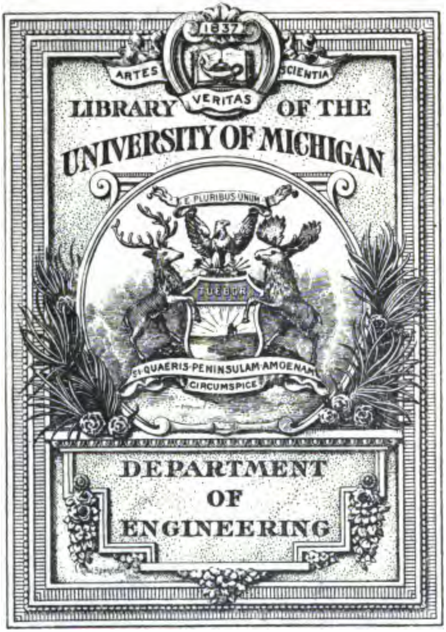
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HANDBOOK

FOR THE

CARE AND OPERATION

OF

NAVAL MACHINERY

BY

LIEUT. H. C. DINGER

U. S. NAVY

ONE HUNDRED AND TWENTY-FOUR ILLUSTRATIONS

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PREFACE

The larger part of the contents of this book appeared as a series of articles in the "Journal of the American Society of Naval Engineers." With slight modifications and numerous additions the handbook is now offered in its present form, and it is hoped that it may serve to fill a demand for a concise and simple description of the care and operation of naval machinery on many points not largely touched upon in the standard treatises on Marine Engineering.

The information contained in this handbook has been derived from personal experience, from consultation with engineer officers and the enlisted men of the engineer force, from various engineering books published in the United States and in England, also very largely from catalogs published by manufactures of naval machinery and fittings.

Grateful acknowledgment is made to Rear Admiral C. W. Rae, U. S. N., Chief of Bureau of Steam Engineering, and to his assistants, for the use of material available at the Bureau, and to the manufacturers of various naval specialties for valuable information and the use of cuts.

H. C. DINGER.

NEW YORK, *January*, 1908.

The following authorities have been consulted: "Journal of the American Society of Naval Engineers"; "Machinery Specifications of U. S. Naval Vessels"; "Naval Engines and Machinery," by J. K. Barton; "Practical Marine Engineering," by F. W. Durand; "A Manual of Marine Engineering," by A. E. Seaton; "The Marine Steam Engine," by Sennett and Oram; "Engine Room Practice," by J. G. Liversidge, R.N.; "Naval Boilers," by B. C. Bieg; "Breakdowns at Sea," by A. R. Leask; "Experimental Engineering," by Carpenter; "International Marine Engineering."

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HANDBOOK

FOR THE

CARE AND OPERATION

OF

NAVAL MACHINERY

PART I

OPERATION OF NAVAL MACHINERY

INTRODUCTION

THIS handbook is designed to be suggestive and educational for the use of those interested in naval machinery, and especially for the requirements and needs of the petty officers and mechanics of the engineers' force on naval vessels. It is also hoped that it may prove a convenient book of reference and information to all connected with or interested in naval machinery.

It has been the intention to give in as simple a manner as possible, details and methods of work met with in the service in connection with the care, overhaul and management of naval machinery. The aim is especially to furnish in a concise and simple shape general information of practical value to those handling naval machinery. The methods of work described are those current in the service, and are all based on practical experience.

It is hoped that this book may be of value in assisting the enlisted men of the engineer's force to acquire information and knowledge to fit themselves for higher ratings and for warrant rank.

The reader is requested to familiarize himself at first with the general plan and the subdivision of the subjects of this book in order that he may be able to turn readily to any part required. When any particular subject is looked for the index will be found of great value in readily locating it. Much time will be saved by consulting it.

CHAPTER I

Getting Underway — Boilers — Engines — Trying Engines.

Getting Underway — Boilers. — The time required preparing to get underway depends upon the type and size of the boilers in the vessel, as well as upon the character of the engines.

Ships having large Scotch boilers will require six to eight hours at least, twelve hours is better. Vessels with water-tube boilers may require less than an hour for the boilers, but it is difficult properly to warm large engines in so short a time.

The boilers to be used and the number of them should be selected with due consideration for the location of coal supply, and the condition of all the boilers in regard to repairs, state of cleanliness, etc.

If the boilers are empty, they must be pumped up to slightly below steaming level; if kept full of water, water is run down; the usual practice being to pump the water into some double-bottom or reserve tank with auxiliary feed pump, and if no special system of piping for this purpose is fitted, use fireroom hose.

The water line at starting fires should be several inches below working level, especially in water-tube boilers. On starting up there may also be considerable water which has collected in condenser or feed tank; to prevent the necessity of its being run into bilge, this water should be pumped to boiler.

Make sure that all broken joints about the boilers are remade, and that everything is tight; that all surface and bottom-blow valves of boilers not in use are closed.

Prime fires by placing a thin layer of coal on grates (not done till water is at steaming level). Start fires, generally by using live coals from boilers in use.

Keep ash-pit doors closed at first and open furnace doors to allow air to reach the fire above the fuel. In Scotch boilers, start water-circulating apparatus, if any be fitted, as soon as fires are lighted. If there is no water-circulating apparatus, a circulation may be set up by putting auxiliary pump on the bottom blow of boiler and discharging into feed line. The general type of circulator in Scotch boilers is the hydrokineter where the circulation is produced by a steam jet. By means of this device the water in boilers may be kept at 150 to 180 degrees Fahrenheit, using steam of auxiliary boiler, and under these conditions steam can be got up in a very much shorter time without injuring the boilers. With hydrokineters in use steam has been raised in very large boilers in less than two hours.

If there is no boiler in operation the fire is started with kindling wood or oily waste, laying this near front and topping it with small lumps of coal, which will take fire as the wood burns. Adding a little oil to the coal will cause it to catch fire more quickly.

The fire is allowed to burn up gradually and is pushed back as it burns, new coal being added from time to time till full thickness, 6 to 10 inches, is reached.

After fires have been started, the fire doors are closed and ash-pit doors opened.

As soon as a slight pressure is shown on gage, open air cock to allow air to escape. Other practice is to allow all air to pass into steam line and engines during warming up, boiler stop valves being opened for this purpose, but it may not be desirable to start to warm up engine till some time after steam has been formed in the boilers.

With Scotch boilers great precautions must be taken that the boiler is gradually heated and that one part is not cold while another is hot.

Steam in Scotch boilers should form in about five or six hours after fires are started.

In water-tube boilers fires can be pushed as much as possible, and a great many precautions that have to be observed with Scotch boilers can in a measure be disregarded. In emergency, steam can be gotten up to working pressure in water-tube boilers in 20 to 30 minutes, but it is advisable to allow at least one hour.

When steam instead of air comes out of air cock, close it. In Scotch boilers there should be about two hours from time steam begins to form till working pressure is reached. In water-tube boilers it may be only a few minutes.

Engine Room. — About an hour before the time set for getting underway, start to warm up engines. The length of time for this depends on the size of engines. For very large engines more than an hour should be allowed; for small engines an hour is not necessary.

To Get Ready. — See all tools, material, clothing, etc., clear of engine.

See all parts of engine in place and properly secured.

Disconnect jacking gear.

Start circulating pumps, making sure that injection and discharge valves are properly opened.

If vessel has been lying in tropical parts where there are a large number of jelly fish, the injection strainers should be blown out with steam.

Start main air pumps and open main exhaust valves to condensers if valves are fitted.

Open bleeder to drain steam line, open other drains in steam line. On large vessels, and especially where there are pockets in the main steam line, as on *Tennessee* and *Washington*, great care must be exercised that steam line is properly drained.

Open bulkhead stops.

Drain separator.

The draining of steam pipe is very important, for if it is not done there is great danger of water hammer and a rupture of some steam pipe.

Open boiler stop valves, unless they have been open since fires were started, just cracking them open at first, and then open them gradually. This should at first be done with boiler that has steam up, the other boilers being connected as their pressure approaches the pressure of boilers that are connected.

Get reversing engine ready and turn steam on it.

Turn steam on jackets and drain them. Open cylinder drains.

See all working parts ready, oil pipes and cups clear, wicks ready and oiling gear at hand; take gaskets off bearings. Put a little oil by hand on the principal pins, slides and bearings, slack stern gland.

The steam being up to throttle, move links back and forth with reversing engine and crack open throttle slightly. This allows a little steam to pass into H.P. cylinder and warms it up. Crack open pass-over valves to allow steam to enter I.P. and L.P. cylinders.

Continue to work links back and forth, and thus get all parts gradually warmed up.

Turn steam on capstan and steering engine, when ordered from deck, and have pump ready for washing off anchor chain. Try engine-room telegraph, also telegraph to fireroom, voice pipes, bells, telephones, etc.

See that feed pumps are in proper condition and try all that are to be used.

The boilers being connected and all main stops opened, see all oiling apparatus ready, including oil cans, oil syringes, graphite and cylinder oil for swabbing ronds. See reservoir oil tank full and oil cups filled. The boiler stop valves are never opened wide; usually 2½ to 3 turns of the wheel is sufficient.

An efficient aid to internal engine lubrication is to introduce graphite into cylinders just before starting. This can be easily done by mixing it with water and putting it down an indicator pipe, if no lubricator cups are fitted.

Circulate water through thrust bearing and slides.

Make inspection to see that there is plenty of steam, good fires, good vacuum, and everything about engines ready and all men at stations.

Permission to try engines should be obtained about fifteen or twenty minutes before time set to be ready. Permission being granted, engines are tried.

Trying Engine. — Before trying engine, pass order to stand clear. Then open throttle slightly and move links back and forth. The engine will then start one way or the other. If it does not start well, it is probably due to water in cylinders, which must be gradually worked out. A well-handled and properly adjusted engine will start without manipulating pass-over valves.

Try engine both going ahead and astern and see that it reverses easily. Do not move engine more than a few revolutions, usually two, each way, as a greater amount of turning is likely to bring a strain on anchors or moorings.

After trying engines, take final look to ascertain if there is any heating of bearings or any indication of wrong adjustment; everything being ready, the department is reported ready to get underway. After this report is made, a machinist must stand by to answer any signal promptly.

In trying engines, there may be several causes to prevent proper working; below are some of them:

Water in Cylinders. — This will prevent the engine moving full stroke; the engine is likely to start, move a little way and then bring up. The water must be gotten rid of by opening all drains and moving piston back and forth by reversing gear till the engine will turn a complete revolution.

Engine on Center. — This can be guarded against by taking care when engine is stopped that the H.P. crank is up near middle of stroke. Reversing engine, and bringing link back again, will throw most engines off the center. It this fails, pass-over valves can be used. In using pass-over valves, regard must be had for the position of the valves. If the valve ports are closed to steam no steam will enter the cylinder and opening passover will only cause a heavy pressure to form in receiver. The valve ports will be open to steam during the first half of stroke till cut-off takes place.

By opening pass-over too much at starting, in engines having attached air pumps and slide valves, a considerable pressure may be obtained in receivers, and hence on back of valves, if slide valves be fitted. This may be sufficient to prevent the moving of the links. The remedy is to close pass-overs and open drains so that pressure on backs of valves may be reduced.

This failure of reversing gear may also take place at any time engine is stopped during maneuvering when pass-over valves are left open or a considerable pressure on slide valves is produced by other means.

Whenever an engine fails to move with a slight opening of throttle, the cause of obstruction should be found, and the engine should not be forced by opening throttle wide, as by so doing something may be broken.

Valve Rods Sticking. — Valve rods sometimes stick; they may be loosened by applying oil, loosening stuffing box or loosening up on valve-stem guide. Some of the moving parts may be caught in some way, and at times the jacking gear has not been disconnected.

Excess Water on Starting. — With attached air pumps, in starting up, a great deal of water will be thrown into tank; in such cases it is advisable to put a pump on the air-pump channel ways and pump directly to boiler. This will prevent tank from overflowing and losing fresh water in bilge.

Handling, General. — Some engines handle much easier than others, and all have some peculiarities which are only found out by experience; but a great many general features hold for all. The real handling of an engine can only be learned by practical experience where practically all the senses are developed to apply to the case.

Turning Over. — When engine is turned over in answer to signal, wicks should be put in and then special lookout must be had for heating or any maladjustment.

Throttle. — The throttle must not be suddenly opened or closed, but the engine, especially if a large one, should be allowed to work up to full power gradually.

Reversing. — When reversing, the throttle should first be closed, and engine then reversed; but when the emergency signal is received (that is, a signal to back full speed when going ahead), the engine should be immediately reversed, even at a risk of breaking something. This signal should *never* be given from deck unless it is an emergency signal.

CHAPTER II

Running Engines Underway — General Oversight and Watch — Heating — Oiling — Internal Lubrication — Pounding — Leaks — Priming — Water in Cylinders — Steam Jackets — Vacuum — Auxiliaries — Air Pump — Circulating Pump — Feed and Bilge Pumps — Economical Performance — Adjustment of Links — Racing — Waiting — Stopping and Waiting — Management of Steam — Coming into Port — Shutting Down — Routine Underway.

Running Engines Underway. — Whenever there is any doubt or trouble in connection with the operation of the engines, the officer of the deck should be notified immediately so that he can make suitable dispositions to avoid danger.

The most laborious work in connection with the running of engines will be when steaming in squadron, when exact distance must be maintained. With same steam and vacuum and no change in links, the pressure in the H.P. and I.P. receiver will be the same for the same number of revolutions, so that, after some running, these gages can be used as a quick indication of the number of revolutions.

Electric revolution indicators are fitted on some vessels which indicate by a pointer at the end of every minute or half minute the exact number of revolutions the engine has turned during the preceding minute.

With well-adjusted engines and ordinary care in operation, the main engines are not likely to give much trouble.

The points to look out for in the engine room underway are, in general:

1. A watchfulness and oversight where all the senses are used to detect any derangement or improper working.

2. Keep all moving parts properly lubricated.

3. Keep water out of cylinders.

4. Keep steam pressure, links and throttle so adjusted that engines work smoothly and economically and that there is the proper distribution of work between the cylinders.

General Oversight and Watch. — The senses that come into use in connection with the operation of engines are sight, hearing, touch, smell, and taste.

The Eye.—The trained eye is able to detect when various moving parts are not moving with regularity, as well as to notice movement in parts that should not be moving. The eye, of course, can detect such things as steam leaks, water leaks, cracks and breakage.

Hearing and Touch.—A great deal concerning the proper running of an engine can be told by the sounds heard in the engine room. The various sounds tend to combine into a sort of rhythm, and the experienced ear can tell when matters are going well and when even very slight deviations from this ordinary rhythm are present, and this forms a very efficient means of detecting and locating faults.

The chief sound is the rather dull and heavy thump caused by the pounding of the main or crank-pin bearings. This can be located by observing which crank has just passed the center when the thump is heard, remembering that the thump will be heard after and not before passing the center, or by filling bearing with oil the thump will be lessened. If the bearing is felt and found to be warm, or the thump felt by other means, the knock is located. The main bearing will have a duller sound than the crank pin or crosshead, and will be felt all over the structure. The crosshead knock is a sharper sound and is not heard at so great a distance.

Often lost motion can be told by feeling the bearings. Placing a piece of metal against one part and the other end against the teeth or ear will also give indications.

A valve being loose on its stem or piston loose on rod causes a solid, sharp thump or a dull click. On starting up or slowing down, slide valves are apt to rattle or cause a clicking sound due to lack of pressure on their backs.

Attached air pumps, on becoming flooded, give a heavy thump due to excess of water; or this may be caused by the absence of an air cushion, which may be remedied by opening air cock on bonnet for a moment.

Spring rings vibrate more at certain speeds and cause a rasping sound at times. Other sounds inside the cylinder are caused by moisture in the steam and by the rings and cylinder walls becoming dry. When this rasping sound is heard, while engines are in free route, a little cylinder oil put on piston rod or some graphite and water introduced into cylinder will relieve the noise. Scroping and grunting, caused by water in the piston rings, is generally only heard on starting up and slowing down.

The spring rings of piston valves give a sort of whistling sound when dry.

The cylinder relief valves are apt to rattle when there is little pressure on them. Stuffing boxes sometimes squeal, due to insufficient lubrication.

The churning sound noticed about engines is due to the passing of steam through ports. There is a difference in sound showing whether the port opening is ample or not. This difference may be noticed by running cut-off well in and out and observing the change.

Touch is of great use in feeling the degree of heat and to determine slight movements not otherwise noted.

The sense of *smell* is of great value in detecting heating or improper lubrication, as the smell of heated and burning oil can be noticed.

Taste comes into use in tasting feed water to see whether it is fresh or brackish.

Heating. — Various moving parts are liable to heat. This is caused by (1) improper or insufficient lubrication, (2) bearings being out of line, (3) bearing set up too tight, (4) grit or dirt from inferior oil or from engine room, getting into bearing, (5) uneven surface of bearing or brass.

Bearings must be frequently felt and special regard had for lubrication. If there is a sort of lather on the bearing, it is a sign of proper lubrication. Good oil running out shows that there is too much oil. Heating or the smell of burning oil shows a lack of lubrication.

If bearings get warm, the supply of oil should be examined and increased. If it gets warmer, water may be sprayed on or circulated through, according to which arrangement is supplied. But water should be avoided, if possible, the danger being that all parts are not cooled at the same time, and there is danger of bending, warping, or cracking due to sudden and unequal contraction caused by the cooling effect of the water.

If the temperature of a bearing continues to rise after having increased the oil supply and we have a hot bearing, other means must be taken.

The danger of a hot bearing is that the brasses may expand till they grip the journal, thus causing a constant increase in the friction and heat.

With increased heat the white metal may run.

Slowing down will reduce the friction.

Slacking back on cap bolts will increase the clearance and prevent gripping; but these cannot be slacked back too much as pounding will result.

By stopping and readjusting the heated bearing, the matter may be remedied. This is probably the best way, as it is the surest. If the bearing is not large, it can be taken off, cleaned out, covered with graphite and a liner inserted in a few minutes, and on starting off it will be all right. It is thus a very good practice to have paper and thin copper liners, already cut, at hand for all bearings, so that there is no delay in fitting them.

For cooling a bearing, tallow, black lead and sulphur are advisable as they absorb heat.

Water should not, except in most extreme cases, be sprayed on a hot bearing, and should only be used before very great heat is manifested. A great objection to the use of water is that, being heavier than oil, it gravitates to the lower part of the bearing, and thus displaces the oil, and after water is once started in a bearing, it is difficult to get it properly oiled. Water may be constantly used on guides and thrust bearings, which are arranged hollow so that the water does not come on to the sliding surfaces.

Often on trial trips streams of water are run continually on all the principal bearings, but in those cases the water is started before the heating begins. This is, however, not good practice for ordinary running.

Heating due to bearings being out of line, or poor surfaces cannot be effectively remedied except by readjusting the parts, the only remedy in these cases being to run slow and to use oil freely.

Oiling. — Oiling in connection with the operation of engines consists in, (1) keeping the oil boxes or cups supplied with oil, (2) supplementing this supply by hand where necessary, (3) oiling by hand small bearings that do not have separate pipes, (4) lubricating piston and valve rods, (5) internal lubrication, (6) regulate water service.

The oil boxes are usually filled from a reservoir tank located in top of engine room, with pipes leading to all the various boxes so that they can be filled. Where no such system is provided, the boxes are filled by using an oil measure. Oiling by hand is done with the squirt can; a small half-pint can is usually the handiest. In addition to the squirt can the oil syringe is used to reach parts that are out of the way, such as slides, piston rods, etc. For the fast moving engines, syringes are generally used in place of the squirt can.

Piston rods and valve rods are lubricated by means of swabs, using cylinder oil mixed with graphite, also by oil syringes.

On large bearings tallow cups are provided, and these have to be filled by hand.

The covers of all oil boxes and cups should be kept closed to prevent dirt from getting into oil.

There are no definite rules to be given regarding the frequency of lubricating. This can only be told by experience in each particular case.

Amount of Oil Required. — This will depend largely on the skill of the oiler, the adjustment of the bearings and their condition, the quality of the oil and the temperature of the engine room. In hot weather the oil will run freer and wicks should be decreased; in cool weather the oil will run slower and wicks should be increased.

In time wicks rot and also become clogged, thus changing the amount of oil supplied.

Fair practice is to use about one gallon of oil per ton of coal, or one gallon per 1,000 H.P. per hour. For small engines, such as torpedo-boat engines, considerably more oil per horse-power will be used than for large engines. This amount can be reduced by careful attention.

Internal Lubrication. — For vertical engines no internal lubrication is necessary other than the swabbing of rods and wiping out of cylinders and vaselining them at times when they are opened. The addition of a small quantity of graphite from time to time as cylinders give indications of becoming dry is advisable. When cylinders have once obtained a good surface by the use of graphite, they will run well without much further lubrication.

Pounding. — Results from three general causes:

1. Too much clearance in a journal, slide or connection.
2. The use of too light oil on heavy pressure.
3. Improper distribution of power between the different cylinders.

The first is remedied by readjusting, and in part by slowing down or changing speed, as at certain speeds pounding is greater.

By the use of heavier oil the second cause may be removed, for then a heavier and thicker film of oil is provided.

The third cause is remedied by a readjustment of cut-off. Means for increasing compression will generally reduce pounding, but as a rule this can be determined from trial.

Leaks. — *The stuffing boxes* as well as various joints may leak slightly. These leaks make themselves visible by the issue of steam or water. Steam joints are likely to leak slightly on starting up when there is considerable water in the pipes, but as they become hot and water is driven away they again become tight. Tightening up on the bolts of such joints slightly will often stop the leaks, provided the gasket is still good.

Stuffing boxes, when they leak, may usually be set up while running, but care must be taken that they are not set up too tight so that they do not produce excessive friction or cause the rods to become hot. It is better to have a little steam leak than to have a hot rod. With well-fitted metallic packing, there is little danger of either excessive leak or of great friction, and for all rods of any size metallic packing is fitted. It must be remembered that all steam leaks are a direct loss of power as well as of fresh water, and the loss by leakage sometimes amounts to 5 per cent of the total steam used.

Priming, Water in Cylinders. — The presence of water in cylinders is dangerous, especially in quick moving engines having small clearance spaces. A great many broken cylinder heads and other serious accidents have been due to this cause. The presence of water is shown by a cracking or snapping noise when there is not very much, and by a heavy, sharp thump when there is a considerable quantity. The relief valves cannot very well take care of this because the pressure comes all of a sudden at the end of the stroke. When the presence of water is noticed, the drains should be opened. If this does not relieve the cylinder, close down throttle somewhat, thus wire drawing the steam more. If the water still increases, the throttle should be closed further, steam line drained, and the cause of the priming looked for at the boilers and there remedied.

Separator. — The separator must be kept drained, for if a large amount of water collects it may go over in a mass to the engines, thus defeating the very purpose for which the separator is fitted.

Jackets. — Most large engines are fitted with steam jackets. These are very useful in warming up cylinders since they distribute the heat to all parts of the cylinder walls.

Most engines have all cylinders jacketed; others only have the I.P. and L.P. cylinder jacketed.

The office of the jackets is to prevent liquefaction in the cylinders, and they thus increase the economy of the engine, the jacket steam giving up its latent as well as its sensible heat to prevent the steam in the cylinders from condensing. Since none of the heat of the jacket steam is lost in the condenser, its apparent theoretical economy is very great.

Considering the action of the steam alone, the most efficient practice would be to carry full boiler pressure in each jacket, but due to mechanical considerations, such as strength of castings, etc., this is not done, and if jackets are used the steam pressure in each should be kept slightly higher than the pressure in the corresponding receivers in order that the jacket steam may be hotter than the steam in the cylinders.

With slow moving, medium pressure, long-stroke engines, jackets undoubtedly result in economy, but with high-pressure, high-speed, short-stroke engines, there are various mechanical considerations that tend to reduce the advantages from their use. With that class of engines it has also been demonstrated by experience in some special cases that jacketing has little advantage in economy.

High-pressure jacket steam causes the cylinders to become hot and dry, prevents steam from being moist, and thus reduces the natural lubrication in the cylinders. This results in what is known as scrooping. When this is noticed the jacket pressure should be lowered. The steam being dry and likewise the rubbing surfaces, there is considerable friction, as well as wear, with attending difficulties, scoring of cylinders and breaking of rings, so that though jackets may have an economy, other troubles brought about by their use may at times be sufficient to make it advisable not to use them. As the greatest trouble due to friction and wear occurs in the H.P. cylinder, where there is probably the least economy due to their use, it would appear that jackets should only be used on the I.P. and L.P. cylinders.

In cold weather it would seem to be more advisable to use jackets than in warm weather.

It is very possible that the use of high-pressure steam in jackets is responsible for many troubles experienced with cutting of cylinders, breaking of rings and increased internal friction. These difficulties can, however, be overcome by proper design and lubrication.

Vacuum. — The maintenance of a good vacuum is a most important aid to economy. This depends on the proper action of air pump and a sufficient supply of circulating water, and on the tightness of parts of condenser and exhaust system.

A loss of vacuum may be accounted for by leaks in exhaust pipes whereby air is drawn in. This may be through open exhaust valves of auxiliaries not in use (chief cause), leaks around stuffing boxes of exhaust valves or other valves leading to condenser, leaky low-pressure piston-rod stuffing boxes; leaks in exhaust joints or joints on condenser, defective air pump. In these cases condenser remains cool.

If vacuum drops and the discharge from air pump is found to be hotter than usual, the circulating water is not sufficient. This may be caused by an extra amount of exhaust steam, a slowing down or stopping of the circulating pump or a stopping up of injection pipes, in which case these pipes will become hot. The division plate in condenser head, or the valves connecting injection and discharge may leak and thus water is allowed to short circuit without passing through condenser tubes. In the above cases the condenser will become hot.

A ready indication of loss of vacuum is the slowing of the engines or a dimness of the electric lights when dynamo exhaust is turned on main condenser. A loss of vacuum shown on gage without any other indication of change is probably due to the gage pipe becoming plugged up, or a cock or pipe may be closed.

Auxiliaries. — The auxiliaries, air, circulating and feed pumps, are likely to give the most trouble, and these require constant attention and oversight.

Air Pump. — Separate air pumps, when running very slow, may sometimes stop. Usually the steam end of the air pump gives very little trouble.

The principal trouble with air pumps is the water valves carrying away. If bucket valves are gone, the vacuum will drop very materially and the speed of pump will increase. If foot valves go, vacuum will not drop but pump will work jerky and hard, vacuum gage will move with pump. If head valves are gone, vacuum will decrease somewhat and pump will work with a somewhat jerky movement.

Air pumps may become overloaded with water, due to some obstruction in pipes. This will cause them to thump and the vacuum to drop.

The stuffing box of air-pump piston rod should be kept tightly packed with flax packing, and the gland may from time to time require setting up while running.

With independent air pumps, the valve gear must be kept in proper adjustment to give proper length of stroke.

Circulating Pump. — This, as a rule, only requires regulation and oiling. The speed of the pump should be so regulated that the temperature of the discharge water is a little, not over, 20 degrees below the temperature corresponding to the vacuum that is being maintained. To have this temperature much below the temperature corresponding to the vacuum is simply throwing away heat by means of the circulating water, and reducing the temperature of the air-pump discharge.

The temperature corresponding to vacuum is as follows:

28 inches	100 degrees Fahrenheit.
26 inches	125 degrees Fahrenheit.
24 inches	140 degrees Fahrenheit.
22 inches	152 degrees Fahrenheit.
20 inches	161 degrees Fahrenheit.

The runner is sometimes likely to come loose on shaft due to key becoming loose. This can be told by a rattling inside the pump chamber. The shafts of pumps are liable to corrosion and become weak and sometimes crack, thus making it necessary to fit new ones.

Operation of Feed and Bilge Pumps. — On starting a reciprocating pump, the proper suction and discharge valves should first be opened, making sure that when there are two valves in the connection both are opened.

Open exhaust and cylinder drains and turn steam on slowly to warm cylinder, then open up gradually. If pump fails to start, move valve gear by hand, observe whether there is an excessive pressure on discharge gage; if so, a discharge valve may be closed.

If pump starts all right close drains and adjust throttle to suit.

If pump works quickly with a jerky motion the suction may be defective; open pet cock to see whether water is present in suction chamber and ascertain whether there is enough water in tank or bilge to cover end of suction pipe. In some cases it may be necessary to prime pump.

A bilge pump may be primed from the sea, but a feed pump should not be primed from the sea but from some fresh-water tank.

Irregular working may be due to —

Shortness of water in tank.

High temperature of feed suction and accumulation of vapor in pump. To overcome this difficulty the pump may be cooled by putting it on a cold suction for a short time and trying it again, or by cooling it off with a hose.

Sudden change in opening or closing of discharge valves may be noted by observing the pressure gage.

If pump runs fast without an appreciable discharge the trouble may be due to pump valves being carried away or a leaky piston.

Trouble with Valve Gear. — On every vessel general directions as to the operation of the pumps should be obtained from the manufacturers, for there are many special points peculiar to each type. The drawings of valve gear should be studied so that the operation may be thoroughly understood.

Most difficulties with the valve gear of pumps are caused by neglect and bad treatment. Generally it is the secondary valve which controls the operation of the main steam valve that becomes stuck or fails to move properly. A few general rules as to care of these parts may be given.

a. Remove valve gear frequently and clean off all parts, apply a little kerosene and graphite, the graphite for lubrication and the kerosene to remove rust.

b. Do not keep pump standing for any length of time without moving valve, for it may become rusted in places, due to the presence of moisture.

c. Don't keep drains open when not in operation. Open drains allow access of air and thus allow rusting.

d. Do not supply heavy cylinder oil to valve gear in operation since this oil is liable to cake and cause the valve to stick.

e. Keep pump in continuous operation as much as possible. This applies especially to feed pumps which, if kept going continuously, give little trouble, whereas if intermittently stopped and started are not apt to work well.

The chief trouble experienced is caused by rings of rust or burrs being formed on the moving parts. The best way to remove such obstructions is to take the bonnet off and clean the parts.

In pumps having a valve gear operated by tappet motion and distance nuts the valve stem may be too tightly or too loosely packed so as to necessitate too much force, or, on the other hand, allow the valve to drop of its own weight before it should. (This is especially so in Dow pumps, where a tightening up on valve stem stuffing box will often remedy trouble.) The distance nuts may be not properly set for full length of stroke and the cushioning valve may not be properly adjusted.

Lubrication of Pump Barrel. — The water cylinders of salt-water pumps require a certain amount of lubrication for both rods and pump barrel. Feed pumps and bilge pumps generally have sufficient oil in the water they handle to give proper lubrication.

Difficulties Experienced with the Water End of Pumps. — Considerable difficulty is found in properly packing the plunger and in securing reliable packing material. Soft packing for this purpose is generally either square braided, flax or square cotton hydraulic. In packing the plunger, especially with cotton packing, care must be taken that the packing is not put in too tight, since it will swell and this may take place to such an extent that the plunger will stick. In putting on the packing it is advisable to coat it with graphite.

Hard Vegetable Packing. — This is made of preparations of rubber, lignum vitæ or paper. These are often used and give reasonable satisfaction; they are supplied in the form of rings, and act in a manner similar to piston rings.

Metallic packing for this purpose consists of *brass rings*, which often cause excessive wear, and *antifriction metal rings*, which are more satisfactory, chiefly because they are less likely to wear the surface of the barrel.

Outside-packed plungers are packed with flax packing, and in these pumps special care must be taken to keep the gland free from dirt and grit which would cut the metal of plunger. If plunger becomes cut there is likely to be a considerable loss of fresh water.

Valves of Pumps. — Feed pumps use bronze valves with springs and guards. These springs often break and the nuts holding them in place sometimes come loose. In overhauling the pump, special care must be taken to see that these parts are properly secured by split pins and that the springs are set up to the proper tension. The valve seats are in many cases removable and can be taken out and refaced when they become rough. The valves should always have a smooth bearing surface, and in overhauling the tightness of valve should be tested.

Bilge pumps use rubber valves. In time these valves become soft and begin to decompose; this is generally caused by the action of the oil. Rubber valves may be trimmed and turned, but in most cases they should be removed as soon as they become soft or worn.

Economical Performances. — On the management of engines in connection with regulation of pressure and the adjustment of cut-off of H.P. cylinder depends in a great measure the economy during running.

An increase in the number of expansions will increase the economy. Hence for economy the H.P. cut-offs should be run in, but if anywhere near full power is required and cut-offs are in, a limit to the power of the engine is reached, and if the boiler pressure is at the limit the cut-offs will have to be moved out to obtain the increase of power. To get the greatest power with greatest economy the H.P. cut-off should be run in as far as possible, while at the same time using all steam made by boilers. Where the boiler power is considerably in excess of engine power the cut-offs may be run all the way out and still the boilers will furnish more steam than engine can use. If this is the case the pass-over valves, first the I.P. then the L.P., may be opened and then the limit of power of the engines is reached. There is some question about opening L.P. pass-over since this has the effect of raising the back pressure in L.P. by choking exhaust.

Steam Pressure. — As long as the cut-offs, by being run in, will take care of the steam with throttle open wide, the steam pressure should be kept at the greatest working pressure. The *H.P. cut-off*, and ***not*** the ***throttle***, should regulate the steam.

In working at reduced powers (below ½ power) conditions become such that steam pressure will drop in H.P. cylinder with cut-off all the way in. Then a lowering of pressure should be resorted to until a point is reached at which the H.P. cut-off will take care of steam, maintaining it at a constant pressure for the desired revolutions. The pressure should, however, not be permitted to go below 80 or 90 pounds for triple-expansion engines in order to make sure that they can be properly handled, so that when the pressure is reduced to this with H.P. cut-off run in throttling must be resorted to if it is desired to go slower.

It is thus seen that the working pressure should be kept up and throttle open as long as the H.P. cut-off will take care of steam. When the power is further reduced, the boiler pressure may be reduced, keeping H.P. cut-off in. On reaching a boiler pressure of 90 to 120 pounds, throttling should regulate the supply. In this way the initial pressure will be kept up until cut-off takes place. By keeping a high pressure in steam pipe and throttling, the initial pressure is greatly reduced at point of cut-off and the gain in economy due to the high pressure is lost in a large measure though the steam is superheated by throttling, so that something is here regained.

The smooth working of the engines may govern the position of I.P. and L.P. cut-offs; often when they are run in to limit the engines do not work well.

Running cut-offs in shortens the travel of valve and is likely to wire draw the steam through ports, and this should not be carried too far.

Adjusting Links. — Each cylinder should do an equal share of the work. How matters stand in this respect can be told from working up the indicator diagrams, and also roughly by observing the steam pressure in the receivers, the vacuum, and having in mind the cylinder ratios. The drop in pressure in each cylinder multiplied by its ratio to the H.P. should be nearly equal. Taking an engine whose ratio H.P., I.P., L.P. is 1 — 2.5 — 6; pressure in steam pipe, 160; first receiver, 50; second receiver, 10 pounds; vacuum, 20 inches. The drop in H.P. cylinder is 110 pounds, drop in I.P. 40 pounds, drop in L.P. 20 pounds, $40 \times 2\frac{1}{2} = 100$, $20 \times 6 = 120$. In this case, the power of cylinders is somewhere nearly equal, but L.P. is doing the most work. On account of initial condensation an extra allowance should be given the H.P. If in this case the pressures are changed to 48 for first and 7 for second receivers, a more nearly equal division of work would result. When running at low powers, owing to the drop of initial pressures and wire drawing, the drop in the H.P. should be considerably more.

The work done by each cylinder can be regulated by adjusting the link. The following rules for adjusting link may be given.

