WAR SHIPPING ADMINISTRATION
TRAINING ORGANIZATION

UNITED STATES MARITIME SERVICE

TRAINING MANUAL

ENGINEERING BRANCH TRAINING

TABLE OF CONTENTS

ADAPTED IN PART FROM PUBLICATIONS OF THE CORNELL MARITIME PRESS

THE FOLLOWING PHOTOGRAPHS ARE SHOWN THROUGH THE COURTESY OF

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.

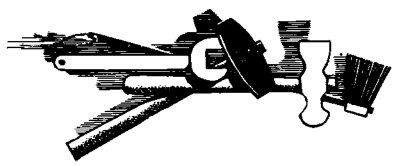
These events are serious in that the stopped vessel would have to drop out of convoy making it easy prey for attack. A smoking stack may give away your position to the enemy and bring on attack.

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.

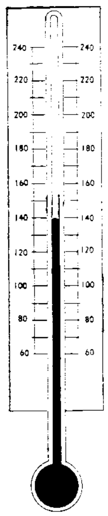
The heat may be produced by burning fuel such as coal or oil. The larger and hotter the fire the more energy produced and the more work accomplished. To control the power of the engine we regulate the amount of fuel being burned. The burning of fuel is known as combustion.

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.

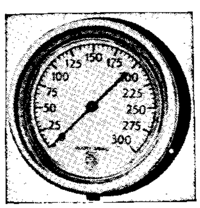
The boiler is a closed steel vessel partially filled with water. To illustrate the principle, assume that the boiler is like a steel barrel in a horizontal position. Fuel is burned just below the boiler and the heat given off radiates against the outside of the boiler, and is conducted through the steel 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 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

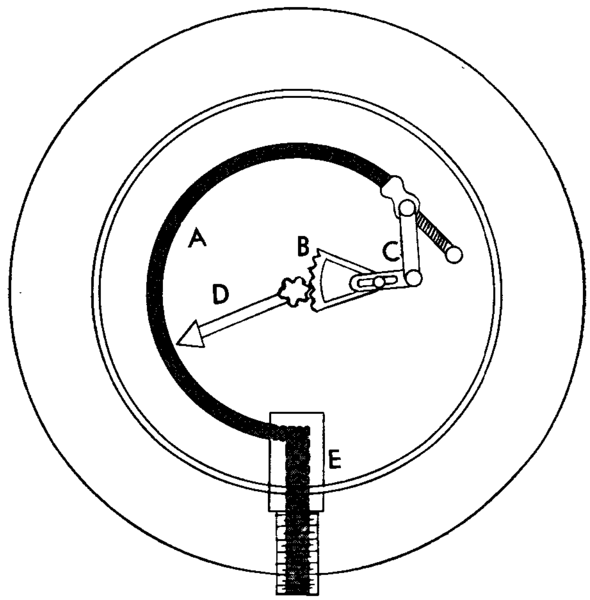
Pressure–When dealing with the temperature of steam we must consider pressure, for when the temperature of steam increases or decreases so does the pressure. Pressure is a force of energy and is recorded in pounds per square inch. If a boiler is said to have a pressure of 200 pounds it means that a force 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.

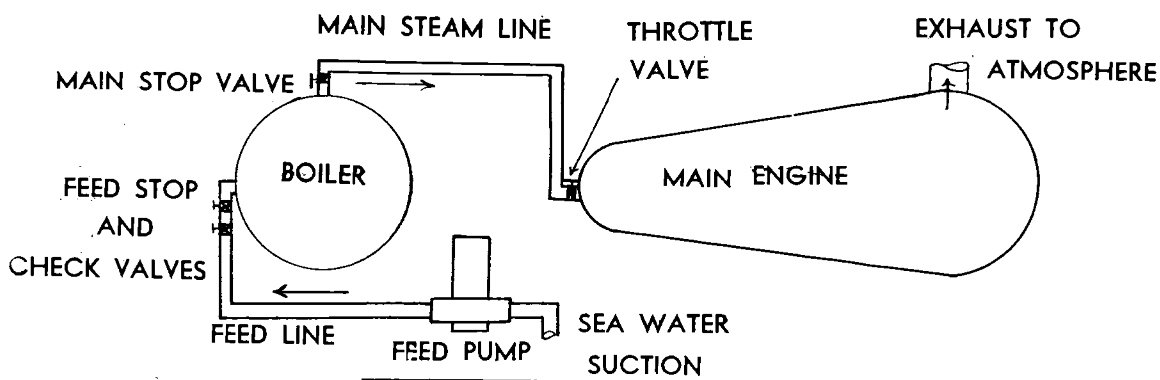
Boiling Temperature of Water–The temperature at which water will boil depends upon the pressure resting upon the surface of the water. At sea level with 14.7 pounds per square inch atmospheric pressure against the surface of the water, it will boil at 212° F., but if we were on top of the mountain it 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

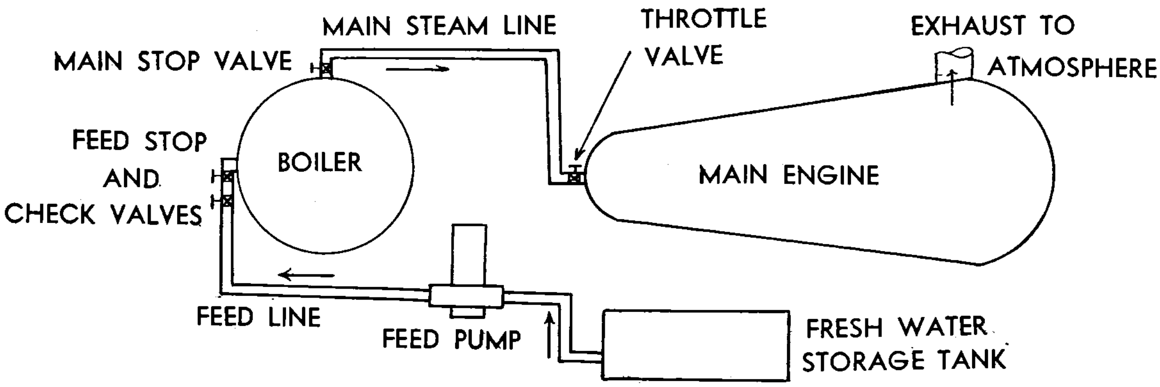
The flow of the steam and water through the various pieces of machinery that make up the main engine power plant is known as the steam and water cycle.



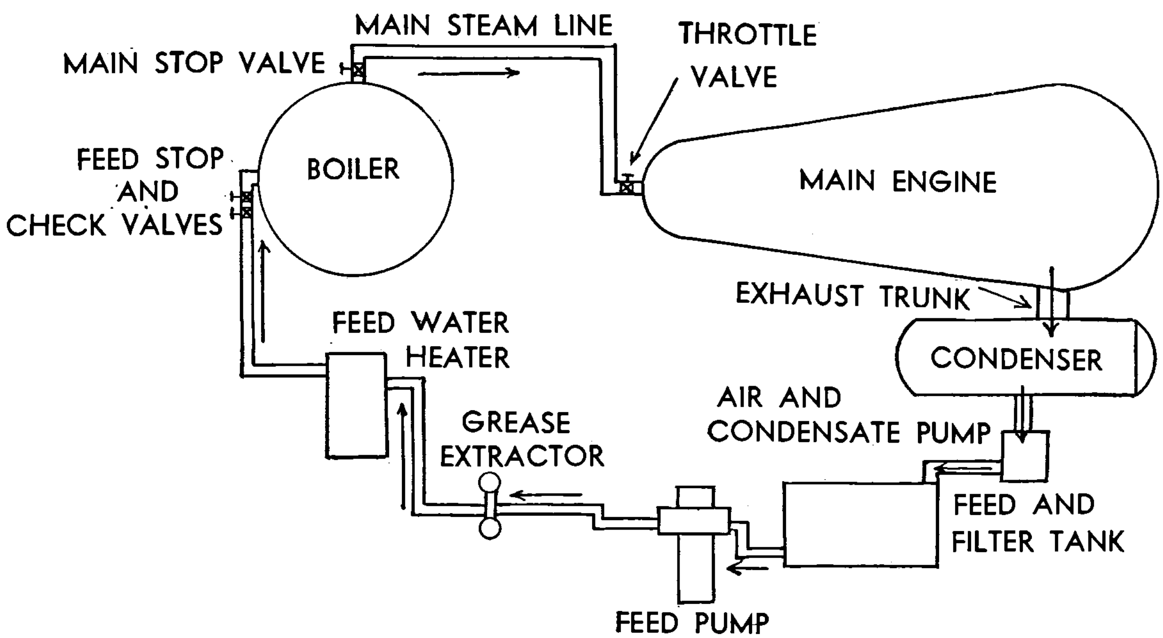
SIMPLE CYCLE–USING SEA WATER

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

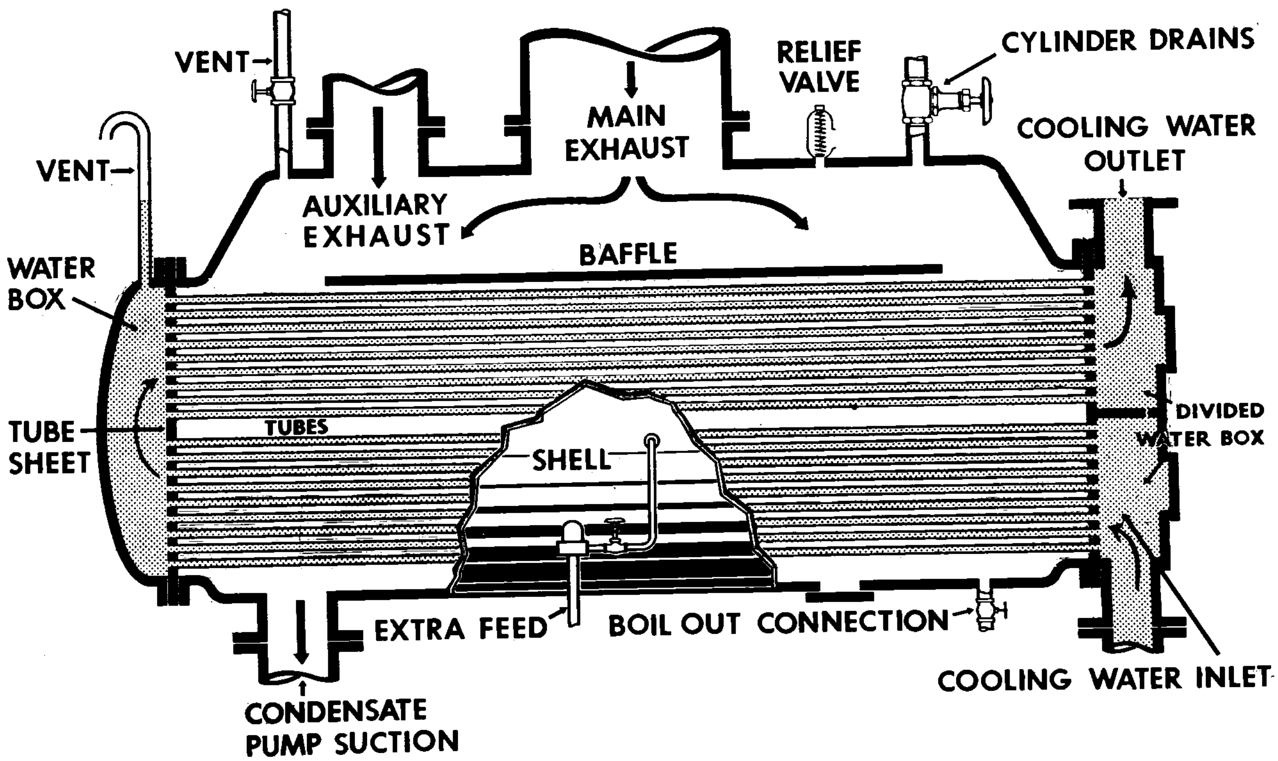


SIMPLE CYCLE–USING FRESH WATER



SIMPLE CYCLE–USING FRESH WATER WITH CONDENSER mous 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 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 hotwell, 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.

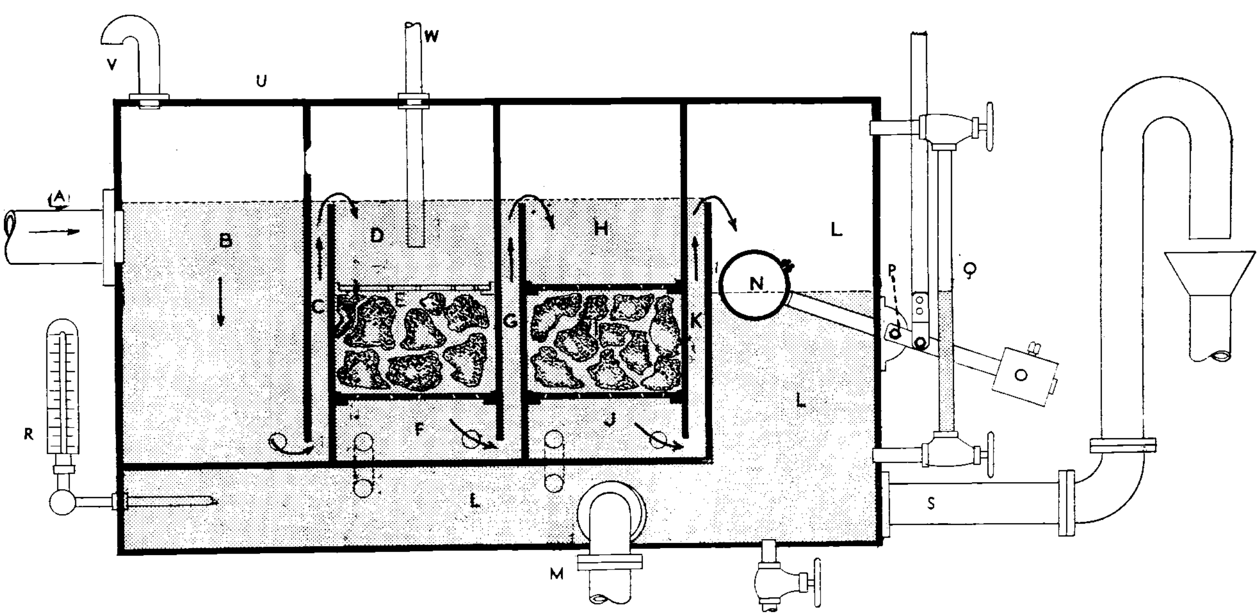
It is important that there always be a feed pump in operation while the boiler is in service, otherwise the water level in the boiler will quickly drop below the lowest safe point, resulting in overheating of the boiler metal unless it is immediately removed from service.

