends on top of the reservoir, and, if necessary, a fibre asbestos washer is fitted at the bottom.

The safety lamp is so called because it is safe to use in a mixture which would be exploded if a candle or ordinary lamp were brought into it.

It has been seen in considering the question of the burning of gas given off by coal in a boiler that it is necessary for combustion that the gases should be at a certain temperature.

In the safety lamp the explosive mixture goes into the lamp and lights or explodes inside the gauze screen in much the same way as the mixture immediately around a naked light would, but as the gases pass through the wire gauze they are so cooled that they do not burn outside; this action of wire gauze in so cooling a flame that it will not burn after it has passed through it is readily demonstrated by holding a piece of wire gauze on top of an ordinary gas jet, when it will be found that the gas will not burn on top of the wire gauze even if it is lowered to touch the gas burner; and if this flame is put out and the gas agained turned on, it may be lit above the gauze wire without lighting below.

Safety lamps are always trimmed, lit, and locked ready for use before they are issued, but the person using them should himself see that the glass shade is not broken or damaged and that the gauze wire is in good condition in the shield round the flame or in air inlet tube; injury to these parts allowing free communication between the air outside the lamp and that inside will cause an explosion if the air outside the lamp contains explosive gas.

For this reason no attempt should be made to clean gauze wire on the lamp with anything which may injure it. If the lamp does not burn properly after trimming with the apparatus fitted on the lamp, it must be returned to the person who trims the lamps and seen to and cleaned as necessary by him.

If explosive gas is present, a safety lamp indicates it by the flame burning blue, and if the gas is present in large quantities the force of the small explosion inside the lamp may be sufficient to blow out the flame.

When a coal bunker is opened, a safety lamp should be taken in and held as high above the head as possible and the condition of the flame observed; the lamp must be held high because explosive gas is generally lighter than air and rises to the top of a space. If explosive gas proves to be present, extra ventilation must be afforded by taking off bunker lids or by opening doors, no naked light must be used to work by, and safety lamps must be used if light is necessary when removing the lids or opening the doors. After the extra ventilation has been in operation for some time, the safety lamp should again be taken into the bunker to test the air, and no naked lights should be brought in till all parts of the bunker have been proved by it to be free from foul gas.

In the case of a double-bottom or wing compartment or similar confined space, where either explosive gas or foul air may be present, the safety lamp should be used in the first instance to test for explosive gas, and after this has been proved to be absent, naked lights should be tried to see that there is no undue proportion of foul air.

It has been stated that explosive gas is generally lighter than air, but some heavy gases also are explosive, and the safety lamp must be tried in the top and bottom of the compartment by some one standing outside, a line being used if necessary. In this way the bays near the top and bottom manholes may be tested, and when it is seen that the safety lamp burns in them with normal flame, they may be entered with the lamp for the purpose of testing the air in the next bays, and so on till the whole of the compartment is seen to be safe.

Afterwards, as an additional precaution, although the fact of the safety lamps having remained alight has shown that the compartment contains air which is not very foul, lighted candles should be tried, their flames being more easily observed to be burning dull and giving a better indication of foul air than that of a safety lamp.

A copy of the instructions on this subject is appended; candidates for advancement ratings of Chief Stoker and Stoker Petty Officer will be questioned in them by the Engineer Officer, and must show a good knowledge of the same, to be considered qualified to hold a higher rating. The fact that he has such knowledge will be noted on the candidate's passing certificate.

PRECAUTIONS WHEN ENTERING CONFINED SPACES.

The following precautions are to be observed while men are engaged in cleaning and coating the double bottoms of a steel ship, and in every other confined space, including boilers and coal bunkers which men have to enter :—

(*a*) Naked Lights.—When opening up a confined space no naked light is to be used inside the space or within 20 feet of the opening, until it has been ascertained by means of a safety-lamp that it does not contain explosive gases. Every bay of a confined space is to be tested.

(*b*) Air Fans.—The air fan with hose is to be freely used for pumping in fresh air before the men are sent down, and while they are at work.

