WAR SHIPPING ADMINISTRATION
TRAINING ORGANIZATION

UNITED STATES MARITIME SERVICE TRAINING MANUAL

ENGINEERING BRANCH TRAINING

TABLE OF CONTENTS

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BABCOCK AND WILCOX COMPANY	PAGES 30, 32
COMBUSTION ENGINEERING COMPANY	PAGE 36
BAILEY METER COMPANY	PAGE 37
THE HAYS CORPORATION	PAGE 39
TODD SHIPYARDS CORPORATION	PAGES 50, 51
UNITED STATES METALLIC PACKING COMPANY	PAGE 62
KINGSBURY MACHINE WORKS	PAGE 72
GENERAL ELECTRIC COMPANY	PAGE 81
WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY	PAGE 83
AMERICAN HOIST AND DERRICK COMPANY	PAGE 103
AMERICAN ENGINEERING COMPANY	PAGE 106

ALL OTHERS UNITED STATES MARITIME COMMISSION PHOTOS

GENERAL NEEDS OF SHIP'S PLANTS

The first sight of a ship's power plant in operation is apt to be a fascinating spectacle of large whirling cranks; gleaming piston rods, sliding in and out of huge lofty cylinders, and of roaring fires in the furnaces. The maze of pipe lines and smaller machinery gives the impression of a complicated assembly requiring much time to understand. Nothing could be further from the truth, for the principles of operation are simple if followed step by step. In this manual the story of the ship's power plant unfolds in simple language.

The safety of the ship is dependent to a considerable degree on you Firemen, Watertenders and Oilers, for one of the most important needs of a ship's power plant is a well trained and competent engine room crew. The best machinery is no better than the men who operate it and care for it.

The members of the Engine Department with brief mention of their duties are listed according to their rank and authority.

LICENSED OFFICERS

Chief Engineer-In charge of and responsible for all of the machinery aboard ship.

First Assistant Engineer-In charge of maintaining machinery in fireroom and engine room. Stands 4-8 watch.

Second Assistant Engineer-Responsible for fuel oil, fresh water and care of the boilers. Stands 12-4 watch.

Third Assistant Engineer-Maintains electrical equipment and auxiliaries under direction of the first assistant. Stands 8-12 watch.

Junior Engineer- (May or may not be licensed.) Stands engine room or fireroom watch under regular watch engineer on larger ships.

UNLICENSED QUALIFIED MEMBERS OF THE CREW

Deck Engineer-Keeps in repair all deck machinery, such as cargo winches, anchor windlass, etc. Works day work.

Oiler-Oils the bearings of the main engine and auxiliaries. Stands watch in engine room.

Watertender-Maintains proper water level in boilers and has charge of firemen. Stands watch in fireroom.

Fireman-Operates oil burning system to generate steam in boilers and on small and medium sized vessels also acts as watertender. Stands watch in fireroom.

UNLICENSED AND UNQUALIFIED MEMBER OF THE CREW

Wiper-Performs manual labor in engine department, such as cleaning and painting and assists in repair work. Works day work.

UNLICENSED MEMBERS CARRIED ON SOME VESSELS IN ADDITION TO ABOVE

Machinist-Performs necessary machine repair work. Works day work.

Refrigerating Engineer-Operates and maintains refrigeration systems on refrigerator vessels.

Electrician-Carried on vessels which have considerable electrical equipment.

Pumpman-Always carried on tanker vessels. Operates and maintains cargo pumps and valves.

Storekeeper-Keeps check on supplies and spare parts on large vessels.

The importance of the duties of each member of the crew cannot be overemphasized.

Should the fireman through neglect or ignorance allow the water level in the boilers to drop below the lowest safe point, serious damage may occur with resultant loss of use of the boilers and stoppage of the ship's engine.

Likewise, should the oiler burn up a bearing on the engine, the engine may have to be stopped for repairs.

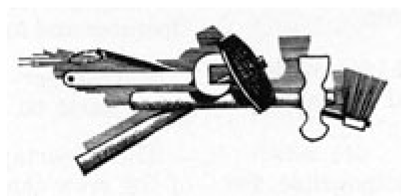
These events are serious in that the stopped vessel would have to drop out of convoy making it easy prey for attack. A smoking stack may give away your position to the enemy and bring on attack.

It is therefore evident that these duties must be carried out by men who know their business. No one in training can afford to waste a single moment of the time, for your life may depend on what you know. Close attention should be paid to all lectures and practical work. The manual should be thoroughly read and understood and kept with you for reference when you go aboard ship.

The prompt execution of orders is an absolute necessity for safety of the vessel and crew. Delay in the closing or opening of a valve for example can result in serious damage.

MACHINERY AND EQUIPMENT

To propel the ship through the water a propeller is used at the stern. It must have an engine, either steam or internal combustion to turn it. Various smaller machines are necessary for the operation of the main engine. If a steam engine is used, boilers will be required to furnish the steam for the engine. Fuel and a place to store a sufficient amount for a long journey is also required. Tools and spare parts for the various machinery must be aboard. Sufficient fresh water for the crew and plant's needs and a place to store it is necessary. It must be remembered that a ship is a virtual floating city which must be able to maintain itself and effect necessary repairs independent of any outside help for considerable periods of time.



THE SUN IS THE SOURCE OF ALL ENERGY

FUNDAMENTALS OF ENGINEERING

EXPLANATION OF HEAT

In operating the ship's power plant you will constantly be working with heat, in making it by burning coal or oil and in tending the engines wherein the heat made is turned into work. So it is important that the following simple facts and habits of heat be understood.

Heat is the source of all energy. Going further we find that energy is the ability to do work. Therefore all engines are heat engines because heat must be supplied before energy can be produced to turn the engine so that it can do useful work, such as turning the propeller of a ship.

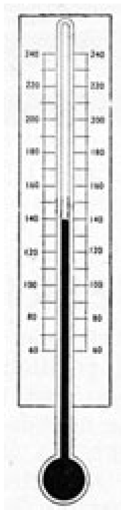
The heat may be produced by burning fuel such as coal or oil. The larger and hotter the fire the more energy produced and the more work accomplished. To control the power of the engine we regulate the amount of fuel being burned. The burning of fuel is known as combustion.

Internal Combustion-In an internal combustion engine such as the gasoline or diesel engine the fuel in the form of light oil is burned directly inside the cylinder of the engine. The energy derived from the heat of the burning oil pushes the piston downward and through a mechanical hook-up revolves the crankshaft which in turn spins the propeller. This method of supplying heat to the engine is known as internal combustion.

External Combustion-In steam engines the heat is developed by the burning of the fuel in a boiler, separate from the engine.

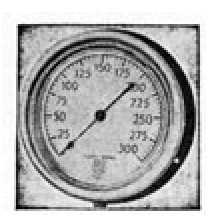
principle, assume that the boiler is like a steel barrel in a horizontal position. Fuel is burned just below the boiler and the heat given off radiates against the outside of the boiler, and is conducted through the steel walls into the water. The heat then circulates throughout the boiler by convection currents until such time as the water has absorbed so much of the heat that it begins to boil and a vapor called steam is given off. Some of the heat from the fire is now in the steam, which is led to the cylinder of the engine through a pipe line. The heat in the steam produces in the cylinder the energy that pushes the piston downward and through a mechanical hook-up revolves the crankshaft in the same manner as the internal combustion engine. This method of supplying heat is known as external combustion.

Temperature-The degree of heat is called temperature and is the number of degrees Fahrenheit of the steam or other substance considered. Fahrenheit is a graduated temperature scale widely used in this country. It is measured by a thermometer. The thermometer consists of a small glass tube one end of which opens into a glass bulb filled with mercury. If the bulb is placed in hot water or steam the mercury becomes heated and expands upward in the glass tube. The hotter the water or steam the higher the column of mercury will go, so that by reading the degree graduation on the frame along the mercury column, the temperature of the water or steam can be measured. Thermometers are located at various points in the fireroom and engine room and one of the duties of the firemen, watertenders The boiler is a closed steel vessel partially filled with water. To illustrate the and oilers is to interpret the meaning of the readings several times a watch. For high temperatures, such as the fire box of a boiler or smokestack, a pyrometer is used. A pyrometer works on the principle of expanding metal pushing against a hand on a recording dial.



FAHRENHEIT THERMOMETER

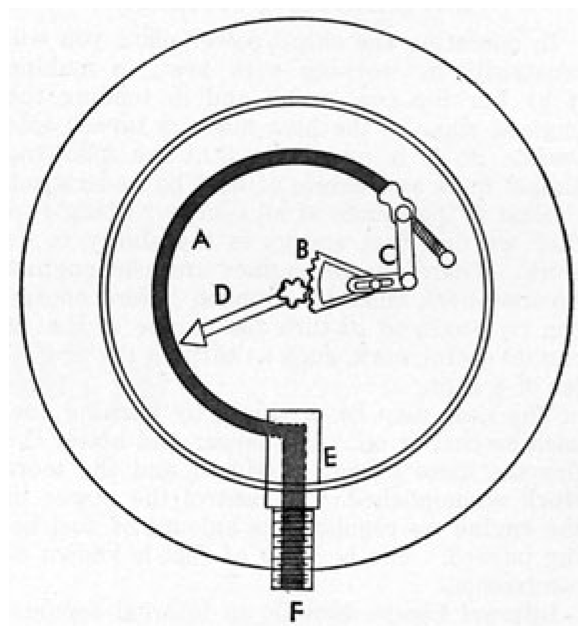
Pressure-When dealing with the temperature of steam we must consider pressure, for when the temperature of steam increases or decreases so does the pressure. Pressure is a force of energy and is recorded in pounds per square inch. If a boiler is said to have a pressure of 200 pounds it means that a force of 200 pounds is pushing outward on every square inch of the inside boiler surface. Pressure is exerted equally in all directions throughout the steam and water spaces of the boiler. The pressure of a boiler is determined by the steam pressure gage.



