STEAM TUG "WATTLE"

an engineering perspective

Although built in 1933, the Steam Tug 'Wattle' uses technology which was common place for steamships from the turn of the century.

Boiler

The Wattle is fitted with a two furnace 'scotch marine' steam boiler, as pictured. The 'scotch' boiler was introduced to marine engineering in 1862, with the introduction of the compound marine steam engine, which consumed 12% less fuel than the simple steam engine, but required steam at higher pressures. The introduction of steel and improved alloys for boiler plates and tubes allowed the construction of these higher pressure boilers (up to 1800 kpa). The oil fuel is burned in suspension within the two large, independent furnace tubes, then travels to the combustion chamber, where the burning is completed, and the hot gas is then passed through the small smoke tubes, leading to the smoke box and hence to the funnel. Because the gas leaving the boiler is hot, it rises in the funnel, which pulls the air required for combustion into the burner, and through the boiler tubes. This design is known as a 'fire tube' boiler, because the fire passes through the small fire tubes, which are surrounded by the boiler water. This process helps to transfer the heat in the gas into the water, to produce the steam efficiently. The boiler is 3/4 full of water, which cools all the heating surfaces.

Although water tube boilers gained popularity for larger applications such as liners and bulk cargo vessels from the 1930's, the popularity of the 'scotch' boiler is evident by there use in smaller coasters and steam tugs (like "Wattle") until the death of steam in ships in the 1950's. They were built with 1, 2, 3 or 4 furnaces, and in some larger vessels where double ended, having 6 or 8 furnaces (as pictured).

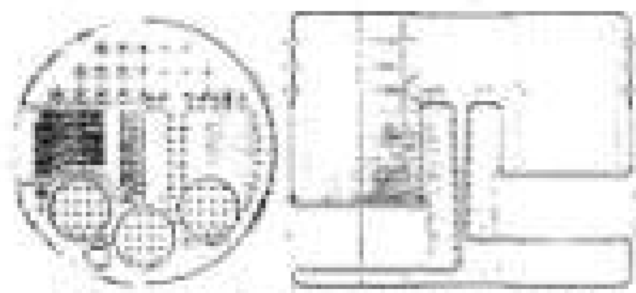


Fig 1. A typical Double ended Scotch Marine Boiler

Despite being fine steamers, these boilers are renown for their poor water circulation, with instances having occurred where the boiler is in steam, but the bottom is still cold, causing massive thermal straining, due to unequal expansion of the boiler plates. It is for this reason that our boiler is brought up to steaming from cold very slowly, taking a minimum of 24 hours, and steam is then kept on the boiler for the entire steaming season. At the end of the day, the boiler is shutdown with a full head of steam, and although some cooling causes the pressure to drop, steam is available many days later. The fireman arrives 2 hours before sailing time, and lights a fire in the boiler to bring the steam pressure back to a full head. Steam is also required for heating and pumping our fuel, and if the boiler has no steam to start up, lighting a fire is very difficult, so the boiler must always have steam available.

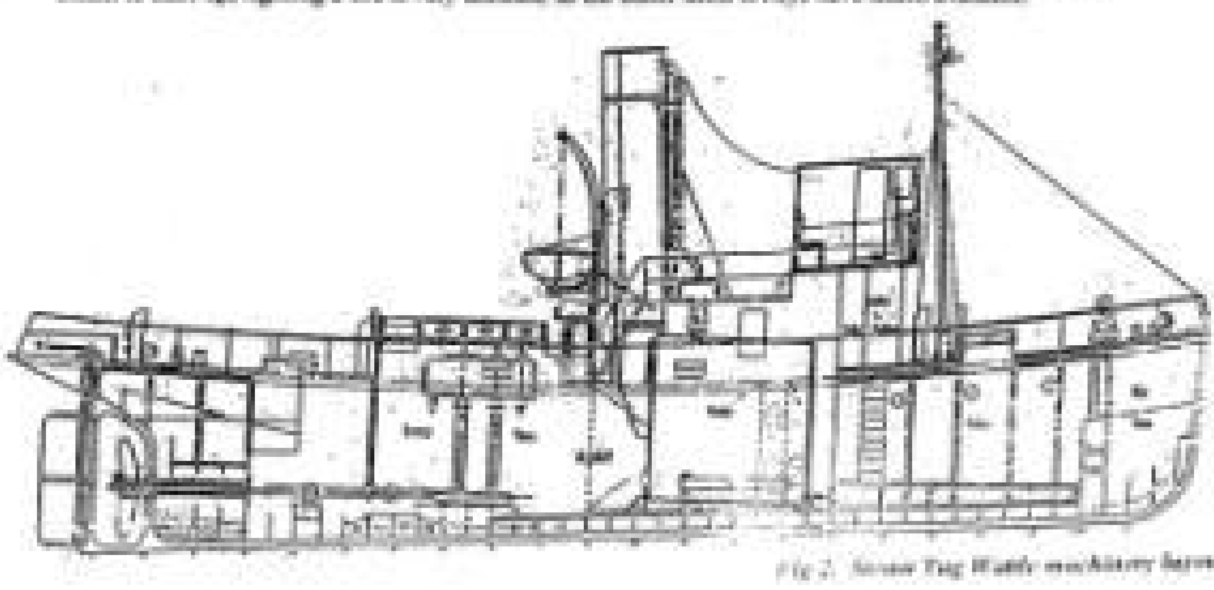


Fig 2. Steam Tug Wattle machinery layout

Main Engine

'Waratah' is propelled by a two cylinder, double acting, compound, reciprocating steam engine, of 283 indicated horsepower. Although sounding complicated, this simply means, that the engine is double acting, because it uses steam underneath the piston, as well as on top, so that each piston delivers 2 power strokes per revolution. *(This makes 4 power strokes per revolution, equivalent to an 8 cylinder car engine!)*