(*c*) Precautions before entering Compartment.—A chief stoker or stoker petty officer is to be responsible under the engineer officer in charge of the party that no man enters the compartment except as required by paragraph (*g*) until a lighted candle has been placed inside it and has been found to burn clearly and steadily for at least five minutes.

(*d*) Compartment with only one exit.—Still greater caution is required when the compartment has only one exit.

(*e*) Communication.—Communication is always to be kept up between the men in the inner compartment and those who have access to the outer air.

(*f*) Light burning dimly.—The men are to be warned that they should leave a compartment immediately the light begins to burn dimly. Candles only are to be used by the party as a surer test than lamps, since it might be thought that lamps burn dimly for want of trimming.

(*g*) Danger of Bogies, &c.—Every man working in confined spaces should be specially cautioned as to the danger of taking bogies or burning fuel into such places.

(*h*) Persons using safety lamps should be carefully instructed as to the uses of these lamps for ascertaining the condition of the air in any confined space, bunker, or tank in respect to the presence of dangerous gases.

(*j*) It should be understood that such gases may be inflammable or explosive, or they may be dangerous to breathe without being inflammable or explosive.

(*k*) The non-explosive gas is usually heavier than air, and remains in the lower part of a space, whether closed at the top or not.

(*l*) The inflammable or explosive gases may be heavier than air, and also remain in the lower part of a space, or they may be lighter than air and collect in the upper part of a closed space.

(*m*) In the presence of the non-explosive gas, the flame of the safety-lamp burns dimly or is extinguished. When inflammable or explosive gases mixed with air are present, the flame and the space inside the wire gauze of the safety-lamp must be carefully watched for unsteadiness or additional flame. When air in sufficient quantity to produce explosion is not mixed with the inflammable gas, the flame of the lamp may be extinguished by the gas.

(*n*) For the safe use of a safety-lamp as a means of testing the state of the air in any space which contains inflammable or explosive gases, it is necessary not only that the gauze be sound and undamaged, but also that the lamp be carried steadily and shielded from draught, that the wire gauze be kept clean and free from soot or coal dust, and that the lamp burns with a clear flame while outside the space to be tested.

(*o*) When using a safety-lamp for ascertaining that the air in any confined space does not contain explosive gases as required by paragraph (*a*), the absence of gases dangerous to breathe must also be ascertained by means of the safety-lamp.

(*p*) If the flame of the lamp is unsteady, increases in size, and is drawn upward with a fine point; if it burns dimly or goes out, the space is dangerous and is not to be entered until it has been thoroughly ventilated. The safety-lamp is to be extinguished or withdrawn without delay.

(*q*) Before men enter any compartment, bunker, tank, or boiler which is not already known to be free from dangerous gases—

i. A locked safety-lamp is to be tried as far inside the opening of the confined space as the lamp can be held without losing sight of the flame.

ii. The lamp is first to be held in the upper and then in the lower part of the space, being lowered by a line, if necessary, to reach the bottom of the space.

iii. If the lamp will burn steadily in those positions the compartment may be entered. The flame of the safety-lamp is then to be tried in the upper and lower parts of each bay of the compartments, keeping up communication with those outside the compartment. Should any indication of the presence of dangerous gas be observed, the space is to be quitted immediately, and is to be further ventilated until the lamp will burn steadily in all parts of the space. During the test, should the person using the safety-lamp fail to keep up communication with those outside the compartment, steps are to be promptly taken to bring him out and force fresh air into the space.

2. Special care is to be taken that every man in the ship is made acquainted with these precautions.

PRECAUTIONS WHEN ENTERING COAL BUNKERS.

Safety-lamps.—No naked light should be used inside the coal bunkers, or within 20 feet of any opening into the bunkers, until it has been ascertained by means of a safety-lamp that they do not contain explosive gas, and special precautions in this respect are to be taken for a few days after coaling. In any case in which the distance of 20 feet is impracticable the distance maintained should be as great as possible.

In ships with upper bunkers, on the first occasion after coaling, when opening the doors between the upper and lower bunkers, a safety-lamp only should be used, and the man holding it should remain on the deck above on the top of the coaling trunk while the door at the bottom is being unfastened in order that the flame of the lamp may be observed and the lamp removed in the event of inflammable gas coming from the lower bunker into the trunks when the fastenings of the doors are slackened.