PRESSURE GAGE

Steam pressures are usually measured by an instrument known as the Bourdon pressure gage, which consists of one or two brass tubes bent into an elliptical shape. A single tube Bourdon pressure gage is shown.

This consists of a single curved brass tube (A), one end of which is secured to the base of the casing (E), the other end being free to move. When pressure is admitted into the tube through connection (F), it tends to straighten out, causing the free end to move. This movement pulls on the lever (C), which turns the geared quadrant (B), through an arc of a circle. The quadrant meshes with a pinion on the pointer shaft, and moves the pointer (D) over a graduated scale showing the pressure acting in the tube. The greater the pressure the more the tube will straighten out, causing the pointer to indicate to a higher pressure reading on the graduated scale. The fireman reads the pressure in front of the pointer.



BOURDON PRESSURE GAGE

Atmospheric Pressure-That pressure normally existing in the air. It is all around us pressing upon our bodies. At sea level, atmospheric pressure is 14.7 pounds per square inch, and is created by the weight of a column of air one inch square resting upon the earth. On the top of a high mountain the atmospheric pressure would be less, due to the column of air being shorter.

Gage Pressure-The pressure registered on a pressure gage is above atmospheric pressure. For example if the gage pointer points to 10 pounds, the pressure in the boiler is 10 pounds greater than the atmospheric pressure, and is the kind of pressure always spoken of aboard ship.

Absolute Pressure-Gage pressure plus atmospheric pressure. In the above example if we add the gage pressure of 10 pounds to atmospheric pressure 14.7 pounds, we get 24.7 pounds absolute pressure in the boiler. This kind of pressure is rarely referred to aboard ship.

Vacuum-When atmospheric pressure is removed from a closed vessel, such as a steel tank, a vacuum is left. The more atmospheric pressure removed, the greater the vacuum. A perfect vacuum is attained only when all atmospheric pressure is exhausted, and is practically impossible to achieve. The amount of vacuum is registered on the vacuum gage which operates on the same principle as a pressure gage except that the face is graduated in inches instead of pounds. Each two inches of graduation being equal to one pound absolute pressure, 29 inches of vacuum would be a nearly perfect vacuum.

British Thermal Unit-"B. T. U."-Heat has a unit of measure just as liquids are measured by quarts or gallons. The heat unit known as the British Thermal Unit or "B. T. U." is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. It is also equal to 778 foot pounds of work. Different kinds of fuel do not contain the same amount of heat. For instance, a pound of coal may contain 14,000 "B. T. U.s" while a pound of oil contains 19,000 "B. T. U.s". A pound of oil then will make more steam than a pound of coal. This is one of the reasons why fuel oil is burned in nearly all American marine boilers today. A lesser weight of fuel oil will be required for a voyage than coal, making more room for cargo.

Boiling Temperature of Water-The temperature at which water will boil depends upon the pressure resting upon the surface of the water. At sea level with 14.7 pounds per square inch atmospheric pressure against the surface of the water, it will boil at 212° F., but if we were on top of the mountain it would boil at a lower temperature, perhaps 180° F. If we place the surface of the water under a greater pressure than atmospheric, a higher temperature will be required before the water will boil and give off steam. As an example: A boiler containing a pressure of 450 pounds per square inch would require a temperature of approximately 460° F. before the water would boil.

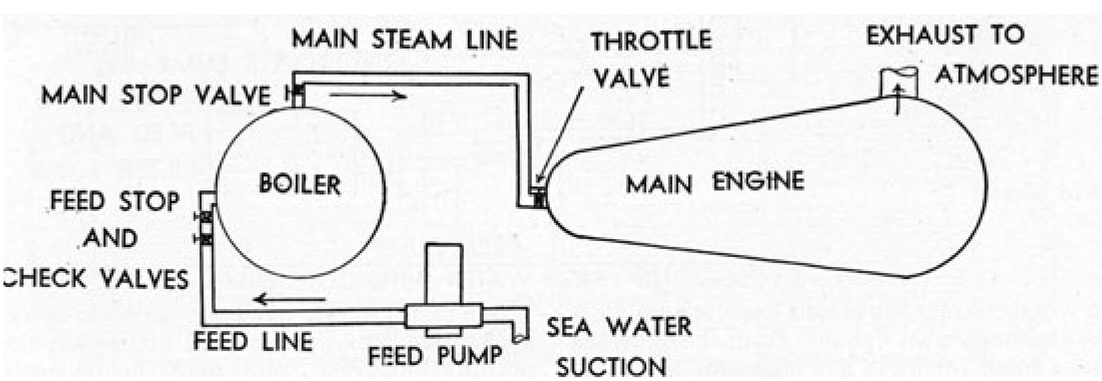
Saturated Steam-Steam that is in direct contact with and has the same temperature as the water from which it was formed. It is steam which at a given temperature always has a given pressure. Saturated steam can be either wet (moisture particles in it) or dry (containing no moisture).

Superheated Steam-Saturated steam that has been passed through a superheater which increases its temperature but not its pressure. This steam contains more heat than saturated steam and therefore can do more work. It contains no moisture particles and is used in modern reciprocating and turbine engines.

THE STEAM AND WATER CYCLE

The flow of the steam and water through the various pieces of machinery that make up the main engine power plant is known as the steam and water cycle.

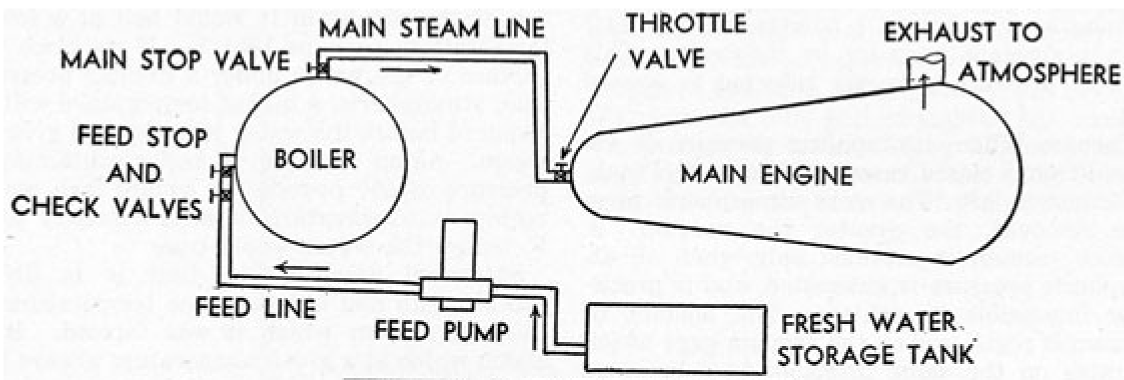
The operation of a steam power plant depends upon water for conversion into steam by applying heat. A simple method would be to assume,



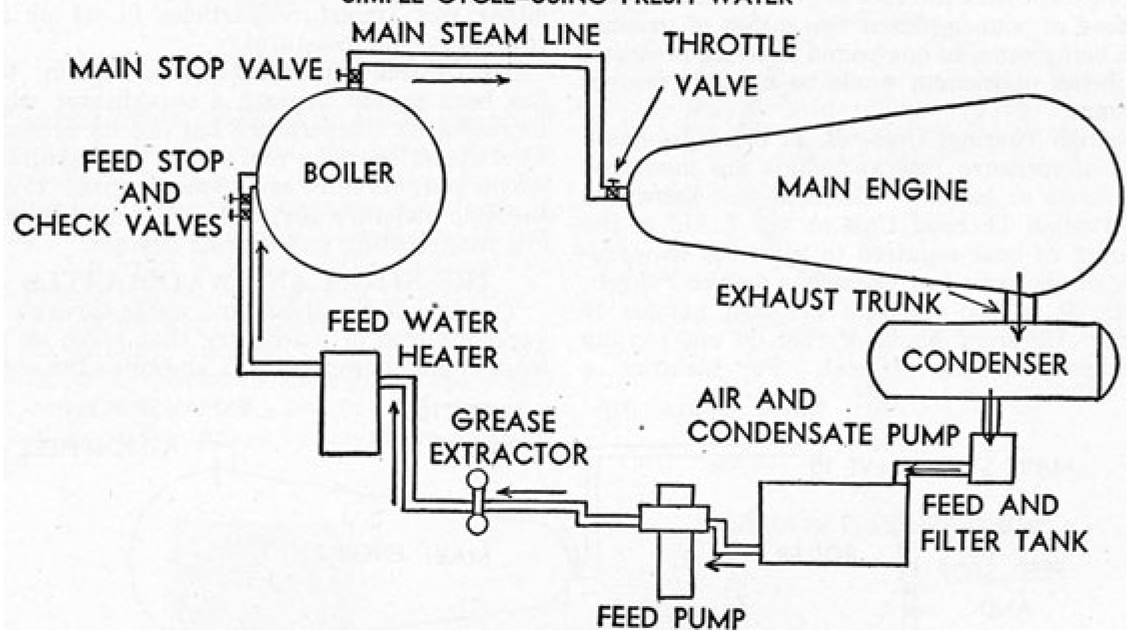
SIMPLE CYCLE-USING SEA WATER

in the first figure, that the boiler is filled with sea water to its proper level. As the fuel burns beneath the boiler, the water inside is heated until it boils and gives off steam which accumulates in the upper part of the boiler. The steam leaves the boiler at the top through the main stop valve and then flows through the main steam line to the throttle valve on the engine. When the throttle valve is opened the steam flows into the cylinders of the engine, causing it to do work. When the steam has done its work in the engine it must exhaust from the cylinders to make room for more live steam to enter. In this particular cycle the steam exhausts to the atmosphere and is lost. As the water in the boiler is changed into steam, it must be replaced or the boiler will run dry. This is done by means of a feed pump, which is a mechanical device having the ability to force water into the boiler against the boiler pressure. In this particular cycle the pump takes its suction from the water surrounding the ship. This would not do for ocean-going power plants due to the impurities in sea water which would damage the boiler. Where this cycle can be used, it has the advantage of requiring a minimum amount of machinery.

