disposal is eliminated. The engine compartment and the ship in general can be kept much cleaner. The steam pressure can be kept steadier than with coal. When burning oil it is not necessary to continually open and close the furnace doors, doing away with large amounts of cold air rushing into the furnace and chilling the boiler which often results in leaky tubes.

Although the price of oil is usually higher than coal its many advantages make it more economical to burn in the long run.

Fuel oil is a heavy-bodied oil that is the residue left from crude oil after the various grades of gasoline, kerosene and lubricating oils have been removed at the refinery.

It consists of about 85% carbon and the remaining 15% consists of hydrogen, oxygen, nitrogen, sulphur, sand and water.

The principal measures of the properties of fuel oil are:

Flash Point–The temperature at which the oil gives off vapors that will ignite but will not burn steadily. The oil becomes dangerous at this point, as explosions can occur. When handling and storing, fuel oil must be kept below this temperature for safety's sake. Rules and regulations require that marine fuel oil shall not have a flash point below 150° F. This is to prevent inflammable vapors from forming in the storage tanks under ordinary atmospheric conditions. The flash points of fuel oils vary according to the body of the oil. It can only be determined by test.

Fire Point–is a temperature above the flash point at which the oil gives off vapors that burn continuously.

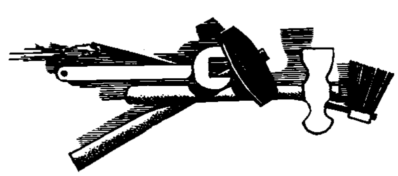
The flash point and fire point may be determined by heating oil in an open dish in which is placed a thermometer. An open flame is held above the oil. When spurts of flame occur the temperature of the oil is noted. This is the flash point. When the vapors given off burn steadily the temperature is again noted. This is the fire point.

The temperature of the fuel oil at the burners must be sufficient to permit the oil to atomize thoroughly.

Viscosity–is a measure of the oil's body, which means its rate of flow. A heavy-bodied oil flows more slowly than a light-bodied one.

Temperature affects the viscosity. When an oil is cold the viscosity increases, when hot it decreases.

The viscosity of an oil is determined by passing a sample of the oil to be tested through a viscosimeter. Briefly, a viscosimeter consists of an open dish in which 60 c.c. of the oil to be tested is poured. It is heated to a standard temperature of 70° F. When 70° F. has been reached the oil is allowed to run out the bottom of the dish through a standard-sized opening. The number of seconds it takes for the oil to run through is the Saybolt second viscosity of the oil. The heavier the oil the longer it will take for it to run through and the higher will be its viscosity. The lighter the oil the quicker it will run through and the lower will be its Saybolt second viscosity.



OIL BURNING INSTALLATION

The simple principle of burning fuel oil is to reduce the viscosity to the proper point and place it under pressure so that the oil burner can break it up into many small particles like a mist, in which form it sprays into the firebox or furnace. This permits the thorough mixing of air with the oil, necessary for good combustion, and is known as atomization.

Several pieces of equipment, which are known as the Oil Burning Installation are required for the storing, handling and heating of the oil. The sketch shows the relative location of the various pieces of equipment in a typical mechanical pressure type oil burning system.

STORAGE TANKS

Storage tanks are located in the ship's double-bottoms beneath the cargo holds and wing tanks on the ship's side. Several pieces of equipment are required to be fitted to the tanks.

For filling the tanks a filling line which branches off to each tank is installed from topside. The branch lines are equipped with shutoff valves to control the flow of oil to each tank. The filling line enters the top of the tanks and must extend downward to discharge within 6 inches of the bottom of the tank or be equipped with a gooseneck to discharge the oil upward. When taking fuel aboard constant vigilance must be maintained to prevent one or more of the tanks from being overflowed. Besides wasting the fuel, it is difficult to clean up. If fuel oil should spill into the harbor the ship may be heavily fined by the port authorities.

A vent pipe leading from the top of the tank is required to permit air and any inflammable vapors to escape to a safe point above the ship. The discharge end of the vent pipe is provided with a gooseneck and must be covered with a flame screen. The flame screen is made of wire gauze and its purpose is to prevent flame from burning vapors on the outside traveling down the vent into the tank. The screen must be kept in good condition, never painted and always in place.

Steam heating coils are necessary along the bottom of the tank so that the heavy oil may be heated to lower its viscosity so that it may be pumped. This is especially necessary when the ship is in cold water. The fuel in the tanks should never be heated higher than 150° F. To go above this may cause inflammable vapors to be given off.

Entering the top of each tank is a fire smothering pipe line equipped with control valve. CO_2 (carbon dioxide) is the most popular agent used on modern ships for fighting fire. Previously live steam was used. In the event of fire in the tank the smothering valve is opened allowing the CO_2 to flow into the storage tank and extinguish the fire.

A manhole is provided in the top of each tank to permit entrance for cleaning and repairs. *A fuel oil tank should never be entered until it has been gas freed and tested for sufficient oxygen.* Never enter without a safety line attached and someone tending it on the outside. Men have lost their lives by being careless in this respect. The breathing of oil vapors or the lack of sufficient oxygen will cause a man to be overcome very quickly.

Fuel oil is sold by volume, making it necessary to consider the temperature when purchasing.

Storage tanks are not filled more than 90% full, allowing room for expansion in the event the oil should become warmer after being stored.

TRANSFER PUMP

Transfer pump removes the oil from the storage tanks through the suction valve and line, and discharges it through the discharge line into the settling tanks.

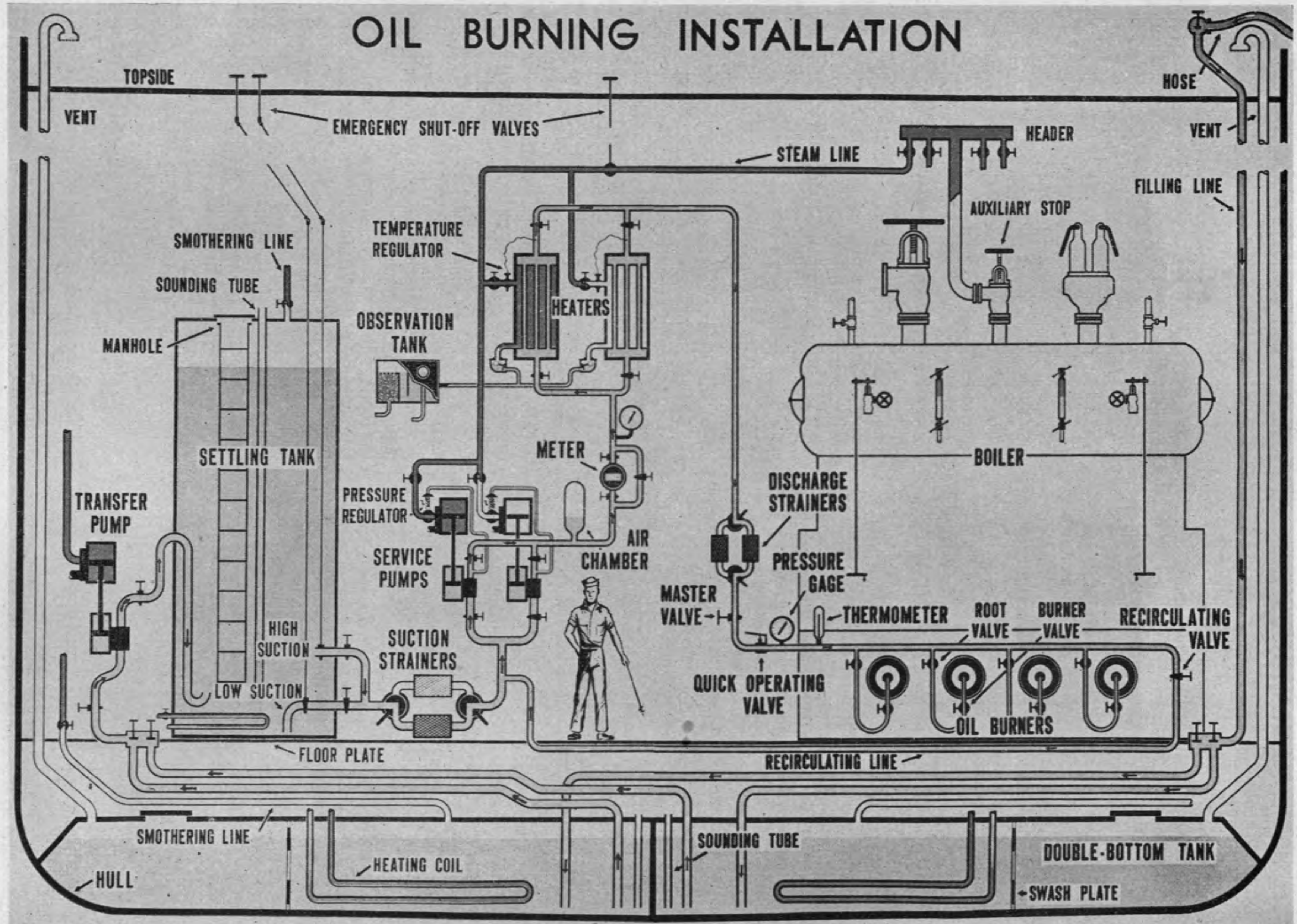
SETTLING TANKS

Settling tanks are located in the fireroom, usually one on each side. Here any water that may have come aboard in the oil is allowed to settle to the bottom. Also there is always the possibility of sea water entering the storage tanks through leaks in the ship's hull.

If water reaches the burners in any quantity the fires will go out. A slight amount will cause the fires to sputter.

The water that accumulates on the bottom of the settling tanks is pumped out through the low suction valve and discharged either overboard or into a disposal tank while the oil for the fires is usually removed through the high suction.

It will be noted that internal gate type shutoff valves with extension control rods to



U. S. Maritime Service Training Aids Unit Chart topside are provided at the high and low suctions. This is required by Rules and Regulations, to prevent flooding of the fireroom with fuel oil in the event of an emergency, such as a fire in the fireroom.

Settling tanks are provided with internal filling line, heating coils, vent pipe, and a smothering system the same as the storage tanks. After the oil passes through the external high or low suction shutoff valves it passes through the duplex suction strainers.

DUPLEX SUCTION STRAINERS

Duplex suction strainers are a basket type strainer of coarse mesh to prevent stones or other good-sized foreign matter in the oil from entering and damaging the fuel oil service pumps. Only one strainer is used at a time, the other being cleaned and kept as a standby. The strainers must be changed and cleaned each watch, otherwise they may become clogged with dirt preventing the flow of oil to the pumps.

FUEL OIL SERVICE PUMPS

Fuel oil service pumps take the oil from the settling tanks and discharge it under pressure to the fuel oil heaters and burners.

At least two pumps are required, one being a spare ready for instant service in the event of trouble with the other.

Regulation of the speed of the pump varies the pressure of the oil and controls the amount of oil being burned. The desired oil pressure for best atomization in most modern burner systems is from 100 to 250 pounds per square inch.

The steam line supplying steam to operate the pumps is provided with a shutoff valve having an extension rod leading to the topside, preferably the boat deck. This makes possible the stopping of the pump from outside the fireroom in an emergency.

METER

The oil leaving the pump under the desired pressure passes through a meter which registers the amount of oil flowing to the burners in gallons. The meter is read at the beginning and end of each watch by the engineer or fireman to determine the amount of fuel burned during the watch. Readings are entered in the engine room logbook. The meter is equipped with a by-pass line in the event of trouble.

AIR CHAMBER

An air chamber is located in the system on the discharge side of the service pumps, acting as a cushion to reduce pressure fluctuation caused by the operation of the pump.

OIL HEATERS

In the oil heaters, the oil is heated to the proper temperature to reduce its viscosity to the point where it will atomize best. This temperature will depend upon the grade of oil being used, and is usually posted in the fireroom.

All fuel oil heaters use steam as the heating agent.

One type heater is a closed steel vessel through which a number of steel coils pass vertically from head to head. As the fuel oil flows upward through the coils, which are surrounded by live steam piped from the boilers, the heat in the steam is conducted through the walls of the coils into the fuel. Since the temperature is regulated by the amount of steam allowed to enter the heater, to increase the temperature open the steam valve wider which allows more steam to flow in around the coils. To reduce the temperature, close in on the steam valve and reduce the amount of steam entering. Remember that when the amount of oil flowing through the heater changes, the amount of steam for heating must be changed.

Generally temperature is regulated by the fireman but some heaters are equipped with automatic temperature regulators which admit just the right amount of steam at all times to maintain the proper temperature.

Another type heater uses just the opposite type principle, in which steam passes through the coils while the oil surrounds them. The temperature is controlled in the same manner.

If the oil temperature is allowed to become excessively high in the heaters the fuel will carbonize in the coils and its heating ability will be reduced. This will also make it necessary to clean the coils.

Excessive temperature also causes the oil to vaporize resulting in the fires pulsating.

At least two heaters are required, one being a stand-by while the other is in service. In most systems both heaters may be used simultaneously if necessary.

The steam line leading to the heaters also has a shutoff valve with control rod reaching to topside for emergency shutoff outside the fireroom.

THERMOMETER

Thermometer is installed in the oil line on the discharge side of the heater so that the temperature of the oil is visible at all times to the fireman on watch.

DUPLEX DISCHARGE STRAINERS

Duplex discharge strainers, through which the oil next flows are of the same general construction as the suction strainers except that they are smaller in size.

As the hot oil is thin (low viscosity) it is possible for it to pass through fine mesh strainers which remove fine particles of foreign matter such as sand, which would interfere with the atomization of the oil in the burners. It is important that strainers be changed over each watch and the dirty one cleaned and left ready for the next change.

MASTER VALVE

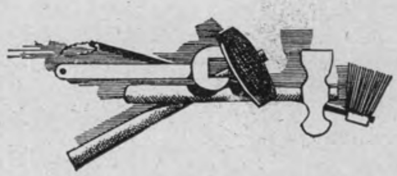
Located in the branch oil line to each boiler is a master shutoff valve. By closing them the flow of oil to all burners is stopped. Used in an emergency or when a boiler is out of service.

BURNER VALVES

Two shutoff valves are installed in the branch line to each burner providing double insurance against leakage of oil into the firebox when the burner is shut off.

RECIRCULATING VALVE

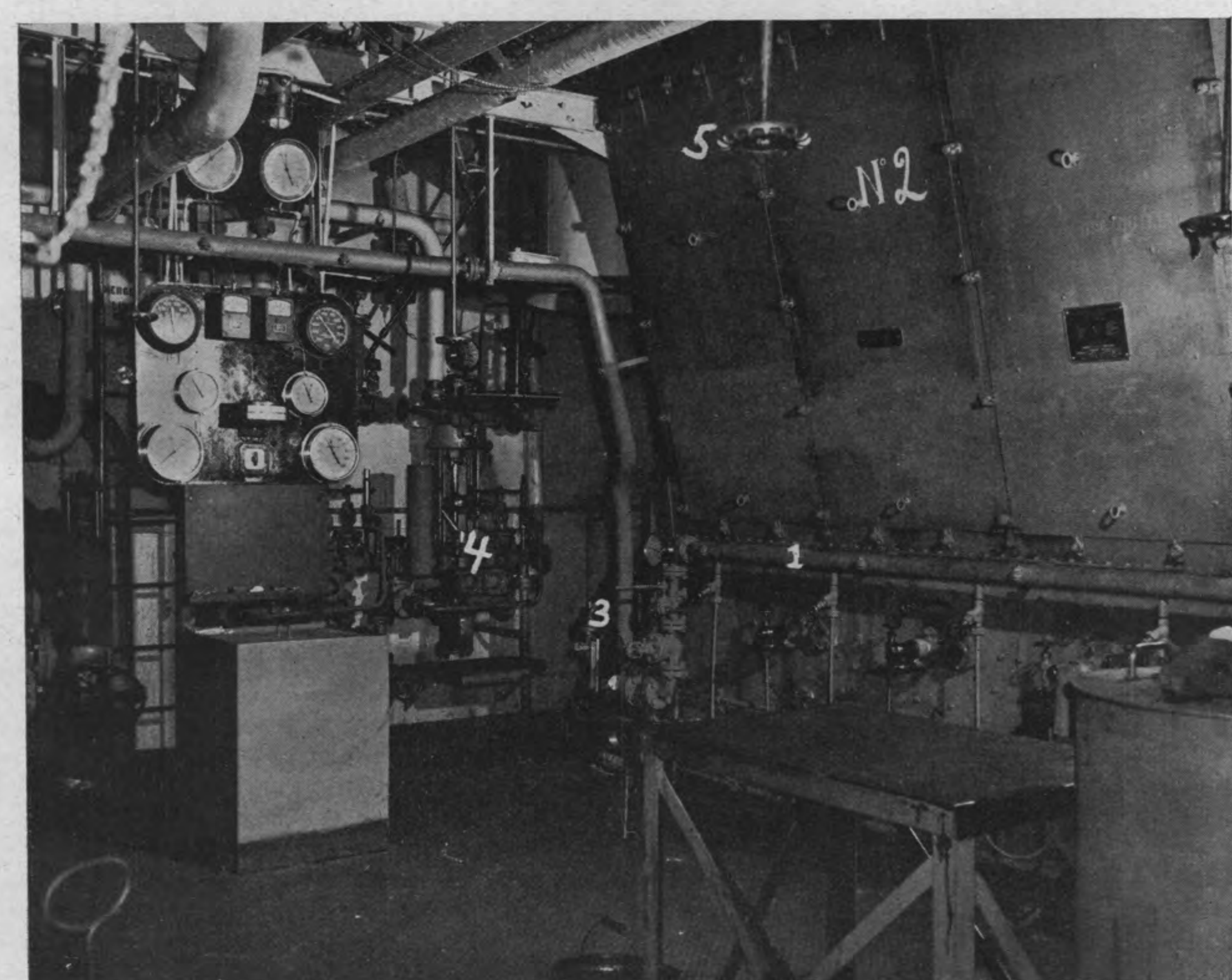
When starting up a cold oil burning system the recirculating valve at the end of the oil line is opened permitting the cold oil to return through the recirculating line back to the suction side of the service pump. When hot oil reaches the burners this valve is closed and the burners lighted.