CHAPTER XII.

Precautions against Fire.

Fire main pipes are led forward and aft in a ship with deliveries in each compartment to which hoses may be attached for delivering water at the fire. The water is pumped into the fire main by the steam fire engines and also by the hand or electrically worked Downton pumps. The suctions for the latter are usually left connected to the sea so that the pumps may be immediately available in case of fire.

On the outbreak of a fire all communication with other compartments is cut off by closing doors, ventilating valves, &c., to prevent the fire spreading; and to extinguish it the air supply is cut off, as far as consistent with the safety of men working to extinguish the fire, by closing ventilation including side scuttles and hatchways.

Details of precautions taken to prevent outbreak of fire with coal and oil fuel and in connection with working of boilers have already been given, but attention is required to the following items in addition.

Combustible Matter not to be placed in Ventilators.—No oakum, paper, articles of clothing, or any other combustible matter is to be allowed to be placed in the ventilators, or in any holes or ledges that are not easily seen, as a fire might be caused by the spontaneous combustion of any of these articles. All ventilators are to be periodically examined to guard against accumulations of rubbish.

Care in extinguishing Lamps.—Lamps should never be extinguished by means of a piece of oakum or rag put on the flame, as portions of the burning wick are likely to adhere unobserved to the oakum, which, smouldering for a time, may eventually burst into flame.

Use of Mineral Oil.—No mineral oil of any kind, except as may be approved, is to be used for lighting purposes.

Lights to be extinguished.—Care is to be taken that all lights that have been used by Dockyard or other artificers are properly extinguished.

Spontaneous ignition of Cotton Waste, &c.—Cotton waste which has been used as wipings for oil is very liable to become ignited through the heat developed by the rapid oxidation of the oil; and it has been demonstrated by experiment that this action is not confined to drying oils, such as boiled and raw linseed, rape, &c. All the oils, except mineral, must, therefore, be considered as more or less liable to cause the spontaneous ignition of cotton waste and similar fibrous or other porous materials.

Greasy wipings to be destroyed.—Cotton waste, and other wipings saturated with oil or grease, are to be destroyed immediately after use.

1. *Iron Bins.*—All lockers and bins, in which wipings or other combustible materials are deposited, are to be constructed of iron, in order to guard as much as possible against accident by fire.

2. *Storage of Oil, Tallow, Cotton Waste, &c.*—Oil, tallow, and cotton waste, and other wipings are to be kept in the iron tanks supplied for the purpose, which should be placed as far from the boilers or steam pipes as convenience will permit.

Storage of inflammable Liquids.—A special store-room is generally appropriated for spirits of turpentine, varnishes, &c., and, where this cannot be done, fittings for the stowage of these inflammable liquids are provided in the spirit-room.

Inflammable liquids to be stored in spirit-room. Spirits of turpentine, varnishes, compositions for the ship's bottom, and any other highly inflammable liquids, specially allowed, are to be stowed only in the spirit-room, or store-room specially appropriated, *into which no lights are to be allowed.* They are never to be drawn off from any cask or vessel anywhere but on the upper or main deck, and this is to be done during the day-time and away from any fire, and lights also if possible; but if a light be absolutely necessary, a safety-lamp is to be used.

The casks and cans used for each description of oil and composition are painted the distinguishing colour authorised for each; and when issued to ships are fitted with screw bungs or lids in accordance with the established patterns.

Inflammable stores are only to be drawn and kept on board in the approved casks, drums, or cans; and a label designating the liquid with the words "Inflammable—no light to be brought near this" is to be attached before issue to every cask, drum, or can which contains any inflammable liquid.

Oils and tar are also to be drawn in iron casks, &c., with screw bungs.

No cask, &c., containing oil, varnish, or other liquid, is to be completely filled, but sufficient space is to be left to allow for the expansion of the liquid under increase of temperature.

All casks and cans are to be drained out immediately after emptying. The screw bungs and screw lids are to be carefully cleaned and oiled, and they are to be at once screwed up tightly so as to exclude the air and keep them clean till again required for use.