1. Moving H.P. cut-off makes little or no difference in the distribution of the work.

2. By running cut-off in, that is, cutting off earlier, the work of that cylinder is increased and the work of the cylinder above it decreased, since it produces a higher initial pressure in the receiver of the cylinder on which the cut-off was removed and a higher back pressure on the cylinder above it.

3. By running cut-off out the power of that cylinder is decreased while that of the one above is increased.

4. These effects are produced by altering the pressure in the

receivers and not by a change in the ratio of expansion. Moving the I.P. and L.P. cut-offs does not effect the ratio of expansion of the engine as a whole.

From the above it will be observed that altering the cut-off of a cylinder will not change the total amount of work done by it and the cylinder next below, while it does affect the individual power of its cylinder and also the one above it.

To give a few practical examples: Suppose it is found that the L.P. is doing most of the work, the H.P. next and the I.P. least. Move out cut-off of L.P. cylinder. This will decrease the power of that cylinder and increase the power of the I.P. and thus make them both approach to the power of the H.P. If the H.P. is doing most of the work and the I.P. the least, move in the I.P. cut-off. This will decrease the power of H.P. and increase both I.P. and L.P. Now run L.P. cut-off in and the power of L.P. is increased and the I.P. decreased, thus bringing all equal.

The total number of expansions used (neglecting clearance) is found by dividing the decimal of the stroke at which the H.P. cylinder cuts off into the ratio of L.P. to H.P. Thus with H.P. cut-off $= .8$, Ratio $\frac{\text{L.P.}}{\text{H.P.}} = 4$; the number of expansion is 5. If clearance is considered, and to be accurate it should be, the total number of expansions equals

$$\frac{\text{L.P. plus cl}}{\text{K} \times \text{H.P. plus ch}}$$

K equals decimal of cut-off of H.P.
ch equals clearance of H.P.
cl equals clearance of L.P.

Most *four-cylinder triple engines* in U. S. Naval Service are designed so that the sum of power of two L.P. cylinders equals that of either the H.P. or I.P.

Racing. — Racing of engines is caused by rolling and pitching, heeling and the action of the waves on the propeller. Whenever the propeller leaves the water the load upon it is removed and the engine will tend to race. When this happens suddenly there is a danger of breaking something, due to the sudden change of load on the engines. When racing takes place it is safer to reduce the power of the engines, as then the power is limited and there is not as much danger of engine tearing itself to pieces. When racing becomes excessive, throttling will have to be resorted to. Then the machinist will have to stand by the throttle and, by watching the movement of the ship and the engine, must anticipate when the propellers are lifted out and close the throttle to prevent running away, and, as the propeller dips again, to give more steam.

The best indications are the movements of the engine itself. If it slows down and seems to work hard it shows that the propeller is deep in the water and also that it is likely to be lifted out very soon afterwards, so that while the engine is still working hard is the time to start to close the throttle. After a little practice the engines can be so handled by throttling that no sudden changes in revolutions take place.

Waiting. — If engine is required to be ready at immediate notice everything must be kept in readiness, with auxiliaries running slowly. If there is to be about one-half or an hour's notice steam may be turned off engine.

Stopping and Waiting. — For stopping momentarily while maneuvering, the reversing lever is moved to stop and throttle closed, if necessary, with everything ready to move at the next bell. When there is a stop for a longer period, the wicks should be taken out or oil shut off and the air and circulating pumps slowed down.

Management of Steam. — When stopped or waiting the steam pressure must be looked after. The fireroom must be notified so that fires may be regulated. If pressure rises some auxiliary may be started, such as evaporator, but the bleeder is the direct means of regulating the pressure. The bleeder valves should not be opened suddenly, as the sudden admission of steam is liable to damage the tubes of the condenser. Special precaution should be taken not to allow safety valves to blow, since there is a loss of fresh water and generally some difficulty about the valve reseating promptly is encountered.

Coming into Port, Shutting Down. — When the ship is about to come into port all derangements and maladjustments that have been observed should be examined and their character, position, extent and importance made note of, to enable a plan to be made for making repairs. To insure this, each machinist should submit a list of all repairs required in his particular station.

The fires should be allowed to burn down gradually, making sure, however, that there will be sufficient steam for all needs. It is quite important that due notice of arrival in port be obtained so that necessary disposition can be made. All ashes should be hoisted and things prepared for the most important repairs.

When engines are done with, fires are hauled or banked as ordered.

The oil and water serivce should be shut off, all wicks taken out, the drains of engines and steam pipes opened, and the bleeder allowed to take care of any surplus steam.

The drains are opened to free the machinery of water that is being condensed. Boiler-stop valves should be closed and then bulkhead stops, and every measure taken to drain pipes and engines. To this end jackets and separator should be drained. The air and circulating pumps should not be shut down immediately, but allowed to run for about half an hour in order to cool condenser and draw all moisture out of cylinders. When air and circulating pumps are stopped, all valves and sea connections should be properly closed. The drains should then be closed and internal parts of engine kept free from access of air. When main condenser is shut down, fresh water side should be pumped out dry to prevent water going into engines.

In coming into port various dispositions must be made of auxiliary steam and exhaust. If exhaust is on L.P. receiver it must be turned into condenser before engine is stopped. The auxiliary stop, if fitted, on all boilers not to be kept under steam, must be closed. The auxiliary stops of boilers to be kept in use must be open.

Oil cups, pipes and drip pans should be cleaned at once, using hot water and lye to remove oil.

All grease and oil should be cleaned off engines before engines cool and deposit becomes hard. A great deal of dirt can be washed off by using a fresh-water hose.

After this crank pits should be cleaned out and bright work attended to. Gaskets and other coverings should be put over ends of bearings and other parts to prevent dirt from dropping in. The stern gland should be tightened up to stop too much water coming in.

The machinery should be put in best position to make the desired repairs, and tools and material got ready for overhauling.

Routine Underway. — The routine of engine watch underway should be as indicated in a routine table kept on board ship. A sample is here given.

The watches are relieved just before eight bells, it being the general practice to have all the new watch on when eight bells strike. On relieving, all orders should be passed along on each station, and a general statement of how everything is working should be given.

After relieving, a general inspection of everything should be made and defects adjusted.

The machinist in charge of watch should read over the logs of the previous watches to see how matters have been going and whether any new disposition is to be made.

On some ships a condition blank, as per sample, is kept and turned over by the machinist of the watch.

The log data should always be carefully taken, and if it is not possible to be accurately taken, should be left out or noted as such for misleading or inaccurate data are worse than none.

Routine Watch at Sea

Engine Room

1. At relief get all orders.
2. Make inspection of all machinery in operation.
3. Read over log and remarks of previous watch.
4. Take log data each hour.
5. Test water in hot-well } 2d hour.
6. Oil blowers. }
7. Pump bilges and clean strainers. } 4th hour.
8. Clean floor plates, etc. }
9. Oil blowers. }

Fire Room

1. Relieve watch, get all orders.
2. Clean fires during first hour; examine and oil forced-draft blowers if in operation.
3. Sweep tubes.
4. Haul out and sprinkle down ashes.
5. Blow through gage cocks (not to be neglected).
6. Hoist ashes after five bells, or when ready.
7. Get out round of coal; examine and oil forced-draft blowers, if in operation.
8. Clean up floor plates.
9. Allow cleaning fires to burn down, and pump up cleaning boiler.
10. Blow boilers through surface and bottom blow on watch, as directed; with water-tube boilers to be done at least once a day. Surface blow should be used whenever oil shows.

DATE ______________________________

U. S. S. MARYLAND. ENGINEER DEPARTMENT

CONDITION BLANK

To be kept in engine room and passed over to relief by machinist on watch

Watch							
Boilers banked.							
Boilers steaming							
Coal from bunkers							
Reserve feed from							
Leak in boilers.							
Coal allowance.							
Steam pressure.							
Revolutions							
Evaporators							
Ice machine							
Steering engine							
Dynamos							
Dynamo condenser							
Heaters							
Pantry circuits.							
Bath heaters.							
Auxiliary exhaust on. . .							
Pumps, feed in use							
Pumps, fire and bilge . .							
Heated bearings.							

Engine room

Extra work going on

Fireroom

Officers on duty

____

Machinist on Watch.

U. S. S. MARYLAND

DAILY AND WEEKLY ROUTINE. ENGINEER DIVISION

	From "turn to" till twenty minutes to breakfast.	"Turn to" after breakfast (8.15) until noon. Knock off work at 11.30.	After dinner till time for knocking off work of day (this may vary). Until further orders, 4.30.	Evening.
Sunday	Finish cleaning stations. 6.00 A.M. "turn to."	Prepare for inspection and inspection by commanding officer. (Preliminary inspection by engineer officer.)	Port watch. (Holiday)	Evening inspection and reports. Storerooms secure. Water in tanks. D. B. sounded. Lights out. Bilges pumped. W. T. doors secured.
Monday..........	5.30 to 6.00 A.M. wash clothes. 6.00—7.10 A.M. hoist ashes, move machinery and valves. Detail work and prepare tools. Clean stations.	Muster at stations. Work of day. Drills as per orders.	Work of day.	Ditto.
Tuesday	Ditto.	Ditto.	Ditto.	Ditto.
Wednesday	Ditto.	Ditto.	Half-holiday. Inspection of clothing, small stores, etc., as directed.	Ditto.
Thursday	Ditto.	Ditto.	Work of day.	Ditto.
Friday	Clean bilges, move machinery, etc.	Muster at stations. Finished bilges and work of day.	Instructional drills, boats, etc. Inspect and test mechanical devices, compartments, etc.	Ditto.
Saturday	Clean stations, move machinery, etc.	Muster at stations. Clean stations; clean out wash rooms for Sunday inspection.	Half-holiday.	Ditto.

MODIFICATIONS.—Section having 12 to 4 A.M. (mid. watch) is aux. watch off for day succeeding. This section will have liberty after working hours on liberty days.

The hot-well water should be frequently tasted so that it may be known immediately when it becomes salty and the way by which salt has come in can be looked for. In addition to tasting the feed water the silver nitrate test may be applied from time to time.

The periodical oiling and feeling of bearings must be kept up, and the round of all the auxiliaries frequently made.

Bilges should be pumped and strainers cleaned during fourth hour, so that the new watch may come on with bilges in good shape.

The double bottoms should be sounded each day at a special time, generally 6 to 8 P.M. watch.

During the time on watch spare time should be used in keeping engine room clean. If this continual cleaning is kept up on the run, there will not be so much work when coming into port, and if an engine room is *never allowed* to get dirty it is more easily kept in good condition.

CHAPTER III

Accidents Underway — Hot Piston Rod — Hot Valve Rod — Hot Condenser — Air Pumps Flooded — Breakages — Disconnecting Cylinders — Running Engine Single Cylinder — Broken Cylinder Heads or Castings — Blocking Ports — Repairing Covers or Bonnets — Bonnet Completely Broken — Broken Pistons — Piston Rod Fractured — Fishes and Clamps — Crank Pin Broken — Shaft Broken — Bent Piston Rod.

Accidents Underway. — The best prevention for accidents underway is to have everything in proper shape and adjustment so that defects are not likely to develop.

An occasional defect is a great teacher, and the sea experience gained on an old, broken down installation is perhaps the most valuable that could be obtained. When nothing ever breaks, the attendants are not likely to be very familiar with ways of repairing.

Besides the points enumerated under running of engines, the following are among the accidents most likely to occur. With the great improvements in design tending to reliability and freedom from accidents, some of these may very seldom occur.

Hot Piston Rod. — Hot piston rods are caused by packing being set up too tight, by being out of line, by grit in stuffing box, or insufficient lubrication of the rod.

A hot rod is told by the smell of burning oil and by the fact that the engine appears to work hard, or a thump may develop.

If the rod is quite warm, water or oil applied with a syringe will hiss and run off in little globules (spherical condition), and if very hot, oil will cause a dense smoke.

A hot piston rod is very serious, as there is danger of the rod bending.

If rod is only warm, it may be relieved by slacking back on stuffing box gland and applying oil liberally and reducing the speed of engines.

If rod is hot the engines should be slowed down to reduce load on piston. The gland must be slackened up to reduce friction. Then oil should be applied with a brush, swabbing all sides of rod so that the different portions may be cooled down at the same time. Water should not be put on a hot rod, as it is liable to cool it suddenly and cause the rod to bend.

With approved kinds of metallic packing, there is not much danger of rods heating. When, however, rods are packed with soft packing and an ordinary gland there may be danger. One of the causes for this is an unequal setting up on packing, whereby one side is too tight and presses hard against the rod.

The packing should not be ragged or too hard, and above all, lubrication must be provided in the packing and also by swabbing rods. There are cases where soft packing (Selden's) has actually caught on fire and caused considerable blaze in the engine room.

One of the principal causes of a piston rod heating is that the piston is thrown out of line with the crosshead slide; in other words, the packing in stuffing box becomes a guide, something it should not be. At top of stroke the entering steam may throw the piston against the cylinder and thus throw it out of line. If the edge of groove in piston becomes burred, the rings will not come to the center again, and thus the piston runs out of line and the rod gets hot.

Valve Rods. — Valve rods, especially when they pass through guide bushings, sometimes heat and stick, due chiefly to improper lubrication or grit getting onto wearing surface. The remedy is to cool the parts by a good supply of oil, and, if possible, loosen up on guide.

Hot Condenser. — This, of course, will be noticed by a fall in vacuum, and may be caused by a variety of things, the principal thing, a lack of circulating water. When a condenser has become hot due to lack of circulating water, the engine should be stopped and all exhaust turned off the condenser; otherwise the condenser will get hotter and burn out the packing in glands. The air pump should be continued on the condenser. If the air pump is attached to engine, the feed pump should be put on channel ways to take water out of condenser. If there is any engine-room pump by which water can be put into the condenser, a slight circulation can be set up by opening drain and pumping in. Usually the water-service pump has some sort of a connection by which this can be done. If there are any connections by which another supply of circulating water can be obtained and condenser thus cooled, the engines may continue to run, but unless this can be done they must be stopped until condenser is again in working order.

The following are some of the different things that may happen to prevent a supply of circulating water:

1. Injection or discharge valves not opened or stopped up. — Sometimes the injection valve may work loose from its stem and remain closed, in which case divers must be sent down to plug opening and then valve may be taken out and repaired. The strainer, if stopped up, will have to be cleared in some way.

2. Runner of circulating pump getting loose from shaft. — This may happen if key gets loose.

3. Shaft of circulating pump breaking due to corrosion. — In these two cases, the pump engines will run without a load.

4. The stopping of pump engine.

Leaks. — Leakage of steam and fresh water is a matter that should be very carefully looked after; a steam leak not only means the waste of so much fresh water, but also a loss of heat. Small steam leaks may not appear to have very great importance, but when it is considered that there are hundreds of them and that every particle counts, some idea of what it may amount to can be gathered.

To state roughly, it requires about 4 tons of extra feed per 1000 horse-power per 24 hours. If more than this is used the cause should be located and leakage stopped.

Leakage is reduced by keeping all joints tight, especially in piping and boilers, by keeeping valve spindles properly packed, by keeping valves tight, and by properly packing all stuffing boxes.

Air Pump Flooded. — The air pump may become flooded from a variety of causes. The discharge opening may become obstructed and the water may then not be able to flow away quickly enough. The suction may be suddenly opened and then too much water will come to the pump.

The flooding of the pump will make itself known by heavy thumps and a fall in vacuum. With attached air pump, it would be well to slow down until pump has freed itself of the overload of water, otherwise there is danger of the bonnet of air pump being broken.

With independent air pumps there is less likelihood of pump becoming flooded.

Breakages. — Fractures in cylinders, pistons, piston rods, crossheads and connecting rods are caused by —

1. Water in cylinders.
2. The slacking back of nuts on piston or follower.

3. A dropping down of piston so that the piston strikes at one end.

4. Obstructions such as tools or material left in cylinder. Aside from fractures caused by priming, the causes above are due to lack of care when engines are overhauled or adjusted, and will thus be seen that it is of extreme importance to see that all parts, especially nuts, are properly secured and that no obstructions are left in the cylinders. Nuts, bolts, wrenches and the like have sometimes been left in cylinders without causing accident. At other times they have been pressed into the metal of piston and in other cases ground into small bits. The causes and treatment of priming have been discussed under operation of engines.

Disconnecting Cylinders. — In cases where some of the working parts enumerated above are broken so that they cannot be repaired or spares fitted, it may be necessary to disconnect one cylinder and run with the remaining ones.

Where none of the auxiliaries, such as air and circulating pumps, are operated from the main engines, any one of the cylinders may be disconnected by taking out or securing its connecting rod, securing piston in place and taking out the valve for that cylinder. In such cases the steam will pass directly from the admission to the exhaust ports and into the next receiver or condenser, as the case may be. In order to prevent loss of steam in the disconnected cylinder by radiation and condensation, the admission ports for that cylinder should be blocked up. Soft wood or melted lead or babbitt may be used for this purpose.

The valve gear in these cases must, of course, be disconnected, the stuffing box for valve stem blanked off and cylinder closed.

Adjusting Pressures. — A triple-expansion engine can run as a compound with any two cylinders. The cut-off and pressure should, however, be adjusted to suit each cylinder. If the H.P. cylinder is cut out, the boiler pressure should be reduced to the pressure of safety valve on I.P. receiver, or steam must be throttled a suitable amount. If I.P. is cut out a greater range of expansion should be used in the H.P. and the cut-off of L.P. run out so that the pressure on L.P. piston will be the same as before.

Pumps Operated from Broken Cylinders. — When this is the case it is necessary to keep these auxiliaries in operation. If the cylinder and piston are intact and the connecting rod or piston rod broken, these parts may be taken from one of the other cylinders and thus the cylinder kept in operation. If the connecting rods are intact and it is the piston or cylinder that is broken, the cylinder should be disconnected, broken parts removed and piston rod allowed to work through stuffing box as a guide, the pump rods, etc., working from crossheads as before.

Rod Broken or Bent. — If the piston rod is broken or bent it should be disconnected to allow the connecting rod and crosshead to drive the pumps.

Running Engine Single Cylinder. — When it becomes necessary to run an engine with a single cylinder there may be some difficulty at starting to bring her over the center. In order to help matters along, shift valve or eccentric so that you have a big lead on bottom and small cushioning. The weight will then tend to drive her over the top center and the big lead at bottom will give steam to drive her up.

Broken Cylinder Heads or Castings. — Where cylinder heads or castings are broken beyond repair they must be disconnected and the ports leading to it blocked up and valve taken out.

Blocking Ports. — For blocking up ports or filling up small holes in a cover or any other part of cylinder where there is no great stress and where the pressure is not great, as I.P. and L.P. cylinders, melted lead or babbitt poured into such holes makes a very satisfactory and easily made patch. Where great pressures come upon the blocking, measures will have to be taken to strengthen it sufficiently.

Repairing Broken Heads. — Broken heads can usually be repaired in some way.

Heads Cracked. — This may generally be repaired by putting a plate on top and securing it by set screws, and, in order to make it steam tight, imbedding it in putty made of red lead, hemp and asbestos or other suitable material. Some sort of plate can generally be found on board, and, if necessary, a door or some other fitting made of plate may be utilized. Patches over broken cylinder covers are often secured by shoring from the deck above.

Head Completely Broken. — When the head is completely broken up a wooden one may be made, strengthened by plates or iron ribs and placing several courses of sheet packing under it to insure steam tightness. In such cases shoring from above would be advisable. In order to avoid unnecessary shoring, etc., the pressure that is to come upon the cylinder should always be taken into consideration.

Broken Cylinder Bottom. — This is, in general, a more difficult job to repair since there is no good opportunity for shoring or securing. In this case it may be advisable to put a patch on the inside by any means available. Then put liners under piston rod to raise it and a distance piece under cylinder cover. To make such repaired joints tight melted babbitt will be very useful.

Broken Piston. — If the piston is not broken into many or small pieces it may be repaired as described by Mr. A. R. Leask (in "Breakdowns at Sea"). In this case a ring of diameter nearly equal to diameter of piston is made and shrunk on the body of piston. The height of this ring should be equal to the difference between the height of piston hub and piston at point where ring is shrunk on. A circular plate is then taken of diameter equal to ring, a hole cut out to fit snugly, and ring laid on. Drill several rows of holes into this plate and corresponding tap holes in piston; then tap in iron rods through holes in plate into piston, cutting off ends and riveting them over plate, or put nuts on top of plate. The repair will then look as sketched in section. (Fig. 1.)

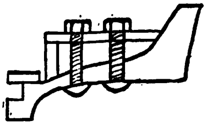


FIG. 1.

The plate should preferably be in one piece, but, if necessary, several may be taken, care being had that the joints do not come over the break in piston.

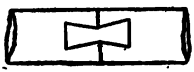


FIG 2.

Broken Rods. — Broken rods may be repaired by using the dovetail key (A. R. Leask's "Breakdowns at Sea"). The broken parts are put together and a dovetail (as shown in sketch) is marked thereon, making it slightly larger on one side so as to form a draw or taper for the key. The dovetail is then cut out and cleaned carefully, a corresponding dovetail key made and driven home and riveted over into countersink at smaller end, if necessary, to prevent working back. The key can then be smoothed off and, if necessary, can work through a stuffing box. By this means the rod can be made nearly one half the original strength. (Fig. 2.)

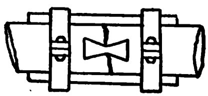


FIG. 3.

Fishes and Clamps. — In addition to the dovetail key, where a strong support is desired, fishes and clamps may be used. (Fig. 3.)

Here a bar is placed on either side of the broken rod and strong bolted clamps made and bolted up as in sketch. The number of clamps and length of bar will, of course, always depend upon circumstances. The bars should be placed over the key to prevent it coming out, and on fitting key the direction of the strain brought upon the rod should be considered. In eccentric and connecting rods this strain is athwartship.

Broken Crank Pins. — A break in the shaft may occur at the fillets or at fracture shown in sketch. The best way to repair such a fracture would be to bore a hole through crank pin and webs and insert a pin to fit tightly into the hole. The size of such pin should be about three-fourths the diameter of the crank pin, provided the area of pin does not exceed one third area of web. (Fig. 4.)

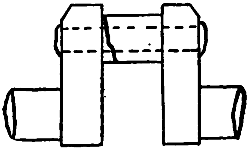


FIG. 4.

To bore the hole, first use an ordinary drill, then rig a boring bar and take successive cuts; as the hole increases use a larger boring bar and stronger tools. A wooden bush to prevent bar getting out of line will be useful. The pin, being prepared to fit the hole closely, should be driven in hard and the ends riveted over.

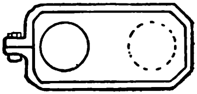


FIG. 5.

If anything like full power is desired, the repaired crank should be shifted to the forward cylinder, since the after crank has to stand the twisting movement of the whole engine while the forward has only that due to one cylinder.

The original surface of crank pin must be retained to give the bearing surface; in case this is broken out or rough it may be smoothed up with white metal and then scraped.

Broken Crank Web. — Crank shafts may break at webs. The repair for this is to put a strap around the web as shown. The size of strap should be such that the area of section of strap is about one quarter area section of web. The strap should be forged to shape, the holes bored for bolt, and then should be put on hot, tightened up and allowed to cool. The strap will then firmly grip the web. (Fig. 5.)

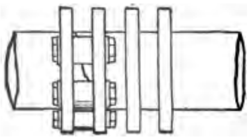


FIG. 6.

Shafts. — A fracture may take place at thrust collar, and an example of a repair of this nature is given.

Generally this may be repaired by fitting a clamp around the shaft to keep the parts together and fitting bolts with distance pieces between the collars as shown in Fig. 6.

Bolts or some other means of bringing the two parts together tightly must be provided.

When the break extends over several collars, long bolts must be used. It is also better to use a larger number of small bolts than a few large ones.

A break in the line shafting is harder to repair. Means must be provided, first for bringing the two parts together, and then material for taking the twisting movement. A method of making this repair is given on page 130, Leask, "Breakdowns at Sea." See Fig. 7.

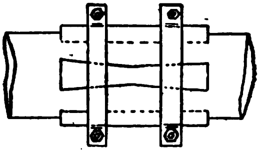


FIG. 7.

The dovetail keys keep the parts of shaft together and the clamps bind the keys close to the shaft. To fit clamp so that they come up real tight, the bolts should be put on hot and nuts set up; as they cool the bolts will contract and grip the shaft securely.

A shaft broken at a coupling is a more serious repair. Such a repair may be accomplished as shown by sketch taken from pages 127 and 128, Leask, "Breakdowns at Sea," Fig. 8. The angle plates are cut out so as to fit exactly between the bolt heads and the other edges into a recess cut into shaft. The angle plates are fitted and secured in place by set screws. A stout clamp should be fitted around all of them to keep them securely in place.

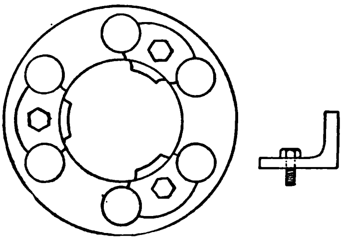


FIG. 8.

Bent Piston Rod.—To straighten the rod it is heated over bent portion in a wood fire (to prevent scaling). The rod should be heated very slowly and so as to just turn red; care should be taken not to get it too hot. Then it is placed between the centers of a lathe, so that the bend is up. At either side of bend a strong bearing support is placed under the rod, a movable hydraulic or screw jack is then applied to a middle bearing at the bend, and as pressure is applied by the jack the rod is forced into a straight line. The surface of rod at points of contact should be protected by pieces of copper or other suitable material.

For a small rod a strong back clip may be employed. The strong back bears on the rod at three points, the two outside ones being underneath the rod, and the middle one, which is between the other two, above. The middle point of contact is made by an adjustable screw arranged to be operated by a long lever, and this applies the straightening force. The points of contact should be well protected.

After a rod has been straightened a thin cut should be taken off in a lathe to ensure that it is truly cylindrical.

For very large rods a portable gas furnace of annular shape may be built around the rod to heat the bent portion and the rod can be straightened under a steam or hydraulic hammer. The propeller shaft of the U. S. S. *Illinois* was straightened in this way at the Navy Yard, New York.

PART II

CARE AND OVERHAUL OF MAIN PLANT

CHAPTER IV

General Rules for Overhauling Machinery — Table of Overhaul Requirements — Inspections.

General Rules for the Overhauling of Machinery. — In making repairs the most important ones should be begun first, and due consideration should be given to the different jobs. The allotment of work should be made so that there is the least interference between the various gangs of mechanics.

The repairs to make first should be those designed to get the machinery of the vessel into efficient steaming condition, and to this end the necessary adjustment of bearings should be made first. If there are no special repairs the whole department should be thoroughly cleaned.

The following is a list of ordinary repairs generally necessary:

Adjust all loose bearings.

Remake all leaky joints; overhaul and grind in all leaky valves; open and examine cylinders and valve chests of main engines.

Examine and overhaul valves of air and feed pumps, water end.

Clean bilges.

Clean and overhaul wicks, oil cups and oil piping.

Open and examine main condensers; test for tightness; boil out condensers if tubes show grease on them.

Clean feed and filter tanks, and renew filtering material.

Scale evaporators.

Table of Overhaul Requirements

Daily. — Move all machinery not in operation and water-tight doors. Take temperature of bunkers. Test boiler water with litmus paper, and take saturation.

Weekly. — Inspect mechanical devices for the safety of vessel, including sluice valves, and mechanical gear for operating safety, stop, drain and ventilating valves, mechanical telegraphs for transmitting orders, and all compartments outside of double-bottom compartments. [*Art.* 396, *Par.* 5, *N. R.*]

Three Weeks. — Clean feed tanks.

Monthly. — Test and inspection of mechanical devices for safety of vessel. [*Art.* 1637, *N. R.*]

Test blowers and pumps that have not been used, or connections that have not been used. Flush main drain and try circulating pumps on drainage system.

Quarterly. — Inspect holding-down bolts. Regular inspection of boilers. All cylinders and valves, main and auxiliary. All pump barrels and valves. Examine and overhaul all auxiliary machinery. Examine valves in manifolds. Test or compare steam and vacuum gages. Clean propellers and sea-strainers. Examine and overhaul double-bottom compartments. Paint coal bunkers. [*Art.* 1640, *N.R.*]

Semi-Annually. — Test and examine outboard valves. Vessel docked. Grind in sea valves. Renew zinc protectors. Examine propeller shaft, stern bearings and lignum-vitæ.

Yearly. — Take inventory of stores. [*Art.* 486, *N. R.*]

Overhaul Requirements for Various Appurtenances

Boilers. — Fire sides to be cleaned whenever steam is taken off. Fire sides to be thoroughly cleaned after every two weeks' steaming.

To be thoroughly examined once in three months.

Blowers. — Test by running once a month. Overhaul each quarter.

Bunkers. — Paint once a quarter. [*Art.* 1640, *N. R.*]

Double Bottoms. — Examine and overhaul each quarter.

Cylinders. — Open and examine after runs, and at least once a quarter.

Main Engines. — Take clearance every quarter.

Cylinders of Auxiliaries. — Open up and examine frequently and at least once a quarter. Take clearances of reciprocating engines.

Condensers. — Thoroughly examine and test every six months. Test for leaks and boil out with soda frequently.

Evaporators. — Scale every two weeks if running continuously.

Feed and Filter Tanks. — Clean out every three weeks.

Steam and Vacuum Gages. — Test or compare every quarter.

Auxiliary Machinery. — Overhaul and examine every quarter; operate and test at least once a quarter.

Pumps, Air. — Overhaul and examine thoroughly at least once a quarter.

Pumps, Circulating. — Overhaul thoroughly at least once a quarter. Try on drainage system once every month.

Pumps, Main Feed. — Overhaul thoroughly at least once a quarter.

Pumps, All Other. — Overhaul thoroughly at least once a quarter.

Propellers. — Examine at least every three months after being out of dock.

Examine before going to sea. [*Art.* 1640, *Par.* 7, *N. R.*]

Strainers on Sea Chests. — Examine and clean by divers at least every three months after being out of dock.

Valves, Main Engines. — Examine after runs and at least once a quarter. Setting to be verified every six months.

Valves, Auxiliary Engines. — Examine frequently and at least once a quarter.

Valves in Manifolds. — Examine at least once a quarter.

Valves in Steam and Exhaust Line. — To be ground in or examined at least once in six months.

Valves, Safety. — Test every month. Try gear every week.

Valves, Stop. — Work every week. Test gear.

Valves, Sluice. — Work every week.

Inspections

Monthly Inspection. — The Executive Officer and the Senior Engineer shall each inspect monthly all compartments, water-tight doors, and mechanical devices, for the management and safety of the vessel for which each is especially responsible, and shall make to the captain, after each inspection, separate written reports of the condition of the parts of the ship and of the mechanical devices thus inspected. [*Art.* 1637, *N. R.*]

Weekly Inspection. — Water-tight doors, cocks, valves, ventilating appliances, pumps, water-tight compartments. [*Art.* 396, *Par.* 5, *N. R.*]

CHAPTER V

Cylinders — Scoring — Piston Rings — Clearance — Testing for Tightness — Closing Cylinders.

Cylinders. — The cylinders are opened for the purpose of examining the interior surfaces, also to examine piston rings and springs; to test the tightness of piston-rod nut and follower bolts; also to wipe out moisture and put on a coat of vaseline for lubrication and to protect the surfaces of the cylinders from rust while engine is standing idle.

In opening cylinder care should be taken not to destroy the gasket, which should have been thickly covered with graphite to ensure an easy parting. The cylinder should first be wiped out with kerosene or turpentine in order to remove the moisture and any rust that may have formed. After this the surface can be examined.

Examination. — Any scores or flats should be observed and a record of them made, so that any further increase in such defects may be known. The follower should be lifted occasionally; rings cleaned, springs examined and broken ones replaced.

Points to be noticed in examination are: whether the surface of cylinder is smooth and bright all over, whether the wear is on one side (this can be told by observing the appearance of surface before the cylinder is wiped out). If one-sided wear is observed the piston is probably out of line. The surface of piston ring should be smooth and bright all over. If rod is bent or piston not working in line the ring may wear wedge-shaped in cross section. The edges of ring may become very sharp and in such condition may at times nip the cylinder walls. It may often be advisable to round off slightly both the edges of the rings and those of the pistons and followers. The ends of the split rings should be fitted with efficient keepers to prevent them from vibrating.

The prominence of the shoulder at the end of stroke on pistons that do not overrun the counterbore should be noticed and, if of any amount, the shoulder should be scraped down. With pistons that overrun the counterbore, as is the case on all late vessels, there will, of course, be no shoulder.

If the cylinder liner is badly scored or worn it may have to be rebored or a new one fitted.

Scoring. — Scoring of cylinders is caused by (1) Hard particles of dirt or grit left in the ports or in the cylinder itself, or brought from the boilers through priming, or from particles of rust that have scaled off from the surfaces. (2) By the edges or ends of rings nipping cylinder walls; this may be caused by countersunk bolts not being perfectly flush with the surface. (3) Packing ring being pressed out too hard against the cylinder walls by the steam pressure. To avoid this solid rings, or rings whose extension is limited, are employed.

A one-sided wear or flat is caused by the piston being out of line. If the piston has considerable clearance in the cylinder it is likely to be shoved from one side to the other by the action of the steam, and this also may cause local wear. The breaking of several springs in one place may cause the piston to be shoved over to this side so that the edge of follower or piston will wear on the cylinder.

Piston Rings. — The purpose of the piston ring or rings is to maintain a steam-tight joint between the piston and the walls of the cylinder. This steam-tightness must at the same time be maintained without excessive friction which would cause wear on the walls of the cylinder.

The following are the requirements for piston rings from the machinery specifications of the armored cruisers *Montana* and *North Carolina*.

"Each piston will have a packing ring one inch thick and two inches wide on the bearing surface, cut obliquely and tongued. The play of the ring will be limited by an adjustable distance piece, lug and clamp, or some other suitable device.

"The packing ring will be set out by steel springs of approved pattern, all set to an equal and proper tension. The springs will be so secured in the piston as to be firmly held in place and easily inserted or removed."

The pistons of the auxiliaries generally use cast-iron snap rings cut diagonally. If these rings and the cylinder walls have a good bright surface all over, it shows that they are properly tight. If the surface is not bright in spots the ring is loose and a new one should be fitted. For small engines new rings can be made on board from castings kept for the purpose. The ring is turned slightly larger than the diameter of the cylinder and is then cut diagonally in one place and then sprung into the piston; the natural tendency is for the ring to spring out to its former shape, and it thus presses against the cylinder walls. Special care must be taken that the edges of the ring make a good, tight fit with the flange of the piston. The principal trouble encountered with these rings is the breaking off of the ends.

Large pistons are fitted with followers. To examine the ring the follower is lifted. The follower holds the packing ring in place. The follower is secured by steel studs screwed into the piston; the bodies of the studs are usually square and pass through square holes in the follower. The studs are made square in the body where they pass through the follower so as to prevent their turning, and thus coming out. The nuts are each secured by a brass or steel split pin or else all the nuts are wired together. In overhauling, special precautions must be taken to see that the nuts are tightly secured and all split pins in and their ends properly flared.

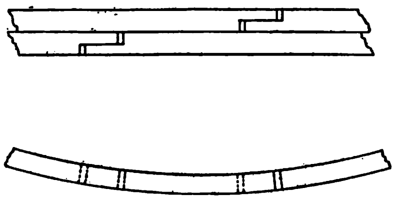


FIG. 9. — Low-Pressure Sectional Ring.