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.

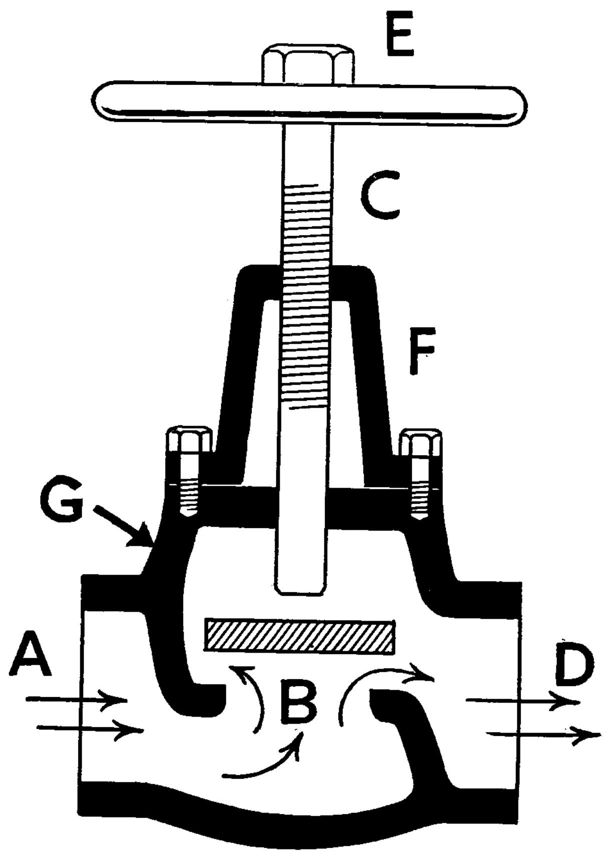
Feed Check Valve And Its Relation To Boilers In Battery–The feed check valve is located in the feed line near the boiler, between the feedwater heater and the feed stop valve. It is a one-way valve, and one of its purposes is to prevent the feedwater from returning through the feed line once it has entered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



FILTER TANK AND HOTWELL

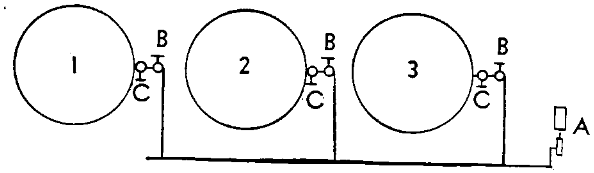
and flows downward and then turns up against the bottom of the movable disc (B) which acts as a plug to close the opening. When the pressure of the entering feedwater against the bottom of the disc becomes greater than the pressure within the boiler pushing downward on the top, the disc lifts. This leaves 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 feedwater 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.

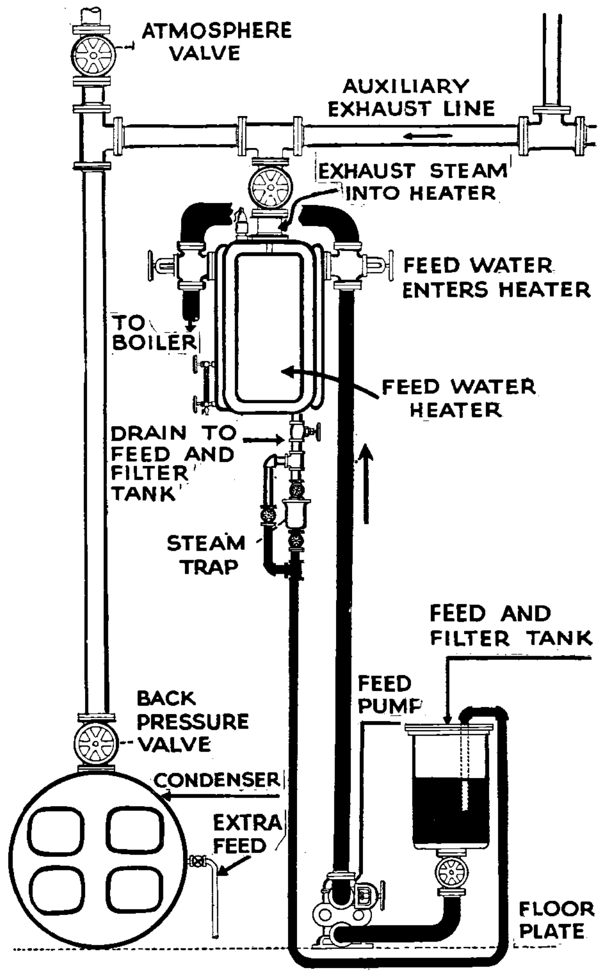
The steam leaves the boiler through the auxiliary stop valves and flows through the auxiliary steam line to all parts of the ship, branching off to the various auxiliaries.

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.

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.



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 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 feedwater 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.

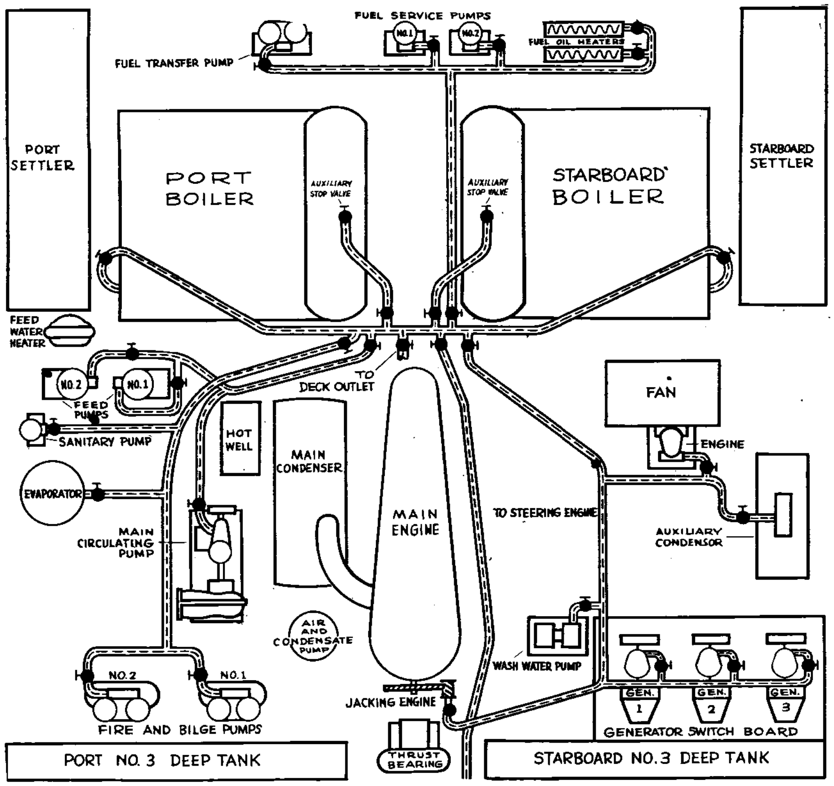
Auxiliary Condenser–The construction of the auxiliary condenser is the same as the main condenser outlined on page 9, except that it is considerably smaller, as the amount of steam exhausting from the auxiliaries is not as great as that from the main engine.

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.

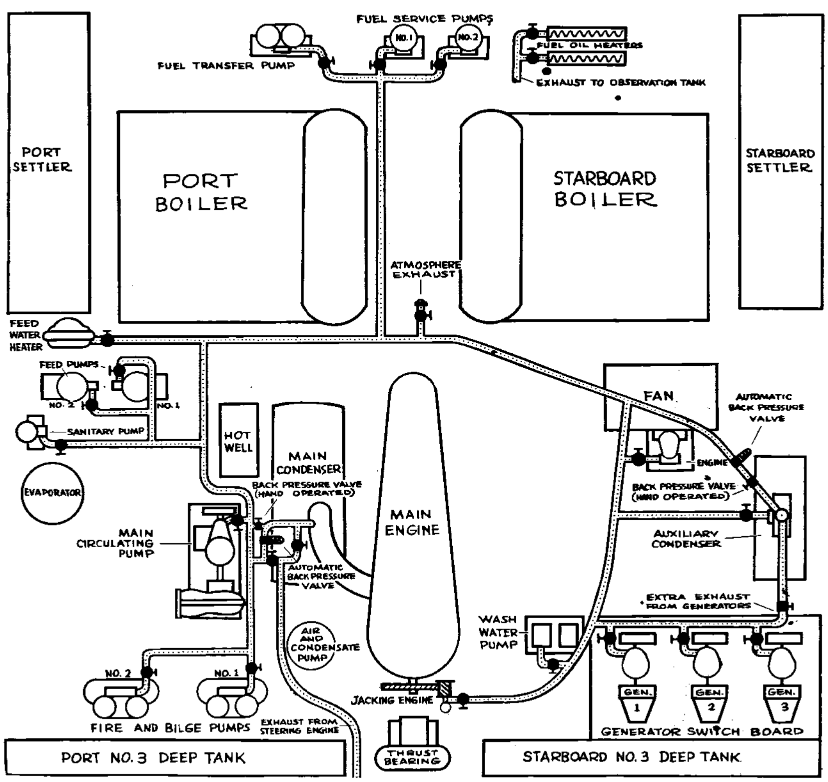
The auxiliary condenser has its own independent steam-driven circulating pump which continuously pumps sea water through the tubes. It also has its own condensate pump which continuously removes the condensate from the condenser and discharges it into the feed and filter tank. The pumps are located in 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.

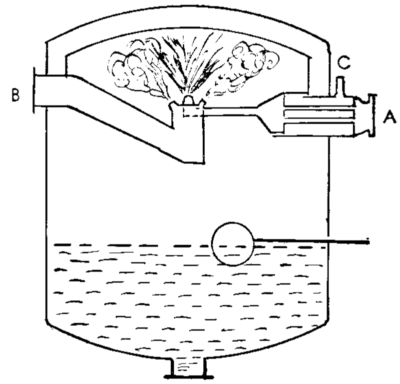
CONSERVATION OF HEAT AND FUEL

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 feedwater 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 feedwater 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.

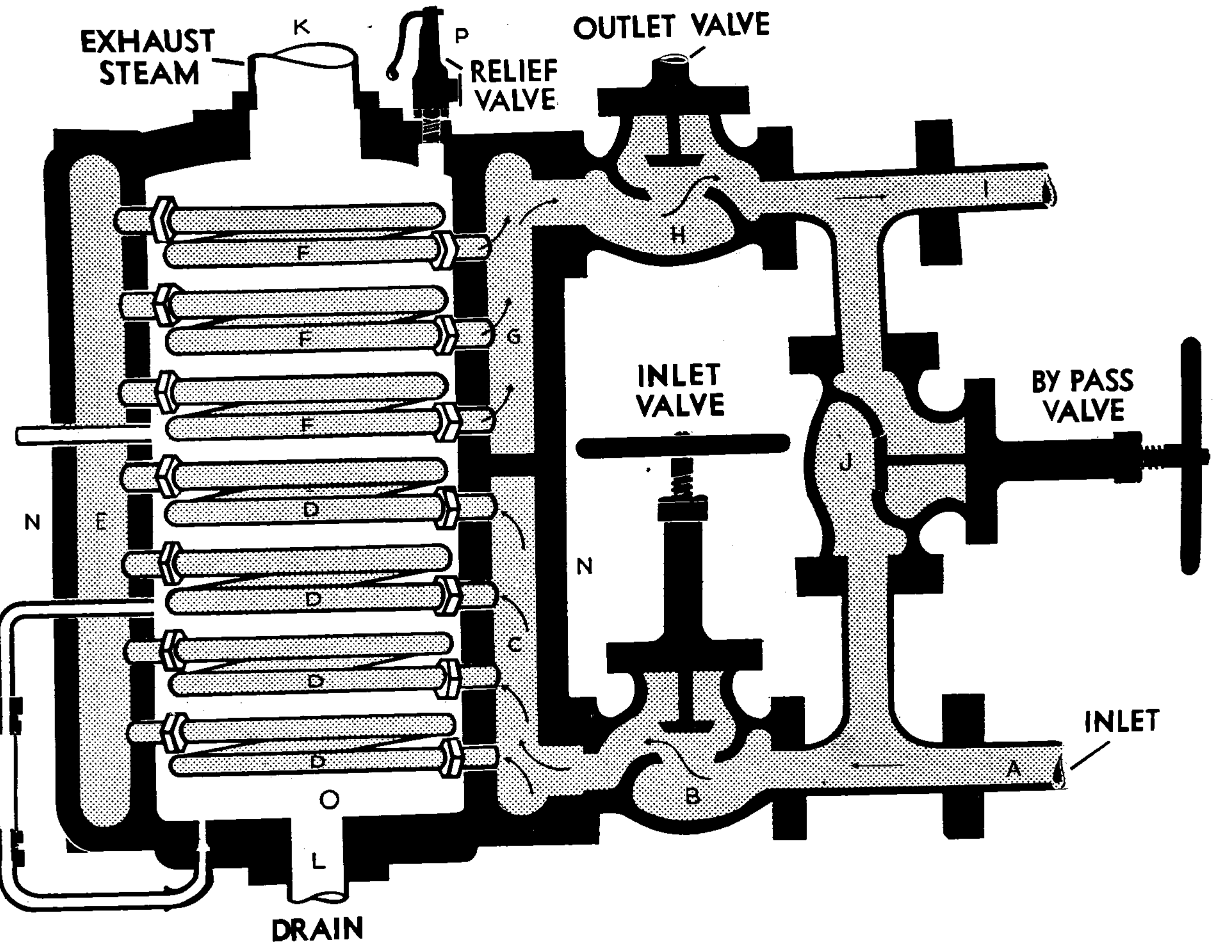
Feedwater from the condensate pump enters through the water inlet (A) where it is led to the center of the heater and sprayed upward from a nozzle in a fine spray. Steam at low pressure enters the heater through the steam inlet (B) and is also led to the center of the heater, where it is allowed to shoot 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.