Nightly report as to condition of Tanks, Casks, &c.—At evening quarters the responsible persons are to ascertain and report that all tanks, casks, drums, &c., containing inflammable liquids in use are in good condition, do not leak, and are stowed in their proper places, with their taps properly turned off or bungs screwed down.

Used coal sacks and bags are to be opened out from time to time, as fine coal dust remaining in them may generate heat.

In stowing the bag lockers, the bags should be stacked in bundles in such a manner as to admit of circulation of air amongst the bags. For the preservation of the bags, frequent attention to the dryness and ventilation of the locker is to be given.

Acids.—Acids are not to be kept near any article of an easily inflammable character, nor where they can damage other stores.

CHAPTER XIII.

Tools, &c.

Bolts.—The common method of securing one piece of machinery to another is by means of nuts and bolts. Referring to the figure a bolt consists of two parts, the head A and the shank B, which has a thread cut on it on which to screw a nut C. The nut and bolt head are shaped as shown to allow of their being gripped by a spanner.

The bolt is passed through a hole drilled in the two surfaces to be secured and a nut screwed on to the bolt until the surfaces are drawn tightly together.

Spanners.—Consist as shown in figure of a steel or iron flat or round bar forming a handle, enlarged at one or both ends, where there is a hole or gap so shaped as to allow it to fit over a nut or bolt head, and is used for screwing or unscrewing nuts and bolts.

They are made in various shapes according to the purpose for which they are intended to be used and are named accordingly, viz., single-ended double-ended, ring, socket, or box spanner.

Spanners are known by the diameter of the bolt whose head or nut it is intended to fit. Thus a half-inch spanner is one of such a size that it fits a nut or head of a bolt the diameter of whose shank is half an inch.

A MacMahon spanner is an adjustable spanner with a shifting jaw that can be moved so as to fit nuts of various sizes.

Drills.—Are steel tools made in various sizes and shapes and are used for making round holes. The drill requires to be revolved and this is done either by a machine or by hand by means of a ratchet brace, carpenter's brace, or an archimedian brace, according to the class of work that has to be done.

Chisels.—Are steel tools hardened and ground to a fine edge for cutting metal or wood. They are of various forms and shapes according to the purpose for which they are intended and are named accordingly, viz., chipping, cross cut, diamond-pointed, round-nosed, &c.

Hammers.—Are made in various forms for different purposes as follows :—Hand hammers for ordinary work, hack hammers for removing rust or scale, sledge hammers for forge work, copper or lead hammers for giving a blow on any iron or steel surface withont injuring it, &c.

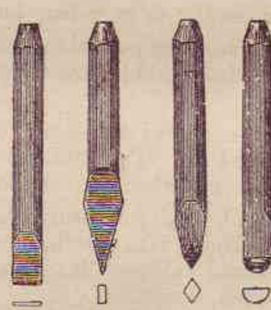
Crow-bars or Pinch-bars.—These are lever of steel used for moving heavy weights.

Hydraulic jacks are used for lifting heavy weights.

The jack consists of a hollow cast cylinder containing a large piston rod or ram, the gland being packed by a cup leather, the hollow end of which is open to the pressure in the cylinder. A small force pump actuated by a lever worked outside the jack supplies the pressure under the ram.

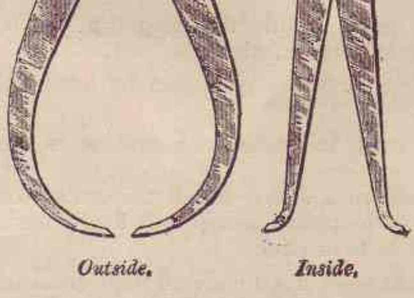
Stock and Dies.

Chisels.



Flat. *Cross Cut.* *Diamond* *Half Round.*

Callipers.



Outside. *Inside.*

Fresh water should be used in hydraulic jacks on ordinary occasions. When it is probable that the temperature will be sufficiently cold to freeze water, spirit (rum) or glycerin in the proportion of one to two of water should be mixed with the water in the jacks.