Compounding means that the steam is expanded out from the high boiler pressure to the low condenser pressure (nearly a perfect vacuum), in 2 separate stages. The steam is admitted to the smaller high pressure cylinder (355mm – 14") where it expands as it pushes the piston, this is then exhausted into the larger low pressure cylinder (762mm – 30") where the expansion is completed and exhausted to the condenser. The low pressure cylinder needs to be twice the size of the high pressure cylinder for two reasons: a) the LP steam has only half the energy of the HP steam, therefore the cylinder needs to be larger to achieve the same amount of work as the first cylinder, b) because the steam is expanding in doing work, the volume is more than double the original volume.

Looking at the main engine from the top, it is evident there is 3 circular chambers varying in size across the engine. The first and smallest chamber is the piston valve, which controls the admission and exhaust of steam to the high pressure cylinder. This type of valve is circular in shape, and looks like a cotton reel, with the inlet steam in the centre, and the exhaust steam on the outside. The symmetrical shape of this valve balances the forces acting on it from the high pressure, high temperature boiler steam. The next circular chamber is the high pressure cylinder, then the larger low pressure cylinder, and the square chamber on the back face of the engine, contains the square low pressure valve which is very large to accommodate the large volume, the exhaust steam occupies after it final expansion.

Why Compound?

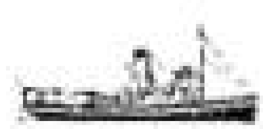
As the steam expands through the engine, doing work, the steam temperature also drops with the expansion. When steam is expanded in a single stage, the exhaust temperature will be very low, which tends to cool the cylinder walls when it is exhausted. The fresh high pressure steam entering the cylinder is much hotter, and tends to give up some of its heat in warming up the cylinder wall again, a loss of energy, which reduces the overall efficiency. By expanding the steam in stages, the temperature difference between the inlet and outlet is greatly reduced, thereby reducing heat loss within the cylinder.

The development of the compound engine led to savings of around 12% on fuel, and the triple expansion engine was developed, which used 20% less fuel than the simple expansion engine. Some larger vessels were fitted with quadruple expansion engines, but the savings where not much better the triple expansion engine which remained the most popular arrangement of expansion. Some triple expansion engines divided the large LP cylinder into 2 half sizes, creating the 4 cylinder triple expansion engine which has superior balancing for very smooth operation.

Small vessels such as 'Waratah' continued to use the 2 cylinder compound type of engine as there size did not warrant the extra cost of construction and maintenance, of and extra cylinder. Small coastal vessels fitted with compound engines such these were often referred to as 'tramp steamers', as the engines looked like an old tramp walking down the road.

Control of the Engines

The engine is controlled from the engine room only. The ship's Master communicates his commands to the engineroom through the telegraph. The engineer then answers to indicate his response, and then changes the admission of steam with the throttle valve to change the speed of the engine as required. The engine is directly coupled to the propeller shaft so that every turn of the engine is one turn of the 8' – 2.5m diameter propeller. For movements astern, the engine is reversed through the stephenson link motion (as pictured), which changes the engine valve timing to reverse the steam admission.



Engine room auxiliaries

'Wattle' is powered completely by steam, there is not an electric motor on board the ship, and some of the auxiliary engines include, a generator engine, a circulating water pump, a fire and salvage pump, fuel pumps, general service pump, and steering engine, all steam powered. The main engine also drives crosshead levers for the boiler feed pump, condenser air pump, and bilge pump.

Fig 3. 'Wattle's 2 furnace scotch boiler

Diameter	*xxxx*
Length	*xxx*
Pressure	*130 psi, 91.4 kpa*
Total Heating Surface	*xx sq ft*
Fuel	*waste oil*