BURNING FUEL OIL

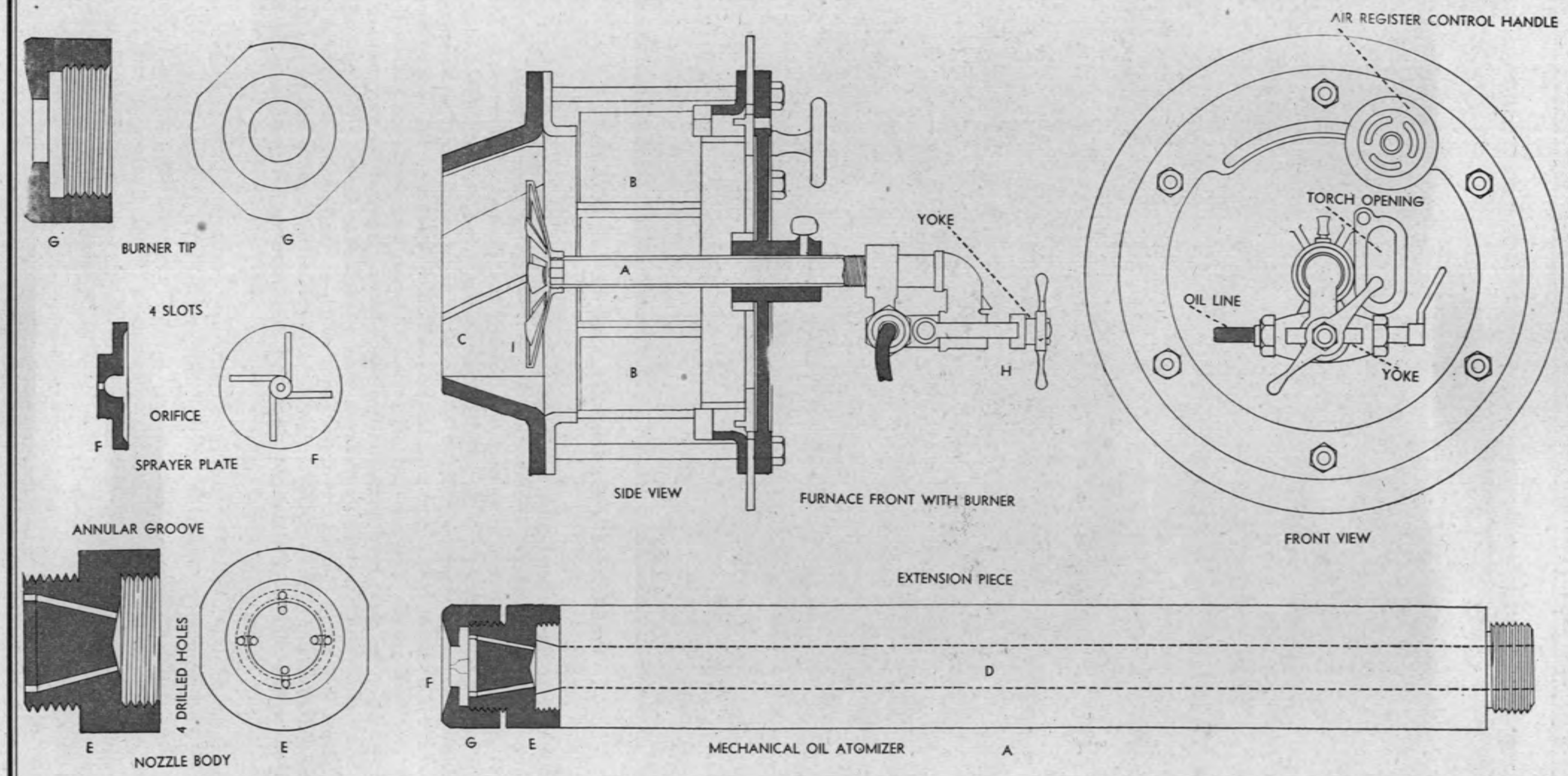
To burn well, fuel oil must be sprayed into the firebox in the form of a mist. This is known as atomization and is accomplished by the oil burner, a cross section of which is shown. The oil enters through the atomizer (A) which is the heart of the burner. The air enters the firebox around the atomizer through the air register openings (B). The air scoops (C) direct the air into the firebox in the proper direction to mix thoroughly with the atomized oil.

In the enlarged cross-sectional view of the atomizer the fuel oil enters the atomizer from the fuel oil line after passing through the two



LIBERTY SHIP FIREROOM

This view of the Liberty Ship fireroom shows the front of the number 2 (starboard) boiler. The fuel oil line (1) is across the front of the boiler with two shutoff valves in the branch line to each burner. Directly below (3) is the fuel oil thermometer and master valve. One of the fuel oil service pumps is on the forward bulkhead at (4) while a feed check valve adjustment wheel is overhead at (5).


AIR REGISTER CONTROL HANDLE
G
BURNER TIP
G
B
YOKE
A
TORCH OPENING
OIL LINE
4 SLOTS
C
I
B
H
YOKE
ORIFICE
F
SPRAYER PLATE
F
SIDE VIEW
FURNACE FRONT WITH BURNER
FRONT VIEW
ANNULAR GROOVE
EXTENSION PIECE
4 DRILLED HOLES
F
D
E
E
G
E
MECHANICAL OIL ATOMIZER
A
NOZZLE BODY

OIL BURNER

FIREROOM WORKBENCH AND GAGE BOARD

This is a view of the fireroom burner bench and gage board of a Liberty Ship, showing the fireman on the left cleaning oil burner atomizers while the engineer on the right reads the various gages. A complete atomizer lies in the center of the bench with the atomizing end toward the fireman. Spare, clean atomizers with the connection ends up are in the rack at the left end of the bench. The non-adjustable vise for holding the atomizer when taking apart for cleaning is located at the right front corner of the bench.

On the gage board the pressure in the port and starboard boilers is read on the large gages at the bottom of the board. The pointers are on 220 lbs. per sq. inch. The two smaller gages above these indicate the pressure of the feedwater in the main feed line. The two black faced gages at the top corners are temperature gages which show the temperature of the superheated steam from each boiler. The pointers indicate about 440°. The HAYS gages in the top center are draft gages which at that particular moment read slightly less than 1 inch. The stack temperature of each boiler can be determined by turning the switch pointer at bottom center to the position on the dial for the desired stack and then reading the gage directly above it.

burner shutoff valves, and the burner connection made tight by the quickly removable yoke. Traveling down the inside of the atomizer extension piece the oil comes to the nozzle body through which four drilled holes lead the oil to the outer ends of the tangential slots in the sprayer plate. The oil rushes down these slots into the conical center chamber, in such a manner as to give the oil a whirling motion with which it passes through the orifice in the sprayer plate to the firebox in the form of a hollow cone of mist. The sprayer plate is held in place by a tip nut which is threaded to the nozzle body.

The successful operation of the atomizer depends upon the oil being at the proper viscosity (controlled by the oil temperature) and the oil being under pressure (controlled by pressure regulator on the fuel oil service pumps). Also the sprayer plate and nozzle body must be kept free of all dirt or foreign matter. This necessitates the atomizer in each burner being removed and cleaned each watch by the fireman. To do this both burner shutoff valves and the air register are closed. This stops the oil from entering the atomizer and prevents unnecessary cold air from blowing into the firebox while the burner is shut down. The yoke is then slacked off and the complete atomizer drawn out of the burner barrel first allowing the small amount of fuel oil in the atomizer to drain into the drip pan hanging beneath the burner. A spare cleaned atomizer is then installed by sliding it into position in the burner barrel and connected to the oil line by tightening the yoke. Make sure this yoke is tight otherwise hot oil will spray out into the fireroom when the burner valves are opened. A torch consisting of a steel handle about three feet long with a small ball of braided asbestos soaked in kerosene at one end is lighted. This is inserted through an opening in the front of the burner to permit the flaming torch to be directly in front of the sprayer plate. The burner valves are then opened, permitting the oil to rush through the atomizer emerging in a fine mist where it is ignited by the torch. The air register is then opened wide permitting air from the forced draft blower to enter and mix with the atomized oil. When the burner is operating the air register is always in the wide open position. When shut down it is fully closed. There is no intermediate adjustment.

BURNER TORCH

Always stand to one side of the burner when lighting off and do not look into the firebox. Should a flareback occur flame may shoot out in your face.

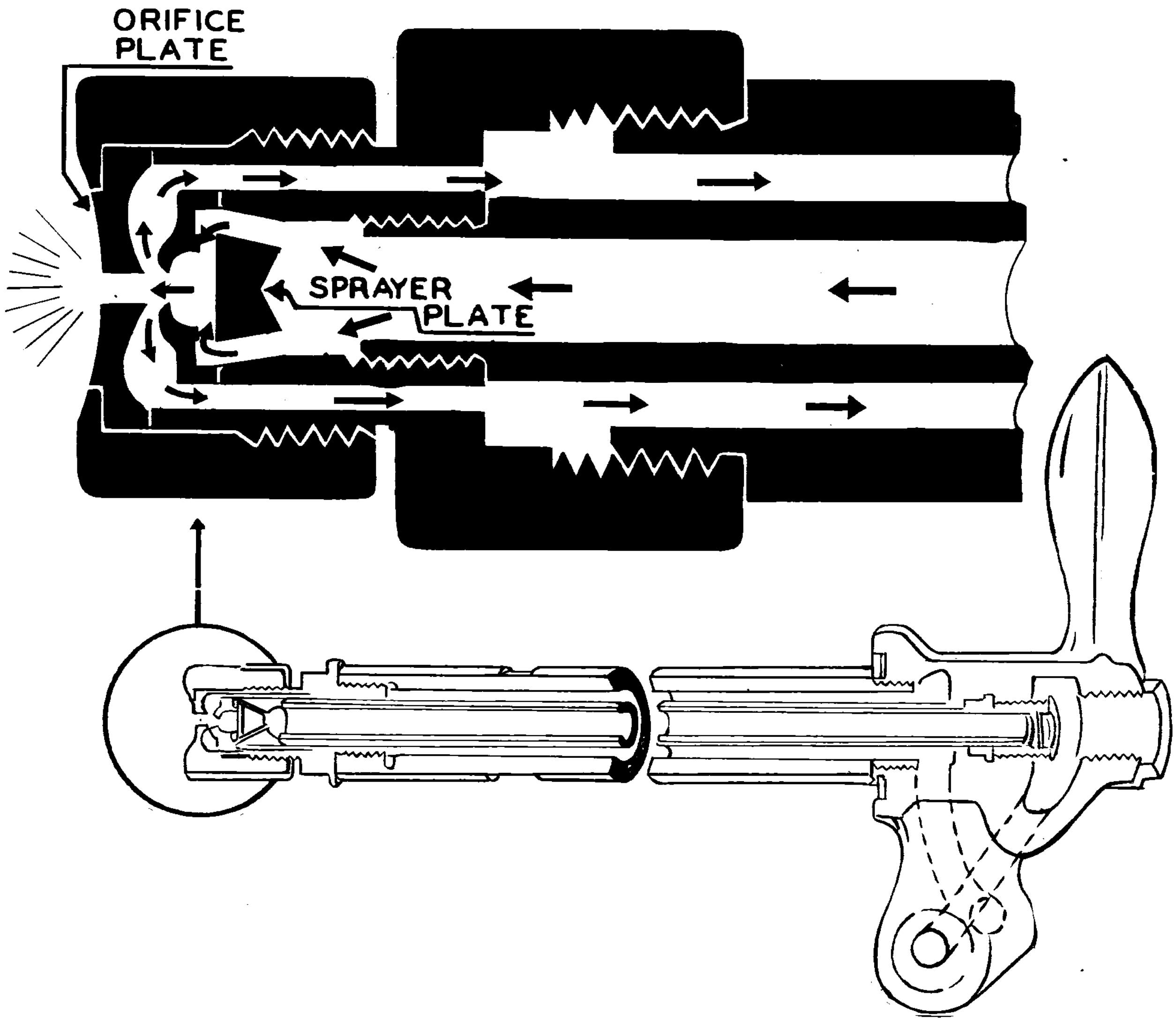
To clean the dirty atomizer it is placed in a special non-adjustable vise secured to the fireroom work bench. If it should ever be necessary to place the atomizer in an adjustable jaw vise do not squeeze it too tightly as to do so will permanently distort the atomizer, ruining it for further use. Back off the tip nut with the burner wrench. The sprayer plate is then lifted off with the fingers and washed in kerosene. Never use anything but a pointed stick or a copper wire for removing carbon or other sticky substance. A knife or steel nail will scratch the metal surface and enlarge the orifice which destroys the effectiveness of the atomizing action. Remember the sprayer plate is an accurately machined part which must remain that way to atomize the oil. After the four holes in the nozzle body have been cleaned the sprayer plate is replaced and the tip nut screwed on and tightened with the burner wrench. The B. & W. oil burner has a small fine mesh strainer in the entering end of the atomizer which must also be removed and cleaned each watch.

Sprayer plates are made in sets, each set having a different sized orifice. The larger the orifice the more atomized oil can enter the firebox, so when the oil pressure is at its highest permissible working pressure and more steam is needed, the burners will have to be shut down one at a time and sprayer plates with a larger sized orifice installed in the atomizers. Size numbers are stamped on the outside face of all sprayer plates, the engineer determines what size sprayer plates are to be used.

In the burning of atomized fuel oil the proper amount of air must be supplied at all times. Not enough air will cause incomplete burning of the fuel which causes black smoke to pour out of the stack. Too much air causes a chilling of the fire, with white smoke coming from the stack. In peacetime smoke is a sign of fuel being wasted. In wartime it can easily result in an attack by the enemy, for smoke rising into the air can be seen for many miles by a prowling enemy submarine. **It is most important that the fires be carefully tended to eliminate all smoke.**

VARIABLE CAPACITY BURNER

Oil Burners in General–Modern burners have two basic parts: the fuel oil atomizer which breaks up the solid oil stream into spray and the air register which controls the air admitted for combustion and directs the flow of air into and around the oil spray. Most burners have changeable tips to provide for changes of load; the variable capacity burner uses one tip for all loads.



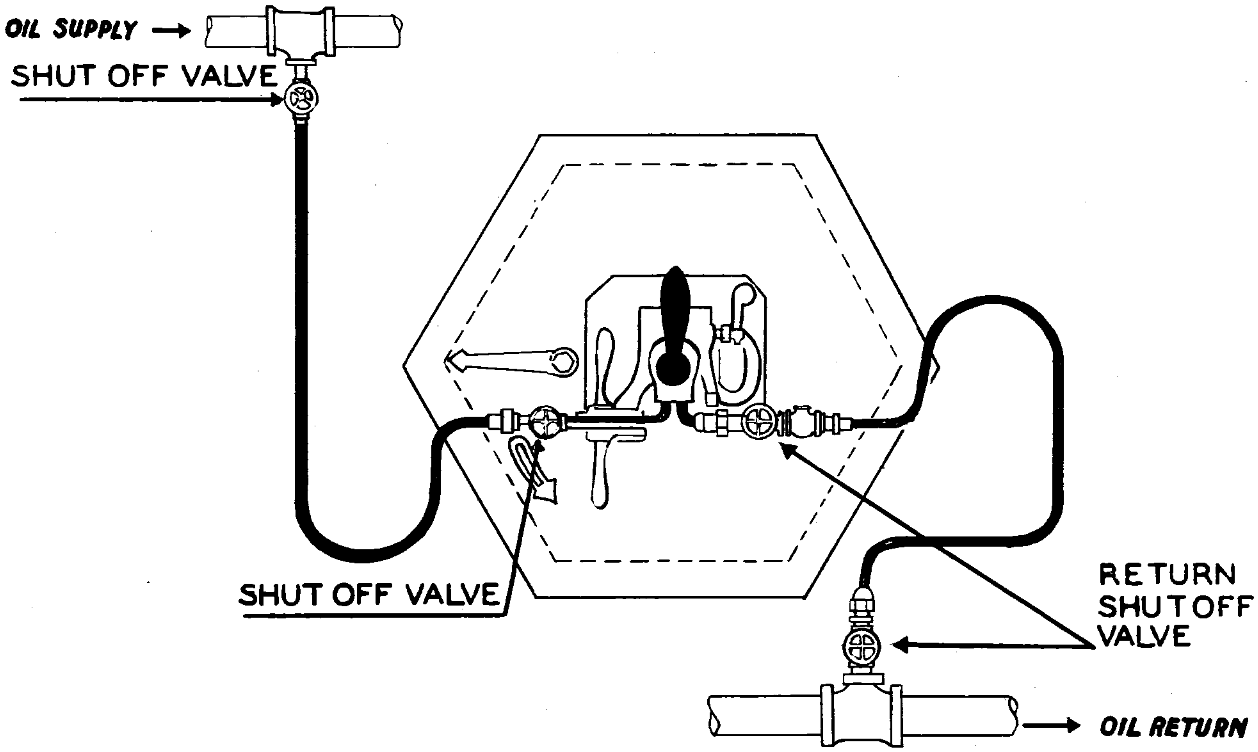
Variable Capacity Atomizer and detail sketch of sprayer plate.

Variable Capacity Burner–This type of burner is designed primarily for boilers using forced or induced draft. The oil supply is constantly recirculated as indicated by the arrows on the enlarged drawing of the atomizer. The oil enters the large supply tube and flows toward the tip. The oil supply pressure is kept constant.