The jacks should be pumped up once a week, the rams cleaned and oiled, and then run down.

The jacks are at full height when the water comes out of the small hole behind the claw.

To charge a hydraulic jack, care is to be taken that the ram is quite home, and then the cistern is to be filled with clean water.

If the valves fail from misuse, screw up the lowering screw tight, then stand the jack upon its base, and pull the cylinder up upon the ram, this will cause a rush of water through the pump and so cleanse it.

Handspikes.—Are levers similar to crow-bars but are made of wood.

Punches.—Are steel pins used for punching holes in plates or driving out rivets or pins; they are also made hollow for cutting holes in leather or similar material.

Vice.—An appliance by means of which any object can be securely held whilst it is being worked on. They are of various forms according to the purpose for which they are intended, viz., bench hand, &c.

Callipers.—An instrument used for measuring sizes where a rule is unsuitable and are of two kinds, viz., external callipers for measuring outside dimensions and internal callipers for measuring dimensions for which external callipers cannot be used.

Straight Edge.—This is a flat piece of wood or steel one edge of which is made perfectly straight, and is used to test if any surface is straight and true.

Taps are used for cutting screw threads in holes; they are of hardened steel and screwed to the thread it is desired to form.

Each tap has three or more grooves running its length, which allow metal cut away from the sides of the hole to escape without damaging the thread which is being cut.

In the *taper tap*, which is first used, the whole of the thread is cut away at the bottom to enable it to enter the hole, it increases in diameter gradually all the way to its top.

The *second tap*, next used, is similarly ground away but not so much.

The thread is finished with the *plug tap*, which is of the same diameter for the whole of its length.

Stock and Dies.—Threads may be cut by hand on bolts by using *stocks and dies.*

Dies are hard steel half nuts with grooves in them allowing the cuttings to escape.

The dies are held in a frame called the stocks, and by means of a screw the dies may be brought together and finally made to touch as the thread is cut on the bolts or stud.

Die Nut is a hard steel nut furnished with clearing grooves. It is used to run down over the threads of bolts or studs to make sure they are of the proper size for the nuts.

Oil or some other lubricant should be used with taps, stocks, and dies and die nuts.

FILE.—A file is a flat or round pice of steel furnished with teeth. It can be fitted into a handle and cuts away iron or steel with its teeth when rubbed over it.

SCRAPERS are furnished with edges like ordinary knives or chisels, but the metal behind the edge is kept stronger than with them. They are used to scrape cuttings off the surface of metal.

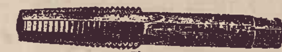
Spanners.

Single Ended.

Double Ended.

Adjusting.

Taps.

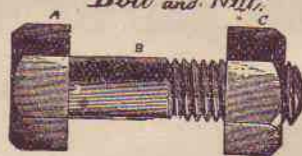


Taper.

Second.

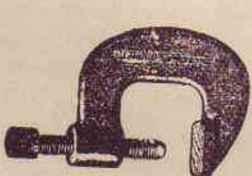
Plug.

Bolt and Nut.

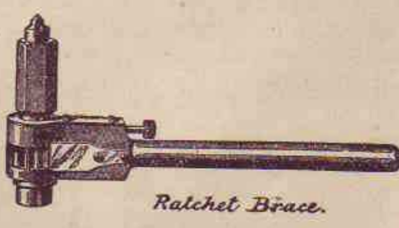


Drilling Post.

Stud.



Clamp.



Ralchet Brace.

Files.

Flat.

Half-round.

Taper saw.

Square.

Round.

Drills.

Machine Twist Drill.

Ratchet Twist Drill.

Pliers.

Screws.

Countersunk.

Roundhead.

Cheesehead.

CHAPTER XIV.

Materials.

The material most extensively used in the construction of machinery is cast iron or steel.

Wrought Iron.—Is the purest form of iron. When heated to a white heat it can be wrought or hammered into any desired shape. It also possesses the valuable property of welding, that is, being joined together by raising to a certain temperature and closely united by hammering.