In the next figure, it can be seen that a fresh water storage tank has been added to the cycle. With this hook-up the feed pump is pumping nothing but fresh water into the boiler to replace the water being boiled away. This cycle is an improvement over the first, however, it has certain disadvantages which make it unfit for ocean-going vessels. As fresh water is being continually pumped into the boiler, an

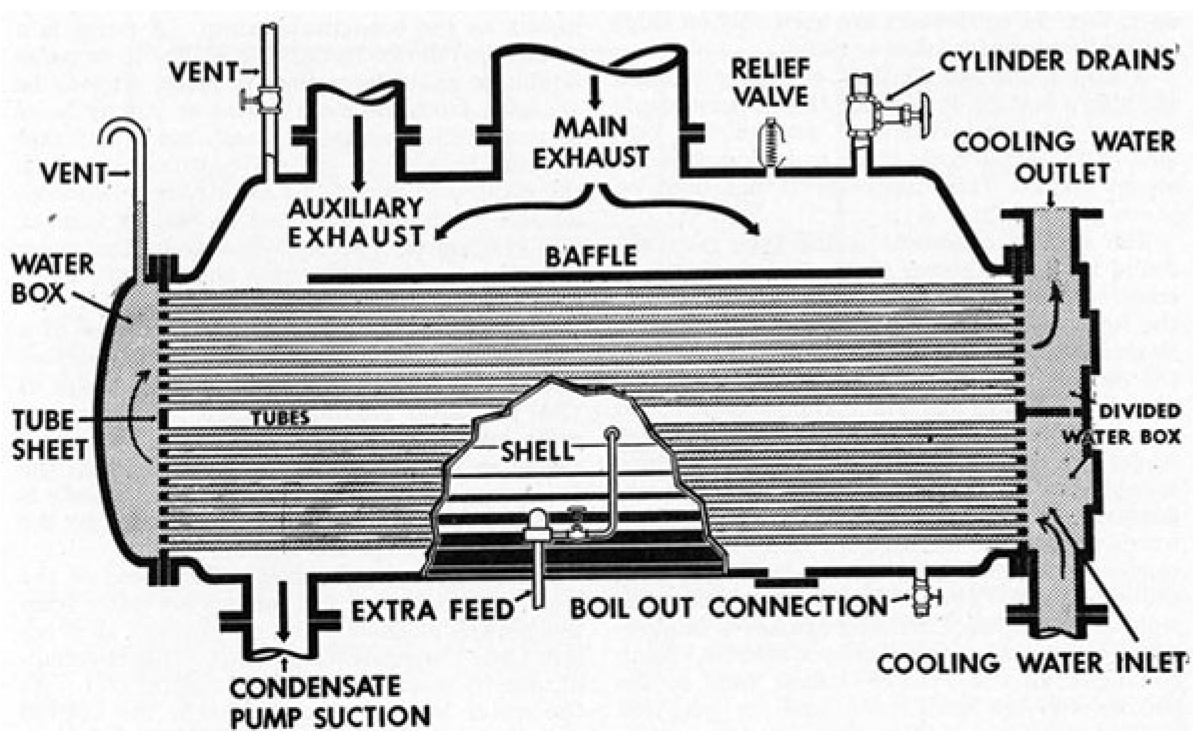


SIMPLE CYCLE–USING FRESH WATER



SIMPLE CYCLE-USING FRESH WATER WITH CONDENSER enormous supply of fresh water would be required aboard the ship when starting on a long journey. Otherwise, it would be necessary to make fresh water from sea water, which is a very costly process and usually only resorted to in an emergency. Also, raw fresh water contains various solids in varying degree which accumulate in the boiler when the water is boiled off, and in time will harm the boiler unless carefully treated and cleaned. Small craft, such as Harbor Towboats, quite often use this type of system because they never venture far from shore and can refill their fresh water storage tanks at frequent intervals.

The third figure is the steam and water cycle actually found aboard ocean-going vessels. The steam is produced from fresh water and flows to the main engine in the same manner. When the steam exhausts from the engine, however, it enters a condenser, where the exhaust steam is condensed back into fresh water. This fresh water is known as condensate and is removed from the condenser along with any air present, by the air and condensate pump. This pump then discharges the condensate into the feed and filter tank, where any lubricating oil which may have entered the condensate through lubrication of the main engine is removed, as far as possible. This tank also serves as a small storage tank for the feed pump. The feed pump takes the condensate (now known as feedwater) from the feed and filter tank and discharges it through a grease extractor, and a feedwater heater back into the boiler. The purpose of the grease extractor is to remove any oil from the feedwater which may have succeeded in passing through the filter tank. It is extremely important, as will be pointed out later, that no oil be allowed to enter the boiler. The feedwater heater increases the temperature of the water entering the boiler considerably, thereby effecting a considerable saving in fuel. It will also be noted that the feedwater passes through a feed check valve and feed stop valve just before entering the boiler. The check valve is a one-way valve allowing the feedwater to enter the boiler, but preventing its return. It also regulates the amount of water entering the boiler. It can be seen that with this system, the fresh water leaving the boiler in the form of steam returns in the form of water after the heat in the steam has done its work in the engine. If there were no loss of water from the system, it would never be necessary to add any raw fresh water, but in actual practice there is always some loss due to leaks, etc. It is, therefore, necessary from



SURFACE CONDENSER

time to time to add fresh water from the ship's storage tanks. One great advantage of this cycle is, of course, the ability to use the same water over and over, effecting an enormous saving of fresh water. Another advantage is that the condensate is practically the same as distilled water and contains no solids to harm the boiler. The heat in the exhaust steam, which was lost entirely in the other cycles due to the engine exhausting into the atmosphere, is in small part returned to the boiler with the condensate. The disadvantage of this system is that it requires more machinery than those where the engine exhausted to the atmosphere, but the great saving in fresh water and considerable saving in fuel and more trouble-free boiler operation far outweighs the cost of the additional equipment.

CONTINUATION OF CYCLE

Condenser-The condenser was included in the cycle for the purpose of changing the steam, exhausting from the engine, back into water. There are three types of condensers: jet, keel and surface.

In jet condensers fresh water is sprayed into the exhaust steam, thereby condensing it. As fresh water must be plentiful for this kind of operation, jet condensers are used only on ships sailing fresh water lakes or rivers.

A keel condenser consists of piping beneath the ship's bottom, into which the exhaust steam passes. The water flowing around the outside of the pipes cools them and condenses the steam inside. This condenser is not used on ocean-going ships.

The surface condenser is the type generally found in marine power plants and is shown in cross section. The condenser is constructed in the form of a cylinder, being round or elliptical shaped, with flat heads at each end. As for size, the outside measurement might be 7 feet long by 4 feet 6 inches diameter. The exhaust steam enters the condenser through the top of the shell where it strikes the steam baffle plate which spreads the exhaust steam throughout the condenser. As the exhaust steam passes downwards around the hundreds of small tubes, it is condensed into water by coming in contact with the cold tubes. This works on the same principle as steam vapor striking against a windowpane on a cold day. The condensate, being heavier than the exhaust steam, falls to the bottom of the condenser and is removed through the condensate pump suction. The tubes are kept cold by pumping sea water through them continuously. The sea water enters the condenser through the inlet into the lower half of the divided water box and then flows through the lower bank of tubes into the water box on the opposite end. It then flows upward as indicated by the arrow, and enters the upper bank of tubes through which it passes into the upper half of the divided water box. The sea water then leaves the condenser through the outlet and is discharged overboard.

The temperature of the sea water leaving the condenser will be higher than when entering, as some of the heat in the exhaust steam is picked up by the sea water in passing through the tubes. This type of surface condenser is known as a "two-pass" because the sea water flows in two directions, being reversed in its travel through the tubes.