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 feedwater 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.



CLOSED TYPE FEEDWATER HEATER

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

The feedwater enters the heater from the feed

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 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 (O) 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.

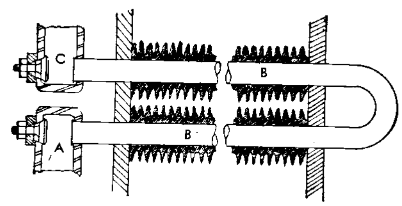
A relief valve adjusted to open at about 25 or 30 pounds per square inch pressure is installed at the top of the steam space to prevent the back pressure from rising above that pressure.

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 feedwater 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 hotwell (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 feedwater 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 feedwater 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.

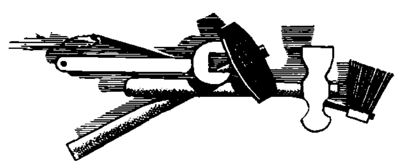
Storage–Fresh water for boiler use is usually stored in the double-bottom tanks beneath the fire and engine rooms, and in the forepeak and afterpeak tanks.

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 hull.

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.



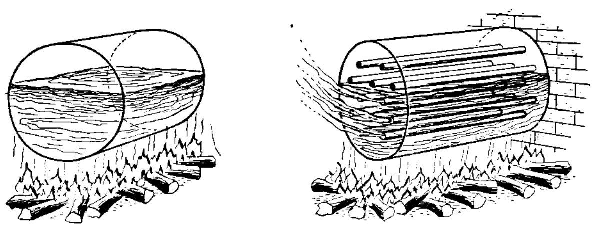
BOILERS

SIMPLE BOILER

Principle–A boiler is a closed vessel in which steam is generated from water by the application of heat.

The simple boiler is like a barrel, consisting of a cylindrical steel shell, with the ends closed by flat steel heads. It is partly filled with water and then sealed, after which a fire is started beneath it. The fire and hot gases rise around the lower outside of the shell, the heat being conducted through the steel into the water. This heats the water on the bottom of the boiler first. Hot water being lighter than cold water, it rises, while the colder water in the upper part, being heavier, sinks down to replace it and is in turn heated. These are convection currents, and the process is known as circulation, which goes on continually while a boiler is in service. Circulation is good in some boilers and poor in others, depending upon the design. This is important as will be pointed out later.

The water gradually reaches the temperature where steam is given off, which accumulates in the space above the water known as the steam space. As the steam accumulates, a pressure is built up which would create a very dangerous condition with the simple boiler. As pressure is exerted in every direction, the flat heads would bulge outward because a flat surface cannot support itself. The boiler would hold very little pressure and would be useless.

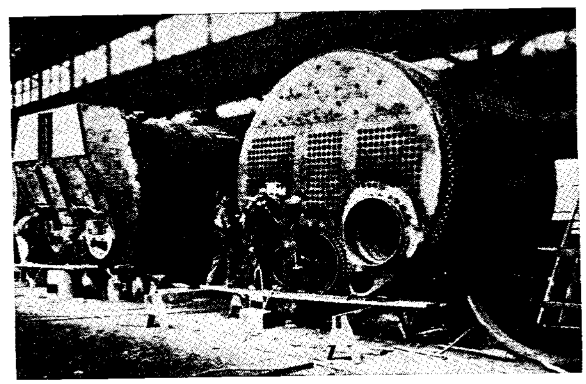


SIMPLE BOILER AND SIMPLE FIRETUBE BOILER

The first thing that has to be done with this boiler is brace the flat heads in order to keep them from being pushed out by the pressure. This is accomplished by placing heavy steel rods, called stayrods, from head to head as shown in the next view of the simple boiler, thereby tying the heads together.

The boiler can now safely carry more pressure, but it would still be an unsatisfactory boiler due to the small heating area. An improvement is made to allow more surface area of the boiler to come in contact with the hot gases of the fire by making some of the stayrods hollow and directing the hot gases through them after passing along the bottom of the shell. The water surrounding them is heated.

These hollow stayrods are called tubes and as the fire passes through them they are called firetubes, hence the name, firetube boiler. The tubes are all located below the water level so that they are protected from the heat.



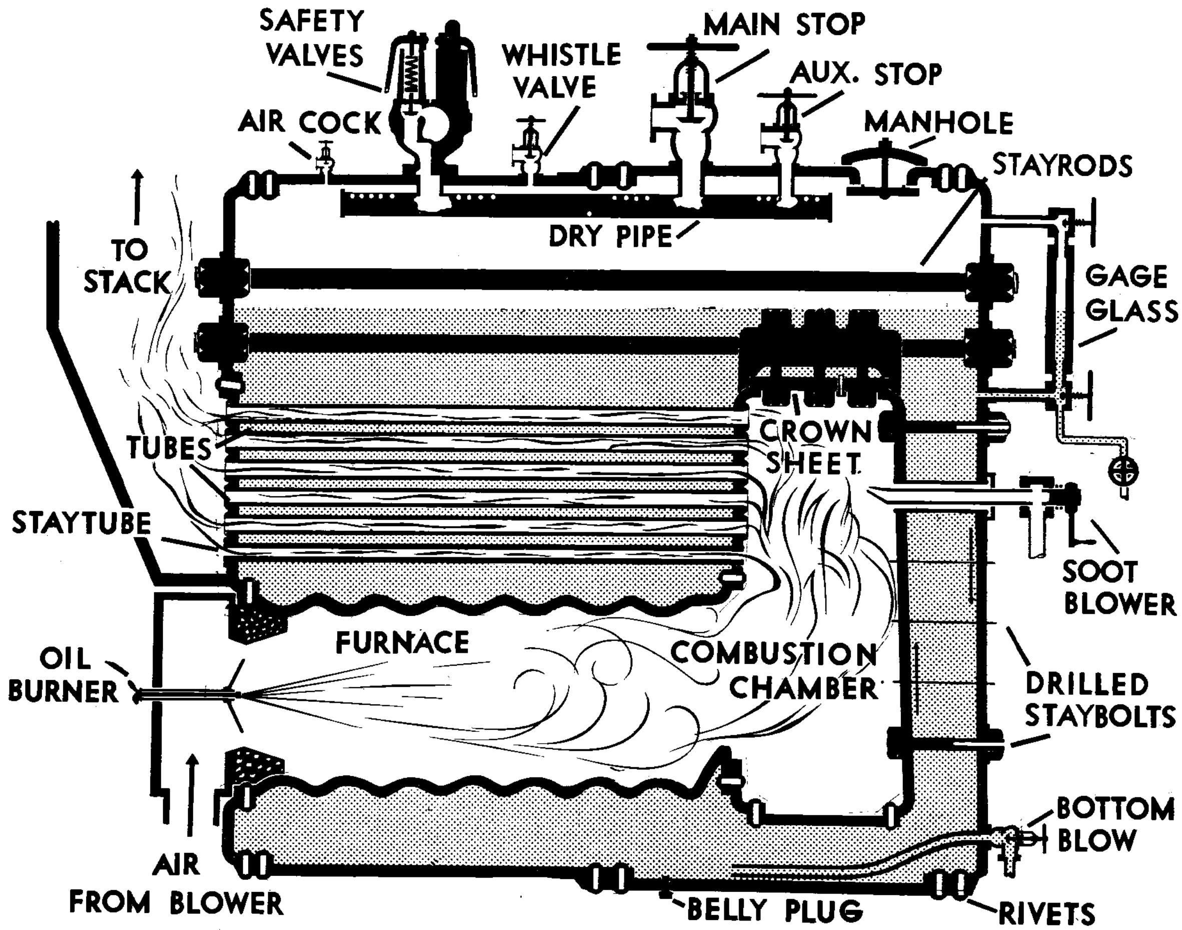
SCOTCH BOILERS UNDER CONSTRUCTION

SCOTCH MARINE BOILER

The only type firetube boiler used aboard ocean-going ships is the Scotch marine. It is a famous boiler, the first one having been installed in a ship in about 1862 and up until around 1900 was practically the only type boiler found aboard merchant or Navy ships. At that time watertube boilers began to come into use but for a number of years the Scotch marine still remained the dominant boiler. With the advent of modern high pressure power plants the watertube boiler became a necessity. However, there are still a considerable number of older American ships with Scotch boilers.

Shells and Heads–In the cross-section side view of a Scotch boiler it can be seen that the boiler has a cylindrical steel shell and flat heads the same as the simple firetube boiler. Also the upper portion of the heads are braced with stayrods in the same manner. A further study, however, reveals that something has been added to the simple boiler.

Furnaces–The fuel in the Scotch boiler is burned in a cylindrical steel furnace located



SIDE VIEW SCOTCH MARINE BOILER

inside the water space of the boiler. The furnace is secured by rivets to the front head and is corrugated for strength to resist the crushing effect of the boiler pressure in the water which surrounds it. The number of furnaces depends on the size of the boiler, there usually being three or four.

Combustion Chamber–The furnace opens into a combustion chamber which is simply a rectangular steel box standing on end and surrounded with water.

In the combustion chamber the unburned gases, given off from the burning fuel in the furnace, mix with air and burn.

The flat sides and top of the combustion chamber must be supported the same as the flat heads of the boiler or they will bulge inward from the surrounding boiler pressure. Small stayrods, called staybolts are used for the rear and side sheets and sometimes for the bottom. They are threaded into the sheets and in some cases have nuts at the outer ends. From the rear sheet of the combustion chamber they extend through the water to the rear head of the boiler. In this manner the lower portion of the rear head is also supported against being pushed outward. From the side sheets the staybolts extend through the water to the shell of the boiler or the side sheet of an adjoining combustion chamber. The bottoms of combustion chambers are usually curved to make them self-supporting in which case staybolts would not be needed as shown. The front or tube sheet is supported by the firetubes which extend through the water space of the boiler to the front head.

The top sheet or roof is known as the crown sheet and is supported by crown bars and crown bolts. The crown bar acts as a bridge span from which the crown bolts hold up the crown sheet. The crown sheet is the highest heating surface in this type boiler and the water level must be kept above it at all times or it will become overheated.

It is the usual practice to have a separate combustion chamber for each furnace, although Scotch boilers have been built with all the furnaces opening into one large common combustion chamber. There are also double-ended Scotch boilers where separate furnaces from each end of the boiler enter into one combustion chamber.

Tubes–The tubes are made of seamless drawn steel, a popular size being 3¼ inch outside diameter which is the way all boiler tubes are measured.

When tubes are installed they are pushed in through the holes in the front head which are slightly larger than the outside of the tubes, and back through the water space and through the corresponding tube holes in the combustion chamber tube sheet. The tubes are made tight in the holes by rolling them around the inside at each end, with a tube expander which works on the principle of a wedge. This squeezes the tube outward tight against the inside of the hole. If properly expanded the joint will not leak unless the tube is overheated, or is disturbed by improper warming up of the boiler or becomes thin with age and wear. After the tubes are expanded, the projecting ends are bent outward and back against the tube sheet. This is called beading and is done to protect the ends from being burned off due to the heat of the fire. The beading also prevents the tubes from pulling out of the holes in the event they should loosen up.

As the number of tubes in a boiler is large, they provide by far the largest amount of heating surface.

Staytubes–A small proportion of the tubes, scattered among the firetubes, are staytubes. They are heavier tubes and are threaded into the tube sheets to give added support to the flat tube sheets and heads.

Operation–The oil burner and air registers are located in the front end of the furnace. The oil is sprayed into the furnace, mixes with the air and burns. In operation some of the heat of the burning fuel passes through the furnace walls into the water. The remainder is carried by the draft into the combustion chamber, where more of it passes through the sides into the surrounding water. The gases, still at a high temperature, next pass into the tubes where the greatest portion of the heat enters the water. The gases still containing some heat flow out the front ends of the tubes and turn upward through the smoke box, uptake and stack, from which they are lost overboard.

