# ENGINEERING OF THE STEAM TUG

# "FORCEFUL"

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21.903 Project.

# PREFACE

This project was written as an attempt to record and set down the operations involved in the engineering of a large steam reciprocating marine power plant.

The tug was selected, as the larger examples built had comprehensive engineering, and some were still in existence. No other such examples remain today.

The S.T."FORCEFUL" was studied as it is one of the last large steam tugs left. Most have been scrapped and broken up, and if not for the drive and foresight of her present owners, the "QUEENSLAND MARITIME MUSEUM ASSOCIATION", she herself would now be scrap.

This report describes the "FORCEFUL" and its' operation. While it is specific to the "FORCEFUL" alone, translation to other steamers can be made, if the differences in engineering are taken into account.

Unfortunately it has been impossible to capture the atmosphere of the steamship engine room. Suffice to say, it is very hot, about 40°C. , and humid. It is wet and oily, and the massive moving parts inside the open main engine shuffle smothhly and with little noise. Such power and relative silence contrast with the engine rooms of Diesel ships, where noise and vibration are uncomfortable.

The "QUEENSLAND MARITIME MUSEUM ASSOCIATION" must be thanked for giving comprehensive access to the S.T. "FORCEFUL" , and for their ready help. Thanks are also due to people who loaned books, some old and valuable, for long periods.

Andrew Munns

21/11/75

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# 1. BACKGROUND

The Steam Tug "FORCEFUL" is owned by the Queensland Maritime Museum Association and is based at the South Brisbane Dry Dock.

She was built and engined in 1925 by Alexander Stephen and Sons Ltd. at Linthouse, Glasgow. She then steamed out to Brisbane arriving in March 1926.

"FORCEFUL" is a triple expansion engined steamer with two scotch marine boilers, hand fired with coal. She was used for river towage as well as for ocean salvage work which she did up until 1970. For a period during World War II she was requisitioned by the R.A.N. and became H.M.A.S. "FORCEFUL".

After 1970 she was laid up and in June 1971 she was donated to her present owners.

After a period of maintenance she went into steam in August of that year and from that time active restoration and steaming has taken place.

Steamings took place in the last week of June 1975 and the study is based on information collected then. The information is general to all steamers but will describe the "FORCEFUL". It is beyond the scope of this project to complete an adequate treatise on marine engineering.

TABLE 1.1 SPECIFICATIONS= S.T."FORCEFUL".

| | |
|---|---|
| Length overall | 121 ft |
| Length between perpendiculars | 115 ft 1 in |
| Beam moulded | 27 ft 2 in |
| Maximum draught aft | 14 ft |
| Gross tonnage | 288 tons |
| Maximum speed | 13 knots |
| Service speed | 8 knots |
| Bunker capacity- gross | 93.5 tons |
| - hatch | 9.5 tons |
| - total | 103.0 tons |
| Water capacity- after peak | 27.8 tons |
| - forward peak | 18.3 tons |
| - head tank | 2.4 tons |
| - ballast(under forecastle) | 24.8 tons |

Hull:rivetted steel construction with steel main deck and wood/steel superstructure.

Main Engine:3 cylinder triple expansion,187.5 nominal H.P.,1000 indicated H.P.

Boilers:two 2-furnace scotch marine,coal fired, forced draught,175 p.s.i. max. pressure.

Auxiliaries:condenser,circulating pump,slave air pump,two boiler feed pumps,feed filter,feed heater,general service pump,forced draught engine, two slave bilge pumps,110 v. D.C. generator, steering engine,capstan,and windlass.

Propellor:11 ft 3in diameter by 11 ft 9 in pitch, 4 bladed.

Accommodation:four officers' cabins and saloon on main deck,twelve crew in f'csle.

## 2. PERSONNEL

It is the responsibility of the marine engineer to operate the power systems of his vessel. He will be in charge of the main and auxiliary machinery and will also service, repair and make adjustments.

He is in charge of other engine room and stokehold crew, these being junior engineers, greasers, firemen and trimmers if carried.

In terms of authority he is under the captain, but the chief engineer's department is his concern and not the captain's direct responsibility.

On larger ships the engineering crew (read "black gang"; "down below") tend to remain separate from the deck crew and rivalry exists between the two. This probably stems from when the first engines were fitted to sailing ships and sailors had to work inside a smoke pall.

On a tug the size of "FORCEFUL" all crew and officers share accomodation and while a rivalry exists here also it is not that strong.

"FORCEFUL" on one engineering watch will carry an engineer, a greaser, and one fireman. At sea they worked four hours on, eight hours off, while for day work the crew works an eight hour day plus overtime.

The engineer started as an apprentice fitter and turner. He has also done time in the drawing office and in ships during actual repair work and trial trips.

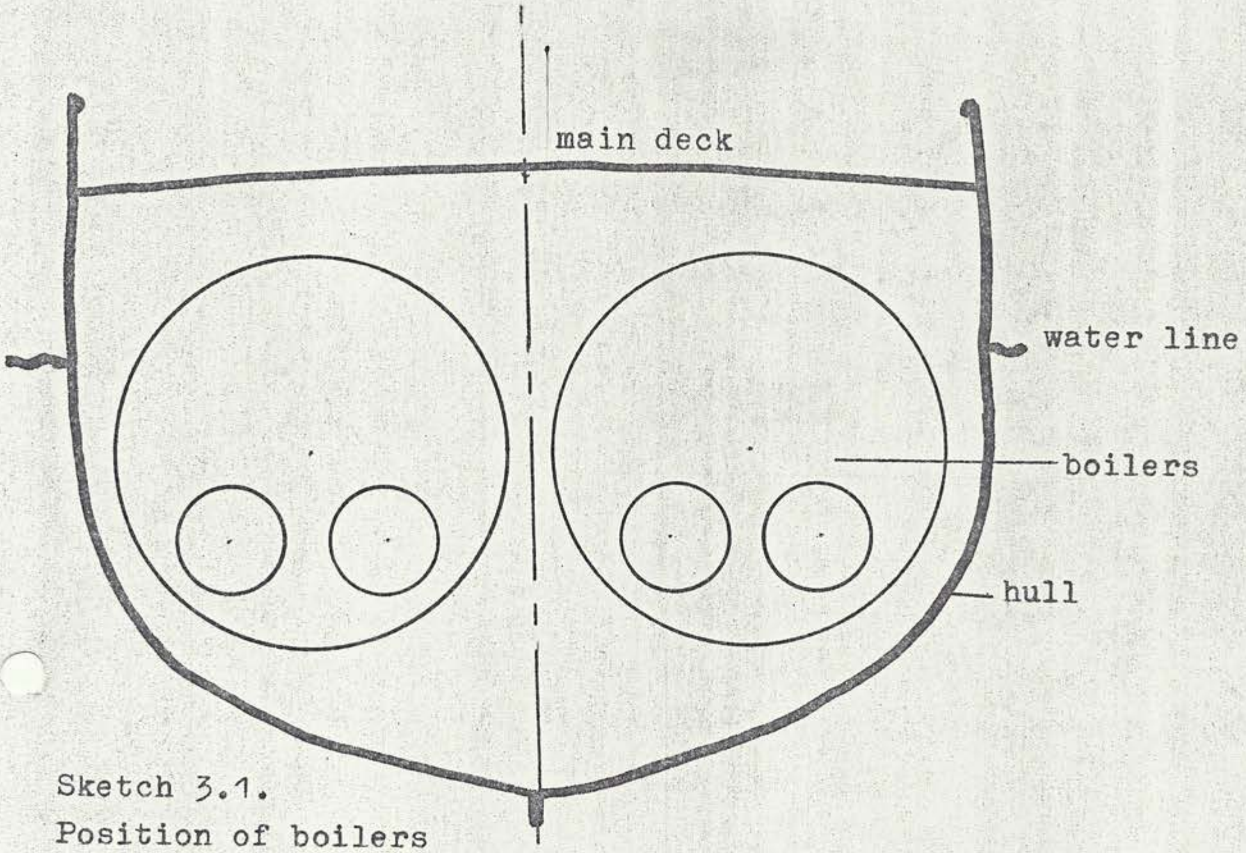
He joins the ship as a junior engineer and here will be given a 'watch'. As his experience increases and sea time accrues he will be given more responsibility and the chance to go for higher engineers tickets.

"FORCEFUL" will require an ocean going chief's ticket owing to the nature and size of her engines. On long runs a second engineer will also be carried.

It is the job of the greaser to oil the main and auxiliary engines. In most cases he began as a fireman and has been promoted. In the engine room work is easier, cleaner and more highly paid.

The fireman started work as a bunker trimmer - one who carries coal to the fireman. Owing to "FORCEFUL'S" size she does not carry one, so firemen have been trained elsewhere. But note that no certified training scheme for firemen exists.

If required the engineers can also fire the boilers and they often do so in "FORCEFUL" when steam raising. But note here that their skill is not intensive. In the past it was also known for promising greasers to train for engineers tickets but as engines increased in complexity fully trained engineers became necessary.




Sketch 3.1.
Position of boilers
in ship.(midship section)

Sketch 3.2. 'Ghost'
scotch boiler.
(stays,fittings,
etc. removed)

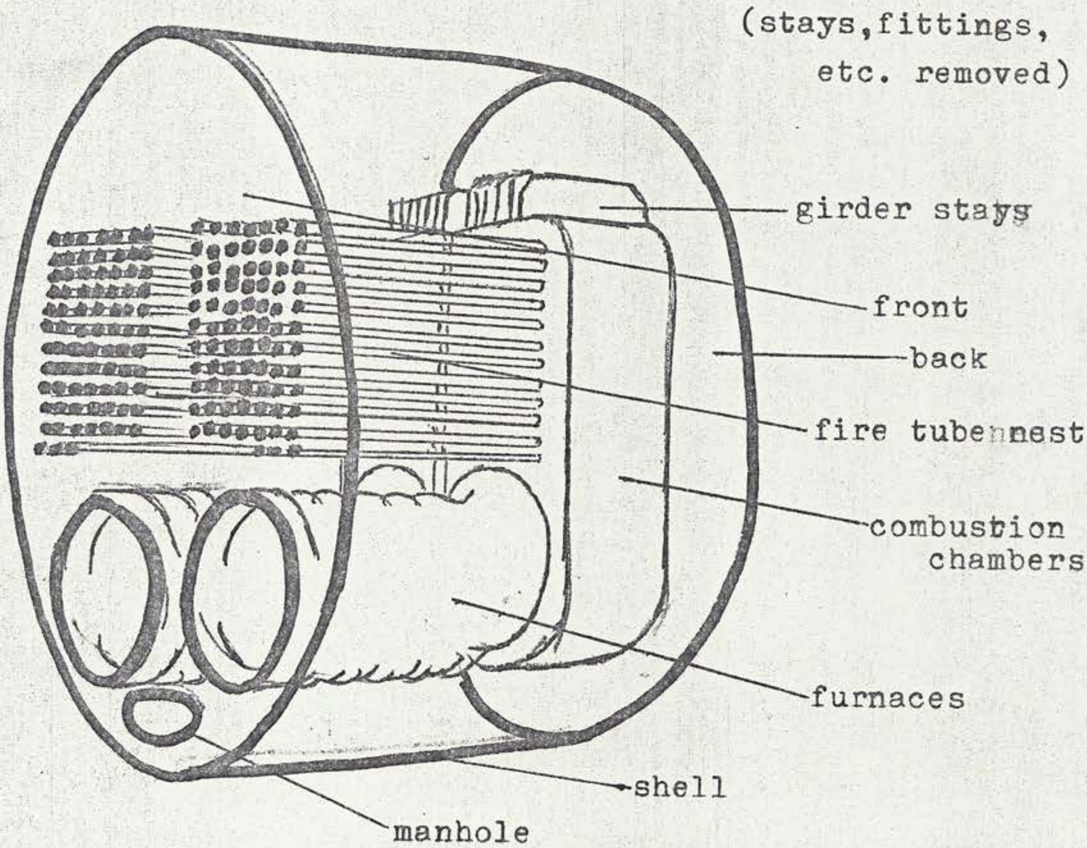


Photo 3.2. Fan engine.

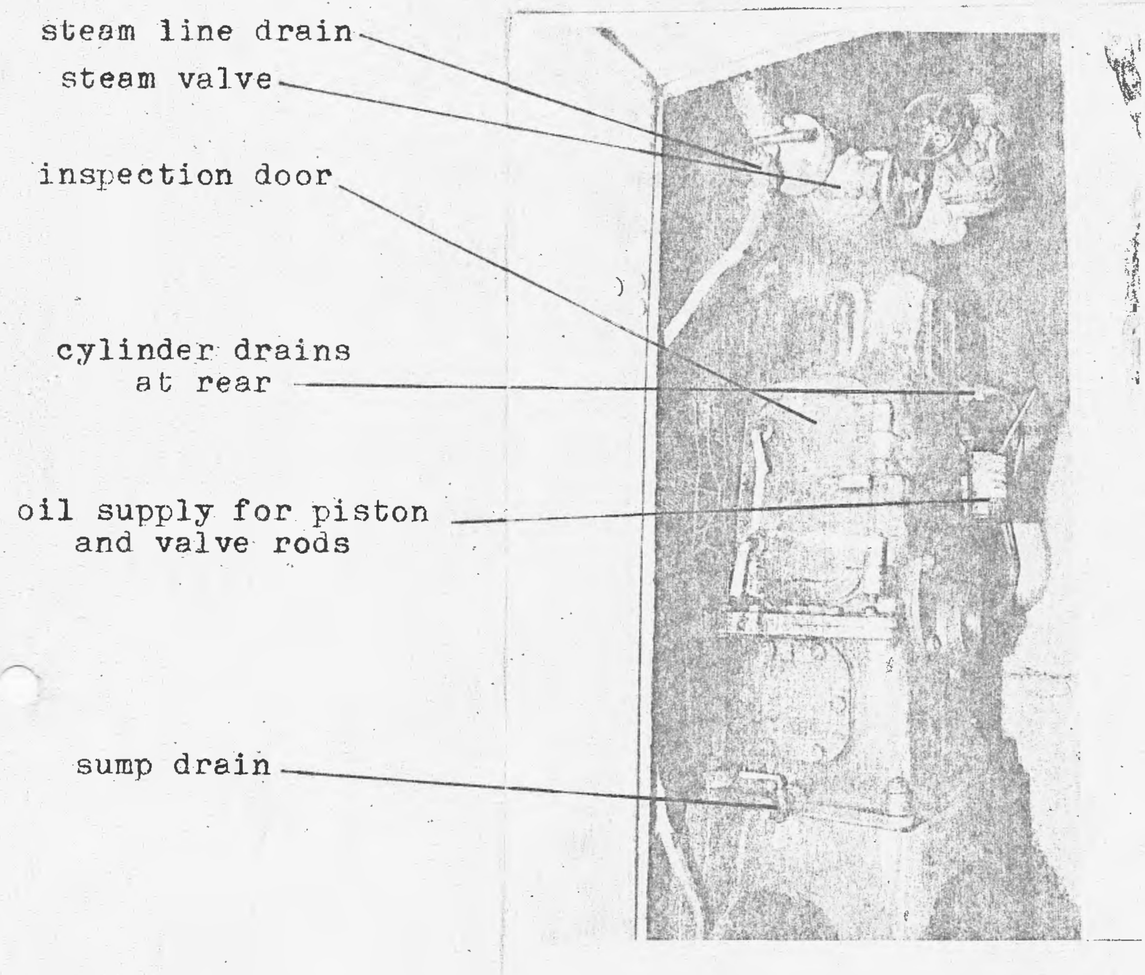
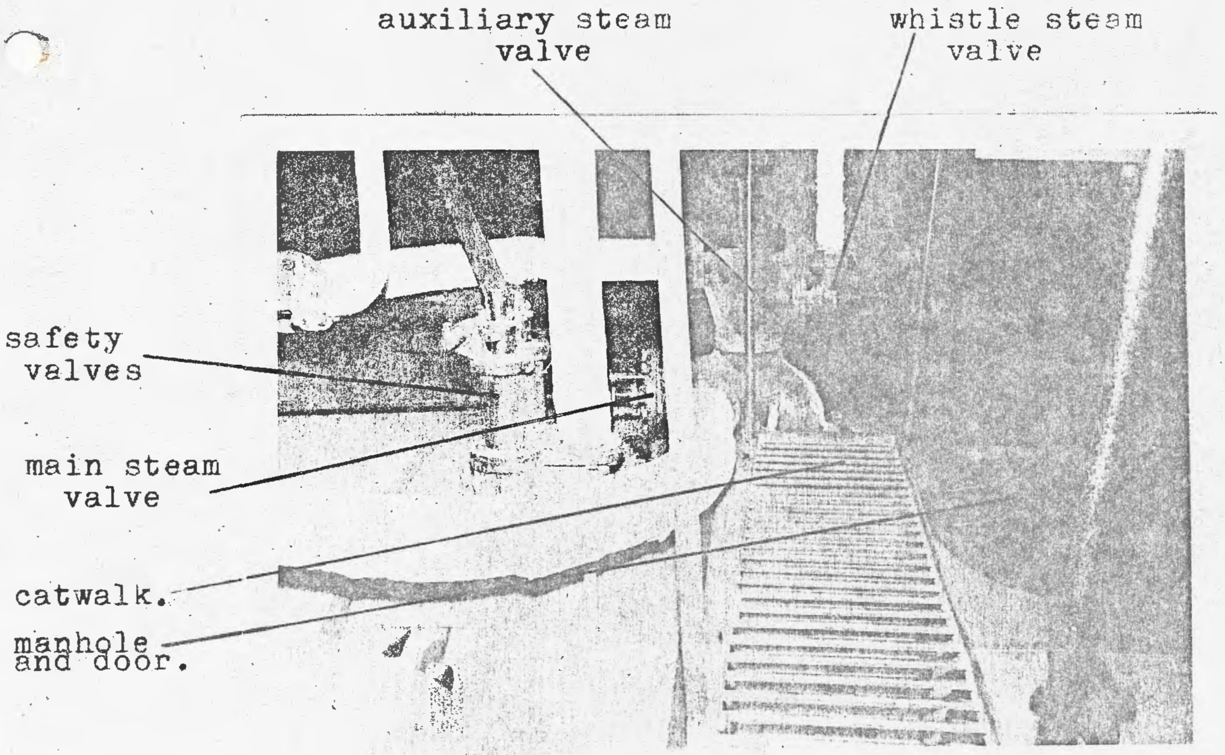
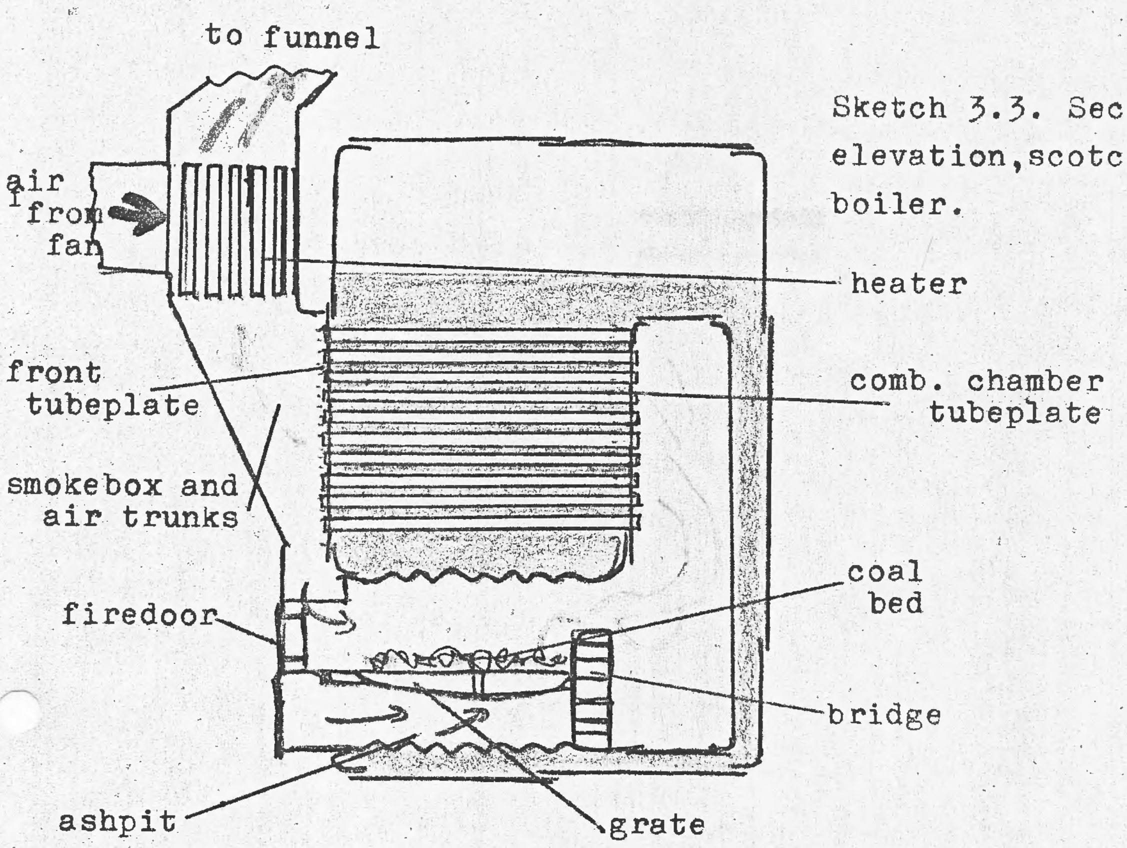


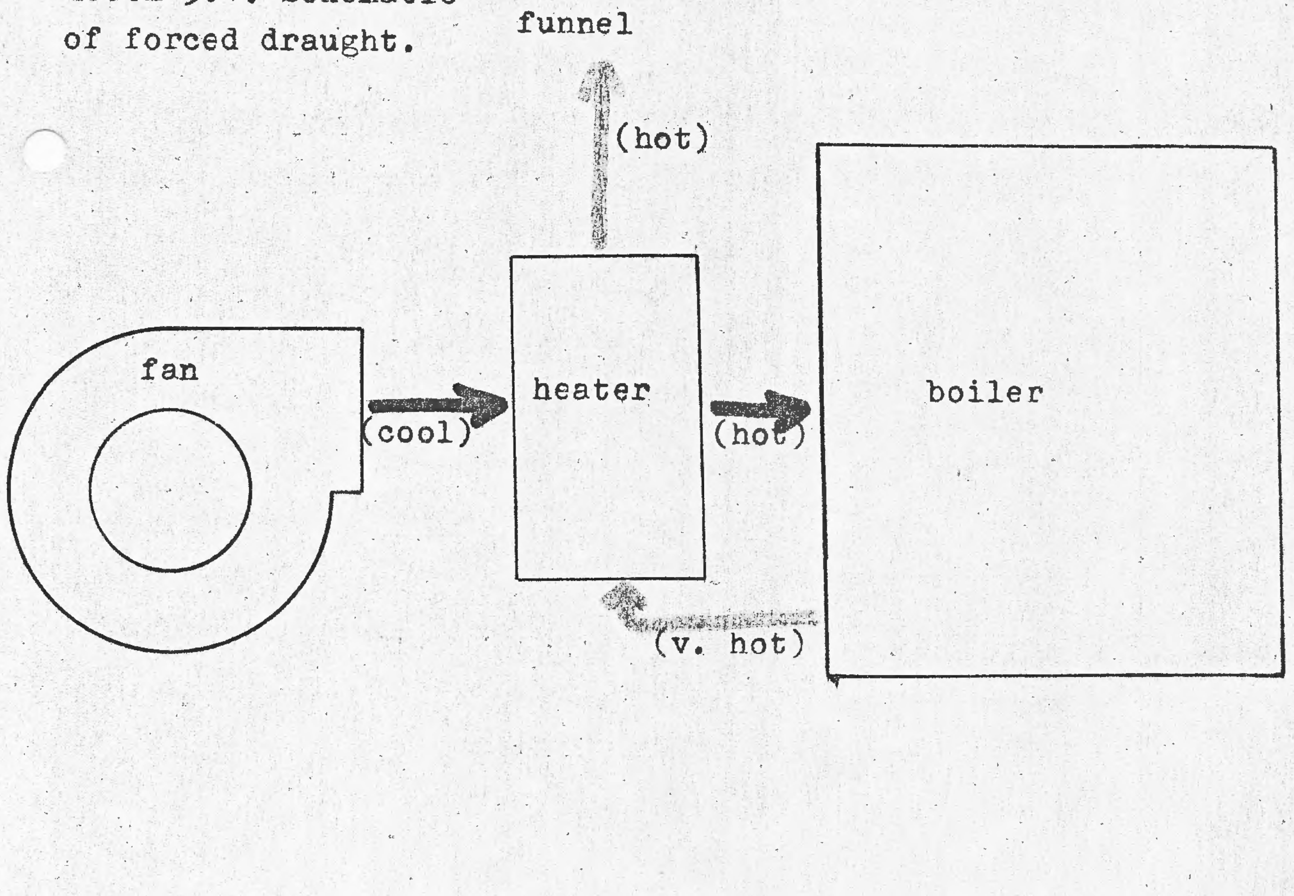

Photo 3.3. Boiler tops

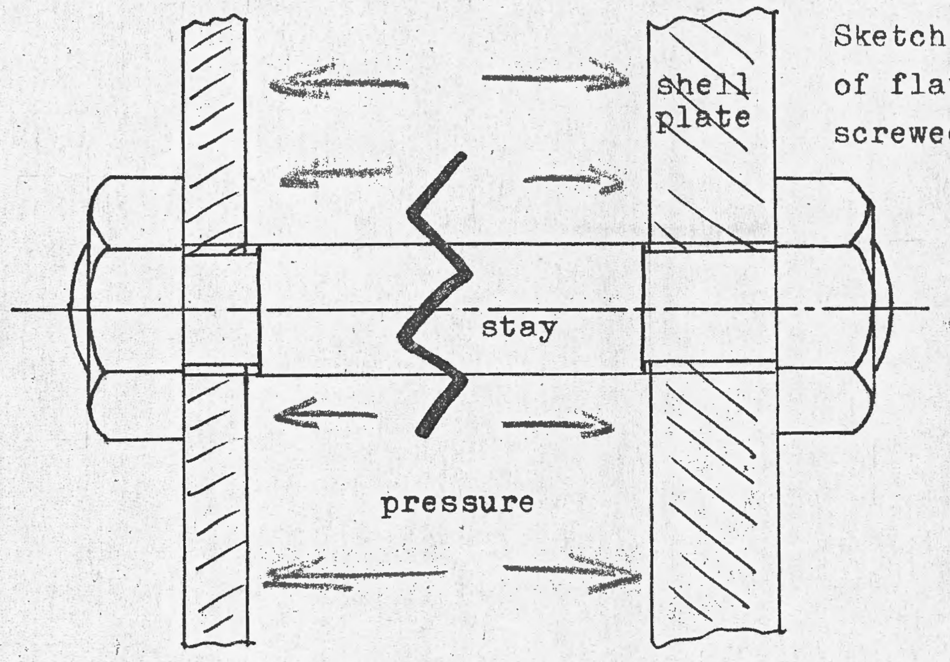


Sketch 3.3. Sectional elevation, scotch boiler.




Sketch 3.4. Schematic of forced draught.






Sketch 3.5. Support of flat plates by screwed stays.

Sketch 3.6. Firetubes, common and screwed stay types.