Piston Springs. — The type of piston spring usually used in the Navy is the ordinary steel coach spring. These springs are inserted in the space between the rings and the body of the piston. They press the rings out against the cylinder wall and make a steam-tight joint. They also serve to center the ring over the piston, and in this way tend to guide the piston centrally through the cylinder. Springs occasionally break and have to be renewed.

For low-pressure cylinders the piston rings are generally made in sections and double, one ring resting on the other. The sections are arranged so that the parts of the two rings break joints with each other. The springs behind the rings are depended upon to give tightness. It would be somewhat difficult to get single rings, in one piece, for the large low-pressure cylinders, hence the use of sectional rings. (Fig. 9.)

For small engines, and for the intermediate cylinders of triple-expansion engines, ordinary split cast-iron rings are generally used.

To prevent the ends of rings breaking off, due to vibrations, they are held to each other by various styles of keepers which, in holding the ends together, check the vibrations. Tongue pieces are fitted between the ends to prevent the passage of steam. (Fig. 10.)

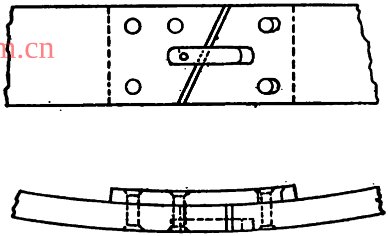


FIG. 10. — Ordinary Split Ring with Tongue Piece.

For high-pressure cylinders and for intermediate-pressure cylinders using very high-pressure steam, many difficulties have been encountered with packing rings. With the ordinary split ring the steam gets in behind the ring and presses it out hard against the cylinder walls to such an extent that the cylinder walls are cut and scored and the rings broken. When double rings are

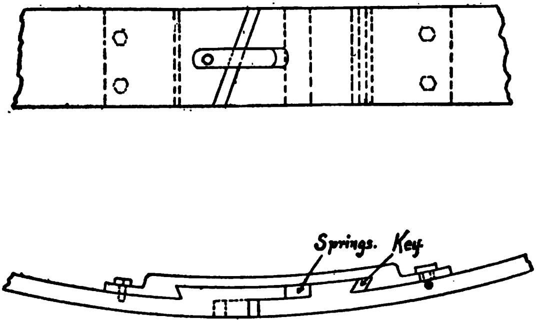


FIG. 11. — Device for Limited Extension.

usd there is also the liability of the steam coming through the joint between the two rings.

To prevent these troubles spring rings fitted with a device for limiting their extension are used. (Fig. 11.) This ring is adjusted so that it can open to a fit in the cylinder, but no further, and can close within certain limits. When the ring wears sufficiently to cause leakage additional extension can be given by filing out on the clearance spaces on lugs or keys till ring is sufficiently enlarged.

This type of ring sometimes gives trouble by reason of bolts, screws or other parts coming loose or breaking.

Another practice is to use a solid ring bored out to fit the cylinder snugly when warm. With this type the danger of ring expanding too far, bolts getting loose, or leakage past joint is entirely avoided. These rings, when carefully fitted to an accurately bored cylinder, give good satisfaction. There is naturally very little wear since there is no pressure forcing the ring against the cylinder. A new ring can be fitted when sufficient wear to warrant it has taken place.

To enable an adjustment for wear to be made and at the same time secure the advantages of the solid ring, the ring can be cast solid with lugs in one place. Then cut the ring square at the lugs and fit a clamp over the lugs to hold the ends tightly together. When wear takes place the lug or clamp can be shaved off slightly and a liner inserted between the ends to make up the necessary distance, and the lug replaced. (Fig. 12.)

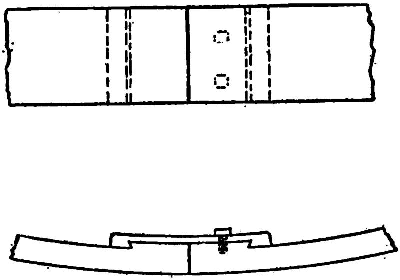


FIG. 12. — Solid Ring Cut and Fitted with Clamp.

Springs are fitted behind the solid ring in order to keep the piston centered and to help guide the piston through the cylinder.

It is of the utmost importance to have the joint between the edges of ring and flanges of piston an absolutely tight fit. To ensure these surfaces being true the edges of rings may have to be scraped to a fit, and the follower may have to be lined up so that it will allow exactly enough space for the ring. The follower should not be brought down enough to grip the ring, the ring should be free to move on the application of pressure.

In adjusting rings for tightness it will be safe to get the ring so that it is a tight fit in the cylinder, but at the same time so that it can be moved around without great difficulty. When the engine is warmed the cylinder liner should expand about the same amount that the ring does, so if it is tight when cold it should also be tight when warm. If on examination the surface of ring is bright all around it shows that the ring is a tight fit.

Clearance. — The clearance of the piston, top and bottom, must be verified and measured from time to time. With continual use, on account of wear at crossheads, crank-pin and main bearings, the piston drops down. Marks showing the clearance should be stamped on crosshead slide; these should be verified occasionally by disconnecting piston rod, allowing it to touch at top and bottom and observing whether the positions correspond with the marks. The distance from mark when piston is on striking point to mark when on center and connected up is the linear clearance for that end. The actual clearance can also be measured by putting pieces of putty above and below piston and moving the engine over the center. The thickness of these pieces of putty will be the clearance.

The dropping down of piston may be rectified by placing liners under piston or under the end of connecting rod sufficient to raise it up the necessary distance.

Testing for Tightness. — The tightness of piston may be observed by passing a light around the edge of ring and at the same time jacking piston down, with link central; where the flame is caused to flicker air is leaking through, and at this point the piston is not tight. The ease or difficulty with which an engine can be moved with links in center will give a general indication of the degree of tightness of pistons and valves.

To test tightness of piston under steam, put engine in position so that steam is admitted to top of piston, then open lower indicator cock. If steam is now admitted and it is found to issue through indicator cock, it shows that the piston is leaking.

Closing Cylinders. — Everything should be replaced in proper shape and carefully and tightly secured. Special precaution should be taken to see that follower nuts are tight and that all split pins are in place with ends properly flared. Great care should be taken that no tools, waste or material of any kind is allowed to remain in the cylinder. A special inspection should be made just before putting on the cylinder head. Before closing up, the cylinder should be coated with vaseline mixed with graphite. The vaseline preserves the surface from rust while the graphite serves as a lubricant and develops a good wearing surface.

CHAPTER VI

Valves and Valve Gear — Valve Chests — Valve Balancing Devices — Assistant Cylinders — Reversing Gear — Setting of Valves — Putting Engine on Center — Care of Valve Gear.

Valve Chests. — Valve chests should be overhauled at the same time that the cylinders are, so that one job can be made of the whole thing. The surfaces of the valve chests are subject to the same general treatment and care that the cylinders are. It is extremely important that the surfaces of packing rings and the wearing surfaces of liners be bright, smooth and of a tight fit. Graphite should be liberally supplied to the working surfaces so that a good wearing surface may be developed.

Special care should be taken that the valve-rod nuts are tight. The wear of valves should be examined periodically. Where piston valves are fitted with solid rings, split and secured with clamps or bolts, and arranged so that they can be extended as wear takes place, liners to make up the wear and make ring tight should be fitted when necessary.

The surface of slide valves must be kept in good condition in order to avoid excessive friction and steam leakage. Whenever scores or rough places are discovered they should be smoothed. Small slide valves can be brought to a true surface by means of the surface plate, and the valves themselves used to bring the faces to a fit.

Valve Balancing Devices. — In order to prevent the weight of the valve coming upon the valve gear and eccentrics, various devices for taking up this weight are fitted.

Balance Pistons. — These work in a small cylinder cast in the upper bonnet of the valve chest. The balance piston is secured to an extension of the valve stem. The part below the piston is in communication with the valve chest and the part above the piston is piped to the condenser.

The balance piston is designed so that the difference in pressure on the two sides of the piston will be sufficient to take the weight of the valve and its connections.

This balancing is sometimes effected by varying the diameter of the two ends of the valve; the excess pressure on the larger end balancing the weight of the valve and its connections.

Balance pistons are fitted on slide valves as well as on piston valves.

Slide valves are also often fitted with relief rings on their backs, but these relief rings are fitted to take the pressure of the valve off the valve seat.

Assistant Cylinders. — These are sometimes fitted for taking up the inertia as well as the weight of the valve and valve gear.

Both Thom and Joy's assistant cylinders have been used in England extensively.

The Lovekin improved assistant cylinder is an improvement over both the Joy cylinder and the Thom momentum cylinder; it is used on a number of American merchant vessels and is fitted over each valve on the engines of the U. S. S. *Washington*, *Kansas*, and *New Hampshire*, there being fourteen cylinders for the two engines in each vessel.

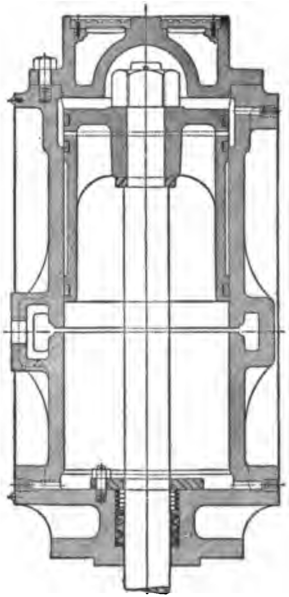


FIG. 13. — Lovekin Assistant Cylinder.

A cut of the arrangement of this device is shown. The annular space at center is connected to some one of the receivers of the engine which will give the desired pressure for operation. Sometimes this steam taken from the H.P. chest is controlled by a differential regulating valve which gives a pressure suitable for any speed at which the engine may be running. By inspecting the sketch it will be seen that there is a cushioning effect at each end of travel of valve, and that the valve is assisted in movement by the expansion of the cushioned steam and admission of receiver steam at about middle of down stroke and near end of up stroke. The object of the assistant cylinder is to take the weight and the inertia forces of the valve and gear off the crank shaft, eccentrics, links and other parts of the valve gear.

Assistant cylinders can readily be fitted to old engines. (Fig. 13.)

Reversing Gear. — The reversing gear consists of the links, eccentrics and eccentric rods; the suspension bars which control the movement of the links by being connected to arms on the reversing shaft; the reversing engine which controls the movement of the reversing shaft; and the system of control levers which govern the movement of the engine.

The type of reversing gear almost exclusively used in the Navy is the Stevenson link floating lever gear. Figure 14 shows the Stevenson link motion in its simplest form. OA is the crank. OB

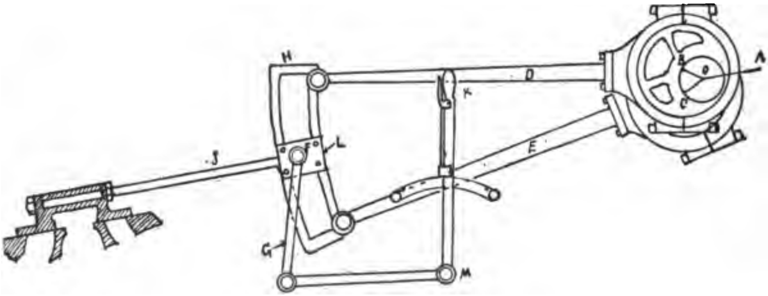


FIG. 14. — Stevenson's Reversing Gear.

and OC are the eccentrics keyed in position on the shaft, and connected by the eccentric rods, D and E, to the ends of a curved bar or link H, whose curvature is that due to a radius equal to the length of the eccentric rod. Within the slot is the link block F over which the links move, the link block being connected to the valve stem J. G is a suspension or hanger rod attached at one end to the saddle plate L on the link, and at the other end to the bell crank lever M by means of which the lever can be moved back and forth by the reverse handle K and the valve placed in gear with either the forward or backing eccentric. In large engines the movement of the link is effected by the steam reversing engine.

If the link is moved to its lowest position, the valve stem is nearly in line with the eccentric rod of B, and that eccentric controls the action, while on being moved to the highest position the valve stem motion is controlled by C and a reverse motion is produced. When in these extreme positions, the link is said to be in full gear ahead or astern. When the link is moved to an intermediate position, the link block is acted upon by both eccentrics, and the valve receives a motion equivalent to that from an eccentric, of shorter throw and greater angular advance, resulting in a reduced travel of the valve and consequent alteration of lead, cut-off and compression.

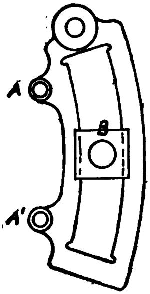


FIG. 15.—Slotted Link.

Hence in addition to furnishing a ready method of reversing an engine, the link is also a convenient means of regulating or changing the rate of expansion and controlling the steam distribution in the cylinder.

Types of Links. — The ordinary form of slotted link is shown in Fig. 15, consisting of a curved bar with a slot in the center in which the block is fitted. The eccentric rods are connected by the pins at A and A′ and the valve rod to the link block at B. The point of suspension

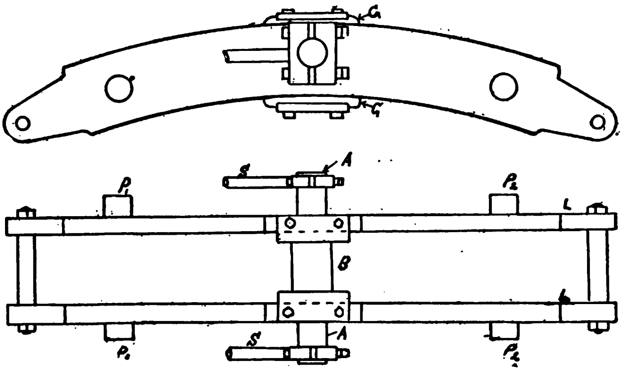


FIG. 16. — Double Bar Link.

is either at the center or the end nearest the eccentric rod in ahead gear. This form of link is very simple, and is largely used for small engines. The principal disadvantages are: (1) No adjustment of the link block is possible, consequently any wear causes considerable jar and lost motion in the gear; (2) since the center line of the eccentric rod end does not coincide with the center line of the link block, the motion given is not very regular.

The double bar link is shown in Fig. 16, and is the one in general use both in the navy and mercantile marine. The gear consists of two curved steel bars, LL, secured together at the ends with distance pieces fitted between the bars. The eccentric rods are connected to the link by means of the pins P_1 and P_2, two on each side, the eccentric having forked ends with adjustable brasses which embrace the pins on each side of the link. The block consists of a steel pin between the bars with top and bottom extensions on each side bearing upon the edges of the bars. Adjustable brass gibs G, are inserted between the bars and the projections on the link block, and form the rubbing surfaces between the block and bars. The valve rod has a connecting rod end with brasses for attachment to the link block pin B.

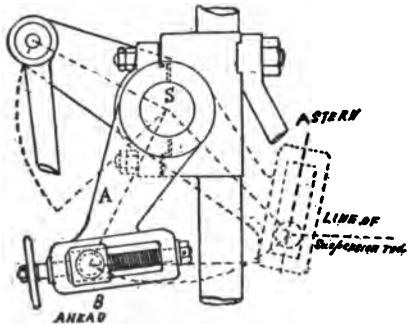


FIG. 17. — Independent Linking-up Gear.

The suspension rod S, generally two for this type of link, one on each side of the bars, is attached in this case at pins A A, at the middle of the bars; in other cases, at the ends to prolongations of the eccentric rod pins. All parts can be easily adjusted, and when in full gear the center of the eccentric rod end coincides with that of the link block so that the motion obtained is very regular.

Independent Linking-up Gear. — The links of the different cylinders of a multiple-expansion engine are connected to the same rock shaft, so that the steam is cut off at a fixed point as designed, and by linking in the same change is made in all of the cylinders together. In order to regulate the distribution of the power between the different cylinders and to make other adjustments for each cylinder separately, independent cut-off blocks are fitted in the ends of the reversing arms for each cylinder.

The detailed features of this gear are shown in Fig. 17. The reversing arm *A*, attached to the rock shaft *S*, is fitted with a slot and sliding block B, to which the link suspension rod is connected, and screw gear fitted for moving the block along the slot and thus changing the position of the link to which it is attached. The direction of the slot is so made that when the link is moved over to the astern position, the slot is approximately perpendicular to the direction of the suspension rod, so that the link is in full gear when in astern position, no matter what the position of the cut-off block, and if the engines require sudden reversal, the links are thrown into full backing gear without changing the independent cut-off. After adjusting the cut-off, the sliding block is clamped in position by means of a nut and washer.

Referring to Fig. 18, the general arrangement of the reversing gear is shown as usually applied to the vessels of the U. S. Navy. A is the steam cylinder, whose piston rod is attached to the crosshead B, and continues up to a piston in an oil-controlling cylinder A′. On each side of the crosshead is attached a link or connecting rod, connected at the other end to the arm C of the reversing shaft D, so that on steam being admitted to either end of the cylinder, the arm C is moved up and down and carries the

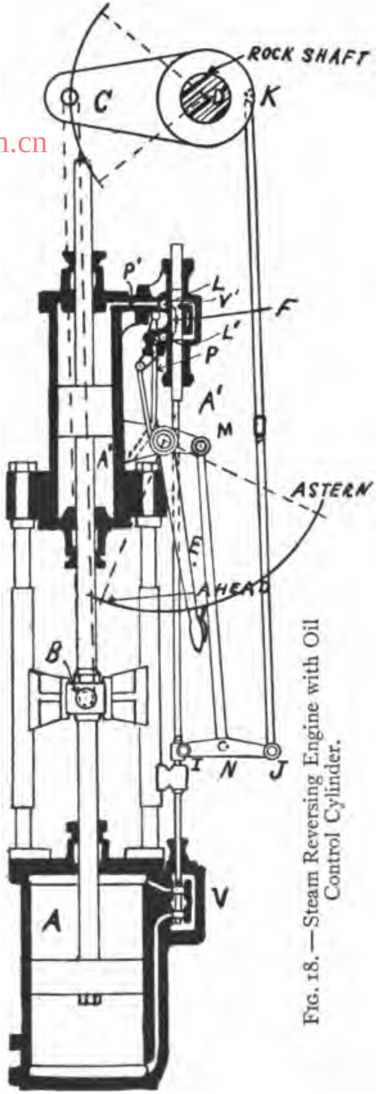


Fig. 18.—Steam Reversing Engine with Oil Control Cylinder.

links to any desired position through their connection to the reversing shaft.

Since it is necessary that the links should be brought to, and held in any position, provision must be made for automatically shutting off steam entering the cylinder A, and releasing it as soon as the links have reached the desired position. This is accomplished as follows:

The steam to the cylinder A is controlled by a slide valve V, usually of the piston type and with little or no lap, so that when covering the steam ports but little motion is needed to open them. The valve stem is prolonged and also forms the stem of the valve of the oil-controlling cylinder. The valve stem is connected by a system of bell-crank levers and links to the reversing lever E. To illustrate the action, let the gear be in the position shown, move the reversing lever to the right, the link MN is raised, and, since K is stationary, J becomes a fixed center for the moment and the valve stem I is raised, admitting steam to the top of the cylinder; since V is an inside valve, the piston descends carrying the reversing shaft arm C with it, and the links by their connections are brought over. In moving the reversing lever, if it be stopped at any instant, the entire gear, piston, reversing shaft and link will be held in that position, for the point N now becomes a fixed center and the piston, moving down with the arm C, turns K upward, and the valve stem downward from the fixed center N, thus closing the steam port. This will occur for every position of the reversing lever, so that if the lever is moved but slightly, the piston will move a short distance, when the valve will be brought into mid-position again, and all parts come to rest. If the lever is thrown all the way over, the valve will be opened wide, and the piston will bring the link to the extreme position and then come to a stop. If the motion is started by moving the reversing lever slightly and left to itself, the piston and gear will move along at an equal rate with the lever, and continue until the reversing lever comes to the limit of its motion. In this case the friction of moving the reversing lever is less than that of moving the valve; the point I becomes for a time the fixed center and the valve is closed.

It will be seen that the gear tends to stop itself, and as it begins to move as soon as E moves, it will stop as soon as it has caught up with E.

In order that the steam piston may not throw the links over too suddenly, with the risk of breaking some part of the machine, the piston rod of the reversing cylinder is continued and connected to another piston A′, working in a second cylinder filled with oil. The valve stem is continued up to join the distributing valve V′ of this cylinder and the ports are so arranged that as the piston moves up and down the oil from one side is forced through small pipes P and P′, to the other side direct, or through an intermediate reservoir. The friction of the oil in these passages thus prevents the steam piston from slamming the link over and checks any violent action. The friction may be increased or decreased at will by throttling these passages with stop valves L and L′.

In case any accident or derangement should disable the action of the steam cylinder A, the hand plunger pump, connected at F, can be used to force oil on either side of the oil piston in A′. and the engine moved, but much slower than with steam.

When reversing by hand it is necessary to work lever E in the same manner as when reversing by steam. When the valve is moved upward it allows the pump to draw from the bottom of the control cylinder and discharge into the top of same, and when moved downward to draw from the top and discharge into the bottom.

This description of reversing gear is largely taken from Barton's "Naval Engines and Machinery."

Care and Overhaul. — The cylinders of reversing engines should be examined every quarter. The connections to the reverse shaft should be kept tightened up and all lost motion or wear in the control levers of engine should be adjusted. The oil-control cylinder should be drained of oil every few months and cylinder cleaned out. The oil, especially if heavy oil is used, if allowed to stay in the cylinder for a long time, is liable to clog up the ports and cause the reversing engine to move very sluggishly.

While standing idle, with steam on, the cylinder is likely to fill with water and then fail to move when wanted. It should be drained from time to time and just before the engine is to be moved.

The reversing gear may be thrown out of proper adjustment by the bending of the rods which control the movement of the slide valve. Sometimes there are screw turn buckles by which proper adjustment for length may be made. Distortion due to disarrangement or bending of the control rods can be told by observing the position of the link when reversing lever is moved to the position of full gear. If the link is not in position of full gear, there is something wrong with the reversing engine or the rods controlling its movement.

Higher Rates of Expansion by Linking in.—By linking in on the lever so that it is held in a position some distance from full gear the reverse shaft is not thrown all of the way over, and a further amount of linking in than that obtained from the cut-off block is obtained.

Setting of Valves.—Opportunity should frequently be taken to examine the setting of valves to see that they are not improperly set. An indication of improper setting of the valve can be observed from the indicator card; this is perhaps the best guide in this matter, as it would appear to be a safe rule that as long as the cards show nothing wrong the valve should not be altered. Engines are usually supplied with steel laths marked with the proper setting of the valves and these are used to verify the position of valves.

In large engines the lap and lead for each end of cylinder are carefully calculated from the original design and measured from the actual setting. These figures are recorded on the drawing of the valve diagram.

To measure the lead of a valve, put engine on center with link in full gear and measure opening of steam port for that end. If this distance corresponds with the lead given on drawing, the valve is set as designed. One end will ordinarily be sufficient for verification, since if lead changes at one end the other should also change the corresponding amount. It is, however, better to measure both ends. Large engines are fitted with peep holes covered with bolted plates, through which the setting of valves can be observed.

Valves Dropping.—In the course of time, due to wear on their collars, valves will drop, thus decreasing the lead at one end, increasing it at the other. If valve takes steam on the outside, a dropping down of valve will increase the lead on top and decrease it at bottom.

On piston valves not fitted with peep holes, taking steam on the inside, it may be impossible to get at the port to measure the opening; in such cases the lead may have to be determined by noting the position of valve by measurement from some convenient point on valve chest, and then, by taking the actual distance, from drawings, the lead may be calculated.

To bring valve up into proper position, distance pieces may be put above shoulder of valve stem, or an easier way is to place liners under the valve stem. This takes into account the dropping down of valve due to wear, and hence the shortening of valve stem. Valves may also be deranged by shifting of the nuts securing the valve.

With smaller auxiliaries, many of which have neither lap nor lead for the valves, and of the setting, of which there are probably no records, the following rough-and-ready method suffices: The engine is put on a center, the valve placed approximately and the lead measured. The engine is then put on the other center and the lead again measured. The valve is then shifted till the leads are equal. On vertical engines allow slightly more lead on bottom than on top to allow for wear and weight of parts.

To measure the leads of valves a long, thin wooden wedge is often used. The wedge is inserted in the opening as far as it will go, the edges of opening will leave a mark on the wedge which is a measure of the lead. When the marks left by either end are alike the leads are alike.

On auxiliary engines having two cylinders working on same shaft special care must be taken that the eccentrics are connected up correctly. It sometimes happens that one cylinder is connected up for backing when the other is for going ahead. When this happens the engine will run neither way.

The following "Valve Diagram Data" form is required to be made out for the main engines of vessels when they are built for U. S. Navy. A copy of this form is kept on board ship. Forms are made out for full gear ahead and backing and for several positions of links.

Engine on Center. — To put an engine on center, or rather an engine crank on dead center, proceed as follows: Put turning engine in gear, move engine so that crosshead is near end of stroke, scribe a mark across crosshead and guide for this position; call this mark A. At the same time scribe mark across shaft and its adjacent brass, or coupling and some adjacent fixed part; call this B, B′ on brass. Then continue to turn engine until the mark A again coincides, then mark adjacent brass at point where B now is; call this C. Now find the center between B′ and C on brass; call this D. Bring B and D together, and the engine will be on the center.

When engine is built, marks are usually put on some coupling or on the turning wheel, which when trammed from some fixed point indicate the dead center of the various cranks. Such marks should, however, be verified from time to time.

Care of Valve Gear. — The overhaul of that part of valve gear outside of valve chest consists of adjusting eccentric straps, link blocks and gibs. The eccentric straps are usually adjusted so that

VALVE DIAGRAM DATA.

NAME OF VESSEL.	
TOTAL I. H. P. AND DISPLACEMENT.	
TYPE AND NUMBER OF ENGINES.	
DIAMETERS OF CYLINDERS AND STROKE.	
VALVE GEAR.	
REVOLUTIONS PER MINUTE.	
PISTON SPEED PER MINUTE.	

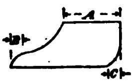
CONNECTING ROD: LENGTH BETWEEN CENTERS = INCHES; RATIO TO CRANK =

	H. P.		I. P.		L. P.		L. P.	
Eccentricity.								
Travel of Valve.								
Type, number, and diameter if Piston Valves.								
Side of Valve on which steam is taken.	INSIDE. OUTSIDE.		INSIDE. OUTSIDE.		INSIDE. OUTSIDE.		INSIDE. OUTSIDE.	
	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.
Width of port, and length if Slide Valves.								
Steam lap.								
Exhaust lap.								
Angular advance.								
Steam lead { Angular.								
Steam lead { Linear.								
Cut-off in inches. (A, see Fig.)								
Cut-off in decimal of stroke. (A, see Fig.)								
Release in inches. (B, see Fig.)								
Release in decimal of stroke. (B, see Fig.)								
Compression in inches. (C, see Fig.)								
Compression in decimal of stroke. (C, see Fig.)								
Steam opening, linear, from diagram.								
Steam opening, area of, in square inches.								
Exhaust opening, linear, from diagram.								
Exhaust opening, area of, in square inches.								
Steam velocity through ports in feet per minute.								
Exhaust velocity through ports in feet per minute.								

Velocity through main steam pipe in feet per minute.

Velocity of exhaust to condenser in feet per minute.

POSITIONS OF PISTONS TO BE GIVEN AS FOLLOWS:



SCALES.

CRANK CIRCLE =

VALVE CIRCLE =

4—486

REMARKS.

COMPUTED BY DATE.

BUREAU OF STEAM ENGINEERING, NAVY DEPARTMENT, WASHINGTON D. C.

FIG. 19.

they can be moved by hand; on large engines "leads" are taken. On cylinder having two piston valves, yokes and guides are fitted; these guides require lining up from time to time.

Other matters in regard to valve gear are treated under the heading of lining up engines.

CHAPTER VII

Engine Adjustments — Bearings — Renewing White Metal — Thrust Bearing — Crosshead Guides.

Bearings. — The overhaul of loose bearings is one of the chief items in the work of repairing on board ship. The bearings that require the most attention are the crosshead and crank-pin bearings.

Removing Parts. — Facilities for handling are of great value in expediting the work of overhaul. The fitting of hooks and eyebolts for hooking jiggers and pulleys, and tapping brasses and other parts for screws and bolts, is of the utmost importance, and these facilities for handling parts can be continually added to by the ship's force.

Crank-Pin Brasses. — Eyebolts are screwed into the upper ends of crank-pin bolts and the ends of chain fall hooked into eyebolts; the nuts are then slacked back till bolts get clear; the brass is then dropped down and swung clear. The crosshead is secured by hanging it, or shoring it up. The crank can now be turned till the upper brass is clear, and that brass can then be removed. To facilitate the examination of the upper brass this may be held fast to the end of the connecting rod by small links and set screws at each side. The crosshead with connecting rod attached is then blocked up, usually done by putting a strongback across crosshead guide. The crank is then jacked away from brass so bearing can be observed from below.

Crosshead. — To strip crosshead it must first be hung up; this is usually done by a bolt screwed into a hole in slide below crosshead. Other times it is done by shoring or blocking it up. Some provision in the way of blocking must be made on which to rest the upper end of connecting rod when free from crosshead, and this must be fitted so that it can slide down to some extent to permit an examination of the bearing to be made. For large engines tackles and eyebolts are necessary to handle brasses. A connecting rod may also be hung up by removing bullseye in cylinder head and attaching a supporting tackle to upper end of piston rod.

Main Bearings. — The top brasses need simply to be lifted, the bottom brasses are made so that they can be rotated till they come clear. For large engines a bar having a projection that will engage the top face of lower brass is secured to crank web. When the crank is rotated by turning engine the bar moves the lower brass around until it can be taken away.

Examination of Brass. — Examination should be made to see the condition of journal — whether scored or smooth, whether truly cylindrical or whether it has hollows or humps. The presence of these irregularities can be told by eye and touch, but to be accurate the journals can be calipered. The white metal of brass should be smooth, clean and sound, the oilways clear.

Oilways. — A very important item is the character of the oilways. Oilways should be cut so that the oil is brought to the point of greatest pressure, and they should not be cut so that the oil tends to run out at end of journal. The figure-of-eight oil groove is generally the most satisfactory for small bearings. Oilways should not be cut in line with the axis of journal, since this may weaken the brass very materially in one place. Oilways and oil holes should not be made too large, since too much oil will collect in one place and this tends to wear a hump.

Readjustment. — Bearings must be tight so that there is little play, but there must also be a certain amount of play to allow a layer of lubricant to keep metal off metal. To reduce this play as much as possible and at the same time prevent heating is the result to be arrived at. The amount of play must be uniform, because if it is not, only a small portion of the bearing is a real bearing surface, and the friction on this limited bearing surface will be excessive. The bearing should therefore be perfectly smooth, the play uniform over the whole surface and as small as possible while still allowing for a layer of lubricant.

Bearings may only require adjustment, that is, a tightening up on the brasses. The amount of play allowed will depend on: (1) The size of bearing. (2) The general alignment. (3) The speed of revolution. (4) Whether the motion is vibratory or revolving. The amount of play is usually expressed by the numbers of the standard wire gage.

Large bearings, such as main and crank-pin bearings, are set up to 27 to 32 lead, American gage; small bearings can be set up as tight as 36, but with this very nice adjustment great accuracy in fitting is necessary.

The clearance in the bearing is measured by taking leads. The upper brass is taken off, a thin lead wire is laid on journal either as in 1 or 2, 2 is perhaps better. (Fig. 20.)

The upper brass is put on and the nuts set up and their position marked. The brass is then taken off; the thickness of the wire shows the clearance at that particular point of the bearing, and, by the way in which the wire has been spread out, the general uniformity of the clearance can be seen. If the lead is thick on one side of journal and thin on the other a liner will have to be taken out on one side. If the clearance is too little a thin liner is inserted; if too much, liners are taken out. If the lead shows a general irregularity the brass will require scraping and fitting.

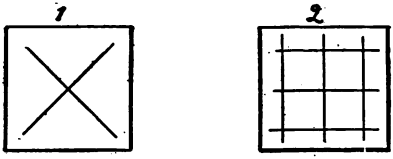


FIG. 20.

Another method of adjusting brasses is to take out all liners, set brasses up hard, and mark nuts; then slack back nuts the necessary amount for clearance, using the fraction of the pitch of nut to determine the exact amount. Liners are then inserted to the required amount. This method is, however, not very general. When the brasses are carefully fitted and where great care in adjustment can be ensured this is an excellent method. This method is also used where time is limited and rapid adjustment or slacking back necessary, as in case of heating, judgment being used to determine the amount to slack back nuts.

Liners. — Copper, brass, paper and tin are used for liners. Tin is more or less objectionable, owing to its liability to rust; it should not be used where there is likely to be salt water.

Fitting Bearings. — Usually the only fitting is smoothing down or scraping scores or rough places.

If the journal is scored or uneven this must first be remedied. Usually a fine file is used to dress the journal, and after this the journal is lapped with an oil stone or with oil-stone powder. Carborundum is sometimes used in dressing journals.

Fitting Brasses. — The bearing surface of brass is smoothed and scraped or bored to an approximate fit. If bored in a lathe it should be bored with sufficient liners in to allow for fitting. To fit the brass the journal is coated thinly with red lead and oil, black lead and oil, lampblack and oil, or putz pomade. The brass is then laid on and moved slightly. Where the coating adheres the surfaces touch, and these spots have to be scraped. This operation is repeated until the spots are many and uniformly distributed all over the bearing surface. To insure accurate fitting the brasses should be tested in this way when in proper position with bolts in, as by reason of the restraint due to bolts the actual position of the brass may not be the same when bolts are not in.

Brasses should not be reduced all from one side; especially is this so on shaft brasses. It must be remembered that both the upper and the lower brass wear. The bottom brasses of crank-shaft journals must be brought up into alignment by putting liners underneath as wear takes place.

Brasses should be eased off at the sides to prevent nipping of journal when they become warm. This is usually accomplished by distance pieces and by cutting out the white metal for a short distance from edge of brass. The space formed by easing also forms a reservoir for holding the oil — a desirable feature.

Small Brasses. — The degree of tightness and fit of bearing for small brasses can be told by the appearance of bearing and by touch. By feeling how a bearing turns the experienced hand can tell whether it is loose or not. In general, a bearing should be able to be turned without undue effort by the pressure of the hand; an eccentric strap by setting up till the rod will just fall of its own weight. On bearings of any size it is always best to take leads, but for a very large number of small bearings this is not necessary.

Overhauling and Renewing White Metal. — If the white metal is rough or scored it should be scraped smooth. If there are holes in the white metal or the metal is spongy in places the spots may be patched. To do this the holes are thoroughly cleaned out and all bad metal removed; the holes are made a little larger at bottom and washed out with hydrochloric acid. A quantity of white metal is then melted, bearing warmed up and metal poured into holes and allowed to come above the rest of the surface. The new metal should then be hammered into place with pene hammer, and, when cold, the surface should be scraped down to a bearing. Solder or tin can be used in an emergency when no white metal is available.

To Renew White Metal. — If the white metal needs renewing due to cracks, running or thinness of metal, the old metal should be taken out. This can be done by heating in a clean coke fire to melt it out. After the old metal is removed the surface should be cleaned with hydrochloric acid and then tinned. The bottom brass should be placed in position a little lower than when connected up; a piece of putty or clay should be used to close up the ends of the bearing. The white metal can then be poured in; pour only from one side to be sure to drive out all air. When metal is nearly hard take out brass and hammer surface all over with a pene hammer to make it solid and fill all holes. The upper brass is treated in the same way. Cast-iron mandrels for all large bearings are now generally supplied, and it is more advantageous to use them since a better position and better facilities for pouring the metal can be obtained. When a mandrel is used the brasses can be bolted together, the mandrel set on end and centered in the brasses, and the metal poured into the annular space from the top. Where no mandrels are supplied they can be made by turning up a piece of cast iron to the dimension of the journal. Pieces kept on board for making piston rings will generally answer. After the white metal has been hammered the brass should be bored in a lathe and then scraped and fitted and oilways cut. A spare brass for principal journals, all ready to fit, should be kept on hand so that in case of accident there may be no great delay in renewing one.