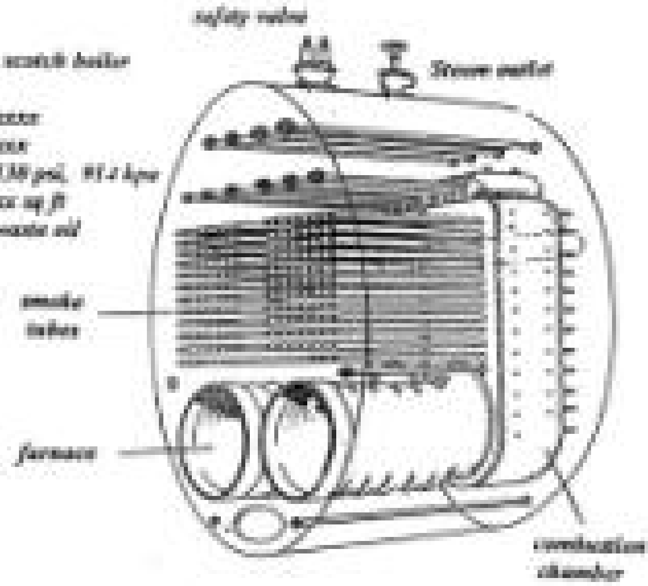


Fig 4. A two cylinder Compound Steam Engine

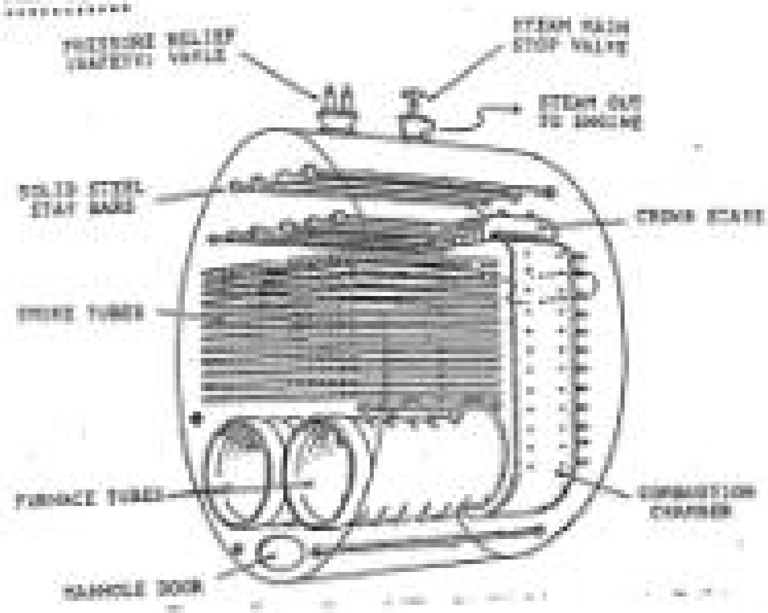
Fig 5. Stephensons Link reversing

Condenser

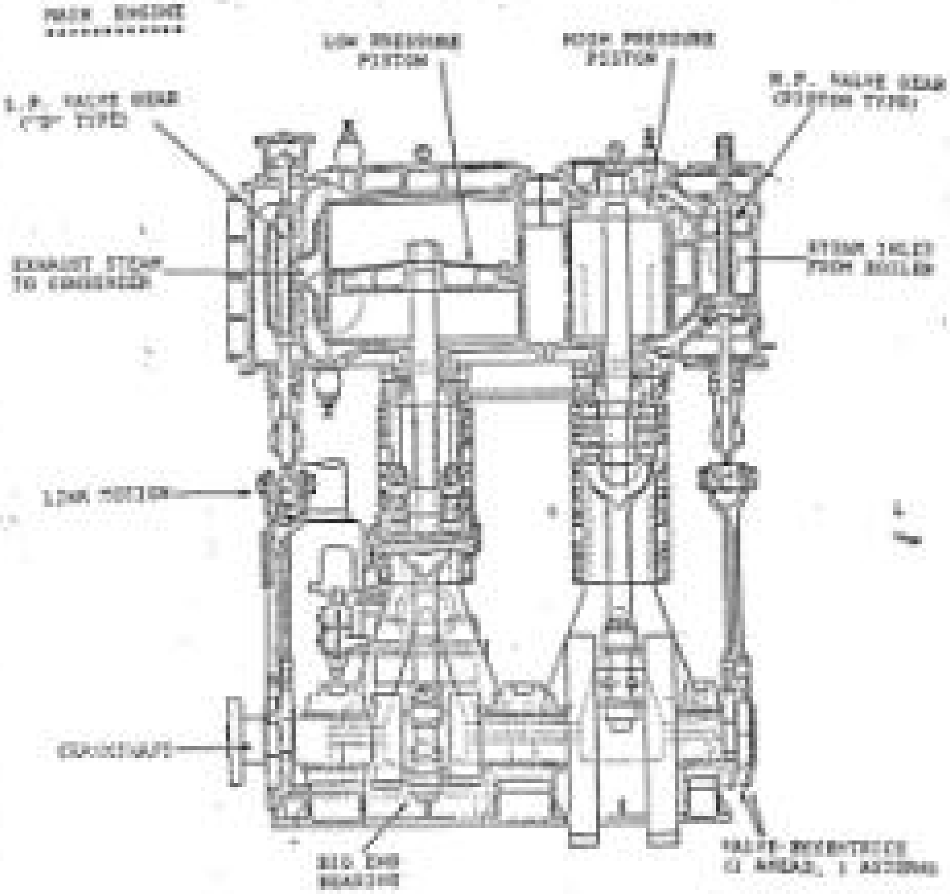
It is the duty of the condenser to receive the exhaust steam from the engine, and all the auxiliaries, condensing the steam back to water by removing the remaining heat from the steam by circulating sea water through the tubes in the condenser. Steam occupies a far greater volume than water, so the condensing process creates a huge vacuum within the condenser, which greatly increases the efficiency of the engine, as it does not have to exhaust to the pressure of the atmosphere. The pure water recovered from the condenser is lifted by a pump driven from the main engine which also extracts the non-condensable gas, and returned to the boiler to be again boiled to steam. This allows the ship to steam at sea for many days, without the need for huge reserves of fresh water for the boiler.