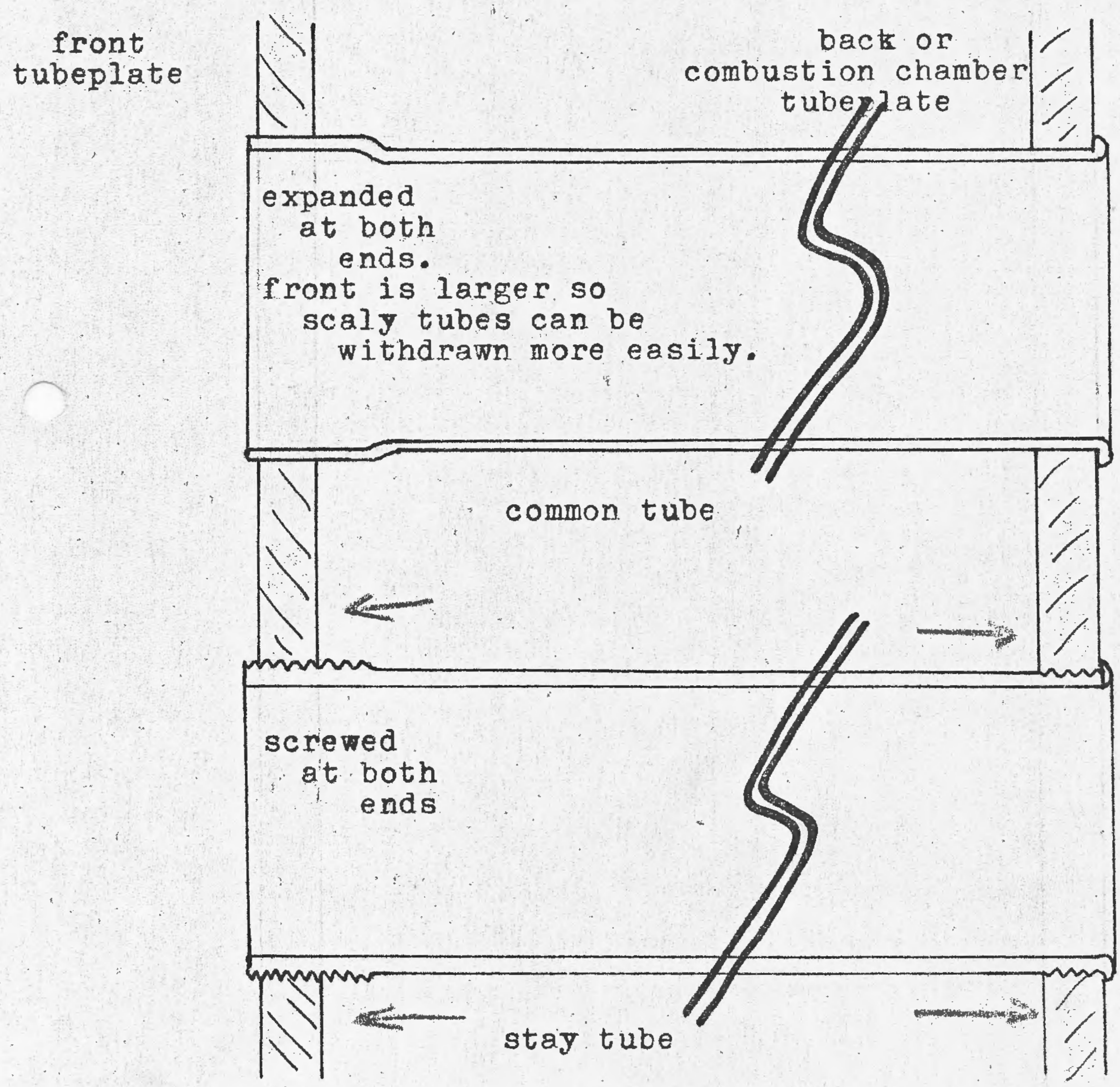
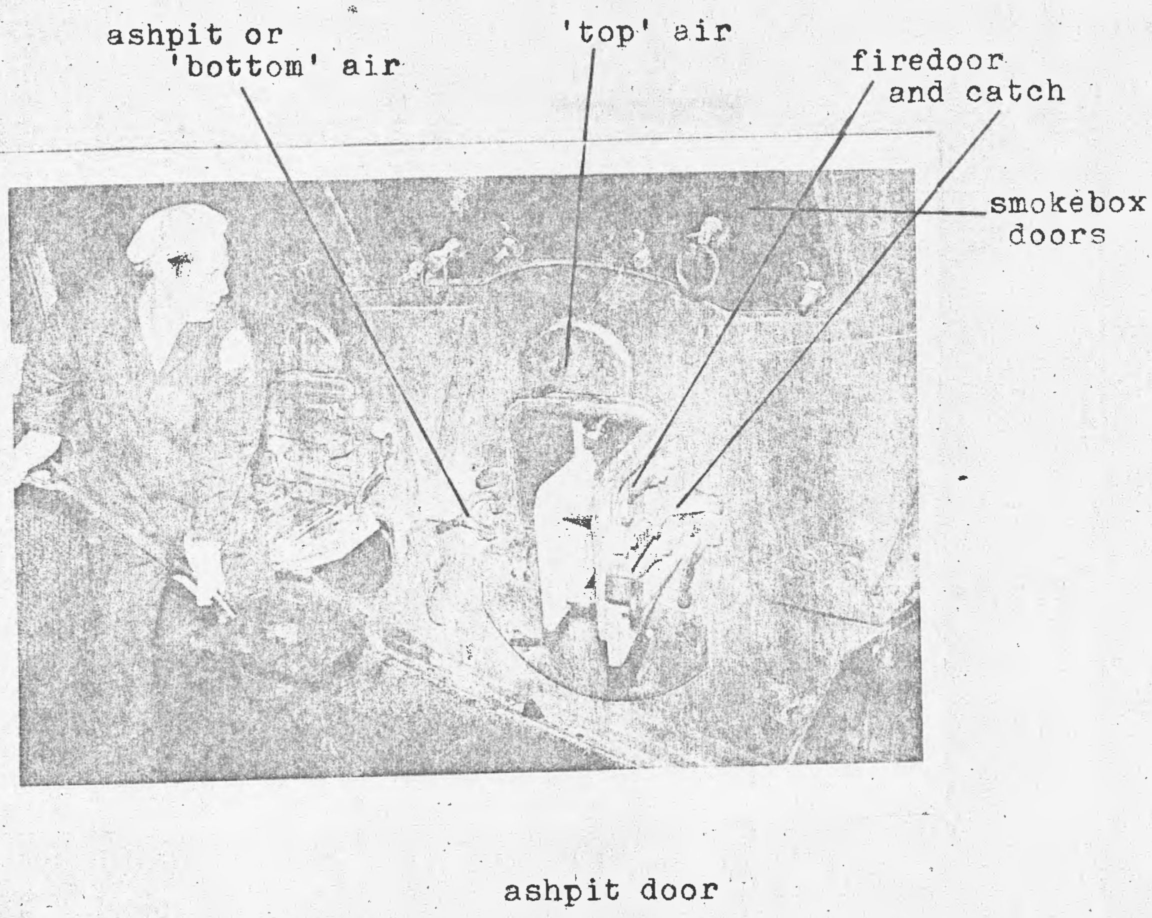
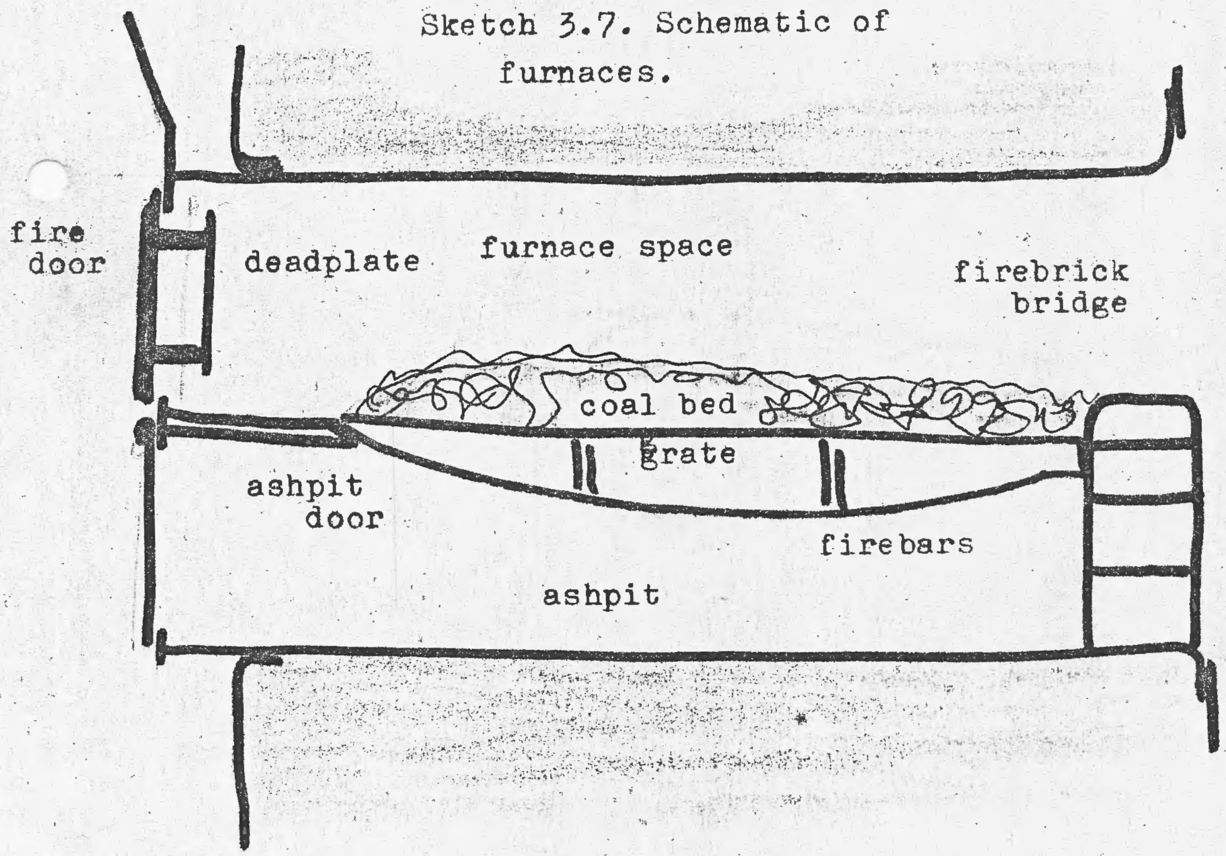


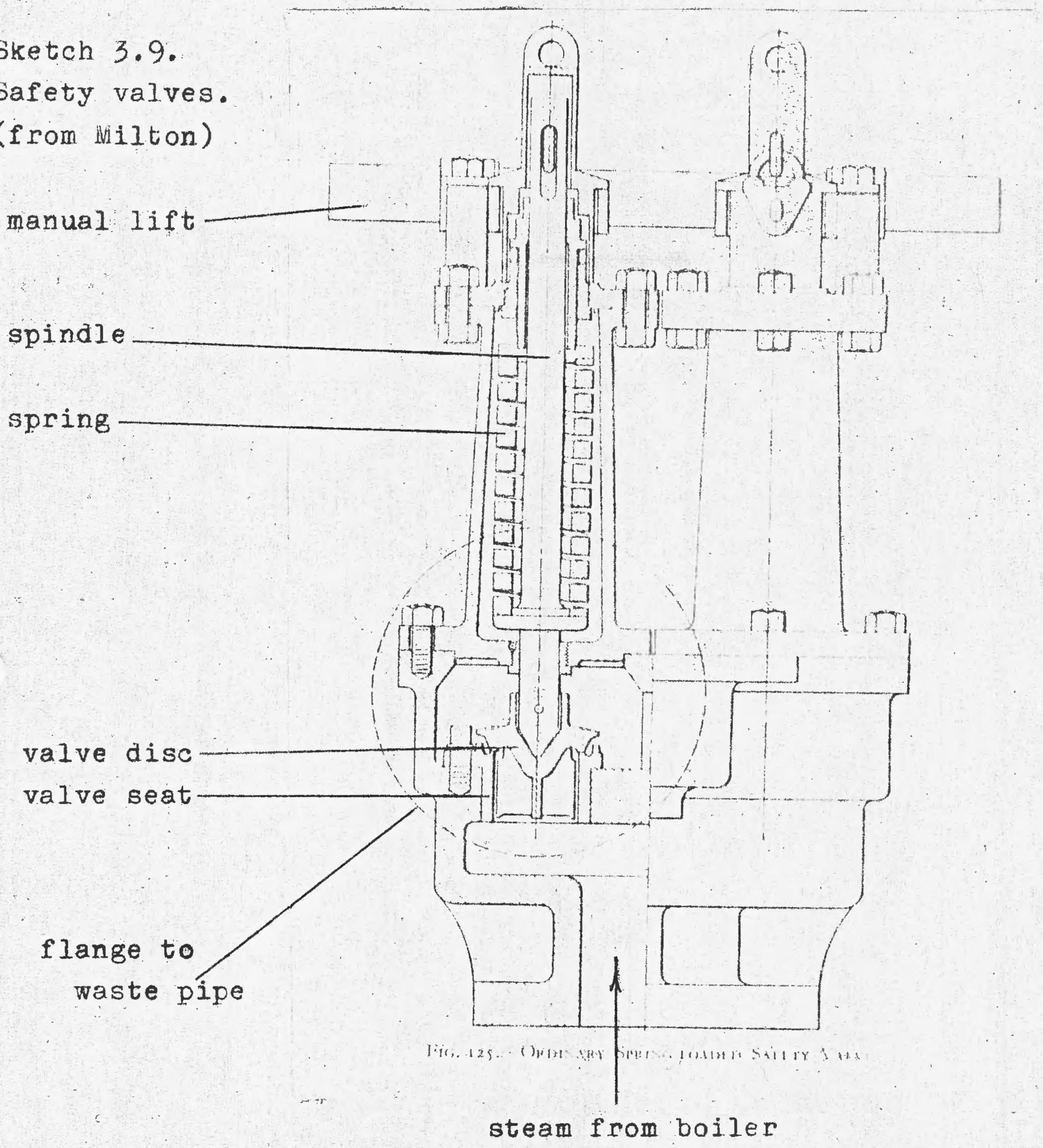
Photo 3.1. Furnace front.



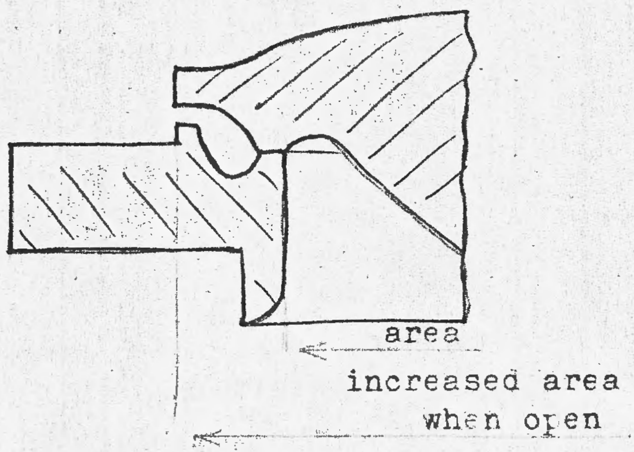

Sketch 3.7. Schematic of furnaces.



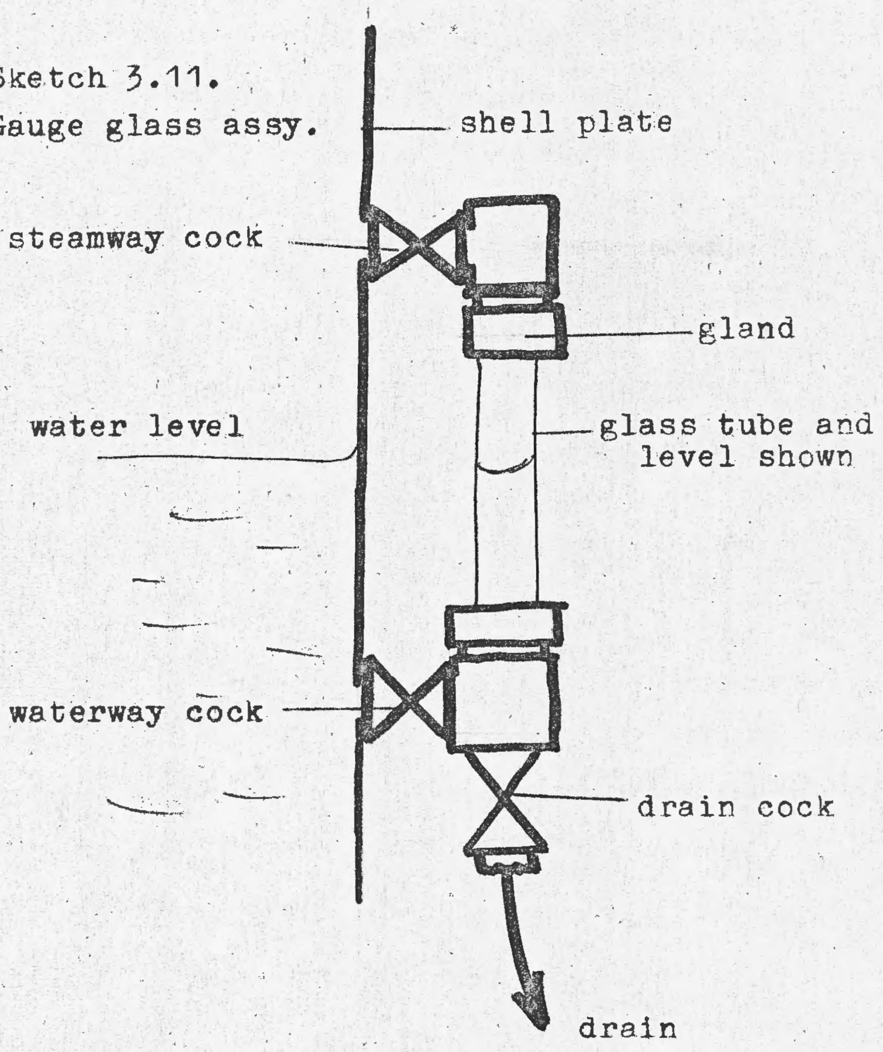
Sketch 3.9.
Safety valves.
(from Milton)



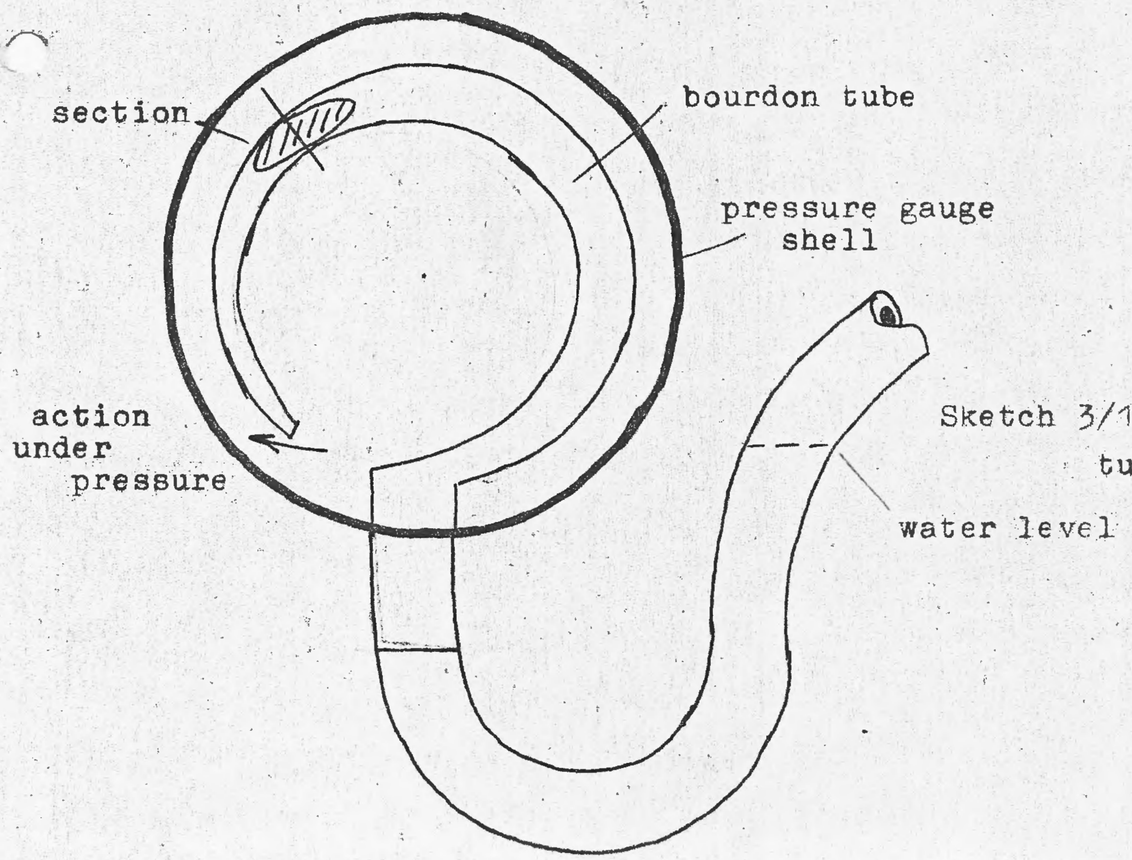

Sketch 3.10. Valve area.



Sketch 3.11.
Gauge glass assy.

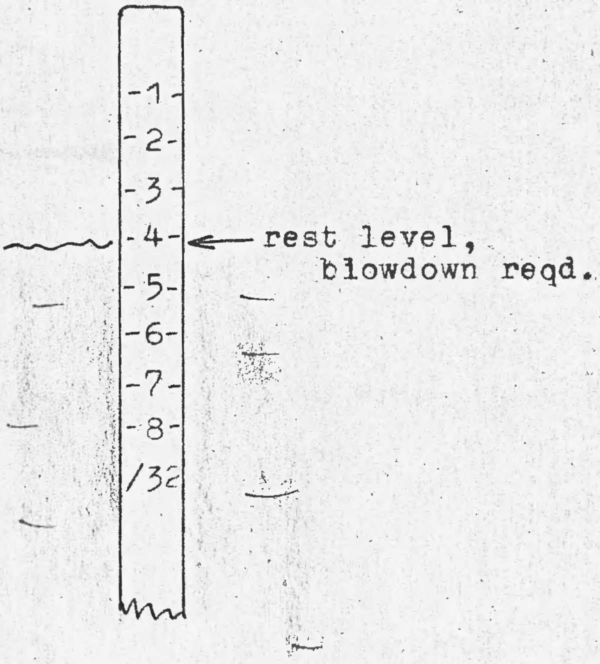



Sketch 3.12. Bourdon tube.

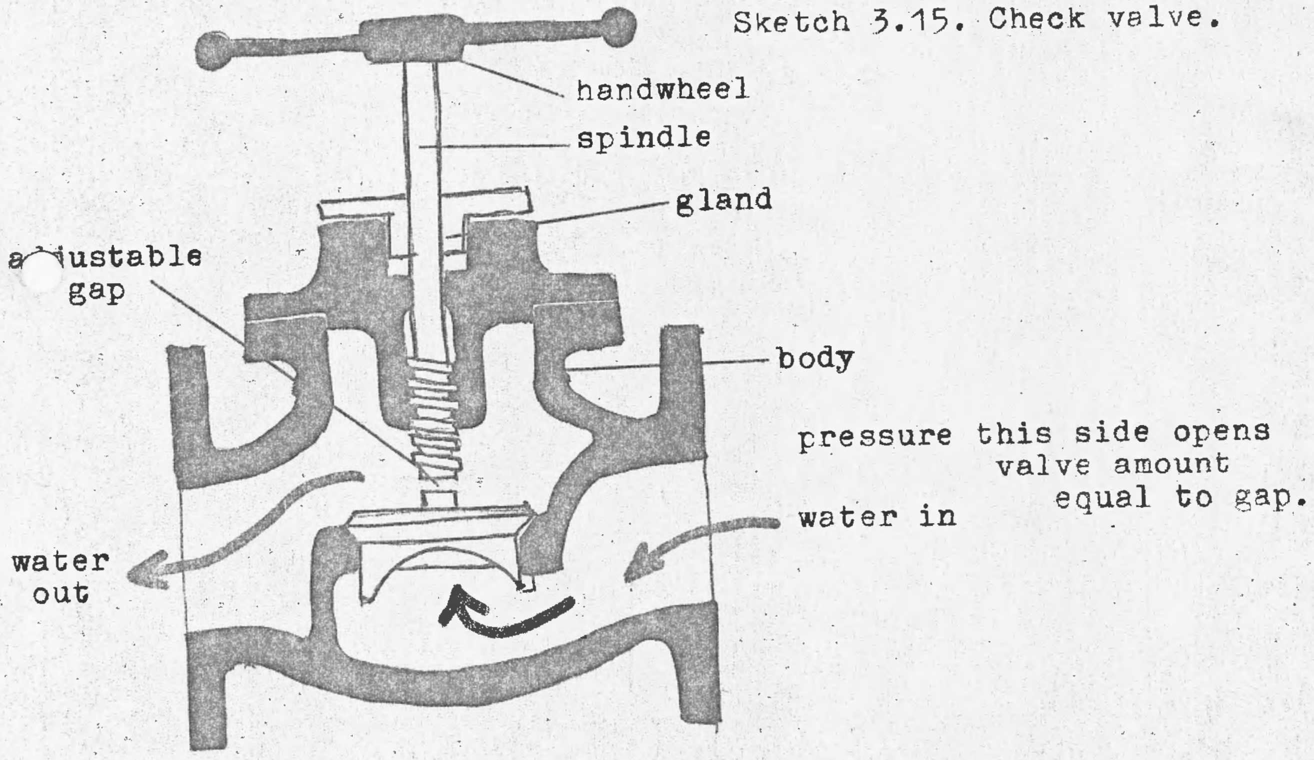


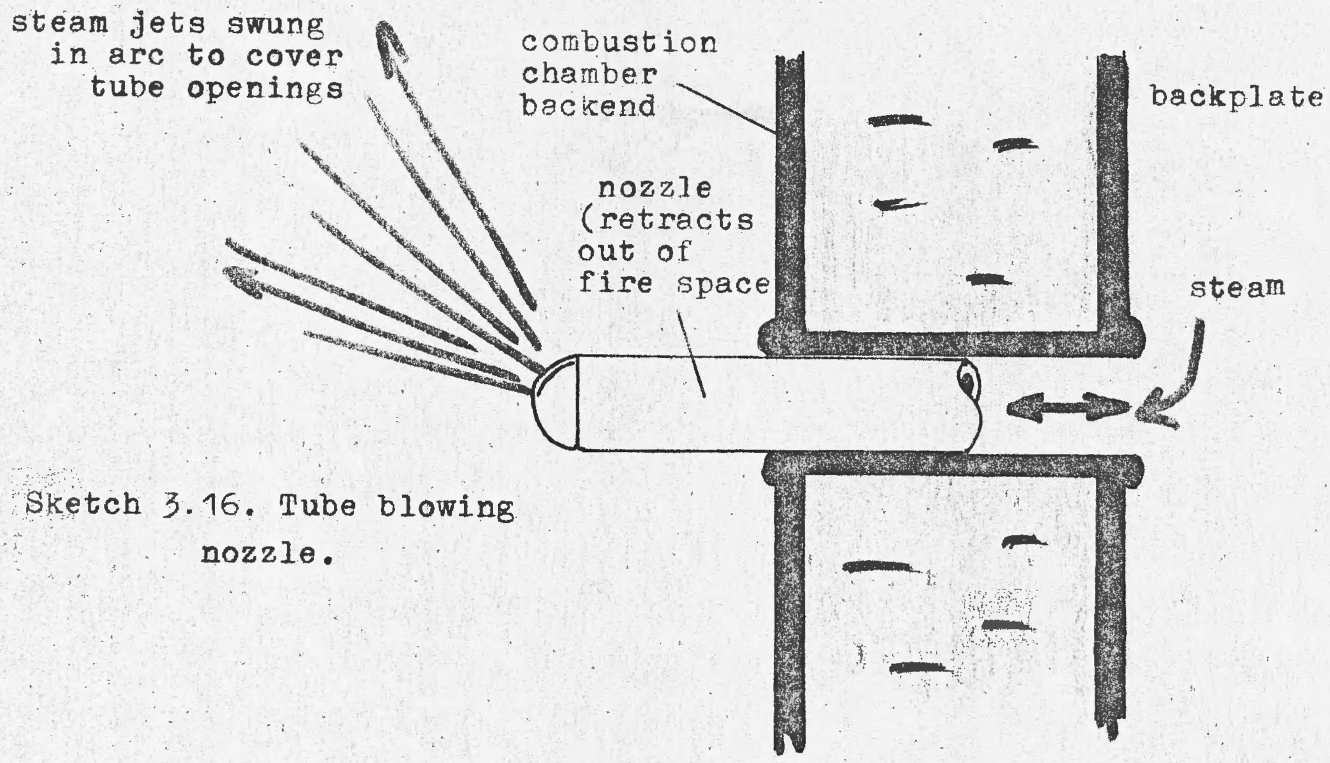

Sketch 3/13. 'U' tube.