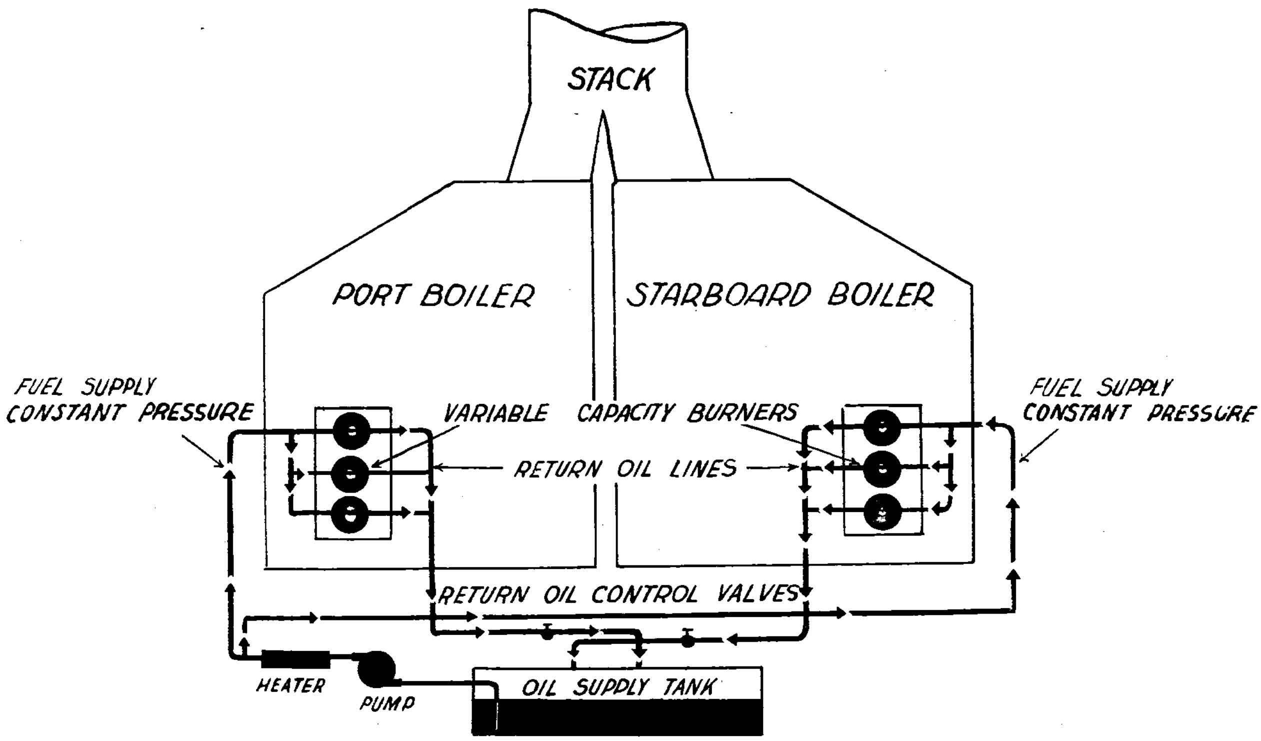
The orifice plate and the sprayer plate change this pressure to velocity and give the oil a swirling action. Some of the oil is now forced into the smaller outside passages and will return to the day tank if the oil return line valves are open. The oil which is **not** returned will emerge from the orifice plate into the furnace in a hollow conical shaped spray of very small particles of atomized fuel oil.

Closing the return oil line shutoff valves stops the flow of oil away from the burner. This increases the amount of oil sprayed into the furnace and, if the mixture of air and oil is proper for good combustion, the capacity of the burner can be increased for hard steaming.

When the shutoff valves in the return line are opened, oil flows out of the burner and the air is cut down, reducing the size of the flame. In this manner the burner can be adjusted for any load without changing the burner tip or the pressure on the service pump.



Sketch showing oil flow to and from burner.



All burners on one furnace can be controlled by one Return Control Valve as shown above.

REMEMBER—A SMOKING STACK INVITES ATTACK

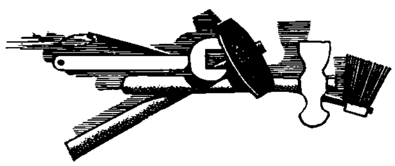
SMOKE PREVENTION

In wartime a smoking stack is to be avoided at all costs, for information secured from the enemy reveals that large convoys have been attacked when their position was given away by smoke from a single ship in the convoy. This can be easily understood when it is realized that under the best of conditions a ship can be seen by a submarine from a distance of not more than 12 miles. Under ideal conditions smoke is visible 30 or more miles.

To keep the ship from smoking requires constant alertness on the part of the engine room crew. When burning coal, thin fires should be carried, the coal being shoveled in the furnaces in relatively small amounts. With oil fuel, the temperature of the oil must be kept at the proper degree, for if it drops below any considerable amount, black smoke is sure to pour from the stack. Oil pressure should not be exceeded one way or the other. When this becomes necessary, change to larger or smaller sprayer plates. Don't fail to clean the burners regularly, for one dirty atomizer can make smoke. Keep a close eye on the draft, for too little will positively result in black smoke. In the daytime it is better to carry a little more draft than necessary than not enough. At night excessive draft may blow sparks into the air above the ship so keep the draft where it should be.

The sootblowers must not be used except when authorized by the engineer as the ship is bound to smoke while this is going on.

Remember—keep a clear stack.



FIRE EXTINGUISHERS IN FIREROOM

In all firerooms of oil burning vessels this fire-fighting apparatus is required by law:

Sand–A minimum of ten cubic feet, contained in a metal receptacle, and provided with a scoop. This receptacle should be kept full at all times with sand and the scoop never used for anything except fire fighting.

Hand System–Either of the following: Two 2½-gallon foamite extinguishers or two 15-pound carbon dioxide extinguishers.

Portable System–Either of the following: One 40-gallon foamite extinguisher or one 100-pound carbon dioxide extinguisher.

Permanent System–This consists of perforated piping running under the floorplates through which the fire extinguishing agent passes. This agent may be steam (although steam is now losing its rank among agents), carbon dioxide, or foamite. The fire extinguishing agent is released from some point outside the fireroom; before it is released, all persons should be warned to leave the fireroom. After such a system has been used, no one should enter the fireroom until it has been found that there is enough oxygen for human existence.

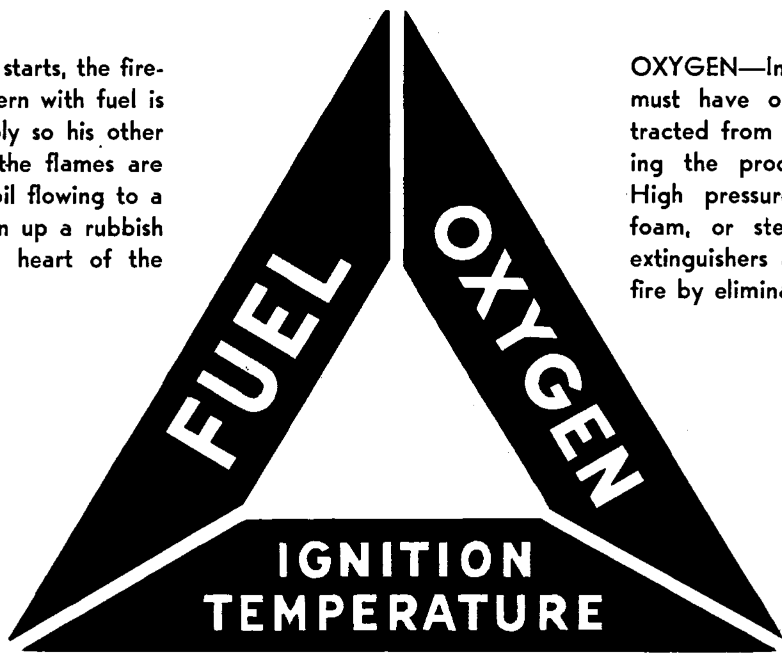
It is the generally accepted theory that water is not good for oil fires. Nor is it good, if played on the fire under pressure and in the form of a powerful stream from a nozzle. However, there is on the market, and has been accepted, a special nozzle which sprays the water in a fine mist in the fireroom. Now, as long as this special nozzle is used water is accepted as an oil fire extinguishing agent. Some vessels use this as their portable system.

When a fire is discovered act quickly, for a small blaze may be easily extinguished by throwing sand on it or using a hand extinguisher whereas a few moments' indecision may result in a conflagration beyond all control. **Remember the ship is your world until you are back on land, so take care of it.**

CHEMISTRY OF FIRE

The triangle shows the combination of elements present in every fire.

FUEL—After a fire starts, the firefighter's main concern with fuel is to cut off the supply so his other efforts to combat the flames are not wasted. Stop oil flowing to a fire with sand; open up a rubbish fire to get at the heart of the blaze.



OXYGEN—In order to burn, a fire must have oxygen, which is extracted from the atmosphere during the process of combustion. High pressure water fog, CO_2, foam, or steam smothering fire extinguishers are used to smother fire by eliminating oxygen.

IGNITION TEMPERATURE—All substances have an ignition temperature. Some must be heated before the temperature is sufficiently high to give off the vapors that burn. If held below this point, a fire is not possible. This indicates the use of a cooling agent, and since water is the most logical, the least expensive, and always available, we use water, selecting the method of applying it according to the type of fire.

RAISING STEAM

In preparing to raise steam on a dead boiler it is necessary that the following accessories and valves be closed:

- Bottom blow valve
- Surface blow valve
- Belly plug, Scotch boilers
- All feed stops and checks
- Salinometer cock
- Drain on gage glass or water column
- All steam stops
- Whistle valve
- All manholes
- All handholes

The following valves should be opened:

- The air cock
- Safety valve
- Top and bottom connections to gage glass and water column
- Valve to steam pressure gage

If there is no water in the boiler, it is put in through the main feed line, if possible, until the water just shows in the gage glass. Then water is put in through the auxiliary feed line to be sure this line is operating properly. After the water is at the proper level the feed stops and checks are all closed again.

Before lighting off an installation of oil burners, the boiler furnaces should be blown through with air to drive out the gases or vapors from the oil which may have accumulated there. This is done by opening the air doors in the registers of several of the burners. Atomizers must be clean, and all valves on pipes leading to the individual burners should be closed. The oil is circulated through the recirculating line until the oil right up to the burner is at its proper temperature, and pressure.

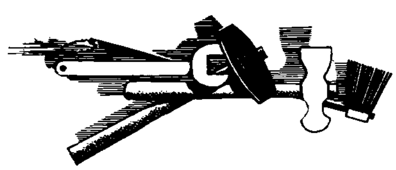
If the temperature of the oil is not high enough to maintain the proper low viscosity, it will be difficult to atomize the oil properly resulting in smoke conditions and carbon deposits in the furnaces. Excessive heating of the oil above the proper temperature will cause carbon deposits in the fuel oil heaters, waste steam, and will cause the burners to pulsate. Whenever the oil is at the proper temperature and pressure, the burners may be cut in.

The burner nearest the center of the boiler is lighted first. A torch is lighted, the air register closed, the torch inserted into the furnace, the oil turned on, and then the air register is opened again.

The boiler should never be forced, and the burners which are lit should be shifted from center to wing to opposite wing, etc., so as to heat the boiler evenly throughout. Steam should never be raised too quickly in any boiler. In Scotch boilers this tends to distort the entire boiler shell, causing ruptures of the tubes, furnaces, or the shell itself. In watertube boilers, raising steam too quickly is not injurious to the boiler itself, but the rapid temperature changes cause furnace brickwork troubles. The bricks tend to buckle and the walls will soon tumble down.

Never in any event, for any reason, should the fires be lit in any boiler without using a torch to light them. It is imperative never to attempt to light fires from hot brickwork. The results of such practice always lead to flarebacks which, although they may not be serious enough to cause injury to the fireroom personnel, will still cause extensive damage to the furnace walls.

When steam blows out of the air cock it should be closed. Likewise the safety valves. Pressure should start to show on the pressure gage very shortly thereafter. Bring the steam pressure up slowly until equal with the live boilers and cut in on the line by carefully opening the auxiliary steam stop valve.



REMEMBER—ALWAYS USE A TORCH TO LIGHT A BURNER

DUTIES OF A FIREMAN

The fireroom watches are of four hours each. This means that in 24 hours there are six watches; the 12-4, 4-8, and 8-12 A.M. and P.M. A fireman stands an A.M. and a P.M. watch, with eight hours off in between.

The oiler on watch rings "two bells" on the engine room bell at ten minutes before the relieving hour. The relieving fireman enters the fireroom at this time and begins his inspection of the plant.

The first and most important thing that the fireman must do on entering is to look at the boiler gage glasses. Make certain that the water in the boiler is at its proper level. If the fireman is responsible for tending the water in the boiler, blow the glasses down to ascertain the accuracy of the water level. The fireman works under the direction of the watertender if one is on watch.

The fireman then makes an inspection of the fires and the burners. Take note of the condition of the tile cone around the burner front to see if there is any carbon built up in front of the atomizer upon which the oil will impinge. Look for oil leaks at the connections of the oil lines and burners. Inspect the fireroom and the tank tops below the floor plates for oil drippings that may cause fires. Make sure that all spots of oil are wiped up on the floorplates and in the pans below the burners. Take note of the pressure gage readings at various points in the oil line to ascertain the conditions of the oil strainers. Check the oil heaters by looking at the thermometer on the oil line to see if the proper temperature is being maintained. Look in the fireroom bilges to see that they are empty, check the pressure of the oil in line at the gage nearest to the burners, and then the steam pressure of the boilers. After everything is apparently all right ask the fireman who is going off watch if he has had any trouble during his watch, and if there are any special orders for you from the engineer. If all is found to be as it should be, take over the watch, relieving the fireman on duty of all responsibility.

The fireman should never be lax or late in his inspection when relieving a watch. Always remember that when you relieve the other man, the full responsibility for the maintenance of the fireroom is yours for the next four hours. Whatever conditions may exist, regardless of who is to blame, the responsibility will be yours alone.

Always allow yourself enough time to make your complete inspection before eight bells ring in the engine room. This marks the beginning and ending of the watches. Never make a man you are relieving remain below after his watch is over unless you find something wrong due to his negligence while he has been on watch. In this case do not relieve him until he has remedied the condition.

After taking over the watch, the next problem is to make sure that everything goes smoothly during your watch. Change over the suction and discharge strainers and clean the ones that have been in use, replacing them in the body of the strainer, and leave the strainer and floor plates around the strainers clean for the next watch.

Next change all burners. These are changed alternately from boiler to boiler and never more than one in a boiler at a time. While a burner is being changed it is out of use for the few minutes that it takes to complete the operation. During these few minutes, there is the same amount of water entering the boiler as before but there is less steam being made. Therefore an excess amount of water accumulates, raising the level in the boiler.

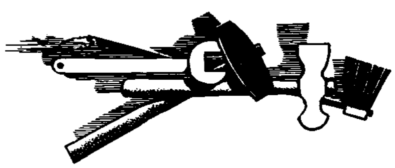
After the burners have been changed and cleaned, the strainers changed and cleaned, and the watch is running smoothly, the fireman's duty is to make an inspection of the plant at definite intervals. Don't just sit down and wait for your relief. Trouble is a thing that will come quickly to the lazy fireman. A small speck of dirt the size of a pin point can stop up a burner to the extent that the direction of the oil spray can be diverted enough to strike the brickwork of the furnace. This oil does not burn but cokes and forms carbon on the brickwork. This carbon continues to build up and in the short period of a half-hour a piece of carbon large enough to completely block the burner opening can form. This will cause improper combustion in the furnace and soot will form on the tubes of the boiler causing considerable loss of efficiency and a lot of work.

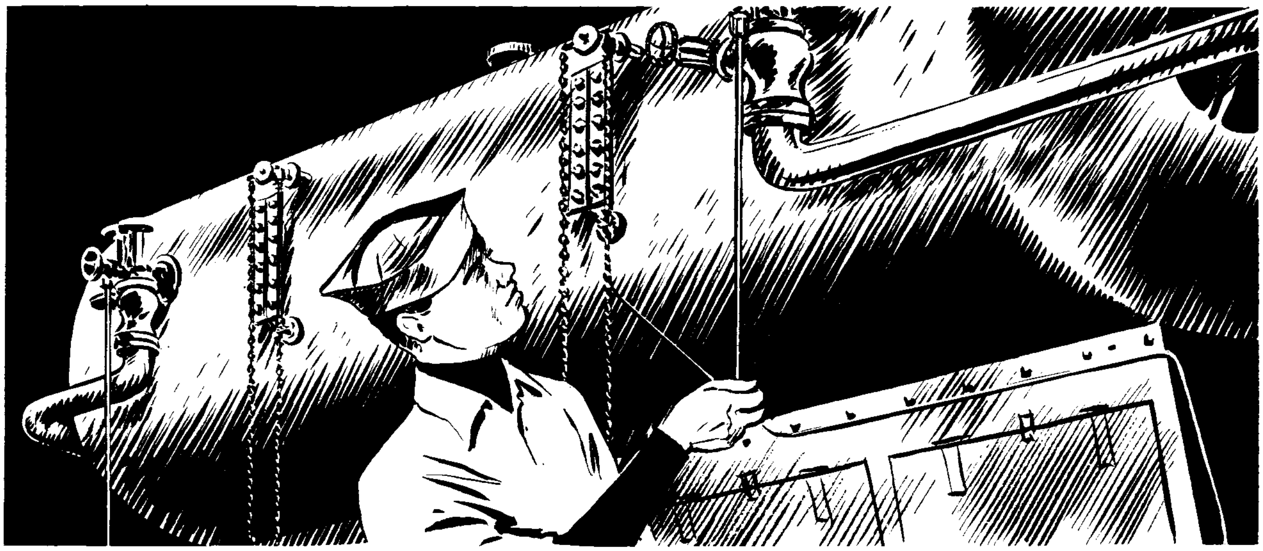
The fireman must watch his plant at all times just as the engineer watches his.

Each fireman is responsible for keeping a part of the fireroom in a neat and tidy condition. The particular part being known as your station. The painting, shining of bright-work, etc., connected with this station is done by the fireman while he is on watch. However, this work is never in such a part of the fireroom that at any time the performance of these duties interferes with the safe operation of the boilers. At all times, the fireman should be at a point where his water gage and steam pressure gage are visible.

A fireman should do everything possible to maintain the boilers in a safe operating condition at all times with a maximum of efficiency. You should be familiar with the pipe lines and auxiliary machinery in the fireroom and know how to prevent and combat fires that may start at any time.

Keep a close watch on the stack for smoke, either by looking at the top of the stack itself or through the smoke density indicator.





DUTIES OF A WATERTENDER

The watertender is carried aboard ships which have several boilers and where the tending of the water in the boilers requires constant attendance. Some boilers, such as the Scotch boiler, although they require constant attention do not require that a change in the setting of the check valves be made often. Other boilers require frequent change in the setting of the check valves in order to maintain the proper water level in the boilers.

The duties of the watertender include the following: Be thoroughly familiar with the construction of the boilers, the accessories connected with them, and know their purpose and operation. These accessories include the external and internal feedwater lines, and the stop and check valves that control the feeding of the water to the boiler, the safety valves, the main and auxiliary steam stop valves, the steam pressure gage, the water column and gage glasses, the injector, the feed pumps, try cocks, bottom and surface blowdown valves and piping connected with blowing down the boiler, the hand release on the safety valve, superheater drains and connections, air cock, all valves used in conveying steam from the boiler to all parts of the ship, sootblowers, etc. The watertender must at all times be aware of the hazards incurred from low water and maintain a safe level in the boilers.