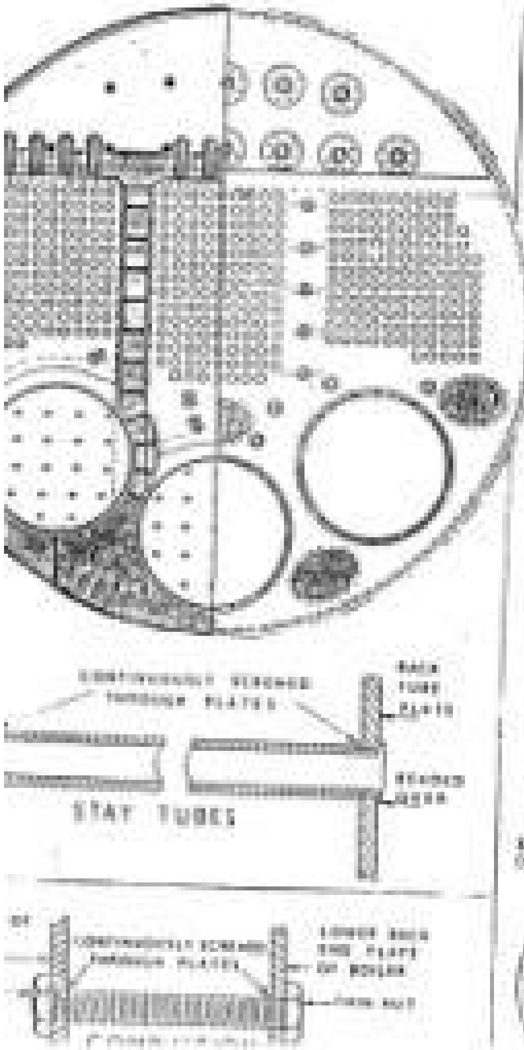
STEAM TUG "WATTLE" ENGINEERING DETAILS

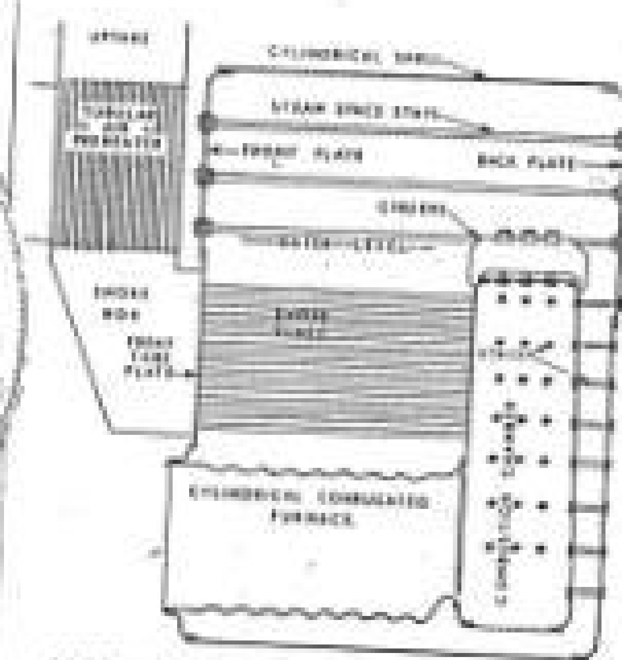
SCOTCH MARINE BOILER (TWIN FURNACE)