Thrust Bearing. — In the course of time the surface of thrust collars wear and give more play than is desirable, the result being that the crank shaft is moved forward. To adjust for this wear, the collars, if of horseshoe type, are moved the necessary amount by means of the adjusting nuts provided for each collar.

If the bearing is of box type, the whole bearing can be moved by means of the adjusting screws or wedges provided.

When the horseshoes of thrust bearing have worn to such a degree as to have any considerable play between collars a great strain is brought on engines in backing. It is, therefore, advisable to renew white-metal lining and refit horseshoes in the course of every few years' running.

Crosshead Guides. — As the result of wear the crosshead may get out of line, the result being that the piston rod is forced over to one side and a cross-breaking stress brought upon the rod at each stroke. The crosshead is brought back into proper position by putting liners under the slipper until the necessary distance is obtained. To determine this disconnect connecting rod and move piston to top of stroke; observe whether there is any clearance between the slipper and the guide. If there is, measure it with a wedge gage, then let piston drop to bottom of stroke and let crosshead go free. Again take the clearance. If the clearance is the same in each case the slide is in line and the clearance can be taken up by putting a liner under shoe. If, however, the clearance is more at one end than at the other, the slide is not in line, but can be adjusted by moving one end out till the crosshead bears evenly all along. The presence of too much clearance can be told without disconnecting anything by inserting wedge gage between slipper and guide. The backing guide will wear very little, so in adjusting, it is the go-ahead side that will require the attention.

CHAPTER VIII

Lining up Engines.

Lining up Engines. — The base of reference for lining up an engine is the center line of shaft. All other parts must be lined up from this as a basis.

All bearings on the crank shaft must be so that their centers are in one straight line from center of propeller hub to center of inner end of crank shaft. The piston rods and pistons must work in a line perpendicular to the line of shafting.

These are the general conditions that must be fulfilled, and in erecting the engine great care must be taken to secure the proper adjustment and fitting of all the various parts in order to avoid the racking and parting strains that may be brought on various parts when they are out of line. The general tendency due to lack of alignment is a loosening of joints and dislocation and distortion of moving parts.

On board ship the adjustments will consist of relining shafts and crossheads, as they are the points where most wear takes place. The minor attachments, such as valve gear, pump levers, reverse shafts, etc., will also require attention from time to time.

Indication of Engine being Out of Line. — Indications that shaft is out of line are extra pounding, apparent up-and-down movement of any of the bearings, observed by watching the change of clearance between shaft and bearing for different positions of crank.

If two sections of the shaft are uncoupled and the flanges do not meet fair it shows that they are out of line. This can be told very accurately by placing pieces of tissue paper at top and at bottom and at each side of coupling and butting shafts together. If the papers grip all around, the shafts are in line; if they grip in one place and not in another, the shafts are not in line.

Indications of crosshead guide being out of line are knocks in crosshead and a non-uniform clearance between slipper and guide. This change in clearance can be found out as explained under crossheads. The proper alignment of connecting rod to piston rod and crank can be told by observing whether there is any tendency for lower end to move in a fore-and-aft direction on turning of crank, or whether lower end is free, by observing the clearance between crank webs and crank-pin brasses.

In general the lack of alignment of the minor parts of engine are determined by watching for undesired movement, which can be told by touch, observation and measuring in various positions.

Lining Up. — To line up an engine the center line of shaft should first be determined.

The shaft being out and engine stripped of piston, connecting rod and crosshead, crosshead guides and lower brasses of main bearings in place, and cylinders opened, proceed as follows:

A line is run in the position of center line of shaft. In order to obtain this line two points of origin must be found. If the whole shafting is to be relined the two points are the center of stern bearing and the forward end of crank shaft. Usually only a portion of the shaft is relined at one time. When engine is installed wearing gages for shafts are provided; by applying these the amount that the shaft is low at certain points can be determined. The center of shaft is also marked on parts of engine seating. From these two guides two points of the center line can be found and a cord or wire stretched between these. Such points must, however, not be far apart, as there is considerable sag in the cord or wire. Points along the shaft may also be determined by lines of sight, and points along the line marked on wood battens.

The center line of shaft being determined, the exact distance down to the bearing surface of lower bearings can be calipered at points along the bearing and they can be raised or lowered till all are in line. A line of sight along the bearings may be of help in bringing them into position. Next, the middle line of all bearings must be brought into the vertical plane of the center line of shaft. This can be done by marking the middle of each brass and then moving brasses sideways till all are in position. When this has been done the main bearings should be in line. By using a straight-edge between each two bearings further discrepancies may be located and rectified. Small discrepancies are rectified either by fitting liners under the bearing or by scraping the surface of bearings at high points. On small engines, and often also on a large one, the shaft itself can be used to fit the bearings. The journals, having been smoothed up, are given a light coat of red lead, then shaft is put in place and moved slightly. The red lead will adhere on the high spots, and these can then be scraped, and the operation repeated till a good fitting line of bearings is obtained.

Lining up Cylinders.—The center line of cylinder must be perpendicular to the line of shaft and in the same vertical plane. The intersection of the line of the cylinder and the line of shaft is obtained approximately by measurement on bearing. The center of upper counterbore of cylinder is taken as the upper point of origin. A board having a hole in it is secured over center of cylinder so that the hole is over the center. A line or wire with a wooden toggle at end is then passed through this hole; the end of line is made fast below so as to come at the point of intersection of line of cylinder and shaft. The upper end of line is then moved till it comes exactly in the center of the counterbore. This may be done by calipering, or by the use of a wooden stick, slightly shorter than the radius of counterbore, having a pin stuck in its end. This pin can be pushed out till the exact radius of counterbore is obtained, and then by measuring around on all sides the line may be exactly centered. The upper end of line having been centered, the lower end must be brought into exact position. First, it must be moved so that it comes just in contact with the shaft line. Secondly, it must be at right angles to the center line of shaft. To see whether it is at right angles a large square may be used. Rest the square with one edge on the main bearings, which have previously been lined up; bring the other edge up to the cylinder line; the line should coincide with the edge of square. If it does not, the line should be shifted forward or aft until it does. The line will now give the true position for center line of cylinder. The alignment of cylinder can be verified by measuring from sides of stuffing boxes, or better, from lower counterbore.

If the cylinder itself is found out of line it will be necessary to adjust the cylinder feet and columns, or the whole cylinder may have to be moved. The cylinders are, of course, accurately aligned when the engines are erected, and should not change unless some part of columns or engine seating has been shifted or displaced.

The cylinder line being established, the crosshead guide can be lined up. This must be exactly parallel to the line of cylinder. This can be found out by calipering or using a wooden stick to measure distance of surface of guide to center line of cylinder at several points along its length. Then the guide can be adjusted so that it is parallel. The surface of guide must also be perpendicular to a plane passed through the line of cylinder at right angles to the line of shaft. To determine this take a square and rest one side vertically on guide so that the edge of square just touches the cylinder line. Keep the corner of square in the same place and move square around. If the edge of square continues to touch the cylinder line the surface of guide is perpendicular; if not, the edge of square will move away from the line. The guide may then be moved till it is parallel. This being done, the standing parts may be considered as being in line.

Lining up Connecting Rod and Slipper. — The slipper and slide should be brought to a true surface, the surface plate being used for this purpose. The surface plate receives a thin coat of red lead; the slipper is placed thereon and moved back and forth. The slipper is then removed and the red spots scraped, and the process repeated till a good surface is established. When the surface is very bad it should first be trued up on a planer. Where no surface plate is available a straight-edge can be used by placing it on the surface in various positions and noting where the high points of the surface exist.

The piston and rod being put in, the crosshead can be attached and the proper clearance between the guide and slipper obtained by liners. The alignment should be such that when the piston moves up and down centrally the slipper should just touch the guide through the whole stroke. The piston should then move centrally through the stuffing box.

Connecting Rod. — The connecting rod should swing in a direction at right angles to the line of shaft and should come fair over the crank-pin journal. To test this, observe whether the clearance between crank webs and end of crank-pin bearing is the same at each end. If the rod does not swing at right angles to shaft the crosshead bearing may be at fault. The two bearings of crosshead may not be in line or one may be bent. If the bearings are all right the fault may lie in that the surface of slipper is not parallel to the axis of crosshead. This can be found out by putting slipper on surface plate and measuring distance to the center of journals. If they are not the same the slipper must be aligned by scraping or by fitting liners in proper place. If connecting rod does not come fair over the crank pin the fault may lie in a wrong adjustment of thrust collars, or the shaft couplings may not be properly brought together. Sometimes it may be necessary to shave off one end of crank-pin brass in order to get the lower end of connecting rod in.

Thrust Shaft. — This should be aligned at the same time with the shaft, for on the proper adjustment of the collars will depend the proper location of the whole shaft in a fore-and-aft direction.

There should be a uniform clearance for all collars. This clearance may be measured by inserting feeler gages. The clearance varies from No. 24 to No. 29, American standard gage. The clearance at thrust should not exceed the clearance between the crank webs and the crank-pin brasses, for if it does the thrust may be transmitted to the crank-pin brass.

The clearance on collars of horseshoe thrust is adjusted by moving the nuts securing the collars. In adjusting, great care must be taken that the surface of horseshoe is at right angles to the line of shaft. This can be done by making the clearance at each side exactly the same.

The horseshoes are generally babbitted, and, as a rule, require re-babbitting in the course of every few years. Care should be taken that suitable oil grooves are cut on the horseshoes. A wavy line over bearing surface of collar makes a very desirable groove.

Various subsidiary parts of engine will require relining from time to time.

The valve gear is susceptible, in general, to the same treatment as the main moving parts. The principal parts to reline are the guide and the link. The guide must be in such position that the valve stems work centrally in their stuffing boxes. Links generally wear on the go-ahead end, the gibs being loose here while tight when at the center of link. To rectify this the high portion must be scraped and the gibs adjusted accordingly.

The reversing shaft, pump link and indicator gear require relining and adjustment from time to time.

CHAPTER IX

Oiling Gear — Friction and Lubrication — Water Service.

Oiling Gear, Friction and Lubrication. — Friction is the resistance of the surface movement of bodies in contact. The substances may be solids, liquids or gases.

In engineering we have mostly to do with the friction of solids. Every metal surface, no matter how smooth apparently, has small irregularities in its surface, and when two surfaces are in contact these irregularities interlock and produce the resistance to motion, friction, which manifests itself as heat.

Friction increases with —

Increase of pressure;
Irregularity of surface;
Softness of surface;
Elasticity of surface.

Solid friction depends directly on pressure; when no lubrication is supplied it is independent of the surface, that is, the pressure being the same.

For slow velocities the friction does not change; for high velocities it changes, but mainly due to other circumstances, such as greater heating.

Similar substances in contact have more friction than two different substances.

Hence, to lessen friction, obtain hardness, lessen pressure, use different substances in contact, use lubricants.

By introducing a lubricant, such as oil or grease, between the two surfaces they are kept apart. The irregularities are prevented from interlocking; solid friction is prevented, and instead we have the internal friction of the particles of oil on themselves and the friction of the solid on the oil.

Spongy metals, as brass and cast iron and various compositions known as white metal or anti-friction metal, can be made very smooth;

hence they are very good for bearing surfaces. Cast iron is an exception to the rule that similar substances increase friction.

Hard cross-grained cast iron wearing on itself has less friction than any other combination of metals; especially is this so where the only lubricant is steam, as in slide valves and steam pistons.

The reason for this property of cast iron is that the surface, when rubbed lightly so as not to produce abrasion, will become very smooth and also very hard.

White metal and brass obtain their properties of lessening friction from the fact that they can develop a very smooth surface. Owing to the difficulty of fitting such places as bearings of fast-moving engines cast iron is not used, but brass and white metal instead. Of these two, white metal is the more easily fitted and it is used on nearly all bearings of any size.

There have been disputed claims as to whether brass or white metal has the less friction. White metal can be more easily fitted and adjusted and made smooth, and it is in general use in the best practice.

Rolling friction is very much less than sliding friction, hence the introduction of roller and ball bearings now largely used on special machines and on naval vessels in gun and turret mounts.

Ball and roller bearings are being introduced in thrust bearings for marine engines, and the use may extend. It is very likely that, if made very carefully, they will be a success on thrusts, but their wide use will probably be checked by the additional complication and difficulty in adjusting after wear.

The best lubricants for metals are —

Lard, olive, sperm, light mineral oil	Ordinary machinery.
Mineral grease, tallow . .	For slow speeds, heavy pressure.
Sperm oil, heavy petroleum .	High speeds, high pressure.
Refined sperm and petroleum .	High speeds, light pressure.
Graphite, sulphur, soapstone, mineral greases . . .	Heavy pressure.
Heavy mineral oil, graphite, vaseline	Steam cylinders.

Mineral grease, tallow and graphite are the best of lubricants, but are more difficult to apply and, as they have little or no flow, cannot be well used where there is any considerable speed on moving parts, owing to the slowness with which these lubricants distribute themselves over the surfaces.

Graphite is not affected by heat, and hence can be used where parts are under temperature, such as high-pressure steam cylinders and cylinders of gas engines.

The requisites of a lubricant are —

Efficiency to reduce friction;

Body, to support heavy pressure;

Fluidity, to avoid resistance and to rapidly cover the bearing surface;

Resistance to and power to absorb heat;

High flash and burning point, so that temperature may rise without danger of the lubricant burning.

Another requisite is the tendency to saponify and form a lather, which has an excellent lubricating value, especially for high speeds and heavy pressures.

From the above it will be seen that no one special lubricant is the best for all various purposes. Each special service should have its own particular oil or lubricant properly suited to its peculiar conditions.

Lubricants are tested: for purity, by chemical analysis; for viscosity, that is body; for gumming action; for flashing and burning point; and for general efficiency in reducing friction in a testing machine where friction is measured by a dynamometer.

Among the different methods of lubrication the following may be enumerated:

1. Oil bath, where the bearing is completely surrounded by oil forced in under pressure. This is often used on large bearings on shore, and is used on the bearings of marine turbines.

Fast-running engines, such as dynamo and blower engines, are fitted with forced lubrication; that is the cranks, piston rods and main bearings being enclosed within an oil-tight casing, through which oil under pressure is circulated with an oil pump. This system is economical in oil, since the oil is used over and over again. Objections to its use are the difficulties of preventing the oil being drawn into the cylinders and delivered to the condensers and boilers.

2. Self-oiling bearing, where some part of the journal distributes the oil from a reservoir. In this class are the centrifugal oilers for

[illegible]heads and crank-pins, and the loose-ring self-oiling bearings [illegible] on high-speed machinery such as turbine pumps (DeLaval). Bearings fitted with such devices, however, usually occupy con[illegible]ably more space than can well be allowed in the limited spaces [illegible] to naval machinery.

Pad lubrication, as in the boxes on car axles of railroads; also [illegible] cups on some forms of large main and thrust bearings. This type is good for large, rather slow-moving journals where [illegible] or tallow can be used.

Automatic sight-feed lubricators. Here the oil cup or box [illegible] with a screw-down valve by which the amount of oil can be [illegible] by opening or closing. The lubricators are usually fitted [illegible] the oil, as it drops, can be seen; and thus the amount fed [illegible] ascertained. This system is very largely used, and answers [illegible] for stationary work, but in marine work the vibrations [illegible]ment of the engines jar the valves so that the amount of [illegible]ged or even shut off. They thus require constant watch[illegible] more attention than wick feeds would require. They [illegible] thorough success on naval engines, though the present [illegible] to have oil boxes fitted with both automatic sight feeds [illegible]. This is done so as to have the sight-feed valve [illegible] full power, when the saving of oil is not a matter of such [illegible].

[illegible] — This is, of course, the most simple, but [illegible] complicated engines many bearings are inaccessible [illegible] and it would entail a very great amount of labor to [illegible] of bearings by hand. Hand oiling is the most [illegible] as they will not care to handle more [illegible] to keep the bearing from running warm, which is [illegible]

[illegible] slow or at moderate speed a great many of the [illegible] accessible bearings should be oiled by [illegible]

[illegible] Here oil boxes are fitted at va[illegible] well above the bearings to be lubricated. [illegible] from a reservoir tank placed above [illegible] are led, without pockets, to [illegible]. The oil is admitted to each pipe by a [illegible] funnel mouth, where the [illegible]. The amount of oil can be regulated by making the wick larger or smaller or by changing the height that the oil is carried in the box.

The wick is weighted at the end resting in the oil box, and the distance that the end of the wick extends into the pipe is adjusted by a copper wire which is hooked over the top of the pipe and twisted around the end of the wick. The end of the wick should be about at the level of the bottom of the oil box to give a proper flow.

The great advantage of the wick feed is that it is easily kept at an almost constant rate, since the jar of the engine has no effect upon it. It also does not allow any dirt that may get into the oil box to be fed down the oil pipe.

A carefully looked after siphon wick system, supplemented by hand oiling at lower speeds, is the most satisfactory system at present devised for lubricating large marine engines.

With wick feed the oil in the boxes should not be allowed to go too low, as the height of oil in the box changes the rate of feed. Wicks should be periodically lifted to keep them clean; if dirt accumulates about their ends they will stop feeding.

Where oil is fed directly to a bearing and not through a wick or long pipe it is of great advantage to add from 2 per cent to 4 per cent by weight of flake graphite. The use of graphite mixed with oil allows a lighter to be used, since the addition of graphite increases the body of the lubricant.

For slow-moving heavy bearings or gearing graphite grease is perhaps the best lubricant.

Oil flows more readily as the temperature rises. This point should be noted and the wicks adjusted for any material change of temperature of the engine room.

A slight rise in the temperature of the bearing reduces friction; hence the oilers' term "working heat." This working heat must, however, be kept within proper limits and not allowed to become the excuse for allowing a bearing to become hot.

Specially Prepared Oils. — Lubricating oils are often specially prepared for the service desired by a compounding of different oils or the addition of other substances. The best results, as far as providing for a lubricant with least friction, is obtained by getting the oil to saponify (that is to form a lather). To do this some water is supplied to the oil in the bearing. This may be done by the water service; but the water service supplies salt water, which does not form as good a lather and is liable to leave salt on the bearing. If a little fresh water is supplied to the oil pipe by means of a syringe or funnel at occasional intervals a good lather can be obtained with high-grade lubricating oil. Adding a little soda to the water will help the formation of lather.

In such places as thrust bearings, which run in a bath of oil, sufficient water to make the proper mixture is added directly to the bearing by pouring it in with the oil.

In adding water care should be taken not to add too much at one time so as to wash the oil out of the bearing.

Storing Oil in Tanks. — In stowing oil in the ship's tanks care should be taken (1) that tanks are properly cleaned, (2) that each tank has a strainer over its suction pipe to oil pump, (3) that different oils are not mixed, (4) that oil when run to tanks is passed through a strainer; cheese cloth or a similar substance will answer for the purpose.

Overhaul of Oil Gear. — This consists in repairing leaky oil pipes, setting up on loose unions and securing screws, etc.

Wicks are cleaned by being washed in soda water. They are made from lampwicking.

Oil pipes are cleaned or scalded out by introducing a little soda and boiling water, but care should be taken that none of the soda reaches the bearing.

All oiling gear should be carefully inspected just before getting under way.

The following are the latest specifications for the lubricating system of U. S. naval vessels:

"There will be fitted in each engine room a steam pump of approved capacity, with hand attachment, for keeping the distributing oil tank supplied with oil. This pump will draw from the storage tanks and discharge into the distributing tank, an overflow pipe from the tank being led to the pump suction.

There will be in each engine room, located at as great a height as possible, a 10-gallon copper distributing tank. The tank will be well tinned on the inside and fitted with a glass gage, air cock and pump connections. Each tank will be connected to all the oil boxes on its engines by ½-inch brass pipes, iron-pipe size, leading in such a way that oil will flow to each lubricator.

All working parts of the machinery will be fitted with approved and efficient lubricators. Generally speaking, there will be cast-iron oil boxes secured to fixed parts of the engine at convenient points and having connections for distributing the oil to the various bearing surfaces. Each connection will have a sight feed, an adjusting valve and a wick feed. The sight feed will have a well-protected glass tube. All oil cups with wick feeds will hold sufficient oil for four hours' running. The distributing pipes will lead to wipers on the moving parts or tubes in the bearings and guides. The oil boxes will be polished on the outside, and will be plainly marked opposite each pipe with the name of the part to which it leads.

Unions will be fitted where necessary, so that the oil pipes may be quickly taken down and cleaned, and each pipe will be connected to the bearings by a union joint. Each main crank pin will be oiled by cups carried on the connecting rod, taking oil from wicks overhead; the oil to be carried to the crank pins by brass pipes secured to the connecting rods. These pipes will have union joints where connected to oil cups.

Each main crosshead journal will take oil from an overhead wick cup.

The crosshead pins will be flattened at the sides, a ring of metal being left at the ends to prevent the escape of oil. The oil will be introduced through a pipe passing through the axial holes and led to the surface of the pins through radial holes, terminating in the spaces formed by the flats on the pins.

In addition, oil will be introduced, through a pipe and oil box on cap bearing, to top of pin.

The crosshead guides will be oiled by tubes connecting with holes leading to above the middle of each guide, as approved, and oil boxes will be fitted under each guide, with draglers, secured to the slippers, dipping into them.

The top of the slipper and the crosshead guides will have a concave bevel to prevent lubricating oil running over the back of the guide and slipper when slipper overruns guide.

The upper end of each eccentric rod will carry oil cups on each fork, long enough to prevent waste of oil. Each link-block pin will be oiled by two wiper oil cups, and each pair of gibs for links by one wiper cup supplied by pipes from the oil boxes.

Each eccentric strap will have a long oil cup fed by a drip pipe, so arranged that the eccentric will be lubricated in all positions, or else an approved telescopic oiling gear.

In general, all the oil for the external moving parts of each engine will be supplied, as far as possible, from oil boxes with separate valve, sight feed, wick tube and pipe, as directed or required, for each part to be oiled.

There will be one such oil box on each cylinder, from which pipes will lead to the following parts: Valve-gear connection, crosshead pins, crosshead guides, crank pins and valve-stem guides.

There will be provided, where directed, an approved number of oil boxes, fitted similar to those described above, so that they may be used either with valve adjustment or with wick tubes for lubricating the main crank-shaft bearings and the eccentrics. These oil boxes will be placed in accessible positions, and at least 5 feet above the center line on shafts, so that oil may be fed to the bearing under this head. Each main bearing will have two oil tubes, and the oil pipes will be so led and oil holes so drilled as to introduce the oil at both sides of each bearing near the middle of the length of the bearing, and as near the division between the cap and lower brass as is possible. These oil boxes will be supplied through ½-inch pipes from the 10-gallon distributing tank in each engine room.

Suitable small oil cups will be fitted for introducing oil into valve chests.

There will be fitted small oil cups as approved, for supplying oil to valve chests of pumps, blowers and other auxiliary engines.

Each blower engine will have a continuous automatic lubricator of approved pattern. All working parts will have oiling gear of approved design, such as will permit of oiling without slowing. All the oiling of each auxiliary engine will be done by one oil box where practicable. All fixed oil cups will have hinged covers, with stops to prevent being opened too far. Moving oil cups, where necessary, will have removable covers. The supply of oils to various parts is to be easily regulated. All oil cups and their fittings, except such as are cast on bearings, will be of finished cast brass, or sheet brass or copper, as may be directed, with all seams brazed.

All fixed bearings will have drip cups cast on where possible; otherwise the drip cups will be of cast brass, properly applied. All moving parts will have drip cups or pans cast on engine frames where directed; otherwise they will be substantially made of sheet brass or copper, with brazed seams. All drip cups will have drain pipes and cocks of at least ⅜-inch diameter, which can be used while the machinery is in operation.

All auxiliary machinery will be fitted, as directed, with ample drip pans, with drains to bilge."

Water Service. — Engines are fitted with a system of water service by which cool sea water may be circulated through a bearing or guide, or sprayed on any part liable to heating.

Collars of thrust bearings, main bearings and crosshead guides are now usually cast hollow to allow for the circulation of water. On some recent large engines the crossheads are fitted with a telescopic water service to enable water to circulate through these.

In order to keep the large amount of water, which comes through the water service, out of the bilge and crank pits, some vessels have the water service arranged so that the water which circulates through the main bearings, guides and thrust bearings is led to the suction of the circulating pump. As thus arranged, the water service for these parts is a closed circuit.

There are usually a number of hose connections on the water service so that a hose can be attached and cooling water led to any desired place in engine room. These connections may also be used in washing down the engine room.

The repair work that the water service will require consists of grinding in its valves, tightening up on joints and unions and re-brazing broken joints.

The water service should be shut off about half an hour before coming to an anchor so as to leave only clean oil on the surface of the bearings when engines are stopped.

The following are the specifications for water service of recent U. S. naval vessels.

"There will be in each engine room a 4-inch water-service pipe, with a 4-inch branch to the main engine and a 2-inch branch to the shaft alley, and smaller branches leading to different parts of the engine and shaft, as follows:

One 1½-inch branch with swivel joint for each crank-shaft bearing;

Two 1¼-inch pipes to each crank pin;

Two 1-inch pipes to each crosshead;

One 1-inch pipe to each go-ahead crosshead guide;

One 1-inch pipe to each pair of eccentrics;

One 1½-inch pipe to each thrust bearing;

One 1-inch pipe to each line-shaft bearing;

One ¾-inch pipe to each hollow brass or its equivalent in crank-shaft bearings;

Two 1-inch pipes to each air-pump engine and to each circulating pump engine.

Each of the above branches will have a separate valve and will terminate, as may be directed or approved, either in a pivoted nozzle, a detachable spray nozzle, a short length of hose, or a permanent connection to the part to be cooled.

The water-service pipe will be connected so as to take water from the casing of the main circulating pump. There will be a stop valve in the water-service pipe near the connection.

The water-service discharge pipes from crosshead guides, main bearings and thrust bearing will connect to the suction side of the main circulating pump, so that the water may pass overboard instead of into the bilges.

There will be a system of water-service pipes for auxiliary machinery in any part of the ship, as may be directed. These pipes will be of approved size, thickness and arrangement, and will connect with sea valves or pipes where directed."

CHAPTER X

Condenser and Pumps — Circulating Pump — Condenser — Air Pumps — Difficulties Experienced with Pumps.

Circulating Pump. — The general type of circulating pump used is the double-inlet centrifugal, directly connected by shafting to the pump engine. The details differ for different vessels, and can be ascertained by an examination of the blue-prints of pump drawings kept on board ship.

The casing is made in two parts, so that the upper part can be removed for purposes of examination.

On recent vessels the circulating pump also supplies the water-service pipe for engine room, and on some vessels the discharge from the closed portions of the water service, such as guides, main bearings and thrusts, discharges to the suction of the circulating pump. This latter arrangement greatly reduces the amount of water in bilges while under way.

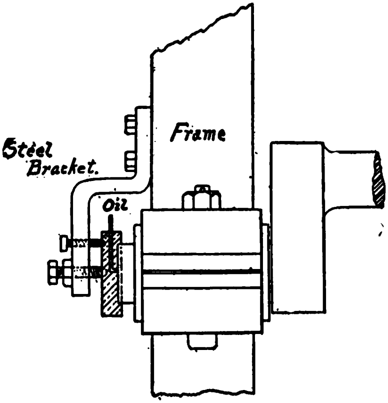


FIG. 21.

There is often an end thrust on the shafting of the pump so that clearance of runner is destroyed on one side or the crank webs are liable to rub against main bearings. To remedy this, an end thrust bearing may be rigged by fitting a bracket to framing so that end of bracket comes abreast the end of shaft. In the end of bracket fit a set screw having a jam nut, the set screw to be in a position so as to be in line with center of shaft. When the set screw is adjusted so as to just touch the end of shaft it will prevent a longitudinal motion outward. (Figs. 21 and 22.)

The circulating pump requires examination from time to time; casing should be removed about once a year. The principal troubles met with are due to the corrosion of pump shaft and the runner getting loose on shaft. To prevent corrosion, zincs are fitted in the pump chamber and in the suction and discharge pipes.

Keys on runners must be properly secured by fitting them with set screws or other convenient way.

More or less dirt or marine growth may collect in the pump chamber; this should be cleaned out.

The lignum-vitæ bushing for bearings wear down in time and thus allow the shaft to drop out of line. They may be brought back

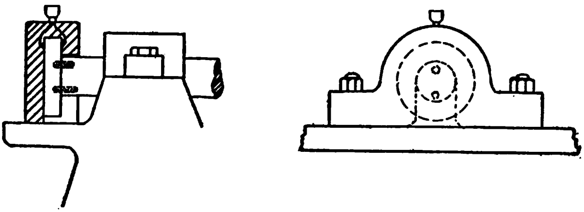


FIG. 22.

into place by turning bushing around, or better, by fitting a new bushing and placing shaft in line with that of the pump engine.

Circulating Pump Engines. — These are usually compound, direct-acting engines. In general these engines require the same care as the main engine. The bearings must be adjusted when they become loose. The valve should be examined and kept properly set. The cylinders should frequently be opened and wiped out. They are usually fast-running engines and require fine adjustment. They run continuously for long periods without stopping, and, as a rule, very little difficulty is experienced with them. After engine has been overhauled it is advisable to run it for a short time to see that there is no danger of heating, otherwise it may be extremely unfortunate that when it is desired to get under way the circulating engine has a hot bearing which may delay the vessel.

Condenser. — The details can be seen by examining blue-prints of condenser drawings kept on board ship.

The perforated baffle plates are provided to prevent the exhaust steam from striking the tubes directly and causing them to be bent out of shape or cut. The plates also serve to conduct the steam among the tubes so that all the surface may come into use.

The tubes are of composition, 70 per cent copper, 1 per cent tin, and 29 per cent zinc. They are fitted with stuffing boxes and ferrule at each end, the glands being packed with corset lacing or cotton tape. The glands are provided with a shoulder which will prevent the tube from crawling.

Zincs are fitted in the salt-water side of a condenser to prevent corrosion from galvanic action, and should be fitted so as to secure a good metallic contact with the heads.

Condensers are provided with the following fittings:

Safety valves;

Drain cocks for both salt- and fresh-water ends;

Air cocks to allow the accumulation of air to escape;

A boiling-out connection to allow steam to be admitted to boil out the condenser;

A connection for admitting soda in solution;

A vacuum gage.

The work of overhauling condenser consists of —

Keeping the cooling surface clean;

Preventing leaks from salt to fresh side;

Keeping shell tight so that there is no leakage of air from the outside;

Preventing the general corrosion and deterioration of parts.

The tubes in the course of time accumulate grease and dirt from the steam. To remove this deposit the condenser should be boiled out. This is done by admitting potash or soda into condenser through the soda cock, the soda being first dissolved in water. After the soda is in, live steam is turned into condenser through boiling-out connection. The mixture of soda and steam dissolves the grease, forming a soapy substance which can be drained off. Additional water is introduced to wash away the accumulation and remove the extra soda. The condition of tubes as to cleanliness should be ascertained frequently. The salt-water side of condenser in time becomes dirty from the accumulation of sand, ashes or gravel that has been drawn in and lodged in the condenser, so the salt side should be cleaned periodically.

Leaky tubes are caused by corrosion due to the action of salt water and of grease. Tubes sometimes appear to be cut due to the direct impingement of steam upon them. On this account baffle plates are fitted so that the steam does not strike the tubes directly.

In the course of time the action of the sea water causes the tubes to become brittle and liable to break. Tubes when made too light sometimes split, and pin holes may sometimes develop.

A most frequent form of leakage is at the glands at the tube ends. This is caused by the tube packing giving out or the gland not being set up tight.

All of the above leaks allow salt water to mix with the fresh, and their presence is indicated by salty water in the hot-well or feed tank. Very often salt-water leaks occur through some form of salt connection on condenser that is not properly shut off. Many old vessels have a salt cock for the supply of extra feed. This should be disconnected to prevent danger of salt leakage.

To Locate a Leak in Condenser. — If in a hurry, take off hand-hole plates on condenser end, start up air pump and get a vacuum. Then take a lighted candle and hold it around the tube ends. Where the flame is drawn in there is a leak, and such tubes should have their glands set up on; or if it is the tube itself it should be plugged by screwing in a metal plug or driving in a wooden one. To locate the other end of tube at the other tube sheet, stick a long wire through the tube.

A more certain way of testing condenser is as follows: Close injection and discharge valves tightly. Take off end bonnets, or the hand-hole plates may be sufficient. Fill steam space with fresh water, usually done by means of hose through man-hole. Then examine the tube sheets to see if there is any leakage through the tubes or around the joints, leakage being told by water trickling out. If a pressure can be put on condenser by means of a hand pump or by running up a standpipe filled with water, the location of leaks is more certain. Care must, however, be taken not to fill L.P. cylinder with water in case no valve is fitted in the exhaust pipe.

The joints of the shell of condenser must be kept tight, as must also the joints in the exhaust piping. Usually condensers are made in one course, but there are some that are made in several courses with joints. Leaks about joints may be located by holding a lighted candle about joint while air pump is in operation and noticing where the flame is drawn in, also by filling condenser with water and observing leakage. Leaks at joints may be repaired permanently by remaking the joint. This is, however, often inconvenient by reason of lack of time or on account of the great number of parts that have to be disconnected. Such leaks may be temporarily stopped by calking with cotton batting or by filling in opening with red-lead putty and fitting a clamp over joint to keep putty in place.

Leaks in the shell and joints are shown by poor vacuum. A very small leak may cause a very perceptible fall in vacuum. If the condenser is tight and the air pump in good condition a vacuum of 26 inches should be maintained even in hot weather.

The corrosion of tubes is guarded against by fitting zincs in the water chests. These zincs should be frequently examined and their proper connections made. The exterior of condensers should be kept clean and dry, and the rusting of the lower parts of lagging prevented.

Portions of water chests showing signs of corrosion may be preserved by coating with a light wash of cement. This is especially advisable around bolts or joints.

Air Pumps. — Air pumps are either attached or independent. With the independent air pumps the steam cylinders and reciprocating parts require the ordinary attention of such mechanical details. The detail of valve gear varies with the different styles of pumps.

The water end of air pumps is similar in most all cases and similar troubles are experienced. The principal points of overhaul are the following:

Cleaning and Repairing Valves. — The latest practice is to use a treble set of manganese-bronze discs kept in place by a guard and spring. In older pumps rubber valves are sometimes used. The valves and the seats become coated with grease from the oil carried over in the steam, and these must be cleaned frequently. Springs sometimes break and guards come loose.

The springs on foot valves should not be set up too tight, as the pressure necessary to lift the valves limits the possible vacuum. On the other hand, the spring must be tight enough to cause the valve to seat properly. The pressure on spring should not be over one pound per square inch on foot and bucket valves, but the pressure on the head-valve springs may be more. The valves should have sufficient lift so that the circumferential opening is equal to the clear opening through the valve seat; as this is usually about 70 per cent of opening the lift should be equal to .17 of the diameter, or roughly about $\frac{1}{4}$ the diameter of opening.

The buckets of air pumps are sometimes packed with bronze rings, but usually they only have grooves on the circumference. Plungers are usually packed with braided flax packing.