Sketch 3.14. Salinometer float scale.



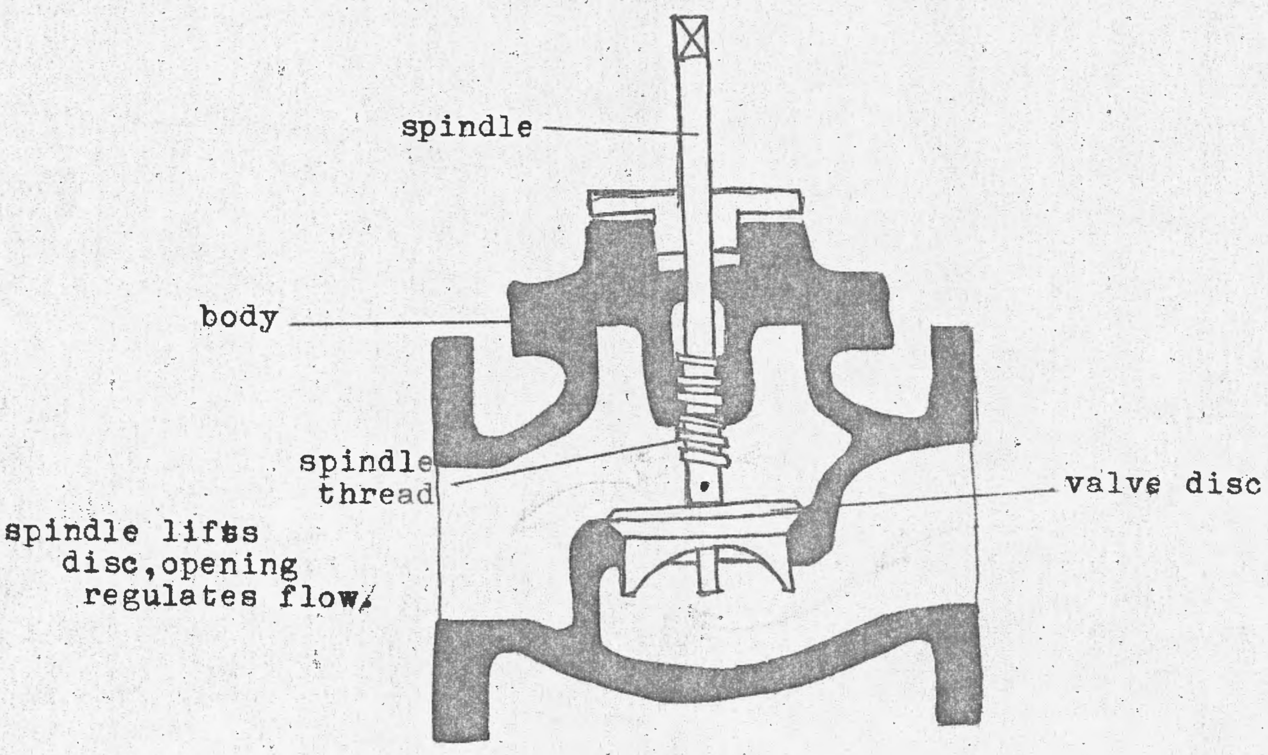

Sketch 3.15. Check valve.

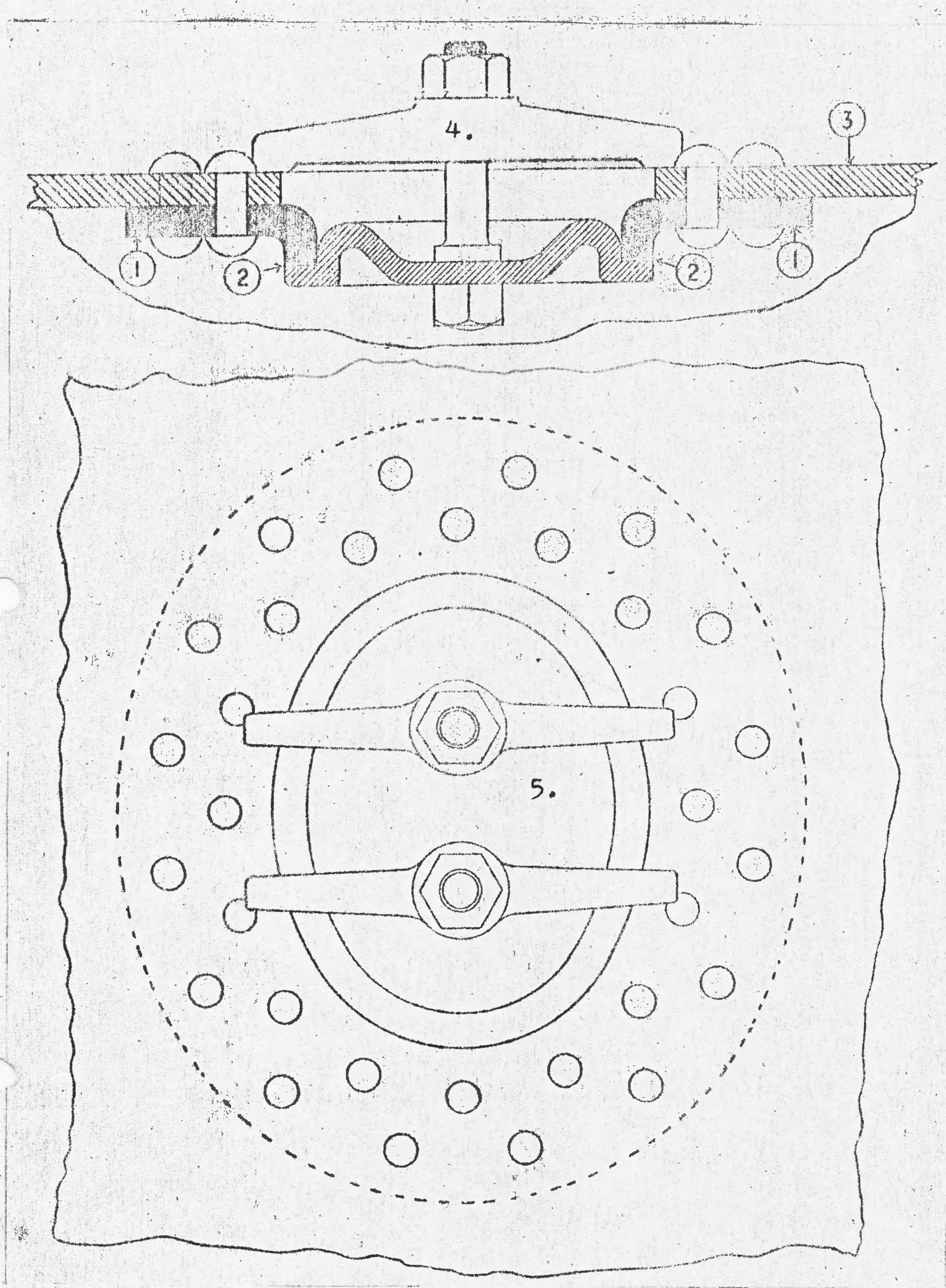





Sketch 3.16. Tube blowing nozzle.

Sketch 3.17. Valve.






Sketch 3.18. Manhole and door.

1.reinforcing ring.(counteracts loss of strength due to hole.)
2.door joint.
3.boiler shell.
4.dogs.
5.door.

## 3.1 BOILERS

The "FORCEFUL" is fitted with two marine return-tube or "scotch" boilers (see sketch 3.1, 3.2)

Each boiler consists of a cylindrical shell carrying two furnaces. Heated air is blown into these, where coal is burning on grates. The hot gases from the furnaces then pass into combustion chambers and return to the front of the boiler through tubes. Here they are collected in the smokebox and taken to the air heater and then to the funnel. (see sketch 3.3, 3.4).

The construction is of rivetted steel. The furnaces are corrugated to increase strength and flexibility. The two combustion chambers are rectangular in shape and their flat surfaces must be stayed against collapsing pressures. (see sketch 3.5). The front tube plates are stayed by the fire tubes themselves. Two types of tube are fitted, the common expanded tube and the screwed stay tube. Stay tubes are of a size and strength to hold the tubeplates in. (see sketch 3.6).

The boiler shell is 11'6" in diameter and has been rolled from a flat plate and buttjoined. The end plates are 11' apart and are stayed by the stay tubes and longitudinal stays. (see sketch 3.6).

The boiler is constructed for 175 p.s.i. working pressure, and is tested to 262 p.s.i. hydraulic pressure.

Each boiler has a heating surface of 2960 sq.ft.

### FURNACES AND DRAUGHT

The furnaces are fitted with grates on which coal is burnt. Air is pumped to the ashpit and to above the grate. (see sketch 3.3).

Air to the ashpit is bottom air whereas top air is supplied to the areas above the grate. Valve handles regulate the amount of air.

A firedoor is fitted for firing and working the fires and an ashpit door enables ash to be withdrawn or the furnace to be run on natural draught. (see photo 3.1).

Coal burns on a grate of firebars stowing between the furnace front and a bridge at the back of the furnace. A dead plate is fitted near the furnace mouth to prevent the fires approaching and warping the firedoor. (see sketch 3.7).

Air is supplied to the boilers by a centrifugal fan powered by a single cylinder, double acting enclosed sump engine. (see photo 3.2). This engine is mounted in a closet in the bunkers, access being from the stokehold.

The engine is started by draining water from the steam line and from the sump. Oil level must be higher than $\frac{3}{4}$ of an inch below the big end at BDC. Steam is passed through the engine to warm it - drains are open.

2/

The surface blowdown removes scum while the bottom blowdown removes sediment.

The blowdowns are also used to remove boiler water for the purposes of water treatment. Water is evaporated continually from the boilers and make up feed is not distilled. Therefore there is a build up of salts in the boiler water. The proportion of solid matter is measured in a salinometer. This is a float in a bucket of boiler water. Water density indicates the concentration of solids. The density of sea water is taken as 1/32. That is 1/32 of the weight of sea water is solids in solution. Salt will deposit at 7/32 density as indicated on the salinometer float. In general practice, the density is not allowed to exceed 4/32. (see sketch 3.14). When this density is reached, some boiler water is blown out and replaced with less dense water from the tanks.

Lime is also added to the boiler in the form of milk of lime in the feed water. This neutralises acid boiler water and retains a favourable alkaline condition. Lime also forms a scale which if thin will protect the boiler from internal corrosion, but large amounts of lime will form a heavy scale. One pound of unslaked lime per 1000 H.P. per day is recommended.

CHECKVALVES

Main and auxiliary feed water check valves are mounted on each boiler back. They are a non-return valve with lift adjustable through a valve wheel and screwed spindle. (see sketch 3.15).

TUBE BLOWERS

Tube blowers are fixed in each combustion chamber. They are worked from the back of the boiler and in use direct a blast of steam through the firetubes, thereby sweeping them of soot.

Frequency of use depends on the coal used, and how it deposits soot in the tubes. The amount of soot deposited in the tubes is gauged by poor air flow through the boiler, and the need to keep up steam with hotter fires. The engineer turns steam on to the blowers and rotates them to sweep all tubes. (see sketch 3.16).

VALVES

Valves are fitted to the plant in order to control the passage of fluids. Flow is adjusted as it passes the gap between a disc and its seat. Height of the disc is set by a screwed spindle and handle. (see sketch 3.17 photo 3.3)

MANHOLE DOORS

Manhole doors are fitted to allow men to squeeze into the boiler for purposes of cleaning, repair, and inspection.

One is fitted at the top and another below and between the furnaces of each boiler (see photo 3.3, sketch 3.18).

The door is elliptical so that it may be placed inside and mounted. Boiler pressure as well as well as fastenings then secure it against the shell.

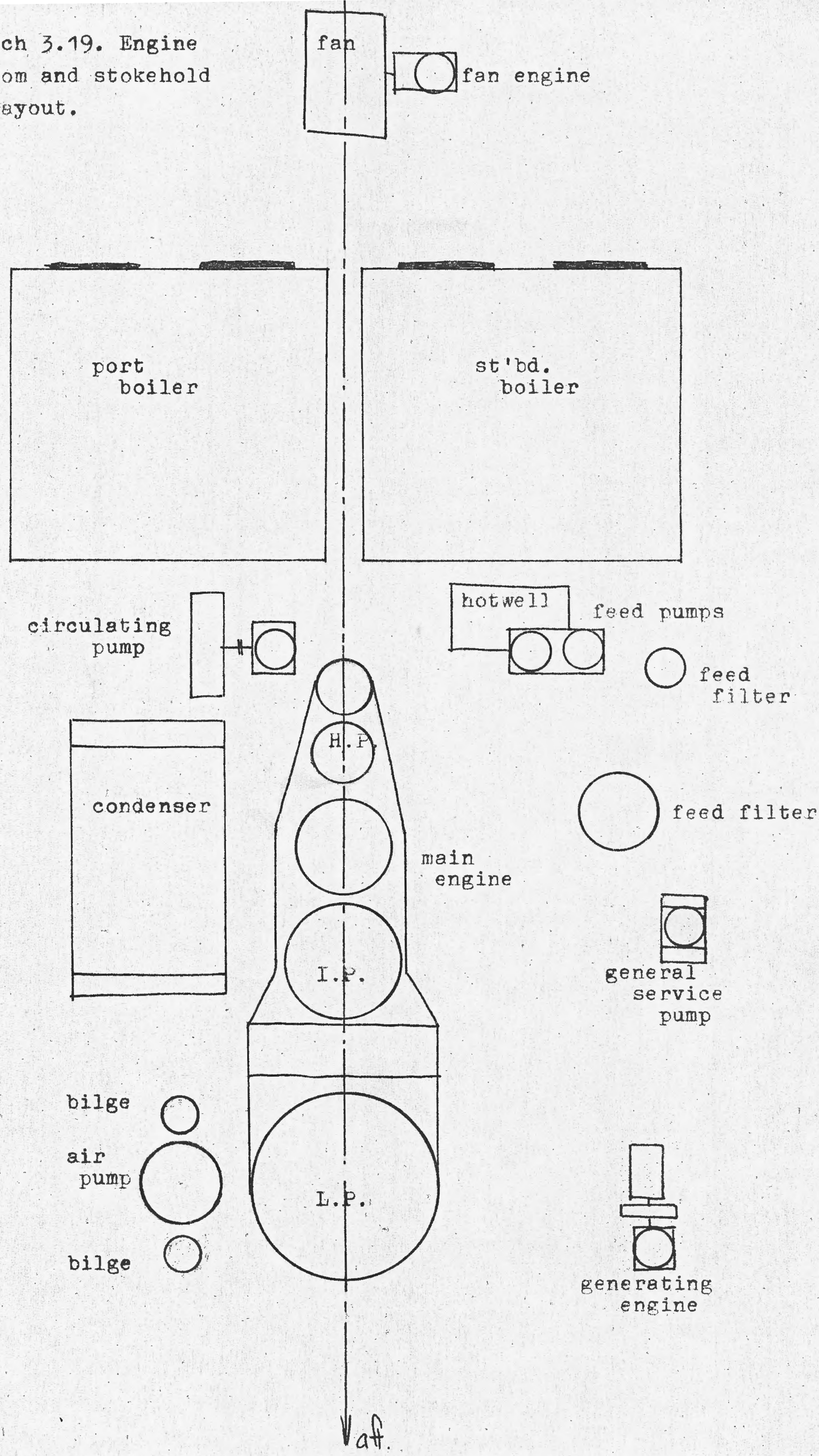
When removing a door all vacuum in the now cold boiler must be relieved. Vacuum has been known to pull the door and the man opening it into the boiler, with injury resulting.

The door is refitted with a new woven asbestos gasket, smeared with graphite grease or red lead. Mating surfaces have been scraped. With the door in place and tight, steam is raised. Pressure will force the door against the shell enabling the door fastenings to be tightened further.

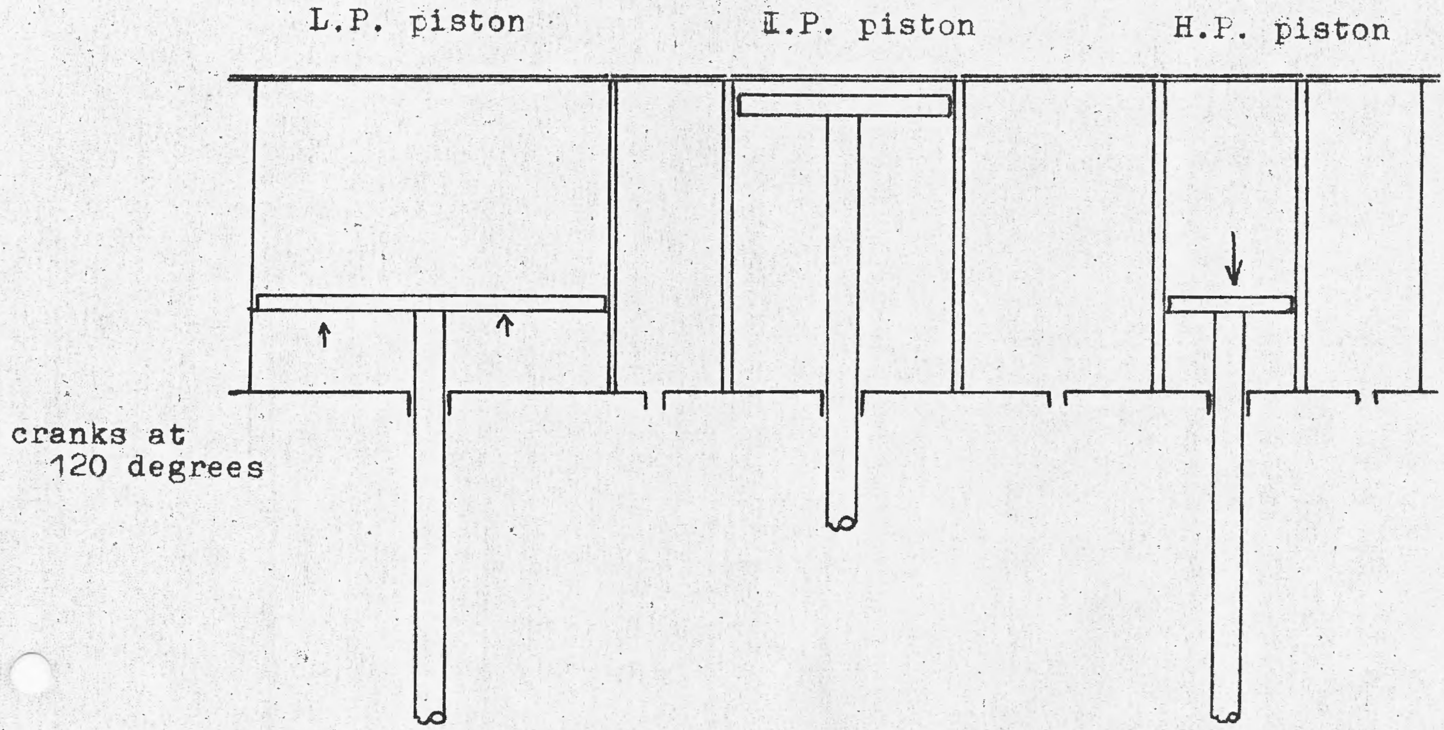
ZINC BLOCKS

Zinc is mechanically attached in the water space of the boiler as anodic protection. Slabs are fitted, these with good electrical contact to their mountings.

Sketch 3.19. Engine room and stokehold layout.



Sketch 3.20. Schematic of main engine.




Sketch 3.21. Schematic of main engine.

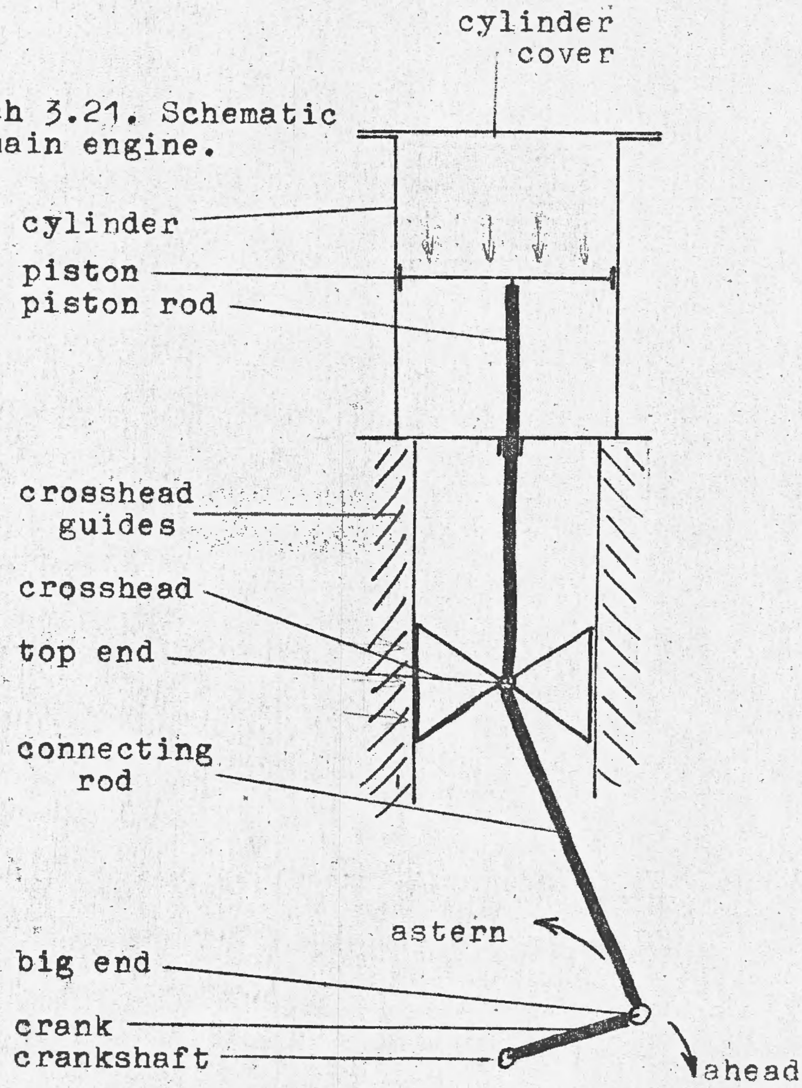
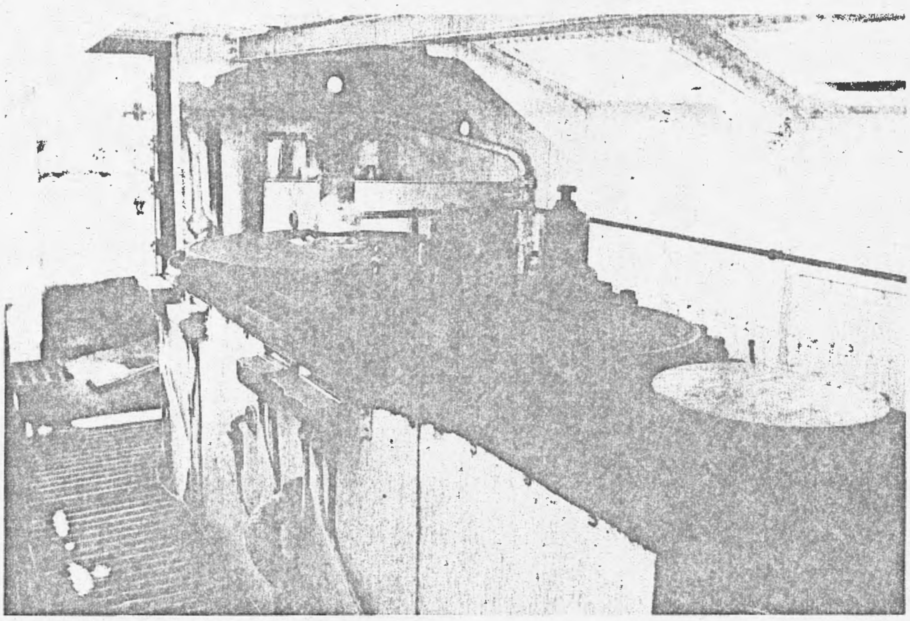
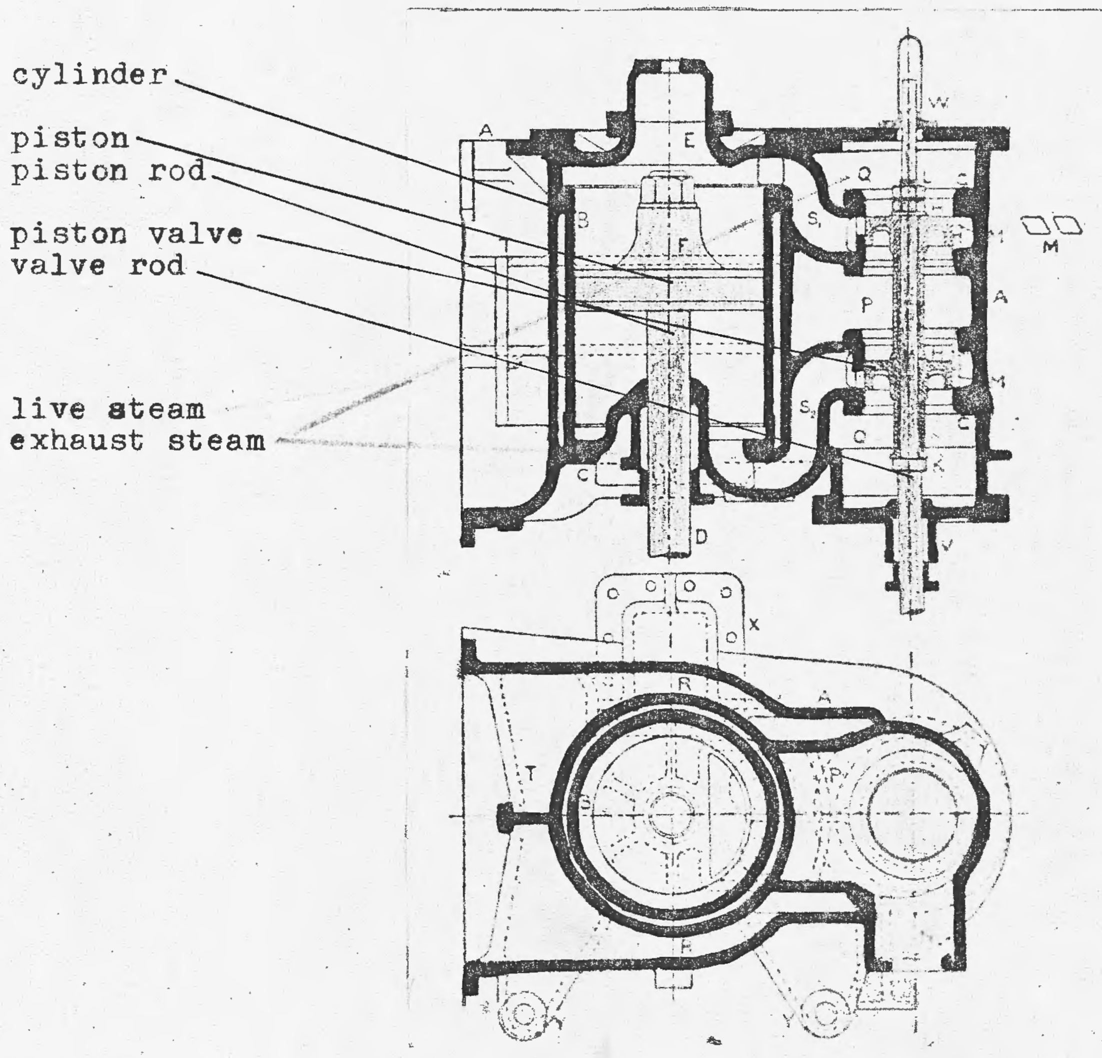


Photo 3.4. I.P. and L.P. cylinders.



Sketch 3.22. Piston and piston valve.



## 3.2 MAIN ENGINE

The general plan of the engine room can be seen in sketch 3.19. The whole of the machinery involved here is used in running the ship in a proper and safe way.