Circulation–The circulation in a Scotch boiler is poor which necessitates care when starting up cold. The arrows pointing upward in the sketch on page 25, indicate the rise of the water being heated around the furnaces, combustion chamber and tubes. As can be seen, this leaves very little space for the cold water at the top to work its way down. This confliction of currents slows down the circulation.

When firing up a cold Scotch boiler, the water below the furnaces tends to lie there and remain cold. If this is not prevented the water in the upper part of the boiler will be boiling while the bottom will still be cold. This condition places a strain on the boiler, causing leaks at the joints. To prevent this, a small fire is lighted in one furnace. After ten or fifteen minutes it is shut down and a fire lighted in another furnace and so on. This shifting of the fire tends to heat up the entire boiler evenly and start the water circulating.

Dangerous Water Level–When the water level drops out of sight in the water gage glass there is no way of knowing where the water level is in the boiler.

Never assume that because the water level was in sight a few seconds before it could not have dropped far enough in the boiler to uncover the crown sheet.

Never try to bring the water level back into sight by opening the feed check valve wide, allowing water to rush into the boiler. If the crown sheet is overheated, the incoming water striking it may cause it to crack or fail, resulting in a disastrous boiler explosion.

Always shut off the oil burners immediately upon discovering a low water condition and notify the engineer.

Advantages–The Scotch boiler has certain advantages over the watertube boiler.

Due to the much larger amount of water contained in the Scotch boiler, there is a much larger amount of heat stored up which makes for steadier steaming pressure and water level.

The Scotch boiler is somewhat cheaper to build and it can use dirtier water, even sea water if necessary.

The Scotch boiler generally requires less repairs than the watertube due to there being no brickwork in the firebox to keep in repair.

Disadvantages–The disadvantages of the Scotch boiler are such as to have caused its replacement with the watertube boiler in new construction of American ships for a number of years.

Its large size and weight prevents carrying as much cargo as with watertube boilers.

Due to the large amount of water and poor circulation, steam cannot be raised quickly.

All of the stored-up heat energy being contained in one large shell makes for a greater possibility of boiler explosion.

There being a limit on the thickness of steel plate that can be shaped, Scotch boilers cannot be constructed for working pressures much higher than 250 pounds per square inch which prohibits their use with modern turbine plants.

Generally speaking Scotch boilers are not as efficient to operate as watertube.

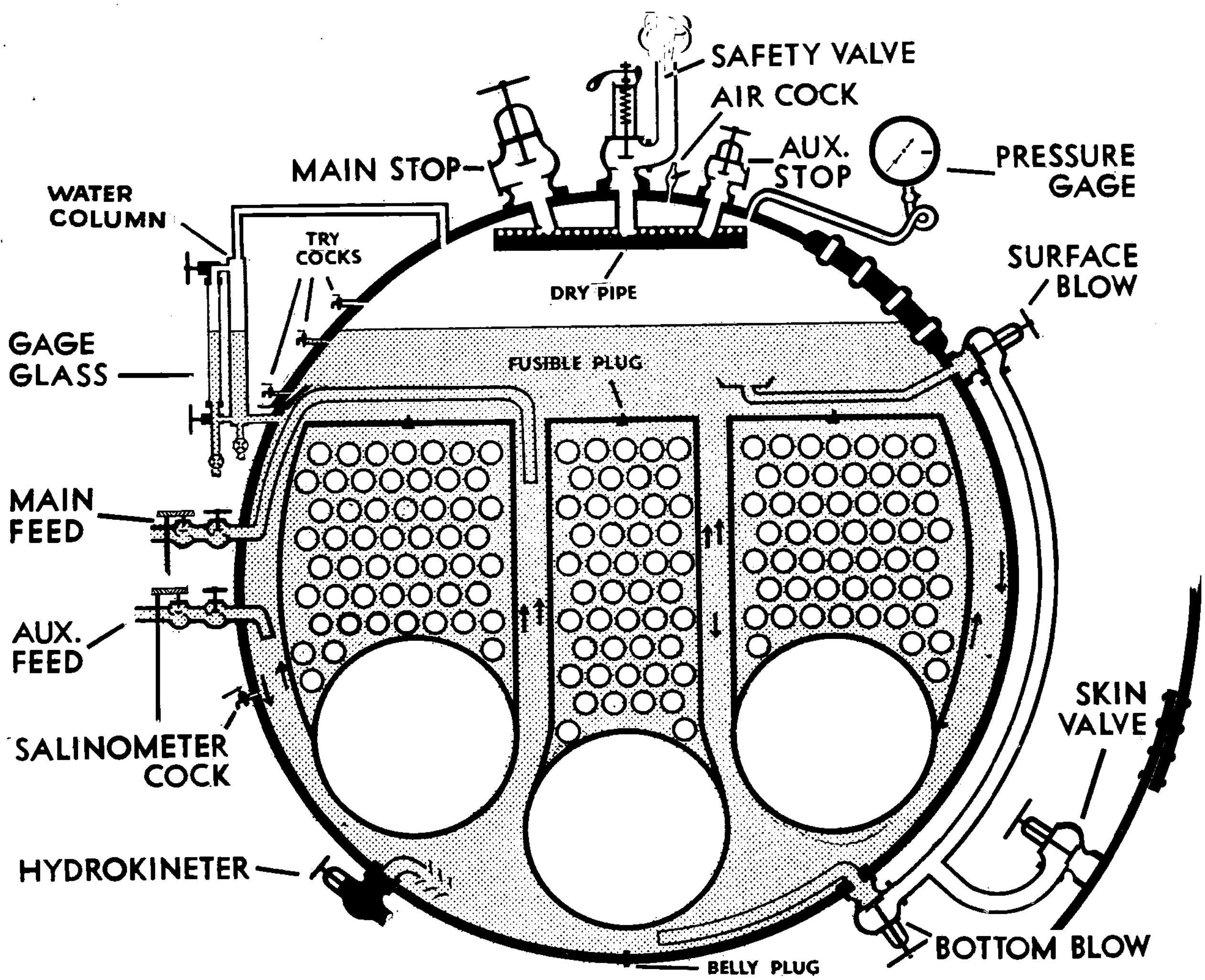
BOILER FITTINGS AND ATTACHMENTS

All boilers, regardless of their type or design, require a number of fittings and attachments in order to render them safe to operate. The relative position of these fittings and attachments is shown in the front view sketch of a Scotch boiler.

The fittings and attachments and their purposes are:

Water Gage Glass–As it is impossible to see the amount of water inside the boiler, a small glass tube about 12 inches long, known as a gage glass, is installed outside the boiler, in a vertical position.

The top end of the glass is connected to the top of the steam space of the boiler by a pipe



FRONT VIEW OF SCOTCH BOILER WITH FITTINGS ATTACHED line while the bottom end of the glass is connected to the water space in the same manner. When the water level rises in the boiler, water will flow in through the bottom connection and rise up in the glass to the same level as the water in the boiler.

The fireman and watertender can determine the water level in the boiler by looking at the gage glass.

The position of the gage glass is such that when the water level is at the lowest visible part of the glass there will still be a few inches of water above the top of the crown sheet or in other types of boilers, the highest heating surface.

The water level should never be allowed to drop out of sight in the gage glass. If this should occur at any time, all fires should be shut down at once, and the engineer immediately notified.

The top of the gage glass is considered the high water level point in a boiler where danger of water carry-over with steam appears.

On most ships the water level should be carried at the center of the glass, however, the correct water level should be determined upon going aboard each ship.

The rolling of a ship has an influence upon the water level to be carried.

Shutoff valves which are operated from the fireroom deck plates by small brass chains are located at the top and bottom of the gage glass. When a glass breaks in service these valves are closed by pulling down on the right-hand chain. This stops the steam and water from blowing out into the fireroom.

A new gage glass can then be installed by backing off the gland nuts, removing the glands and soft rubber packing washers along with any remaining pieces of broken gage glass. A new gage glass complete with new washers is installed and the gland nuts carefully tightened. Care must be exercised to make sure the bottom end of the glass does not rest against the bottom fitting, otherwise the glass will crack and break when the steam and water enter the glass.

When the new glass has been installed, the left-hand control chain is pulled down. This opens the top and bottom shutoff valves and the water and steam rush into the glass, again showing the water level.

To remove mud and sediment accumulation which would in time plug the connection to the glass, especially the bottom one, a drain valve is provided from the bottom of the glass. A drain pipe from the valve usually leads to the bilge. At least once each watch the fireman or watertender opens the drain valve for a few seconds, which allows a small stream of steam and water to blow into the bilge where it is easily heard. This is known as blowing down the gage glass, and is a very important duty which must not be neglected if a true water level reading is always to be had. When the drain valve is closed, the water level should immediately return to the glass. A slow return is an indication of at least a partial obstruction in the connections between the boiler and gage glass and should be immediately reported to the engineer.

To make definitely certain that the top and bottom connections are clear, the following procedure is in order. When blowing down the glass, first the top shutoff valve is closed. If the blowing noise is heard from the drain it is evident the bottom connection is clear. The top valve is then opened and the bottom is closed. If the blowing noise is still heard, it is certain that the top connection is also clear. The bottom shutoff valve is then opened and the drain closed.

The plain round gage glass will break upon becoming thinned from the scouring action of the steam from many blowdowns.

The prismatic type gage glass with which most new boilers are equipped is very unlikely to break and is much easier to read, as the water appears black in the glass while the steam is white.

The water gage glass must be looked at regularly every few seconds, as the water level can change quickly, especially in watertube boilers.

At least one gage glass is required on each boiler. If only one is provided, three try cocks will be required; but if two gage glasses are installed, try cocks will not be required, although some boilers may have them also.

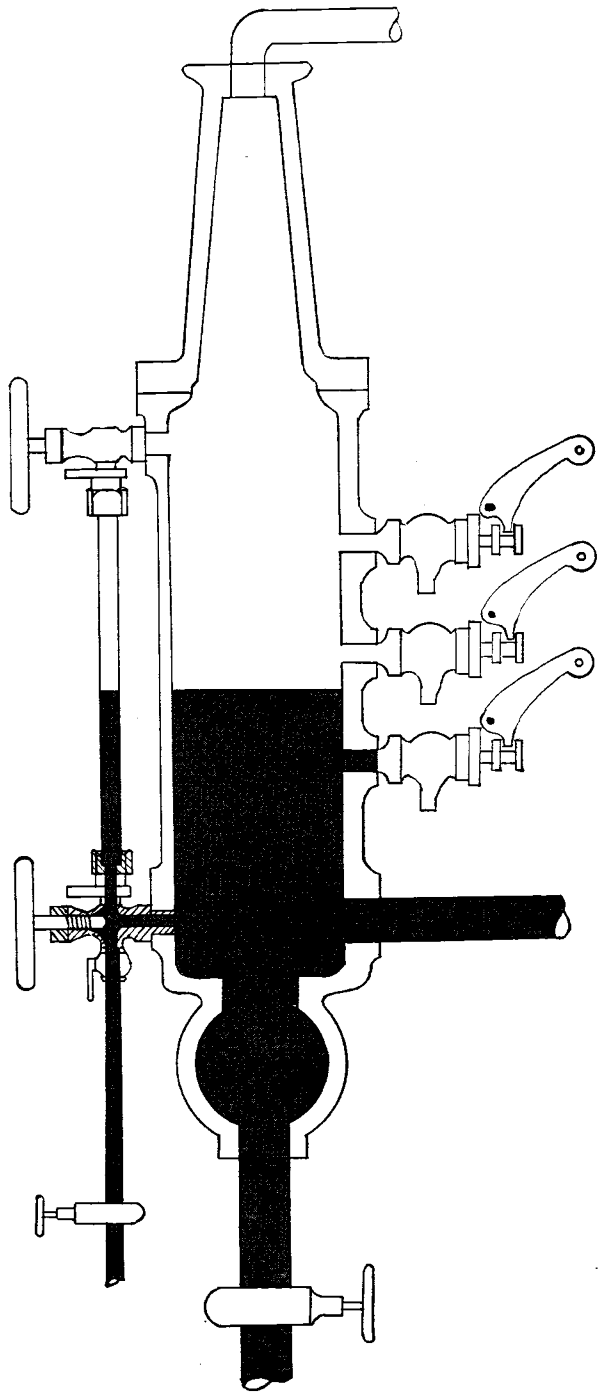
Try Cocks—Another method of checking the water level in the boiler is by "try cocks" shown in the cross-sectional sketch of a water column.

Try cocks are small valves on the outside of the boiler. The lowest of the three is placed on the boiler at a point two inches above the lowest visible part of the gage glass, the center try cock at the center of the glass, and the top one at a point about level with the top of the gage glass. By opening the try cocks one at a time and noting which ones water or steam squirts out of, the water level is determined.

Water Column–Used when gage glass is not connected directly to the boiler.

Consists of a vertical steel cylinder, the top being connected to the steam space and the bottom to the water space.

The gage glass and try cocks connect into the column at the proper level.



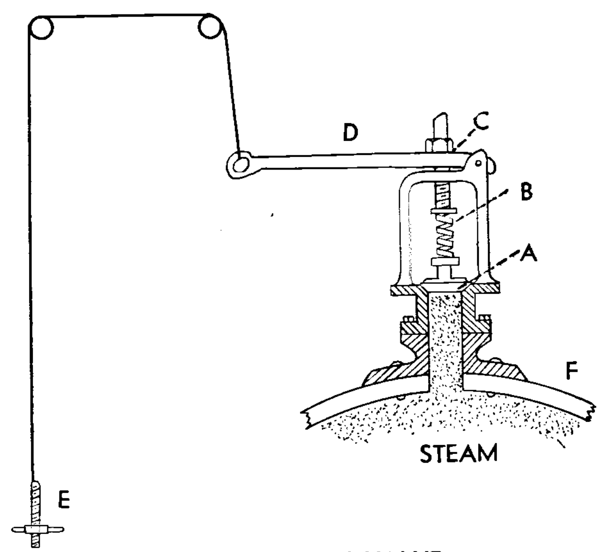
GAGE GLASS–WATER COLUMN–TRY COCKS

Pressure Gage (I)–To show the pressure in the boiler at all times, a pressure gage is installed. This does not have to be mounted on the boiler proper, but should be located at a point in the fireroom that is well illuminated and easily visible to the fireman.