The presence of dirt, grit or pieces of metal in the pump chamber must be carefully guarded against and the formation of burrs or sharp edges prevented. Air-pump cylinders receive a natural lubrication from the oil which is always present to a more or less extent in the feed water.

The plunger rod must be kept tightly packed, and its packing frequently examined. Square flax packing is generally used here. Scoring or cutting of plunger rod must be carefully guarded against. Rods after considerable use may wear elliptical or become tapered. In these cases the gland cannot be kept tight properly, and it will be necessary to turn rod in a lathe till a true cylindrical surface is obtained.

Difficulties Experienced with Pumps.*— The difficulties experienced with pumps are in most cases either in the water end or in the valve gear.

The following points will be taken up in connection with the water end:

Packing. — The proper operation of all pressure pumps depends in a very large measure on the packing of the plunger. For the packing of the plunger many different kinds of packing are used, but a thoroughly satisfactory packing for plungers seems hard to find, especially for high-pressure pumps.

Soft Packing. — The two principal kinds are square-braided flax and square cotton tucks hydraulic. Both these packings should be well treated with some lubricant to prevent excessive friction wearing the pump barrel.

The plunger must not be packed too tight, to prevent excessive friction. Cotton packing should be put on slightly loose, since it swells slightly when moistened. Cotton packing should be soaked in oil and coated with graphite before being put on.

Hard Vegetable Packing. — These are made from preparations of rubber and paper, and lignum-vitæ rings are also used.

Lignum-vitæ rings set out by springs in the packing now required by U. S. Navy machinery specifications for the low-service pumps, such as bilge and distiller circulating pumps. These rings give fairly good satisfaction.

* Some matters previously treated under the operation of pumps will be repeated here.

Rings made of rubber or paper do not cause as much friction as the lignum-vitæ.

Metal Packing. — Brass spring rings were used for feed pumps some years ago. They were not satisfactory, chiefly on account of the wear they brought upon the pump cylinders.

Packing rings of special white metal are sometimes used. These make a tight fit and do not wear the surface of the pump barrel as much as the brass rings do.

Outside Packed-Plunger Pumps. — In order to avoid packing troubles, outside-packed plunger pumps have lately been introduced for feed pumps. With these pumps the packing is put in a gland from the outside, and braided flax packing is used. The outside-packed plunger pump is considerably heavier than the ordinary pump, and if not well cared for there is danger of having considerable leakage at the glands. Special care must be taken to keep gland free from dirt and grit which would cause the plunger to become scored.

Wear on Pump Barrel. — When pump barrel has worn so that the surface is no longer cylindrical leakage will take place around the plunger. If this is badly worn, reboring is necessary. Pumps are usually supplied with a removable liner. To facilitate reboring portable boring bars are provided on some vessels, by means of which the pump barrel may be bored in place.

The stuffing boxes of both steam and water ends of pumps should be kept well packed. In pumps pumping fresh salt water, such as auxiliary, circulating, flushing, and distiller-circulating pumps, the water-piston rod should receive lubrication.

Valve Gear. — Considerable trouble is experienced with the valve gear. In general this is caused by neglect and bad treatment.

As a rule it is the secondary valve, which controls the operation of the main valve, that becomes stuck or fails to operate properly.

A few general rules as to the care of these parts may be given:

1. Remove valve gear frequently and clean off all parts and apply a little kerosene and graphite; the graphite to lubricate the parts and the kerosene to prevent rusting.

2. Do not keep pump standing for any length of time without moving valve, as it may become rusted in place due to moisture which is generally present.

3. Do not keep drains open when not in operation. This allows access of air and will start rusting.

4. Do not supply cylinder oil to the valve while in operation, since this oil is liable to cake and cause the valve to stick.

5. Keep pump in continuous operation as much as possible. This applies especially to feed pumps, which, if kept going continuously, give little trouble, but do not work well when intermittently stopped and started.

The chief trouble experienced is caused by rings of rust or burrs being formed on the moving parts. The best way to remove these is to take off valve gear and clean it. The packing of the valve stem sometimes affects the operation of the valve. If the stem is too tightly packed the stem may not work readily and prevent proper action. If too loosely packed the valve stem may drop of its own weight before it should, and thus cause trouble.

The distance nuts on valve stem which regulate the length of stroke may be improperly set. These should be adjusted to give the proper length of stroke.

The cushioning valves may not be properly adjusted.

A detailed description of each style of valve gear will not here be given, owing to the great number of types met with. By application to the pump manufacturers a detailed description and rules for care, operation and adjustment can be obtained.

Valves for Pumps. — Feed pumps use bronze valves with springs and guards. These springs often break and the nuts holding the guards come loose. In overhauling the pump special care must be taken to see these parts properly secured by split pins and that the springs are set up to a proper tension.

The valve seats are in many cases removable and can be taken out and refaced when they become rough. The valves should always have a smooth bearing surface, and in overhauling the tightness of these valves should be tested.

Bilge pumps have rubber valves. In time these valves become soft and start to decompose, caused by the action of the oil. They may be turned and trimmed; but in most cases when they become soft it is better to fit new valves.

Location of Air Chamber. — The air chamber has a great effect upon the smooth working of the pump, but its efficiency depends very largely upon its proper location. The air chamber should be located so that the opening to air chamber is directly opposite to the direction of the flow of water. If it is at right angles to the direction of flow it is of very little use. Air chambers should be fitted to both suction and discharge sides of pump. Air chambers are specially needed on high-pressure pumps.

PART III

FITTINGS AND AUXILIARIES

CHAPTER XI

Joints and Packing — Classes of Joints — Copper Gaskets — Joints in Metal Fittings — Leaks in Joints — Making Joints.

Joints and Packing. — Joints may be divided into two general classes: (1) Fixed joints like the joint between two flanges; (2) Sliding joints like those of a stuffing box.

For fixed joints a great variety of packings are used, the difference depending upon the pressure, the temperature and the nature of the contained fluid.

For high pressure strength is required, and hence packing for such purposes must be well strengthened.

For high temperature there must be material that will stand the continued action of heat.

For steam joints packing made of asbestos strengthened by being woven into cloth, or with an insertion of copper wire, is used. Asbestos is impervious to heat, but is softened by water; hence in steam joints where there is little likelihood of water being present asbestos sheet packing will answer well.

For steam joints where there is a likelihood of water a strengthened rubber packing should be used.

For water joints rubber packing should be used; for low pressure ordinary sheet rubber will answer; for high pressure cloth or wire insertion packing should be used.

Metal gaskets made of corrugated sheet copper are used for high-pressure flanges. The copper is pressed in tightly between the flanges and makes a metal-to-metal joint which, if it is properly made, will last long and remain tight. With this packing it is especially necessary that the flanges come square to each other and that the bolts are closely spaced and properly set upon all around.

Method of Making a Corrugated Copper Gasket. — The copper sheet is cut to approximate size of gasket; it is then corrugated, usually by being pressed between two heavy cast-iron formers. After being corrugated the gasket must be annealed, because the operation of corrugating it hardens the metal. The gasket is annealed by being slowly heated to a cherry-red heat and then cooled in water.

A thin coat of red lead should be placed on both sides of gasket, but it is wrong to put on a thick paste that will fill up all the corrugations, thus destroying the expansive properties of the gasket.

Wire gauze and red-lead putty, made of red lead, linseed oil and small pieces of hemp, is also used on large steam joints. The wire is flattened out and gives strength to the gasket, while the putty fills up all the vacant spaces between the wires.

Sheet lead is also used for making steam joints, but it is doubtful whether this is good for high temperatures.

A tight water joint can be made by simply using a coat of red lead and oil. Such a joint is not easily broken and has no elasticity and therefore may be caused to leak by vibrations.

Rubber has a tendency to grow hard and brittle under the action of heat; hence for high temperatures rubber packing is treated by special processes, and other material is added to avoid this tendency to break up. The special advantage of the rubber for packing purposes is its elasticity.

For steam joints the latest practice is to use copper corrugated gaskets for permanent work for high pressure. Strengthened rubber packing is used for small joints which have their flanges less carefully fitted and are more subject to vibrations. Strengthened asbestos packing is used for dry joints liable to be broken frequently, such as cylinder bonnets.

For high-pressure hot-water joints copper gaskets or wire gauze and red-lead putty are good; high-pressure rubber packing is also largely used.

For low-pressure steam a great many materials will answer, such as plain asbestos sheet, rubber with cloth insertion, or plain sheet rubber.

For high-pressure hydraulic joints leather is used, but this is not good for hot water. For hot water rubber insertion or copper gaskets are used. Low-pressure cold-water joints are made with plain rubber or rubber with cloth insertion, also canvas painted with red lead and linseed oil. The latter is largely used for hull fittings.

Low-pressure hot-water joints are made with rubber, either plain or with cloth insertion.

For high-pressure pneumatic joints leather or paper is used.

Joints in Metal Fittings. — Bolt heads are made tight by putting a hemp grommet coated with red lead under them.

Threaded-pipe joints are made tight by coating the threads with red lead or white lead. Nuts are made tight on bolts in the same way. Red and white lead, however, cause the joint to freeze, so for threaded joints that may require removal graphite grease is used.

Tube joints in the headers of Niclausse boilers are made tight by using a special form of grease.

Where a permanent tight joint is desired preparations of metallic cement such as Smooth On are of great value, especially for filling up cracks in metal or for tightening up on riveted or bolted joints.

Leaks in Joints. — If a joint is well made, and the pipe kept under the same state of pressure all the time, it should last for many years; but joints that are intermittently hot and cold, moist and dry, will cause the packing to dry out, crack and rot. If the pipe is cold the metal contracts, and if in a dry place the packing dries out and shrinks. If it is a steam joint, when steam is turned on, the joint will not be tight and the steam will work around the packing. If the packing is rotten or cracked portions of it may blow out. If the gasket is good it will swell by being moistened, and, after a time, will fill the joint tightly. Many joints that leak when water is present become tight as soon as the water is drawn off and the steam instead of the water comes in contact.

To Make a Joint. — The following conditions govern the making of a tight joint:

1. The flanges should come square to each other and be perfectly in line. The bolts must fit the bolt holes tightly and be exactly in line. If the flanges are not square to each other they will be open at some point of the circumference, and when the bolts are set up the flange will remain open or else be sprung; in either case the gasket will not be held tight and is in danger of being blown out.

2. There must be sufficient surface inside the bolt holes to enable a good bearing surface for the packing to be obtained.

3. The bolt holes must be sufficiently close so that packing is held securely all around. The greater the pressure the closer must the bolts be spaced.

4. The surface of the flange should be smoothly faced and, if not male and female, should be grooved.

5. For high-pressure steam joints male and female flanges should be used to prevent the gasket blowing out.

6. The gasket must be properly cut and fitted. The gasket is cut by laying it over the flange, marking the holes, either with a scribe or by striking the packing over bolt hole with the ball of a hammer, and then cutting out the holes and shaping the gasket to fit the flange. Special knives and gasket cutters are often provided. Dies are supplied to cut the holes accurately. The holes should be cut slightly large so that the gasket can accommodate itself to the flange, and any bulging between bolts may be avoided. Care should be taken to see that the joint is not blanked off by omitting to cut out center hole. Precaution must be taken to see that the part of gasket in Fig. 23 abreast the bolt holes is not too thin or cut in any way. If there is not sufficient packing here the joint will leak at bolt.

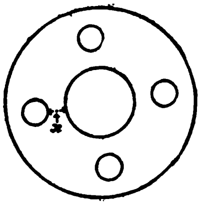


FIG. 23.

Gaskets should always be coated with graphite and tallow on one side to facilitate the breaking of joint. The coating should be on the side of the removable part so that gasket will stick to the other. The joint may then be removed several times without renewing gasket. In order to hold the gasket to the other flange red lead or white lead is often used on the other side.

As a rule with high-pressure joints, the thinner the gasket the better the joint. However, where the flanges are not square to each other or well faced a thick gasket will be tight where a thin one would leak.

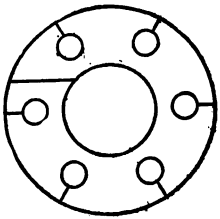


FIG. 24.

To Fit a Gasket where there is Strain on the Bolts and where the Cover or Bonnet cannot be Removed. — This may happen in the case of a stop-valve bonnet supporting the yoke which holds the valve stem. Suppose valve must be kept closed and the joint packed.

The nuts are slacked back gradually, but the valve kept down on its seat by turning handle as nuts are slacked. Sufficient space being obtained, the old gasket is torn out and a new one cut, as shown in

Fig. 24 (published in "Marine Engineering"), is worked around in place. The nuts are set up, the valve stem being turned to allow this, and then the joint is packed. This method may also be used where to fit a gasket ordinarily would necessitate the removal of a great many parts, but where the flange might be backed off far enough to put the gasket in as above.

Joints without Gaskets. — Such joints are ground in and require careful adjustment and a mechanical fit. Some examples of these are in cocks and valves, some tube caps on boilers, and tubes and headers on some boilers (Niclausse). The tightness of these joints will depend especially on the accuracy with which they are fitted.

CHAPTER XII

Stuffing Boxes — General Features as to Care and Fitting of Metallic Packing — Fibrous Packing — Packings Best Suited for Various Purposes — Packing Glands.

Stuffing Boxes. — Stuffing boxes require constant care and attention, and they are one of the chief sources of steam leakage. The large stuffing boxes on main engines and on many of the auxiliaries are now packed with some form of metallic packing.

Stuffing box-packing must be designed to suit the character of the joint. We have, first, the almost rigid joint generally encountered in expansion joints in piping and in valve spindles; second, the plain reciprocating joint, as the stuffing boxes of direct-acting steam pumps; third, the reciprocating and somewhat vibrating joint encountered in piston rods and in valve stems not well guided; fourth, the rotary joint, as on shafts. For the first and second kinds the packing can be more rigid, and the rigid packing of male and female rings will answer well. For joints of the third kind a flexible packing, in which there is some provision for lateral motion and in which the packing does not guide the rod, should be provided.

The kinds of packings used are numerous. Cuts of two forms are shown: Garlock and United States. (Figs. 25 and 26.)

The details of these packings are constantly being changed, so no detailed description will be given here. By getting a catalogue from the manufacturers, detailed descriptions can be obtained which will be up to date.

A detailed description of the various parts and instructions for assembling United States packing is reprinted from a circular issued by the manufacturers.

Instructions for Applying U. S. Metallic Packings. — Ball rings and flat faces of vibrating cups are ground together and plainly marked to show where they belong. The two faces bearing the same number should be put together. Vibrating cup and ball ring having same number as stamped on ball seat should be used in inner set. Vibrating cup and ball ring having same number as stamped on gland should be used in outer set. A little care in placing them as marked will save trouble later. See that all joints are well cleaned

FIG. 25. — United States Metallic Packing. Names of parts: 1, Preventer; 2, Spring Guard; 3, Spring Bushing; 4, Springs; 5, Follower; 6, Vibrating Cup; 7, Ball Ring; 8, Ball Seat; 9, Gland; 10, Babbitt Metal Rings.

and have no burrs on them. After placing piston rod in cylinder, apply in the following order:

Order of Application. — First, preventer, number 1. Second, spring guard, number 2, with flange against preventer number 1.

Third, spring bushing, number 3, with spring holes opening toward cylinder. *Fourth, springs, number 4 placing one spring in each pocket. Fifth, follower, number 5. Sixth, vibrating cup, number 6, with flat face toward crosshead, leaving out babbitt metal rings. (Babbitt metal rings, number 10, to be applied after all parts are placed on rod and rod placed in crosshead.) Seventh, ball ring,

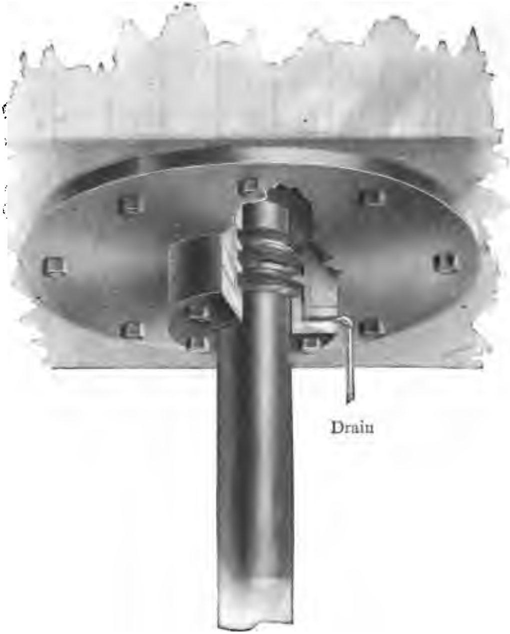


FIG. 26. — Pitt Marine Metal Packing, Garlock Packing Co.

number 7, according to the mark found on it with its flat face against the flat face of vibrating cup of number 6. Eighth, the ball seat or dividing ring, number 8. Ninth, spring guard, number 2. Tenth, spring bushing, number 3. *Eleventh, springs, number 4. Twelfth,

* If desired the springs can be left out until all other parts (except the babbitt metal rings) are in place on the rod. They can be applied just before putting the babbitt metal rings in place. This shortens the time before the rod can be replaced in crosshead and may be better in some cases than inserting springs in order as given in this table.

follower, number 5. Thirteenth, vibrating cup, number 6, according to its mark with flat face toward crosshead, leaving out babbitt metal rings. Fourteenth, ball ring, number 7, with flat face against flat face of vibrating cup, number 6. Fifteenth, gland, number 9.

Now place the piston rod in crosshead, which brings the rod to a central position, and proceed to put in the inner set of babbitt metal rings, taking care to place them so that the joints or openings are well broken. Now see that springs are in proper place in holes in spring bushing, and slip the follower, packing rings, and vibrating cup as far in as possible. Then apply second set of rings in same order. In pulling up the gland, owing to the springs, it is often necessary to use a bar (wood) behind the gland. If the bar should slip and the gland fly back from spring pressure, examine the packing rings before pulling up, as no doubt they will become disarranged by gland flying back. A hole for one-quarter inch pipe plug is drilled in the gland for the purpose of draining the gland when necessary. This hole must always be placed in the lowest position. A small amount of care when applying packings saves a wonderful amount of trouble and worry. *Packings must be applied as above in all cases.*

Packings sometimes require a little time in actual service after first application before rings come down to a bearing on the rod and become tight. If, however, packings should continue to give trouble after a few weeks run, we would be glad to have you let us know. If you have not a blue print of the United States Packings under your charge, we would be glad to send you same upon request.

In ordering babbitt metal rings for renewal, please let us know the number stamped on the face of the packing gland and the exact diameter of the rod.

A general account of the conditions presented in stuffing-box packing is contained in Vol XV, No. 2, "Journal American Society of Naval Engineers."

General Features as to Care and Fitting. — In fitting packing special attention must be taken to see that the surfaces of the rings, especially faces and the walls of stuffing boxes, are perfectly clean and free from grit, that white-metal rings fit the rod exactly, and that the brass distance rings do not touch the rod. If fine graphite is added to surfaces a general improvement in fit will be obtained. Triangular white-metal rings when first put in should have their joints stand open about $\frac{1}{16}$ inch; after a time the ends come together, and in this condition they are intended to wear.

The joint between the packing systems and the cylinder must be made securely and the nuts on the flange properly set up and secured. Care should be taken to see that there is the proper tension on springs when gland is set up in place. Distance rings, vibration cups, or plates, should fit the rod within one sixty-fourth of an inch.

Water is hard on packing, therefore care should be taken to keep the cylinder dry.

If the rod has a taper or a flat, it will be very hard to keep it tight. Such rods should be turned down true and have the packing refitted.

Some forms of metallic packing have rings of soft packing to reinforce them, but the best types of metallic packing do not require these rings of soft packing.

Metallic packing can be made on board ship and fitted into ordinary stuffing boxes when it is desired. Some points to be noted are that the brass rings should be used for distance rings, the white-metal rings to secure the joint on rod. The edges of brass rings should be beveled off to allow a lateral play. The rings should break joints; about $\frac{1}{16}$ inch clearance should be left between ends at first. At least two sets of white-metal rings should be used. In many cases a greater number than two is of doubtful value. The rings can be turned out in a lathe and then can be scraped to a fit. With these home-made sets, especially when no springs are used, a few turns of soft packing should be used to give some elasticity to the joint.

Metallic packings, when well fitted, and with rods kept properly lubricated, will run for years without requiring any attention. They should, however, be examined and cleaned about once a year; but when they are performing their work properly continual examination is bad, since removal will disturb the adjustment that the rings have worn themselves into.

To guard against danger of rust forming on the valve stems all stuffing boxes are required to be bushed with composition at their inner end. Such composition bushes can be fitted with little trouble, and their presence avoids one of the greatest causes for scoring rods and valve stems.

Fibrous Packing. — For auxiliaries which cannot always have the best attention the valve stems may become hot and scored and in time may have to be turned down; then metallic packing will not fit. For such places fibrous packing may be used.

The packing is made in round, square and triangular section, and of the same general material as sheet packing. They are in most cases mixed with some lubricant to reduce friction. Tallow and graphite are generally used. The packings generally have a rubber core to give them elasticity.

Packings Best Suited for Various Purposes. — The packing used should be selected so as to best meet the conditions under which it is to work. The principal points to consider in selecting the kind of packing are the temperature, the pressure, and whether the joint will be dry or wet.

H.P. Steam Rods. — Use strengthened asbestos, with or without rubber core, made in straight lengths or in spiral coils, either in square or round section. Some kinds most largely used at present are Crandall's, Garlock, Peerless, Eureka, Selden's. For large stuffing boxes packing strengthened with brass wire is sometimes used.

L.P. Valve Stems. — Same kind as above, except that it is made softer. Most manufacturers furnish two kinds, one for high pressure and one for low pressure. Canvas packing, such as Tuck's, consisting of a rubber core and canvas wrapped around it, is also used.

Steam Valve Stems. — For valve stems that are generally dry, use braided asbestos rope or light strengthened asbestos packing. Valve stems that are up and vertical will be dry, those that are down will generally be wet. For the latter it will be better to use Tuck's or other canvas packing that the water will not disintegrate. Boiling canvas packing in oil improves its ability to withstand heat. For water-valve stems or rods on L.P. auxiliaries or in exhaust line where water collects, use canvas packing such as Tuck's; for small work, braided flax or cotton tape.

Pump Rods and Plungers. — These rods are of brass, and hence the packing cannot be very hard, as there is danger of wear on rods. Square-braided flax packing of size to fit glands should here be used. Flax packing should generally be used with water and composition rods. It is used for packing a stern gland. Rubbing packing with graphite and tallow lessens friction and adds to tightness.

Pump Pistons. — Considerable difficulty has been experienced in finding a thoroughly satisfactory packing for low-pressure pumps. A packing that will last a long time is desired. Square-braided flax or square canvas (hydraulic Tuck's), also flax braided over rubber core (hydraulic Rainbow), are used. Care must be taken with canvas packing that it is not too tight, since it swells when wet and may cause the pump plunger to stick. Flax packing does not swell much when wet. In cotton packing the rubbing action should be on end of thread; care should be taken that it is put in in this way. The latest practice in the Navy is to use lignum-vitæ rings for packing plungers of low-pressure pumps.

For high-pressure plungers ebonite, lignum-vitæ, woodite and other vegetable preparations are used. Some special forms of woodite and paper packings give a good degree of satisfaction. Brass and white-metal rings are also used.

Condenser Tubes. — Cotton tape (corset lacing) is most commonly used; rubber washers and wooden discs are also used. In case of necessity strings of flax packing can be used.

Heavy Hydraulic Work. — For heavy-pressure plungers cup leather or sheet rubber is used. On rams, stuffing boxes are packed with square flax packing.

Packing Glands. — The gland is packed by placing successive turns of packing in the space around the rod or valve stem. Where spiral or string packing is used it is simply coiled around the rods, the ends being beveled off to make a smooth seating for the bottom of gland, which is then put on and set up with bolts and nuts. In this way there are no joints in the packing, and hence less likelihood of leakage. Where successive rings are used, the ends of rings should be cut so as to make a bevel joint, and placed in the stuffing box so that the pressure tends to close the joint and not to open it. The different rings should break joints. The rings are put in place by packing sticks, and care should be taken that the packing is not split in putting it in. Sketches of proper and improper ways of cutting rings of packing are shown in Fig. 27.

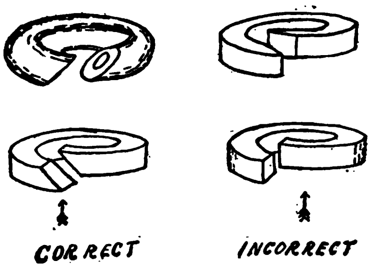


FIG. 27.

The packing is held in place by the stuffing-box gland and by setting up on the gland nuts or by screwing down on gland where screwed glands are fitted, and the packing is forced tightly against the rod. Care should be taken that the nuts are set up alike on all sides, and that the packing is not too tight, for by excessive friction the rod may become hot. On large stuffing boxes gearing is often fitted so that all nuts are moved together. The rod, gland and packing must all be thoroughly cleaned. Pieces of grit are very likely to drop in and later cause the rod to be cut.

Where turns of ordinary soft packing are used, either with or without metal rings, it is not always necessary to pull out all of the packing. One or two turns will in many cases be sufficient to stop a leak. After packing has been in a long time and shows signs of rotting or breaking up, it should be taken out and all renewed. For removing packing from stuffing boxes, packing hooks with gimlet or sharp nib ends are used.

Leaks in stuffing boxes under pressure show themselves by the issue of steam or water, but those under a vacuum will not be indicated in this manner. It is important that the low-pressure stuffing boxes and those in the exhaust piping be tight, since air is being drawn in and the vacuum thus affected. Putting a slight pressure on the exhaust line once in a while will give indications of any leaks.

CHAPTER XIII

Lagging and Clothing — Requirements of the Machinery Specifications — Lagging Materials — Care of Lagging — Necessity for Lagging.

Lagging. — Lagging is a term applied to the non-conducting covering placed on metal services to prevent the radiation of heat.

In the machinery specifications issued by the Bureau of Steam Engineering a distinction is made. The non-conducting material is called the clothing, and the casing for protecting and securing this clothing in place is called lagging.

All steam and exhaust pipes and hot-water pipes are clothed and lagged to prevent the radiation of heat. Cold-water pipes are lagged to prevent sweating. Sometimes cork paint is used for this purpose. Refrigerator pipes outside of cooling chamber are heavily clothed to prevent the absorption of heat from surrounding spaces.

The purpose of clothing and lagging is twofold: (1) to save the heat contained in the steam or water, and (2) to prevent the heating of the machinery compartment.

The following are the requirements of the machinery specifications issued by the Bureau of Steam Engineering, Navy Department:

"CLOTHING AND LAGGING"

There will be clothing and lagging on pipes, boilers and machinery as follows:

MACHINERY	COVERING	LAGGING
Main cylinders and valve chests, after being finally secured in place in the vessel, and tested.	Magnesia	Neatly lagged all over with galvanized sheet iron.
Upper cylinder heads	Ditto	Neatly-fitting iron floor plates, with flat-topped corrugations.
Steam cylinders of all auxiliary engines in engine rooms and boiler rooms	Ditto	

MACHINERY	COVERING	LAGGING
All steam and exhaust pipes, valves and their flanges, separators, feed-water heaters, and all feed, suction and discharge pipes and valves.	In an improved manner, with sectional magnesia covering. When near magazines, steam and exhaust pipes will have a double thickness.	Galvanized sheet iron. Canvas sewed on and well painted.
Main and auxiliary steam and exhaust pipes and valves and their flanges, in engine rooms, boiler rooms, and dynamo room, evaporators, feed-water heaters, main separators, etc., as may be required.	Ditto	Canvas sewed on and well painted and lagged with galvanized sheet iron.
All parts of main, auxiliary and dynamo condensers except water chests at ends.	Ditto	Galvanized sheet iron.
Feed and filter tanks where accessible.	Ditto	Ditto
Heating pipes, from auxiliary steam pipes to radiators or coils, and from radiators or coils to traps.	Heavily clothed, except in compartments that they are required to heat.	
Boiler drums; other exposed parts of boilers, if required.	Magnesia, 2½ inches thick.	Ditto
Other pipes and machinery, as may be directed	As directed........	As directed.

"Lagging will be made removable over all valve-chest covers, manhole covers, etc., and elsewhere will be so secured as to be easily removed, replaced and repaired, and all pieces will be plainly marked to show where they belong.

"All canvas pipe covering to be of approved quality, and in accordance with the 'Specifications for Cotton Canvas,' issued by the Bureau of Equipment. The canvas covering will be secured to bulkheads where the pipes pass through them. All galvanized sheet-iron lagging will be secured with polished brass bands and round-headed brass screws.

"MAGNESIA

"Magnesia used for clothing, lagging and in uptakes, smoke pipes, etc., will be composed as follows:

Carbonate of magnesia ....85 per cent
Asbestos fiber ....15 per cent

Canvas covering will be as follows:

	RAVEN'S CANVAS
Pipes, 2 inches diameter and below	8 oz. per yard
Pipes above 2 inches diameter, separators, feed heaters, etc.	15 oz. per yard"

Lagging Materials. — The principal materials used are cow-hair felt, asbestos and magnesia. Felt is preferred where there is liable to be moisture. It also is generally used on cooling pipes. It is objectionable on high-pressure steam pipes on account of being inflammable.

Asbestos is used in the form of a cement and also in sheets and boards. It is used in combination with magnesia. Asbestos will not burn, and hence can be used for any degree of temperature. It will, however, soften with the application of water, and hence is not desirable where parts are subject to moisture, such as feed tanks, pipes under floor plates or cold-water pipes.

Magnesia is used as a cement or in sheets or blocks. It is more generally used than any other material. Its non-conducting powers are very good. For pipe covering magnesia in combination with asbestos is put on in the form of cement or as sectional magnesia covering formed in the shape of cylinders.

For lagging, canvas, galvanized sheet steel and Russia iron are used.

Canvas is used for pipes except the very largest ones in engine rooms. Russia iron is used for large steam pipes in engine rooms and for steam cylinders of main engines and auxiliaries; sometimes also for evaporators, feed tanks, feed heaters and condensers. It makes a very good appearance but is somewhat costly and liable to rust. Galvanized iron is used for large steam pipes, boiler drums and casing, shells of evaporators, condensers, feed tanks, etc., and for steam cylinders of main and auxiliary engines. The latest practice is to use it to the exclusion of Russia iron or wood. It is cheaper and more durable than Russia iron and more durable than wood, and will not burn. Wood, teak and walnut are still largely used, especially for condensers, feed heaters, feed tanks and cooling coils for ice machines. Wood is objectionable on account of being inflammable, and cannot be as readily taken down and replaced, is easily damaged and hard to keep clean. It is not used on the latest vessels.

Refrigerating chambers have their bulkheads lagged with charcoal; magazines are also sometimes lagged in this way to prevent their being heated.

Care of Lagging. — Lagging requires no special care except to keep galvanized or Russia iron from rusting and prevent it being damaged or cut. Whenever lagging is removed for purposes of overhaul special care should be taken to see that it is properly replaced. Russia iron can be cleaned with alcohol or turpentine. Galvanized iron can be painted, or can be kept bare and washed when it becomes dirty. Wood lagging can be brightened up by rubbing with a mixture of turpentine and linseed oil.

Necessity for Lagging. — Lagging is a means for securing economy by preventing the radiation of heat. All possible heated surfaces should be securely lagged. The flanges of steam pipes should be covered with lagging, and even the flanges of cylinder bonnets. A great many places left bare by the builders can be lagged by the force on board, and a considerable increase in economy and comfort can be obtained.

RELATIVE NON-CONDUCTIVITY OF MATERIALS (HASWELL)

	PER CENT		PER CENT
Hair felt	100.0	Pine wood	55.3
Mineral wool, No. 2*	83.2	Loam	55.0
and tar	71.5	Lime, slacked	48.0
Sawdust	68.0	Asbestos	36.3
Mineral wool, No. 1	67.5	Coal-ashes	34.5
Charcoal	63.2	Air space, 2 inches	13.6

EXPERIMENTS MADE BY BUREAU OF STEAM ENGINEERING — COMPARATIVE RESULTS

Felt (as standard)	100.0
Sectional magnesia	103.07
Sawdust	90.3

* Sometimes called silicate cotton.

CHAPTER XIV

Feed and Filter Tanks — Filtering Material — Grease Extractors.

Feed and Filter Tanks. — The water from the air pump discharges into the feed and filter tank. The tanks are often placed under the condenser, and one is fitted in each engine room.

The capacity for large vessels is sufficient for about ten to fifteen minutes' running at full boiler power. For torpedo craft and scout vessels the tanks have less capacity than this.

The tank is divided into two parts, the filter tank and the feed tank proper. The filter tank is about one sixth the capacity of the feed tank. The filter tank is usually a portion of the upper part of the feed tank. The usual construction can be seen from sketch. (Fig. 28.)

The filter tank is arranged so that the air-pump discharge opens into tank at one end and the water flows through the filtering material as indicated by the arrows and then to the feed tank proper.

The top of the filter tank has a hinged or bolted cover over each chamber to enable the filtering material to be removed and the tank cleaned.

Feed tanks are fitted with an overflow pipe with spring relief valve from the top of feed tank to bilge, arranged so that water passing down may be seen; a water gage with suitable shut-off cocks; a man-hole for examination; a drain cock; a thermometer.

The feed tank and each chamber of the filter tank are connected into a vapor pipe which leads to the atmosphere, usually by means of the after escape pipe of the boilers. The bottom of each chamber of the filter tank has a drain with pipe leading to feed tank. The two feed tanks are connected by means of a pipe which has a valve at each tank and one at center-line bulkhead. The feed-pump suctions usually branch off from this pipe. The opening to the feed-tank connection pipe is controlled by a balanced valve operated by a copper float in the tank. The object of this is to cause the

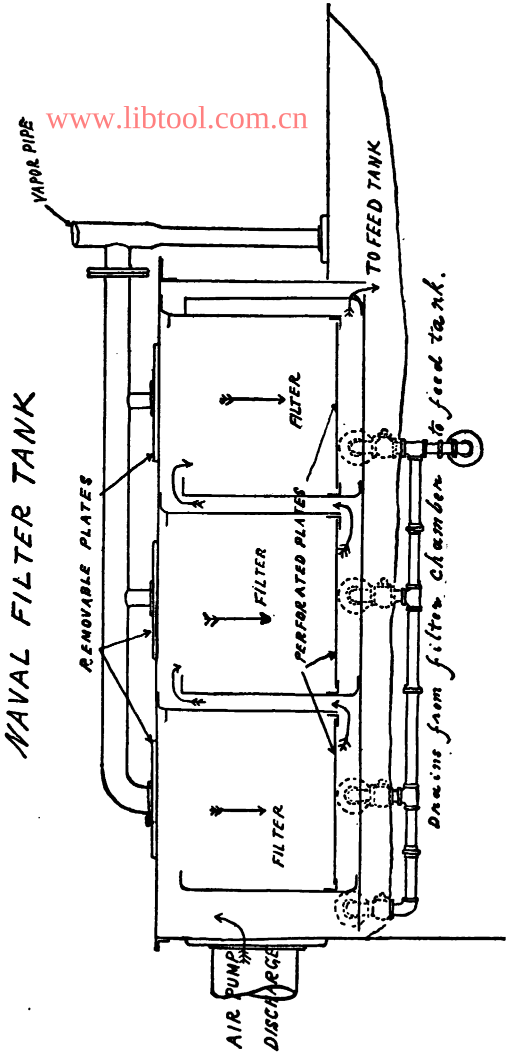

NAVAL FILTER TANK
VAPOR PIPE
TO FEED TANK
REMOVABLE PLATES
FILTER
FILTER
FILTER
PERFORATED PLATES
Drains from filter chamber to feed tank.
AIR PUMP DISCHARGE

FIG. 28.

valve to close when the tank is nearly empty and thus prevent the feed pump from sucking air. The valve and float are so arranged that they may be worked by a lever from outside the tank. To prevent rusting, the fulcrum of the lever is bushed with composition.