Cast Iron.—Is iron which by means of heat can be melted and run into moulds. It is used for making castings of intricate form, such as cylinders, slide valves, &c. Cast iron will stand a great compression but is very brittle, *i.e.*, is easily fractured by a sharp blow.

Steel.—The properties of steel vary considerably according to its composition.

The material known as mild steel has generally superseded wrought iron in the construction of machinery.

Steel is stronger than wrought iron and cast iron and can be melted and cast into moulds or wrought into any desired shape by hammering.

The following parts of engines are now usually made of steel:—

Cast Steel.—Pistons, cylinder covers, engine framing, &c.

Wrought Steel.—Piston rods, connecting rods, crank shafting, engine columns, &c.

Copper.—Is a reddish-coloured metal that can be melted and cast into moulds, and is easily worked.

It possesses the property of being capable of being brazed, that is, if two pieces of copper are placed in contact, heated to a red heat, and a brazing material known as spelter, which consists of a fusible mixture of copper and zinc, applied to the joint, this brazing material is melted and amalgamates with the copper forming a strong joint.

Copper can be rolled into plates or bars, or drawn out into wire. Copper is used for making steam pipes, water service pipes, lubricating pipes, &c.

Brass.—Is a yellow metal made by mixing proportions of copper, zinc, and tin. It can be melted and run into moulds or rolled into plates or rods.

Tin.—Is a metal of a white colour. It does not rust and can be made to adhere to iron so as to protect the iron from rusting. It is principally seen in the shape of tin plates, which are really very thin iron plates coated with tin, from which oil feeders, lamps, cans, and similar articles are made.

The mixture of tin with copper and zinc to form a brass prevents the resulting metal being attacked by sea water.

Zinc.—Is a whitish metal which can be melted and run into moulds or rolled into plates or rods. Zinc plates or bars are placed in the boilers to prevent the boiler itself being eaten away by galvanic action. The zinc plates are attacked and when worn are replaced by new. Like tin, zinc does not rust and is used for coating iron to make it rust proof.

Iron so coated is known as galvanised iron. Boiler tubes, &c., are often given a coating of zinc to protect them whilst lying about exposed to the damp.

Lead.—Is a soft bluish metal used chiefly in the form of sheet lead from which pipes, washers, &c., are made.

Solder.—Is a mixture of tin and lead, and is used for uniting two tinned surfaces. The two surfaces being heated and the solder applied in a liquid state, it amalgamates with the tin and unites the two surfaces.

White Metal.—Most of the bearings in marine engines are filled with a soft white metal made of a mixture of tin, antimony, lead, &c. It is a soft and plastic metal and if well lubricated will sustain a great pressure without heating.

CHAPTER XV.

Stores used in connection with Machinery.

The use of coal, oil fuel, and lubricating oil has already been described in Chapter VII., and the methods of storing the two first named have been dealt with.

Storage &c., of Oils.—It is important that all tanks and drums intended for the reception of oil should be thoroughly cleaned before filling in order to avoid the ill effect of mixing different oils.

The general appearance and smell of "*ordinary*" and "*special*" *mineral* lubricating oils for external lubrication are very similar, and it is therefore necessary in dealing with deliveries of these oils, that great care should be exercised at all times to prevent one from being mistaken for the other. *Special* and *ordinary* lubricating oils are supplied in drums painted *green* and *yellow* respectively.

Rapeseed Oil, which is no longer used for lubrication, and *mineral sperm* are supplied in drums painted *brown*. Rapeseed oil is now only used for lighting purposes where mineral sperm is unsuitable.

Neatsfoot Oil is used in the compression cylinders of the air compressors; it is also used with cod oil and tallow for dressing or preserving leather work.

Glycerin.—*Brown Glycerin* is used in the glands of ammonia and carbonic acid refrigerating machinery.

Refined Glycerin is used in the telemotor gear, also in the recoil cylinders of gun mountings which are not operated by hydraulics. These are necessarily kept full, and if water were placed in them there would be danger of damage being done by its being frozen in cold weather. A mixture of $\frac{1}{3}$ glycerin to $\frac{2}{3}$ water is generally used in the telemotor system. This mixture will not freeze in the temperatures ordinarily experienced in winter; but if it is necessary to provide for extremely low temperatures the proportion of glycerin should be increased.