MAIN ENGINE

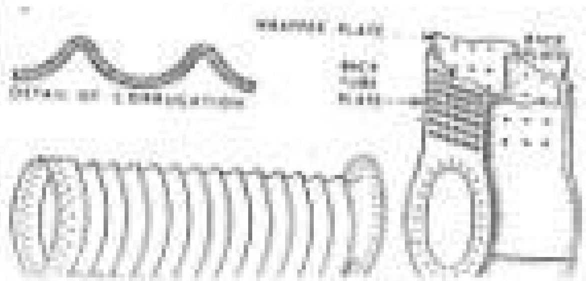


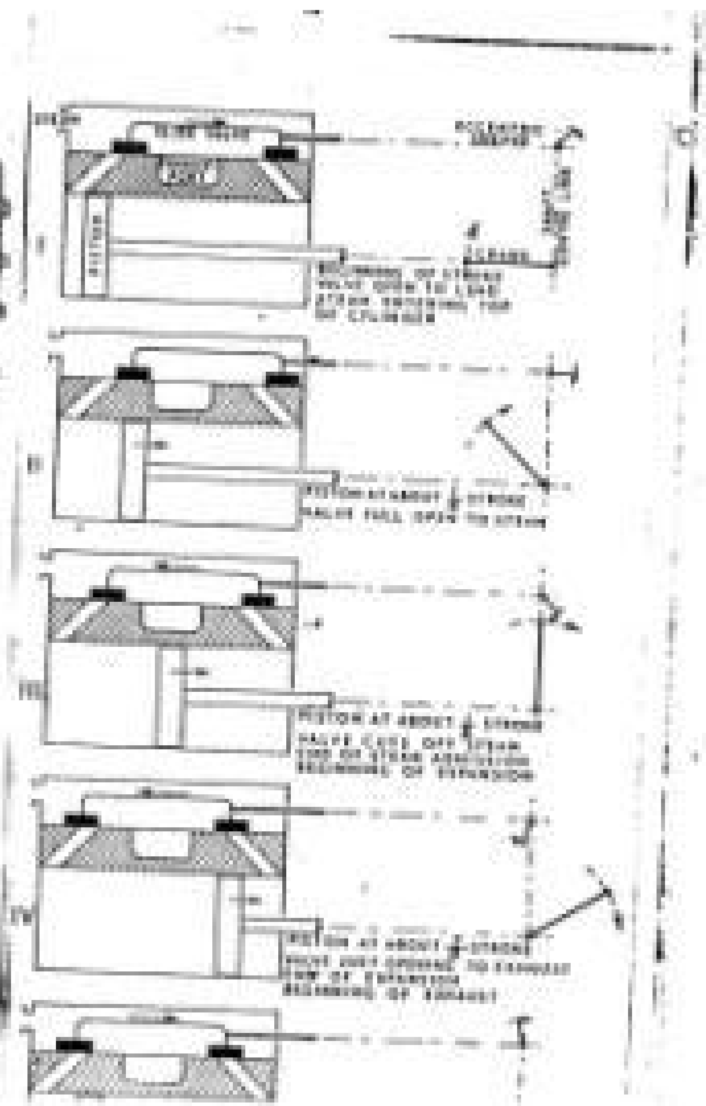




SECTION THROUGH A SCOTCH BOILER

Fig. 2



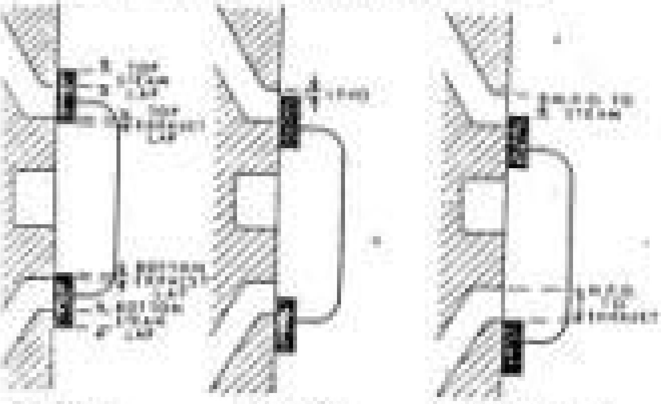


STEAM LAP is the amount that the steam edge of the valve overlaps the steam port when the valve is in mid-position (see Fig. 39).

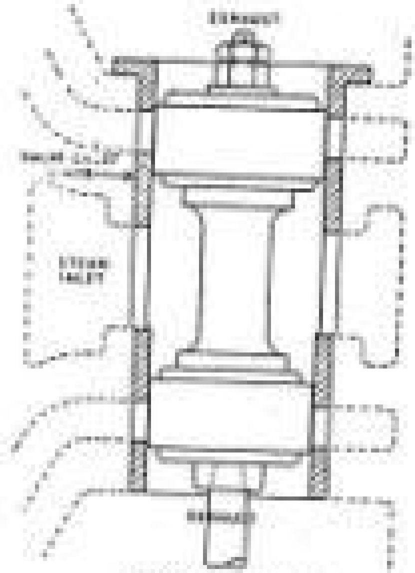
EXHAUST LAP is the amount that the exhaust edge of the valve overlaps the steam port when the valve is in mid-position. (see Fig. 39).

LEAD is the amount the port is open to steam when the piston is at the beginning of its stroke. (see Fig. 40).

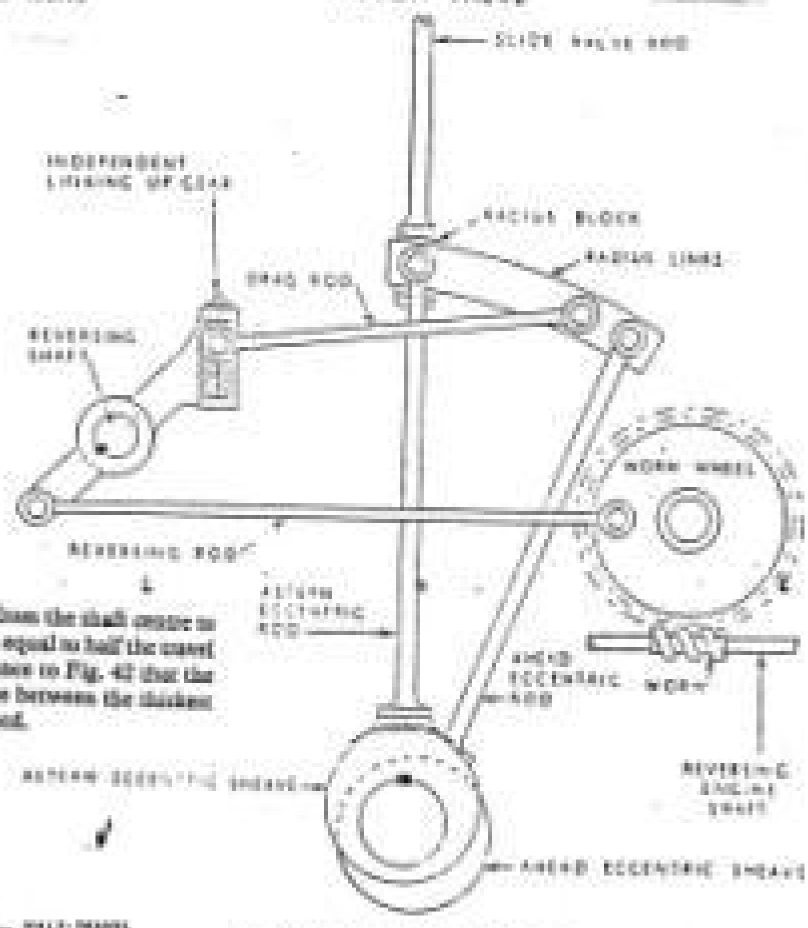
ANGLE OF ADVANCE is the angle through which the eccentric sheave is advanced beyond its normal position of 90° to the crank to allow for steam lap and lead. H P Cr Position Port Opening