The filter tanks are provided with openings to take the discharge from the main and auxiliary air pumps, dynamo, and the drains from all the various traps leading from steam lines, separator, jackets, evaporators, heaters, etc. All these should discharge into the filter tank, and not into feed tank, in order that the water may be filtered. The drains should discharge near the bottom of the filter tank so that the discharge may be covered and avoid the blowing of steam into the tank.

Feed tanks are built of class "C," galvanized steel, boiler plate, for large vessels not less than $\frac{1}{4}$ inch thick. Feed tanks are lagged with cowhair felt $\frac{3}{4}$ inch thick, in sections to be easily removed and replaced.

Filtering Material. — Filtering material is of different kinds. Hay and excelsior are used, but are objectionable on account of dirt in renewing the material. Coke put up in bags of burlap or heavy toweling is fairly satisfactory, and as this can be made on board ship it requires no special stowage. When the filtering material is renewed the greasy coke is burned and the bags washed with soda, refilled with new coke and replaced.

The best filtering material at present is the loofa sponge. These sponges are shaped like gourds and readily absorb the oil. They can be removed and boiled out and replaced several times. They may be either packed loosely in the filter chamber or placed in bags.

A special machine for cleaning filtering material has been installed on some recent vessels (Waste-oil Saving Machine). The machine consists of a chamber containing a brass cage into which the filtering material is placed. By turning on steam this cage is caused to revolve rapidly and the oil is thrown out by centrifugal action and is drawn off from the bottom of the chamber.

Filter tanks should be cleaned out and have filtering material renewed after every three weeks' use. If oil is carried to the boilers cleaning should be more frequent. The feed tank proper should occasionally be cleaned out and washed out with soda water. Zincs are placed in the feed tank, and these should be examined and renewed from time to time.

The prevention of oil entering the boilers is a most important matter, and every means possible should be taken to secure this end. In addition to the feed and filter tanks grease extractors are fitted generally on the discharge side of the feed pumps. In order that these may be efficient they should be frequently cleaned. The following instructions on the subjects are issued by The Bureau of Steam Engineering:

"FILTERING MATERIAL FOR FILTER TANKS

"Coke put up in bags of coarse toweling, burlap, or blanket material give good results, though the coke disintegrates in time and gets into the feed pumps. With good, strong bags and frequent renewal this trouble is largely obviated.

"Excelsior sewed up in bags of material similar to the above may also be used.

"Loofa, the vegetable filtering material, is in high favor with several engineers. It may be put in the filter tank loose or in bags to suit special occasions.

"Marine sponges should never be used as they rapidly disintegrate, are efficient for only a very short time, and are very expensive.

"Considerable improvement can undoubtedly be made in the filter tanks at present in use with regard to efficiency and facility for overhauling, cleaning, and renewing material.

"Special care should be exercised that the filter chambers of tanks are easily accessible, and, when possible, the cover should be fitted with hinged bolts to facilitate removal.

"It is important that filter tanks should be cleansed frequently and the filtering material renewed when necessary; once a month will probably be found often enough under ordinary service conditions.

"Drain pipes of every description should discharge into the filter tank, in order that all water taken from the feed tanks by the pumps will have been filtered."

Grease Extractors. — The following is from a circular recently issued by the Bureau of Steam Engineering:

"Grease extractors, in addition to the separate filter tank, are in general to be fitted on all vessels building and on vessels undergoing general overhauling, where circumstances make it desirable and where suitable space and arrangement for their installation may be obtained.

"Grease extractors will be located, in general, on the discharge side of the main feed pump, between pump and feed heater, or in vessels where hot-well pumps are fitted, on the discharge side of hot-well pumps. The location must be such that all parts are accessible for overhauling and cleaning. Especial attention must be given to the details, so that bonnets and filter cartridges can be readily removed and the cartridge eased off its seat by mechanical means.

"Grease extractors will be of the cartridge type, similar in principle to those shown on Bureau Steam Engineering plans. They are to be fitted with by-pass valves.

"The cartridge should be lined with coarse, heavy toweling or linen filtering cloth, and suitable spare filter jackets will be supplied. The surface of filtering jackets should be as follows: Ratio of area of filter jacket to area of feed pipe, not less than thirty. The perforations of filter basket must be at least 50 per cent of its total area.

"Grease extractors will have a drain cock and a ½-inch steam connection for boiling out, a plug for introducing soda, and an air cock.

"Grease extractors should have their filtering material renewed at least once every two weeks, if found necessary, and more frequently if a considerable quantity of grease and oil collects. They should be drained of oil, by-passed, and blown out by steam daily while steaming and twice weekly when in port if necessary. Except when under repairs, they will be kept in continual use."

CHAPTER XV

Feed-Water Heaters — Kinds of Heaters — Open Heaters — Closed Heaters, Advantages and Disadvantages — Piping of Heaters — Position of Steam and Water Connections and Baffling — Details of Heaters — Difficulties Experienced with Heaters.

Feed-Water Heaters. — In all modern marine installations feed-water heaters are now used. The economy and increased efficiency of boiler plant resulting from their use is very great. By the efficient use of feed heaters the wastefulness of auxiliaries is reduced, and by supplying hot feed water to the boilers the wear and tear on them is minimized.

In the exhaust-steam feed heater the auxiliary exhaust steam is led to a vessel where it heats the feed water. The saving is obtained by causing the latent heat of the auxiliary exhaust steam to heat the feed water instead of allowing the circulating water of the condenser to take the heat away.

By increasing the pressure in the auxiliary exhaust pipe a higher temperature of feed can be obtained. But it must be remembered that the feed must necessarily be somewhat lower than the temperature of the steam used to heat it. To get 220 degrees temperature, a pressure of about five pounds above the atmosphere is necessary. An efficient heater will give the feed water a temperature within ten degrees of the temperature of the steam. On account of leakage in exhaust piping and the liability of getting water in the cylinders of the auxiliaries it is not advisable to use a greater pressure than ten pounds above atmosphere in the auxiliary exhaust pipe.

Kinds of Heaters. — Heaters may be open (jet) or closed (surface), according as the water and the steam are allowed to mix or not. The open heater is very simple and is also quite efficient. In the merchant service where a favorable high location for it can usually be obtained it is largely used.

Open Heater. — The open heater, a cut of which is shown, Fig. 29, acts like a jet condenser, all the auxiliary steam entering it being condensed by the cascade of feed water. This heater must necessarily be situated on the suction side of the feed pump, and in order to get a sufficient head to prevent the formation of vapor it

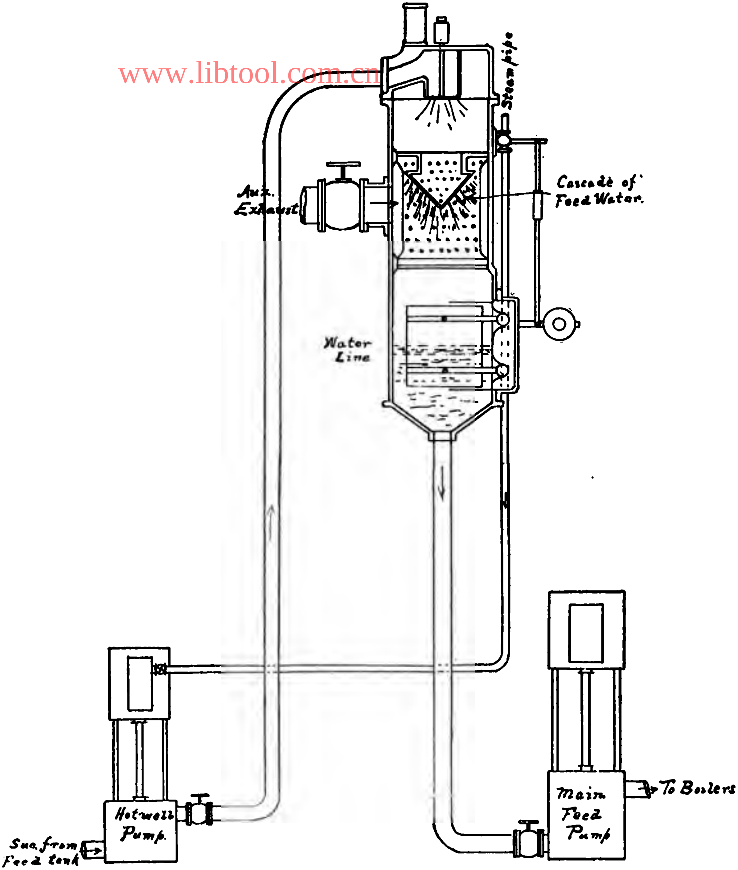


FIG. 29. — Open Feed Heater.

must be located well above the pump. It is on account of this necessity for having it up high that this type is not largely used on naval vessels. To pump the feed water from the hot-well or feed tank a low-duty hot-well pump is provided. The connections for pumping and the attachments are shown in cut. These heaters are

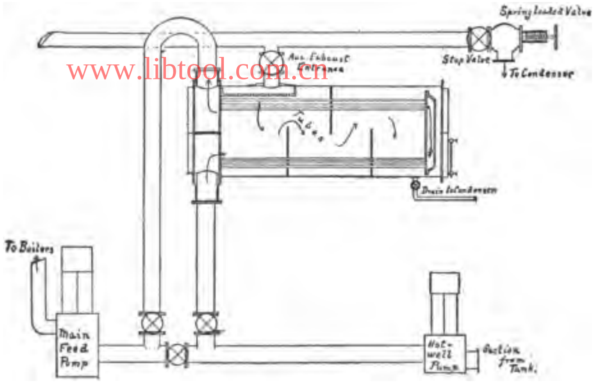


FIG. 30. — Closed Heater on Suction Side of Feed Pump.

usually fitted with an automatic float governor for governing the speed of the hot-well pump so that the water is kept at a nearly constant level in the heater.

With a jet heater the temperature of feed cannot be above about 180 degrees, as a higher temperature will cause vapor to form, and then the feed pump will not have a proper suction.

Closed Heaters. — For naval vessels heaters are generally of the closed-surface type, exhaust steam entering the shell outside of the tubes and feed water going through the tubes. They are either suction or pressure heaters, and both vertical and horizontal heaters are used. They are now installed in two general systems, one where the heater is on the suction and the other where it is on the discharge side of the feed pump. (Figs. 30 and 31.)

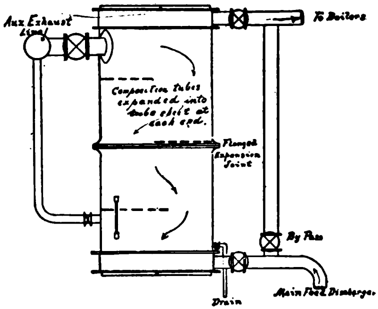


FIG. 31. — Closed Heater on Discharge Side of Feed Pump.

Advantages and Disadvantages. — With heater on the discharge side of pump, the feed when passing through the pump is not warm, hence there is no difficulty in suction due to vapor. No other pump beside the feed pump is needed, and the weight and cost of the hot-well pump is saved. The temperature can be maintained at a temperature very close to that of the exhaust steam, there being no limits due to heating of pump.

The disadvantages are: The parts of heater have to be made extra heavy to withstand the pressure. Owing to the high pressure used it is difficult to secure tight joints, and unless very good materials are used and good workmanship present, there is danger of gaskets blowing out.

With heater on suction side of pump the addition of a hot-well pump is necessary. This introduces another auxiliary to be cared for, and thus increases the work of attendance and makes the whole installation somewhat less reliable. The feed is hot while passing through the pump, consequently bringing harder conditions on the pump. With high temperature in the pump there is difficulty with packing, vapor forming in the pump and the parts of pump becoming heated so that they do not function well. The temperature of feed can probably not be as high as with the pressure type, owing to the fact that the heated water must go through the pump. On the other hand, everything about the heater being under low pressure, there is no great difficulty presented in making joints or parts strong enough.

Piping of Heaters. — The water piping of heater can be seen from the diagrams. For the heaters on the discharge side of feed pump the valves are arranged so that the water passes through the heater on its way to the boilers, there being valves so fitted that the feed can by-pass the heater. The heater can thus be cut out in case of accident or when being overhauled.

For the closed heater on suction side of pump: the hot-well pump, having a suction to the feed tank, pumps the water through the heater (or by suitable arrangement of valves can be by-passed), and to feed-pump suction. In this way the feed pump has a forced suction, and the liability of having vapor in the pump suction is overcome.

Steam Piping Connections. — The steam piping connections should be arranged so that all the auxiliary exhaust steam comes to the heater and that it is condensed there. Adjustable relief valves should be fitted at the connection of the auxiliary exhaust pipe to the condenser so that the pressure in the auxiliary exhaust can be regulated. Connections should be made so that the exhaust steam can, when desired, be passed through the heater on its way to the condenser.

As long as the desired pressure in the auxiliary exhaust line is not exceeded, all the exhaust steam will come to the feed heater. Here it will be condensed and give up its heat to the feed water. When the pressure at which the spring-loaded relief valve is set is exceeded this valve lifts and allows part of the exhaust to go to the condenser direct. The valve will remain lifted until the pressure in exhaust is again lowered sufficiently to allow the valve to seat.

Heaters often have but one connection to the exhaust pipe. If

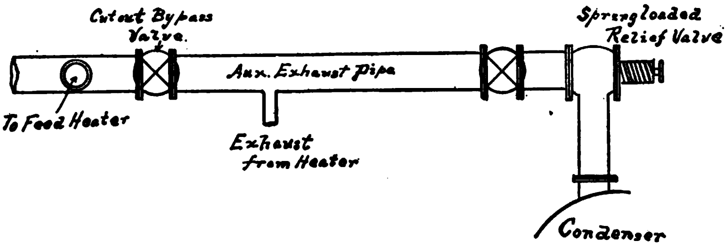


FIG. 32.

a second connection is fitted nearer to the condenser and a cut-out valve fitted between, part of the auxiliary exhaust steam can be passed through the heater on its way to the condenser. This latter may sometimes be desired in port. (Fig. 32.) This connection also insures that a portion of the auxiliary exhaust must pass through the heater, even if the valve on condenser is open, thus producing a positive flow of exhaust steam through heater and preventing heater from becoming air-bound on steam side. Heaters are fitted both with and without this second connection to auxiliary exhaust line. The connection adds somewhat to complication and is not essential to the operation of the heater.

Position of Steam and Water Connections, Baffling. — To secure the highest temperature of feed the heater must be arranged so that the hottest water strikes the hottest steam and that the change in temperature is gradual and continual in each. This can be accomplished by proper piping connections and baffling. In the straight-through-flow type the steam should enter at the opposite end from the water, and the steam should be made to flow across the tubes at right angles to them. The water should enter at the bottom of heater to ensure its always being full. Where a return-flow heater is used, baffling to secure these conditions may be arranged as in diagram. (Fig. 33.) From a glance at the diagrams (Figs. 34 and 33) it can be seen that the vertical direct-flow heater lends itself with greater facility to the above requirements. Other advantages of this type are, (1) less weight than the return-flow type, owing to smaller end castings, (2) simpler baffling. The horizontal-return type does not lend itself as well to proper requirements. In all horizontal types there is the liability of upper rows of tubes becoming filled with air. The horizontal types do, however, in many cases provide greater facility for removal of tubes.

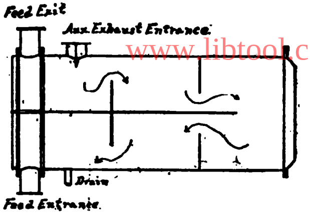


FIG. 33.—Return Flow Heater.

Details of Heaters. — Provision for the difference of expansion of shell and tubes should be made. This expansion is not so great as to require an elaborate expansion joint or gland-packed tubes. Provision for expansion may be made by (1) ends of tubes being packed like the tubes of a condenser; (2) providing for an expansion joint fitted with gland between tube nest and shell, similar to the expansion joint fitted on Bureau Steam Engineering standard distillers; (3) fitting shell with a flanged or corrugated expansion joint as in Fig. 31. This last is the simplest; there is no danger of leakage; it does not add much weight, and is easily made. The difference of expansion between shell and tubes is not likely to be very great. Expansion joints of this type, Fig. 31, have worked with great satisfaction for years.

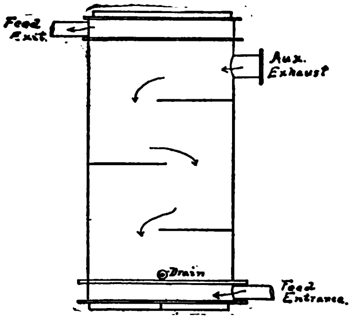


FIG. 34.—Vertical Direct-flow Heater.

Kinds of Tubes. — The tubes of pressure heaters must be made of good material and heavy enough to stand a test pressure of about three times the working pressure on heater. On most of the large vessels of the Navy the tubes of feed heater are of the same material and size as the condenser tubes. For pressure heaters composition tubes ⅝-inch diameter, 16 B.W.G., are largely used. For suction heaters a lighter gage tube is used. Steel tubes are also used, and, if fresh water is assured, their lasting qualities should be satisfactory. Steel tubes are very largely used for feed heaters on the Great Lakes. Spiral corrugated tubes are said to give greater efficiency than plain tubes. The spiral corrugations tend to retard the flow of water, and give it a spiral movement. A hand hole for the examination of the tubes should be put on the shell. A connection for cleaning tubes by boiling out with soda is also desirable. Heaters should be fitted with a compound-pressure gage on steam side, a glass water gage also air and drain cocks for both water and steam side.

Draining of Heater. — The size of drain should be about one tenth the area of the feed pipe discharging to the heater. Drains should be led direct to condenser or feed tank without intervening trap. Check valves may sometimes be desirable.

Difficulties Experienced with Heaters. — With vertical-pressure heaters the chief trouble has been with the joints leaking. If the flanges are made heavy and the bolts closely spaced this difficulty is overcome. Bolted flanges are better than those made with studs and nuts.

With horizontal-suction heaters difficulty has been experienced in not getting warm feed due to heater becoming air-bound or a too rapid flow through the tubes. This latter is in some cases remedied by fitting retarders in the tubes. If tubes are not made of good material or are too light they may break or split. There is, of course, more danger of this happening on pressure than on suction heaters.

From the results of present experience and knowledge, it would seem that the most efficient, reliable, simple and advantageous heater for naval purposes is the vertical, straight-through flow, pressure type. By it the highest temperature of feed can be obtained and the working of feed pump is not affected by the temperature.

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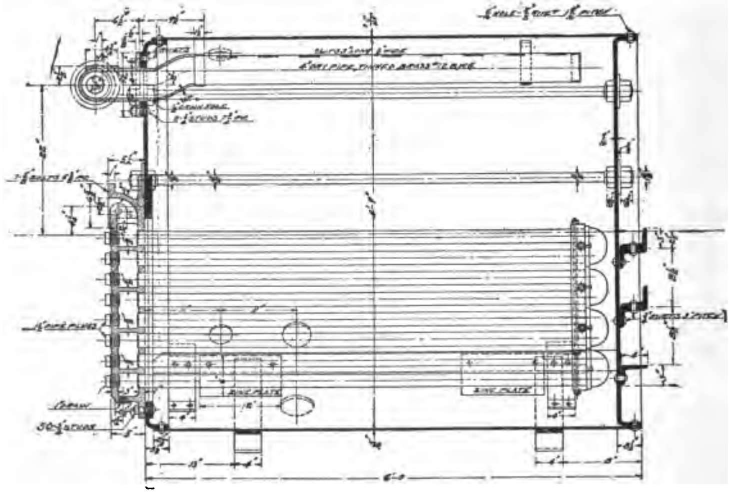
CHAPTER XVI

Evaporators and Distillers — Evaporators — Distillers — Operating Evaporators.

Evaporators. — Evaporators are fitted to supply fresh water for cooking and drinking and to furnish a supply of fresh-water make-



4,000-Gallon Evaporator for U. S. Navy.

FIG. 35. — Horizontal Evaporator Bureau Design.

up feed for the boilers. The present practice in the U. S. Navy is to furnish evaporators having evaporating capacity in gallons per 24 hours equal to the I.H.P. of the main engines. It is assumed that this capacity would enable the loss of feed water to be made up by evaporators when engines are working at full power.

Loss of Feed Water. — A rough rule that appears to come very close to conditions in the U. S. Navy is: Loss in feed water per day in tons is equal to four per every thousand horse-power, with machinery installation generally tight.

A committee appointed in England to report on naval boilers estimates loss on English naval vessels to be six tons per 1000 horse-power per day. On present English trials (1905) the figure two tons per 1000 horse-power per day has been reported.

Water for Ship's Use. — This amount varies greatly with conditions on board different vessels. In the English Navy about 3400 gallons are required for a battleship with a crew of 500 men.

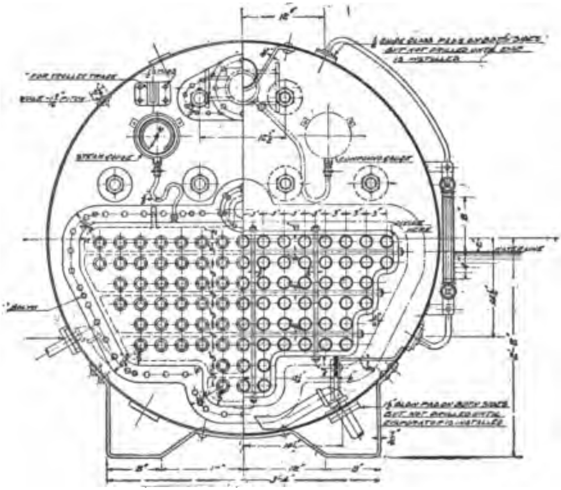


FIG. 36. — Horizontal Evaporator Bureau Design.

From reports of U. S. battleships in commission, about 4000 gallons are required with a liberal allowance for 700 men.

On naval vessels, especially recent ones, copiously supplied with fresh-water bath tubs and showers, laundries, and dish-washing machines, and numerous places where water is likely to be wasted, these amounts are very likely to be largely exceeded.

Amount of Heating and Cooling Surface Allowed. — Eighteen to twenty gallons per day per square foot of heating surface, and fifty gallons per day per square foot of cooling surfaces of distillers is allowed.

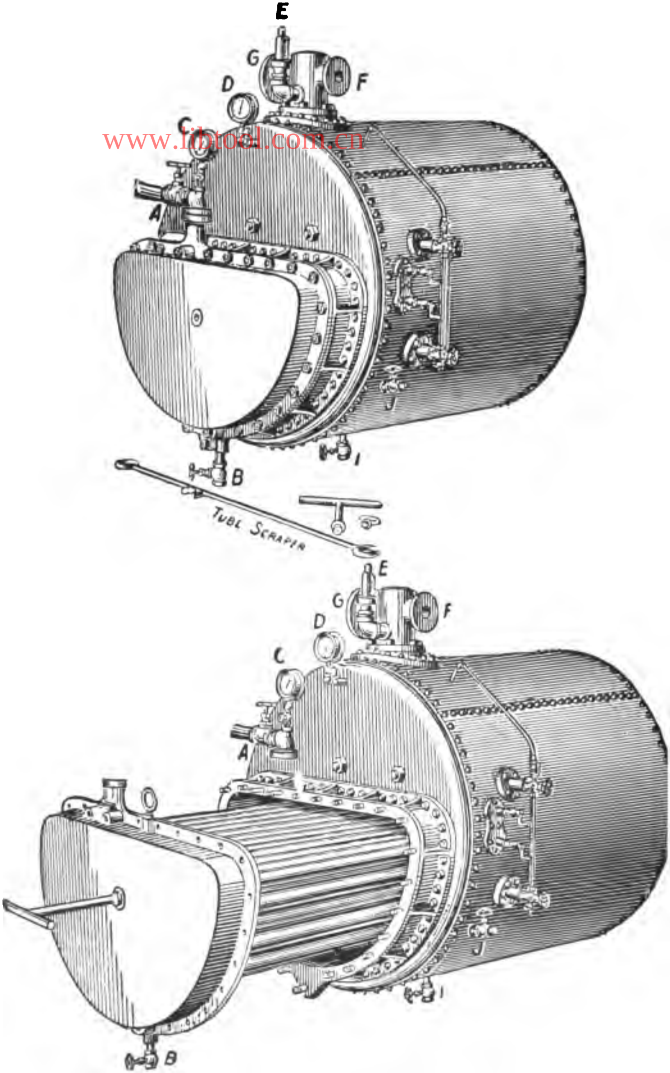


FIG. 37. — Williamson Horizontal Evaporator.

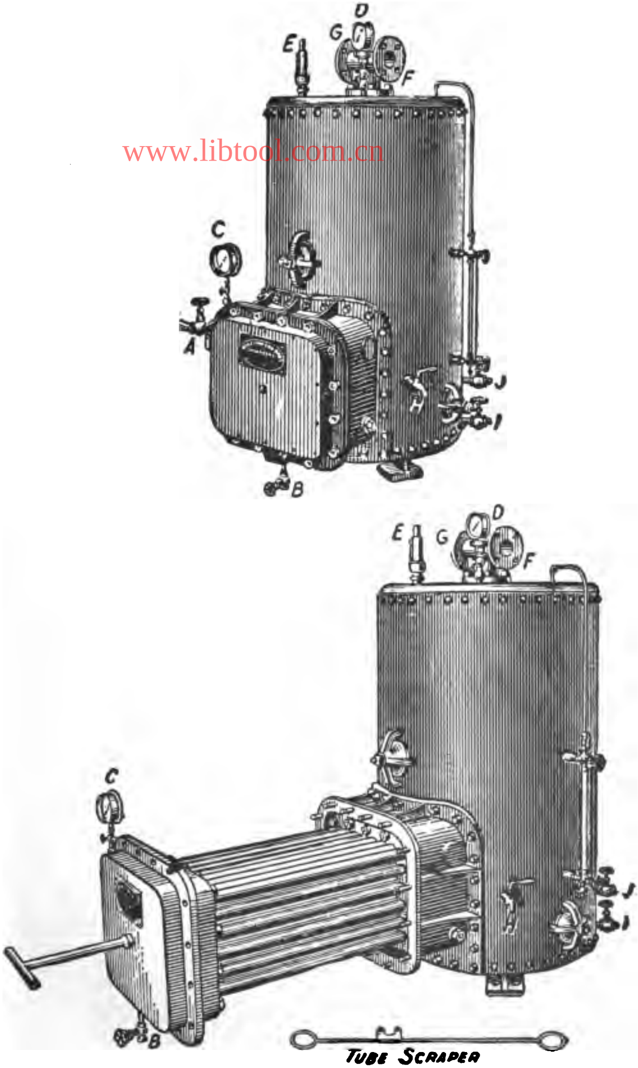


FIG. 38.

Evaporators installed in naval vessels are either horizontal or vertical, conforming in general matters and requirements to those designed by the Bureau of Steam Engineering. There are numerous other patent types in commercial use. See Cuts and Figures, 35–41.

The Horizontal Evaporator shown in plan is one of late design. The shell consists of steel plates, the ends flanged and braced. The

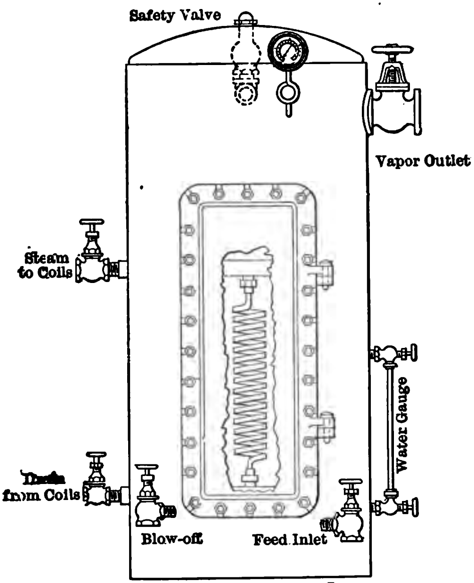


FIG. 39. — Quiggins Evaporator, Griscom-Spencer Co.

heating surface consists of a steam coil. The steam head, a composition casting (attached tube sheet), is secured to the front head by stud bolts. The brass tubes are expanded into the tube sheet and the rear ends are connected by U-fittings. The partitions in steam head are arranged so as to cause the steam to pass several times through the length of the tubes. Instead of the U-fittings many evaporators have an inside steam head into which the tubes are expanded.

The evaporator has a dry pipe for collecting the vapor. The nozzle for vapor pipe is fitted with a safety valve. Steam is supplied to coil through a stop valve, and the drain leads to a trap. The coils are supported in place by supports as shown. Zinc plates are fitted to guard against galvanic action. Evaporators are supplied with a steam gage on coil and on shell. A water gage and gage cocks to tell the height of water, and a salinometer pot to take the saturation is also fitted. Feed is supplied through feed-check valve at

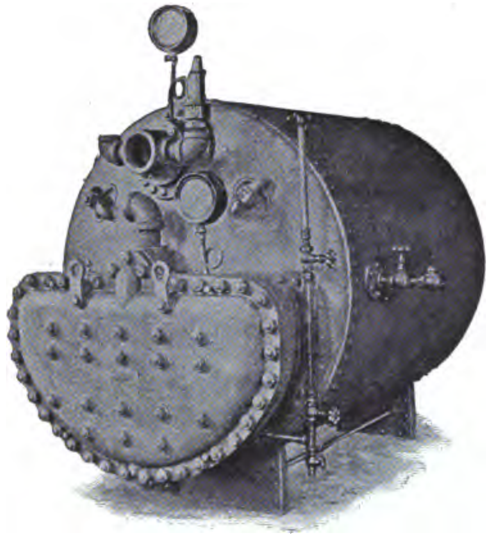


FIG. 40. — Davidson Horizontal Evaporator.

about height of water line. The evaporator can be pumped or blown out through the bottom blow valve.

Distillers. — Distillers are fitted to condense the vapor from the evaporator. The distiller consists of a coil or a nest of tubes and an enclosing jacket. The vapor enters one of these spaces and the cool sea water the other. The circulating water condenses the vapor, thereby giving fresh water. The most general type, that of the Bureau of Steam Engineering, is a vertical distiller having a nest of tubes as shown. (Fig. 42.) The vapor is on the outside of the tubes and the circulating water passes through the tubes.

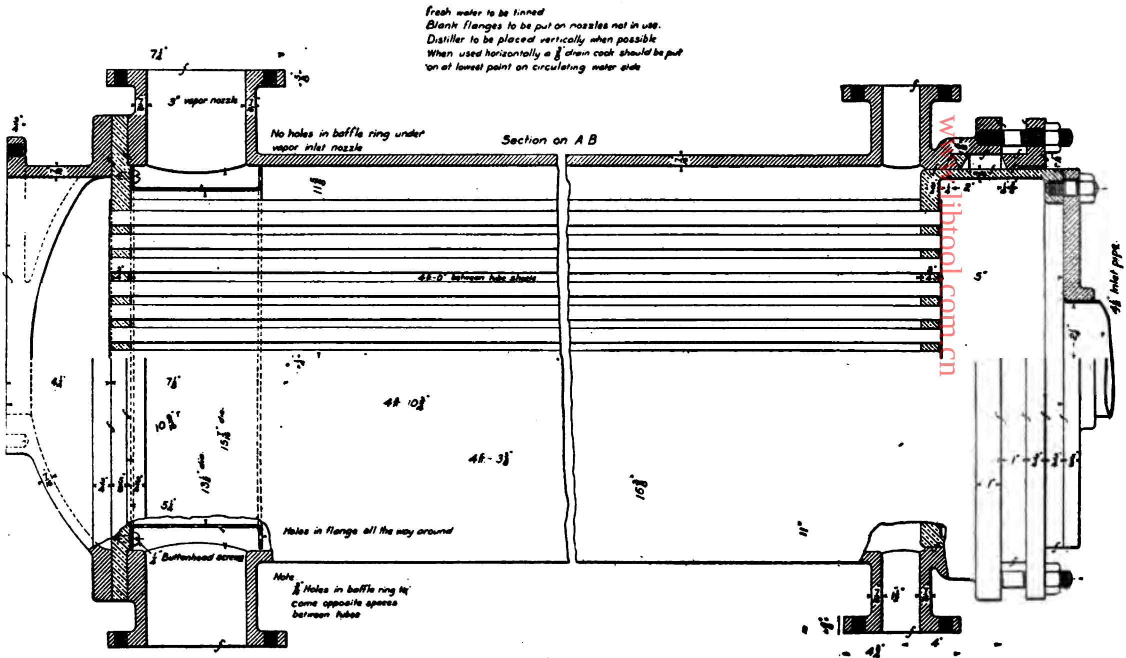
The shell is of cast iron or composition; the tubes and tube sheets are of composition. The tubes are expanded into the tube sheet, and are of the same character and design as the condenser tubes, $\frac{5}{8}$-inch outside diameter.

The circulating water is forced through the distiller by the distiller circulating pump, the discharge from this pump being arranged so that it can pump through distiller and then overboard or to flushing main, or directly to flushing main. There is also usually a connection whereby water from fire main can be utilized for distiller circulating water. Distiller circulating pumps on late vessels are usually duplicated. The condensed vapor falls to the bottom of distiller and is led to a small reservoir tank from which it is pumped by the fresh-water pump to the ship's tanks.

FIG. 41. — Davidson Vertical Evaporator.

Distillers are sometimes placed horizontal, and when so placed it has been found that better results are obtained when the circulating water is outside and steam inside of tubes. On older vessels there are distillers consisting of a single or a double coil placed inside a cast cylinder through which water is circulated. This type is heavier and takes up much more space than the later type having tubes instead of coils.

Operating Evaporators. — *Starting up, Running on Distillers.* — Start distiller circulating pump on distiller to be used. Fill the evaporator shell to about half-gage glass with salt water. Open steam to steam coils; open coil drain connection to steam trap. Allow pressure on coils to come up to about 30 to 40 pounds. When steam in shell is at about 5 to 10 pounds pressure, crack vapor valve to distiller and gradually open it so as to keep about 5 pounds pressure



5,000-Gallon Distiller for U. S. Navy.

FIG. 42. — Distiller, Bureau Design.

on shell. Regulate feed check to keep water at a constant level. Start brine pump slowly so as to be slowly drawing off the dense salt water in bottom of shell. On starting up water should not be sent to tanks until it is known to be fresh.

Prevention of Priming. — The water level should be kept constant and several inches below the upper level of the tubes in order that the vapor formed may be thoroughly dried by the upper tubes. The vapor-discharge valve should not be opened wide, but only sufficient to maintain the designed pressure on the shell. Some evaporators have this valve controlled by a spring set at the desired pressure.

Supply of Feed Water. — Feed water is usually supplied by a branch from the distiller circulating pump; after the discharge passes through the distiller in this way warm feed is obtained. The supply is controlled by feed valves at each evaporator.

Brining. — This is accomplished by keeping the brine pump going slowly and thus having a continuous discharge of brine from the evaporators. Continuous brining thus keeps down the saturation and hence reduces the rapidity with which scale forms. Too much brining is, however, not economical, since the heat contained in the brine pumped overboard is lost.