Jointing Materials.—Joints on steam, feed, and oil fuel suction and delivery pipes are generally thoroughly faced to a surface plate and are bolted together metal to metal with only a smear of read lead paint between, and all joints on oil fuel fittings are similarly made.

Where *red lead* is employed on a steam or water joint it is prevented from squeezing out when the joint is screwed up in the first place, and from being blown out if it should leak in one place by placing a joint of *copper wire gauze* between the flanges. The copper wire gauze is made to fit the flanges by being placed on one of them and tapped round the edges of flange and any bolt holes with the poll of a hammer.

Steam joints are sometimes made of *asbestos and indiarubber wire-woven cloth*, which is made of asbestos woven on brass wire gauze and faced with india-rubber, the joints being cut out as described for the wire gauze and the bolt holes cut with a punch. American cloth and "Klingerit" are also used for jointing stiff and well surfaced flanges.

Jointless rings of asbestos and india-rubber woven on brass wire gauze are supplied for all important doors and flanges on the engines and boilers. These are made to templates or patterns which exactly fit the door or flange and are ready to go in place, except where holes require to be punched for bolts or studs.

Before making or re-making a joint it should be seen that the flanges are fair and level. Any burrs or lumps on the face should be cleared away with a scraper or a file.

The bolts should be held in a vice, oiled, and nuts run down on them, or the nuts should be run down on the studs if fitted, to ensure that when the nuts are screwed up in place they will take on the flange and not on some obstruction on the thread of the bolt or nut.

Joints and rings in which bolt holes have been cut should be placed over the bolts or studs to see that there is no tendency to fold or to stretch the material, and the holes in them should be trimmed as necessary to prevent this. In all classes of joints the use of an unnecessary thickness of jointing material is to be avoided. It should never be thicker than necessary.

Nuts should be screwed up evenly and gradually. If necessary to support the pipe or cover three or four nuts should be run down on their bolts or studs just taking the weight, the rest should then be screwed up similarly. Afterwards the flange should be gone round as often as necessary, each nut being screwed up to the same extent to ensure that the jointing material is equally squeezed the whole way round.

When joints are required to be broken frequently the faces of the sheet jointing material used should be smeared over with plumbago to prevent them from sticking to the flanges when screwed up.

It is most important that the amount of material used on the joints of boiler doors for this purpose should be limited. On no account should material be used on the jointing rings of boiler doors which may be squeezed out and get into the tubes or other parts of the boiler.

Joints on water piping other than feed pipes are usually made with red lead, some temporary joints are made with india-rubber sheeting.

Thicker sheeting of the same material is used in the frames on which the rims of water-tight doors, scuttles, hatches, &c., close.

Sheet india-rubber should not be used for renewing india-rubber valves unless spare moulded valves cannot be obtained. India-rubber speedily loses its elasticity and perishes when it comes into contact with oil and grease.

India-rubber pump valves should be frequently removed and cleaned by washing in a soda solution to remove the grease, after which they should be trimmed to their proper size to prevent overlapping.

The rubber on water-tight doors and scuttles must be kept free from grease. It is best preserved by rubbing French chalk over it.

Packing for Glands.—Glands round the rods of steam cylinders, water pumps, and the spindles of valve boxes, expansion joints, &c., are kept tight by packing placed in them and pressed against the rod by the gland.

Metallic packing is commonly fitted to the piston rods of the main engines and to those of some of the auxiliaries, and this does not need frequent renewal. Asbestos and elastic core packing are often fitted in small glands carried on the outside of the gland containing metallic packing, and are used entirely in glands not fitted with it. These packings are made up in the form of a rope of either round or square section.

Asbestos packing is made from the mineral asbestos and stands high temperatures better than the elastic core packing, which is made of canvas soaked in an india-rubber solution surrounding a rubber core. Asbestos packing is used where the high temperature of high-pressure steam has to be withstood, and elastic core packing on L.P. rods and glands and for other low-pressure and water glands.

Cotton woven packing is employed in pump rod glands.