The main engine is shown schematically in sketch 3.20. It is of the three cylinder, triple expansion type.

Steam from the boilers is throttled into the high pressure (H.P.) valve chest, where it is directed into the H.P. cylinder. Exhaust from this cylinder discharges into the intermediate pressure (I.P.) valve chest, where it is directed to the I.P. cylinder. This cylinder exhausts into the low pressure (L.P.) valve chest where it is directed to the L.P. cylinder.

Work is done by the steam in three stages, the H.P., I.P. and L.P. cylinders all doing equal amounts of work. As steam pressure in the later stages is less than in the H.P., the cylinders for these stages are larger. Thus all cylinders have the same power, the same stroke but different diameters. Steam is used on both sides of each piston to push it up and down. This is called double action.

Steam from the L.P. is passed into a condenser where a vacuum of about 23 inches mercury is maintained. This is due to condensed steam and its collapsed volume. By exhausting into a vacuum, the power of the engine is increased.

Entrained air and condensate is pumped from the condenser by the air pump, and delivered to a tank called the hotwell. From here it is pumped by the feed pump through a filter and heater, and back into the boilers.

The pistons of the main engine transfer their reciprocating power to the crosshead. The crosshead is designed to keep the piston rod moving in one line. (see sketch 3.21). From the crosshead to the crankshaft, the connecting rod is fitted. This converts reciprocating motion to rotating motion which is transmitted along shafting to the propellor. Thus the tug is driven.

CYLINDERS (see photos 3.4)

The H.P., I.P., and L.P. are of 17½", 29" and 47" diameter respectively. Piston stroke is 30".

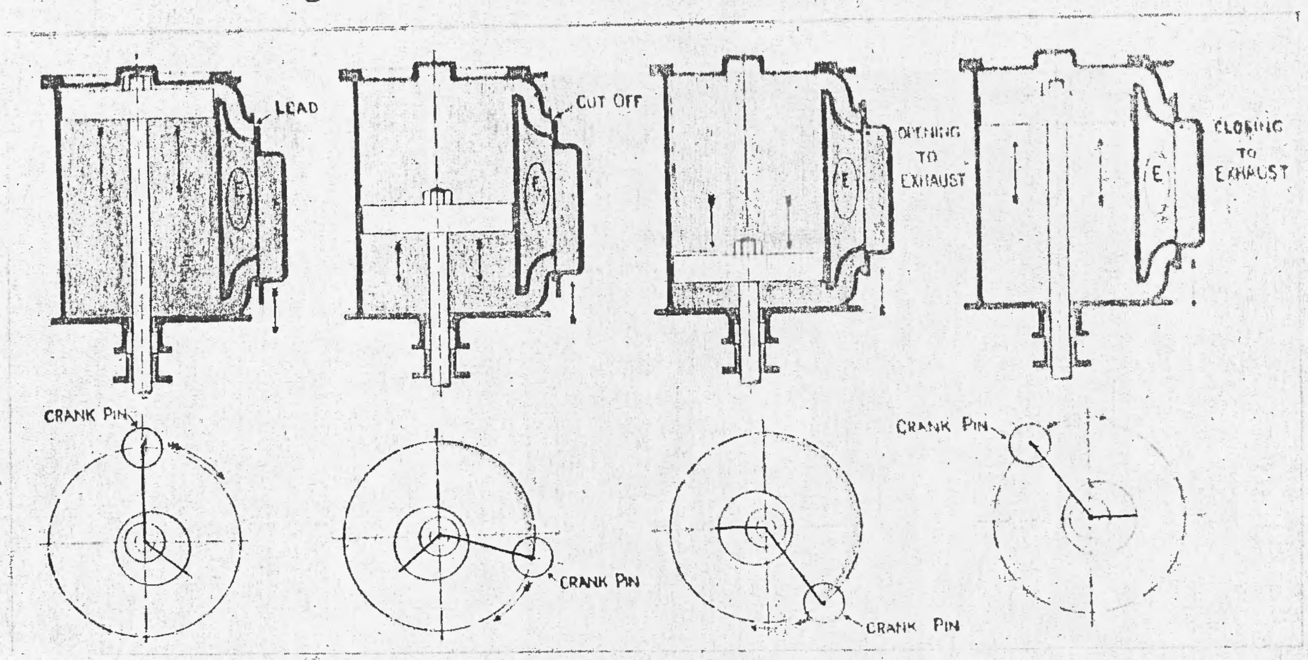
Steam to the H.P. and I.P. is controlled by piston valves. (see sketch 3.22) Steam to the L.P. cylinder is controlled by a slide valve. This and the movements in the working cycle of a steam engine is shown in sketch 3.23.

The cylinders are in two parts and of cast iron. Covers are fitted on top, and glands on the bottom allow the piston and valve rods to work without leakage.

Drain valves are fitted to remove condensate, and relief valves are fitted to the tops and bottoms of all cylinders.

Sketch3.23. Working cycle for engine.

live steam    exhaust steam




1. valve just open to top steam, exhaust open.

2. valve cuts of top steam.

3. top steam expanding, exhaust just closing.

4. bottom steam expanding, top exhaust just closing.

Sketch 3.24. Equilibrium throttle valve.

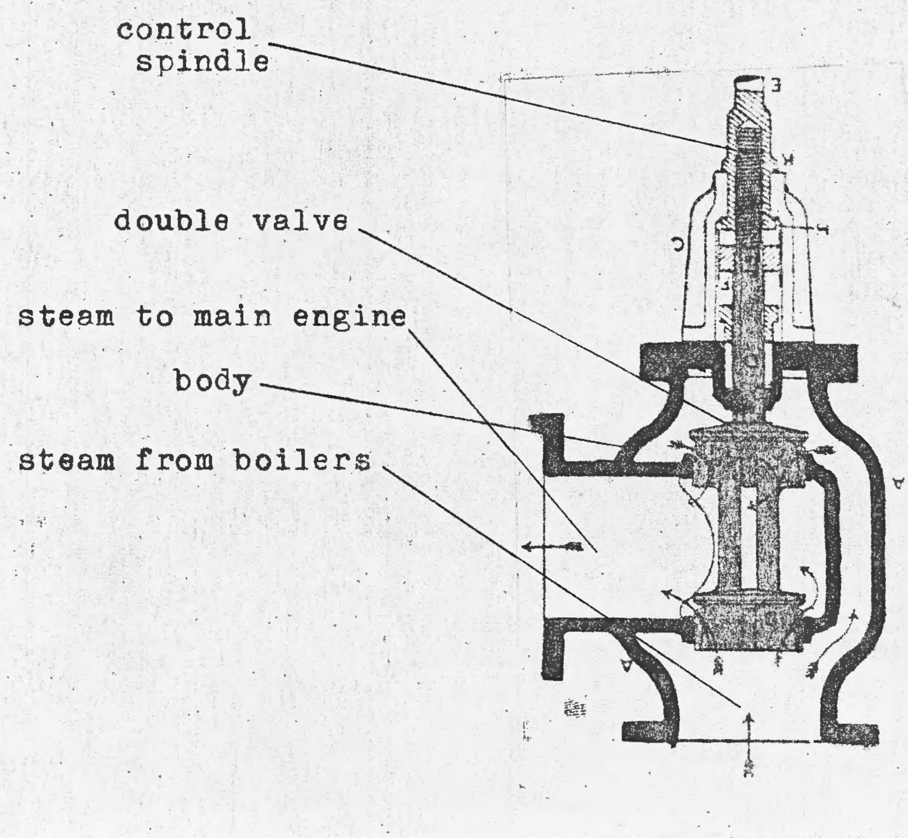


Photo 3.5. Control station.

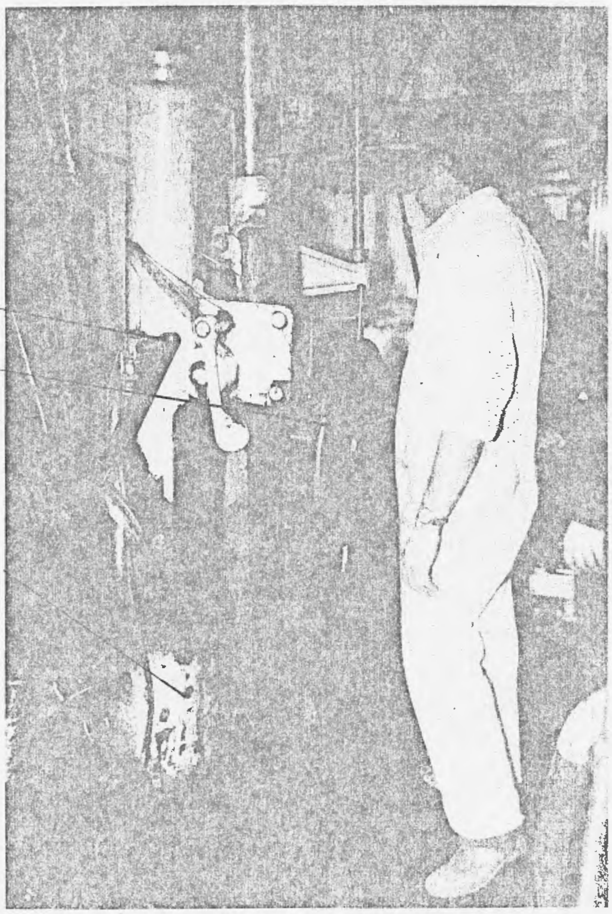
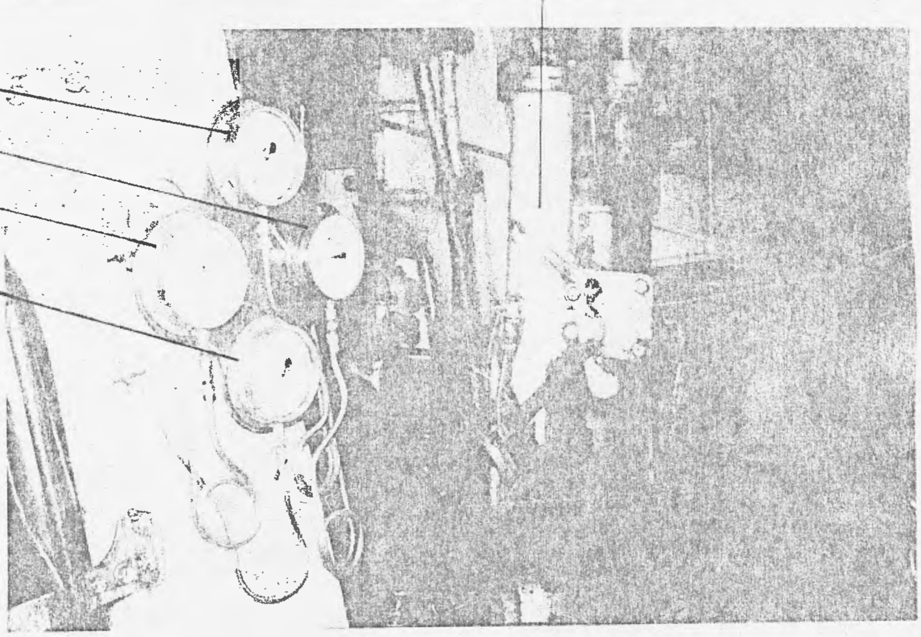
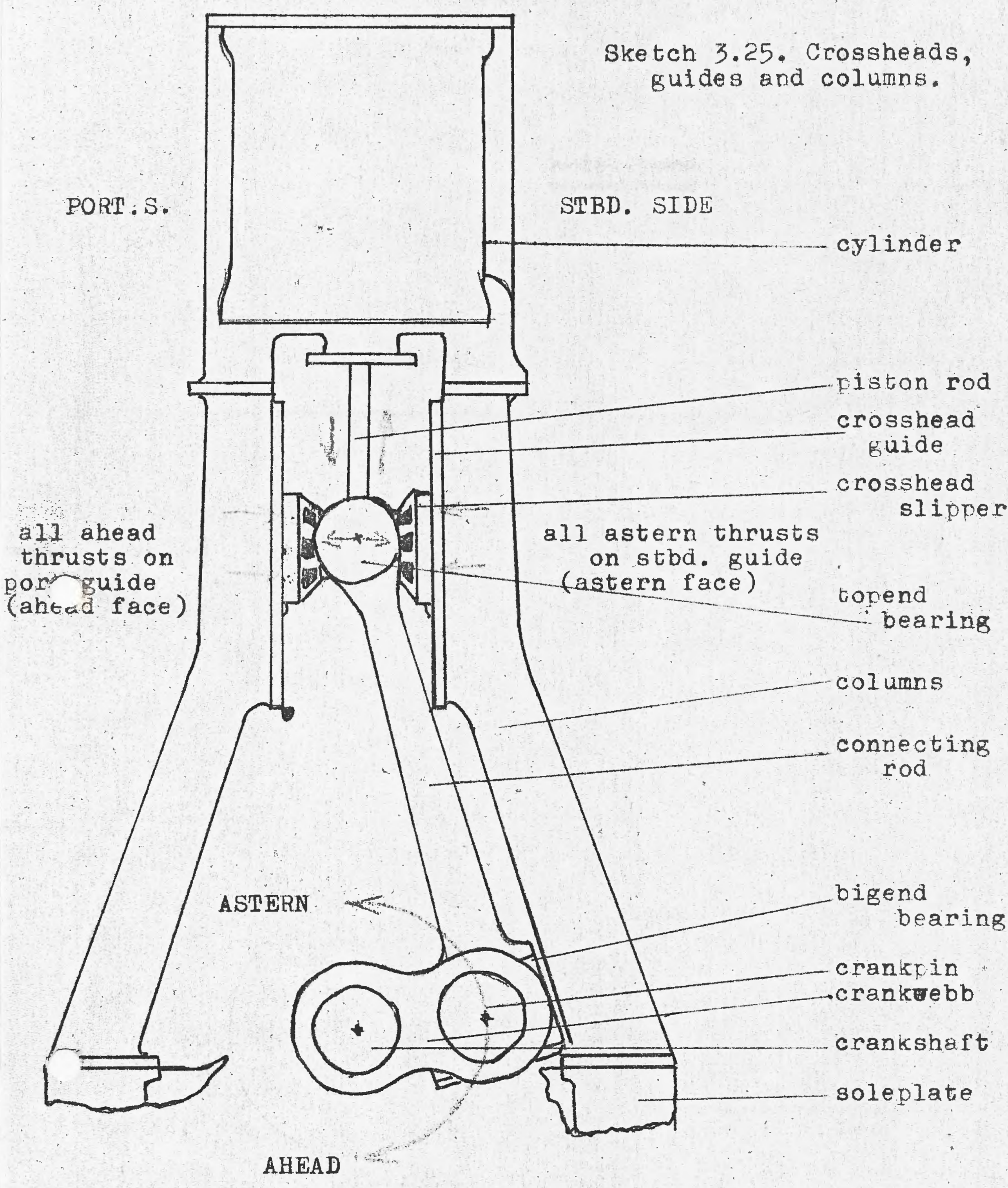


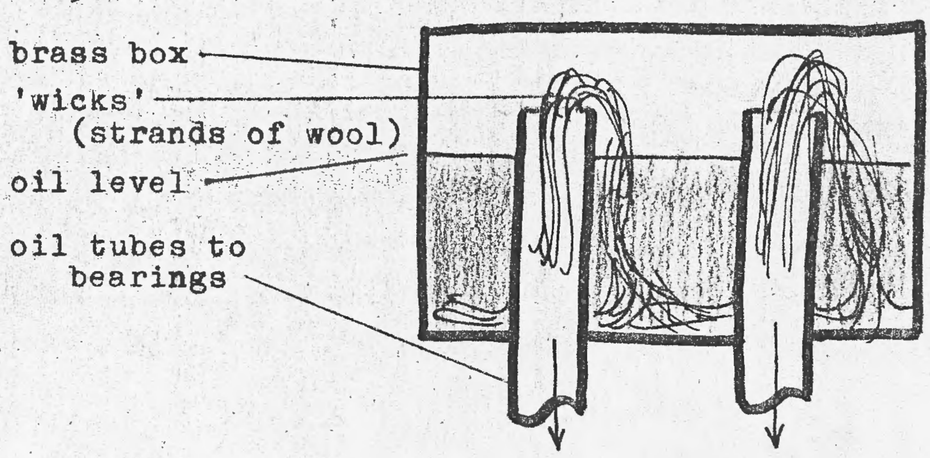

Photo 3.5. incl. gauge board.



Sketch 3.25. Crossheads, guides and columns.




Sketch 3.26. Oil box.



These are set to blow a little above the expected working pressure of the cylinder they are fitted to. They will release water trapped between the piston and cylinder cover. This water being incompressible, can burst the cylinder covers.

Pistons are cast steel and are fitted with cast iron piston rings. They are attached by a taper to the piston rod.

The piston and valve rods work through stuffing boxes. The stuffing box is a recess around the rod which is fitted with seals.

Steam is admitted to the H.P. valve chest through an equilibrium throttle valve (see sketch 3.24). It can be seen that steam pressures across the valve are nearly equal, making for little effort to open and shut the valve under pressure.

This valve controls the speed of the engine and is worked from the engine control platform by a hand wheel and shafting. (see photo 3.5)

CROSSHEADS AND GUIDES

The cylinders are set on columns stepped from the soleplate. These are all alike and made from cast iron. They also form the working force for the crosshead to bear on. When the engine is working ahead, all pressure is on the port crosshead and guide and when astern, pressures revert to the starboard crosshead and guide. (see sketch 3.21).

The crossheads are all alike and one piece with the piston rod. They are fitted with the split top end connecting rod bearing, and also bronze slippers which work on the crosshead guides. (see sketch 3.25).

The guides have zig zag oil channels cut in them to evenly distribute lubrication. A tray is fitted just below each guide face, and a brass comb on the crosshead dips into this and wipes oil over the whole face. Oil boxes are mounted on the cylinders and these supply a constant drip feed to the guides. (see sketch 3.26).

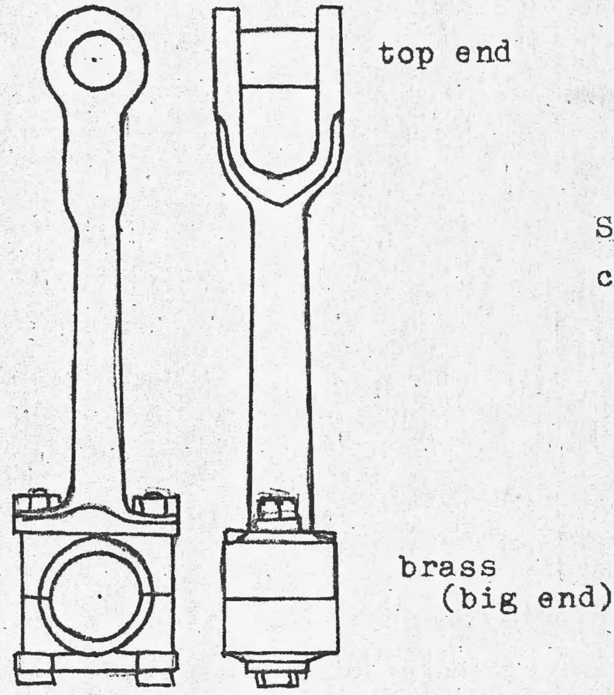
The ahead crosshead guide is able to be cooled by water from the "circ" pump.

CONNECTING RODS

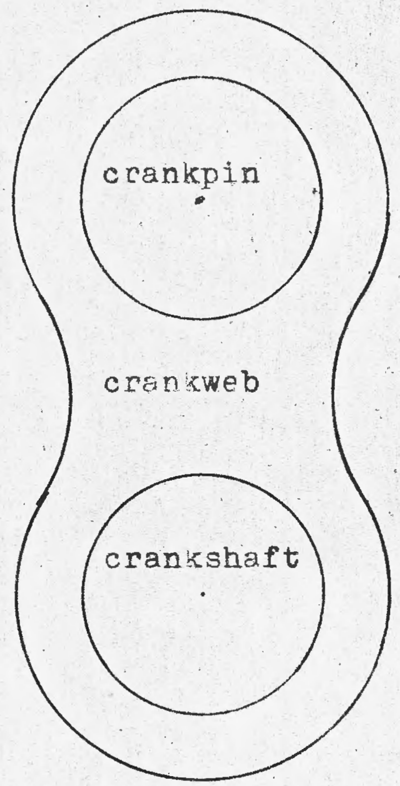
These are all identical, and are jawed at the upper ends to receive the crosshead and shaped at the lower ends to fit the crank pin brasses. (see sketch 3.27).

They are forged steel with a pressed in steel top end pin, white metal lined bronze big ends and steel caps below these.

Oil collectors for the big end are carried on the jaws, oil travelling down copper tubes to this bearing. Oil for the top end comes from a collector on the crosshead. Situated above these collectors are the outlets for oil lines coming down from oil boxes mounted on the cylinders. Oil comes down from these and falls into the moving collectors.

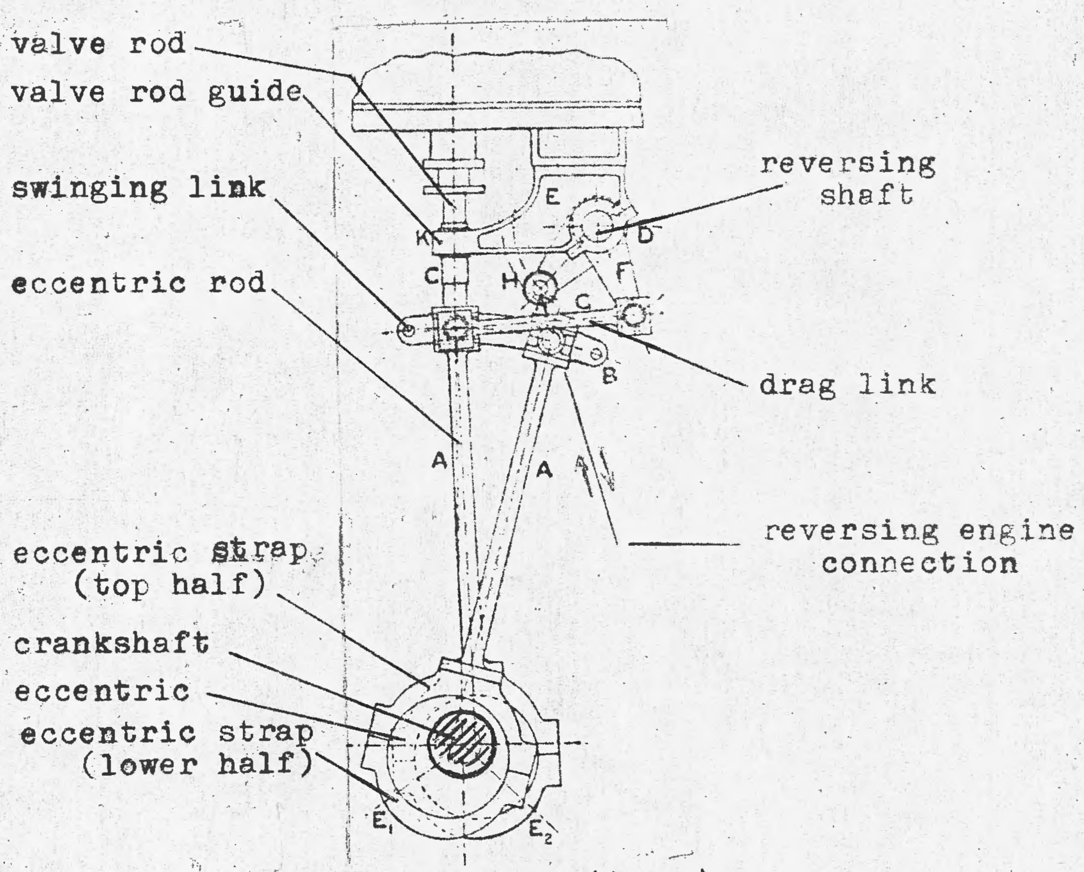



Sketch 3.27. Connecting rods.



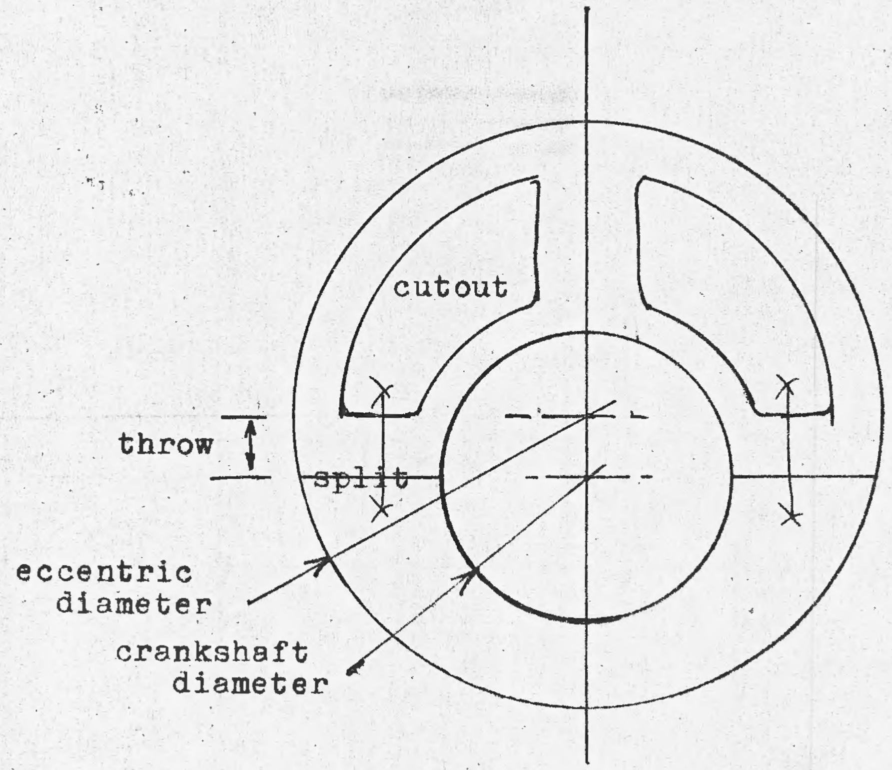

Sketch 3.28. crankwebs.

Sketch 3.29. Valve gear.(STEPHENSON)

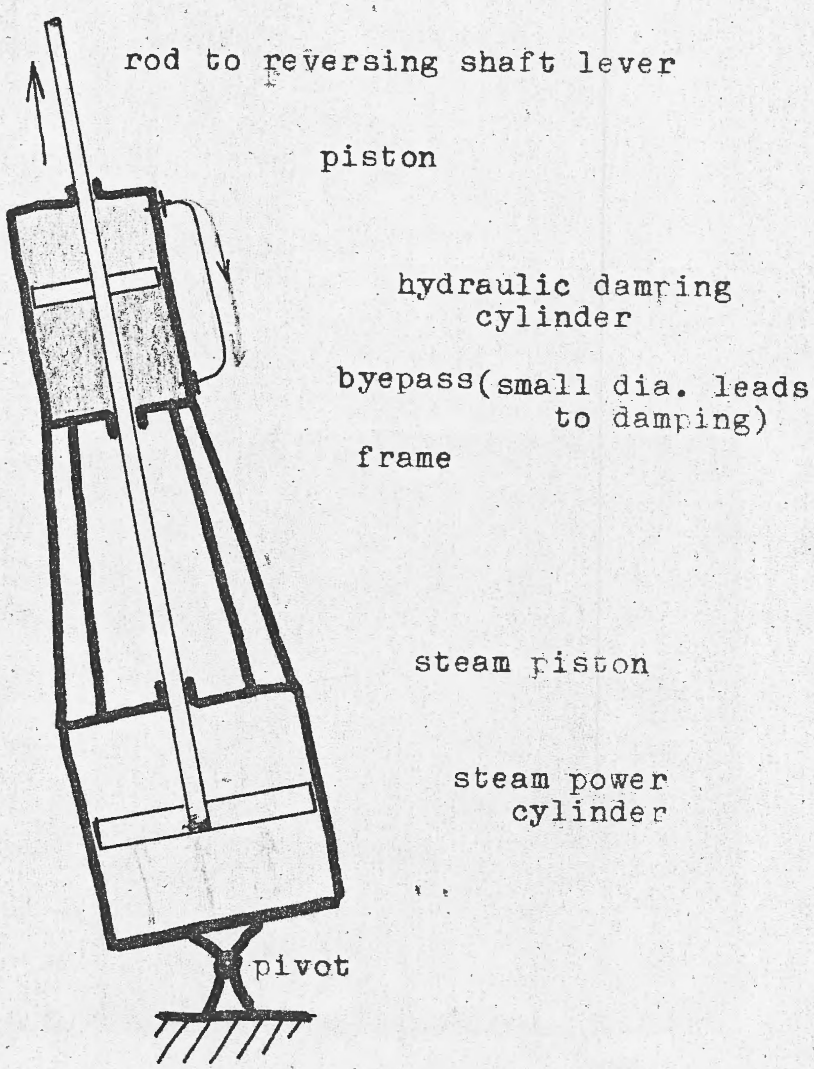



(DUNCAN)

Sketch 3.30. Eccentric.