Blowing Down. — The saturation should not be allowed to go above five thirty-seconds. When this point is reached evaporators should be blown down. To blow down, shut the vapor valve; allow pressure in shell to come up to 20 pounds; then open bottom blow. When water is blown out shut off steam; fill evaporator to working level; then turn on steam, and continue as before. By turning steam on coils while evaporator has cool water the tubes are suddenly heated, and expand. This causes the scale to crack and fall off. However, with evaporators having inside steam heads there is likely to be an unequal expansion resulting in leaky tubes. Evaporators should be blown down once in twelve hours. The presence of oil in water indicates a leaky coil, the boiler steam passing directly to the vapor side.

Scaling. — When evaporators are running continuously and with only slight brining, they should be scaled about every fifteen days. To scale an evaporator it is shut down and allowed about an hour to cool. The nuts securing the steam head to the shell are taken off, other necessary connections are broken, supporting trolleys are hooked to eyebolts in steam head, and coil hauled out to the front. The tubes are scaled with scaling bars and hammers; loose scale is removed from the interior of the evaporator. The scale on the outside shell should not be removed, since it acts as a non-conductor of heat and also protects the inside surface from rust and corrosion. The zincs should be examined and refitted if necessary, blow and feed valves cleaned out and ground in if necessary.

Steam for evaporators is taken from auxiliary steam pipe through a reducing valve. Attempts have also been made to take the primary steam from the second receiver of the main engine (English Navy) and also from auxiliary exhaust; this for purposes of economy. These arrangements have, however, the disadvantage of extra piping and the inability to get the maximum capacity out of the evaporators at times when it may be desirable to have it.

Double and Triple Effect. — In order to obtain greater economy in the consumption of fuel for distilling, evaporating plants of large vessels have recently been fitted with piping to operate evaporators in double and triple effect. Here the primary steam is taken from the auxiliary steam. The secondary steam in the first evaporator (H.P.) is then led to the coil of the second evaporator (L.P.) and the drain led through a trap to the feed tank. The secondary steam from the L.P. evaporator is led to the distiller. In triple effect three evaporators are run in series. Operating evaporators in double effect secures a saving of about 30 to 50 per cent in coal, but the same amount of water cannot be evaporated as when using evaporators in single effect.

Discharging Vapor from Evaporators. — To obtain water for culinary and lavatory use the vapor must be led to the distillers, where the latent heat of the vapor is lost in the circulating water. For makeup feed purposes the vapor can be discharged to the auxiliary exhaust (connections for this purpose being fitted); the heat of the vapor for evaporation is then not lost but is utilized to heat up feed water. The vapor from evaporation should not be discharged to auxiliary exhaust except when this pressure is kept constant, and, if possible, above the atmospheric pressure. This condition of constant pressure is met with when auxiliary exhaust is turned on feed heaters. When auxiliary exhaust is turned on condenser and subject to sudden fluctuation the vapor from evaporator should not be led to it, as the variations in pressure are very apt to cause priming.

Drains. — Evaporator drains are led to steam traps whose discharges go to feed tank. These traps should be tested for proper working several times each watch, and should be cleaned out at the same time that evaporators are scaled. The drains should not be allowed to by-pass the traps except for short intervals to test traps. When the drains are by-passed steam from coils is made to blow directly into the feed tank. The drains from coils should discharge to the feed tanks and not to the condenser, in order that the heat of the drain water may not be lost.

The following is a set of rules adopted on a large cruiser for operating a plant of four evaporators arranged to work in double effect:

"OPERATION OF EVAPORATORS

"Evaporators will be operated in double effect unless otherwise directed. A pressure of 40 pounds will be kept on high-pressure coils. A pressure of 15 pounds will be kept on low-pressure coils. A pressure of 5 pounds will be kept on low-pressure shell. Care will be taken to keep a constant water level.

"Evaporators will be blown down every twelve hours when running steadily or whenever secured. The brine pump will be used with bottom blow slightly cracked to keep the saturation below 3 while running, the salinometer being used at frequent intervals to ascertain the saturation. When opportunity offers, evaporation will be scaled after every fifteen days of operation. Unless otherwise directed the drain from both coils will be run through the traps, and only by-passed for a short time when necessary to clear coil of water. The discharge from traps will be led to discharge to feed tanks. If these discharges cause water in feed tank to go above 160 degrees, discharge from coils will be turned into auxiliary condenser.

"Water, drawn from each distiller, will be tested every hour with nitrate of silver solution. In case this test shows any trace of salt, it should be turned into feed tanks until fresh, and if more than a slight trace shows, it should be turned into bilge till fresh.

"Under no circumstances will the water in the distiller-reservoir tank be pumped below half a glass. The machininst on watch must always be notified in cases of any changes in running water from ship's tanks to feed tanks, bilges, etc.

"Any order received by the men on watch from proper authority must be passed along and strictly adhered to until other directions are given."

CHAPTER XVII

Heating System — General Requirements of the Machinery Specifications — Care and Overhauling.

Heating System. — The general type of heating system is in general described in the machinery specifications of the Bureau of Steam Engineering as follows:

"Radiator coils, 1-inch seamless-drawn brass pipe, iron pipe size.

"Radiators, consisting of pipes led along the decks at bottom of bulkheads, 2-inch brass pipe, iron pipe size.

"Circuit steam and drain pipes, seamless-drawn pipes, brass, iron pipe size, connected by composition fittings.

"The heating plant will be arranged to work at a pressure of about 50 pounds.

"Radiators will be located to the satisfaction of the Bureau of Construction and Repairs.

"Radiators of approved pattern and of areas conforming to the schedule hereto appended will be furnished, fitted and connected in an approved manner in the living and other spaces to be heated.

"The number of cubic feet of space to be heated, allowed per square foot of radiator surface, will be as follows:

	CUBIC FEET
Pilot and chart houses	50
Captain's cabin, staterooms, office, bathroom, and water-closet	60
Sick bay and sick-bay bathroom	60
Wardroom country and staterooms, where outside armor	80
Wardroom officers' bathroom and water-closet and staterooms	80
Storerooms	100
Dispensary	80
Offices on main deck (separate heaters)	80
Wardroom and junior officers' bathrooms and staterooms	80
Berth and main decks forward of redoubts, crew's water-closets and lavatory	100
Main deck inside armor	100
Junior and warrant officers' messroom on berth deck	100
Steering-engine room	125
Berth deck and inside redoubt	125

"The heaters in the base of each 12-inch turret will have an aggregate area of 25 square feet.

"Other spaces as directed.

"Radiators will consist of coils or standing radiators, or pipes led along deck at bottom of bulkheads, as may be necessary or expedient.

"Coils or standing radiators will be divided into two or more parts when the area called for is more than ten square feet, and the shape of each radiator will be adapted to the space on bulkhead and to the space to be heated.

"Radiators, consisting of pipes led along the decks at bottom of bulkheads, will have proper provision for expansion and will be covered with an approved metallic casing, easily removable. They will be reduced at the drain ends, and the fittings and lead will be such that the water will not lodge.

"Where any radiators, coils or piping are fitted on or near joiner work or along wooden decks there will be protecting metal shields between the radiators and the woodwork. The shields will be easily removable, and will be separated from the woodwork by not less than ½ inch of air space.

"All radiators will be fitted with approved air cocks and with valves; those in the crew's space having stems of triangular cross-section, valve-stem guards, and socket keys for opening and closing, those in officers' quarters having fixed handwheels.

"Radiators and heaters will be arranged in circuits, as approved, each circuit being so connected that it can be operated independently of the others. The circuits, divided in an approved manner, will lead to the following parts of the ship:

"Chart house. Base of 12-inch turrets. Main-deck cabins. All parts of the gun and main deck. Captain's, wardroom, junior and warrant officers' pantries, sick bay, dispensary, operating room, contagious ward, and sick-bay bathroom. Steering-engine room, and equipment and other storerooms, as directed. Captain's cabin, stateroom, office and bathroom. Wardroom and junior officers', warrant and petty officers' quarters and mess rooms. Bathrooms, wash-rooms, water-closets, armory, offices and other heater circuits if directed.

"Steam connections for the bath-tubs, shower-baths, and for heating water will be as short and direct as possible. There will be a connection, with valve, leading from chart-house circuit to the gravity tank, to prevent freezing.

"Live pipes of suitable size will lead to such water heaters as are supplied by the Bureau of Construction and Repair. These pipes will be incased or covered in an approved manner. An approved arrangement of piping to drain such will be provided.

"Unless otherwise directed, the steam pipe for the plumbing heaters in hospital spaces will tap the steam pipe of the sick-bay circuit; that for the officers' bath heaters and shower-bath heaters will be taken from the officers' pantry circuit, and that from the wardroom and the junior officers' bath heaters will be taken from the wardroom-pantry circuit.

"The radiator circuits will be arranged in groups, each group having a supply manifold and a drain manifold. The supply manifold of each group will take steam from the auxiliary steam pipe, with a stop valve, an adjustable reducing valve and a steam gage, at the connection with the auxiliary steam pipe. The drain manifold of each group will discharge through a trap with a by-pass into the feed tanks, the main condensers, or the auxiliary condensers at will, and have a stop valve and a check valve for each circuit. Where branches occur in the drainpipes Y-fittings will be used. Arranged as above, each circuit, by means of stop valves at steam and drain ends, can be entirely isolated and water from other circuits prevented from backing up into it.

"Each circuit steam and drain valve will be marked with name, on brass plate. The circuit steam and drain pipes will be suitably connected by fittings in a manner that will permit of their being easily taken down for repairs. Pipes passing through bulkheads and decks will be made watertight by approved stuffing boxes. Pipes passing through storerooms will have the joints located as near the door as possible. Provision will be made for the expansion by horizontal U-bends of copper pipe having the same internal diameter as the connecting pipes. All union joints will be coned.

"Plans of the heating system will be submitted for approval, showing location and areas of heaters, lead of pipes, location of expansion, bends, of principal stop, reducing and check valves and steam gages, and of traps with their drainage connections.

"Other parts of the vessel not here designated will have radiators and heaters as directed."

Care and Overhauling. — The care necessary consists of repairing leaks in the steam and drain line and overhauling traps and reducing valves. The heater reducing valves in service are usually set at 40 or 50 pounds pressure. On a large ship with very long leads of heating pipe, a higher pressure should be carried than on a small vessel when leads are short.

In order to ensure a proper draining of the discharge pipes from heaters to traps they must be overhauled and kept in good repair. When heaters are in use, they should be periodically by-passed to make sure that large quantities of water do not collect in the pipe.

The steam to pantries is taken from separate circuits each with its own reducing valve and drain lines. The steam for bath heaters is taken from the pantry lines or from separate circuits.

The drains from bath heaters are led direct to auxiliary exhaust line. This ensures a proper flow of steam through the heaters necessary for their efficient operation. When the drains from such heaters are led to the traps frequent difficulty is met with in their being improperly drained. When the drains are led direct to the auxiliary exhaust this difficulty is entirely avoided.

The type of bath heaters installed consists of a double copper tube. The steam enters the inner tube and is drained off at the bottom; water is admitted to the annular space between the tubes and discharges to tub or basin. The heat of the steam heats the water as it passes through. The degree of heat can be regulated by opening or closing the steam valve. Heaters are arranged with both fresh and salt water connections.

CHAPTER XVIII

Steam Launches — General Rules for Operation — Difficulties in Operation — Care and Overhaul.

General Rules for Operation. — The machinery of the steam launches requires considerable care. For operation the following rules established on one of the large cruisers are given:

"*Boilers.* — A pressure of 150 pounds will be carried. Fires should be carried light, not over six inches thick. Steam blast will not be turned on except in case of urgent necessity. Ash pans will be kept wet and as clear of ashes as possible. Fires will not be coaled when alongside of any vessel, or at landings while passengers are going aboard or leaving. Feed pumps will be kept going continuously, while engines are in operation.

"*Engines.* — The speed of engines will not be suddenly changed. Cylinders will be kept clear of water by opening drains when necessary. Special attention will be paid to see that all parts are well lubricated. A little graphite and kerosene will be put into cylinders occasionally. The feed tanks will be frequently cleaned and sponges replaced. The engine and boiler space will be kept thoroughly clean at all times. In case of improper working, or any need of repairs, the chief machinist's mate in charge of steam launches will be notified at once. The launch-engineman will report the need of coal and water to the coxswain. He will obtain his regular amount of supplies from the storekeeper and keep same in the launch ready for use. Other supplies will be obtained upon an order from engineer officer on duty, warrant officer in charge of auxiliaries, or chief machinist's mate in charge of steam launches."

Some of the causes of improper operation of launch machinery are the following:

Boiler Furnishing Insufficient Steam. — This may be due to improper firing. The fires should be carried light and evenly spread over the entire grate. Inexperienced firemen are apt to carry a heavy fire around the door and allow the distant portions of the grate to become filled with clinkers. The water level also may be carried too high for free steaming. A high-water level will generally be shown by water being carried over with the steam into the engine. After steaming several days the tubes become covered with a coating of soot and this greatly reduces the efficiency of the heating surface. Insufficient steam is often due to this cause.

Loss of Vacuum. — This may be due to a defective or leaky air pump or to leaks in the condenser. Condensers are apt to leak at the points where they have connections brazed on. A vacuum of 20 to 25 inches should be carried when all parts are in proper condition.

Water in Cylinders. — This can be told by the knocking sound that is heard, and is due to carrying water level too high, excessive rolling of launch, irregular firing, sudden changes in the speed of engine. This is to be carefully guarded against as water in the cylinders is apt to cant the piston, bend or break the rod or knock out cylinder head. When water is noticed in the cylinder the drains should be opened, the throttle closed somewhat, and then the cause for the priming should be located and remedied.

Difficulty in Starting or Reversing. — This is liable to happen when the H.P. crank is near the center. A movement of the reversing lever back and forth will generally throw the crank off center and start the engine. The by-pass to L.P. cylinder can be used in case the engine sticks on its center. The reversing lever should not be moved back and forth with a slam or roughly handled. A rapid slamming of the reversing lever does not help matters, and may damage some part of the valve gear. The shifting of the slide valve on its stem on account of the nuts becoming loose may sometimes cause difficulty in reversing.

Care and Overhaul. — The tubes of boilers should be blown with a steam hose occasionally to remove the soot. Water should be kept in the ash pan to prevent grate bars burning out. Boilers should be painted with paint that will withstand a high temperature. — Lamp black and kerosene will give a good black coating; brown zinc will give a brown coating; aluminum paint will stand well if put on over another coat such as brown zinc. In cold weather, fires should be under boiler all night to guard against water freezing. When launch is hoisted, boiler should be kept full of water. The gage glasses are not usually well protected and are in danger of being cracked by spray. To avoid these difficulties, Klinger reflex glasses can be fitted. Soda should be occasionally fed into the boiler to keep the water alkaline. Sponges should be put into the feed tank to take up oil. Leaks in boiler tubes are repaired either by replacing tube or by plugging hole with a tap plug.

The plunger air pumps wear down in time and leak. New ones should be fitted when this leakage becomes extensive.

Lignum-vitæ stern bushings wear down and cause the shaft to be thrown out of line. These should be renewed periodically. In place of lignum-vitæ, a white-metal bushing may be used.

On most vessels there are spare engines. These spare engines can be overhauled when not in place, and when engine in place is in need of extensive overhauling it can be removed and the spare engine put in. In this way the service of the launch is not interfered with to any great extent.

When launches are hoisted for several days the bearings of the engine should be adjusted and the cylinders and valve chests examined. Feed pumps should be examined, especially the water end. The keel condenser should be examined for any dents or corroded parts and to see that the fastenings are in good condition. Propeller blades should be cleaned and polished and, if bent or chipped, they should be bent back into shape or the irregularities smoothed up as much as possible.

About once a year the boilers should be hoisted out of the launch and all its parts thoroughly cleaned and tested. At this time the bilges, bunkers, water tanks, floor plates and other parts which are more or less inaccessible when boiler is in place should be thoroughly cleaned and painted.

CHAPTER XIX

Refrigerating Plant — Allen Dense Air Ice Machine — Attendance and Overhaul — Return Air Coolers.

Refrigerating Plant. — The refrigerating plant consists of the ice machine and the refrigerating chambers. On large vessels of late design two 2-ton machines are supplied. On other vessels one 3-, one 1-, or on small vessels, such as gun boats, one ½-ton machine.

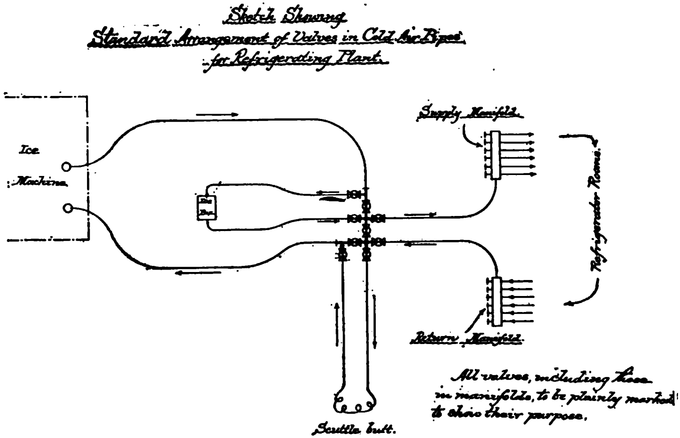


FIG. 43.

The Allen dense-air machine is the one almost exclusively installed. The 1-, 2-, and 3-ton machines are horizontal. The 1-ton and ½-ton machines are both vertical and horizontal.

A 1-ton machine means a machine having the cooling effect of one ton of ice per day; but this does not mean that a 1-ton machine will make one ton of ice per day. A 1-ton machine will make about one half a ton of ice per day.

On late vessels the refrigerating pipes are led to conform to the Bureau of Steam Engineering standard arrangement. See Fig. 43.

Allen Dense Air Ice Machine. — The following description, illustrations, and instructions for operating are taken from pam-

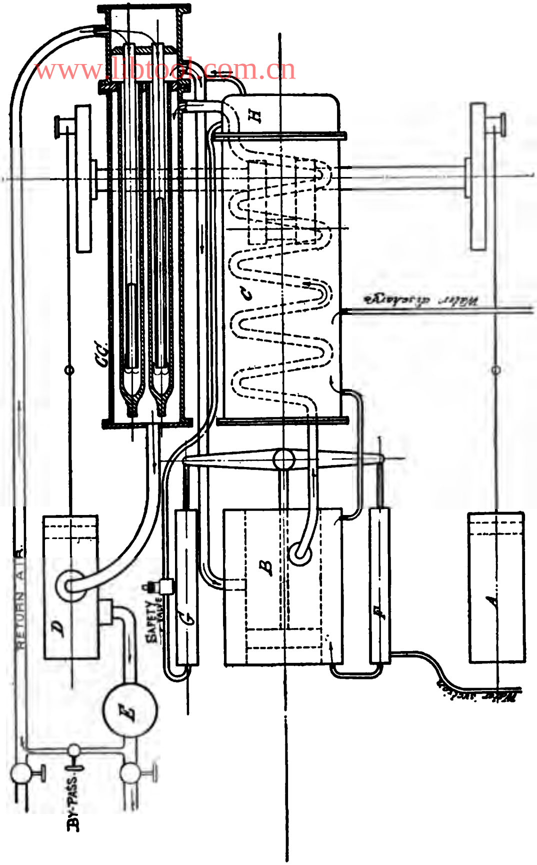


FIG. 44. — Allen Dense Air Ice Machine, Plan.

phlets issued by H. B. Roelker, manufacturer of the Allen Dense Air Ice Machine:

The Allen Dense Air Ice Machine produces cold by the expansion of air which has previously been compressed and then cooled

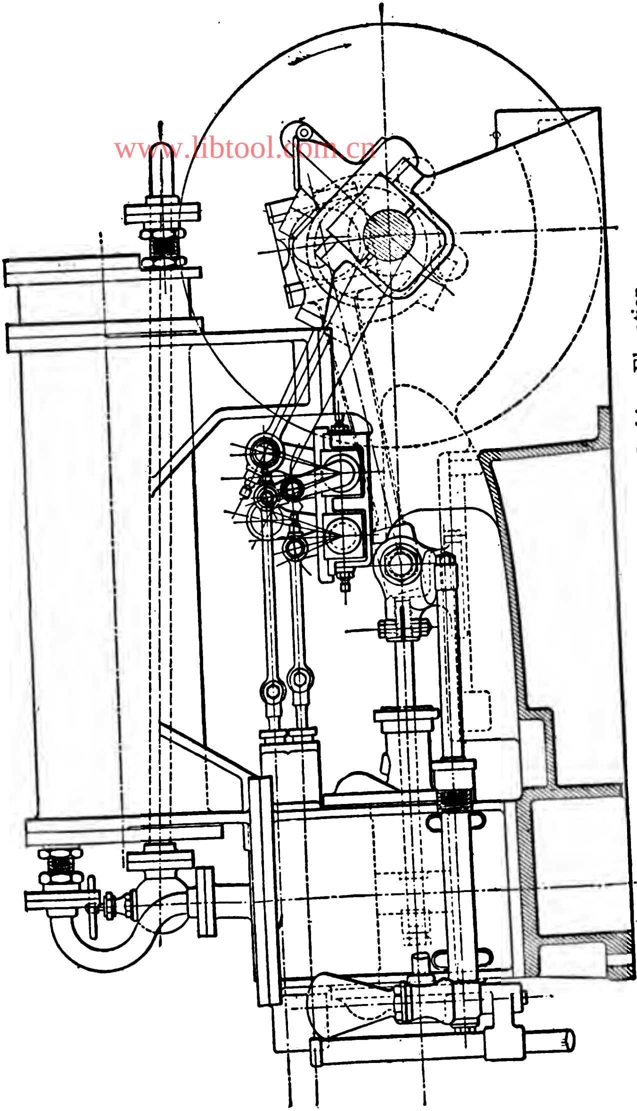


FIG. 45. — Allen Dense Air Ice Machine, Elevation.

by circulated water. It uses air of about 65 pounds pressure, and compresses the same to about 235 pounds pressure, then cools this by passing it through a coil immersed in water, then an expanding engine brings the air back to 65 pounds pressure and to a very low temperature.

This cold air under 65 pounds pressure is then led in well-covered pipes first to the ice-making box, which it refrigerates to a temperature much below zero Fahrenheit, and a brine made of about equal weights of chloride of calcium and water is required to keep the ice cans from freezing fast in the pockets of the ice making box. From there the air is led through the refrigerating pipes in the meat room, and then through the coil in the scuttle-butt, whence it returns to the suction side of the air compressor of the machine.

The machine consists of the following eight parts:

A. The Steam Cylinder which furnishes the power required by the whole apparatus.

E. The Air-compressor Cylinder which compresses the air to fully three times the entering pressure (absolute), which compression causes the air to heat considerably. This cylinder is, therefore, surrounded by a water jacket in order to keep the piston packings from withering up.

C. A Copper Coil in a Bath of Water. The compressed hot air passing through the coil cools to the temperature of the cooling water.

CC. The Return Air Cooler further cools this compressed air by means of the cold air returning from the meat house. This is not always used in the Navy Machine, the scuttle-butt taking all the cold out of the air.

D. The Expander Cylinder, to which the cool compressed air is admitted till it fills somewhat more than one third of the volume of the cylinder. It is then shut off, and the piston, continuing its passage to the end of the cylinder, the air is expanded to one third the compressed tension (viz., to the same tension which it has when it enters the compressor). This expansion cools the air about as much as the compression heated it; therefore, the air leaves the cylinder at a very low temperature. This air is then discharged into a well-insulated pipe, which conveys it to the point where the cold is to be utilized. There the pipe surface is exposed and the cold given out by radiation, etc., as heat is given out by a steam radiator, and after the utilization the air is returned to the machine, continually contained in pipes, and it enters the compressor for a new turn of compression, cooling, and expansion. Before the expanded refrigerated air goes into the conveying pipe, after leaving the expander it passes through a trap.

E. Which gathers the lubricating oil used in the cylinder, and also a slight amount of snow, leaving the air very pure and clean when it runs through the pipes. This trap is provided with a heating jacket and pipe, and once in twenty-four hours this trap should be warmed up and the deposits be drawn off by the bottom cock. The machine is arranged at the same time to thaw out and blow into the trap any possible frozen deposits from the expander cylinder. This trap is bolted directly to the expander cylinder in the vertical machines.

F. Is a common Plunger Water Pump, which supplies the cooling water for the bath around the copper coil *C*, and for the water jacket of the compressing cylinder *B*, and the machine must be stopped if the supply should fail.

G. Is a small supplementary Air Pump which, at starting, primes the machines and the run of pipe with air to the requisite pressure, 65 pounds, and which replaces losses of air from leaks through stuffing boxes and joints.

H. Is a small Trap, which extracts atmospheric moisture from this newly supplied air, so as to have it enter the machine as dry as possible. The gathered water must be drawn off occasionally from the bottom pet-cocks. This is attached to the crank end of *C* in the horizontal machines, and along the compressor leg of the frame in the vertical machines.

The air-compressor valves are regular engine slide valves, moved by eccentrics. The expander is also similar to a regular steam engine, with a cut-off valve.

The piston packages in both of these are leather, soaked in castor oil.

Special Supplies for the Ice Machines. — Chloride of calcium is used for making the brine for ice-making box (about equal weights of chloride and of water).

Leonard & Ellis Extra Machine Oil (11 Broadway, New York), for the lubricators of the air compressor and the expander cylinders and the stuffing boxes.

Leather packing discs of $\frac{5}{8}$ to $\frac{3}{4}$ inch larger diameter than the cylinder, and with central hole in them to fit piston hub, cut from white oak-tanned leather, scant $\frac{1}{8}$ inch thick. These are to be soaked in castor oil, and must be impregnated with that oil when put in. The leathers for vertical machines are scant $\frac{3}{16}$ inch thick.

Square Garlock packing for piston rods.

Square Garlock packing for valve stems.

Square Garlock packing for primer pump plunger.

Directions about Running the Allen Dense Air Ice Machine. — On starting the machine have the blow valves of the expander and the pet-cocks of the various traps open until no more grease or water discharges.

The two valves of the main cold air and return pipes must be open and the 1-inch by-pass pipe closed; also the $\frac{1}{2}$-inch hot-air valve from the compressor to the blow-pipe of the expander cylinder must be closed.

Be sure that the circulating water is passing through.

The full pressure is 65 to 70 pounds, low pressure, and 235 to 250 pounds high pressure for horizontal machines, and 65 to 75 pounds and 235 to 275 pounds for vertical machines.

During the running, open the pet-cocks of the water trap (which takes the water out of the air from the primer pump), frequently enough that it will never be more than half filled. If the water should be allowed to enter the main pipes, it is liable to freeze and clog at the valves. This trap is at the crank end of the cooler in the horizontal machines and along the compressor leg of the frame in the vertical machines.

By keeping all stuffing boxes well lubricated by the lubricator cups the pressures are easily maintained with but little screwing up of the packing. If the low pressure is not maintained, the fault is almost always due to leaks at the stuffing boxes. Under all circumstances it is due to some leak into the atmosphere, as we have very seldom found the primer pump valves at fault.

The packing of valve stems and piston rods consists of a few inner rings of soft metal packing, then a hollow greasing ring, then soft fibrous packing (Garlock packing).

The sight feed lubricators of the compressor and expander should only use a light, pure mineral machine oil, from which the paraffine has been removed by freezing — usually about five drops per minute in the compressor and about two in the expander.

The pistons of the compressor and expander-cylinder cylinders are packed with cup leathers, which commonly last about one or two months of steady work. When these leathers give out the high

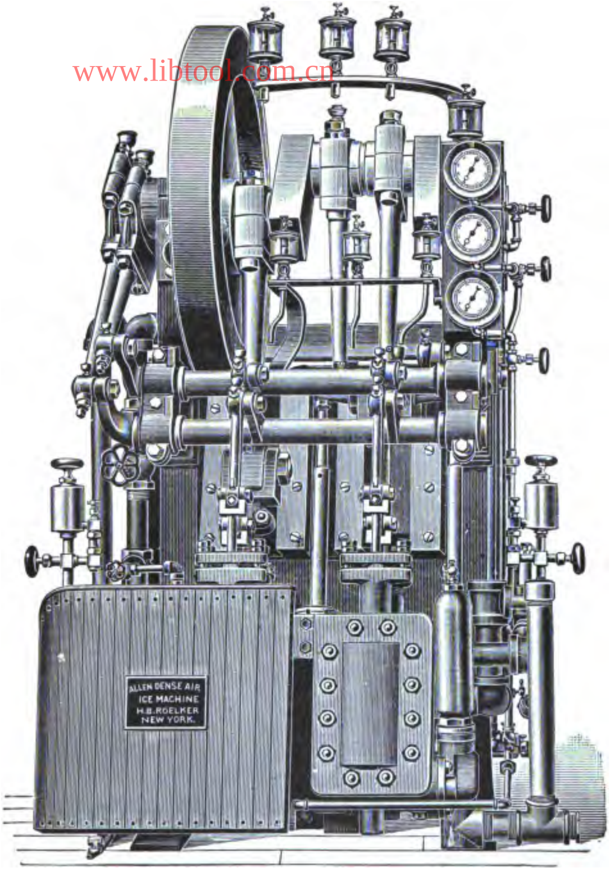


FIG. 46. — Vertical Ice Machine.

pressure decreases in relation to the low pressure, and the apparatus shows a loss of cold. A leak at any other point of high pressure into low pressure will have the same effect.

These packing leathers are made of white oak-tanned leather of somewhat less than $\frac{1}{8}$-inch thickness. They are cut $\frac{5}{8}$ inch to $\frac{3}{4}$ inch larger in diameter than the cylinders, according to size. The leathers must be kept soaked with castor oil and must be well soaked in that before using; and a tin box containing spare leathers and castor oil must be kept on hand. The leathers of the vertical machines are scant $\frac{3}{16}$-inch thick.

Once a day it is necessary to clean the machine by heating it and blowing out all the oil and ice deposits. This is done as follows:

The 1-inch valve of the by-pass pipe from the oil trap to the return air pipe is opened. Then the two valves in the main cold air and return pipes are closed; then the valve in the small hot-air pipe from the compressor valve chest to the expander blow-pipe is opened and also the two angle valves of the blow-pipe. The valve on expander inlet is closed partly; then the live steam is let into the jacket of the oil-trap slowly, keeping the outlet from the steam jacket open enough to drain the condensed steam.

Run in this manner for about one-half hour; during this time frequently blow the bottom valve of the oil-trap, also the pet-cock at end of the expander blow-pipe until everything appears clean. Then shut off the steam and drain connections of the jacket of the trap and the hot-air pipe from the compressor valve chest to the expander and the two angle valves in the expander blow-pipe. Then open the two valves in the main pipes, and the valve on expander inlet. Then close the by-pass pipe and run as usual.

Whenever opportunity offers to blow out the manifolds of the meat room and the ice-making box (that is, whenever they are thawed), this should be done.

The clearance of the two air pistons and of the primer pump plunger is only $\frac{1}{8}$ inch, and that of primer pump $\frac{1}{16}$ inch, therefore not much change of piston rods and connecting rods is permissible, and when the piston nuts are unscrewed to change the piston leathers, the rod should be watched that it does not unscrew from the cross-head.

Whenever it is noticed that the brine of the ice-making tank freezes, more chloride of calcium should be added and should be well stirred into the brine.

The machine is constructed to use an air pressure of 60 pounds in the conveying and refrigerating pipes, and the air compressor compresses this to 210 pounds. If these pressures cannot be maintained, it is an indication that leaks have occurred, and the piston packings, and possibly the run of pipes, have to be examined. If the trap or any portion of the run of pipes is allowed to be choked by frozen oil or snow, or by closing of valves, the relation of the pressures will be disturbed. The cylinders have to be lubricated by the best quality of mineral lubricating oil, from which the paraffine has been removed by freezing. We recommend Leonard & Ellis' Extra Machine Oil. The air-compressor valves are regular engine slide valves, moved by eccentrics. The expander is also similar to a regular steam engine.

The piston packings in both of these are especially prepared leather, of which duplicates are furnished with the machine.

Particular attention is to be drawn to the necessity of a constant good water supply, as the very life, as well as the efficiency of the machine, depends upon it.

The working principle of air ice machines is based on the creation of heat during the compression of air, and the creation of cold to an about equal amount during the expansion of the same. The machines, therefore, consist of an air compressor, which compresses the air and passes it into a cooling coil of pipe surrounded by circulated water. This removes the heat of compression and passes the compressed cooled air to the expander, a regular cut-off steam engine into which the air is admitted during a portion of the stroke of the piston; the admission is then cut off and the air in the cylinder is expanded as the piston proceeds to finish its stroke.

During this expansion the air is cooled to a very low temperature, and the return stroke of the piston pushes it out, and pipes convey it to the place which is to be cooled by it. It was usual to take air from the atmosphere and to refrigerate it in the above manner, and this is the principle of the English (Bell, Coleman) air ice machine. A difficulty was experienced in the lightness of the air, and the low capacity for cold, which was lost very quickly, and caused the machine to be large and cumbrous and expensive in steam, and necessitated it to be placed immediately adjacent to the cold room.

This again caused a special set of engineers to have charge of the same unless the cold room was placed adjoining the engine room. The American air ice machine (Allen Dense Air Ice Machine) was constructed to overcome these difficulties, and does it in the following manner:

Instead of taking air from the atmosphere or from a cold room, and after refrigeration discharging it again into the room, the Allen machine keeps a charge of air of five atmospheres pressure (sixty pounds gage pressure) contained in the machine, and the conveying and refrigeration pipes, and uses the same over and over again, compressing it, cooling it in a copper coil, surrounded by circulated water, expanding it in the expanding engine, and pushing it, when cold, through the conveying pipes to the cold room, where it also remains inside of pipes and does its refrigerating through the surfaces of the pipes. Then it passes back to repeat the performance.

As air of five atmospheres pressure contains five times as much cold as air of atmospheric pressure, and as it is conveyed in quite small pipes, the loss of temperature is small, and this makes it possible to have the machines in the engine room under the care of the engineers while they are attending to their regular duty, and to lead the cold to any place which may be most advantageous to use as the meat house of the vessel. It can also be led to a place where ice-making can be attended to by one of the butchers or stewards along with his other work, and where the ice is easily taken care of.

The only part additional in the Dense Air Ice Machine over the old machine is the so-called primer pump; a single small plunger pump which compresses the atmospheric air into the machine at the starting and makes up the losses caused during the running by leakage from stuffing boxes and pipe joints. There are also two traps which remove lubricating oil and water from the air and keep it pure while passing through the pipes.

As no absorbed water vapor has to be cooled from the vapor to the frozen state; and as the very much increased efficiency of the dense air causes this machine to be very much smaller than the old machine, and as the losses of temperature of the air are also very much smaller, a great reduction in steam expenditure results (fully 50 per cent). No adjustment or manipulation of any part is required in order to produce best results. Whenever the steam sets the machine going it will produce its cold.

The temperature at which the air passes through the conveying pipes is practically 60° F. below zero.

Attendance and Overhaul. — *Oiling.* — Great care must be taken to see that compressors and expanders are properly oiled. If they are allowed to run dry the valve seats will begin to cut.

Leaks. — Leaks in joints and stuffing boxes will constantly develop. Their presence is told by failure to maintain the air pressure.

Corrosion of Joints of the Cooling Coil. — This can very largely be guarded against by fitting and frequently overhauling zincs.

Stuffing Boxes. — The stuffing boxes should be kept well packed with packing specially designed for the service, and the packing lubricating system must be kept in proper order. Special care must be exercised to see that the lagging of all pipes outside of the refrigerating chamber is kept in good condition.