Some pressure gages are equipped with a stationary red hand which points to the desired operating pressure. The pressure hand or pointer should ordinarily not be allowed to go above this, as to do so may cause the safety valves to lift.

The operation of a pressure gage was explained on page 6.

Safety Valves (D)–If the pressure in a boiler were allowed to increase without restriction, it would become so great that with even the strongest boilers, an explosion would occur. To prevent this happening, safety valves set to open at a pressure far below the bursting pressure of a boiler are required.



SIMPLE SAFETY VALVE

The cross-section sketch is of a simple safety valve to show the principle of operation.

The safety valve is attached to the top of the boiler shell (F). The steam under pressure from the boiler pushes upward against the bottom of the valve disc (A). The tension in a coil spring (B) pushes down on the top of the disc holding it on its seat which plugs the opening.

When the pressure in the boiler pushing against the bottom of the disc becomes greater than the tension of the spring, the disc lifts, leaving an opening through which the steam escapes to the open air. As long as the pressure in the boiler is kept at this point, the valve will stay open permitting the steam to rush out of the boiler as fast as it is made. This, of course, prevents the pressure from building up any higher.

When the pressure within the boiler drops, the valve spring is then stronger than the boiler pressure and pushes the valve down on its seat, which closes the opening, stopping the flow of steam from the boiler.

The pressure at which the safety valve will open is determined by adjusting the spring tension with the adjusting nut (C). The greater the tension on the spring, the higher will be the boiler pressure before the valve opens and vice versa.

To permit opening of the safety valve by hand at any pressure, a hand-relieving gear is provided. A steel cable leads from the relieving gear on the safety valve to within easy reach of the fireman on the fireroom deck plates so that in an emergency, the safety valves may be opened by simply pulling down these cables by turning the wheel screw (E).

No one should ever tamper with a safety valve. It is set by the boiler inspectors and is the only insurance against excess boiler pressure.

Safety valves have been known to stick in the closed position which in some cases resulted in a boiler explosion. To prevent this, two safety valves are required by law, being commonly built in one valve body and are known as duplex safety valves. One valve opens a few pounds before the other.

The modern safety valve is somewhat more complex than the simple one shown, although its principle of operation remains the same. By adding a pop chamber and blow-down ring the modern safety valve is able to remain open until the pressure in the boiler has dropped a few pounds. This prevents chattering of the valve due to repeated openings and closings.

Main Stop Valve–To control the flow of steam into the main steam line leading to the main engine. It is located on top of the boiler and is usually of the non-return angle globe type shown.

When this type valve is in the open position, steam can flow from the boiler but cannot return. This prevents the possibility of steam entering the boiler through the main steam line from another boiler when it is idle.

It is very important that care be exercised when opening a main stop valve or any other stop valve on a boiler. When opening, the valve wheel should be turned to the left just enough to raise the disc slightly from its seat. The minute the steam starts to flow through, it can be heard. This is known as cracking a stop. Leave the valve in this position until sufficient steam has passed through to build up a pressure in the cold line. The stop valve may then be opened slowly to full open position.

Carelessness in opening these valves may cause some of the water in the boiler to carry over with the steam into the line, causing water hammer, which is a severe hammering action in the pipe line. If severe enough, it can cause a sudden and disastrous failure of the steam line.

Auxiliary Stop Valve–To control the flow of steam into the auxiliary steam line, the auxiliary stop valve is located on the top of the boiler. It is of the same general design as the main stop valve except that it is smaller.

When opening, the same procedure should be followed.

Dry Pipe–Located inside of the boiler at the very top of the steam space is the dry pipe. A simple type commonly used consists of a steel pipe about six inches in diameter in a horizontal position with each end closed. Many small holes are drilled along the top of the pipe. The main stop valve, auxiliary stop valve and safety valves are connected into the dry pipe. The steam leaving the boiler through any of these valves must first pass through the small holes which tends to remove water which might be traveling with the steam. This makes drier steam, hence the word "dry pipe." They will not remove large amounts of water.

Air Cock–To allow the air to escape when filling the boiler and getting up steam and to let air into the boiler when draining, the air cock is installed on the top of the boiler. It may be either a small valve or a cock.

Feed Lines–Two ways of supplying water to a boiler are required and are known as the main and auxiliary feed lines. They are identical, the main feed line being regularly used, with the auxiliary as a stand by ready to go into instant service if trouble should develop with the main feed line.

Usually both lines are equipped with internal feed pipes which discharge the water away from the heating surface.

Main Feed Stop and Check Valves–Located in the main feed line with the stop valve next to the boiler. The operation of these valves is explained on page 12. Reach rods are provided on the check valve so that it may be adjusted from the fireroom floor plates.

Auxiliary Feed Stop and Check Valves–Located in auxiliary feed line in same position as in main feed line. Same construction as those in main feed line.

Surface Blowoff Valve–In boiler operation, certain impurities in the boiler water tend to collect and float on the surface of the water. To remove these a surface blowoff valve is installed on the side of the boiler. It is usually an angle type globe valve and is provided with an internal line and scum pan as shown.

When the valve is opened, the pressure in the boiler sweeps the floating scum with the water through the scum pan, internal line, surface blowoff valve, external blowoff line, and overboard through the skin valve.

Bottom Blowoff Valve–To remove the heavier loose impurities which accumulate on the bottom of the boiler, the bottom blowoff valve is installed near the bottom of the boiler. Blowoff valves may be of the angle globe type or of a type especially designed for blowoff service. In the Scotch boiler, it is provided with an internal line as shown.

When the valve is opened the pressure in the boiler blows the sediment through the internal line, bottom blowoff valve, external blowoff line, skin valve and overboard.

Skin Valve–Although not attached directly to the boiler, the skin valve must be considered, as it is used in conjunction with the surface and bottom blowoff valves. The blowoff lines from all boilers lead to the skin valve. It is always of the globe type. It is attached directly to the inside of the ship's hull, hence the name skin valve.

When blowing down a boiler, the skin valve is opened first and closed last. Its purpose is to prevent flooding of the ship in the event the external blowoff piping between the boilers and the ship's hull should break.

Salinometer Cock–Located on the boiler below the water level for removing small amounts of boiler water for testing purposes. Derived its name from the Salinometer, a crude device for determining the amount of salt in water, which at one time was the most widely used method for testing boiler water for salt.

Belly Plug–A small metal plug threaded from the outside into a hole in the bottom of the shell of a Scotch marine boiler.

Removed when cleaning boiler, to allow small amount of water lying on bottom of boiler to drain into bilge.

Never attempt to tighten if leakage should occur when in service. The threads may be worn causing the plug to blow out, allowing scalding water to blow out.

Hydrokineter–In some Scotch boilers hydrokineters are installed near the bottom to aid the circulation when starting up a cold boiler. Steam from shore or another boiler is fed to the hydrokineter which consists of a series of nozzles inside the water space. The steam picks up velocity passing through the nozzles into the water. This pushes the water ahead of it from beneath the furnaces as shown. Steam can be raised much quicker on a boiler so equipped.

Fusible Plug–To give warning of low water condition in Scotch boilers fusible plugs are required. They are made of bronze, being round about one inch in diameter and three inches long. A tapered hole in the center extending from end to end is filled with tin which has a melting temperature of about 450° F.

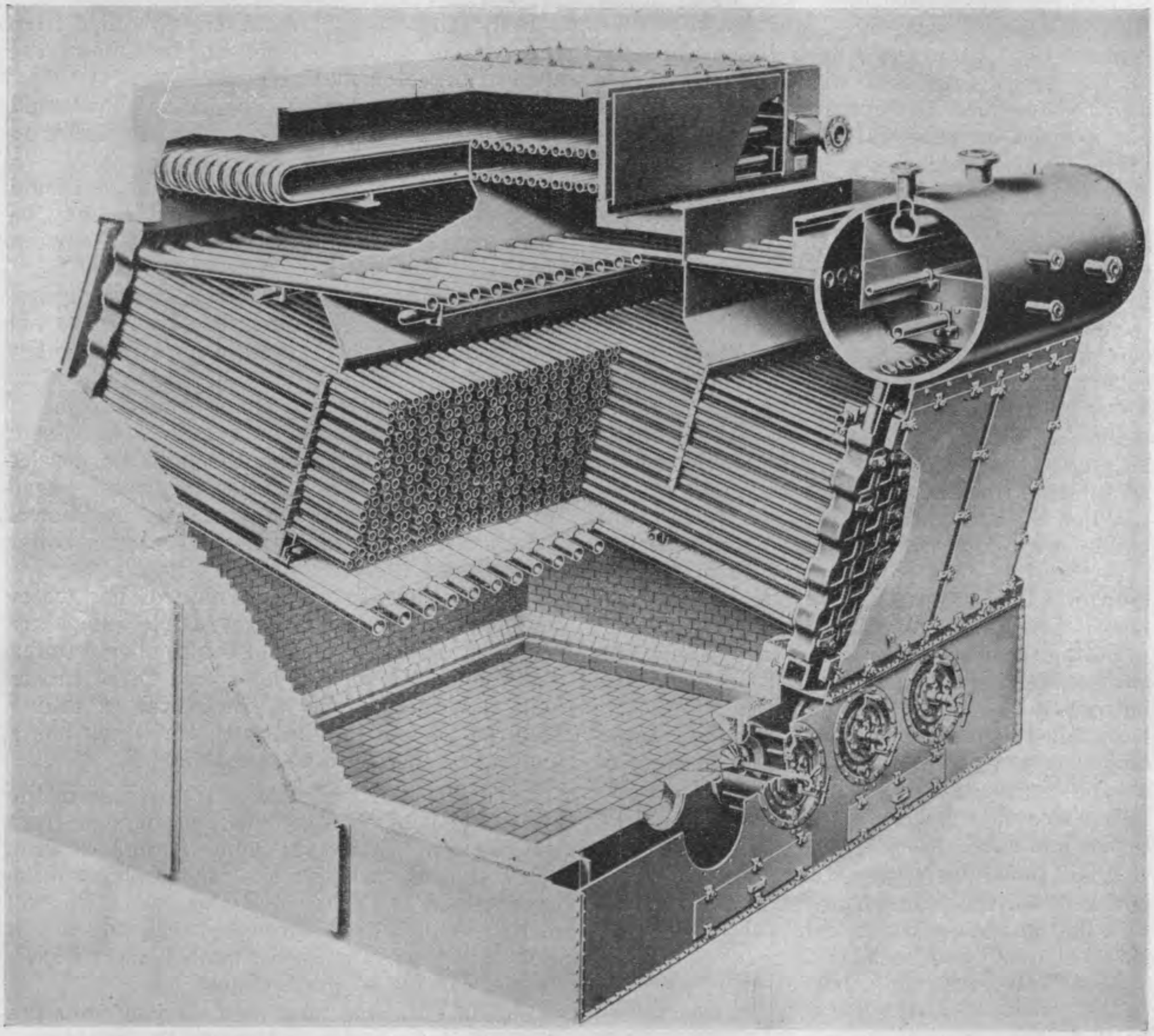
A fusible plug is threaded into a hole in the crown sheet of each combustion chamber from the fire side. Should the boiler water level drop below the crown sheet, the fusible plug will be unprotected by water and the banca tin will melt, leaving a hole through which steam will blow into the combustion chamber and furnace, giving warning to the fireman.

Should a fusible plug melt on you, shut the fires off immediately and notify the engineer.

Fusible plugs are ordinarily renewed once each year.

WATERTUBE TYPE BOILERS

Due to the many disadvantages of the Scotch boiler, marine engineers began to develop the watertube boiler for marine use, starting around the year 1900. As watertube boilers require much purer feedwater than Scotch boilers, their general acceptance was slow for a time due to lack of water-treating knowledge in those days. Many watertube boilers were installed in American ships during the large ship construction program of the first World War and since



B & W (BABCOCK AND WILCOX) STRAIGHT TUBE, CROSS DRUM WATERTUBE BOILER

that time the majority of boilers installed in American ships have been watertube.