VALVE IN MID-POSITION | VALVE OPEN TO LEAD (PISTON AT TOP OF STROKE) | VALVE AT BOTTOM OF TRAVEL

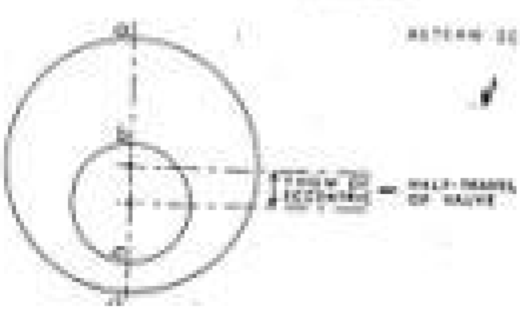


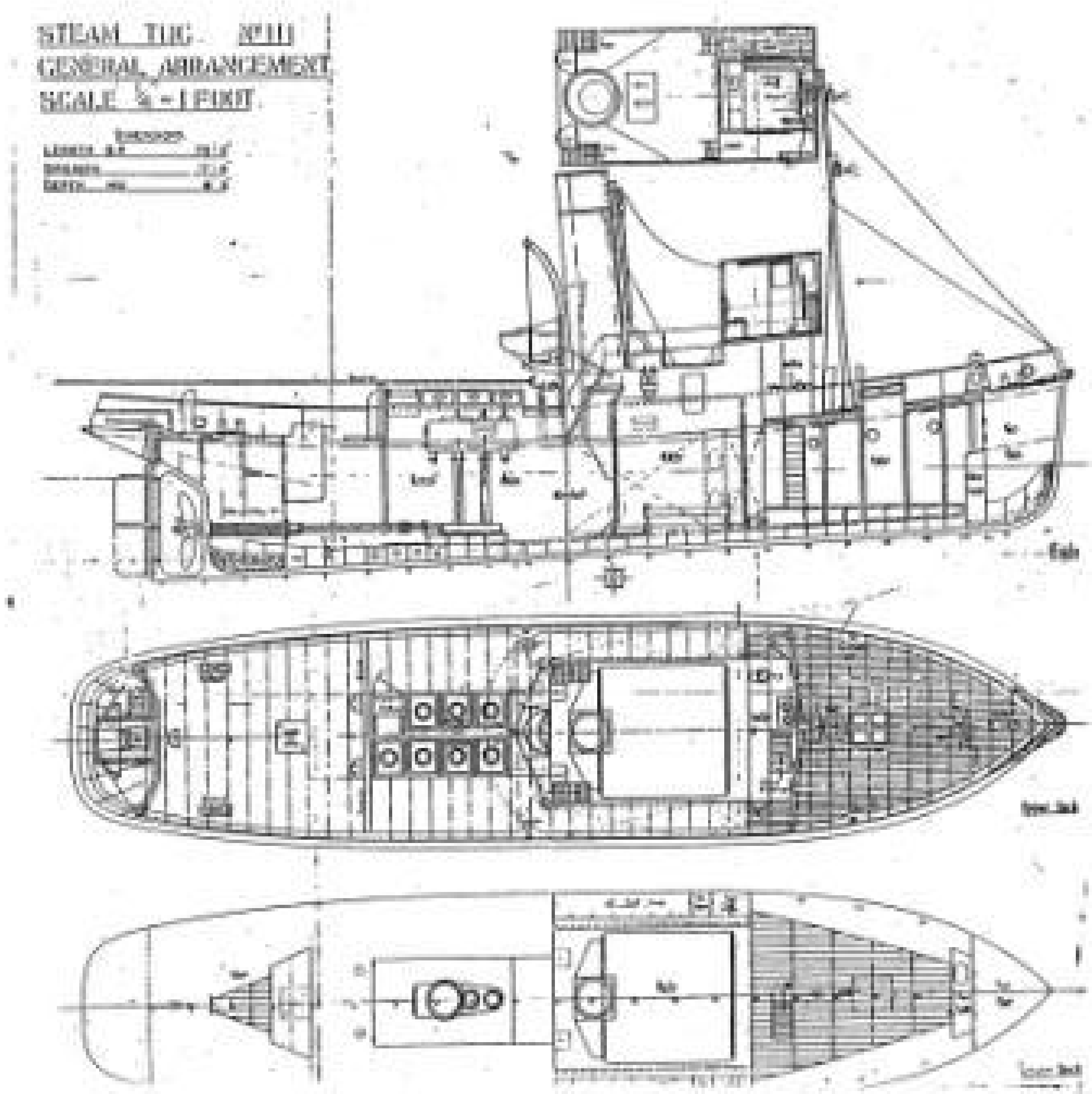
PISTON VALVE



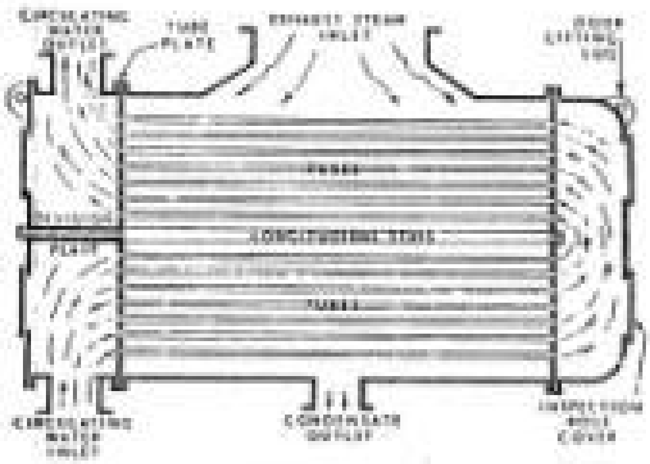
LINK MOTION GEAR

THROW OF ECCENTRIC SHEAVE is the distance from the shaft centre to the geometrical centre of the sheave, and this is equal to half the travel of the slide valve. It will also be seen by reference to Fig. 42 that the full travel of the valve is equal to the difference between the thickest part and the thinnest part of the sheave, *i.e.* ab-ad.




STEAM TUG
GENERAL ARRANGEMENT

All ships' condensers are of the surface type and vary in shape and design. A surface condenser commonly used in conjunction with steam reciprocating engines is a two-pass type consisting of two nests of sea water cooled tubes as shown in Fig. 52. It consists of a shell constructed of mild steel plates welded together, either cylindrical or pear-shaped in section, with a flange around the periphery of each end to which is bolted a