Because the firing of the boiler directly affects the water level in the boiler, the watertender must direct the fireman in his duties. He oversees the fireman and as a rule, is responsible for maintaining a steady steam pressure in the boiler.

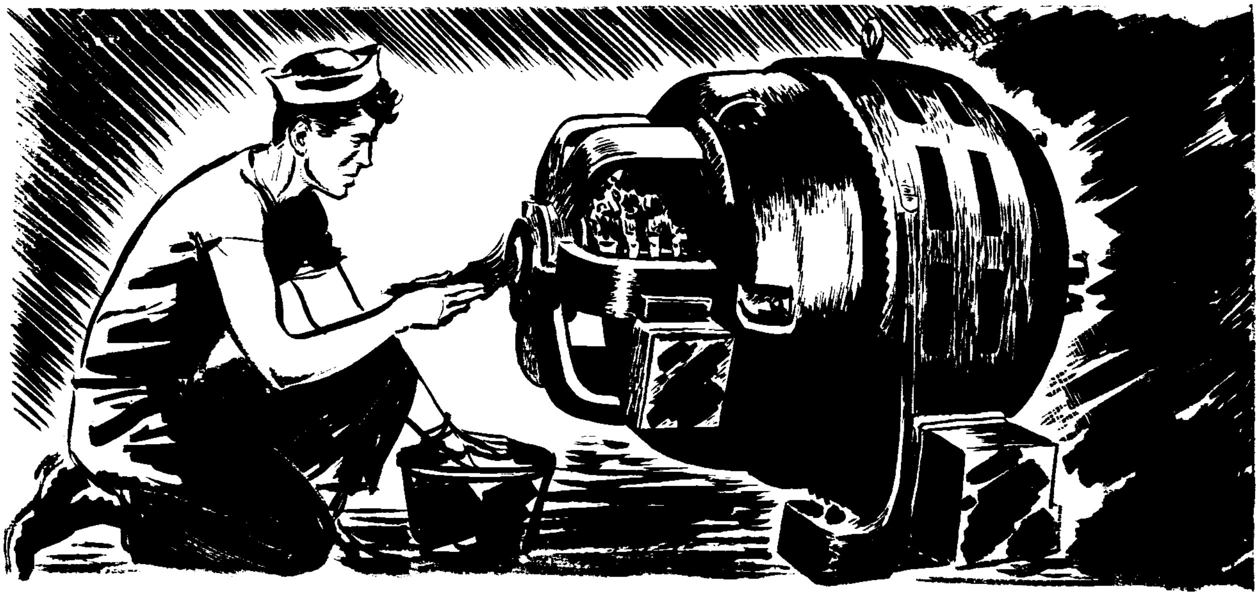
When the boilers are supplied with automatic feedwater regulators, the watertender should be familiar with their operation, and should never rely entirely on their operation, but still maintain a constant surveillance of the water level.

The watertender must have a thorough knowledge of the engine and fireroom firefighting equipment.

The watertender should be thoroughly familiar with the safe handling and burning of fuel oil. He must be able to properly operate the fuel oil system from the tanks to the burners. This requires a thorough knowledge of all the oil burning equipment including the transfer lines and pumps, valves, manifolds, etc., strainers, service pumps, heaters, control valves, atomizers, and regulating valves.

He should have a good working knowledge of draft, and the particular draft equipment on the vessel on which he is employed, for it is his duty to minimize smoke conditions at the stack, and maintain good furnace conditions.

In short, the watertender should be able to operate and maintain the fireroom watch with as little assistance from the engineer as possible.



THE WIPER'S JOB

The wiper is not a qualified member of the engine room in the true sense of the position. He is an all-around worker in the Engine Department of an oil-fired vessel. His is the only position open in that department for beginners and others not qualified in the more responsible ratings. The wiper washes paintwork, chips, scrapes, paints, and performs all those various duties tending to maintain the machinery spaces in a clean condition.

Generally he is a day worker, and is not assigned to a watch. He should, as quickly as possible, familiarize himself with the hazards of using oil fuels, and operating pressure vessels.

Since he is first, last, and always a seaman, he should be familiar with nautical terms. He should realize the importance of emergency drills, know his stations in each, and be able to fulfill his part should the necessity arise to combat fire or abandon ship. As an engine department worker he should have an interest in mechanics, and be familiar with the names and the purposes of all the units in the power plant of the vessel.

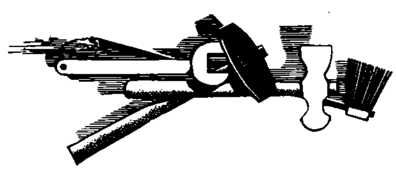
Where overhauling and repair work of boilers and machinery is carried on, the wiper helps in various ways, and it is through the knowledge that he gains while doing this work that he prepares himself for advancement.

The records of all successful men show that they were not afraid to assume additional duties. They were not hesitant about asking questions—nor did they begrudge a small portion of their leisure time for study.

This applies to any line of endeavor and even if the job is temporary, the knowledge gained will always be useful.

Duties aboard ship, particularly in the engine room, are unique in the large number of opportunities available.

The operation of a ship's engine room covers many subjects. There is much to learn that is both interesting and profitable—get as much as you can, make the most of your opportunities. Help the oiler, the fireman, the watertender, learn the other fellow's job and don't hesitate to do a little extra work. Use at least part of your leisure time every day to read about the equipment around you. Every Chief Engineer was once a wiper who took advantage of his opportunities.

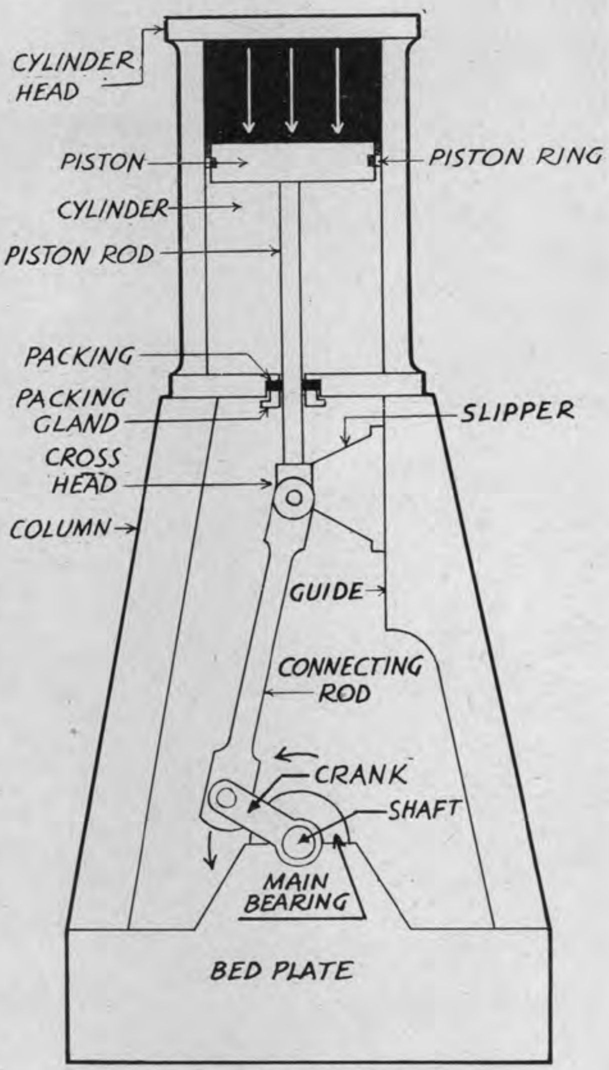


RECIPROCATING STEAM ENGINES

Reciprocating type main engines have been used to propel ships, since Robert Fulton first installed one in the Clermont in 1810. The Clermont's engine was a small single cylinder affair which turned paddle wheels on the side of the ship. The boiler was only able to supply steam to the engine at a few pounds pressure. Since that time the reciprocating engine has been gradually developed into a much larger and more powerful engine of several cylinders, some having been built as large as 12,000 horsepower. Turbine type main engines being much smaller and more powerful were rapidly replacing reciprocating engines, when the present emergency made it necessary to return to the installation of reciprocating engines in a large portion of the new ships due to the great demand for turbines. It is one of the most durable and reliable type engines, providing it has proper care and lubrication.

Its principle of operation consists essentially of a cylinder in which a close fitting piston is pushed back and forth or up and down according to the position of the cylinder. If steam is admitted to the top of the cylinder, it will expand and push the piston ahead of it to the bottom. Then if steam is admitted to the bottom of the cylinder it will push the piston back up. This continual back and forth movement of the piston is called reciprocating motion, hence the name, reciprocating engine. To turn the propeller the motion must be changed to a rotary one. This is accomplished by adding a piston rod, crosshead, connecting rod, crank and crankshaft. When the piston goes up and down it pushes the piston rod up and down with it. This through the crosshead pushes the connecting rod, the bottom end of which is attached to the crank. The crank is merely an arm, one end of which is fastened to a round shaft (crankshaft) free to revolve in a fixed bearing and the other end to the connecting rod. As the connecting rod is pushed up and down it pushes the crank around in a circle the hub of which is the crankshaft. A propeller attached to the end of the crankshaft will revolve at the same speed as the crankshaft.

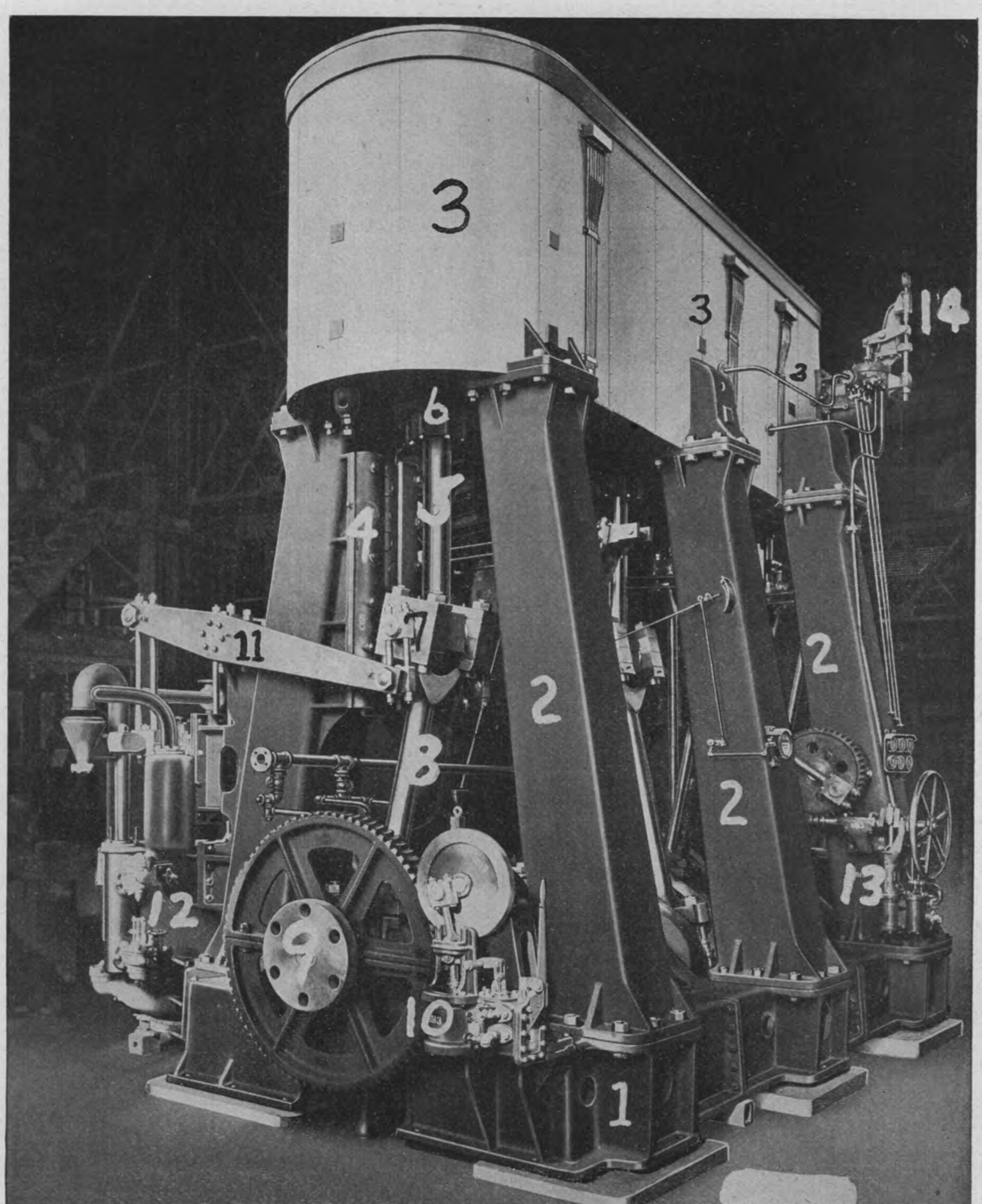
The hole in the center of the lower cylinder head through which the piston rod passes must be sealed otherwise steam will blow out. Packing is installed around the piston rod in the stuffing box for this purpose. For the packing to be effective the piston rod must travel in a straight line and not move from side to side. This is accomplished by the guide and slipper shown in the drawing.



SIMPLE ENGINE

(Valve and valve gear not shown)

The slipper or shoe, as it is known, is attached to the crosshead and as it travels up and down the slipper is pushed by the angularity of the connecting rod against the guide which is a flat lubricated metal surface in line with the cylinder. Thus it is impossible for the piston rod to move sideways in its travel.

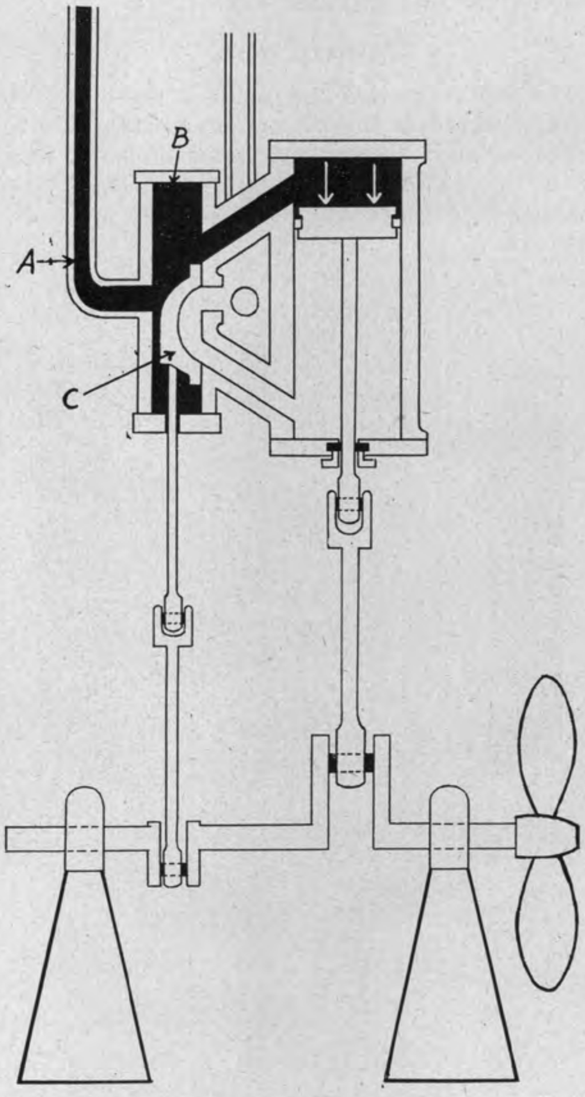


TRIPLE EXPANSION RECIPROCATING STEAM ENGINE FOR EC-2 (LIBERTY) SHIP

1. BEDPLATE
2. COLUMNS
3. CYLINDERS
4. GUIDE
5. PISTON ROD
6. PISTON ROD PACKING
7. CROSSHEAD
8. CONNECTING ROD
9. CRANKSHAFT COUPLING
10. JACKING ENGINE AND GEAR
11. AIR PUMP BEAM
12. DEPENDENT AIR PUMP
13. REVERSING ENGINE
14. THROTTLE.

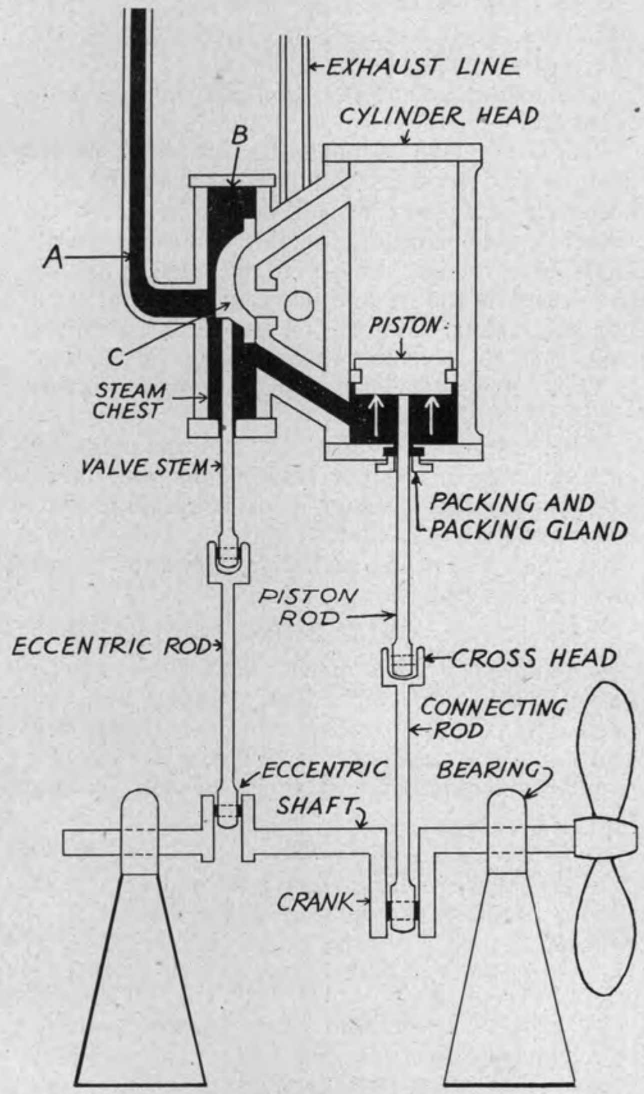
The alternate entry of steam to the top and bottom of the cylinder is made possible by an automatic valve (C) shown in the side view of a simple engine.