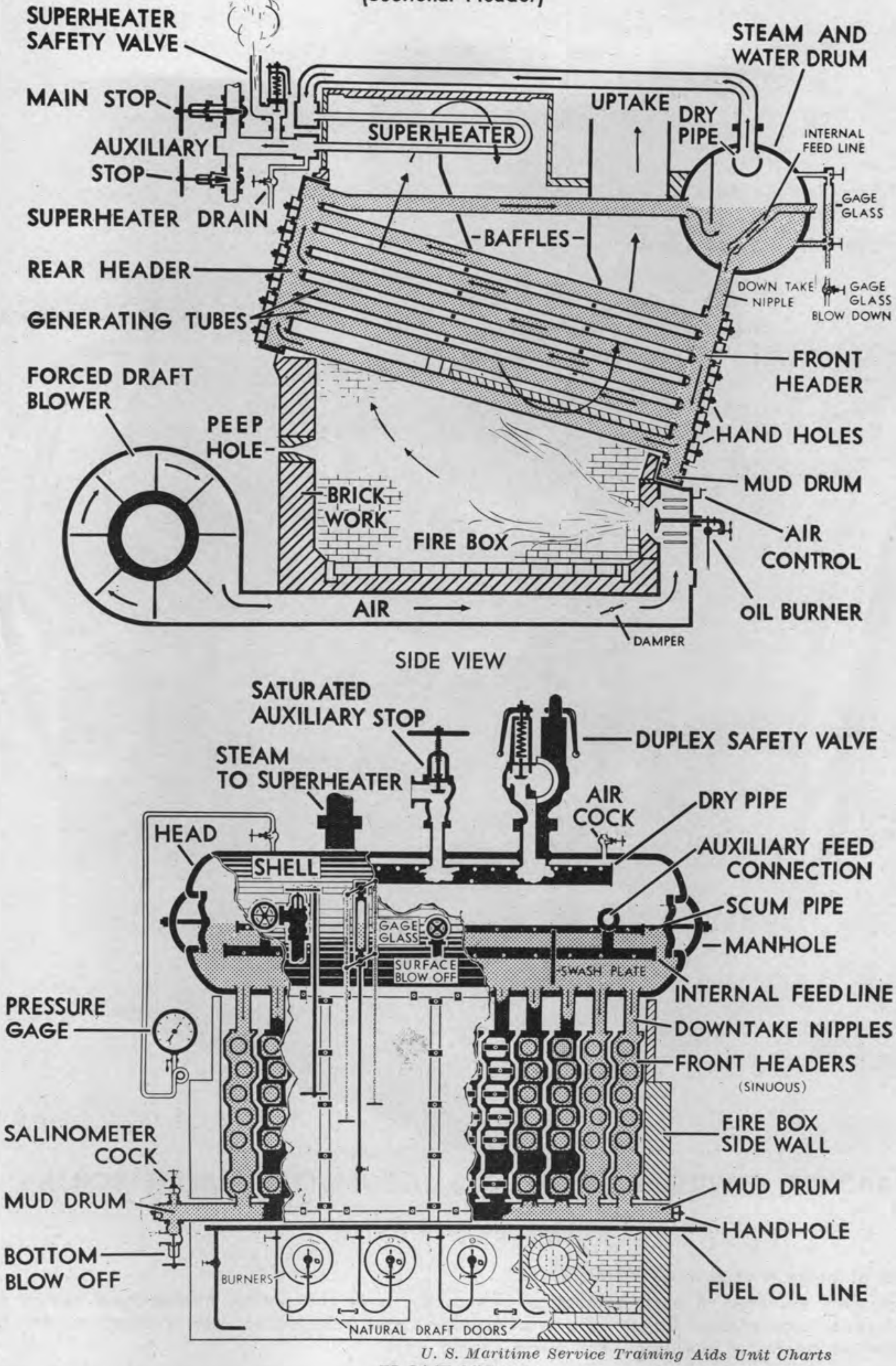
The principle of operation of a watertube boiler is the opposite of a firetube in that the water and steam are inside the tubes while the fire flows around the outside.

There are several different types of marine watertube boilers depending upon the pressure desired, amount of steam needed and the type of ship. A type that is very popular, having been installed in most of the older ships having watertube boilers, and in practically all of the new Liberty Ships and many others, is the B & W "straight tube, cross drum." The cross sectional sketches are of this type.

The steam and water drum consists of a cylindrical steel shell about 42 inches in diameter and several feet long, the ends being closed with dished steel heads. Downtake nipples (short tubes)–lead from the bottom of the drum into the top of the front headers. Hundreds of tubes in an inclined position lead from the after side of the front headers to the forward side of the rear headers. The top of the rear headers is connected to the after side of the steam and water drum by the return tubes. Below the tubes is located the firebox which consists of four brick walls and a brick floor.

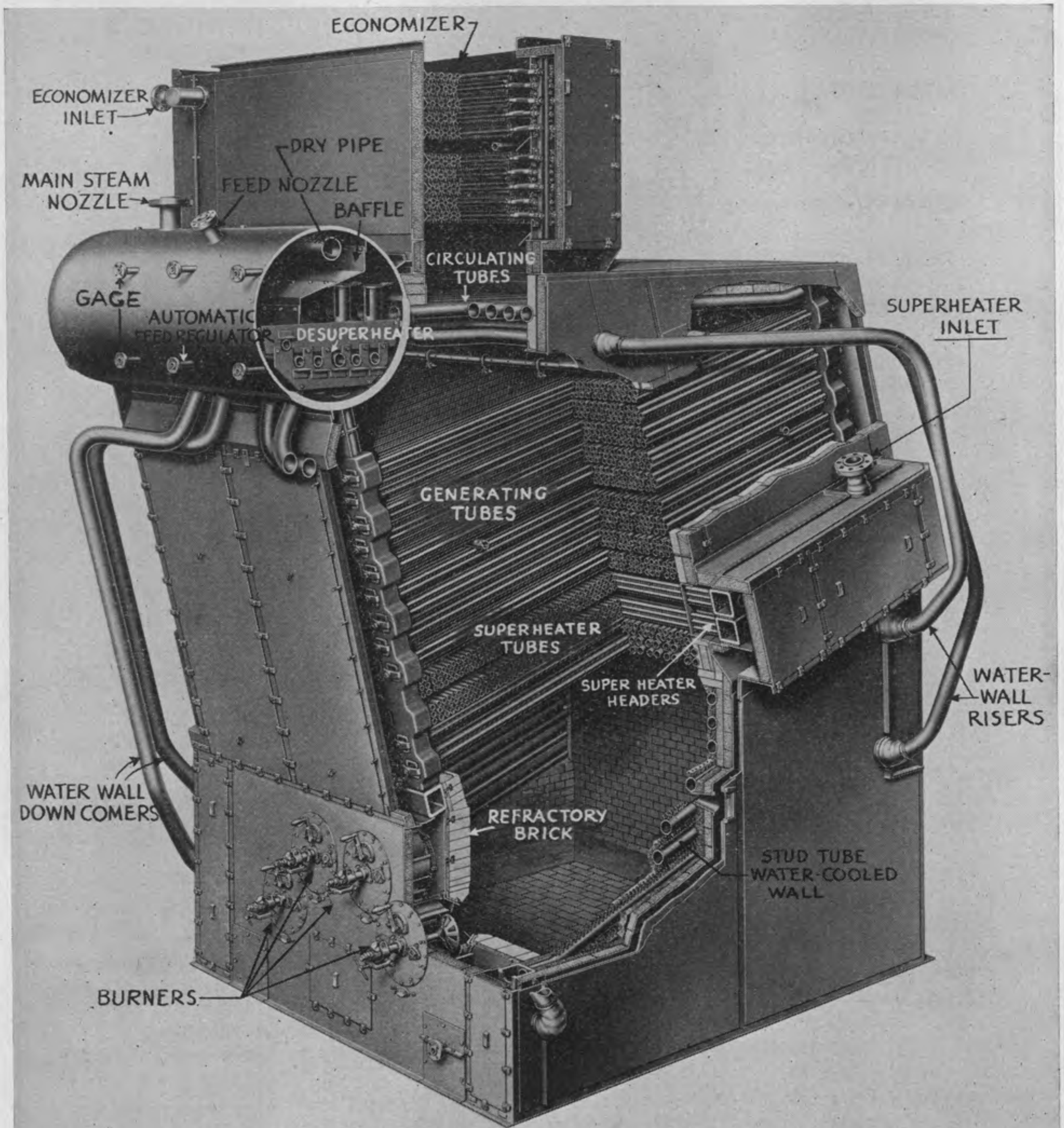
B & W STRAIGHT TUBE, CROSS DRUM WATERTUBE BOILER

(Sectional Header)



U. S. Maritime Service Training Aids Unit Charts

FRONT VIEW



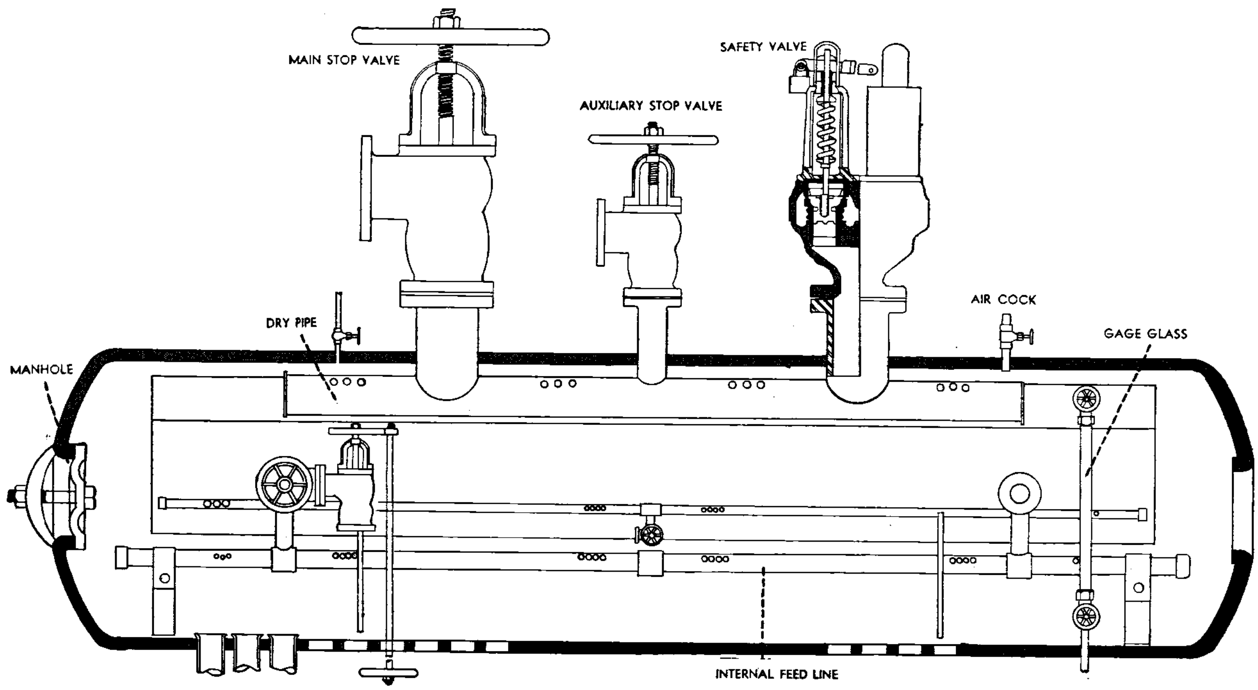
BABCOCK & WILCOX SINGLE-PASS HEADER-TYPE MARINE BOILER

VICTORY SHIP BOILER

This type of boiler is used in all Victory ships.

Two such units are used in each installation. The boiler is of the sinuous header type and is equipped with an interdeck superheater. Other apparatus includes a stud tube economizer, a desuperheater to supply low temperature steam for auxiliaries; and water cooled walls.

This type of boiler operates at a pressure of about 450 lbs. per square inch and at 750° F. steam temperature.



STEAM AND WATER DRUM

The oil burners are located in the front wall of the firebox.

The boiler is filled through the steam and water drum. As the water enters, it flows downward through the downtake nipples, gradually filling up the headers and tubes. Water is allowed to enter until the drum is half filled.

When the oil burner is placed in operation, the fire and hot gases produced in the firebox pass upward around the rear portion of the tubes as shown by the arrows, being directed in their travel by the baffles which are nothing more than partitions between the tubes. The hot gases pass to the top, around the superheater tubes and then turn down passing around the center portion of the tubes. The gases upon striking the top of the horizontal baffle resting on the top of the bottom row of tubes, turn under the bottom of the second vertical baffle and then flow upward around the front portion of the tubes, from there passing into the uptake and smokestack.

This is known as a three-pass boiler, as the hot gases pass in three different directions over the tubes causing the gases to slow down, giving the water in the tubes more time to extract their heat.

As the fire and hot gases pass around the outside of the tubes much of their heat is conducted through the walls of the tubes into the water inside.

As the water in the inclined tubes is heated it becomes lighter and rises, flowing into the rear headers where it rises to the top and flows to the steam and water drum through the return tubes.

In the meantime the cold water in the drum being heavier sinks down the downtake nipples into the front headers from where it flows into the tubes replacing the water heated. This cold water is in turn heated and rises. This circulation goes on continually while the boiler is in service. As the water is all flowing in one direction the circulation in a watertube boiler is good.

Tubes—The tubes are known as generating or evaporating tubes and are made of seamless drawn steel. Although their size varies in different boilers, the majority are 4-inch diameter in the bottom row and 2-inch for all others. Some of the newest of this type boiler, however, have very small tubes, 1-inch or 1¼-inch diameter, being installed very close together, which slows down the speed of the rising gases, making it possible to operate efficiently without baffles. The tubes are expanded for tightness in the tube holes of the headers in the same manner as the firetube boiler. The projecting ends, however, are flared or belled outward instead of beaded as the ends are in water and not exposed to fire. The flaring prevents the tubes from pulling out of the headers in event of loosening up.

Headers–The headers are of the sectional type, being sinuous from top to bottom. This permits staggering the position of the tubes vertically which aids in slowing down the flow of fire and gases. The headers are made of forged steel, their cross section being square. Opposite the tube ends are handholes to permit tube cleaning and repairs.