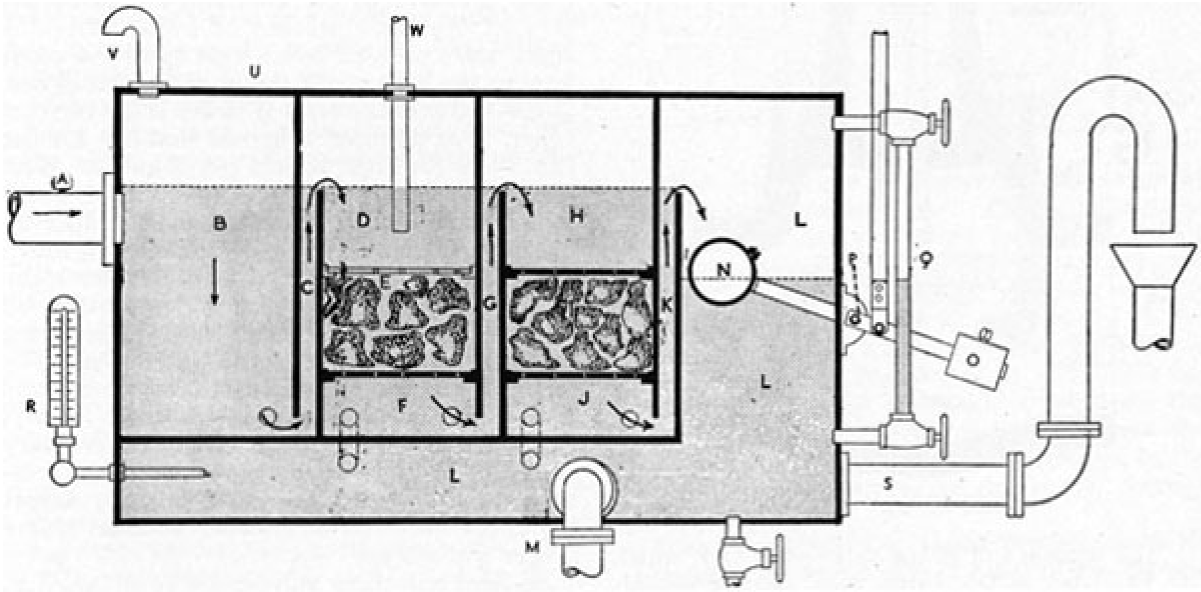
The tubes are made of either admiralty metal or brass and are secured tightly in the tube sheets at each end. This prevents the sea water from entering the fresh water space. Should the tubes leak, sea water will enter the fresh water side and contaminate the condensate.

The shell is generally made of cast iron or steel plate, the water boxes of cast iron.

Condensate Pump-The condensate is removed through the bottom by means of a pump known as the condensate pump. A pump is a mechanical device having the ability to transfer liquids or gases from place to place. It may be operated from the main engine or it may be of a type which operates by itself, but at any rate it must be able to operate continuously while the plant is in service, so as to remove the condensate from the condenser as fast as formed. The condensate is discharged from the pump into the combined filter tank and hotwell, which is also known as feed and filter tank.

Hotwell-In the cross-sectional side view of a common type filter tank and hotwell, section (L) is the hotwell. The condensate enters at (A), and after passing through the filter box, spills over into the hotwell (L). The hotwell serves as a small storage tank from which the feed pump takes its suction. The condensate is removed from the bottom of the hotwell by the feed pump through the opening (M).

The problem is to regulate the speed of the feed pump so that it will remove the water from the hotwell at exactly the same speed as it enters from the condensate pump. This is accomplished by means of the float control (N). As the water level rises and falls in the hotwell (L), the float (N) floats up and down on the surface



FILTER TANK AND HOTWELL

of the water like a rubber ball. The float is fastened to an arm which has a counterbalance weight (O) on the opposite end. This arm pivots like a see-saw at (P). As the arm moves up and down it moves the vertical rod which is fastened to the steam valve that controls the speed of the feed pump. In this way, when a large amount of water suddenly enters the hot-well, such as when the engine is speeded up, the float control automatically speeds up the feed pump, removing the water more rapidly from the hotwell, preventing its overflowing. Should condensate stop entering the hotwell, as when the engine is stopped, then the float will drop down, shutting off the steam to the feed pump, stopping it and preventing the hotwell from being pumped dry.

The level of the water in the hotwell can be seen by looking at the water gage glass (Q).

The temperature of the condensate may be determined by reading the thermometer (R).

In case the hotwell should for any reason become full, it will overflow through the pipe line (S) which leads to one of the ship's fresh water storage tanks.

The filter tank and hotwell is usually a rectangular shaped box made of steel plate having a removable cover (U) to permit cleaning. When cleaning becomes necessary, all the water may be drained into the bilge by opening the drain valve (T).

(V) is an open vent pipe.

Feed Pump-In addition to being able to move the feedwater from the filter tank and hotwell to the boiler, a feed pump must be able to force the feedwater into the boiler against the boiler pressure, which in some boilers is several hundred pounds per square inch. At least two feed pumps, known as the main and auxiliary, respectively, are required; one being in use while the other stands by, ready for instant service.

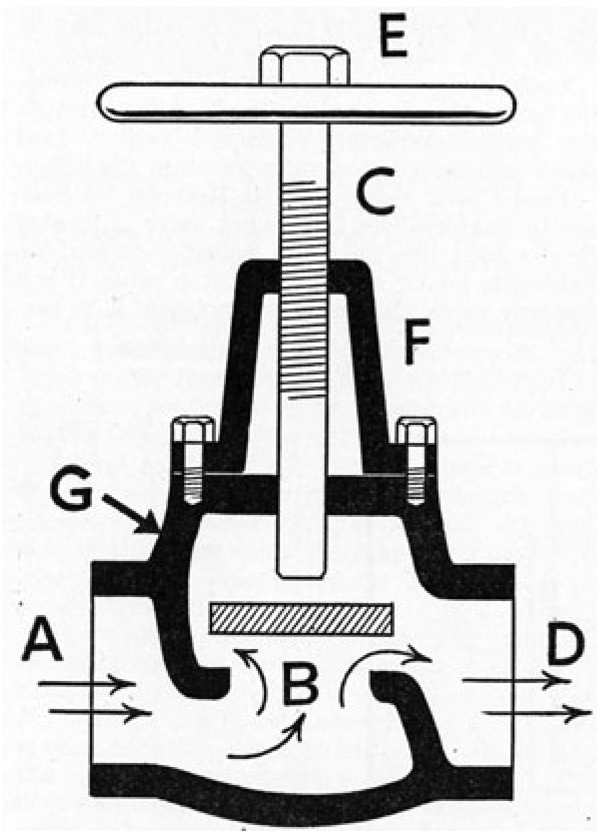
It is important that there always be a feed pump in operation while the boiler is in service, otherwise the water level in the boiler will quickly drop below the lowest safe point, resulting in overheating of the boiler metal unless it is immediately removed from service.

Feed pumps may be of the steam reciprocating type or centrifugal type. The latter may be driven by a steam turbine or electric motor.

Upon being discharged from the feed pump, the feedwater passes along the feed line through the grease extractor, feedwater heater, feed check valve, feed stop valve and into the boiler.

Feed Check Valve And Its Relation To Boilers In Battery-The feed check valve is located in the feed line near the boiler, between the feedwater heater and the feed stop valve. It is a one-way valve, and one of its purposes is to prevent the feedwater from returning through the feed line once it has entered the boiler.

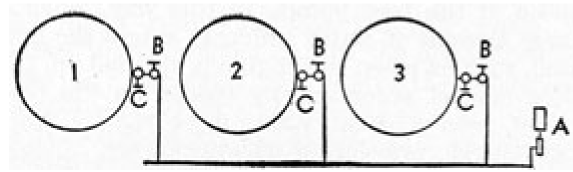
The cross-sectional view is of a simple feed check valve of a type used aboard ship. The body (G) of the valve is made of bronze or cast steel. The feedwater enters the valve through the feed line from the feedwater heater at (A) and flows downward and then turns up against the bottom of the movable disc (B) which acts as a plug to close the opening. When the pressure of the entering feedwater against the bottom of the disc becomes greater than the pressure within the boiler pushing downward on the top, the disc lifts. This leaves an opening through which the feedwater flows to discharge at (D) to the stop valve and boiler. When the incoming pressure drops below the boiler pressure, the pressure on the top of the disc becomes greater, causing the disc to drop, close the opening and prevent the water in the boiler from flowing backwards into the feed line.



FEED CHECK VALVE

The bottom end of the valve stem (C), which is threaded in the valve yoke (F), is not attached to the disc (B). When the valve wheel (E) is turned clockwise (to the right) the stem screws downward until the bottom end of the valve stem is against the top of the disc. With the stem in this position the disc cannot be raised by the incoming water pressure, due to the valve stem holding it on its seat. This is closed position; no water can enter boiler.

If the hand wheel is turned counterclockwise (to the left), the valve stem is screwed upward, leaving a space between the top of the disc and the bottom of the valve stem. This is the open position, as the disc is free to open and close with the incoming water.



BOILERS IN BATTERY

Another purpose of the check valve is to control the amount of water entering each boiler. As all ocean-going ships have more than one boiler, it is necessary to have a check valve in the branch feed line to each boiler. In this figure, three boilers are being operated in battery (together). Feed pump (A) pumps feed-water to all the boilers, the feedwater traveling through the feed line branching off to each boiler.

The water level in all three boilers must be kept as nearly equal as possible, even though at times the fires in the different boilers do not give off the same amount of heat. With the check valve on each boiler wide open, the water level in the boiler with the least fire would rise, as less water in the form of steam is leaving that boiler. For example: Suppose that No. 1 boiler has a less fire than boilers No. 2 and 3. With all check valves wide open, No. 1 boiler would soon become flooded. This is prevented by closing in on the check valve on No. 1 boiler, which consists of screwing down on the valve stem. This allows the valve disc to raise a small amount to allow just enough water to enter the boiler to maintain the proper water level. The remainder of the feedwater enters boilers 2 and 3 through the wide open check valves.

As the firing conditions in the boilers vary from time to time during the watch, it is necessary for the watertender to frequently adjust the check valve on each boiler in maintaining proper water level.