As shown in the sketch steam from the boiler enters the steam chest through the steam line (A) completely filling the chest (B). The slide valve, which is somewhat in the form of the letter D is in the down position, uncovering the top steam port (hole between the steam chest and cylinder) which allows the steam to flow into the top of the cylinder. When the piston has been pushed downward a short way the valve moves up, covering the top port, stopping the steam from entering. The steam in the cylinder expands pushing the piston ahead of it to the bottom of the cylinder. As the steam expands its temperature and pressure drop due



SIMPLE ENGINE–CRANK ON TOP CENTER

In the above sketch the crank is shown in the top center position. The arrows indicate the direction of force and the movement of the piston. The valve will move up to cut off flow of steam to top of piston.



SIMPLE ENGINE–CRANK ON BOTTOM CENTER

The above sketch shows the crank on bottom center and the arrows below the piston indicate the upward force of the steam. In this case the valve will move down to cut off the flow of steam.

in contact with the rod. The metal used in this type packing is relatively soft, being a form of babbitt. The coil springs (10) provide the tension to hold the rings tight around the rod. The piston rod sliding through the metal rings must be lubricated otherwise the friction will cause overheating.

CROSSHEAD

A crosshead is a square steel block rigidly fastened to the bottom end of the piston rod. On the forward and after side of the block is a round steel pin known as the crosshead pin, around which the crosshead bearings fit. These bearings are rigidly fastened to the top of the connecting rod fork and in operation the bearings revolve back and forth around the pins and must be lubricated.

To the back side of the crosshead a slipper is attached.

SLIPPER

A slipper is made of cast iron with the flat bearing face being coated with babbitt metal. Some engines have one slipper and some two depending on whether it is a single or double guide engine. The great proportion of engines being built today being of single guide construction, the text will deal with that type.

GUIDES

The ahead guide is a flat face made of cast iron and bolted against the column. The astern guide consists of two cast iron side bars which fit around the outside of the slipper preventing it from being pulled away from the guide when the engine is turning in the astern motion. Lubrication must be provided between the sliding metal faces of the slipper and guides.

Guides are usually cooled by sea water passing through a core in the back of the ahead guide face.

CONNECTING ROD

The connecting rod is made of steel, the top end usually being forked in large engines and attached to the crosshead with bearings so that the crankpin is free to turn as the crank goes around. The crankpin bearing must be lubricated also.

CRANK

The crank is constructed of steel and consists of the following parts. Webs which are the two side pieces connecting the crankshaft with the crankpin. Crankpin which is a round steel pin between the outer ends of the crank webs, around which the crankpin bearing is fitted.

CRANKSHAFT

The crankshaft is a large round steel shaft to which the cranks are attached. Those portions of the shaft which revolve in the main bearings are known as journals. Mounted on the shaft are the eccentrics.

ECCENTRICS

The eccentrics which move the engine valves up and down are merely an off center or eccentric wheel secured around and keyed to the outside of the crankshaft. Two are required for each valve, one being for ahead motion and one for astern. The motion of the moving eccentric is transmitted to the eccentric rod by the eccentric strap which extends entirely around the outside of the eccentric, the eccentric turning inside of it. The inside surface of the strap which bears on the eccentric is either lined with babbitt metal or bronze. Lubrication must be provided between the strap and eccentric.

COLUMNS

The columns are made of hollow cast iron, box construction and are used to hold the cylinders and steam chests in position, two columns supporting each cylinder and chest. The columns stand on and are bolted to the bedplate.

BEDPLATE

The bedplate is securely fastened to the ship's hull forming a true surface for the main bearings and columns. In assembling, the bedplate must be true and ridged, otherwise the engine will be thrown out of line.

MAIN BEARINGS

The main bearings support the crankshaft, one being required on each side of every crank.

The bottom halves are fitted into a recess in the bedplate, all bearings being in direct alignment. When the crankshaft is lowered into place, the top half of the bearings are put on and adjusted for clearance after which they are secured with bolts which extend through the bedplate.

The inside surface of the bearings is lined with babbitt metal requiring lubrication. This is supplied through oil holes leading from the top of the bearings through to the shaft. Oil grooves cut in the face of the babbitt metal enable the oil to spread evenly the length of the bearings. The revolving shaft carries the oil entirely around the bearing providing an unbroken film which keeps the metal of the bearing from coming in contact with the journal. This principle of lubrication applies to all bearings.

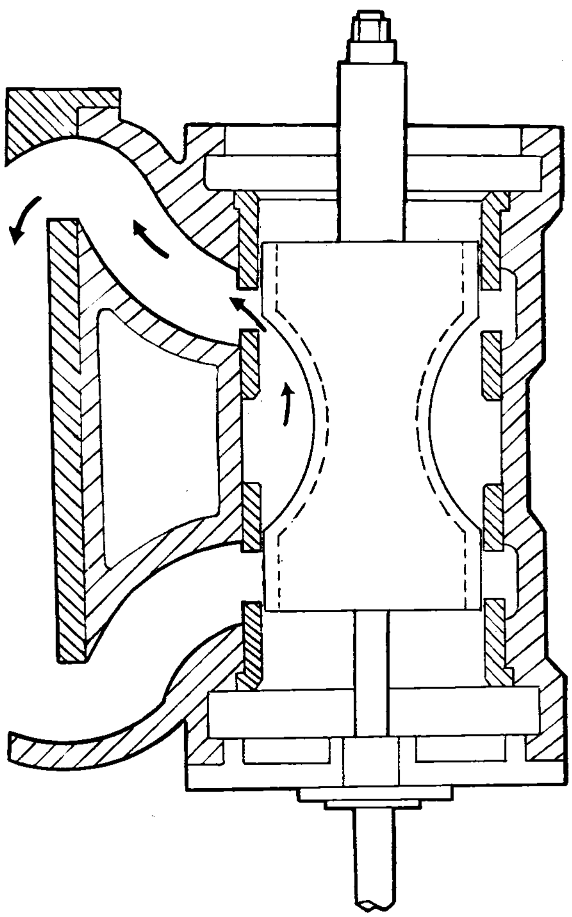
The lower half of main bearings on larger engines is usually cooled by sea water flowing through a core in the bearing shell.

CRANKPIN BEARING

The crankpin bearing is bolted to the bottom end of connecting rod and of same general construction as main bearings. Lubricated from oil cups on the crosshead, the oil passing down oil lines on the forward and after side of the connecting rod.

CROSSHEAD BEARINGS

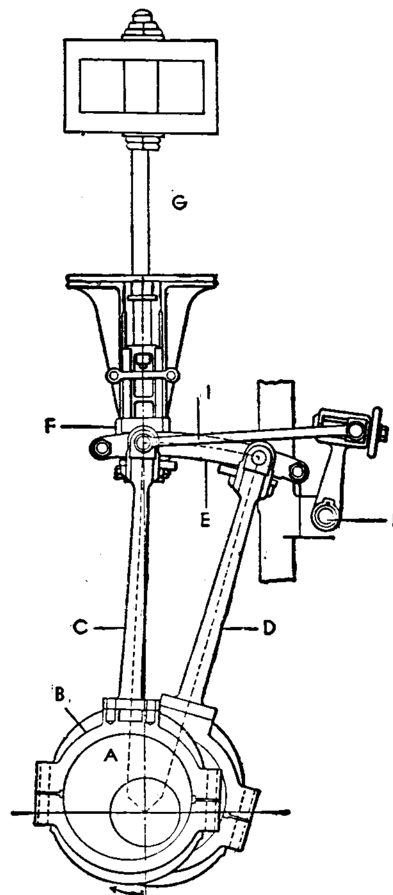
The crosshead bearings are bolted to the top end of the connecting rod and may be constructed of brass or with a babbitt lining. Lubricated through an oil cup on top of the bearing.



PISTON VALVE

VALVES AND VALVE GEAR

The D-type slide valve is held on its seat by the steam pressure pushing against the back of it. This sets up considerable friction which requires a great deal of power to move the valve when high steam pressures are used. For this reason, another type of valve is used to a great extent on marine engines. This is known as a piston valve, and is, in fact, a flat slide valve developed into the form of a cylinder, presenting no flat surfaces upon which the steam may act.



STEPHENSON LINK VALVE GEAR

The piston valve consists of two pistons joined by a hollow casting as shown in the drawing. The valve slides inside two removable sleeves or liners which form a cylindrical valve seat. Steam ports communicating with the ends of the cylinder are cored into the sleeves. The valve is secured to the valve stem and is controlled by the eccentric the same as a flat slide valve.

The steam may enter at the center of the valve, or at the ends of the valve. The exhaust piping connects just the opposite from the steam inlet. In the drawing, the steam enters at the center, and this is known as an inside valve. It is impossible to use a slide valve as an inside valve, as the steam pressure acting under the valve would force the valve from its seat. Therefore, a slide valve is always an outside valve.

If steam pressure is allowed to enter the cylinder during the full stroke of the piston, it would be a very expensive engine to run. For this reason, the steam is permitted to enter the cylinder only during part of the stroke. During the rest of the stroke, the steam expands in pushing the piston through the cylinder. Thus the expansive quality of the steam is used for doing work.

As the marine engines must be reversible in order for the ship to be made to go ahead or astern, we must have some way to cause the reciprocating engine to run in the opposite direction. In almost all types of reciprocating engines used on board ship for propulsion, we use the type of valve mechanism shown in the drawing. This consists of two eccentrics (A) and what is known as a Stephenson link. One eccentric is set to control the valve for go-ahead motion and the other eccentric is set to control the valve for go-astern motion.

An eccentric rod (C) is run from one eccentric to one end of the link (E) and another eccentric (D) to the other end of the link. This is clearly seen in the drawing. The link is made to slide along a block (F) attached to the foot of the valve stem (G). The valve is thus moved by the eccentric whose eccentric rod is directly beneath the valve stem. This type of link is known as the Stephenson link.

The link is made to move by a reversing ram or reversing engine. The engine or ram turns a rock shaft (H), mounted on a back column, by means of a connecting rod. The rock shaft connects to the Stephenson link by means of drag links or tie rods (I) as shown in the drawing. The rock shaft in turning through a part of a revolution throws the links from ahead to astern, or from astern, to go ahead, as the case may be.

If the link is moved until the center of the link is directly under the valve stem, with the throttle open, the engine would not run. This is due to the fact that the eccentrics operate against each other and the center of the link has no up and down movement. By using this knowledge, if the link is moved from one eccentric, a short distance toward the other, the amount of steam that will be admitted to the cylinder will be less than if the valve stem were directly over the eccentric rod. By moving the link in this fashion, the valve travel will be less. With less valve travel, total distance the valve moves, the valves will close the steam port to the cylinder earlier in the stroke, cut-off is sooner. With earlier cut-off less steam is admitted to the cylinder which takes us back to the statement, that if we move the link from one eccentric a short distance toward the other, the amount of steam that will be admitted to the cylinder will be less and the amount of work accomplished is less. The amount of steam admitted will be less due to a shorter valve travel giving an earlier cut-off.

On marine propulsion engines, it is possible to move the links on each individual engine by the use of an individual cut-off gear which has the reversing rocker, or the rock shaft, slotted at the end. The tie rods, reaching from the Stephenson link to the reversing rocker are attached to a movable block, that is closely fitted into the slot. By means of a screw, the block may be readily moved to the right or left, thus moving the link either toward mid-gear or full gear ahead, without affecting the other links. That is, the cut-off on the H. P. and M. P. and the L. P. may each be independently adjusted with the engine stopped or with the engine in motion.

When the rock shaft is turned to its astern position, the slot in the reverse rocker arm will be vertical, and thus the cut-off gear has no influence on the astern power of the engine.

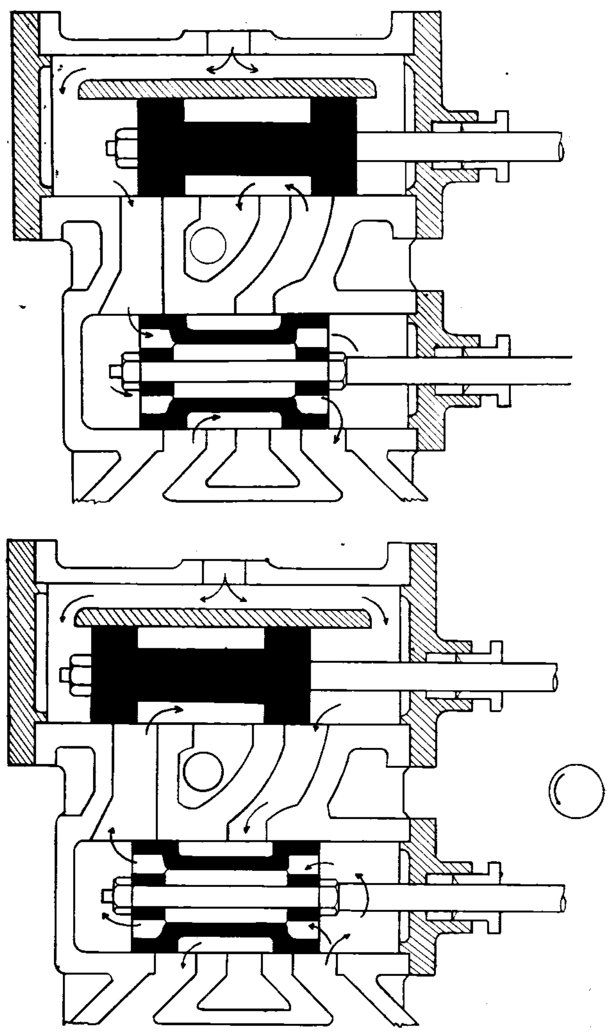
REVERSING ENGINES

On the Liberty ships a reversing engine is used to move the Stephenson links from ahead to astern or astern to ahead. This is known as "throwing the links." The reversing engine is a small single cylinder steam engine with the cylinder on the bottom and crankshaft on top as shown in the chart on page 68. The reversing engine is controlled by a lever on the H. P. front column.

As the reversing engine runs, the rotary motion of the crankshaft turns the worm which is keyed on the reversing engine crankshaft. The worm meshes with the worm wheel and causes it to turn. The pin is connected to the reversing shaft of the reverse gear by a drag rod. Half a revolution of the worm wheel causes the connecting rod to the rock shaft to turn the rock shaft sufficiently to throw the links from ahead to astern or astern to ahead and thus change the direction of rotation of the main engine.

Differential Valve–As the reversing engine has only one eccentric, the reversing of it is made possible by using a differential valve for controlling the steam and exhaust to and from the steam chest. The differential valve is the top piston valve shown in the cross-sectional sketch.

In the first sketch the differential valve is moved to the right which allows the steam to flow by through the port to the engine steam chest, where the steam passes through the length of the hollow piston valve to the opposite end of the chest where it enters the right-hand end of the engine cylinder through the open port. This starts the engine rotating in a clockwise direction.



DIFFERENTIAL VALVE

In the second sketch the differential valve has been moved to the left but the engine valve is in the same position. The steam now enters the engine steam chest from the opposite end of the differential steam chest and passes around the inside of the engine valve from where it flows through the port to the left end of the engine cylinder. This starts the engine turning in the opposite direction as shown by the arrow in the circle.

While the steam is entering one end of the cylinder, the spent steam is exhausting from the opposite end through the ports and valves as shown by the arrows.

The differential valve is moved back and forth by a lever.

Differential valves are also used to reverse steering engines and winches as will be brought out later in the manual.

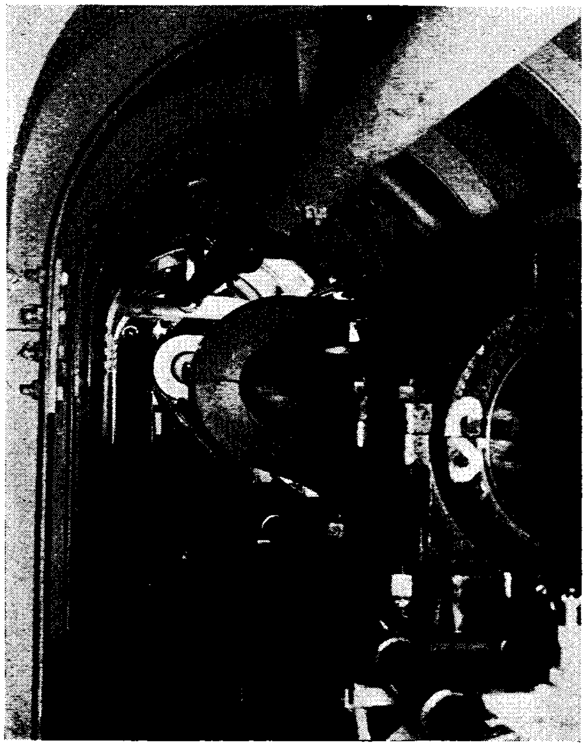
LINE SHAFT AND SPRING BEARINGS

Except in oil tankers and ore carriers, most vessels have their engine and boiler rooms located amidships. This means that a long steel shaft, as shown in the shaft alley illustrated on page 67, is needed to connect the revolving crankshaft with the propeller. Several bearings known as spring bearings, marked (S), support this shaft at the necessary points along its length. A tunnel, known as the shaft alley, houses the line shaft, from the after bulkhead in the engine room to the afterend of the line shaft at the stern gland. The alley provides sufficient room for the oiler to walk alongside the revolving shaft so that he may feel and oil the spring bearings. Usually only the bottom half of these bearings is lined with babbitt metal, the top half being a cast iron shell which has a relatively large clearance between it and the shaft. The lubricating oil is poured in the top after the cover has been raised, and runs down around the shaft to form a film between the babbitt metal in the bottom half and the shaft.

The C-shaped objects around the line shaft are guards surrounding the couplings.