Muddrum–Attached to the bottom of the front headers by short nipples is the muddrum which is a small square box of forged steel extending entirely across the boiler beneath the headers. This being the lowest point in the boiler circulation, the mud and sediment settle into the muddrum and to protect the box from over-heating, brickwork is installed between it and the firebox. Attached to the bottom of the muddrum at one end is the bottom blowoff valve and to the top the salinometer cock.

Steam and Water Drum–On page 33 a cross-sectional view of the steam and water drum shows the various valves and fittings. The dished heads at each end are secured to the ends of the shell plate by fusion welding in all modern boilers. In the center of each head is an elliptical shaped manhole opening, about 11 inches by 16 inches in size, which is sufficiently large for the average sized man to enter the drum for cleaning and repair work. The left-hand head has the manhole plate in place with a gasket between it and the head for tightness. The gaskets are the ring type generally of woven asbestos. When installing they should be well coated with a mixture of flake graphite and steam engine cylinder oil, to prevent the gasket from burning fast to the plate and head. Never enter an empty boiler until positive that all valves are closed, sign on front of boiler stating that there is a man inside, and the engineer knows you are entering. Men have been scalded to death from steam or boiling water entering through an open valve from another live boiler.

Attached to the top of the drum are the pipe line to the pressure gage, the main stop valve, auxiliary stop valve, duplex safety valves and air cock.

Inside of the drum the dry pipe may be seen running along the top with the main and auxiliary stop valves and safety valve connecting into it. A few of the small holes through which the steam enters along the top can be seen.

The small perforated pipe line running along the center of the drum is the surface blowoff scum pipe which takes the place of the scum pan. The surface blowoff valve shown attached in the center of the pipe is actually on the outside of the drum.

The main feed check valve and stop valve are on the outside of the drum near the left end. The check valve is provided with a reach rod to permit its adjustment from the floor plates by the fireman. The feedwater passes into the perforated internal feed line which extends the length of the drum to permit the feedwater to be discharged downward into all the downtake nipples. The auxiliary feed check and stop valves not shown, connect onto the right-hand end of the same internal feed line.

One of the water gage glasses complete with its top and bottom connection shutoff valves, is shown near the right-hand end of the drum. In most of the boilers the water level should be carried midway of the glass.

The downtake nipples lead out of the bottom entirely acros the drum, each nipple discharging into the top of a separate front header. Only three of these are shown.

Superheater–The convection type superheater shown at the top rear of the boiler consists of a number of 2-inch tubes bent in the shape of the letter U, which allows the tubes to expand and contract at will. The saturated steam from the steam and water drum passes through the steam line into the superheater inlet header, then through the U tubes into the outlet header from which it passes into the main steam line. The steam passing through the U tubes picks up considerable heat from the hot gases flowing around the outside of the tubes. This added heat gives the steam more energy without increasing its pressure. At the superheater outlet a main and auxiliary steam stop valve and a thermometer and pressure gage connection are provided. (See page 31.)

Other type superheaters are interdeck, installed about midway between the banks of boiler generating tubes; and radiant located near the radiant heat of the firebox. The nearer to the fire the superheater is installed, the hotter will be the superheated steam.

When firing up a cold watertube boiler care must be exercised not to put too large a fire in the firebox, otherwise the superheater tubes will be damaged from overheating due to the fact that there is no steam to flow through the tubes to protect them until steam is formed in the boiler.

Firebox–The firebox walls are of high temperature firebrick to resist and hold inside the 2000° F. or more temperature of the burning fuel. The front wall around the oil burners is formed with special cone-shaped high temperature refractory material. Unless the brickwork is treated properly it will soon crack, crumble and begin to tumble down. This means repair work for the crew in port. Even slight flarebacks (combustion explosions) from careless handling of the oil burners can cause damage to the brickwork. Allowing cold air to blow in on the hot brickwork when shutting down a boiler will also cause damage.

When this type boiler is built to operate at high pressures it is necessary to protect the firebox brickwork from the increased firebox temperatures. This is accomplished by installing waterwall tubes. These tubes are of the same general type as the generating tubes but are located either in an inclined or vertical position in front of or within the firebox brick walls. The tubes are connected into the circulation of the boiler and installed very close together. In this manner practically the entire brickwork is protected from the heat by a wall of water. The heated water in the tubes rises to the steam and water drum and returns to the tubes from the drum by an outside pipe connection. Besides protecting the brickwork, the waterwall tubes provide additional heating surface, making it possible for the boiler to produce more steam.

Baffles–Act as partitions between the tubes to slow down the hot gases and direct them over all of the tube heating surface. Those near the firebox are made of high temperature refractory material to withstand the heat while those between the tubes may be of cast iron.

Baffles can also be damaged by slight flarebacks.

Sootblowers–With the best combustion, burning fuel oil produces some soot, which travels with the hot gases and lodges on the outside of the tubes. Ordinarily this should be removed each day, otherwise the heat has difficulty getting to the tubes, resulting in fuel wastage. Today practically all oil burning boilers are equipped with sootblowers which make an easy job of removing the soot. Four sootblower elements are usually installed in the straight tube cross drum type watertube boiler shown in the two views. A sootblower element consists of a long pipe extending through one side wall of the boiler, between two rows of tubes nearly to the opposite side wall. Holes are located all along one side of the pipe. Dry steam is admitted from the boiler through the sootblower control valve on the end of the pipe outside the boiler side wall. As the pipe is slowly turned from the outside, the steam escapes through the holes, blowing the soot from the outside of the tubes. An excessive amount of forced draft is used during this operation to carry the loosened soot through the passes and up the stack overboard.

When operating it must be made certain that dry steam is used, as wet steam will mix with the soot, setting up a condition that will cause rapid corrosion of the tubes.

Sootblowers must be kept in adjustment, otherwise the escaping steam may rapidly cut holes in the tubes.

During wartime sootblowers must only be used when authorized, due to the danger of smoke being seen by the enemy.

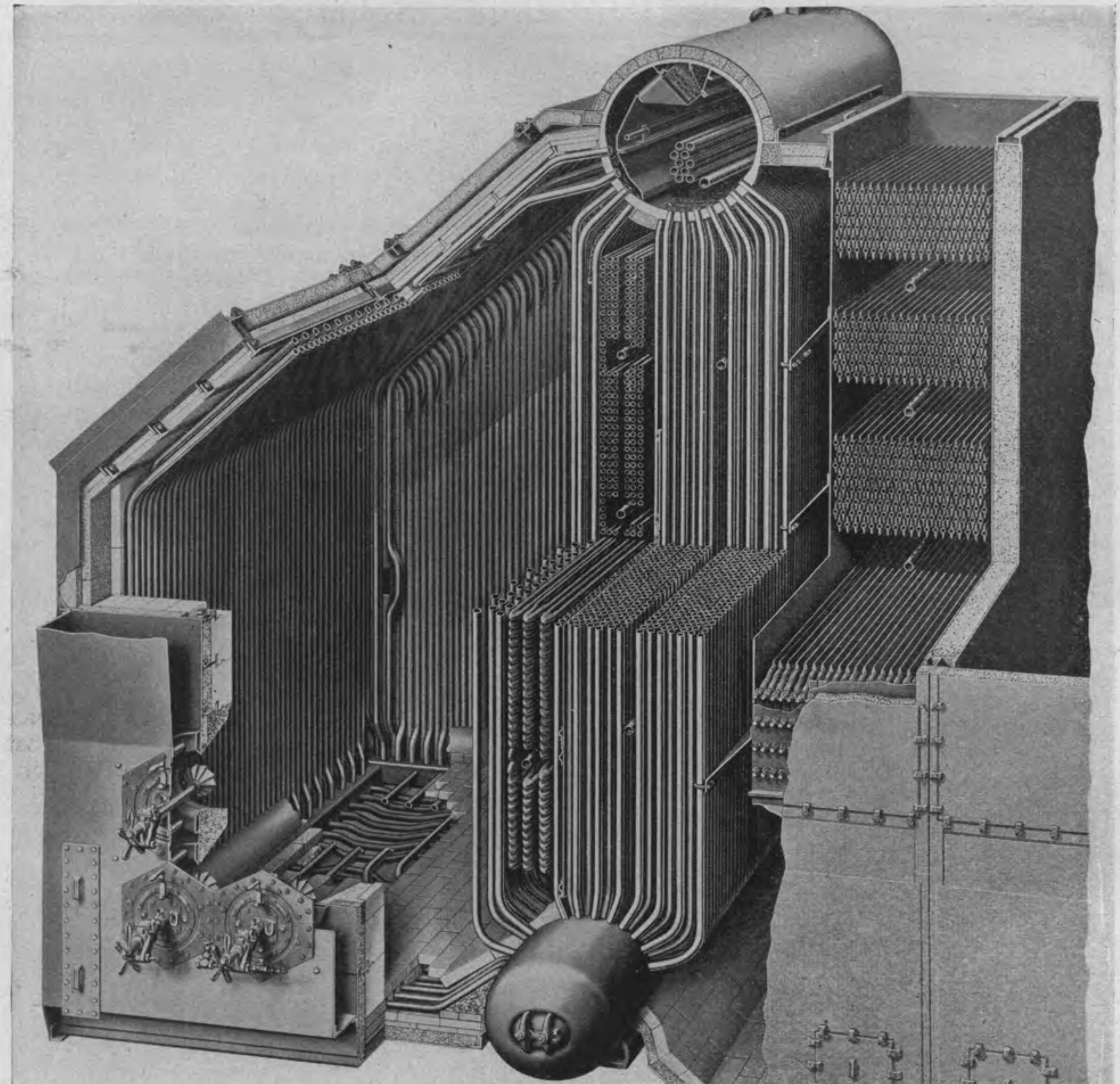
Scale and Oil–One of the most important things in successful, trouble-free, watertube boiler operation is to keep the water side of the boiler clean. Any appreciable formation of scale or mud in a tube directly over the fire is almost certain to cause overheating with resultant tube failure. Modern methods of treating the water in the boiler practically eliminate this possibility if the treatment is properly kept up.

Oil and grease are almost certain to cause tube failure, especially if the boiler is being forced.

Dangerous Water Level–As in all boilers, the water level in a watertube boiler must not be allowed to drop below the bottom of the gage glass. To do so may leave some of the boiler tubes dry, resulting in their overheating. Although the danger of disastrous explosion may not be as great as in a Scotch boiler, terrific damage has been done to both men and property by a bursting boiler tube. The most important job of a fireman and watertender is to keep the water level in sight and at its proper steaming level.

Advantages–Due to the diameter of the drums being relatively small, watertube boilers may be constructed for very high pressures, at least one boiler having been built for 2,000 pounds per square inch. Since they are smaller and lighter than the Scotch boiler, it is possible for the ships to carry more cargo.

Steam may be raised quickly on a cold boiler. If necessary it may be safely done in an hour with most boilers.



C-E MARINE TWO-DRUM WATERTUBE BOILER

This modern type, high pressure, bent tube boiler, is also known as "D" type. It is installed on some of the high speed tankers and cargo vessels.

Its construction is compact, fitting nicely into the ship's hull.

The oil burners are located in the front of the firebox at the left side. The firebox walls are lined with waterwall tubes, the top ends of which enter the steam and water drum. The bottom ends are expanded into a header, which is connected to the muddrum by floor tubes.

The superheater tubes are of the radiant type, located near the firebox, between the vertical generating tubes.

The economizer tubes are at the lower right-hand corner and above them the air preheater tubes.

In operation the fire and hot gases pass upward around the waterwall tubes and generating tubes nearest the firebox. A vertical baffle directs the hot gases downward around the right-hand section of generating tubes. From here they turn upward passing around the economizer and air preheater tubes to the uptake and stack.

The hottest gases are in the firebox, causing the water in the tubes surrounding it to rise upward from the muddrum to the steam drum. From there it settles down the cooler generating tubes at the right side.

Watertube boilers may be forced without harming them.

The water and steam being separated into relatively small sections reduces the possibility of a disastrous explosion.

Watertube boilers may be assembled in the ship, making for easier installation in many cases.

Disadvantages–Due to the small amount of water contained and steam stored it is more difficult to maintain a steady steam pressure and water level, especially when the main engine is being maneuvered. The fireman must act quickly at this time, when lighting off and shutting down burners and adjusting feed check valves.

Watertube boilers must have better water than the Scotch marine.

Watertube boilers cost more to build.

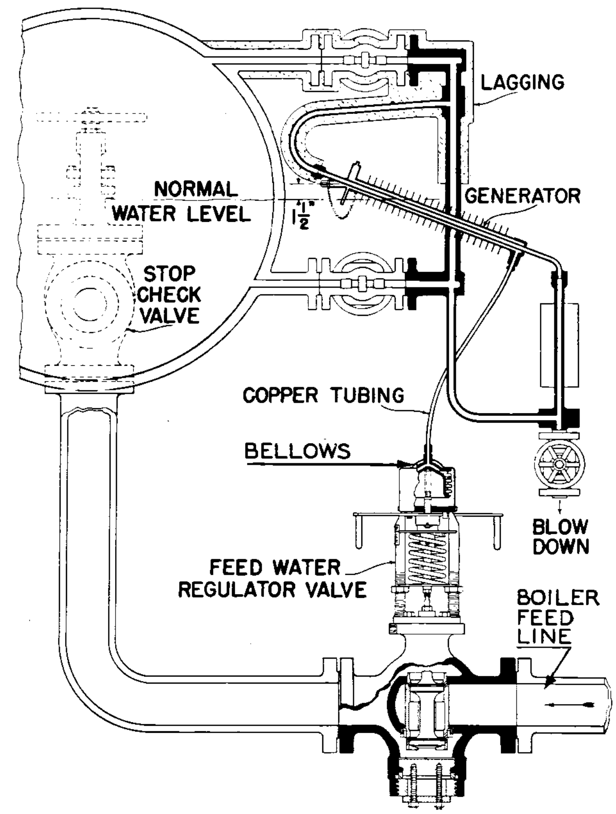
Due to the firebox being constructed of brickwork there is apt to be more repair work.