Where it is desired to avoid friction as far as possible, in such positions as the glands on the spindles of the gear of an automatic feed regulator an anti-friction packing is used.

The Belleville anti-friction packing which is sometimes used contains—

46 parts of lead.
40 ,, ,, tin.
10 ,, ,, graphite.
4 ,, ,, mineral oil.

Leather Work.—Leather is used for packing the plungers of hydraulic machinery; it is also used for jointing oil pipes on the forced lubrication service and on the oil fuel filling pipes.

Hides, crop, are used for jointing manhole doors, to double bottoms, for oil fuel and filling pipes, and the leather is soaked in cod oil and tallow and termed liquored leather.

Hydraulic leather for joints on forced lubrication system.

Hides, dintle, for leathers for gun mountings.

Leather was used until lately for packing the plungers and glands of air compressors, but fibre rings and washers are now used.

Leather hoses after being used should be carefully drained. They should be dressed with a mixture of equal parts of neatsfoot and cod oils.

All leather work should be kept in a cool place and should be treated with the preservatives mentioned, which should be well rubbed into it.

Packing for Plungers.—Fibre washers for use in the air compressor plungers are sometimes carried as stores, and space leathers for Downton's pumps are supplied. It is necessary to dress these leathers by rubbing neatsfoot and cod oils mixed into them, and they should be kept in a cool place.

For use in the water plungers of Weir's feed pumps, vulcanised india-rubber rings are supplied.

Lagging.—It is important that the lagging fitted to engines and boilers should be kept in good condition; and for making renewals, magnesia in blocks to suit the steam pipes, silicate cotton, asbestos millboard, and asbestos twine are carried.

Hair felt is also carried for fitting on exhaust pipes and on the less hot surfaces.

Lagging, when fitted in place, should always be protected from damage.

STORES FOR PRESERVING MACHINERY.—The exteriors of the boilers and all parts of the machinery and spare gear which it is desired to keep painted are given two coats of *oil paint* when the machinery is new, and this must be renewed from time to time.

Shafting inside the ship, rods, and any bright work not in use and which cannot otherwise be kept from rusting, should be coated with *white lead* and *tallow*, or with *mineral grease*. The propeller shaft outside the vessel is painted with three coats of red lead paint. It is of the greatest importance that this paint should be firmly set on the shaft. Before any paint is applied the shaft should first be scraped till the bare metal is visible everywhere; after this it should be washed with a hot solution of soda to remove any grease which may prevent the paint from properly adhering.

After the shaft is thoroughly dried one coat should be given; the next coat of the paint should not be given till this is thoroughly dry, and the third coat should not be applied before the second is thoroughly set. Whenever a ship is docked the same precautions should be taken in re-coating any bare spot.

Bath brick and *polishing* paste are supplied for polishing bright work.

Sponge cloths for cleaning purposes.

Cotton waste and Oakum are allowed for cleaning bilges.

MISCELLANEOUS.—*The Unslaked Lime* used in the feed water of boilers is supplied in airtight drums. It is absolutely necessary that it should be kept in these, and not exposed to the air open tanks, as it absorbs CO_2 from the air and loses its preservative qualities.

Portland Cement is supplied to ships for renewing that fitted in the double bottom, and at other places in the hull; it is also used mixed with soda for coating places in tank boilers, other than surfaces exposed to flame, where corrosion has begun to take place. It is also used on condenser tube plates.

For building brick bridges and the brickwork lining of furnaces *fire bricks* are supplied. They are laid in a mixture of two parts of *Stourbridge Clay* to one of *firm salt-water sand.*

Fireclay is supplied for use in the furnaces of steamboats, and *gannister* for ships carrying the Babcock and Wilcox boiler.

Chloride of Calcium is used for the brine employed with refrigerating machinery, because while it freezes at an equally low temperature, it does not corrode the iron or steel casings and coils with which it is in contact so quickly as salt brine does.

Coal Bags.—The condition of all strops and coal sacks and bags (particularly the beckets) is to be examined after each occasion of coaling, and in cases where the sacks or bags are seldom used they should be examined at intervals of six months, and any which may be found to be defective should be repaired or renewed as necessary.