TAIL SHAFT AND PROPELLER

The last section of the line shaft is known as the tail shaft. It extends through the stern tube into the sea and on its end is secured the propeller. The stern tube is fitted with lignum-vitae wood bearings to support the tail shaft. The steel tail shaft is protected from the corrosive action of sea water by a bronze sleeve



SHAFT ALLEY

shrunk on around the outside of the shaft. As the bronze-covered shaft revolves in the wood bearings, sea water flowing in from the sea end of the tube acts as a lubricant. To prevent the sea from flooding the shaft alley and ship, a stuffing box packed with several turns of flax packing is provided at the forward or shaft alley end of the stern tube. When the ship is underway the gland should be slacked off just enough to permit a small stream of sea water to flow out of the stern tube into the shaft alley bilge, to insure that the bearing is being lubricated. It is very important that the outside of the stuffing box be felt by the oilers for overheating at each round, as the packing may overheat and burn up if too tight. Upon leaving dry dock, where the stuffing box has been repacked, an especially close watch should be kept.

In this picture a propeller can be seen in place on a single-screw ship in dry dock. A propeller is simply a large screw which, when revolved in one direction, will screw itself forward through the water, like a steel screw in wood, pushing the ship ahead of it. If revolved in the opposite direction it screws itself backward through the water, pulling the ship with it.

STERN OF LIBERTY SHIP

Propellers are usually made of bronze to resist corrosion and are secured to the end of the tailshaft with a tapered fit and large nut.

To do their best work, propellers must be designed to turn at relatively slow speeds, 100 R.P.M. or below. With the conventional type, reciprocating main engine, the propeller turns at the same speed as the engine, but with turbine engines which turn at several thousand R.P.M., it is necessary to reduce the speed between the turbine and the propeller.

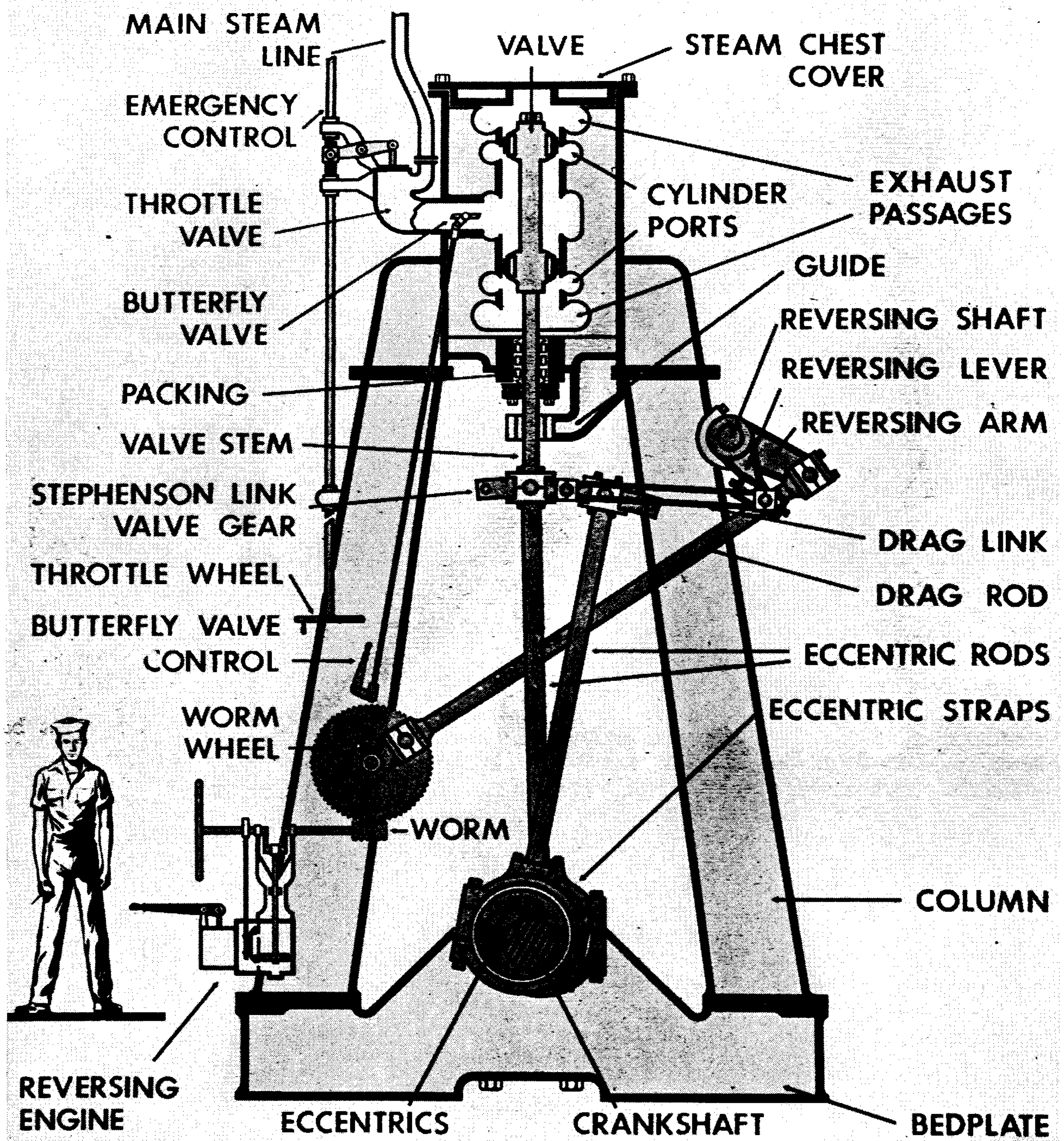
When the ship is loaded, the propeller is well below the surface of the water, but when light it may break the surface when turning. Extreme care must be exercised when alongside the dock or when anchored that no obstructions, such as small craft, are near the propeller before moving it.

In heavy seas the propeller may frequently break water, causing the engine to race.

Also, in this picture may be seen the rudder for steering the ship and the depth markings in feet on the side of the hull.

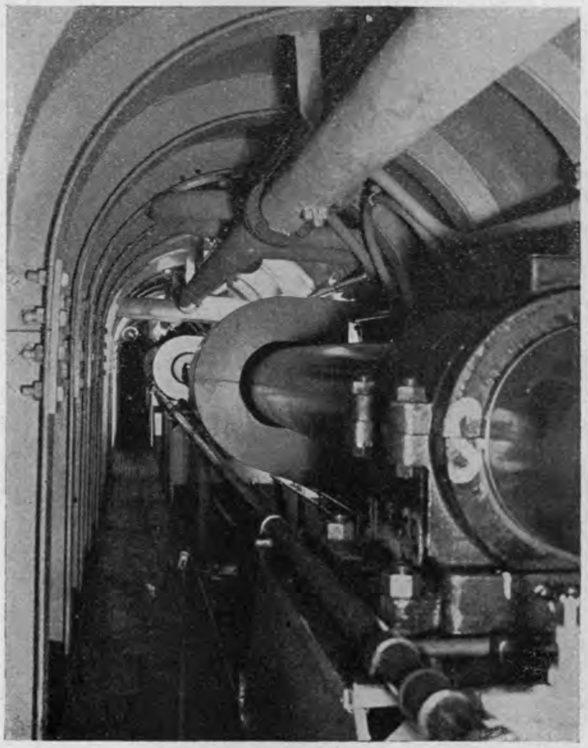
LIBERTY SHIP ENGINE

H. P. (HIGH PRESSURE) END)



U. S. Maritime Service Training Aids Unit Chart

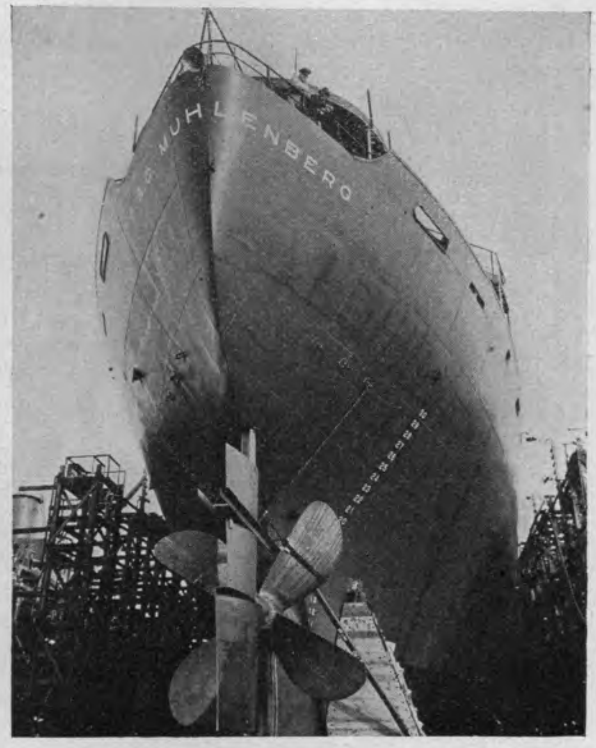
propeller. The stern tube is fitted with lignum-vitae wood bearings to support the tail shaft. The steel tail shaft is protected from the corrosive action of sea water by a bronze sleeve



SHAFT ALLEY

shrunk on around the outside of the shaft. As the bronze-covered shaft revolves in the wood bearings, sea water flowing in from the sea end of the tube acts as a lubricant. To prevent the sea from flooding the shaft alley and ship, a stuffing box packed with several turns of flax packing is provided at the forward or shaft alley end of the stern tube. When the ship is underway the gland should be slacked off just enough to permit a small stream of sea water to flow out of the stern tube into the shaft alley bilge, to insure that the bearing is being lubricated. It is very important that the outside of the stuffing box be felt by the oilers for overheating at each round, as the packing may overheat and burn up if too tight. Upon leaving dry dock, where the stuffing box has been repacked, an especially close watch should be kept.

In this picture a propeller can be seen in place on a single-screw ship in dry dock. A propeller is simply a large screw which, when revolved in one direction, will screw itself forward through the water, like a steel screw in wood, pushing the ship ahead of it. If revolved in the opposite direction it screws itself backward through the water, pulling the ship with it.



STERN OF LIBERTY SHIP

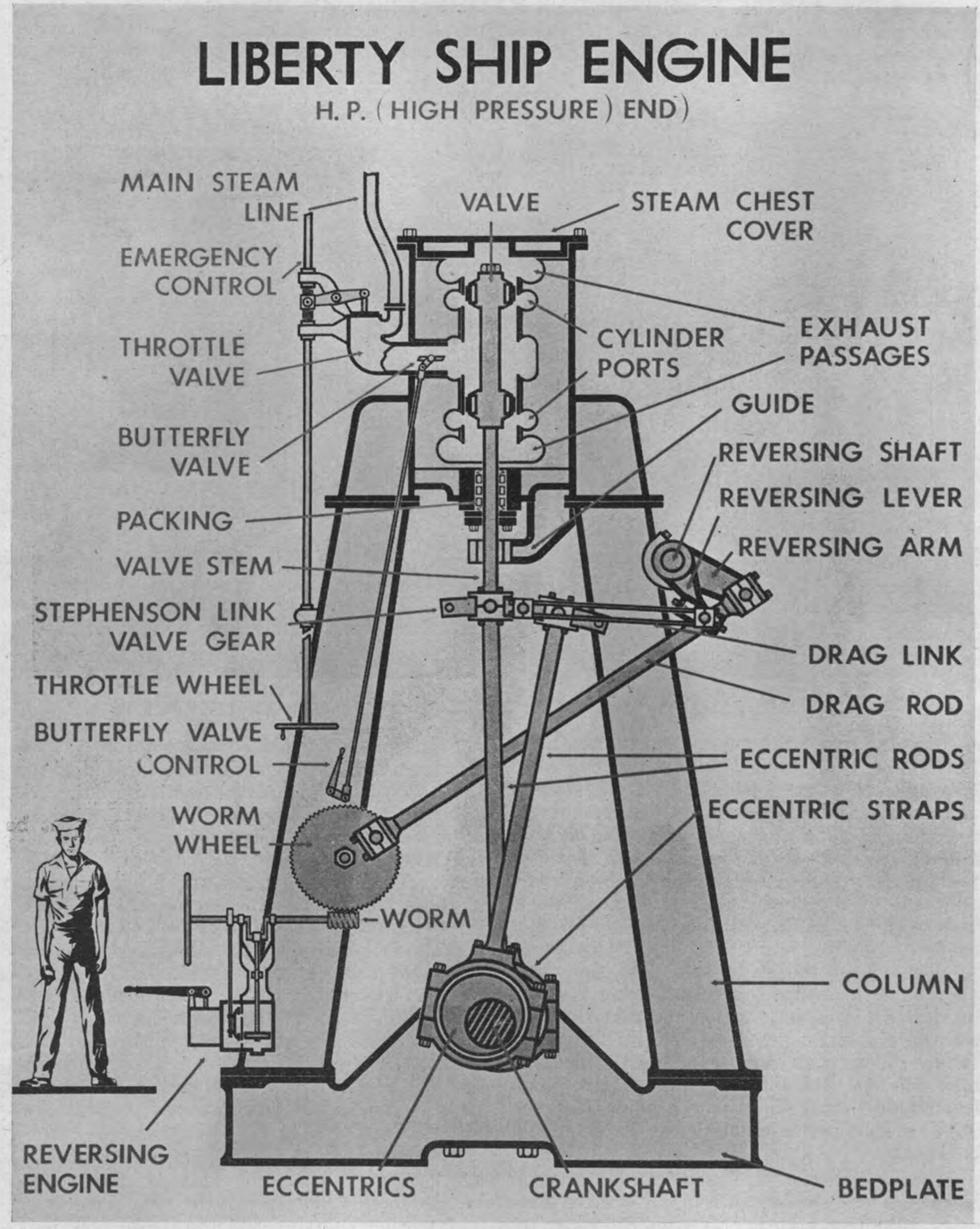
Propellers are usually made of bronze to resist corrosion and are secured to the end of the tailshaft with a tapered fit and large nut.

To do their best work, propellers must be designed to turn at relatively slow speeds, 100 R.P.M. or below. With the conventional type, reciprocating main engine, the propeller turns at the same speed as the engine, but with turbine engines which turn at several thousand R.P.M., it is necessary to reduce the speed between the turbine and the propeller.

When the ship is loaded, the propeller is well below the surface of the water, but when light it may break the surface when turning. Extreme care must be exercised when alongside the dock or when anchored that no obstructions, such as small craft, are near the propeller before moving it.

In heavy seas the propeller may frequently break water, causing the engine to race.

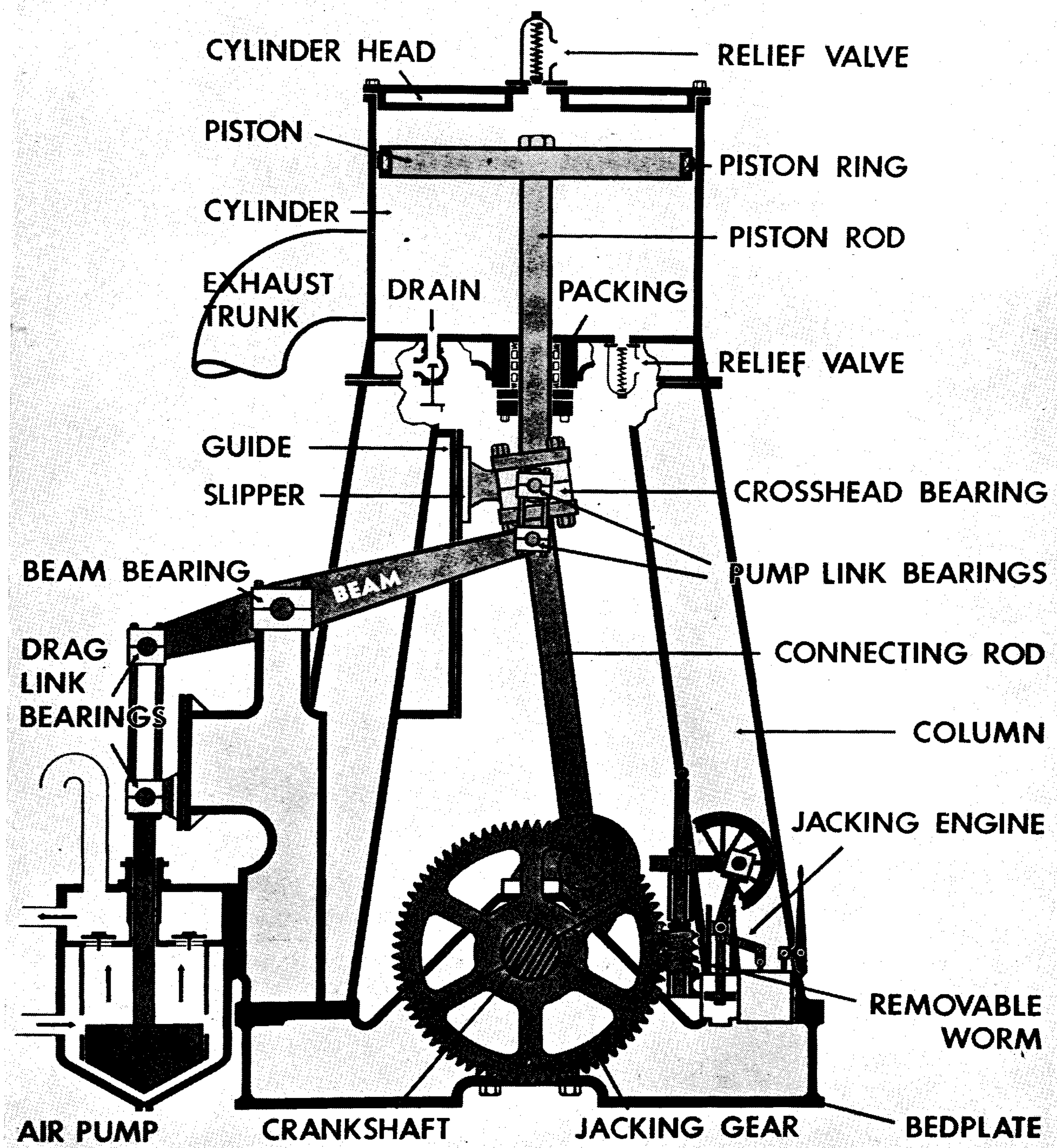
Also, in this picture may be seen the rudder for steering the ship and the depth markings in feet on the side of the hull.