AUTOMATIC BOILER FEEDWATER REGULATORS

Most modern marine boilers operating from pressure of 400 lbs. upward are equipped with automatic feedwater regulators which maintain a proper water level without the necessity of manual regulation of the feed check valves. Each boiler has its own regulator located in the main feedline just before the feed check and stop valves. Although most regulators satisfactorily maintain the proper water level always remember that, as a mechanical device, it should not be trusted. The water gage glass should be watched as closely as though the feedwater was being regulated by hand.

One type of automatic regulator works on the principle of a float on the surface of the water in the steam and water drum. As the float rises and falls it operates, through a lever arrangement, a regulator valve in the feedline. When the float drops, the regulator valve opens, allowing feedwater to enter the boiler. As the water level rises so does the float which, by closing the regulator valve, decreases the amount of water entering the boiler.

Shown in the cross-sectional sketch is another type of feedwater regulator, known as the Bailey Thermo-Hydraulic Feedwater Regulator, which operates on the thermo-hydraulic principle. This consists essentially of a pressure generator and a feedwater regulator valve. The generator is a metal tube which is surrounded by a larger metal tube. The upper end of the inner tube is connected to the steam space of the boiler. The lower end of the inner metal tube is connected to the water space of the boiler. The outer is connected by copper tube to a metal bellows in the feedwater regulator valve. The space between the inner and outer tubes is filled with water. The steam in the inner tube causes the water surrounding it



BAILEY AUTOMATIC FEEDWATER REGULATOR

to flash into steam, building up a pressure which forces the water down the copper tube into the bellows. This pressure causes the metal bellows to expand, forcing the feedwater regulator valve open against the tension of the coil spring. When the water level rises in the boiler it also rises in the inner tube taking the place of the steam. As this water is relatively cool from having been trapped in the U-leg, it lowers the temperature of the water between the inner and outer tubes. Contraction of the water in the bellows permits the coil spring to close the regulator valve.

To remove any accumulation of sediment in the water leg, the blowdown valve should be opened once each twenty-four hours.

DRAFT

To make steam, fuel must be burned, but before fuel can burn oxygen must be supplied to it as it is the oxygen combining with the carbon in the fuel that results in combustion. Air contains oxygen, so air must be supplied to the furnace or firebox of a boiler and the method of doing this is called draft.

NATURAL DRAFT

The only type of draft known for many years was natural draft. When a fire burns in the open, such as a bonfire, natural draft occurs. What happens is that the hot gases given off by the burning fuel are lighter than the surrounding air and rise upward. The colder surrounding air being heavier sinks down and flows into the fire.

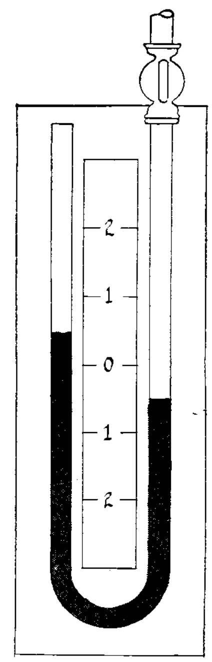
In a boiler the hot gases rise up the stack and the relatively cold air in the fireroom sinks down and flows into the front of the furnace. The hotter the gases in the stack and the colder the air outside, the better will be the draft. The direction and strength of the wind and the ship's course and speed also have an influence on natural draft. It is evident then that the amount of natural draft is for the most part dependent upon several uncontrollable factors, which limit the amount of fuel that may be burned in a boiler. This in turn limits the amount of steam that can be produced. When a greater quantity of steam is necessary some other means of supplying air must be provided. This is known as forced draft.

FORCED DRAFT

Forced draft is used entirely with oil-burning marine boilers and to a considerable extent with coal. There are several types of forced draft, the most popular type being where a large steel-bladed fan known as a blower is used. The fan takes air from the fireroom or engine room and blows it through a sheet metal duct (trunk) to the furnace front which is sealed from the fireroom to prevent natural draft from entering. By controlling the speed of the fan the exact amount of air needed for proper burning of the fuel can be supplied at all times. The blower is driven by a steam engine or an electric motor.

Closed Fireroom–In a few large passenger ships a type of forced draft known as closed fireroom is used. With this type the fireroom is sealed and the blower, which is located above it, forces the air directly into the fireroom, placing the entire fireroom, including the fireman, under pressure. The furnace fronts around the oil burners are left open, allowing the air to rush into the furnaces. When entering or leaving a fireroom of this type it is necessary to pass through an air lock, otherwise the air pressure would rush out when the door is opened.

Induced Draft–Still another type is induced draft. With this the blower is located in the uptake leading from the boiler to the stack. The blower creates a small vacuum in the furnace, causing the fresh air in the fireroom to rush in through the open furnace fronts. Another method of producing induced draft, no longer used, is a steam jet pointing upward in the stack. The velocity of the escaping steam leaving the nozzle creates a vacuum which causes the air to rush into the furnace. The large waste of heat and water prohibits its use.



MANOMETER (DRAFT GAGE)

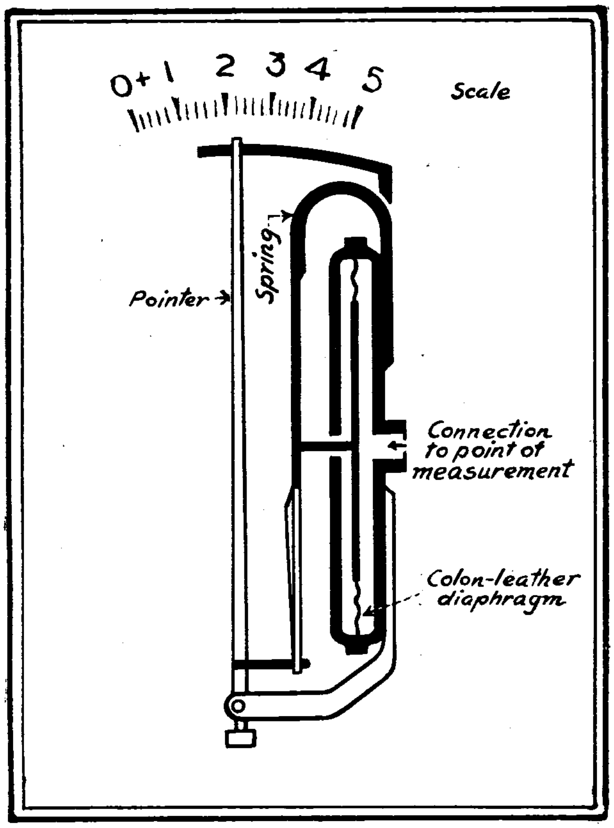
DRAFT GAGE

Draft pressure is so slight that it cannot be measured with an ordinary pressure gage so a glass U tube known as a manometer is used. One end of the tube is connected by a small pipe line to the duct through which the air is being blown to the furnace or to another part of the boiler or uptake. Between the legs of the tube is a scale graduated in inches. The U tube is half filled with colored water. When the blower is started up, the air pressure in the duct becomes greater than the atmosphere and travels down the pipe pushing the water down somewhat in that leg of the U tube. This causes the water to rise up a corresponding amount on the open leg. The distance in inches between the water levels in the two legs is the pressure of draft. When the blower is speeded up the number of inches between the water levels becomes greater. When slowed down they become less. Draft then is measured in inches of water, one inch being equal to about .036 of a pound pressure.

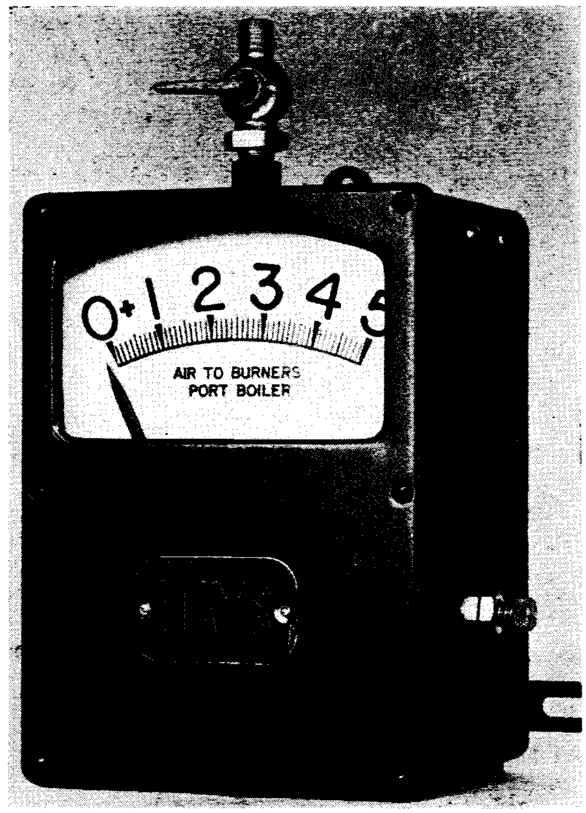
against the side of a slack leather diaphragm. This pushes the diaphragm in and through a series of connected levers, links and springs the pointer is moved over a graduated scale marked in inches. To determine the amount of draft the fireman merely has to note the particular number of inches in front of the pointer.

Draft gages are usually located in the fireroom at a point easily visible to the fireman.

Draft pressure drops rapidly as it flows along a duct or passes through the boiler. In modern boilers draft gages are connected to several points in the boiler and uptakes so that the draft pressure all through the boiler may be known at all times.



CROSS SECTION HAYS GAGE



HAYS DRAFT GAGE

Modern marine power plants quite often use the Hays leather diaphragm type gage, which operates on an entirely different principle. In this gage the air pressure enters through a connection from the duct or furnace and pushes

In wartime it is especially important that the proper amount of draft be carried at all times to prevent a smoking stack. In the daytime a little too much draft is better than too little. At night excess draft may cause sparks to fly from the stack.

FUELS

Anything that will burn may be called a fuel. The only kinds used in marine boilers are coal and fuel oil.

COAL

Up until the first world war, bituminous (soft) coal was about the only fuel used in marine boilers, but at that time fuel oil began replacing coal in American ships until today nearly all burn oil. There are, however, a few coal burners left which necessitates a brief discussion of coal and its burning.

Bituminous coal contains on the average about 14,500 B.T.U.'s per pound, and upon analyzing the coal we find that it contains more than half carbon, about a third volatile matter and a small ash and sulphur content. It is the carbon in the coal uniting with the oxygen in the air that produces the fire.

Handling and Firing Coal–All coal burning marine boilers are hand fired, which means that more firemen are required than when oil fuel is used, and in addition, several coal passers.

Greater time and expense are required to load coal and more space is required for its storage, resulting in less cargo space than with oil fuel. The coal is stored in bunkers (compartments) adjacent to the fireroom, from whence it is removed in buckets or wheelbarrows by the coal passers who pile it on the fireroom deck plates as needed. The firemen, using scoops, shovel it into the furnaces.

The best firing results, with least smoke, are usually obtained by carrying a thin fire. This requires that the fireman shovel in coal in small amounts and often, rather than large amounts less often. This procedure will depend somewhat upon the quality of the coal; however, it is generally found to be the best firing method.

In most cases it is best to spread the coal evenly over one-half of the fire at a time rather than to cover the entire fire with green coal. This alternate firing makes for steadier steaming and less smoke.

As the coal burns, ash and clinkers form within the fuel bed next to the grate bars and must be removed. To remove the ashes, the slice bar is pushed inward beneath the fire on the top of the grate bars. This causes the ash to drop through the grates into the ash pit. This also breaks up the fuel bed sufficiently to permit air to pass through.

The presence of dark spots in the ash pit indicates that clinkers have formed in the fuel bed. These must be removed, as they reduce the heat of the fire. To do this requires that the fire be cleaned frequently.

To clean a fire, one side of the fire is allowed to burn down until only the clinkers and ashes are left. These are pulled out the furnace front onto the deck plates by the fireman, using a long-handled hoe. The heat of the clinkers falling on the deck plates is quenched by sea water from a hose in the hands of the coal passer. The clinkers and ashes are placed in steel buckets, hauled topside and dumped overboard, unless an automatic ash ejector is provided.

When the one side of the fire has been cleaned, the best part of the uncleaned side is thrown over on the clean grates with a slice bar, and a little green coal is then spread lightly over this new fire. The clinkers and ashes are then hoed out of the unclean side. By the time this is completed, the first side cleaned is burning up brightly and may be spread evenly over the entire grate surface. It is sometimes necessary to take a scoopful or two of burning coal from another furnace. A fire must be cleaned very quickly, as cold air is rushing into the furnace while the door is open, chilling the boiler.

Removable ash pit doors are used to cut down the natural draft, should it become too strong. Also to control the draft, adjustable dampers are installed in the uptakes.

Only through experience is a good coal burning fireman made. No amount of theory can teach him the proper handling of the scoop, hoe and slice bar, upon which depends entirely the efficient burning of the fuel and steady steam pressure.

FUEL OIL

Fuel oil has a number of advantages over coal as a fuel for marine use. Being in liquid form, it is brought aboard through a hose, eliminating much hand labor. It is stored in spaces of the ship not possible with coal, such as the double-bottoms, which means more space available for cargo. Less firemen are required in the handling and burning of coal. The problem of ash