At least one check valve must be left open at all times, otherwise excess pressure will build up and damage the feed pump or feed line when the feed pump continues to operate with no opening for the feedwater to discharge through.

On the larger ships the check valves are adjusted by the watertenders, while on medium and small-sized ships the fireman quite often tends the water.

The feed stop valve (C) for each boiler is located in the feed line between the check valve (B) and the boiler. A stop valve is of the same general construction as a check valve except that the disc is fastened to the bottom of the valve stem, and when the valve stem is screwed upward the disc moves with it and is held open until the valve stem is screwed down by hand.

The purpose of the stop valve is to prevent the water in the boiler from backing out the feed line in the event the check valve should fail. This valve is ordinarily open at all times when the boiler is operating, except in the event of failure of the check valve, when it would be closed by hand.

When the boiler is shut down the stop valve is closed and is left closed until such time as the boiler is returned to service.

THE AUXILIARY STEAM AND WATER CYCLE

Before the main steam and water cycle can operate, a number of smaller pieces of machinery must be provided. Also additional machines are necessary to make the ship livable and to make possible the many other operations carried on, such as loading and unloading of cargo. These machines are known as auxiliaries and the manner in which steam is supplied to them is known as the auxiliary cycle.

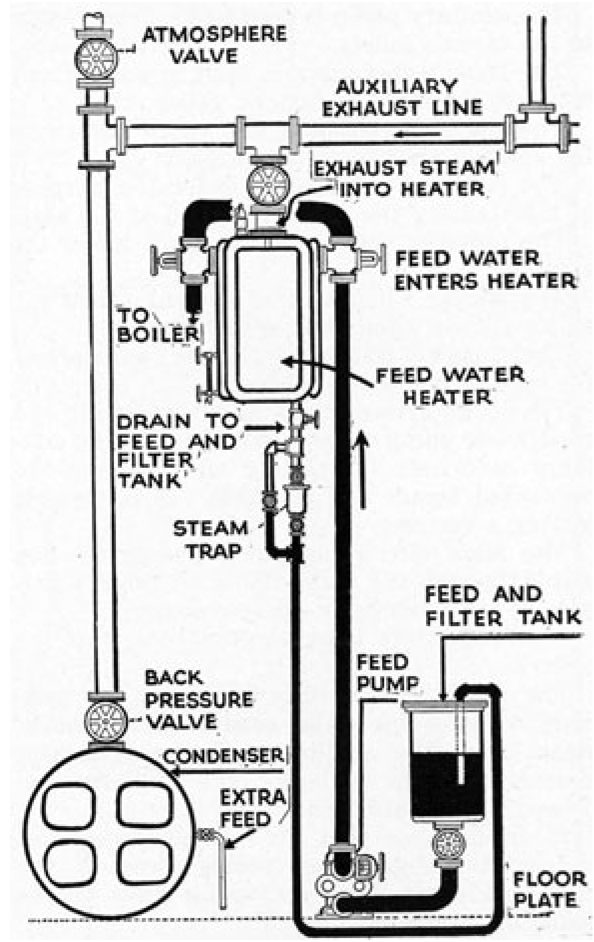
The upper drawing on page 15 shows the auxiliary steam lines (broken lines) running from the boilers to the various steam-driven auxiliary machines in the fireroom and engine room of a Liberty Ship. It will be noted that beside the auxiliary stop valve connection on each boiler, there is an auxiliary steam line connection from the rear of each boiler. These connections are to supply superheated steam to the auxiliaries, instead of saturated, should it be desired.

The lower drawing shows the auxiliary exhaust steam lines (dotted lines) in the Liberty Ship fireroom and engine room.

The steam leaves the boiler through the auxiliary stop valves and flows through the auxiliary steam line to all parts of the ship, branching off to the various auxiliaries.

The steam-driven fan supplies air to the fire boxes of the boilers so that the fuel may burn.

The fuel service pumps pump the fuel oil under pressure to the oil burners in the boilers.



BACK PRESSURE SYSTEM

Back pressure is the pressure of the steam in the auxiliary exhaust line. This auxiliary exhaust steam has exhausted from the various auxiliary steam engines driving pumps, electric generators, steering engine, winches, etc. It flows through the auxiliary exhaust line to the feedwater heater, condenser and atmosphere valve. Instead of allowing all of it to enter the condenser, wasting the heat it contains, the steam enters the feedwater heater. Here the heat in the exhaust steam is transferred to the feedwater before it enters the boiler, thereby saving fuel.

The temperature of steam depends upon its pressure. To heat the feedwater to the highest practical temperature, the pressure of the auxiliary exhaust steam must be kept between 15 and 20 pounds. This pressure is controlled by the back pressure valve restricting the flow of exhaust steam into the condenser. The valve must be adjusted from time to time during a watch to maintain the desired back pressure. The fuel oil heaters are where the heavy fuel oil is heated to thin it so that it will burn.

The fire pump is required on every ship to pump sea water for fire-fighting purposes

The sanitary pump is used to pump sea water to the various toilets.
The fresh water pump is used to pump fresh water to the crew's quarters, galley, etc.
The electric generators are where electricity for lighting and power is produced.
The refrigerating system is for the purpose of maintaining the perishable food of the ship.
The steering engine (not shown) steers the ship.
The anchor windlass (not shown) raises the ship's anchor when getting underway.
There are several cargo winches (not shown) for loading and unloading cargo.
The steam-driven combination circulating and condensate pump supplies sea water to the auxiliary condenser for cooling and removes the condensed steam and air from the condenser, leaving a vacuum.
The main circulating pump pumps the sea water through the main condenser for the purpose of condensing the exhaust steam.
The feed pumps pump the feedwater into the boilers.
The single dotted lines represent the auxiliary exhaust line which conducts the exhaust steam from the auxiliaries to the feedwater heater, the main condenser, the auxiliary condenser and the atmosphere valve.
It will be noted that the steering engine has a separate exhaust line leading direct to the main condenser. The reason for this will be taken up later.
As previously mentioned, the purpose of the feedwater heater is to increase the temperature of the feedwater before it enters the boiler. This is accomplished in the heater by transferring the heat in the auxiliary exhaust steam to the feedwater.
A pressure of from 15 to 20 pounds is maintained in the auxiliary exhaust line and feed-water heater. This is known as back pressure and is regulated by the automatic back pressure regulating valve. When the amount of auxiliary exhaust becomes sufficient to increase the back pressure above 20 pounds, the back pressure valve automatically opens, allowing the excess exhaust steam to flow into either the main condenser or auxiliary condenser, depending upon which one is in service. When the auxiliary exhaust enters the main condenser, it is condensed along with the exhaust from the main engine, and is returned to the boilers through the feed and filter tank, feed pumps, and feedwater heater as in the simple cycle shown on page 8.
In many marine power plants the main condenser cannot be used when the main engine is idle, such as in port. Then the auxiliary condenser is operated and the exhaust steam enters through the back pressure valve and stop valve. The hand-operated back pressure valve on the main condenser would then be closed to prevent the auxiliary exhaust from entering.

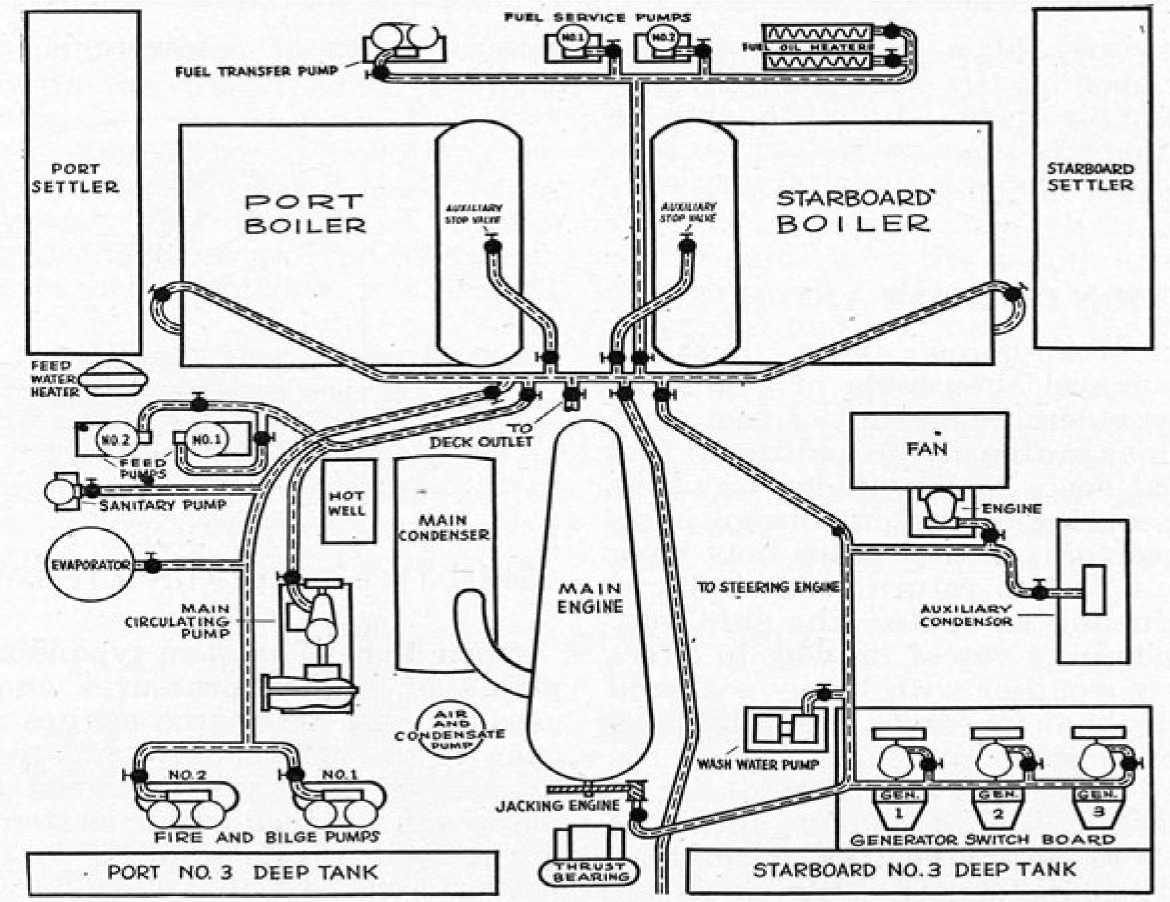
Auxiliary Condenser-The construction of the auxiliary condenser is the same as the main condenser outlined on page 9, except that it is considerably smaller, as the amount of steam exhausting from the auxiliaries is not as great as that from the main engine.