Sketch 3.31. Power reverse engine.



Sketch 3.32. Principle of Michell thrust block.

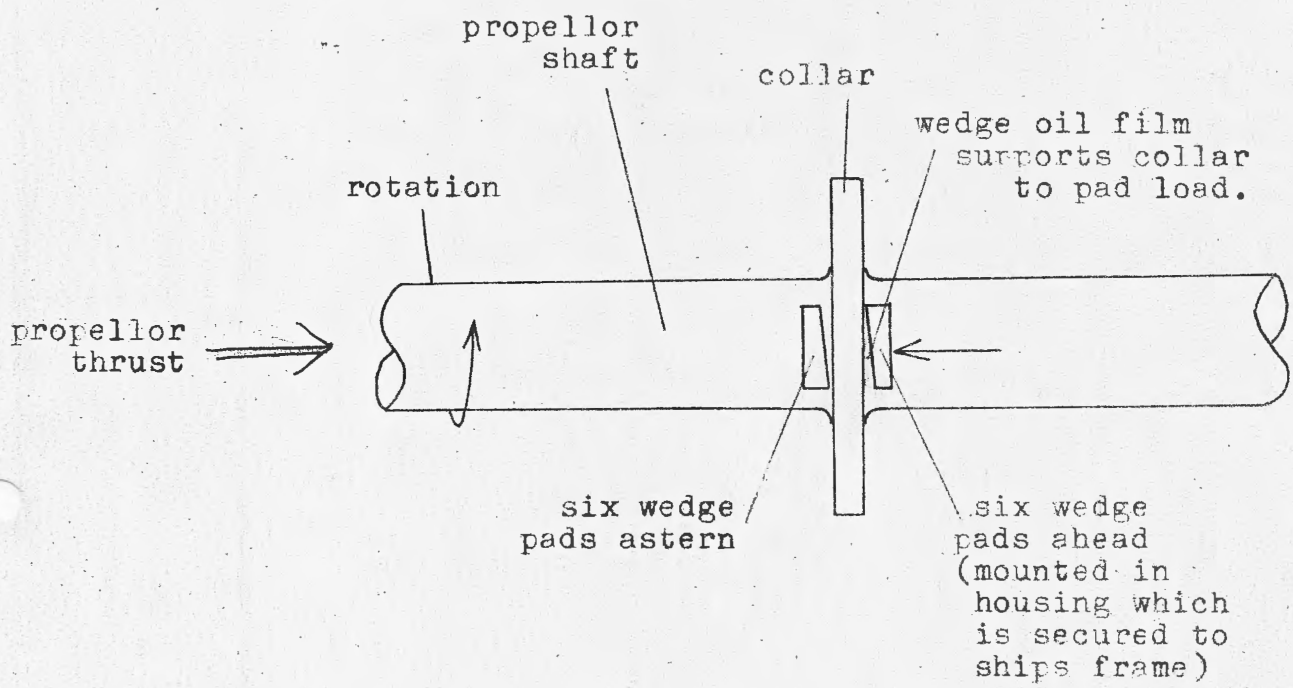
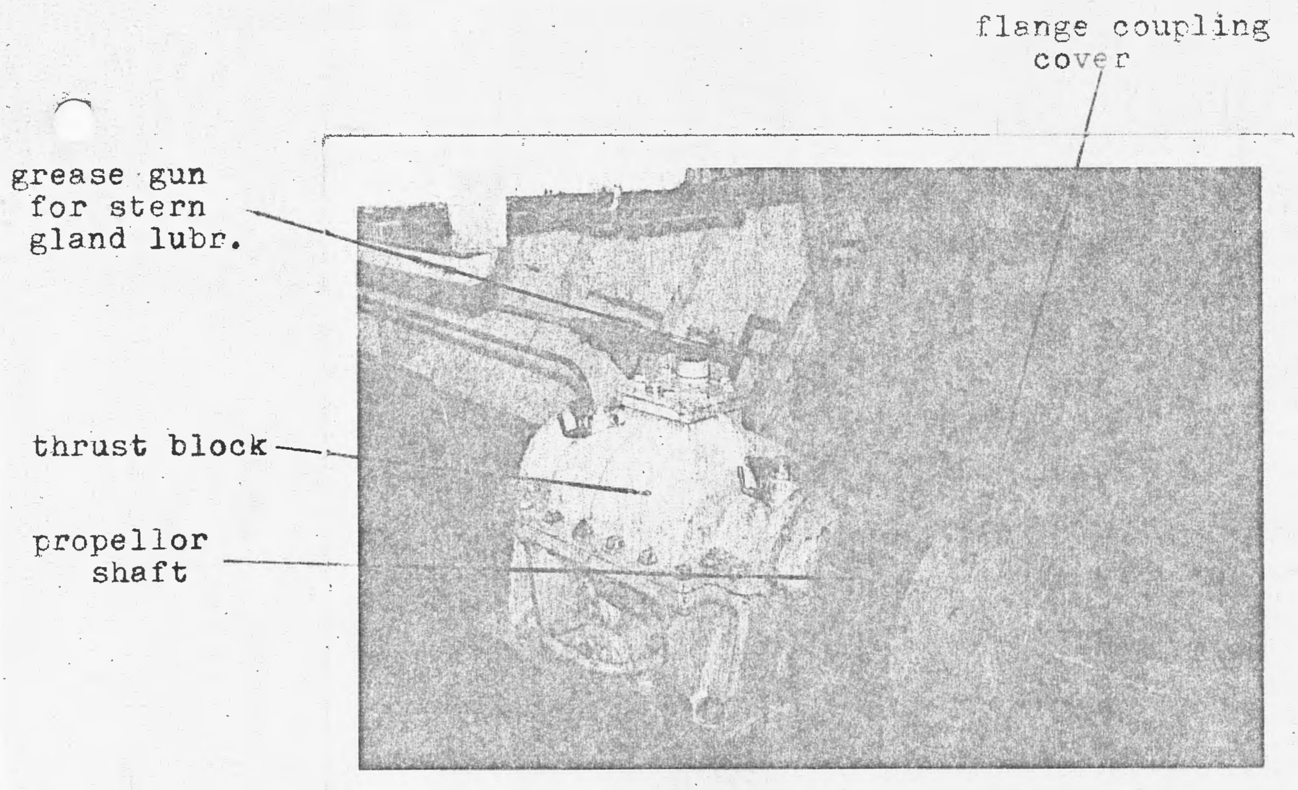



Photo 3.6. Michell thrust block.



On the L.P. connecting tod the top end pin is extended to carry links that drive the rockers for the air and slave bilge pumps.

THE CRANKSHAFT

This with the connecting rods, transmits the reciprocating motion of the pistons to rotative motion. This crankshaft is three throw, built up and with figure eight crank webs at 120$^{\circ}$. Crank pins and shafts are shrunkfit into the crankwebs. (see sketch 3.28).

The crankshaft is carried in six main bearings which are in turn held in the sideplate.

The main bearings are white metal lined bronze, held down by steel caps. The soleplate is the bed of the engine. It is a large cast iron structure mounted to the ships frame, and extending above the engine room floor plates. From it also rise the columns supporting the cylinders.

The main bearings are lubricated by oil boxes mounted on them. (see sketch 3.26).

THE VALVE MOTION

Stephensons Link Motion is fitted, arrangements being the same for all cylinders. (see sketch 3.29).

For each cylinder two eccentrics are fitted (see sketch 3.30). Eccentrics are a form of crank with the crankpin larger than its shaft. They impart a reciprocating motion to the eccentric sheaves and rods. One eccentric is set to run the engine ahead, while the other will run the engine astern.

Choice between the two eccentrics is made by swinging the curved link between the ahead and astern eccentric rods. With the ahead rod under the valve rod, the engines will run ahead.

The link is swung across by drag links from the reversing shaft. The reversing shaft is hung on brackets from the cylinders. Levers from the reversing shaft are attached to the power reverse. This is a hydraulically damped steam cylinder and is operated by a lever near the starting platform. (see sketch 3.31), photo 3.5).

The valve spindle or rod is attached to the link through a slipper block, (see sketch 3.[illegible]) and is guided by a bracket.

Bearings are fitted with grease cups, this being their only lubrication.

SHAFTING AND PROPELLOR

The shafting to the propellor is connected to the crankshaft by an 8 bolt flange coupling.

Propellor thrust is transmitted to the ship by a Michell thrust block (see sketch 3.32, photo 3.6).

This works on the principle of maintaining a wedge film of oil between a shaft collar and the body of the thrust block. The collar is immersed in an oil bath.

Sketch 3.33, Layout of steering linkage.(from Macgibbon)

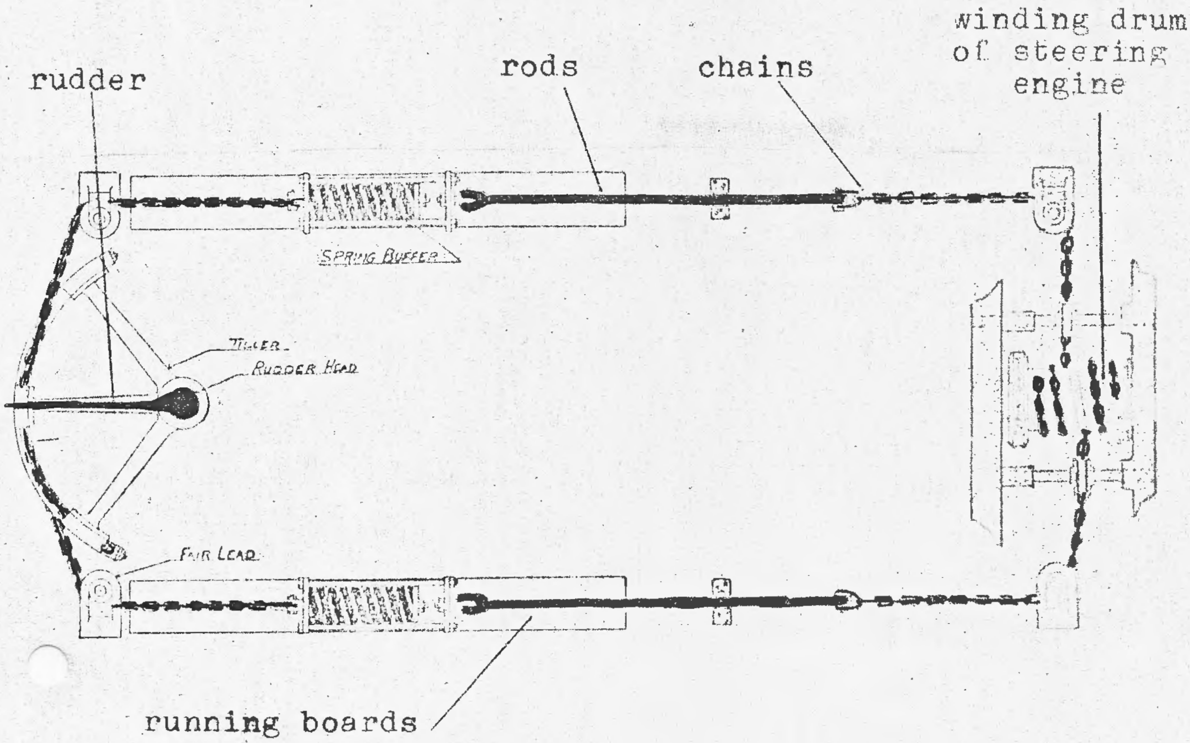
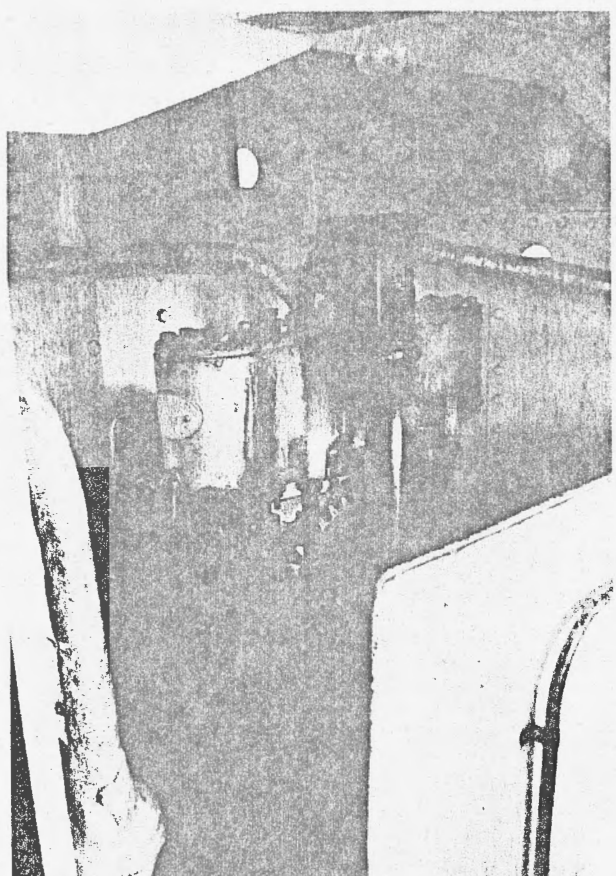



Photo 3.7. Steering engine.

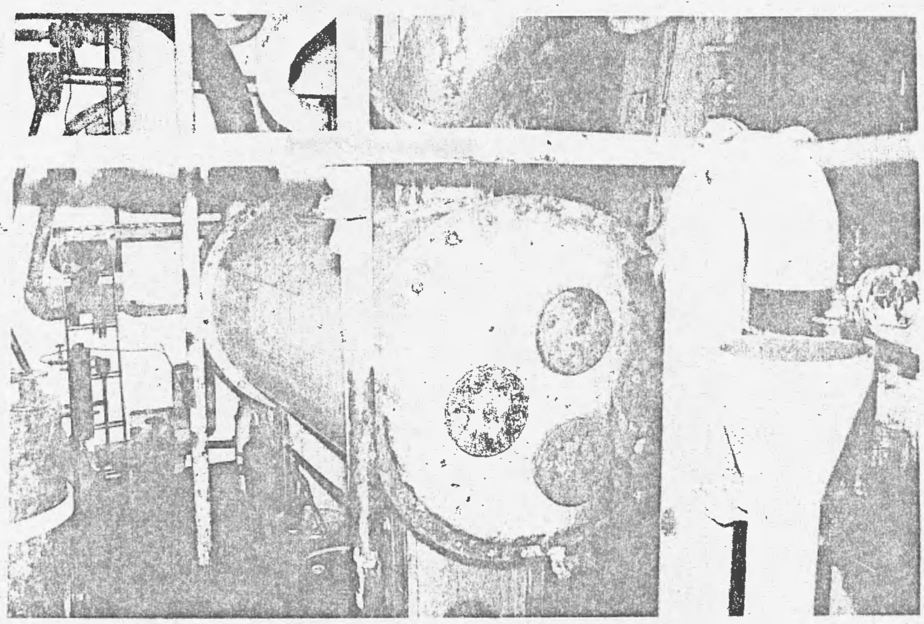


The shaft then extends aft through a shaft support bearing and another flange to the stern gland. This gland prevents sea water from flowing into the ship. A grease gun is filled with graphite grease which can be pumped into the gland. Woven greasy hemp is the packing used.

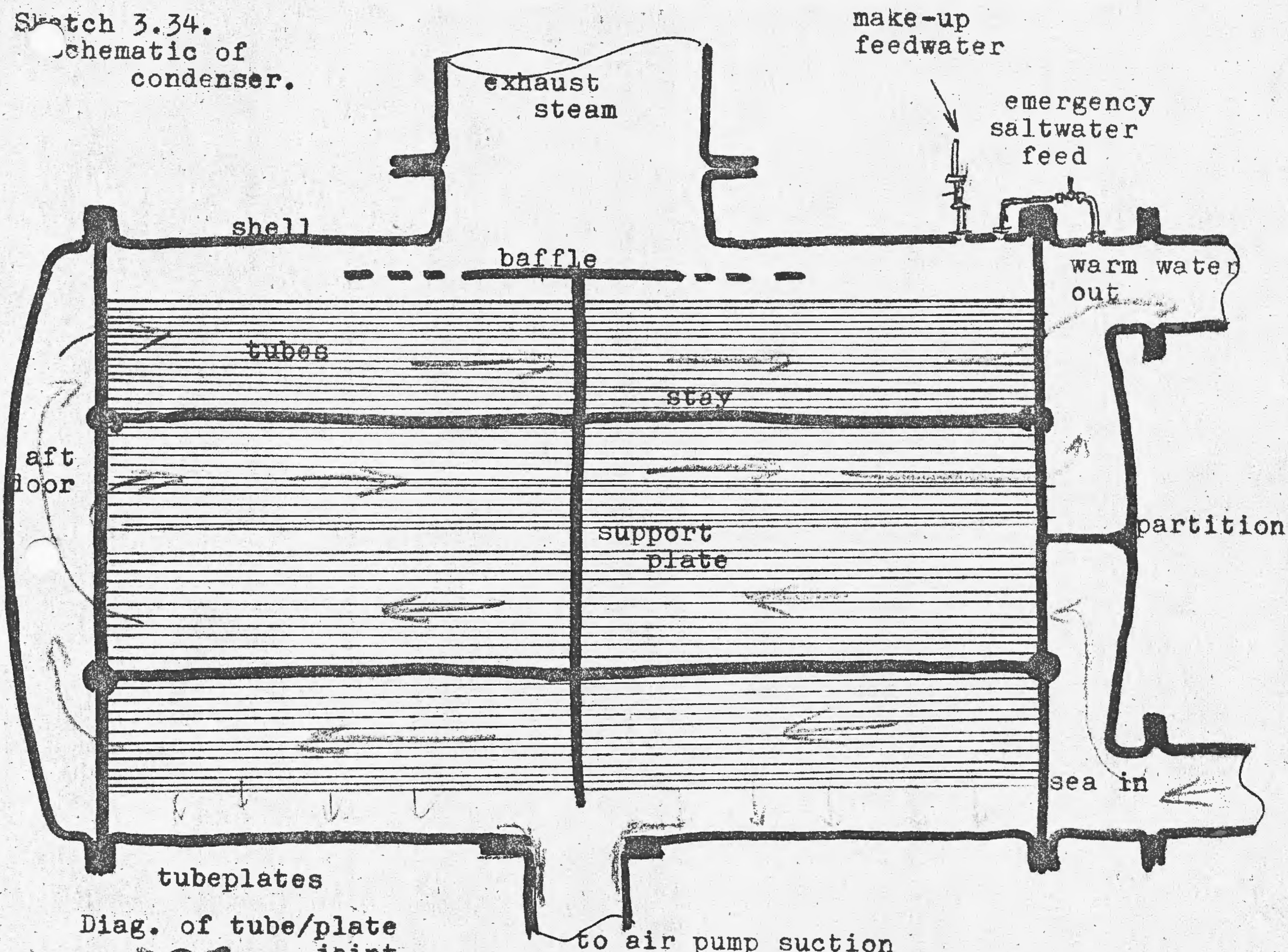
The shafting extends aft through the stern tube, at the end of which is fitted the propellor. This is a 4 bladed type designed for towing and high thrust. It is of 11'3" diameter and 11'9" pitch. The pitch is the distance the propellor will screw itself forward in one revolution, assuming no slippage.

While on the subject of the propellor, the rudder can be mentioned. This is a flat platelike structure mounted aft of the propellor. It can be swung in an arc by a steam steering engine mounted in the engine room upper platform. Shafting from the bridge operates the engine control valves and hence through chains, the rudder. (see sketch 3.33, photos 3.4, 3.7).

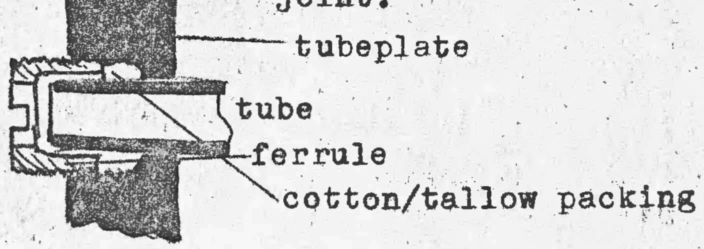
Photo 3.8.
Surface
condenser.

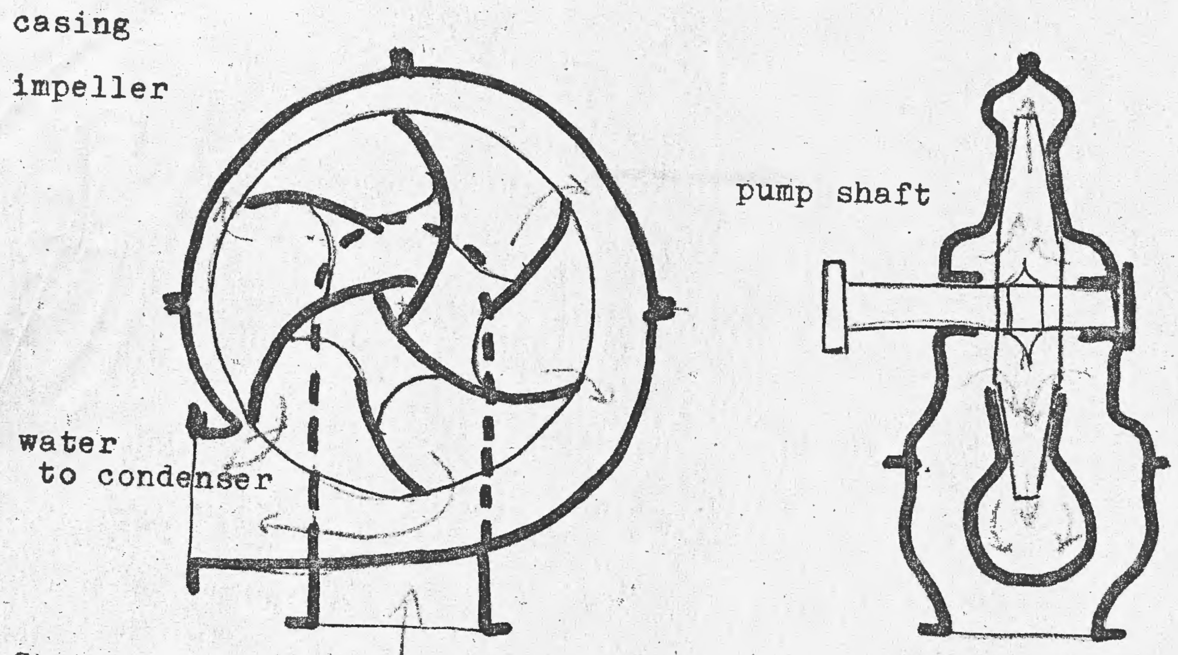


Sketch 3.34.
Schematic of
condenser.



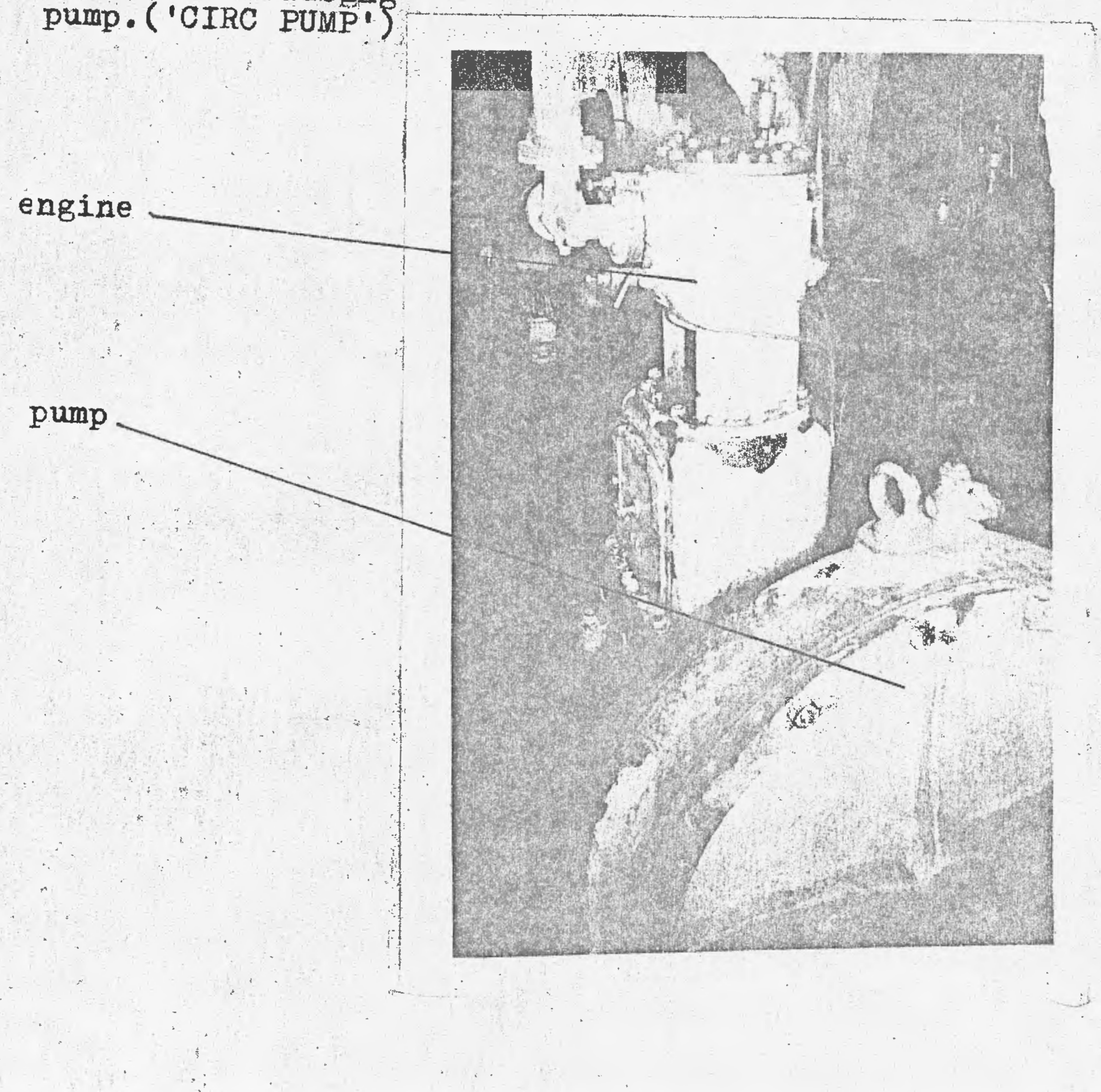

Diag. of tube/plate
joint.