brass tube plate. The tube plates are drilled and tapped to allow the ends of the tubes to pass through and form a small stuffing box with screwed ferrule to make a water-tight gland for each tube, thus allowing for longitudinal movement of the tube due to thermal expansion and contraction. The tubes are about $\frac{5}{8}$ in diameter and $\frac{1}{16}$ in thick, and may be made of brass or a copper-nickel alloy. A

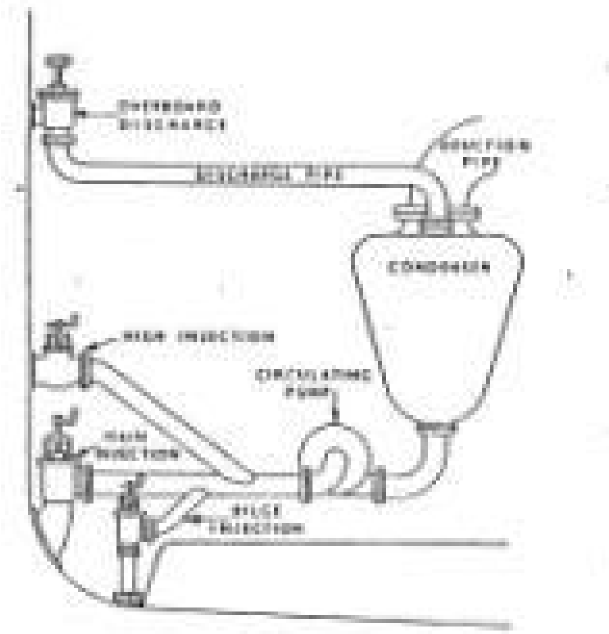


SURFACE CONDENSER

Fig. 52

cast iron water chamber is bolted to the tube plate at each end. One of these water chambers is formed simply by the convex shape of the condenser door, the other consists of a box with a sea water inlet branch at the bottom, a horizontal division plate across the centre, a sea water outlet branch at the top, and a separate door bolted on the outside. A large opening in the top of the condenser shell forms the inlet branch of the exhaust steam from the engine and a small opening in the bottom forms the branch through which the condensate and air is drawn by the air-pump.