The auxiliary condenser can be used only for condensing the exhaust steam from the auxiliaries. In other words, in the event of failure of the main condenser the main engine could not exhaust into the auxiliary condenser.

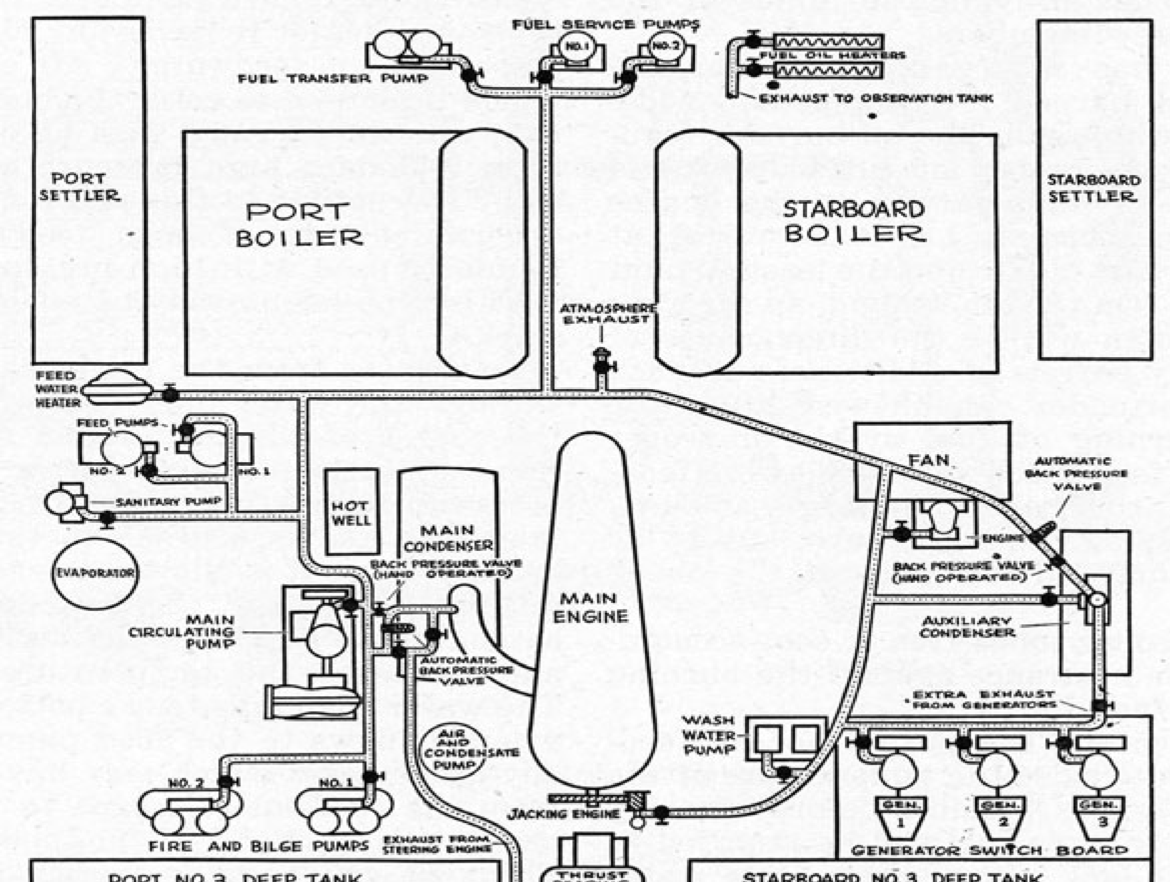
The auxiliary condenser has its own independent steam-driven circulating pump which continuously pumps sea water through the tubes. It also has its own condensate pump which continuously removes the condensate from the condenser and discharges it into the feed and filter tank. The pumps are located in a horizontal position below the auxiliary condenser. To operate the pumps a steam cylinder with piston is located between them. The piston of each pump is connected to the steam piston by piston rods. When steam is admitted to the steam cylinder, the moving piston operates both pumps.

The auxiliary condenser is ordinarily only operated in port, because at sea the main condenser is sufficiently large to take care of both the main engine and auxiliary exhaust. The usual practice is to place the auxiliary condenser in operation when approaching the pilot station or anchorage of the port at which the ship is to tie up. The reason for this is that the main condenser on many ships becomes at least semi-inoperative when the main engine is stopped for intervals, such as to pick up the pilot and maneuvering the engine when docking. As soon as the ship is tied up and the main engine is secured, the main condenser is shut down, as there will then be no exhaust steam entering it. The auxiliary condenser continues to operate while in port and until the ship is again at sea, when the main engine may be expected to operate continuously. Then the exhaust from the auxiliaries will be directed into the main condenser by opening the back pressure valve, and the auxiliary condenser will be secured.

Should the auxiliary condenser fail in port, the auxiliary exhaust may be discharged into



AUXILIARY STEAM AND WATER CYCLE (AUXILIARY STEAM LINES)



AUXILIARY STEAM AND WATER CYCLE (AUXILIARY EXHAUST LINES) the atmosphere (air) at a point aft of the smoke-stack by opening the atmosphere valve. This arrangement is used when the ship is in dry dock as there is then no sea water surrounding the ship for cooling the auxiliary condenser.

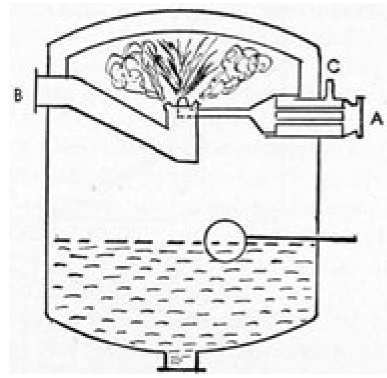
CONSERVATION OF HEAT AND FUEL

Operation-As ocean-going ships must in many instances travel thousands of miles between ports, a considerable amount of fuel must be stored aboard, as ordinarily no additional fuel can be secured at sea. Today, under war-time conditions, the securing of fuel in foreign ports is sometimes uncertain, so that ships may have to carry sufficient fuel to return to their home port without refueling en route. The ship may have to go considerably out of its way to effect a rescue. Stormy weather with heavy seas and head winds results in an increased amount of fuel burned. Any of these occurrences means the burning of more fuel than anticipated. It is evident then that the ship cannot afford to waste fuel if it is to be in a position to meet all emergencies and still make port. In view of this the conservation of fuel becomes an important matter and is constantly in the minds of the engineers and crew members.

The fireman has a large control over the amount of fuel burned. A competent wide-awake fireman who cleans the oil burners regularly, maintains the proper amount of draft and keeps the fuel oil temperature at the degree most efficient for burning, has made sure that he has done his part in burning the least amount of fuel possible. On the other hand, an ignorant or careless fireman will be the direct cause of consuming many barrels of additional fuel each day. The watertender can likewise cause the unnecessary burning of fuel by the improper handling of the feed check valves, allowing feed-water to enter the boilers in large amounts rather than keeping the water level steady by frequent and small adjustments of the check valves.

Keeping the boiler tubes free of soot accumulation is another insurance against the burning of unnecessary fuel.

Feedwater Heaters-The purpose of all feed-water heaters is to raise the temperature of the feedwater as high as possible before entering the boilers, so that less fuel will be required to make the water boil. In addition, cold water entering a boiler places a strain upon the metal parts, which must be avoided. There are two general types of feedwater heaters, open and closed.



OPEN TYPE DEAERATING FEEDWATER HEATER

Open Type-The open type is used with power plants of higher pressures employing turbine engines. As the name suggests, the heater is open to the atmosphere, and therefore must be located in the cycle between the condensate pump and the feed pump, as there is no pressure in the cycle at this point.

The cross-sectional view is of a deaerating type open feedwater heater. In addition to increasing the temperature of the feedwater, this type open heater removes any air which may be present in the feedwater. Air contains oxygen, which if allowed to enter the boiler in any quantity, will cause a rapid wasting of the metal surfaces. Modern high pressure boilers are especially susceptible to this and for this reason the deaerating type of open feedwater heater is regularly used with high pressure systems.

This type heater may be made of cast iron or steel.