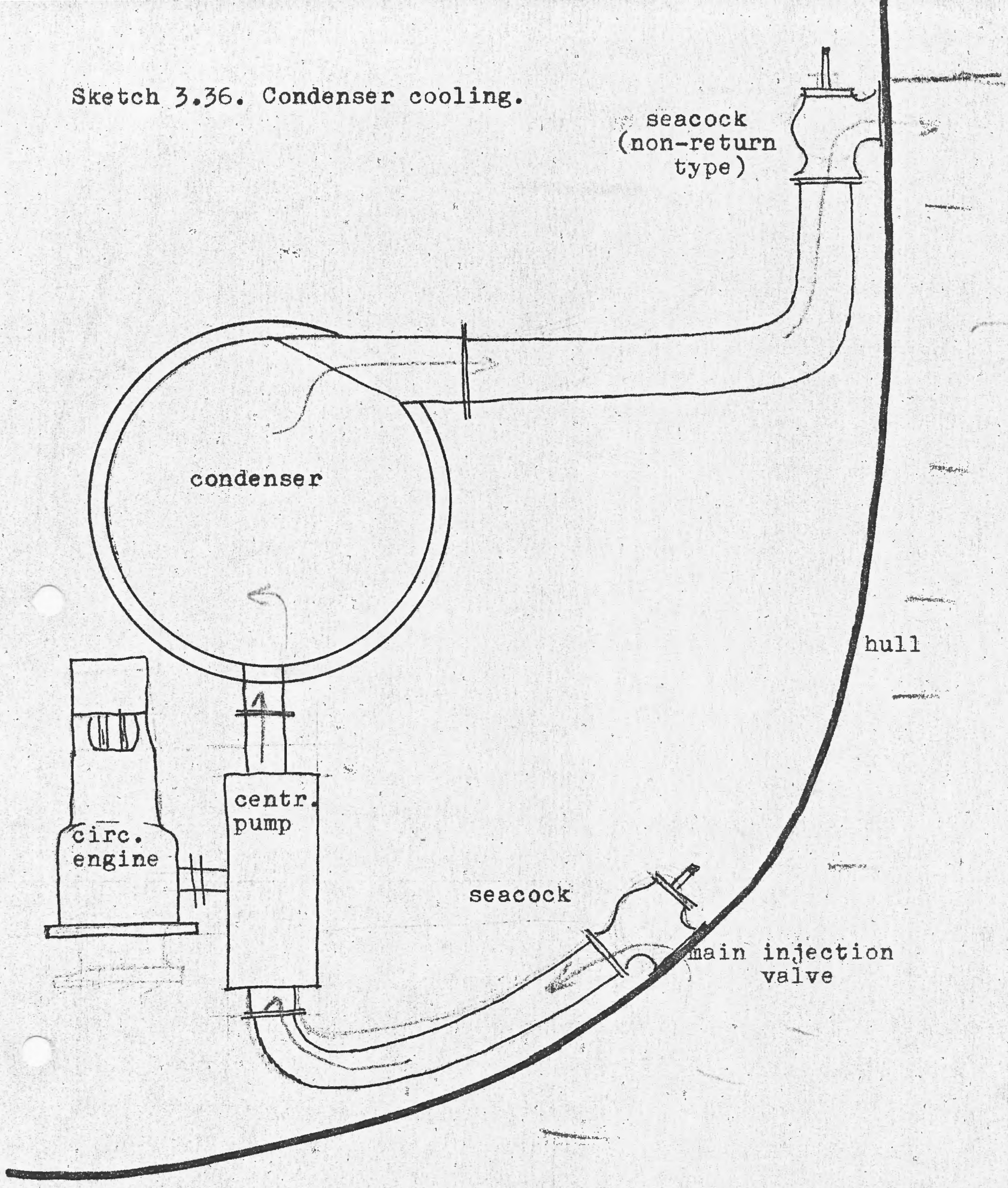



Sketch 3.35.
Centrifugal
pump

Photo 3.9. Circulating
pump.('CIRC PUMP')



Sketch 3.36. Condenser cooling.



THE CONDENSER (see photo 3.8)

The surface condenser consists of a circular steel shell with rolled brass tube plates at each end. Between the tube plates are fitted ¾" diameter brass tubes. Support plates are fitted to hold up the long runs of tube. The tube ends are set in glands.

These glands allow for differential expansion between the tubes and condenser body. They also prevent leakage of cooling water (salt) into the vacuum space and hence, into the boiler.

The tube ends are capped by cast iron doors. Sea water is pumped into one door where it flows aft through the lower run of tubes to the after door. From here it returns to the front door and is piped overboard. This type of condenser is termed a two pass surface condenser. (see sketch 3.34).

Exhaust steam from the engines is led to the top of the condenser vacuum space where it meets a baffle and is distributed evenly. Steam passes around the cool tubes and condenses. From here it falls to the bottom of the condenser body, and collects in the air pump suction line.

A valve from the condenser to the fresh water line is fitted, and may be used to replenish lost boiler water. Condenser vacuum draws the water into itself. Sea water is also able to be drawn in a similar fashion but this is an emergency measure.

Salt cooling water may also be drawn in around leaky tube to tubeplate stuffing boxes. They should be kept tight and the packings, greasy cotton, must not be dry or damaged.

By subjecting the condenser to about 7 p.s.i. internal water pressure, leaks can be found and repaired.

Stuffing boxes can be replaced but perforated tubes must be plugged or replaced. Wooden plugs are pushed in to plug a tube. They will not loosen under condenser vacuum and also swell when immersed.

CIRCULATING PUMP

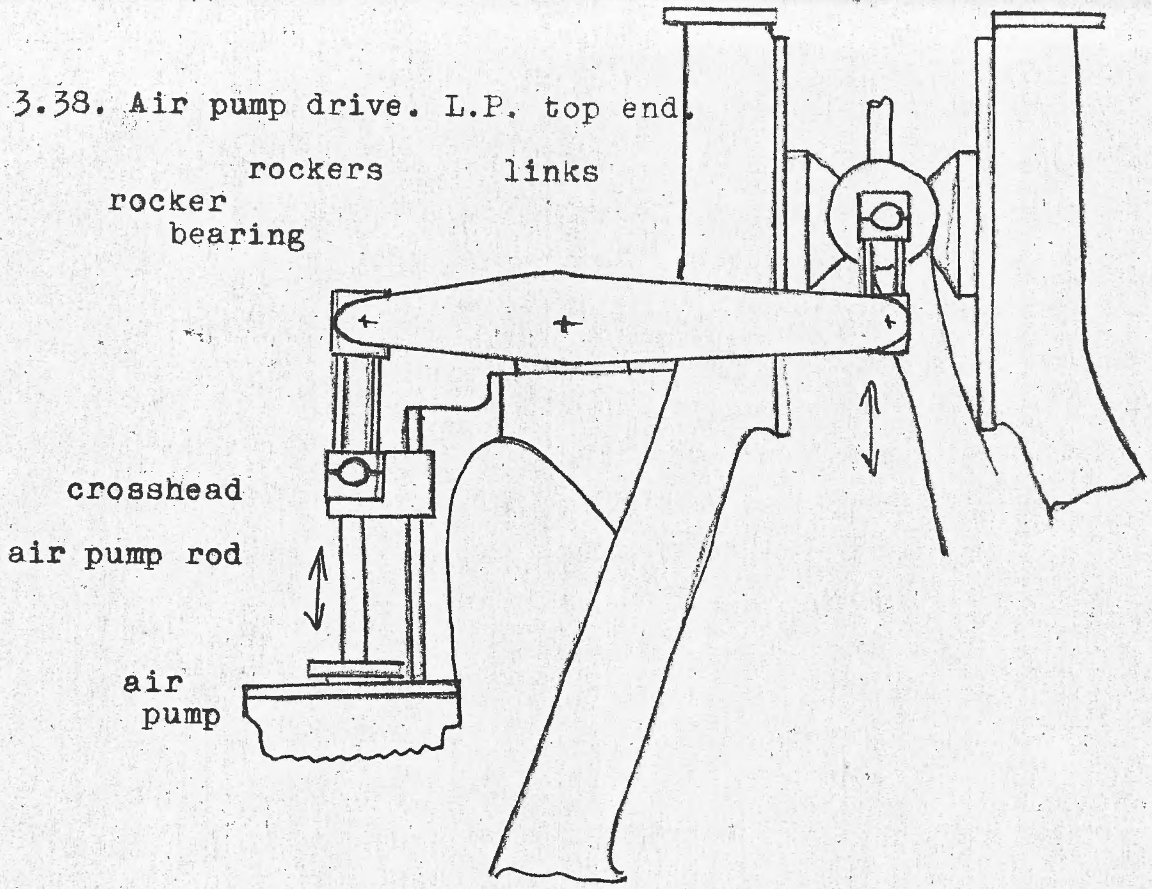
The function of the 'circ' pump is to deliver cooling water to the condenser. Sea water flows into a centrifugal pump (sketch 3.35). where it is delivered to the condenser. It then flows to sea. (sketch 3.36).

The pump, made by DON-ACCORD, is driven by an enclosed sump, single cylinder steam engine. The pump impeller acts as the flywheel. Refer to the description of the fan engine for running details. (photo 3.9). Peg holes in the engine to pump flange coupling enable a "c" spanner to turn the engine past dead centres.

Speed of the engine is regulated at the steam valve. This engine should be run at a speed just sufficient to maintain vacuum. Usually 30 to 40 lbs. of sea water is required to condense 1 lb. of steam. Excessive water may not improve vacuum, but it will chill the condensate which must be heated later on.

2/

Sketch 3.38. Air pump drive. L.P. top end.




Sketch 3.39. WEIR'S steam pump. Two such are fitted. (from COLE)

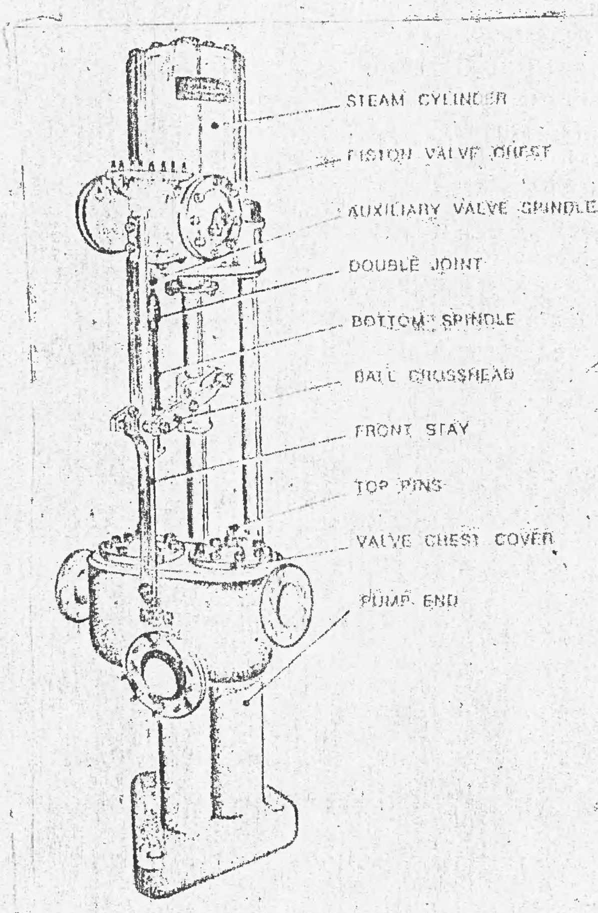
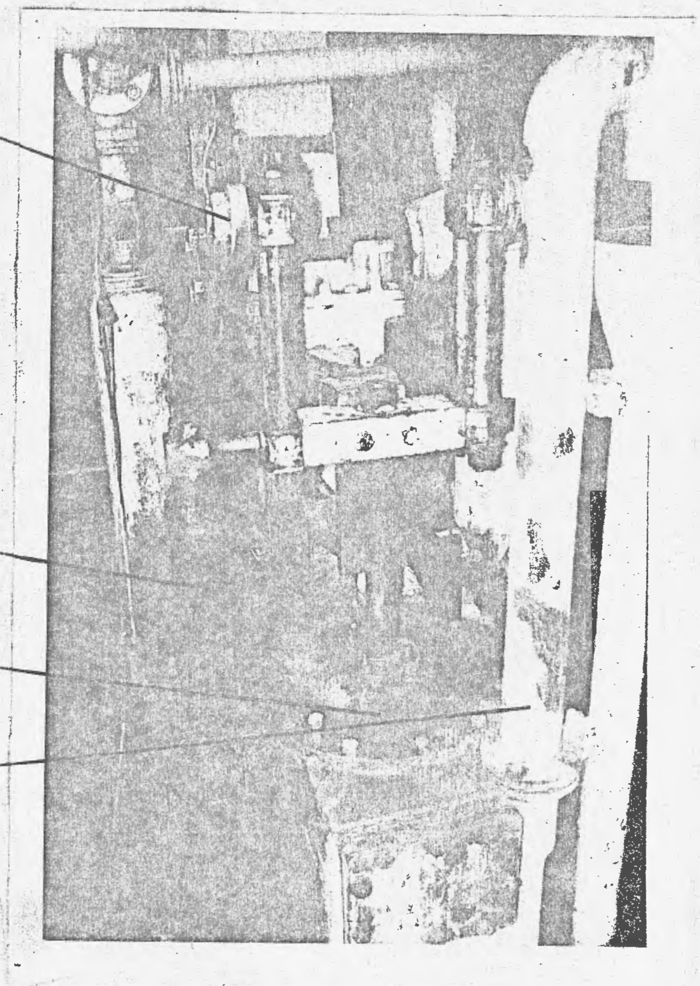
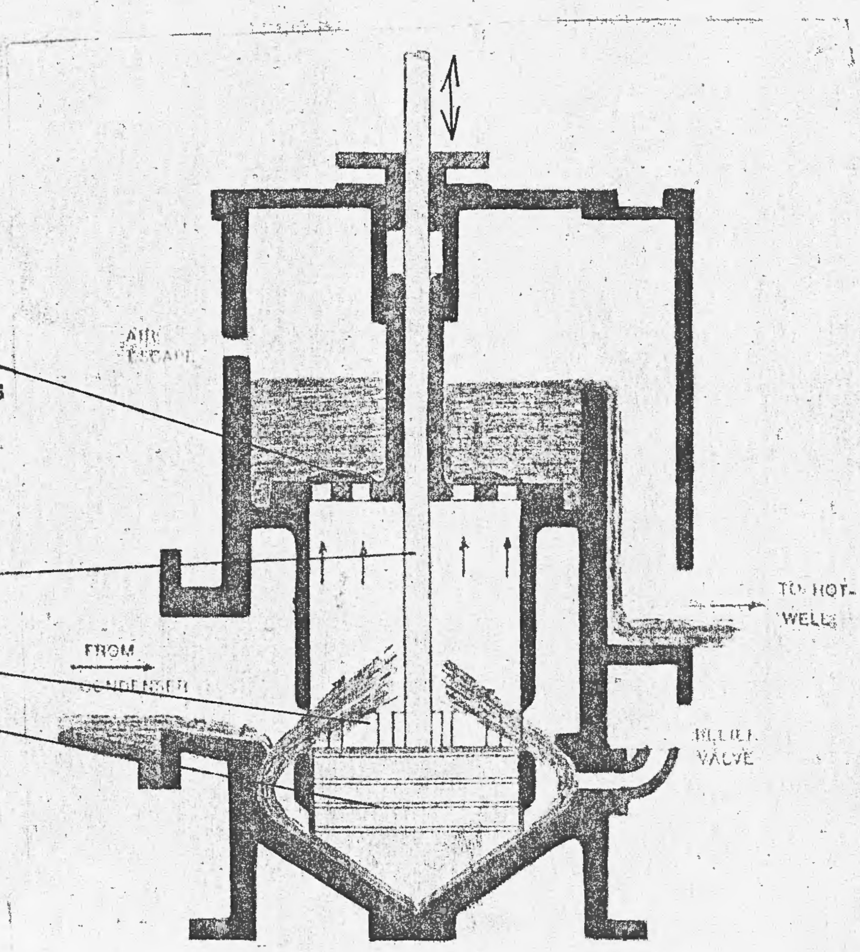


Photo 3.10. Air pump.
"EDWARDS" type.




Sketch 3.39. Scematic
of air pump.
(from Cole)



Slower pump speeds will improve economy of steam and promote longer working life.

THE AIR PUMP

This pump draws condensate and entrained air from the vacuum space of the condenser. (see photo 3.10, sketch 3.37). The air pump is of the Edwards design and operates with only one set of valves.

The pump rod passes through a stuffing box (hemp packed) and to rockers operated by the main engine. The pump rod is also guided by a small crosshead (see sketch 3.38).

The same rockers operate bilge ram pumps on each side of the air pump body. These are continually keeping the bilges free of water.

The air pump discharges into the hotwell, which is a holding tank for feed water. It is mounted under the feed pumps. It is fitted with a float and linkage to the throttle valve on the feed pump. By assuming a constant volume of water in the system, this float maintains a constant water level in the boilers.

THE FEED PUMPS

Two Weirs independent simplex feed pumps are fitted. These are vertical single cylinder steam pumps. (see sketch 3.39), photo 3.10).

The inboard pump is used as the main feed pump, the outboard pump being a backup. The pump draws from the hotwell and delivers through the filter and heater to the boiler feed check valves.

The steam piston receives steam from a steam operated piston valve. This valve is operated by a small slide valve driven by linkage from the pump rod. (see sketch 3.40). Note that the steam piston is larger than the water pump piston. This enables higher pressures to be developed in the pump end.

If both pistons had the same diameter, the pump could not push water into the boiler as pressures each end would balance.

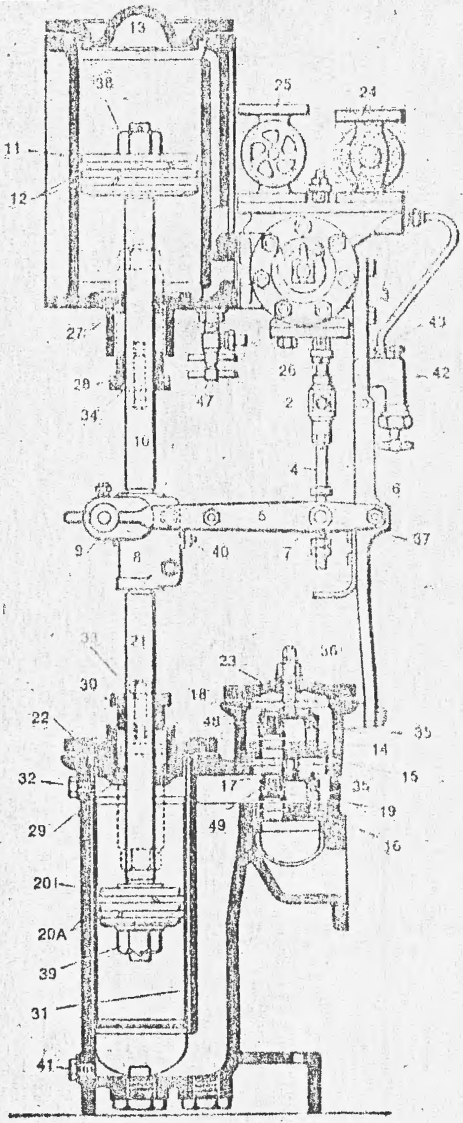
By manipulating pump discharge valves, water can be delivered to the auxiliary feed check valves on the boilers, straight from the pump. This would be done in event of filter or heater breakdown.

The pump is started by filling the cylinder lubricator with steam oil and pumping lubricant in. The cylinder drain is opened and steam turned on to warm the cylinder. Suction and discharge valves are opened and the bearings lubricated with engine oil.

A Weirs slotted spanner is fitted over spigots on the double joints and front stay. Steam is turned on and the pump should start. The valve gear is moved with the spanner so as to prevent the pump from nearing full stroke.

This ensures the pump does not stall at B.D.C. or T.D.C. where it will be hard to restart.

Sketch 3.40. Sect. el. of WEIR'S pump. (from COLE)



LIST OF PARTS

Part No.

1. Steam slide valve chest
2. Double joint
3. Front stay
4. Bottom spindle
5. Valve gear levers
6. Front stay bush
7. Ball crosshead
8. Main crosshead
9. Crosshead pin
10. Piston rod
11. Piston body
12. Piston rings
13. Cylinder cover
14. Discharge valve seat
15. Discharge valve seat ring
16. Suction valve seat
17. Suction valve guard
18. Discharge valve guard
19. Water valves
20. Bucket
20A. Bucket rings
21. Pump rod
22. Pump cover
23. Valve chest cover
24. Steam stop valve
25. Exhaust stop valve (when fitted)
26. Auxiliary valve spindle
27. Cylinder neck ring
28. Cylinder gland
29. Pump neck ring
30. Pump gland
31. Pump liner
32. Liner fixing pin
33. Pump gland studs
34. Cylinder gland studs
35. Suction and discharge columns
36. Top pins
37. Ball crosshead bushes
38. Piston rod nut
39. Pump rod nut
40. Crosshead taper pin
41. Pump drain plug
42. Plunger lubricator
43. Adapter for lubricator
44. Ball valves and spring for lubricator (not shown)
45. Gland packings complete
46. Pump and cylinder joints
47. Cylinder drain valve
48. Discharge valve spring
49. Suction valve spring

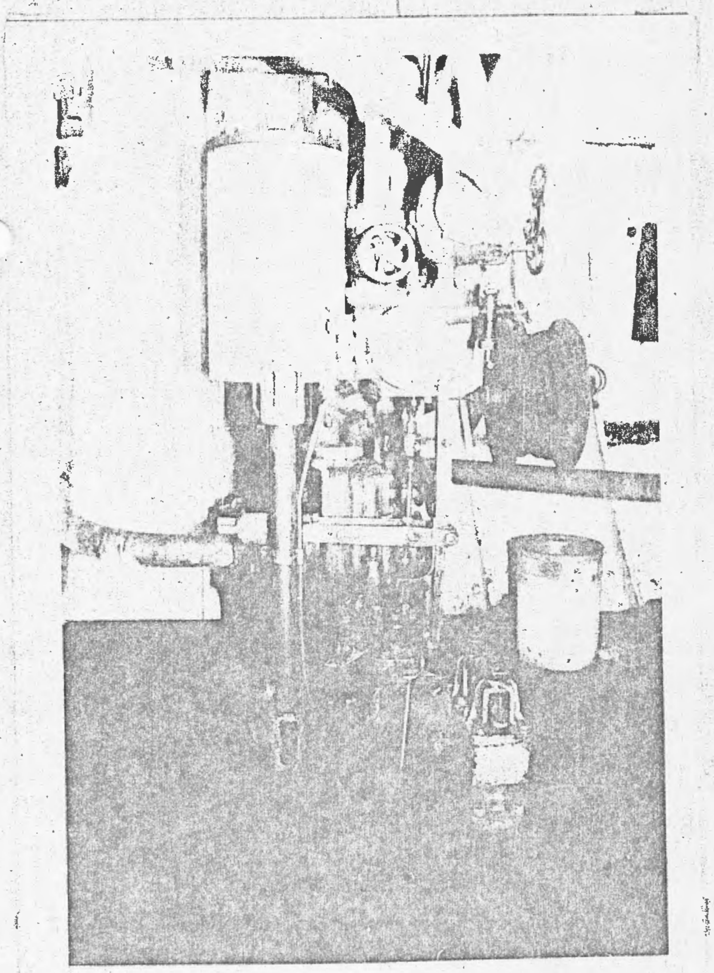
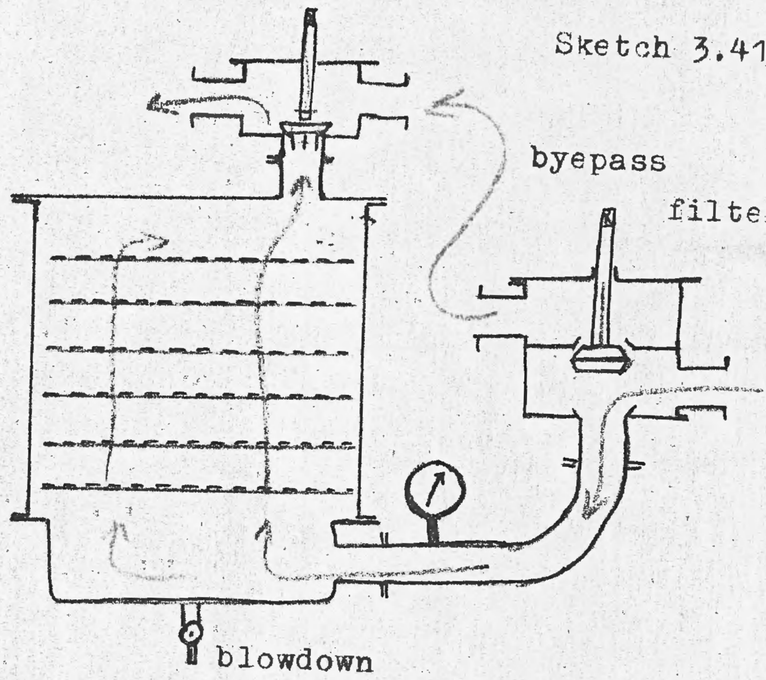
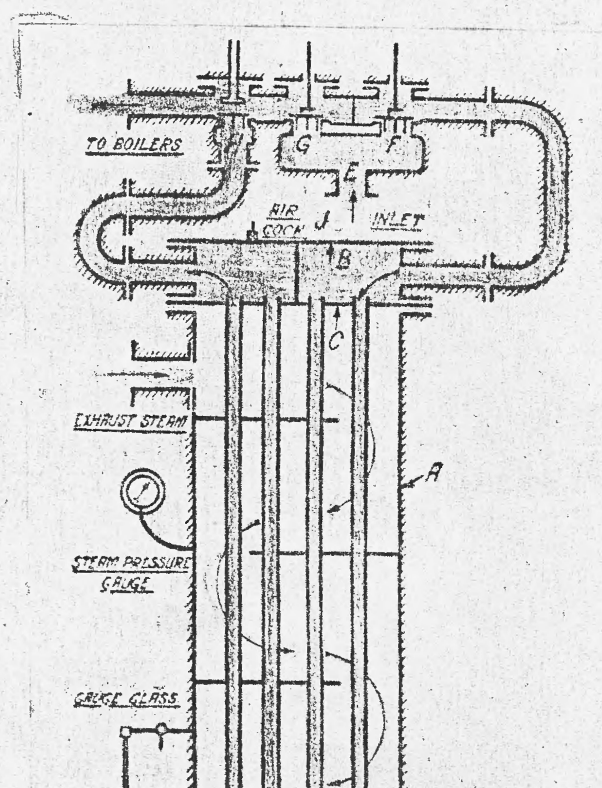


Photo 3.10. WEIR'S feed pumps as fitted.

Sketch 3.41. Feed water filter.




Sketch 3.42. Feed water heater. Surface type. (SOUTHERN)



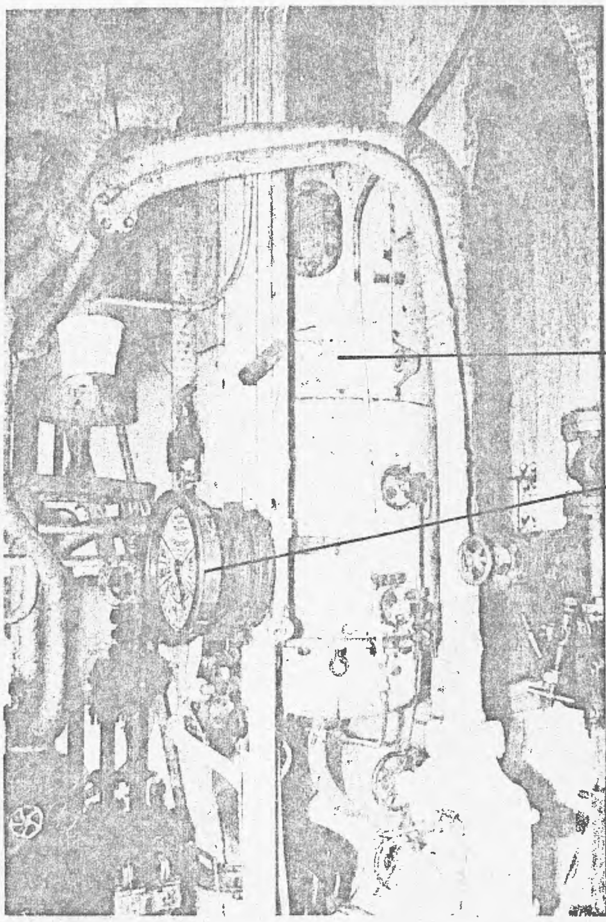


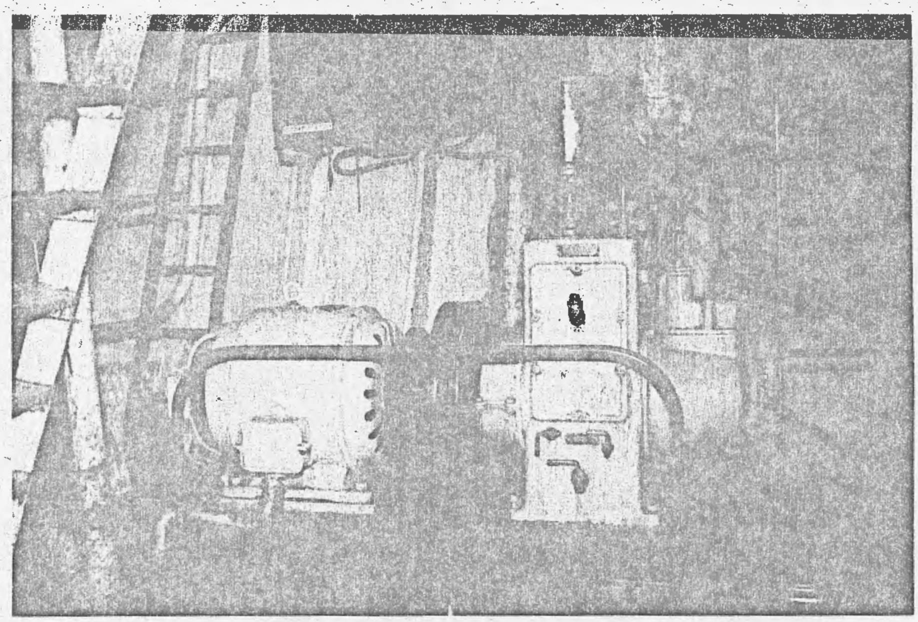

Photo 3.11. Surface feed water heater.