Sea water is drawn from the sea through the main injection valve by a large centrifugal pump which discharges it through the inlet branch of the condenser water box (Fig. 53). The water flows along through the bottom nest of tubes, into the opposite water chamber, up and back



CONDENSER CONNECTIONS

Fig. 53

through the top nest of tubes, out through the outlet branch and overboard via the overboard discharge valve higher up on the ship's side. Sometimes there is an extra main injection valve at a higher level than the standard valve which can be used when the ship is in shallow water and there may be a possibility of pumping sand through the condenser. A bilge injection valve (non-return) is branched into the suction pipe-line between the main injection valve and the circulating pump as an emergency arrangement for pumping out the bilges when there is danger of the engine-room flooding.

water gauges. The water gauge is a glass tube gripped in steam tight glands with steam and water shut-off cocks, thus the water level in the boiler can be seen as it takes up the same level in the glass. The steam cock is fitted in the steam space of the boiler, the water cock in the water space, and the gauge is so positioned that the glass is half-full of water when the boiler water is at working level. The bottom of the glass is usually about 4 to 6 in above the combustion chamber tops, the highest heating surfaces in the boiler. It is most essential to maintain the correct water level. If the water level falls too low there is danger of the combustion chamber tops and top rows of tubes becoming exposed due to shortage of water, these parts would then become overheated, lose strength and distort or collapse under pressure. If the water level is allowed to rise too high there is danger of water being carried over with the steam into the engines (this is known as "priming") with resultant damage to the engines.

For small boilers and on the drums of water-tube boilers, the water gauge is fitted directly on the shell (Fig. 14). This is the simplest arrangement and has three cocks only, a steam cock, a water cock, and a drain cock, the working conditions being steam and water cocks open and drain cock shut. The water gauge should be blown through at regular intervals, usually once a watch, to prevent accumulation of scale or other foreign matter which might choke the passages and result in a false water reading. To blow this gauge, (i) with steam cock open and water cock shut, open drain to allow steam to blow through, (ii) with water cock open and steam cock shut, open drain to allow water to blow through.

In the average sized marine Scotch boiler it is necessary to dampen the movement of the water in the glass caused by rolling and pitching and one common method of fitting the water gauge is to mount it on a hollow column which is connected to the steam and water spaces of the boiler by pipes, additional steam and water cocks are provided so that the connecting pipes can be shut off. This method of fitting is sometimes referred to as the double-shut-off system and a complete test of the gauge is as follows, referring to Fig. 15.

(i) With water cocks C and D closed, and steam cocks A and B open, drain E is opened and steam blown through steam pipe, steam cocks and glass.

(ii) With steam cocks A and B closed, and water cocks C and D open, drain E is opened and water blown through water pipe and water cocks.

If, during the above straight tests, there is the slightest suspicion of a choked or partially choked cock or connection, a cross-blow test is carried out to ascertain the faulty part, thus:

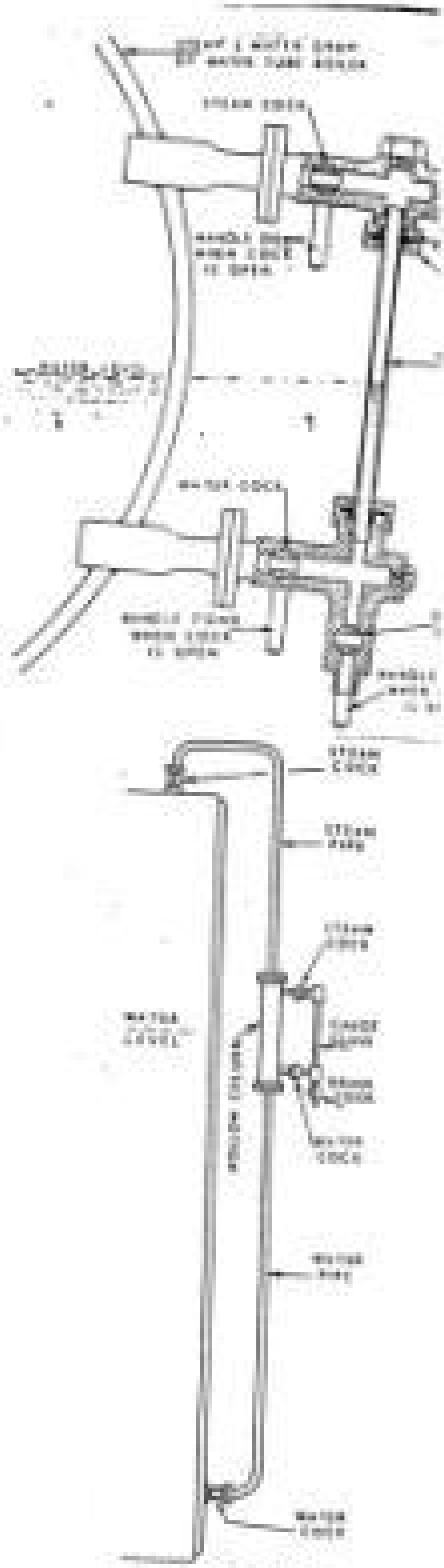
(iii) With B and D closed, and A and C open, open drain and blow steam through to test cock A, steam pipe, hollow column and cock C.

(iv) With A and C closed, and B and D open, open drain and blow water through to test cock D, water pipe, hollow column, cock B and glass.

By a combination of the straight blow and the cross blow, any individual cock or connection partially choked can be detected.

There must be two methods by which the water level in the boiler can be ascertained. Obviously two sets of water gauges is the best way to satisfy this regulation but some boiler manufacturers may fit one water gauge and one set of three test cocks. The set consists of one cock at about 6 in below working water level, one at water level, and one at

C



WATER GAUGE CONNECTIONS ON A SCOTCH BOILER
Fig. 15