Feedwater from the condensate pump enters through the water inlet (A) where it is led to the center of the heater and sprayed upward from a nozzle in a fine spray. Steam at low pressure enters the heater through the steam inlet (B) and is also led to the center of the heater, where it is allowed to shoot out into and mix with the spray. This produces a scrubbing action which separates the air from the water and increases the temperature of the water. The water then falls to the bottom of the heater where it flows to the feed pump. The air and any other gases which may have been liberated from the feedwater, escape to the atmosphere through air outlet (C) on the vent condenser. The vent condenser is merely a small surface condenser in which steam vapors seeking to escape through the air outlet are condensed upon coming in contact with the tubes, made relatively cold by the incoming feedwater which flows through them.

The feedwater temperature in this type heater cannot be increased above the normal boiling point of water which is 212° F. In actual operation the temperature of the feedwater leaving the heater will probably not exceed 200° F.

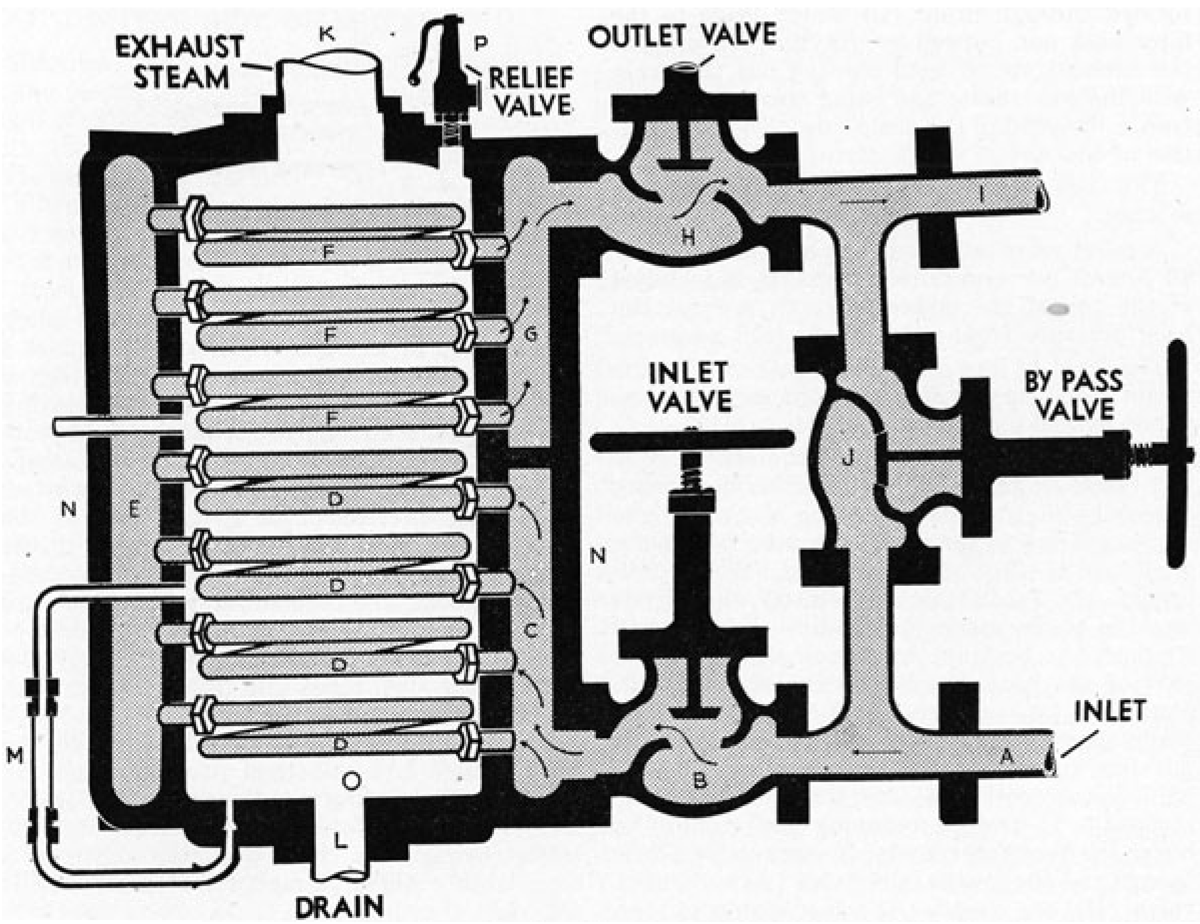
Closed Type-Closed feedwater heaters are installed in practically all marine power plants and are located in the cycle between the feed pump and the boiler. As this portion of the cycle must be under a pressure greater than the boiler pressure, the heater must be closed, otherwise the feedwater would shoot out into the fireroom.

This cross-sectional view is of a closed feed-water heater of popular modern design, with control valves.

The feedwater enters the heater from the feed pump through feed line (A) and inlet valve (B) into water chamber (C). The feedwater then flows through the copper coils (D) , discharging into the water chamber (E). It then flows upward and enters the upper group of copper coils (F). After flowing through these coils the feed-water exits into the water chamber (G) and then proceeds to leave the heater through outlet valve (H) and continues on its way to the boiler through the feed line (I).

The temperature of the feedwater leaving the heater should be about 100° F. higher than when it entered. For example: The inlet temperature might be 140° F. while the outlet temperature then should be about 240° F. Now let us see what caused the increase in temperature.

As the feedwater was flowing through the copper coils, exhaust steam from the auxiliary exhaust line was entering the top of the heater through opening (K), at about 20 pounds back



CLOSED TYPE FEEDWATER HEATER

pressure and traveling downward, completely surrounding the coils. The heat in the exhaust steam was conducted through the walls of the copper coils into the feedwater, increasing its temperature about 100° F. in its travel through the coils.

The temperature of the feedwater before entering the heater may be found by looking at the thermometer on the hotwell and, after being heated, by the thermometer on the feed line between the heater and the boiler.

The purpose of the back pressure valve should now be clear.

As the heat is removed from the steam, the steam condenses and falls to the bottom of the heater (0) where it is drained as rapidly as formed through drain (L) which leads to the filter tank and hotwell by gravity. To prevent the exhaust steam from blowing out the drain with the condensate and being wasted, a steam trap is installed in the drain line. The construction of this device will be discussed later.

The shell (N) of a heater of this type is made of steel.

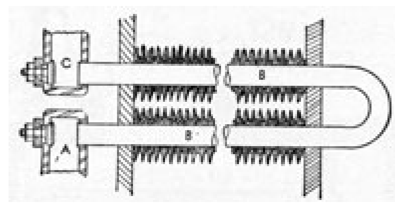
A relief valve adjusted to open at about 25 or 30 pounds per square inch pressure is installed at the top of the steam space to prevent the back pressure from rising above that pressure.

The level of the condensate collected in the steam space surrounding the coils can be determined by looking at the gage glass (M).

Occasionally one or more of the copper coils will crack or break off while in service, being especially likely to happen when the coils have seen considerable service or when the feed pump is allowed to slam while operating. When a coil breaks, the feedwater immediately shoots out into the steam space surrounding the coils and if allowed to continue would completely fill this part of the heater and flood the auxiliary exhaust line. As soon as a coil breaks, the feed pump speeds up tremendously as it no longer is pushing against the boiler pressure. This is immediately noticeable and the pump must be stopped. To resume pumping water into the boiler the feedwater heater by-pass valve (J) is opened and the heater inlet valve (B) and outlet valve (H) are closed. The feed pump is then started up and the feedwater will flow from the pump through the feed line (A) and then turn upward, passing through the by-pass valve (J) and on into the feed line (I) to the boiler. When the shut-off valve in the auxiliary exhaust line entrance (K) to the heater is closed, the heater will be entirely isolated and the inspection door on the front of the heater may be removed and the broken coil replaced with a new one. The heater may then be closed up and returned to service.

While this is going on, the fireman on watch has found it necessary to burn considerably more oil in order to hold the desired steam pressure while the heater was out of service.

Economizers-In modern high pressure marine power plants the temperature of the feedwater is raised still higher before entering the boiler proper by passing the feedwater through an economizer after it leaves the closed feedwater heater. An economizer consists of a number of small steel tubes which are located in the uptake from the boiler.



ECONOMIZER

This cross-section view is of a single economizer tube in an uptake. In a boiler where a steam pressure of 450 pounds per square inch is carried, the temperature of the gases leaving the boiler on their way to the stack would probably be around 600° F. and if allowed to escape up the stack all of this heat would be wasted. By placing an economizer in the path of the gases a portion of the heat is returned to the boiler. This is accomplished by passing the feed-water through the economizer tubes which are surrounded by the hot flowing gases. Some of the heat in the gases is conducted through the walls of the steel tubes into the feedwater with which it is carried into the boiler.

The feedwater enters the tube through the inlet header (A) and then flows through the tube (B) discharging into the outlet header (C) from whence the feedwater discharges into the boiler through the check and stop valves at a considerably higher temperature than when it entered.

Economizers are not warranted on lower pressure boilers, meaning around the pressure of 250 pounds per square inch or lower, as the temperature of the escaping gases is not sufficiently high.

Air Preheaters-As a further conservation of fuel in high pressure boilers, air preheaters are sometimes installed. They also consist of a number of steel tubes located in the uptake, being just above the economizer tubes. The air from the blower to the fire box passes through the tubes, picking up some of the heat of the gases which escaped the economizer and carrying it into the fire box. The blowing of hot air into a fire box generally results in better burning of the fuel than cold air.

High pressure boilers equipped with economizers and air preheaters are found to be very efficient in operation. By efficiency is meant, a large portion of the heat produced by the burning fuel is turned into steam and only a small portion is lost up the stack.