Photo 3.12. General service pump.

Photo 3.13. Generator and switchboard.



Photo 3.14. Generator and engine.



The pump should be stopped half way on the up stroke. This will help in restarting the pump next time.

THE FEED WATER FILTER (see sketch 3.41)

The function of the pressure feed filter is to trap oil and sediment in boiler feed water. It consists of a cast iron body into which are fitted perforated plates. Coarse towelling is placed between the plates, this being the filtering medium.

The filters must be kept clean otherwise they will become choked and will burst, releasing the oil and sediment to the boilers.

THE FEED WATER HEATER (photo 3.11, sketch 3.42)

The surface feed heater heats boiler feed water. This utilises the heat in exhaust steam and by pumping hot water into the boiler, increases economy and decreases thermal shock to the boiler.

Feed water is passed through tubes around which exhaust steam is directed. This steam gives heat to the feed water, is condensed and drains to the hotwell. The hotwell drain valve is set to keep half a glass in the gauge glass fitted.

In case of breakdown, the feed heater may be bypassed.

THE GENERAL SERVICE PUMP (see photo 3.12)

This is the donkey pump and performs general duties in the engine room. It is of the Weirs pattern whose design has been covered in the description of the feed pumps.

This pump can draw from the fwd peak tank, aft peak tank, hotwell, main bilges, independent bilges and the sea. It can discharge to the deck fire main, overboard, the condenser (cooling), the day tank, auxiliary boiler feed, the fwd peak tank and the aft peak tank.

It is warmed up and kept hot all day in case instant operation is required.

THE GENERATOR (photo 3.13, 3.14)

The generator supplies electric power to lights and navigation lights at night. It was made by ASTON and develops 2.97 Kw at 110 v.DC and 27 amps.

The generating engine is a single cylinder enclosed sump engine made by HINDLEY and SONS. The speed of the engine is governed by a throttle valve governor.

The electrical installation of a ship must be two wire. This is because currents in the ships hull will lead to extreme stray current corrosion.

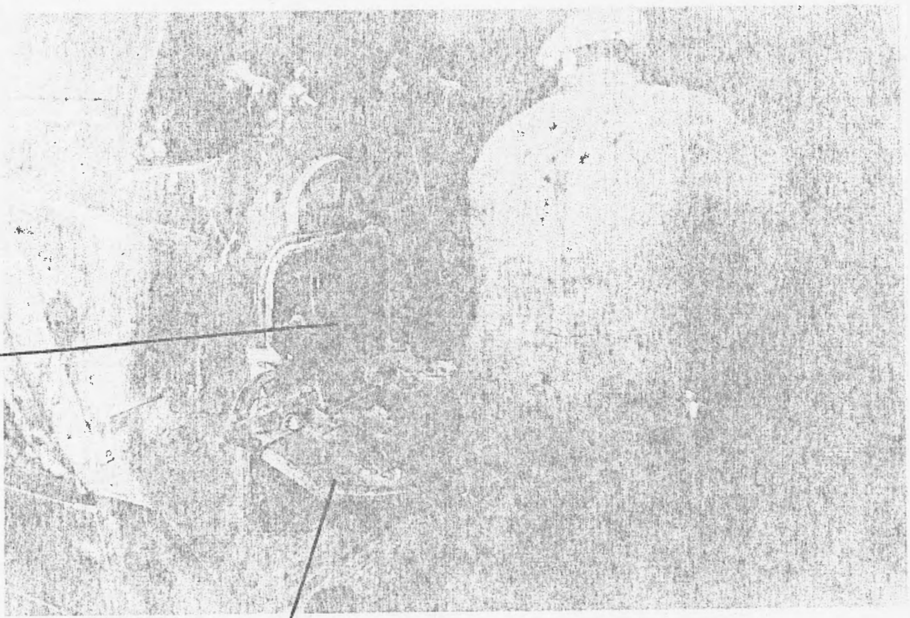
Leaks to the ships frame are detected on lamps which bridge the two power leads to earth. If they light up when switched on, an earth in the power lead is indicated. This is traced and remedied. ([redacted]).

Both lights should light when both are switched on.

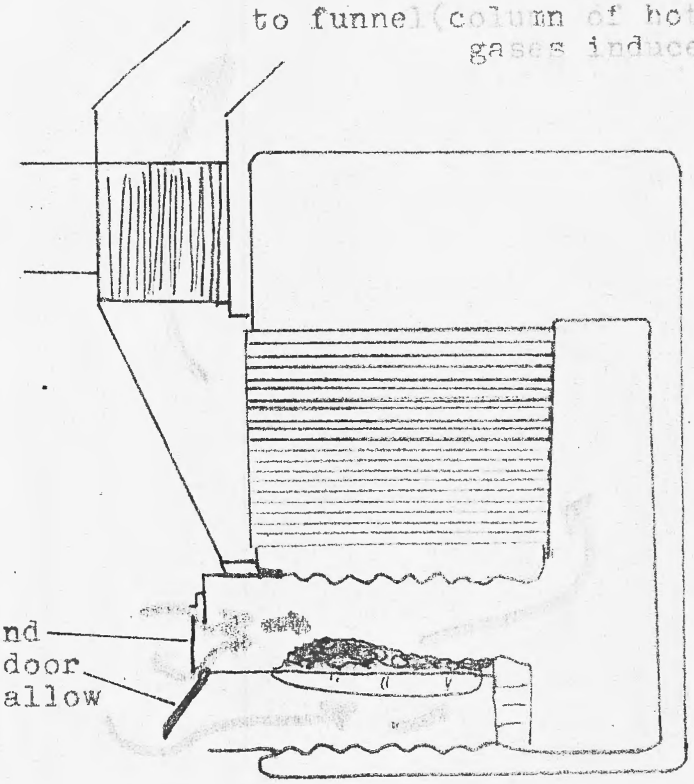
## 4.0 PROGRAMME OF OPERATIONS

| | |
|---|---|
| Wednesday night | - light fires - 12 hour bank. |
| Thursday morning | - rebank - 12 hours |
| Thursday night | - rebank - steam showing |
| Friday morning | - 7 a.m. - build up fires |
| | - 8.45 a.m. - slipped berth and steamed to coaling wharf. |
| | - 11.30 a.m. - secured berth - banked fires |
| Saturday morning | - build up fires |
| | - 1.00 p.m. - slip berth - steam down river. |
| | - 4.45 p.m. - secure berth - bank fires |
| Sunday morning | - 7 a.m. - build up fires - breakfast |
| | - 9 a.m. - slip berth for Moreton Bay. |
| | - 4.15 p.m. - secure berth - drop fires |

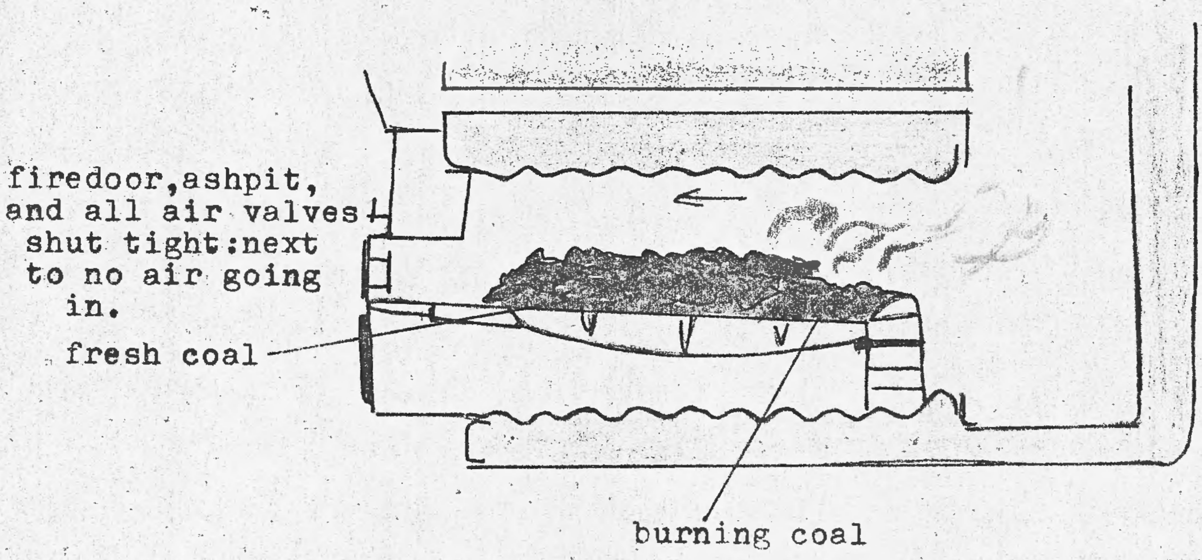
Photo 4.1. Natural draught set up.



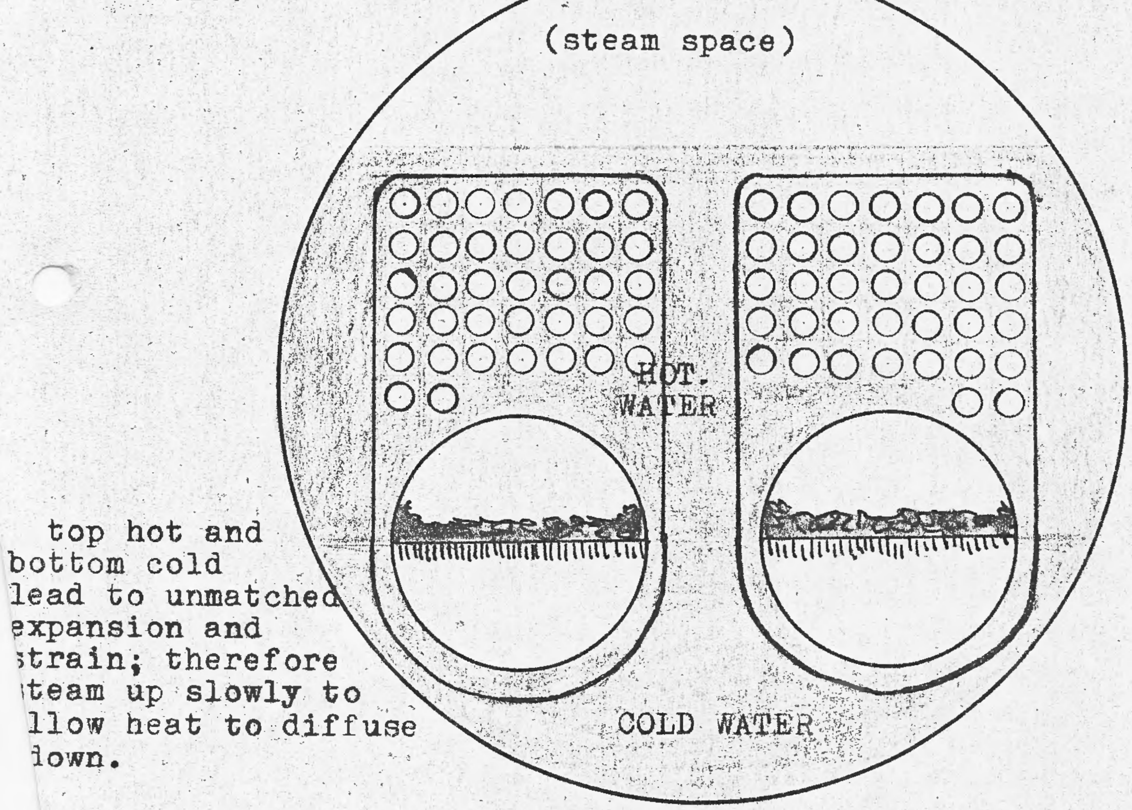

Sketch 4.1. Boiler under natural draught.



Sketch 4.2. Banked fires.




Sketch 4.3. Scotch boiler,
sect. front el. from
stokehold.



## 4.1 STEAM RAISING - GETTING UNDERWAY

Steam raising from cold took a total time of 36 hours. The fires were started in one furnace by lighting a small paper and kindling fire. More wood is added and then coal, when the fireman is confident it will catch fire. The ashpit doors were opened so that the furnaces may run on natural draught. (see photo 4.1 and sketch 1.)

When a large firebed has been built up, burning coal was collected on shovels and placed in other furnaces. Fires were then built up in all furnaces.

All of the burning coal was then pushed back on to the last fifth of the grate and fresh coal shovelled in to cover the front of the grate. Ashpit firedoors were then closed as were all other air valves and dampers. This is called banking the fires and is done when low heat output over a long time is required.

The coal must backburn through itself and very little air is supplied for this. (sketch 2.)

Valves on top of the boilers are opened so as to purge the boilers of air when steam is made. Air at high pressure and temperature will increase corrosion in the boiler and must be exhausted. When steam is issuing the valves are closed. (about Thursday late).

With boilers of this type steam must be raised slowly. 12 hours is generally regarded as being a safe minimum. 36 hours is long but fits in very well with the crew and imposes low strains on the boiler.

During the floods in 1974, steam was raised in 6 hours but this necessitated re-expanding leaking boiler tubes that had worked loose through the strains generated by unequal expansion. (see sketch 3.)

Thursday morning and night saw the fires rebanked from the fires left in the furnaces.

Friday morning saw the ashpit doors opened and the fires built up to working pressure, about 150 p.s.i. When under natural draught the firedoors are cracked open so as to allow top air into burn off the volatiles.

The boilers can be coupled by the engineer when the difference in pressure between them is less than 10 p.s.i. To achieve this, one boiler may be fired harder or slower. The main steam valves are then cracked open so as to warm the steam lines up slowly. When warm they may be opened fully.

Auxiliary steam mains are also opened up in the same way.

If steam were to be admitted quickly into a cold steam line it will condense and create a vacuum. It is possible for this to draw a plug of water along through a pipe at high speed: this may burst pipes and valves causing serious accidents.

When the steam spaces of both boilers are interconnected they are said to be "married".

2/

The forced draught is started by opening the trunk dampers, draining the steam line to the fan engine and then starting the fan engine with the auxiliaries exhausts to atmosphere.

Air pressure in the trunks is adjusted by speeding up or slowing the fan engine. "FORCEFUL" is run at 1" of water as measured on a manometer. The ashpit doors are shut and the air valves beside the firedoors are opened, thus admitting bottom air. From time to time this pressure will have to be re-adjusted as it will fluctuate with changing boiler pressure and when the auxiliaries exhaust is switched from atmosphere to the condenser.

The top air valve was not opened when burning Blair Athol coal. However Ipswich coal will smoke heavily if top air is not admitted. This is because of the greater quantity of volatiles in the alternative Ipswich coal, and the way they burn.

About 1½ hours before departure the engineer and greaser start preparing the main and auxiliary machinery for operation.

First job is to check the boiler water level. The gauge glass cocks are opened and the level should soon settle down to about ½ glass. The gauge glass is tested - each cock independently for free passage. This is essential for a true reading. In addition the glasses are also tested ("blown down") about every 4 hours by opening the drain cock, shutting it and watching the speed of water return and the new level.

Pressure gauges for each boiler are on the boiler fronts so the engineer must walk through the alley between the boilers and into the stokehold (see photo 4.2). Pressures are noted and the readiness of the stokehold checked.

If the pressures are equal the engineer will "marry" the boilers. If not he will use steam from the boiler with the higher pressure and "marry" them when equalised.

If light is poor the engineer will start the generating engine, exhausting to atmosphere. Speed of this engine and hence power output must be adjusted to the number of lights being used, however the governor will handle small fluctuations.

Unfortunately this governor was sticking, leading to dim or overbright lights at various times. Tapping the control linkage when stuck freed it.

Meanwhile the greaser will be on the top engine room platform. He draws the wicks through his fingers to clean them of gum and sludge, fills the oil boxes to ¼" below the tube mouth, dips the wicks well and inserts the wicks in the tubes.

He then goes down below and does the same for the main bearing boxes. Grease cups are filled and screwed in until pressure is felt and a little more.

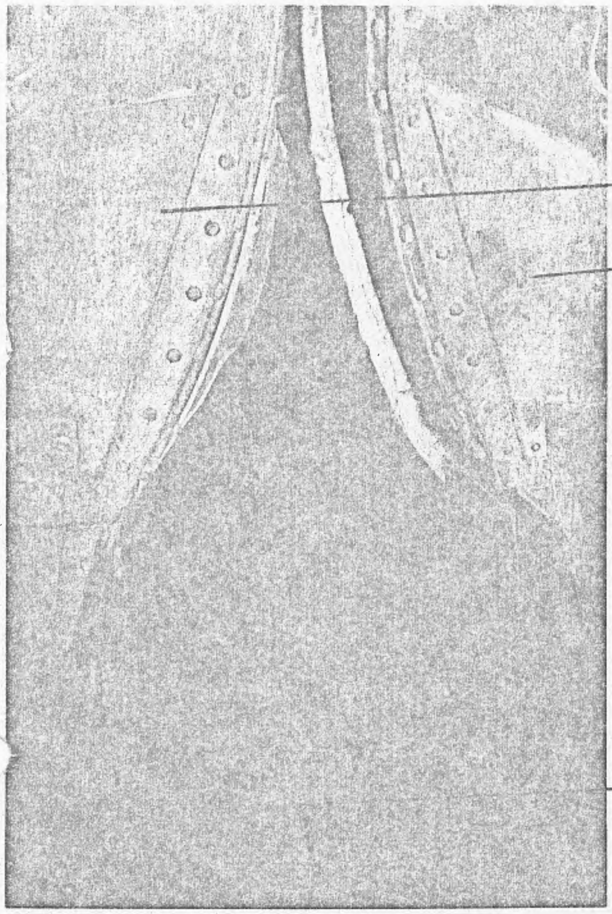
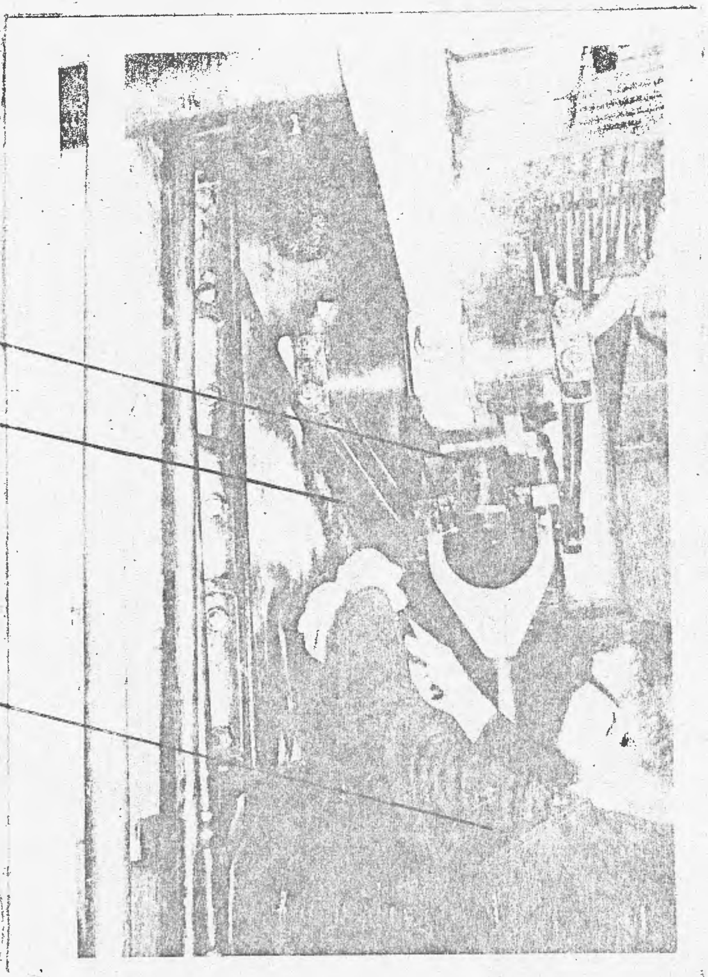



Photo 4.2. Alleyway between boilers,(from stokehold)

Photo 4.3. Swabbing H.P. piston rod with cylinder oil,using long handled brush.



Trays under the eccentrics are filled with water so that the strap is partly immersed. Evaporation then keeps this bearing cool. The same principle follows when the crosshead guide trays are filled with oil and water.

Oil is run on to the crosshead faces, big end and small end bearings cups. The shaft bearings are oiled and the thrust block must be filled with oil, the oil present being checked for quality and quantity. The stern gland grease gun is turned and all piston and valve rods are painted with cylinder oil. (see photo 4.3).

During this time the engineer has set the main feed pump away slowly, drawing from the after peak tank. By opening the supply valve at the after peak tank water is supplied to the general service and feed pump suction valve chests.

The valves on the feed pump discharge chest are set so that feed water is pumped through the filter and heater into the boiler through the main boiler feed check valves.

These check valves are adjusted during boiler feeding so that different amounts of water may be pumped into each boiler as required. For instance, if the port boiler has less water than the starboard boiler, the port boiler check valve will be opened further than the starboard check valve and thus more water is delivered into the port boiler.

During steaming the number of turns open for each check valve are chalked in on small blackboards on the back of the boiler. The check valves are adjusted to control the relative amounts of water entering each boiler.

The engineer now checks that main engine steam drains are open. He will then crack the main steam throttle valve and open the starting valves to the I.P. and L.P. Steam passing through the engine will warm it.

So that the condenser will not overheat now, it must be coded. The 'circ' pump is started away slowly after opening the sea inlet and outlet valves. When getting underway it must be run at high speed as it must not stall. If it did the condenser would soon overheat and start the tube to tubeplate packings leaking.

Now that the condenser is being cooled, the auxiliaries exhaust may be switched from atmosphere into the condenser. This is done by altering one valve on the auxiliaries exhaust main.

Back pressure in the exhaust line is set to about 7 p.s.i. by a valve wheel near the starting platform. This enables auxiliary exhausts to be used in the feed water heater and also allows the engineer to readjust all engine speeds at once when condenser vacuum is brought up.

The steering engine is warmed up and oiled as for the main engine. Steering chains and blocks are oiled.

4/

Photo 4.3.1 Engineer starting main engine.

power reverse lever in ahead

Engineers right hand opening throttle

The main engine is now started. The engineer warms up the power reversing cylinder. Then by moving the valve gear lever between ahead and astern the valve gear is also moved. This also warms up both ends of the cylinders more effectively.

The starting valves are shut and with the valve gear in ahead or astern. The throttle valve is opened until the engine turns, usually stopping when steam in the H.P. is cut off. H.P. drains are shut otherwise the engine room fills up with steam and the engineer cannot breathe.

The valve gear is swung from astern to ahead alternatively and the steam opened on each reversal.
The engine will become warmer and when the H.P. runs over dead centre the engine is run for 3 or 4 revolutions ahead and astern until it starts easily on each reversal. It can then be made to run dead slow astern for several minutes to warm it completely. The bridge is informed of the engine room's readiness, through the voice pipe.

Another duty done now is to start the general service pump filling the day tank - this tank provides a head of water for showers, taps and toilets.

Upon bridge orders ("STANDBY" first) the engine is started with I.P. and L.P. drains open. (see photo 4.3). If the engine should stall after cutoff in the H.P. the starting valves to the I.P. and L.P. can be opened, pressure in these valve chests starting those cylinders. They are then shut.

This has not been necessary so far as the engine is positioned for an easy start.

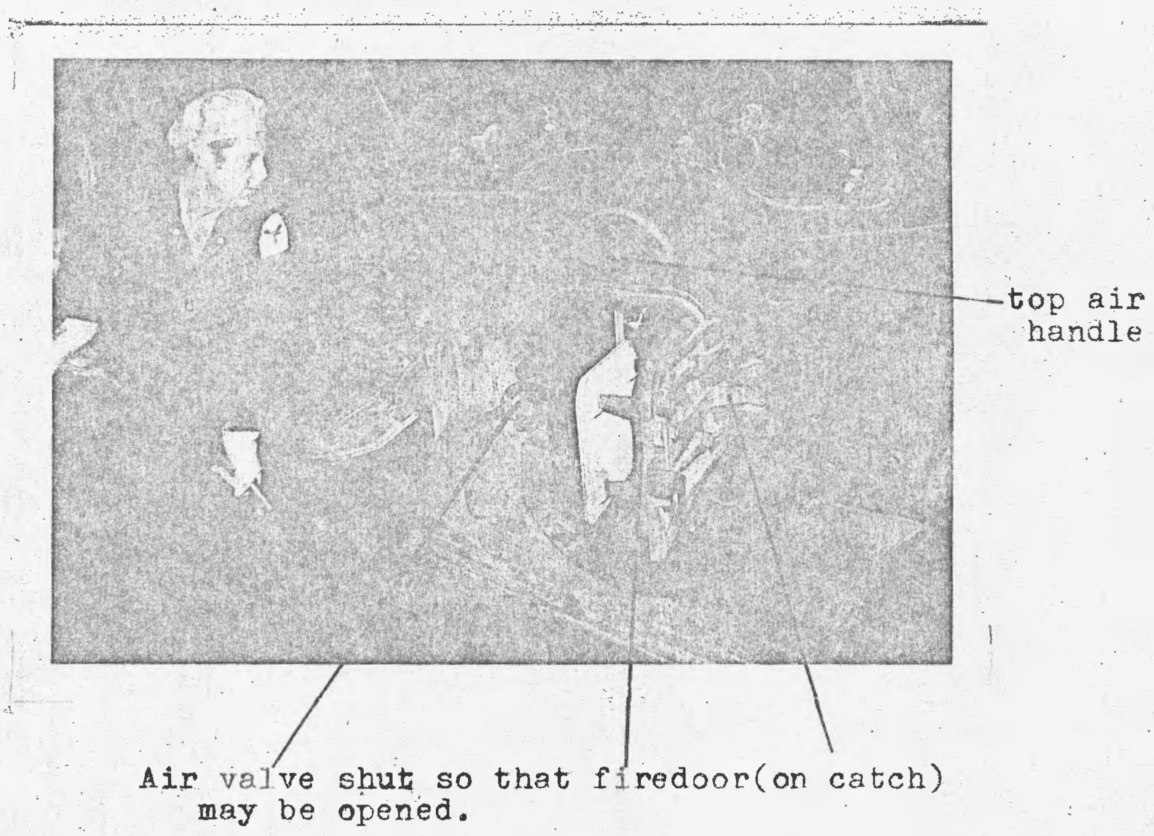
Drains are then shut and the engine brought up to speed. Back pressure in the auxiliaries exhaust is reset and the 'circ' pump slowed so that condenser vacuum is just maintained at about 22 inches Hg.

Exhaust steam from the auxiliaries is then run into the feed water heater - this is adjusted for water level by the drain valve. The feed pump is set to speed and the hotwell level float connected to the throttle valve on the feed pump.