U. S. Maritime Service Training Aids Unit Chart

LIBERTY SHIP ENGINE

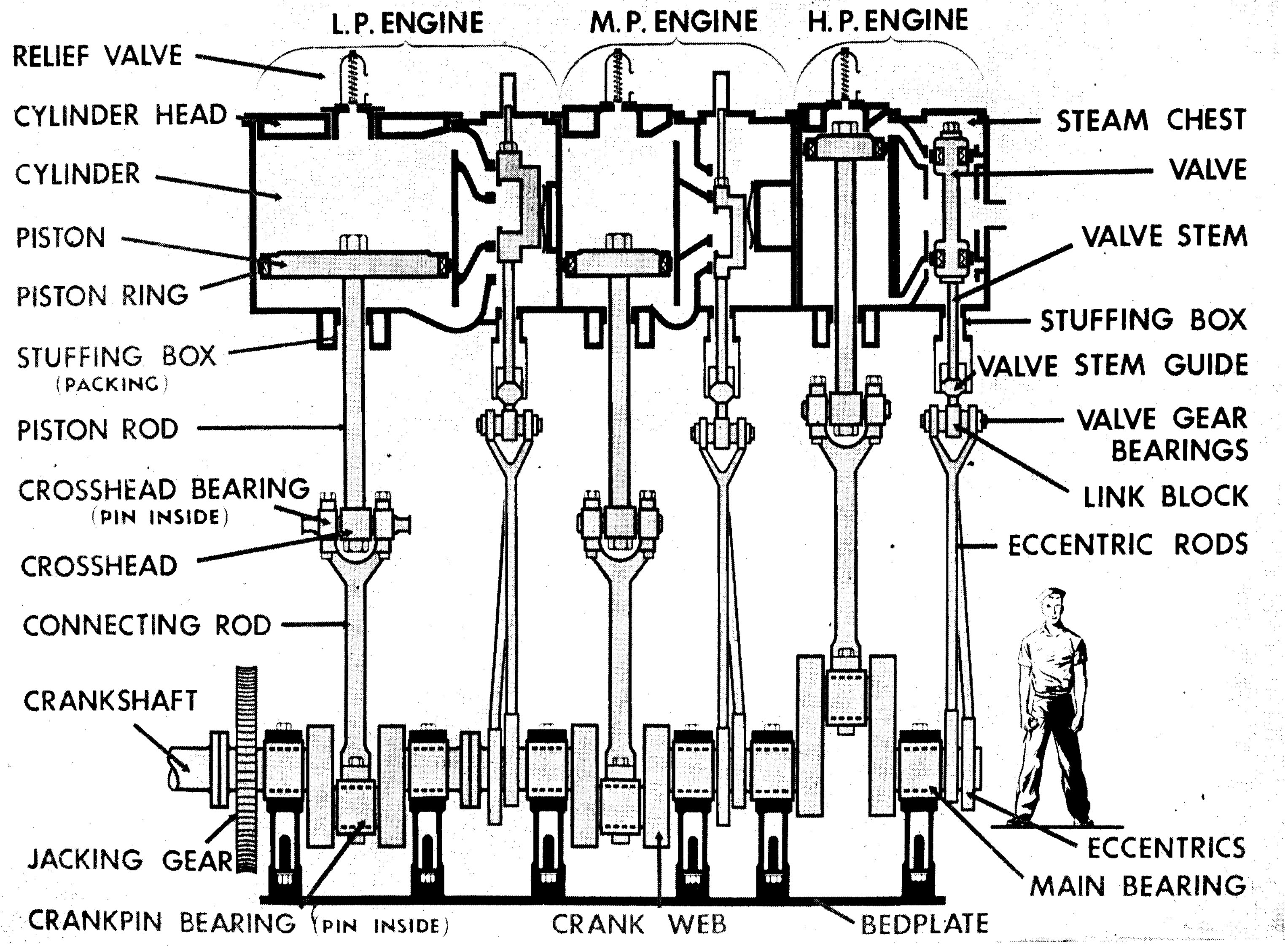
L.P. (LOW PRESSURE) END



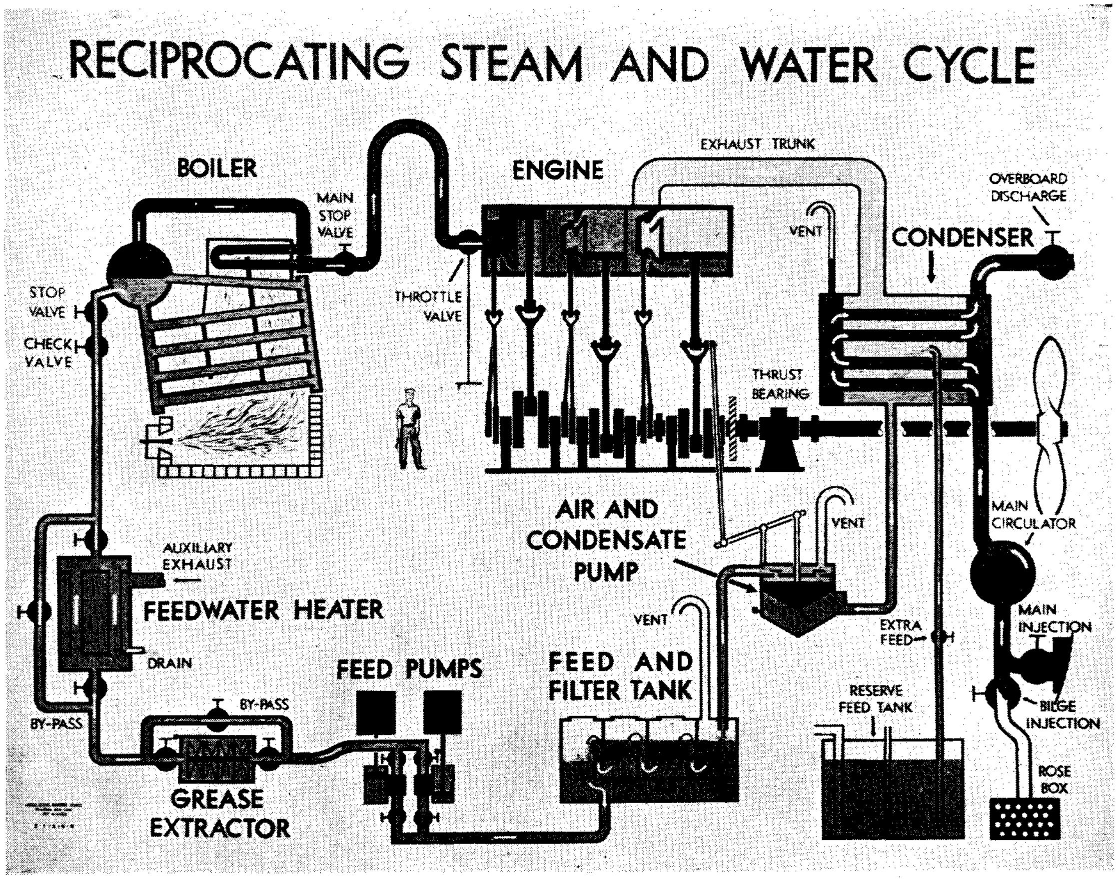
U. S. Maritime Service Training Aids Unit Chart

LIBERTY SHIP ENGINE

TRIPLE EXPANSION



U. S. Maritime Service Training Aids Unit Chart



U. S. Maritime Service Training Aids Unit Chart

MULTIPLE EXPANSION ENGINES

The single cylinder reciprocating steam engine used extensively to operate ship's auxiliaries would be too inefficient for propulsion. After the steam in the cylinder has expanded and pushed the piston there is considerable heat left in the exhausting steam. It is to put this to work that additional cylinders are added.

Compound Engine–A compound engine has two cylinders, the one in which the first expansion takes place being known as the "high pressure" cylinder, the other as the "low pressure" cylinder. To provide room for the expanded steam and to develop the same amount of power in both cylinders the "low pressure" one will have to be larger than the "high pressure." Compound engines are used mainly in towboats.

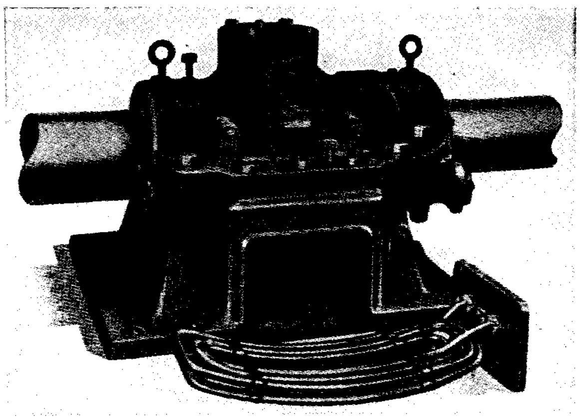
Triple Expansion Engines–In ocean going ships engines with at least three cylinders are used. These are known as triple expansion because the steam expands three times.

In the triple expansion engine used in the Liberty ship, a cross-section drawing of which is shown on page 70, the steam enters the H. P. (High Pressure) steam chest of the engine at about 220 pounds pressure where it is admitted to the cylinder by the H. P. piston type D slide valve. The steam expands in the cylinder, losing temperature, pressure dropping to about 75 pounds per square inch. It exhausts to the M. P. (Medium Pressure) valve chest and cylinder where it expands again, the pressure dropping to about 12 pounds per square inch at which pressure it exhausts into the L. P. (Low Pressure) valve chest and cylinder where it expands for the last time against the large L. P. piston. Equal power is developed in each cylinder. The steam upon exhausting from the L. P. cylinder enters the main condenser through the exhaust trunk. The vacuum of approximately 26 inches maintained in the condenser also is present in the exhaust trunk and in the L. P. cylinder on the exhaust side of the piston. This adds considerably to the power of the engine.

Other multiple expansion engines are four cylinder triple expansion in which there are two smaller L. P. cylinders instead of one big one and quadruple expansion having four cylinders in which the steam expands.

THRUST BEARINGS

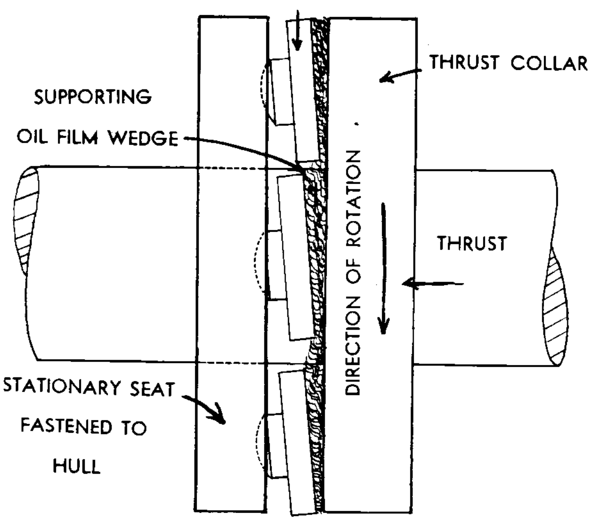
The propeller screwing itself forward through the water will push the tail shaft, line shaft and crankshaft forward through the ship, wrecking the engine unless the shaft is prevented from moving endwise. When the propeller is turning astern, it tends to pull the shafting out of the ship. To prevent this, the thrust bearing is installed on the line shaft just aft of the engine and as the tremendous thrust of the propeller is held in check at this point, the ship is actually pushed here. The thousands of pounds pressure exerted by the propeller create a terrific friction in the thrust bearing requiring excellent lubrication to prevent overheating.



KINGSBURY THRUST BEARING HOUSING

Two types of thrust bearings are in service, the horseshoe or multi-collar, and the Kingsbury. The horseshoe once practically the only type used has been replaced in new construction for a number of years by the Kingsbury. In the horseshoe type, the shaft was made with several circular collars a few inches apart along the shaft. Fastened through the thrust bearing frame to the ship's hull, horseshoe shaped bearings are placed between the rotating shaft collars. As the propeller starts to thrust forward or backward, the shaft collars immediately come up against the babbitt face of the horseshoes which stop the forward or backward movement. Lubricating oil must be continually supplied between the face of the shaft collars and horseshoe bearings. The base of the thrust bearing is filled with lubricating oil in which the shaft collars revolve carrying the oil upward between the collars and horseshoes. As the oil falls back into the base, it carries with it some of the friction heat. A sea water cooling coil running through the oil in the base carries a large portion of this heat away.

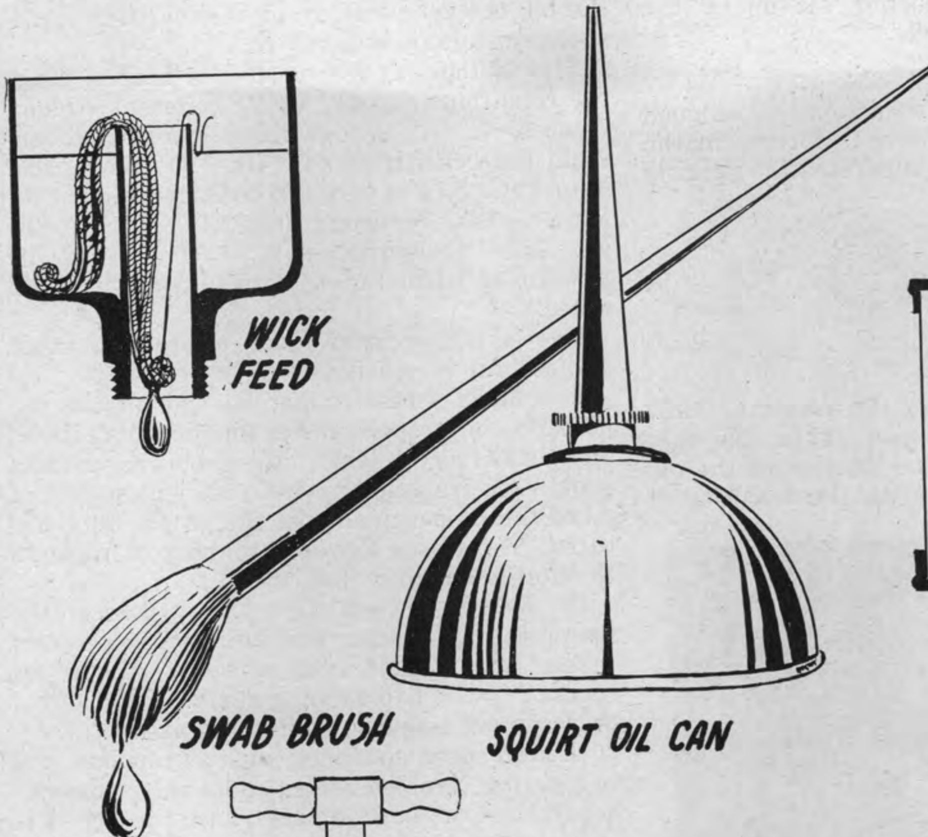
To help carry away the tremendous friction heat, sea water is pumped through the hollow shoes. The discharge side of the cooling water is open to view so that the oiler can readily see if any of the shoes should plug up. Sea water contains impurities which when heated tend to leave the water and cling to the inside of the horseshoes. By connecting a water or steam hose to the plugged shoe, it can usually be cleared. The horseshoes should be felt by the oiler at every round and the cooling water discharge from each shoe noted.



KINGSBURY THRUST BEARING

The principle of a Kingsbury thrust bearing is shown in the simple sketch. A single shaft collar pushes against several pivoted shoes which are held in place by a stationary seat fastened to the hull of the ship. When the shaft is revolved, the shoes pivot to allow the film of oil between the collar and the shoes to take the form of a wedge. The wedge of oil can withstand tremendous pressure without breaking down making it possible to operate a single collar. The entire bearing is encased in a housing, as may be seen in the picture. Lubrication is supplied by the rotating collar dipping in the oil sump.

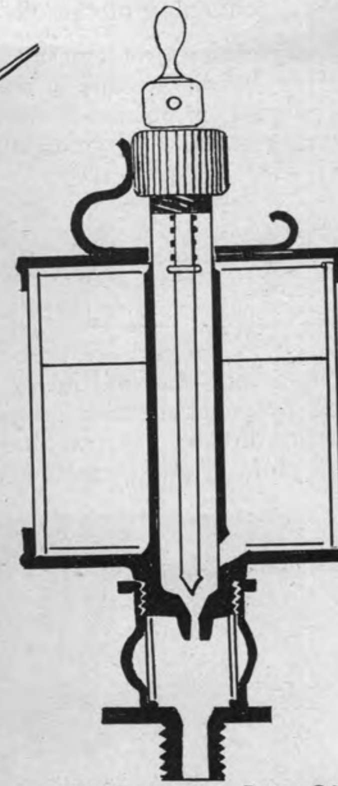
Kingsbury type thrust bearings require much less space than horseshoe and are more efficient.



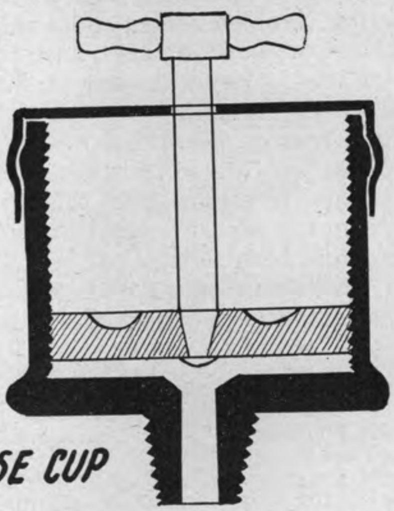
WICK FEED

SWAB BRUSH

SQUIRT OIL CAN



DRIP FEED OIL CAN



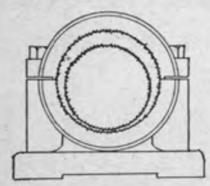
GREASE CUP

LUBRICATION

Friction is, and always will be, present in every moving machine, for it cannot be entirely eliminated.

Friction is that which resists the motion of either of two bodies when in contact with each other. Friction results in wear and power losses, therefore, there is a great necessity for reducing it as much as possible through the use of lubrication.

If two pieces of metal were polished to the highest degree possible and placed in contact, under a microscope, it would be found that the



JOURNAL IN BEARING

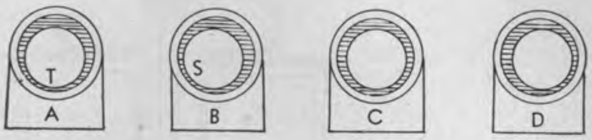
two surfaces were jagged. In the sketch is shown a journal in a bearing as it would appear greatly enlarged. In order to reduce friction between the surfaces, a lubricating oil or grease is used to separate the surfaces.