FEEDWATER-GREASE AND OIL IN THE WATER SIDE OF BOILERS

Results-Even a small amount of grease or oil in the feedwater is very apt to cause overheating if it enters the boiler, as it is apt to circulate with the water and may adhere to a tube or plate located near the fire.

When steel is exposed to fire it cannot retain its strength unless the plate or tube is cooled by water on the opposite side. As boilers are made of steel, it is vitally important that the water side be kept free of any substance which might prevent the heat entering the steel from passing through into the water.

Grease and oil are very poor at transferring heat and even a thin coating in a water tube is sufficient to cause the steel to overheat, losing its strength, which allows the boiler pressure to bulge the area until it bursts like an inflated toy balloon.

Overheating from grease or oil can also cause steel furnaces to collapse and tubes and seams to leak where joined.

At best it means a boiler shut down for repairs, which in most cases are lengthy and expensive. At worst the overheating may result in a boiler explosion, which is very disastrous, resulting in probable loss of life and ship.

Constant care must be exercised to prevent the entry of oil into the boiler. Notify the engineer immediately at the first sign of grease or oil floating on the surface of the water in the water gage glass. Steps can be taken to remove the oil or neutralize its effects if detected in time.

Entry-The greatest danger of oil entry exists in marine power plants using reciprocating type main engines and auxiliaries. With these, lubricating oil must be supplied to the cylinders to provide lubrication between the moving pistons and the cylinder walls and to the piston rods which travel in and out of the cylinders. As the oil is in direct contact with the steam, some of it, especially if an excessive amount is used, travels along with the steam into the main condenser and then on with the condensate through the condensate pump into the feed and filter tank.

Another possible source of oil entry into the feedwater is through the fuel oil heaters. In these, live steam is used to increase the temperature of the oil and should a leak occur between the oil and steam side of the heaters, the fuel oil will enter the steam side and return through the drain line to the feed and filter tank with the condensed steam. As a safeguard against this, an observation tank is provided in most installations.

Observation Tank-Usually consists of a small square steel tank open to the atmosphere, located in the fuel oil heater condensate drain line, between the heater and the filter tank. The condensate entering the observation tank from the heaters is easily visible through a glass port, and at the first sign of fuel oil the condensate is drained to the bilge instead of the filter tank until repairs are made.

Fuel oil may also enter the feedwater through leaky heating coils located in the fuel oil storage tanks. The condensed steam from these also passes through the observation tank.

Filter Box-To remove the grease and oil from the feedwater, the filter tank portion of the combined filter tank and hotwell is provided. In the drawing on page 11, the condensate from the main engine enters the filter tank at (A) while the condensate from the observation tank enters at (W). In compartment (B) the condensate travels downward, passing beneath the vertical baffle and then rises upward through (C), where it overflows into compartment (D) and passes downward through a perforated steel plate into compartment (E) which is filled with a filtering material.

Several kinds of filter material can be used-one of the most popular being loofa sponges, which are secured from the inside of gourds. When dry, they are flat and about the size of a man's hand, but when immersed in water they swell up considerably. Turkish toweling and coke may also be used to remove oil from water. In operation, the grease and oil clings to the filter material while water passes through, and if the material is renewed or cleaned before it becomes saturated with oil, no oil will reach the boilers. It is, therefore, important that the filtering material be carefully watched and replaced as it becomes necessary.

Continuing with the flow of water through the filter tank, it passes downward into compartment (F) and then upward between the vertical baffles overflowing into compartment (H), where it passes downward through (I), which is another compartment filled with filtering material, and then down into (J) and up through (K) where it overflows into the hot-well (L). The top of the shaded area represents the water level in the filter tank.

As oil tends to float on the surface of water, a large portion of the oil is trapped on the surface in compartments (B), (D) and (H), and can be skimmed off by hand as it collects.

Grease Extractor-To catch any oil in the feed-water which may have passed through the filter tank, a grease extractor is installed in the feed line between the feed pump and the feedwater heater.

The filtering material most generally used is turkish toweling. The grease or oil in the feed-water passing through the toweling clings to it, and if the toweling is renewed before it becomes saturated, oil will have been prevented from entering the boiler. Here again vigilance is required to make sure the filtering material is always renewed in time.

One type of grease extractor uses two sets of toweling, the feedwater passing through one set while the other is being renewed.

Another type has only one set of toweling and it becomes necessary to divert the feedwater through a by-pass line around the extractor when the toweling is to be replaced, leaving a short interval of time when the feedwater does not pass through the grease extractor.

Grease extractors are sometimes provided with pressure gages at the inlet and outlet sides to give a comparison of pressures on each side of the toweling. If the toweling is clean the feedwater will flow through freely and the pressures will be equal. With grease soaked toweling, the pressure on the inlet side will be greater due to the feedwater having difficulty in passing through.

FEEDWATER-SEA WATER IN THE WATER SIDE OF BOILERS

Effect-Sea water contains impurities in solution, in the form of sodium chloride (salt), carbonate of lime (chalk), sulphate of lime (plaster of paris), magnesium chloride (magnesium) and small amounts of other impurities, such as silicates. When sea water is boiled the impurities remain in the boiler.

In the boiler water the salt remains in solution, becoming more concentrated as sea water is continually added, until the concentration reaches the point where foaming will occur.

Foaming is a violent agitation of the surface of the boiler water, causing various sized amounts of water to leap upward into the steam space. The water may travel over with the steam into the machinery, causing damage.

Foaming is immediately noticeable by the water level in the gage glass surging up and down.

The remaining impurities for the most part tend to adhere and bake fast to the hot steel surfaces of the boiler, and in time will build up to such thickness as to insulate and cause overheating of the metal. This build-up is known as scale.

Watertube marine boilers, with which modern American ships are equipped, are not able to use sea water as feed for the reasons listed above.

Firetube Scotch marine boilers are able to operate with sea water, although it is not a desirable condition.

The engine department crew is constantly on the alert to prevent leakage of sea water into the boilers.

Entry-The condensers are the most likely place for this leakage to occur, for when in operation a vacuum is maintained in the fresh water side of the condenser. Should a leak develop in one or more of the tubes, the sea water will be sucked through into the fresh water side where it will mix with the condensate, making it more or less salty, according to the size of the leak. If the leak is not promptly detected and repaired, it will cause a concentration of sea water impurities in the boilers with damaging results already mentioned.

A sample of the condensate leaving the condenser and a sample of water from each boiler are usually tested each watch for the presence of sea water. Should any be detected, an immediate search for the leak is started and if the leak is not sufficiently large to permit a serious amount of sea water to enter the boilers before port is reached it may be let go till then, when the leaky condenser tube may be plugged or renewed. A bad leak can sometimes be plugged at sea by pumping sawdust into the cooling water entering the condenser. The vacuum will pull particles of sawdust into the crack, where they will swell up, temporarily sealing the leak.

As the fresh water for reserve boiler feed is usually stored in the double-bottom tanks beneath the fire and engine rooms, a leak in the hull will allow sea water to flow in and contaminate it. If not detected, this contaminated water would in time be fed to the boilers as make-up feed. It is a good policy to test the water in each storage tank regularly.

FEEDWATER-FRESH WATER IN BOILERS

Most fresh water contains various impurities, depending upon the soil structure of the earth where the water is secured. While fresh water from some ports contains only a slight amount of impurities, making good boiler water, the water in other ports will be very poor for boiler use, as most of the impurities tend to form scale.

With modern boiler water treatment, however, scale formation from most fresh water can be kept to a minimum. When testing boiler water a sample from each boiler is chemically analyzed by the engineers each day to determine the amount of impurities present and the amount of chemicals needed to counteract them. Trisodium phosphate and soda ash are among the chemicals injected into the boilers for this purpose. They act upon the impurities to keep them in solution, preventing their forming scale. A number of so-called boiler compounds are also available for this purpose.

Usually the engineer will blow a small portion of the boiler water overboard each day through the bottom blow-off valve, the purpose being to remove some of the collected impurities before they build up and cause foaming.

Reserve Feed (Extra Feed)-As water is lost from the steam and water cycle through leaks, etc., the water level in the boiler gage glasses will gradually drop. To replace this loss reserve fresh water from the storage tanks is fed into the system. Most ships have a pipe line connection from the storage tanks to the main condenser. When extra feed is needed the extra feed valve near the condenser is opened. The vacuum in the condenser causes the extra feed to rush up into the condenser from the storage tanks. The extra feed, of course, travels along with the condensate to the boilers. When the main condenser is not in service the reserve feed is pumped from the storage tanks to the hotwell.

It is much better to take on extra feed slowly over a good part of the watch than to open the extra feed valve wide and bring the boiler water level up quickly. Learn to anticipate the amount of extra feed the boilers will need.

Storage-Fresh water for boiler use is usually stored in the double-bottom tanks beneath the fire and engine rooms, and in the forepeak and afterpeak tanks.

It is important when filling the storage tanks to make certain that nothing but fresh water is admitted, for there have been instances where ships' storage tanks were filled with sea water by mistake. Also ships have left port only to find after a few days out that most of the tanks had not been filled at all. These acts of carelessness are serious and inexcusable.

The fresh water used for drinking and cooking purposes is stored in separate tanks, known as domestic tanks, which are located inside of the ship's Mill.

All fresh water tanks should be sounded daily to determine the amount and a sample of water from each tested.

Fresh water is a precious commodity aboard ship and must be guarded against wastage with unfailing care. Do not let shower baths run unnecessarily. Report fresh water leaks.