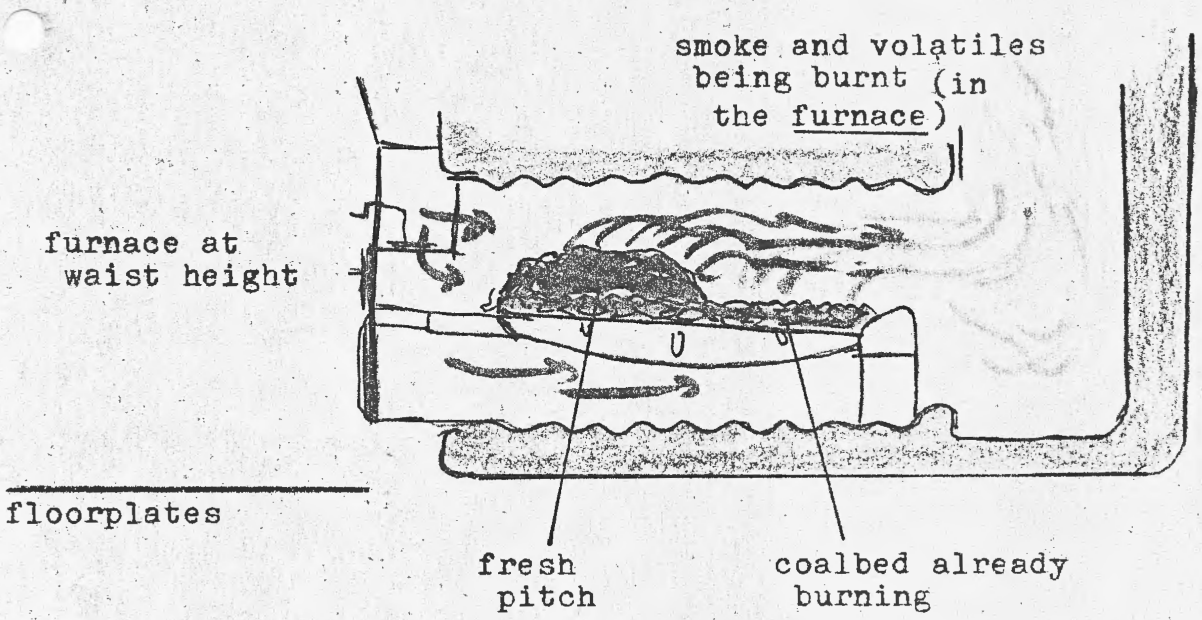
Steam to the feed water heater is opened wide and the drain to hotwell adjusted so that half a glass is showing.

The tug is now underway.

Photo 4.4. "Pitching" coal.(under forced draught)




Sketch 4.4. "Pitching" and the
"Coking" method.



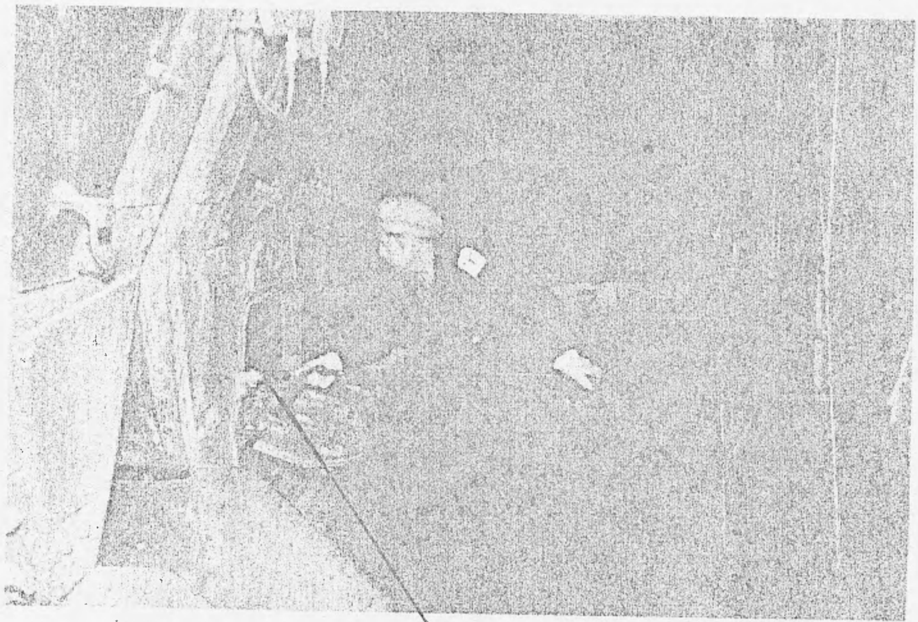
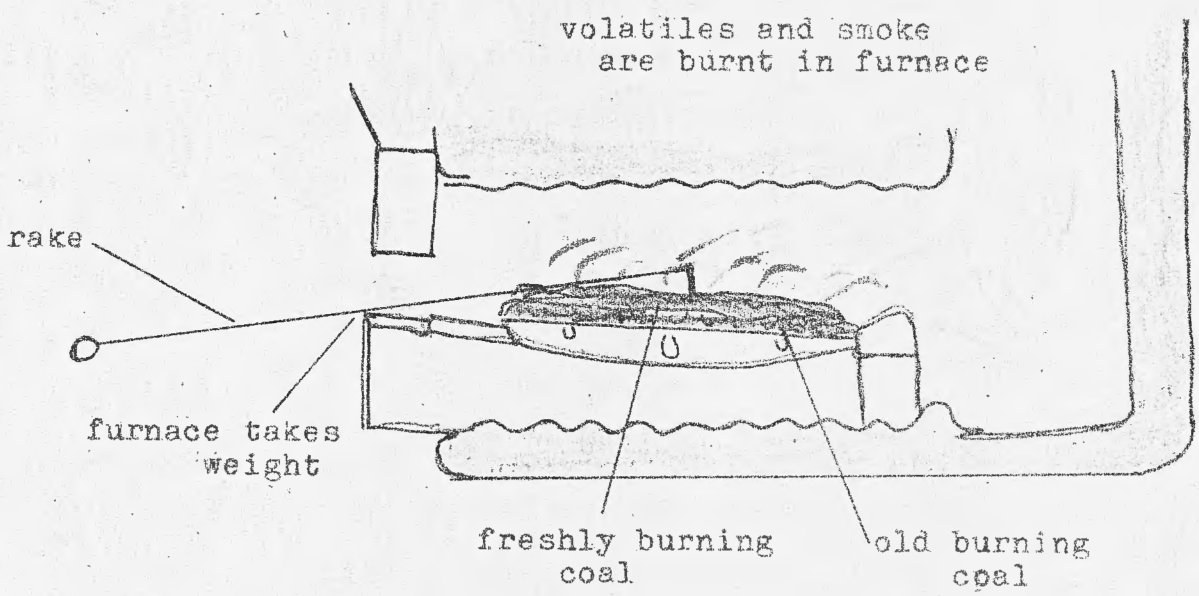



Photo 4.5. Using the rake.

Sketch 4.5. Raking back burning coal.



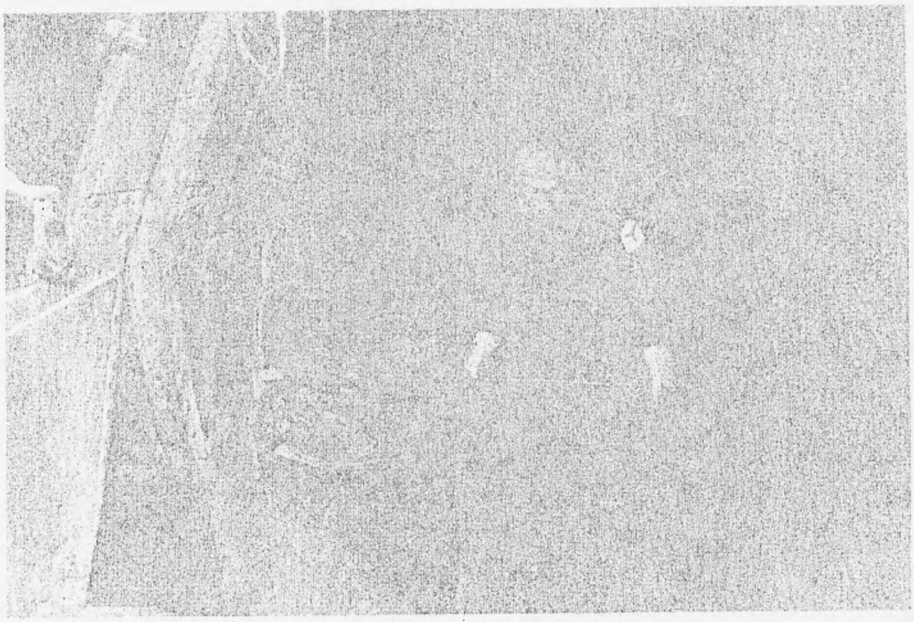
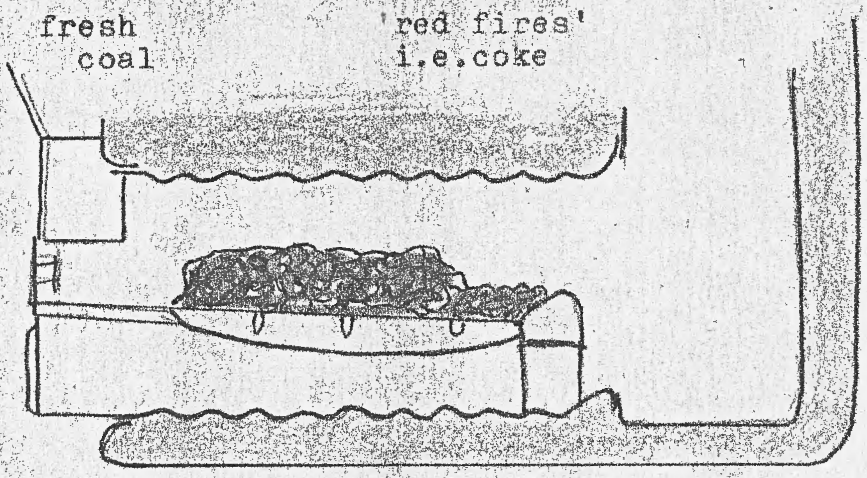


Photo 4.6. Rake passed along grate to drop ash.

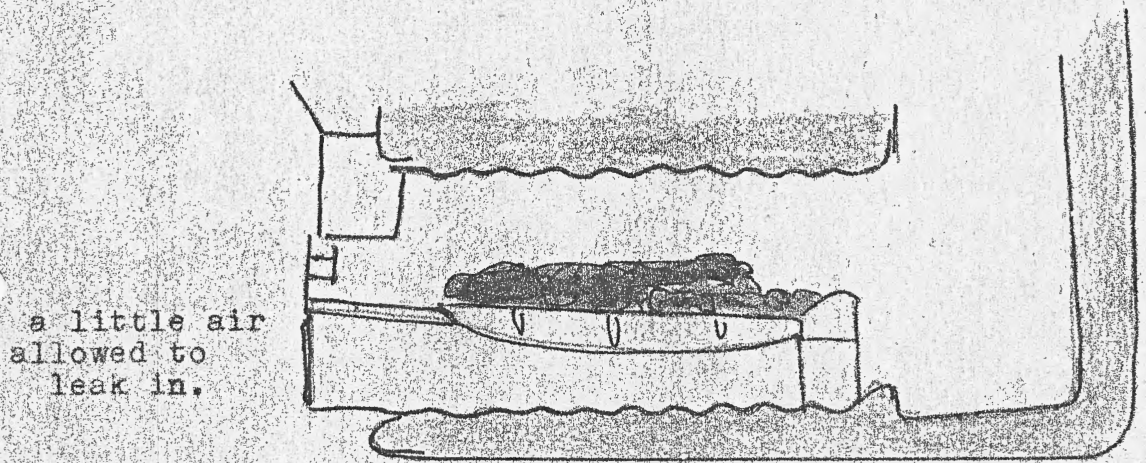
Sketch 4.6. Shape of firebed.(front c.s.)

raised at edges

heaped slightly
in centre




Sketch 4.7. 12 hour bank and 1 hour bank compared.



Ash piling up in the ashpits decreases air supply to the grate. If allowed to rise too high it will cut off air to the fires: as this air also cools the firebars these will overheat, burn, sag and fall into the ashpit. The resulting hole in the fire makes firing difficult and new bars are difficult to fit even when cold.

Therefore ash must be removed. This is done by turning off bottom air opening the ashpit door, pulling out the ash (rake) and returning the furnace to operation. The ash when cool is shovelled into sacks and dumped at sea or on land.

Some coals will fuse into clumps and these must be broken up with irons.

Some coals also have ash that fuses into lumps called "clinker". As these will not fit between the firebars, they must be pulled out through the furnace mouth.

To clean the fires the burning coal but not the ash and clinker is pushed back. The ash and clinker is then raked out through the furnace mouth. The coal is then spread over the grate and the fire rebuilt.

Firemen generally need about half an hours notice before an impending change in operation. If a stop is imminent they will halt pitching and let steam be used up. Shut downs will mean that the fires must be dropped into the ashpit or raked out and quenched. Temporary stops are handled with thin, low fires and the fan engine slowed.

Stops over half an hour will require banked fires, the degree of banking depending on departure time. (see sketch 4.7). With steam up and banked fires, full fires can be built up in less than half an hour.

In contrast, work in the engine room is much easier and cleaner.

The engineer and greaser when they know their plant can set it up so that it will almost run itself.

However the work required is as followed.

Boiler water level maintenance is paramount. Feed checks are regulated to equalise water contents in both boilers and the level set to just below half a glass.

If water level drops below the tops of the combustion chamber, these will not be cooled. They will soon overheat and collapse down, the resulting explosion killing the stokehold crew and disabling the ship. This will start to happen when the water level falls 3 to 6 inches below the gauge glass.

Water levels too high decrease the exposed water surface in the boiler and decrease oxygen liberation from boiler water.

Therefore the engineer trys to keep water levels equal at just under half a glass in both boilers.

3/

Photo 4.7. Blackboard near feed pump.

blackboard

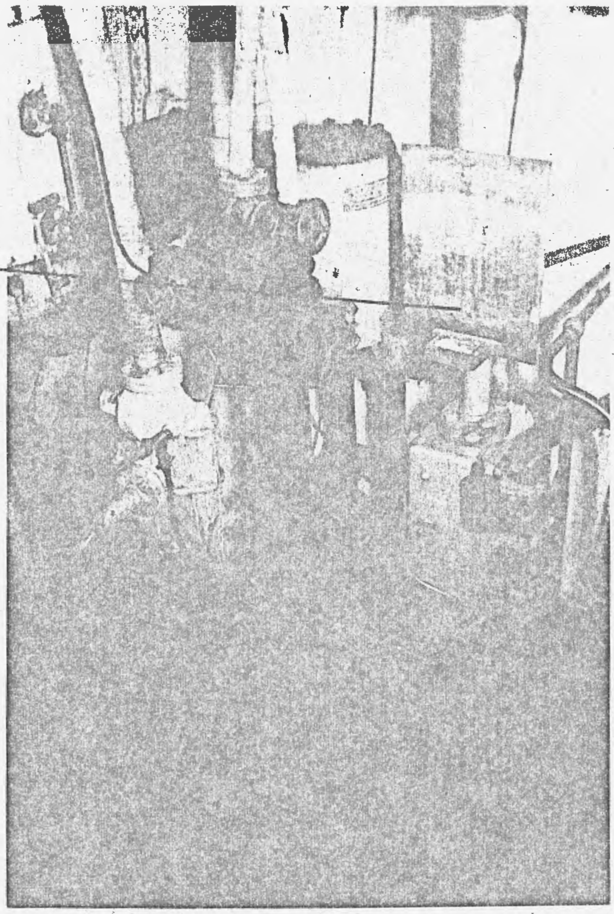
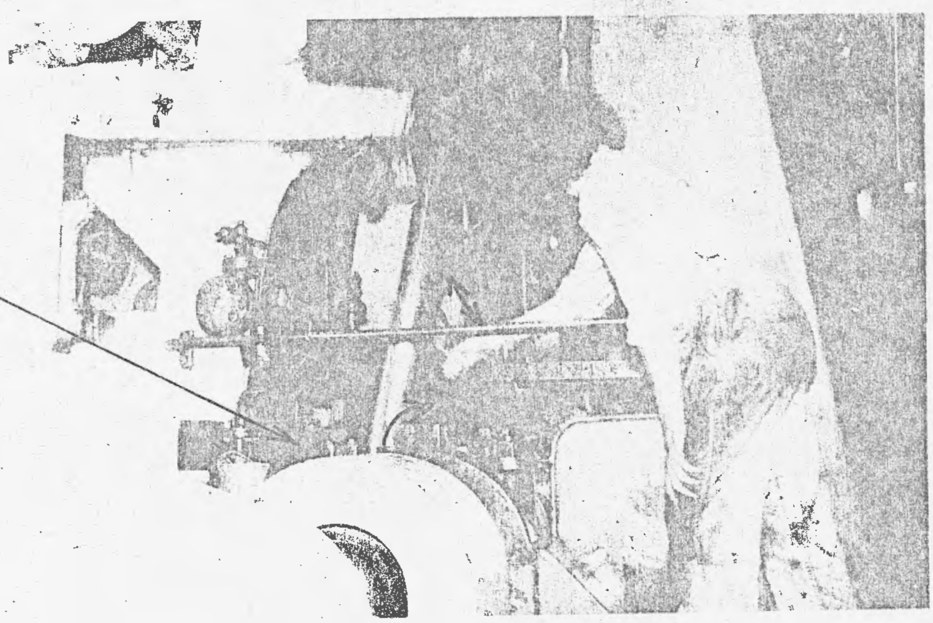


Photo 4.8. Feeling temperature of L.P. big end as it comes over T.D.C.

big end



Speed of the feed pump is controlled by the level of water in the hotwell. Low hotwell levels mean that the boilers have high levels and the hotwell float control slows the feed pump. If more steam is used boiler water level falls., the steam is condensed and pumped into the hotwell; the float control then speeds up the feed pump replenishing the lost boiler water.

But steam and water leakage lead to a general loss of water in the system. This is made up by opening a small pipe line between the condenser and the feed water line. Condenser vacuum pulls water into the condenser. It then mixes with condensate and is pumped into the boilers.

Other ways to replenish lost boiler water are to use the main feed pump or general service pump drawing from the fresh water line.

When make up feed is on, this fact is chalked in on the small blackboard near the feed pump (see photo 4.7). Other pieces of relevant information such as hot bearings are also written down here to remind the engineer on duty, and, to inform the next engineer on duty.

Every 20 minutes the engineer must "feel around". He starts at the H.P. valve gear and with his hand, touches all bearings in order to feel their temperature. Cool bearings will not be unpleasantly hot to the touch. He then works aft through the engine touching all stationary and moving bearings. He knows that the H.P. will run hotter owing to the presence of hotter steam there.

Valve gear and main bearings are easy to feel having little or no movement. But the big ends must be touched and followed as they move over top dead centre. (see photo 4.8). As they come over, the edge of the hand is brought down into the recess between the crank and the big end. This is the only sure way to feel the actual bearing brass.

At 96 revolutions this is difficult to do and the engineer may miss completely, succeed or receive a hard knock.

The crossheads and top end bearings are also felt as they reciprocate. The engineer stands inside the moving engine on a small grating. He must catch the bearing as it comes up and allow it to take his hand.

Only the ahead crosshead and guide need be felt, there being no pressure on the astern crosshead. The guides here are felt at the edges. During towing they can be cooled by water from the 'circ' pump.

As these bearings can move at 10 feet per second at full revolutions mistakes can lead to injury.

The thrust block is then felt all around, and its oil checked for quantity and quality. During towing the thrust block can also be cooled by water from the 'circ' pump, but during cruising this is not necessary.

The shaft plummer blocks are also felt for excessive temperature.

Hot or warm bearings can be cooled by increasing their oil supply. If seizure is imminent oil must be poured through and on approval from the bridge the engine may be slowed until the bearing cools. The engine can then be stopped and the trouble located and remedied.

If the bearing is near to seizure and the engine is stopped, the bearing may weld to the shaft.

Bearings can overheat through insufficient clearance ("tight") or through misalignment. A tight bearing can be shimmed to correct clearance, but realignment is a major job.

On "FORCEFUL", the H.P. top end was running warm, probably due to the unusual trim of the ship that day. It was kept cool by over oiling.

The I,P. valve rod guide also ran hot as its grease cup could not be operated. This was freed and the guide could be greased.

About every 20 to 30 minutes the greaser goes around and oils the main and auxiliary engines. Starting from the top engine room platform, oil boxes are refilled and wicks are dipped and reinserted. Oil may be poured directly down the tubes for a few seconds to augment oil supply to the crossheads, top and bottom ends.

Alternative ways to supply additional oil to these bearings are to catch the oil boxes as they move and give as much oil as is possible in 3 revolutions. Oil may alao be squirted on to oil supply tubes. From here it will drip into moving oil boxes. These methods are done in the engine room below.

Before returning below, the greaser oils the steering engine and paints cylinder oil on its piston and valve rods.

Down below the greaser refills the main bearing boxes and dips the wicks there. All grease cups are turned on until some pressure is felt.

Water in the eccentric strap cooling trays is replenished and the water/oil emulsion in the crosshead guide trays checked. It must be like cream. If it is too thick water is squirted in. If too watery, oil is squirted in. When running ahead, only the ahead guide emulsion requires maintenance.

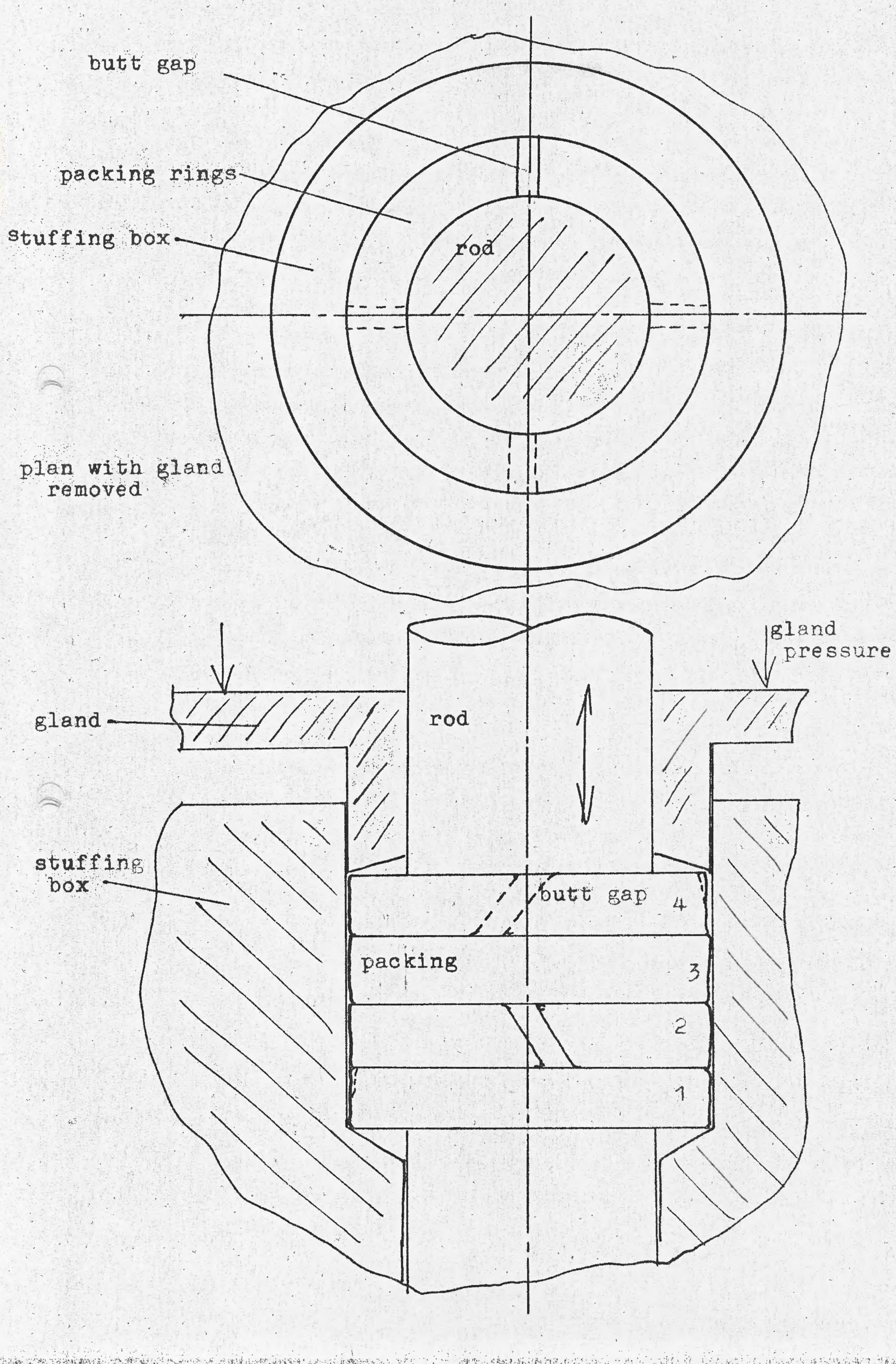
Piston and valve rods are swabbed with cylinder oil if they are dry. If they appear blue and are lacking a wet oily film, they are dry and overheating. If serious, this condition is called "hot rods". They must be swabbed with cylinder oil but if overheating still occurs, the gland may be slackened.

Bent or misaligned piston rods will also lead to "hot rods".

The auxiliaries must also be oiled and lubricators must be turned.

Leaky glands are tightened but not overly so. Excessive pressure in glands will cause the moving rod to become hot, scored and worn. 5/

Sketch 4.8. Stuffing box and gland.



Glands are tightened a little bit more than "finger tight". If leakage persists either the packing has hardened and requires replacement or misalignment has occurred.

To replace packing the machinery must be stopped, the gland dismantled and the old packing pulled out with wire "corkscrews" called packing extractors. New packing is cut in rings equal to the circumference of the rod minus a small butt clearance. (see sketch 4.8). Enough rings and graphite grease to fill the stuffing box are inserted with the butts set out of line to each other.(see sketch 4.8). The gland is then tightened just over finger tight and the machinery started. The gland may then be adjusted until slight leakage is observed.

As the bilges are pumped by the main engine, all that needs doing here is to check that the pumps are working. Bilges fill from leaks in glands, condensation and drains.

When not underway the bilges, if full, must be pumped by the general service pump.

The engineer keeps an ear on his plant. He should know all noises and why they occur. New noises must be located and remedied if necessary. "FORCEFUL'S" main engine had developed a slight knock and this appeared to come from the I.P. piston valve. It was not serious but if it worsened, it would have to be opened for inspection.

During manoeuvres the engine can be started, reversed and stopped with the drain cocks shut. But if the engine is stopped for more than a few minutes, the L.P. drains then the I.P. must be opened to let condensed water out.

For largertemporary stops the H.P. drains are also opened, the 'circ' and feed pumps are slowed and steam to the feed heater reduced.

Telegraph orders may vary from what actually is on the face. "FULL ASTERN" means high revolutions but no overstrain is imposed. But "FULL ASTERN" rung twice is ordering a crash stop and the engine is run at maximum revolutions with the throttle open wide. As the propeller draws air down when running astern, its efficiency is decreased and the main engine will turn at very high revolutions, with consequent increase in inertial loads.

During rough weather the propellor may be exposed by wave troughs. The engine will race, and the engineer must close the throttle to hold back revolutions.

When the telegraph order "FINISHED WITH ENGINES" is rung, the plant is shut down.

The main engine has been stopped with the throttle shut tight.

6/

## 4.2 ENGINEERING UNDERWAY

Drains are opened and the 'circ' pump and sea injection valves are shut. Auxiliary exhausts are switched to atmosphere. The boilers are pumped up to about $\frac{3}{4}$ of a glass with water from the aft peak tank.

Bilges may need to be pumped by the general service pump.

All water tank lines are shut and all oil wicks are removed from oil tubes.

The generating engine is shut down and the gauge glass cocks are shut. This is done so that if gauge glass breakage occurs, water will not be lost from the boiler.

The steam valves on top of the boilers are shut tight and the ship may then be locked up.

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