There are three kinds of friction that involve lubrication:

1. Rolling friction; the tire of an automobile on the road.
2. Sliding friction; a journal turning in a bearing.

3. Fluid friction; friction set up by the churning of the oil.

Lubrication problems are best understood by a thorough knowledge of its action. When good lubrication is obtained, there is formed in the bearing an oil film which separates the bearing



surface and the journal of the rotating shaft. This prevents metallic contact. Then, the only friction involved is the fluid friction of the oil. This fluid friction varies with the viscosity of

OILER FEELING CRANKPIN BEARING

OILER FEELING ECCENTRICS

the oil, the temperature of the oil, the journal speed, and journal pressure.

The sketches of a journal in a bearing show the conditions existing under different circumstances. In (A) the journal is at rest and contacts the bearing at (T). In (B) the journal is just starting to turn and contact point moves to (S). As the journal turns, the oil film forms and lifts the journal in (C). (D) shows the position of journal in relation to bearing at full speed.

The sketches show the clearances exaggerated for simplicity.

Too much stress cannot be laid on the importance of proper lubrication of all units in any machinery plant. All rubbing surfaces should receive a steady and sufficient supply of oil of the proper quality at the proper temperatures. There is a byword around power plants that oil is cheaper than metal.

On heavy slow-speed engines, such as the reciprocating engine, the lubrication problem takes into consideration the one factor of separating the two rubbing surfaces, therefore, only a small amount of oil is required.

In high speed machines, such as turbines, the lubricating problem must not only consider separating rubbing surfaces, but the speed is so great that a large amount of fluid friction, caused by the churning of the oil, is created. This fluid friction generated heat must not remain in the bearing so that the heat is carried away with oil draining from the surfaces. For this reason the pressure lubricating system for turbines has been developed.

With the reciprocating engine the following bearings and sliding parts require lubrication:

Main Bearings	Link Blocks
Eccentrics	Guides
Crankpin Bearings	Piston Rods
Crosshead Bearings	Piston and Valves
Valve Gear Bearings	

Lubricating oil specially compounded to readily emulsify with water is partially fed to the main bearings by wicks located in an oil box on top of each bearing. The oil box must be filled regularly and the wicks kept clean. Additional oil is supplied by hand with a squirt can. Partial lubrication is also supplied to the crankpin, crosshead bearings and guides from brass oil boxes on the side of the cylinders with syphon feed wicks and pipes leading to the oil cups on the individual bearings. Like the main bearings, the remainder of the oil is supplied by hand, the trick being to hit the moving oil cups with the squirting oil from the can. The brass oil cups for the crankpin and crosshead bearings are located on the crosshead, being of good size and filled with horsehair to prevent the movement of the engine from throwing the oil out of the cup before it has a chance to run down into the bearing. The hair is held in place by small copper wire and must be cleaned frequently.

Small brass oil cups filled with horsehair are located on the eccentrics, various valve gear bearings, and air pump drag link and beam bearings. These bearings are usually oiled entirely by hand.

A metal comb attached to the bottom of the crosshead slipper dips into a trough or pan filled with oil and water at the bottom of the guide, carrying this lubrication up on the surface of the guide in addition to the gravity oil feed line.

Lubrication in the form of steam engine cylinder oil is supplied to the piston rods and valve stems by a long handled swabbing brush.

In engines using saturated steam, the particles of moisture in the steam plus what cylinder oil enters the cylinders and steam chests with the piston rods and valve stems are generally sufficient lubrication for the piston rings and valves. However, the newer type engines using superheated steam must have cylinder oil supplied to the valve chests and cylinders. A small mechanical pump forces the oil into the H. P. valve chest from where it travels with the steam through the engine to the various pistons and valves. Excessive lubrication to the cylinders greatly increases the possibility of oil entering the boilers and must be avoided.

RECIPROCATING ENGINE ATTACHMENTS

Drains for Cylinders and Steam Chests–To remove water from the steam chests and cylinders, formed when the steam comes in contact with the cold metal walls when warming up the engine, drain cocks or valves are installed on the bottom of each chest and cylinder. Reach rods are provided so that they may be opened and closed from the operating floor. The drains are piped to discharge into the main condenser where the vacuum speeds the removal of the water. Water may also carry over from the boilers into the cylinders when the ship is rolling heavily or the water level in the boilers is carried too high. Water in an engine cylinder is dangerous, as it will not compress when the piston approaches the head, resulting in severe damage to the engine in some cases. A slapping sound in the cylinders of a moving engine is evidence of water and the drains should be opened at once.

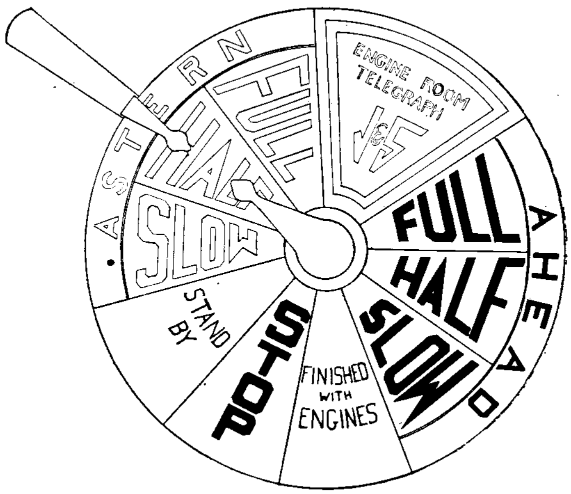
Relief Valves–In an effort to prevent this damage, spring type relief valves are installed at the top and bottom of each cylinder. When the piston tries to compress the water between it and the head, excessive pressure is built up which opens the relief valve, allowing the water to squirt out into the engine room. Faith must not be placed in these as they cannot take care of a very large amount of water.

Throttle Valve–To start and stop the engine and control its speed, the throttle valve is installed in the steam line just outside the H. P. valve chest. It is usually a double seated, balanced valve making it easy to operate. The valve is controlled by either a hand wheel or lever located on the cylinder column at the operating platform. For a quick emergency stop, some engines are equipped with a butterfly valve between the throttle valve and the engine. This operates on the same principle as a damper in a stove pipe and is closed by pulling a lever. In heavy seas the propeller will sometimes come out of the water at frequent intervals which removes the load from the engine, allowing it to race. To prevent its possible destruction the engine must be immediately slowed down by closing the butterfly or throttle valve. This is known as standing a throttle watch.

By-pass Valves–When warming up a reciprocating engine, it is necessary to allow steam to enter the steam chests and cylinders for an hour or so before moving the engine. Without the engine moving, the steam entering through the throttle valve will not pass further than the H. P. cylinder. To supply steam to the M. P. and L. P. a by-pass steam line around the throttle valve is provided. A valve in the by-pass line to each cylinder is provided with an extension rod to the operating floor. The by-pass valves are also used when maneuvering, as it sometimes becomes necessary to push the H. P. crank off dead center before the engine can be started.

Jacking Gear–When making repairs or adjustments to the engine in port, it is necessary to turn the engine to a desired position in order to place a particular crosshead or crankpin in an accessible position for working. This is done with the jacking gear which is a small single cylinder steam engine fastened usually to the L. P. Column. A worm on the crankshaft of the jacking engine slowly turns a large worm wheel secured to the main engine crankshaft. The jacking engine is usually reversible which allows the main engine to be jacked in either direction. Never attempt to do any work on the engine in port unless the jacking engine is engaged. The force of the current or tide against the propeller may cause the engine to roll over, crushing you.

Before turning steam on the main engine, the jacking worm must be disengaged from the worm gear or the jacking gear will be severely damaged when the engine starts.



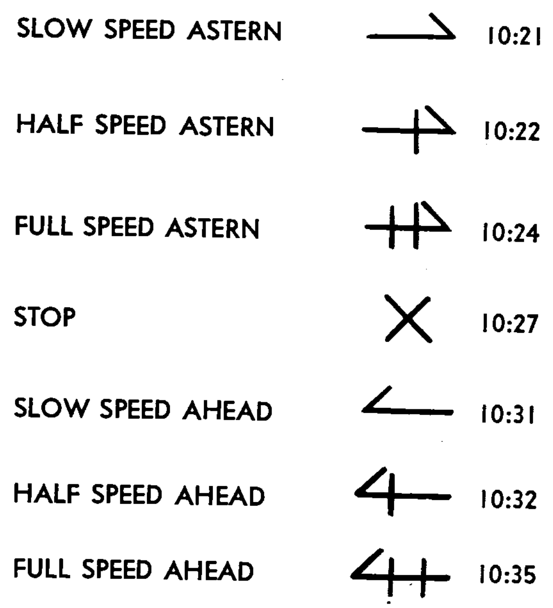
Revolution Counter–In order to determine the number of revolutions the main engine is making per minute, R.P.M., a revolution counter is installed, usually on one of the columns. It operates on the principle of an automobile mileage counter and is operated by a lever from one of the crossheads.

Dependent Air and Condensate Pump–With many reciprocating engines the air and condensate pump is secured to the L. P. column and operated from the low pressure cylinder through a beam arrangement, one end of which is fastened by connecting rods, called drag links, to the L. P. crosshead and the other end in the same manner to the air pump. As the engine operates the beam acts like a see-saw pushing the pump up and down.

Balance Cylinders and Pistons–With engines having large heavy valves, a small cylinder known as a balance cylinder is quite often located on top of the steam chest covers, directly over the valves. A piston secured to the top of the valves by a short rod is fitted inside the cylinder. The top of the balance cylinder is connected by a pipe line to the main condenser. When in operation the pressure in the steam chest pushing up on the bottom of the balance piston plus the vacuum sucking upward on the top combines to produce sufficient lifting force to remove a portion of the valve weight from the eccentric.

WARMING UP MAIN ENGINE

When preparing a reciprocating engine to get underway the first step is to inspect the engine carefully to make sure nothing has been left in the crankpits and that the engine is generally clear.



The jacking gear worm is next removed.

The main condenser circulating pump is then started up after opening the main injection valve and overboard discharge valve.

Steam and exhaust valves to the reversing engine are opened.

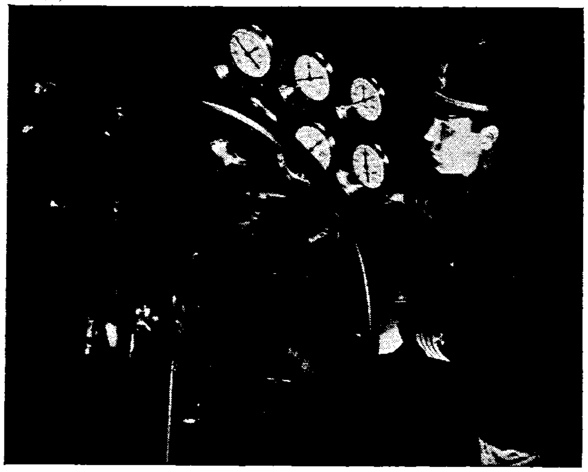
Throttle drain valve is opened.

Main stop on boiler is cracked, allowing steam to flow through main steam line to throttle valve.

Throttle valve is cracked allowing sufficient steam to enter H. P. steam chest and cylinder to warm them up but not enough to move the piston.

M. P. and L. P. by-pass valves are opened sufficiently to warm up these cylinders.

While the cylinders are being warmed the lubricating oil boxes on the various bearings should be filled to proper level and the wick feeds inserted. Lubricating oil should be poured in all oil cups before the engine is moved. Likewise the level of oil in the thrust bearing should be checked and the spring bearings on the line shaft oiled. The eccentric dip pans should be filled with fresh water to proper level.



REVERSING MAIN ENGINE

In the picture the Chief Engineer is maneuvering the main engine. His left hand is controlling the reversing engine and his right the by-pass valves. He is watching the Stephenson valve links, so that when they are in the astern position, he may stop the reversing engine. This is done by moving the differential valve control lever to center position.

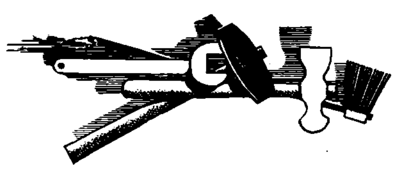
The engine must not be moved until permission has been secured from the officer in charge on the bridge and the cylinders have been warmed for an hour or two. Then the main stop valve may be opened wide and the engine rocked carefully ahead and astern being careful not to make a full stroke until certain all water has been worked out of the cylinders. The engine may then be operated very slowly in the direction permitted by the bridge officer until it is thoroughly warmed up.

MANEUVERING MAIN ENGINE

When docking or undocking a ship or moving in congested waters the bridge officer depends upon immediate compliance with his orders as to direction and speed with which the main engine turns. Delay in reversing the engine for example may cause a serious collision. The engine direction orders are relayed from the ship's bridge to the engine room by the engine telegraph. The sketch of the telegraph is shown. The center hand is turned from the bridge to point to the desired direction the engine is to turn and also the speed. As the hand turns a bell rings loudly to attract attention. Immediately the signal is received it is answered by moving the outside handle to point to the same position as the center pointer. The engine is then reversed, stopped or operated as indicated. The signals are known as bells and are written down usually in a bell book and rough log showing the time received using the symbols shown on opposite page.

When maneuvering, the engine drains are usually left open until underway, although it is sometimes safe to close the H. P. drains when the engine is moving.

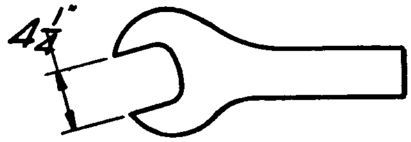
As soon as the engine is required to operate fairly consistently the cooling water service should be turned on the thrust bearing, main bearings and guides.



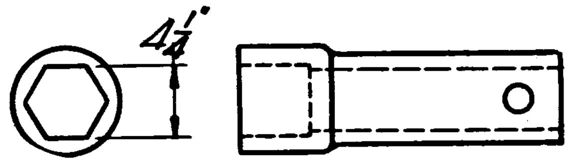
ENGINE ROOM WRENCHES

The following wrenches are principally used in making adjustments or repairs on the reciprocating type main engine of the EC-2 (Liberty Ship).

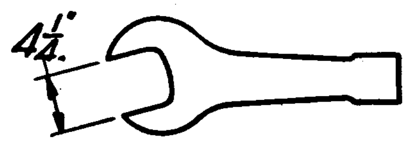
WRENCH FOR VALVE
STEM NUT
DWG. № 18354-8



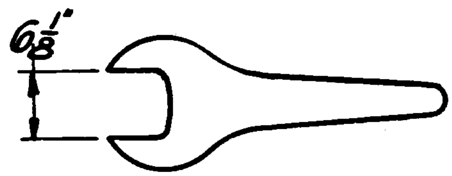
SOCKET WRENCH FOR VALVE
STEM CHECK NUT
DWG. № 18353-8



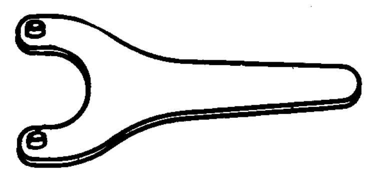
WRENCH FOR CRANKSHAFT
COUPLING BOLTS
DWG. № 18352-8



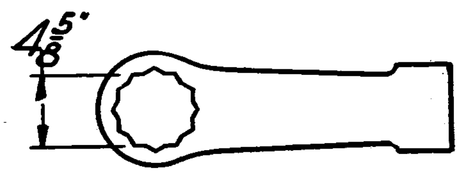
WRENCH FOR AIR PUMP
LEVER PIN
DWG. № 18351-8



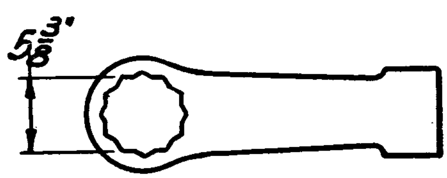
SPANNER WRENCH FOR
AIR PUMP ROD NUT
DWG. № 18350-8



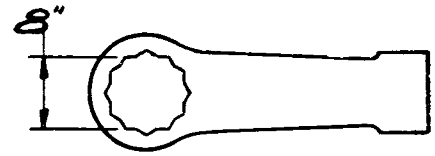
WRENCH FOR CONNECTING
ROD BOLT-X-H'D. END &
MAIN BEARING BOLT
DWG. № 18349-8



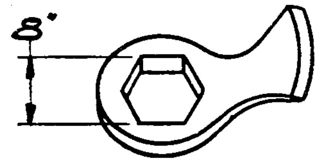
WRENCH FOR CONNECTING
ROD BOLT - CRANK END
DWG. № 18348-8



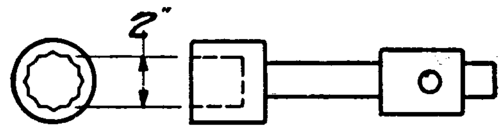
WRENCH FOR PISTON ROD
NUT - LOWER END
DWG. № 18344-8



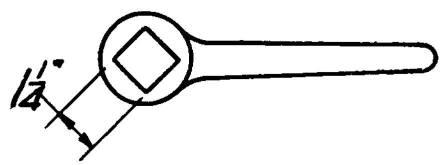
WRENCH FOR PISTON ROD
NUT - UPPER END
DWG. № 18343-8



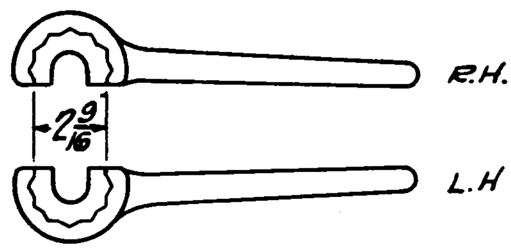
SOCKET WRENCH FOR PISTON
FOLLOWER STUD
DWG. № 18342-8



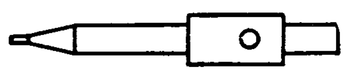
WRENCH FOR REVERSE SHAFT
ADJUSTING LEVER BOLT
DWG. № 18346-8



WRENCH FOR ECCENTRIC BOLT
DWG. № 18345-8



SCREW DRIVER FOR
M.P. & L.P. FALSE FACE
DWG. № 18341-8



MAIN BEARING GAGE
DWG. № 18340-8