Cleaning Cooling Pipes. — The interior of the cooling pipes should be cleaned of the accumulation of oil every few months, by making a steam connection to the supply and opening drain of return to bilge. Steam is turned on and the oil is driven out. The freezing box should also be cleaned out in the same manner.

Another way of cleaning the cooling pipes is to wash them out with water. This is done by connecting fire main with the cooling pipes at such a place that the supply will lead to all of the pipe surface. Take off a bonnet from one of the valves in the return-air pipe near the machine and lead a hose so that the return can be run overboard through an air port on ship's side. The connection from the fire main should be made up with a steam jet so that the water can be heated. Water is turned on and fills up the pipes, the water is then slowly heated by means of the steam jet, and the oil is boiled out and runs out with the water.

Brine for Freezing Mixture. — Proportions of about 25 per cent chloride of calcium has been found best for ship's use. If calcium gives out a freezing mixture of 2½ pounds, common salt to one gallon of water will give satisfactory results.

Pressures not being Properly Proportioned. — This fault can be located by shutting valve and not allowing air to get to the expander cylinder, and then stopping the machine. If the pressures equalize it shows that the compressor cut-off valves are leaking. If while running the low pressure rises above 70 lbs. it shows that the expander cut-off valves are leaking or improperly set. If at any time the required pressure cannot be obtained, and all stuffing boxes and joints are tight, the trouble may be due to the pump valve of priming pump leaking.

Return-air Coolers. — These are sometimes fitted. They consist of a vessel built like a distiller to which the return air from the cooling chamber is led on the outside of the tubes, and the air leaving the compressor, on its way to expander, is led through the tubes. In this way the air, while compressed, is cooled further than the circulating water can cool it, and the result is a lower temperature at the discharge from expander and hence greater efficiency for making ice. With hot circulating water, say 83 degrees, the temperature of the compressed air cannot be cooled below about 90 degrees with the circulating water; but when the return air, which is at a temperature of about 30 degrees, is used to cool the air after leaving the water cooler its temperature can be reduced much more. This, of course, makes the air on entering the compressor warmer, but only operates to raise the temperature of air on leaving compressor. This additional heating is taken away by the circulating water, which will now be more efficient since it comes in contact with air of a higher temperature.

CHAPTER XX

Gages and Thermometers — Steam and Vacuum Gages — The Bourdon Gage, Fitting Gages — Testing Gages — Thermometers — Rules for Care of Thermometers.

Steam and Vacuum Gages. — To indicate the pressure in boilers, pipes, and other places, pressure and vacuum gages are fitted.

A pressure gage is one that records pressure above that of the

FIG. 47. — Star Steam Gage, Double Spring.

atmosphere (pressure gages are marked for pressure in pounds per square inch above the atmosphere).

A vacuum gage is one that records vacuum, that is, a pressure below the atmosphere. Vaccum gages are marked (1 to 30) to indicate the vacuum in inches of mercury. Atmospheric pressure is approximately equal to 30 inches of mercury, or 14.7 pounds per square inch absolute. Zero pressure absolute is equal to a vacuum of 30 inches or 14.7 pounds below atmosphere. One pound difference in pressure is roughly equal to a difference of 2 inches of vacuum.

To change gage pressure to pressure absolute add 14.7, or, roughly for practical purposes, 15 pounds. Twenty inches of vacuum is equal to 10 pounds below atmosphere, or 4.7 pressure absolute.

A compound gage is one that is marked for both pressure above atmosphere in pounds and vacuum below atmosphere in inches.

Zero pressure on all classes of gages generally used means the pressure of the atmosphere.

Steam gages in general use are of two classes, known respectively as the Bourdon gage and the diaphragm gage. In the

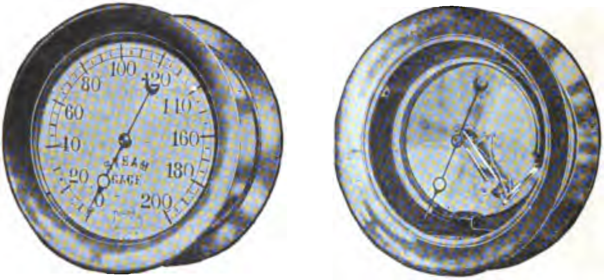


FIG. 48. — Ashton Steam Gage, Single Spring.

diaphragm gage, the pressure is resisted by a corrugated plate. The motion given to the plate by the pressure of the fluid or gas is transmitted to the hand. Diaphragm gages are seldom if ever used on naval vessels.

The Bourdon Gage. — In the Bourdon Gage, the pressure is exerted on the interior of a tube (oval in cross-section) bent to fit the interior of a circular case. The application of pressure to the inside of this tube, which is connected by an external pipe to the vessel whose internal pressure is to be recorded, tends to make the cross-section round and thus to straighten the tube. This motion, communicated by means of racks and gears, rotates an arbor carrying a needle or hand. The forms of levers used for transmitting this motion are numerous. Some of the well-known types met with are shown in the figures. The levers are, in general, adjustable in length, so that the rate of motion of the needle with respect to the bent tube can be decreased or diminished at will for adjustment.

The teeth of the quadrant connected to the levers engage in a pinion wheel which is attached to the spindle actuating the pointer. By shifting the teeth that engage the pinion the position of pointer can be adjusted. On nearly all gages lost motion of parts is to some extent taken up by a light hair spring wound around the needle point. These hair springs should be of non-corrosive material. (Figs. 47, 48, 49.)

Gages are now fitted as single or double spring. The double-spring type is used to overcome the effect of vibration. Double-

FIG. 49. — Ashton Steam Gage, Double Spring.

spring gages are now being made which are as sensitive as the single-spring type.

The following are the requirements of the machinery specifications for steam and vacuum gages:

"All pressure and vacuum gages will be of approved pattern, with seamless Bourdon tubes; those graduated to over 100 pounds will have double tubes. Each gage will have an independent connection with the part whose pressure it is designed to register and will be suitably engraved to show to what it is connected. All interior parts to be made of non-corrosive materials. The dials to be made of brass silvered, with large figures and letters, cut deep and filled with black enamel. All gages to be accurately and correctly graduated to at least one and one half times the highest working pressure they are to register. All steam gages will be plainly marked in red, at the working pressure permissible. The gages to have heavy polished brass cases, with screwed bezels. All gages in the engine room will be nickel-plated.

"The 8½-inch engine-room gages will be grouped on gage plates at the working platform. The other engine-room gages will be on gage plates as near the working platform as possible.

"All gages intended for steam to have siphons placed below them. These siphons must contain sufficient water to fill the spring when under pressure and prevent steam entering therein; the siphons must also be so fitted that the water will not be drawn out of them when pressure is off gage.

"Each boiler gage will be connected to the boiler through an inverted siphon, without drain cock, and fitted with a three-way cock and a coupling for attaching test gage.

Fitting Gages. — All steam-gage connections should be led from the tops of pipes. Boiler gages should be led from the highest point of the boiler shell or drum. Vacuum gages should be led from the tops of condensers.

Shut-off cocks should be fitted at the connection to the pipe or boiler drum, and just below the gage.

A drain cock should be fitted close to the gage. This cock can be used to see whether the gage is working or not or whether the pipe is clogged up.

Drain cocks are sometimes arranged so that either the drain must be open or that the gage is in connection with the cock; in other words, that the gage cannot be shut off without some indication from the drain.

All steam gages should be fitted with siphons (a round turn in the tube connection). The siphon acts as a condenser, and causes the spring tube of the gage to be filled with water instead of steam or air.

Unless siphons are fitted, gages cannot be counted on as being thoroughly reliable. A U-bend in the tube connection just below the gage will act as a siphon, though not as well.

When gages are fitted with a long vertical connection, the connection will in time fill with water, and in this case the pressure recorded on the gage will be the pressure in the pipe or vessel plus the weight of the column of water. Sometimes such gages are adjusted for the amount corresponding to the column of water.

Gages to be accurate must be thoroughly well made of non-corrosive materials. Cheap gages are a dangerous economy.

Gages should be tested for accuracy once a quarter and whenever indications of incorrect readings are apparent.

Gage-testing apparatus is usually supplied. The apparatus consists of a pump or other means of obtaining pressure, and some method of attaching the gage to be tested and a standard with which it is to be compared.

One type (Star Brass Manufacturing Co.) of gage-testing apparatus usually supplied to the Engineer Department of naval vessels is illustrated. (Figs. 50 and 51.)

Testing Gages. — To test the gage see if gage reads correctly with only the piston on. This is usually equal to 5 pounds. Then place the weights successively and note the reading on the gage. The weights should be rotated to overcome the error of

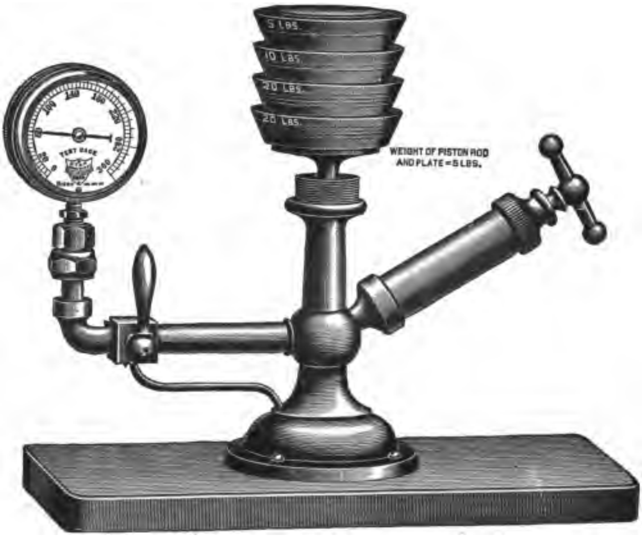


FIG. 50. — Gage Testing Apparatus.

the friction of the piston in the tube. If the gage readings correspond to the weights placed on the tester the gage is correct.

Gages should be more carefully tested at their working pressure, for it is at this position of their travel that correct readings are especially desired. If the readings do not correspond the gage must be adjusted. First, it should be found out whether the gage gives the correct increase for increment of weight. If the increments are the same the pointer only needs adjustment. To adjust the pointer the sector is moved out of gear with the spur wheel or arbor and then put in gear again so that the pointer indicates the proper reading. Most gages are fitted with a round arbor, and then the index can be shifted until it reads correctly.

The hand puller supplied with the gage-testing outfit should be used to remove the index.

If the increments of pressure are nearly constant or gradually increasing or diminishing, though not the same as the weights added, the gage can be adjusted by altering the length of the lever arm between the weight and the gearing, usually by slots or adjustable sleeves.

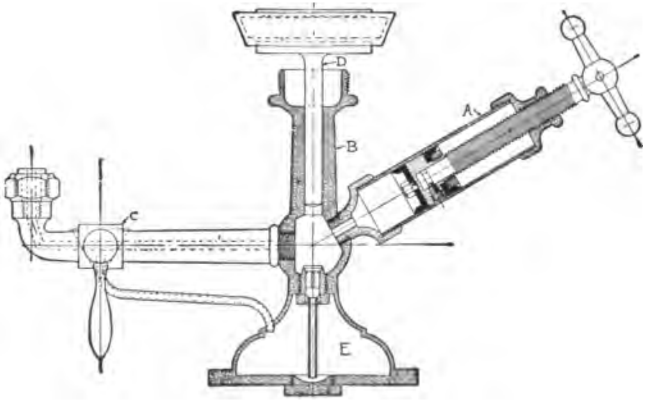


FIG. 51. — Section of Gage Testing Apparatus.

If possible the gage should be made to read correctly at its working pressure even if somewhat incorrect at other pressures.

The pin to stop the motion of the hand is not placed at zero in high-pressure gages, but is usually set at three to five pounds.

Vacuum gages are usually calibrated by a comparison with a U-shaped mercury manometer. They can be compared with the mercury column usually fitted to the main air pumps.

DEAD WEIGHT GAGE TESTER — SECTIONAL VIEW

To Fill Gage Tester. — Place three-way cock with the wording "drain cylinder" on washer up, with piston in cylinder A at the bottom, then pour oil in cylinder B and gradually withdraw piston in cylinder A until oil disappears, gradually filling cylinder B until piston in cylinder A is completely withdrawn, then fill cylinder B to top and the gage tester is then ready for use.

To Test Gage. — Connect gage with suitable connection that is furnished with gage tester to union above three-way cock, place handle of same so that triangular washer showing the wording "to test gage" is uppermost, then insert piston D in cylinder B and add weights to same until required pressure is reached; piston D should be kept revolving while making test. After making test, turn three-way cock so washer shows the wording "drain gage" uppermost, then remove gage, withdraw piston in cylinder A, and remove weights as they were added. Care should be used in turning three-way cock so as to reduce pressure in gage gradually. The plate on end of piston D should be kept about 2½ inches above top of cylinder B; this may be done by screwing piston in cylinder A. After continued use reservoir E will become filled and cylinder A can be filled from same with piston in cylinder B with the wording "drain gage" showing on washer of three-way cock, and gradually withdrawing piston in cylinder A.

After using, remove piston D, and screw cap on cylinder B to protect same from dirt. Any light mineral oil may be used in the instrument. Suitable wrenches, etc., accompany the instrument for connecting gages and adjusting same.

Thermometers. — The thermometers used are either ordinary portable thermometers or stationary ones located at various points.

Permanent stationary thermometers are usually fitted for main injection and overboard discharge, on feed tanks, air-pump discharge, feed pipe, on boiler side of heater, and sometimes on the main steam pipe.

Until recently the type fitted on most vessels was the metallic dial type. The principle of this thermometer is based on the difference of expansion between two different metals, copper and tin; the movement being used to move a pointer over a dial graduated to degrees of temperature. Owing to the corrosive effect of the moisture and the vibrations and shocks present in marine installations, these thermometers are usually found unreliable a short time after they are fitted.

The following is the present requirement for thermometers for naval vessels. (Extract from machinery specifications.)

"There will be the following high-grade, fixed, mercurial thermometers, with 9-inch black scales and white figures, each in heavy brass case of V-section, front protected by heavy glass plate.

"Each will be threaded for ½-inch gas pipe, and will have separable socket threaded for ¾- or 1-inch gas pipe, the socket to be fitted with cap attached to chain. Stems not over 4 inches long.

"Thermometers will be placed so as to be easily accessible for reading and removal, and will be either straight or angle, depending on location.

"Casings and fittings to be of polished brass.

LOCATION AND NUMBER	GRADUATED TO DEGREES F.
1 on each main steam pipe	200 to 750
1 on each main injection pipe	150
1 on each main overboard-delivery pipe	150
1 on each air-pump discharge	220
1 on each feed tank	220
1 on main feed pipe in each engine-room near discharge from feed heater	250
1 straight-stem, nitrogen-filled, flue-gas thermometer, 30-inch stem, 12-inch scale case, with adjustable scale and flange, all in case	1000
1 6½-inch metallic-dial platinum pyrometer with stem at least 30 inches long	2000
2 spare water thermometers	250
2 spare water thermometers	150
1 spare ice-machine thermometer	
8 spare mercurial thermometers for salinometer pots	150 to 240

"The air-pump discharge and feed-pipe thermometers will be so fitted as to waste no feed water.

"Thermometers will be suitably engraved to show to what they are connected."

The separable socket enables the thermometers to be removed for safe keeping during repair operations without delay or disturbance of connections. The requirement of a standard-size connection enables any one thermometer to be quickly replaced by any other.

The detail of thermometers can be seen from the accompanying Fig. 52.

In order to avoid turning thermometer to screw it into the socket, some have this connection made with a union. By means of the union the thermometer need not be turned to fix it in place, and can be made securely tight in any position that may be best for reading it.

The best types of thermometers are now hydrogen filled. The tube of the thermometer has the space above the mercury filled with the gas under pressure, which effectually prevents the scattering or separation of the mercury column and permits attaching the straight-stem type in a horozontal position or at any angle without incurring inaccuracies. This is a feature especially desirable on board ship.

Proper sensitiveness to changes of temperature is secured through a perfect metallic contact between the tapering stem of the thermometer and the surfaces of the socket. The accuracy of this contact should be tested in inspecting thermometers.

The space between the metal sleeve and the glass bulb is filled

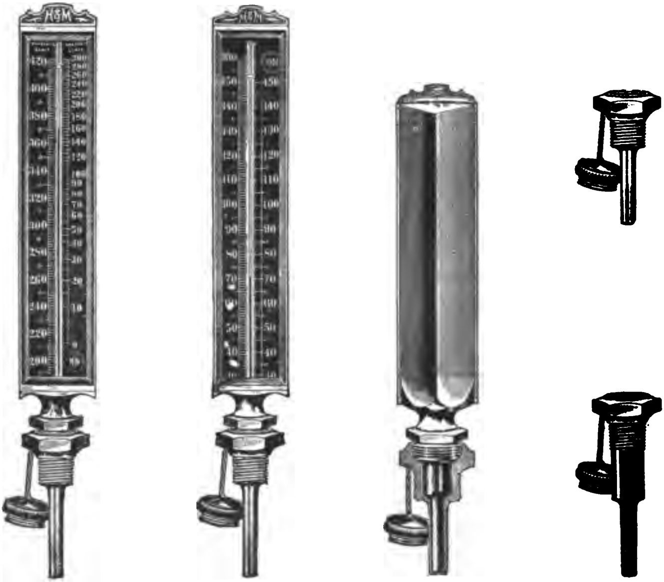


FIG. 52. — Stationary Thermometers with Separable Socket.

with mercury, hence there is direct metallic contact between the glass bulb and the substance whose temperature is measured.

Pyrometers having a long stem are supplied for measuring smoke stack temperatures. They are portable and are only put into position on the smoke stack or uptake while the temperatures are being taken. They are constructed on the same principle that the metallic-dial thermometers are.

The flue-gas mercurial thermometers registering up to 1000 degrees, are used for the same purposes as the pyrometers.

Rules for the Care of Thermometers. — Never expose a thermometer to a temperature likely to be close to or above the limit of its graduation. The mercury will expand, fill up the whole space, and then break the tube. Avoid jars and vibrations as much as possible; this should be considered in locating their positions. Keep thermometers right-end up to avoid scattering mercury.

Thermometers should be frequently tested for freezing and boiling point, and compared with others that are likely to be accurate.

CHAPTER XXI

Revolution Counters — Telegraphs and Revolution Indicators.

Revolution Counters. — The speed of revolution can be obtained either by counting, by noting the reading of a revolution counter for a time interval, or by the use of tachometers or speed indicators.

Continuous revolution counters are fitted to the main engines, air and circulating pumps. These counters consist of a series of gears arranged to work a set of dials which show the number of revolutions. The arrangement of the gearing is shown in the cuts. That shown in Fig. 53 (Star Brass catalogue) is arranged to register rotary or reciprocating motion; that in Fig. 54 is for rotary motion and is a type specially designed for the requirements of the Bureau of Steam Engineering.

Tachometers. — These are illustrated in Fig. 55 (Manning, Maxwell and Moore cata-

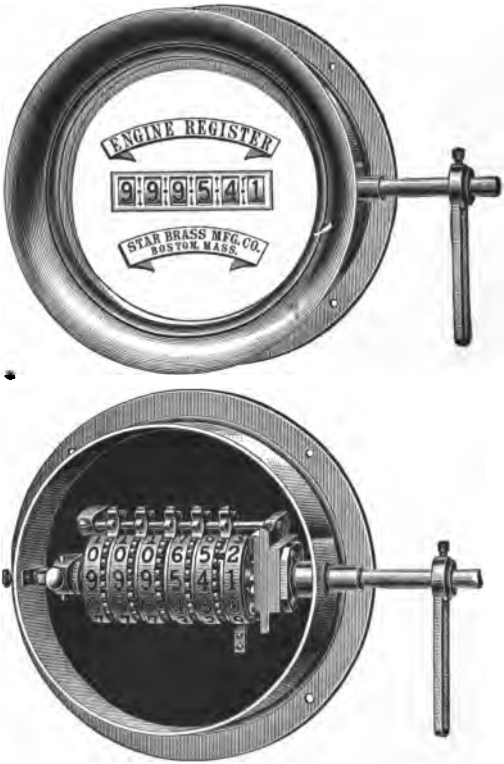


Fig. 53. — Revolution Counter.

logue, 1902). Tachometers make use of the centrifugal force in throwing outward either a weight or a liquid. The resulting motion moves a needle across a graduated dial, a distance proportional to the speed so that the number of revolutions may be read directly. In using the tachometer the pointed end is held against the center

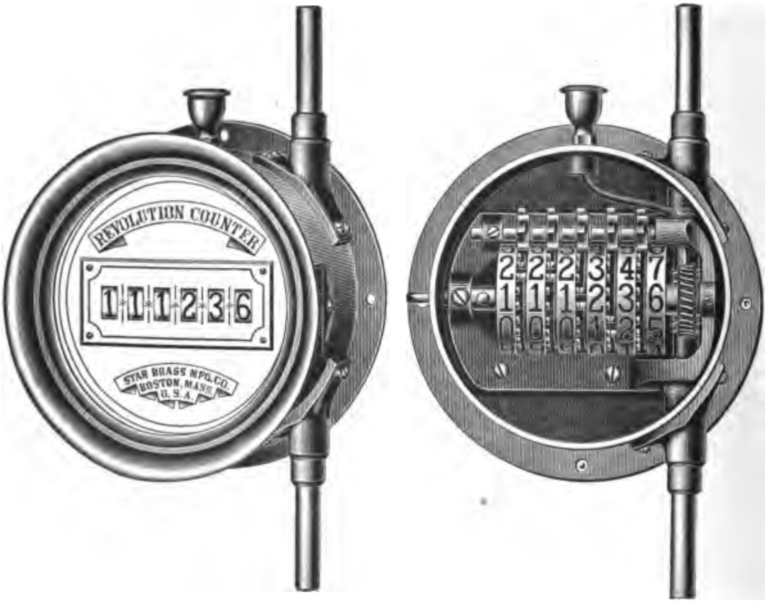


FIG. 54. — Revolution Counter.

of the shaft and the speed read when the dial hand has become fairly stationary.

Self-timing and Registering Speed Indicator. This instrument is shown in Fig. 56 (Manning, Maxwell and Moore catalogue, 1902). These instruments are very handy for use on speed trials. The setting pin, A, should be pressed firmly inward until it stops, which will set the hands at 0 and wind the power spring. The point being attached as in cut, or in case the shaft runs in the direction followed by the hands of a watch, to the upper pinion, is then placed in the center of the shaft to be timed, brought as nearly as

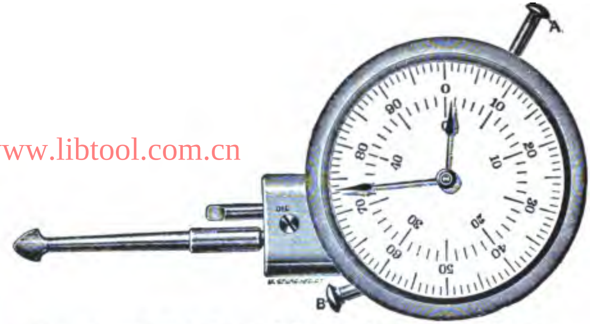


FIG. 56. — Self-timing and Registering Speed Indicator.

FIG. 55 — Hand Tachometer.

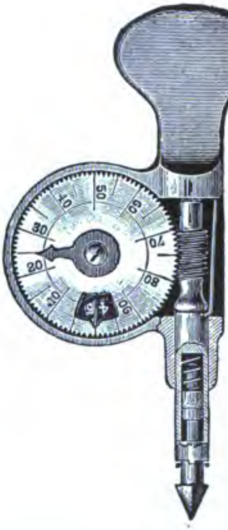


FIG. 57. — Hand Counter.

possible in line with it, and held with just enough firmness to prevent slipping. The starting pin B should then be pressed firmly inward and released, which will start the hands and at the same time release the time train. The instrument must now be held steadily in place until the hands stop, when the rate of speed may be read on the dial, the outer graduated circle indicating revolutions, the inner one, hundreds of revolutions.

The time train runs for half a minute, but the instrument registers the revolutions for a full minute.

Hand Speed Counters. — A simple hand speed counter is illustrated in figures 57 and 58 (Manning, Maxwell & Moore catalogue), and one with a stop-watch attachment in Fig. 59. The hand counter is used in connection with a watch, the number on the dial being

FIG. 58. — Hand Counter.

noted at the beginning and end of a certain time interval; the difference between the two gives the number of revolutions for the interval.

Telegraphs and Revolution Indicators. — Mechanical telegraphs for the purpose of transmitted orders for operating the engines from bridge to engine room are now all made to conform to a certain standard as per Fig. 60.

The principal attention that these devices require are occasional oiling of pulleys and adjustment of the length of chain. In warm weather or where the leads are in proximity to boilers the heat will cause the chains to lengthen. This is especially so on vessels having a long lead.

This slack is taken up by turn buckles placed at intervals. The spiral springs which control the bell clapper sometimes become weak and have to be renewed.

Mechanical telegraphs for transmitting orders from engine room

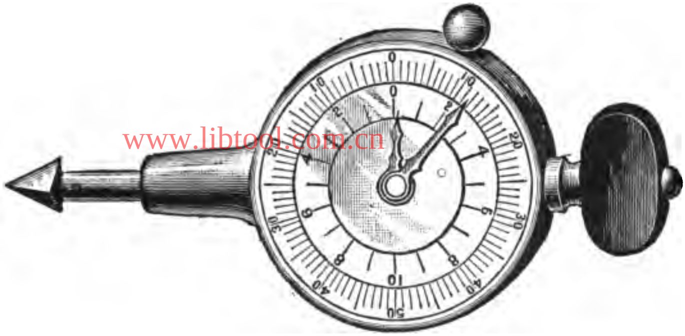


FIG. 59. — Hand Counter with Stop Watch.

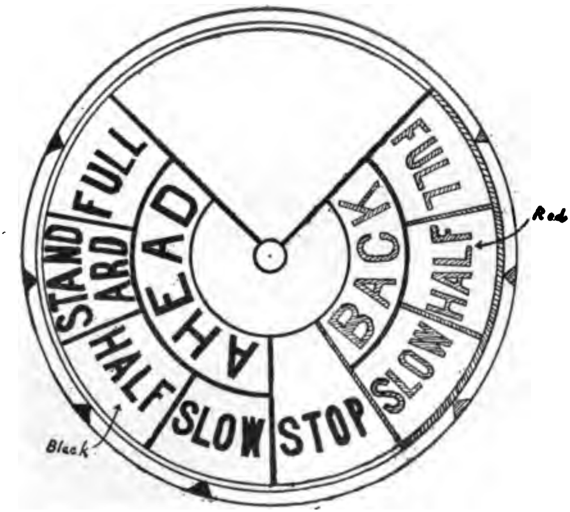


FIG. 60. — Standard Engine Room Telegraph Dial.

FIG. 61. — Monitor Electrical Speed Recorder.

to boiler room are also fitted. These are arranged so that all the dials are operated when any one of them is moved.

An electric revolution regulator to indicate to engine room to go one to five revolutions slower or faster is also fitted; there being a

FIG. 62. — Mechanical Revolution Indicator.

light for each number on the dial and an electric bell which rings when the contact lever is moved.

Electric speed indicators are fitted on some vessels which tell the rate of revolutions at which the engine is moving.

A cut of one of these is also shown. (Fig. 61.)

Electric revolution tell-tales are fitted for each shaft. A contact maker operated by a cam on the shaft and which makes one contact at every revolution is located in shaft alley. This is connected with a case which has mounted on it two small index hands which move at every contact made. The circuit is wired so the go-ahead hand moves when engine is moving, the go-ahead direction, and the backing hand moves when backing. Usually accomplished by a cut-out on the reversing shaft.

A mechanical revolution indicator (Fig. 62), is fitted in each engine room, placed so as to be readily seen from the working platform. They are worked from the engines from positive movements. The dials are graduated to 100 revolutions, each graduation indicating one revolution of the engines.

The object of these indicators is to furnish a means of showing the relative speed of both engines on one dial at the same time. This is done by connecting each of the main engine shafts, by means of gearing, to a separate dial hand on the same dial as shown in Fig. 62. Each engine drives one of the hands; the one connected to the starboard engine is painted green and that connected to the port engine, red. As the engines revolve the dial hands move. If the two engines keep up the same speed of revolution the hands will remain together or keep the same distance apart. If different speeds are kept they will separate. Clutch couplings are fitted to throw hands out of gear and one of the hands is held loosely on its shaft so that it can be adjusted by hand.

CHAPTER XXII

Piping — General Requirements — Description of Piping Systems — Details of Different Systems — Erecting and Repairing Piping on Board Ship — Drains — Steam Traps.

Piping. — The various piping systems are among the chief items for care and repair on board ship. The following general information with regard to the latest practice of the Bureau of Steam Engineering is given:

"PIPE FLANGES AND FITTINGS

"The dimensions of all flanges will be in accordance with the Bureau of Steam Engineering table of flanges.

"There will be no screw joints in steel steam piping. The joints will be made by flanges of stamped or forged mild steel of the same quality as specified for steel steam pipes. The pipe will be either welded to the flange or else rolled into the flanges and beaded over to fit a recess flush with the face of the flange, in accordance with the practice of the Bureau of Steam Engineering. All flanges will be faced and grooved.

"Copper pipes will have flanges or approved composition couplings brazed on, and the end of the pipe will be beaded into a recess in the face of the flange.

"All copper pipes below the floor-plates will have composition flanges.

"All joints between flanges in steam and exhaust pipes will be made with corrugated-copper gaskets.

"All joints between flanges in water-pipes will be in accordance with Navy Department Standard No. 86, 'Method of making joints and of obtaining water-tightness through bulkheads, decks, etc.'

"All flanges on the main drain connections to the main circulating pumps, and Construction and Repair drainage manifolds for connection with steam machinery, will be located to the satisfaction of the Bureau of Steam Engineering and the Bureau of Construction and Repair.

"Flanges for wrought-iron or steel pipes, for salt water, to be cast or wrought steel, galvanized.

"Fittings for steel steam pipes will be of cast-steel, Class B, or composition.

"Fittings for copper pipes will be of composition unless otherwise directed.

"Fittings for wrought-iron or steel pipes, for salt water, to be of cast-iron or steel, galvanized.

"Pipes will be so led and flanges so placed that they may be readily taken down for renewal or repairs, and so that joints will be kept readily accessible.

"All external fittings on boilers will be composition unless otherwise directed, and will be flanged and through-bolted, or attached in other approved manner.

"All internal pipes will not touch the boiler-plates anywhere, except where they connect with their external fittings. The internal feed and blow pipes will be expanded in the holes in boiler shells to fit the nipples on their valves, or will be secured in other approved manner, and will be supported where necessary and as directed.

"All internal pipes and fittings of brass, copper or composition will be tinned.

"All copper pipes intended to convey salt water will be protected on the inside by coats of asphaltum or other approved waterproof varnish, applied as hot as possible and in successive coats.

"All copper pipes in bilges will be well painted, and will not rest in contact with any of the iron or steel work of the vessel.

"All wrought-iron and steel pipes and tubing, for salt water, to be galvanized after they have been bent and flanges fitted.

"Care will be taken that all copper pipes are led sufficiently high to keep them out of the bilge water under ordinary circumstances.

"Feed pipes will be placed, where possible, well above the floor plates.

"Pipes will be led in such a manner that no stiffeners on bulkheads or beams on decks will have to be cut.

"Removable plates will be fitted on bulkheads where necessary to allow flange bolts to be properly set up; these plates to be fitted and made watertight to the satisfaction of the Bureau of Construction and Repair.

"Where pipes pass through watertight bulkheads the holes will be made watertight, by stuffing boxes, flanges, or other approved means, to the satisfaction of the Bureau of Construction and Repair. In no case will any of the watertight structure of the vessel form a part of the piping.

"Where pipes pass through wooden decks, they will be fitted with a hollow casting and a stuffing box, so arranged that non-conducting material may be fitted between movable and fixed parts, the details to be satisfactory to the Bureau of Construction and Repair.

"Where pipes pass through coal bunkers they will be protected by galvanized-iron casings, made in sections, easily removable for repairs.

"When such pipes are clothed or lagged the galvanized-iron casing will be dust tight.

"Pipes will not be led under openings of coal chutes.

"*Material of Pipes.* — Pipes will be of the following materials:

PIPES	MATERIAL
All pipes less than 2 inches diameter	Copper, unless otherwise directed.
All steam pipes 2 inches diameter and above.	Steel, seamless drawn. Copper when directed by Bureau.
All feed suction pipes	Copper, seamless drawn.
All feed discharge pipes	Copper, seamless drawn.
Pipes to reserve feed-water tanks	Lap-welded wrought iron or steel tubing, galvanized.
All steam, air and water pipes of refrigerating plant.	Copper, unless otherwise directed.

PIPES	MATERIAL
Steam fire-extinguishing pipes to bunkers, outsides bunkers.	Copper.
Steam fire-extinguishing pipes to bunkers, inside bunkers.	Galvanized iron.
Cooling pipes in refrigerating room.	Galvanized iron.
Cooling pipes in scuttle butts........	Copper, well tinned on the outside.
Suctions from bilge, crankpits, shaft alleys, and C. and R. drainage manifolds.	Lap-welded wrought iron or steel tubing galvanized.
All internal pipes in boilers.........	Brass or steel, No. 14 B.W.G.
All water-service pipes on main or auxiliary engines.	Brass, polished above floor plates.
Copper and brass pipes 6 inches diameter and less.	Seamless drawn.
Other pipes......................	As directed and approved.

"*Thickness of Pipes.*—All pipes will be of approved size.

"The thickness of pipes will be found by the following formulæ:

"For straight copper pipe—

$$T = \frac{P \times D}{8000} + \tfrac{1}{16} \text{ inch.}$$

"For steel steam pipe—

$$T = \frac{P \times D}{10{,}000} + \tfrac{1}{8} \text{ inch.}$$

"Where P = pressure above atmosphere in pounds per square inch;
D = inside diameter of pipe, in inches;
T = thickness, in inches.

"For the following pipes:

PIPES	$P =$
Steam, bleeder, blow pipes, suction pipes from boilers,	265, boiler pressure.
Feed discharge pipes	$1\frac{1}{2} \times 265$.
Fire main connections, copper water-service pipes, feed-suction pipes..................................	150.
Other water-pipes without pressure.................	50.
Exhaust pipes $4\frac{1}{2}$ inches diameter and less............	20.
Exhaust pipes above $4\frac{1}{2}$ inches diameter..............	50.

"All pipes not included in the above will be of approved thickness.

"No bend will be allowed in copper pipes of which the radius is less than one and one-half times the bore of the pipe. Bends in steel pipes will be as approved.

"In determining the thickness of bent pipes the neutral axis will be considered to lie on the inner surface of the bend, and when, in bending, the outer surface is reduced in thickness more than $\frac{1}{32}$ inch, the pipe must be one gage thicker than given by formula.

"*Expansion or Slip Joints.* — Composition.

"Expansion or slip joints of approved pattern will be fitted where required, and connecting pipes will be anchored in an approved manner. Each slip joint will consist of a composition stuffing box, gland, and entering pipe, the stuffing box and entering pipe having flanges for connecting with the pipe main, and there will be stop bolts and flanges for limiting the motion.

"All slip joints will be packed with approved metallic packing.

"All steam, exhaust and feed piping not fitted with slip joints will be run as approved, with ample bends, to provide for expansion. Such pipes will be so fitted as to put them under stress when cold by allowing for every 10 feet of length when bolting up a clearance between flanges of $\frac{3}{16}$ inch for steam pipes and $\frac{3}{32}$ inch for exhaust and feed pipes.

"*Systems of Piping.* — There will be the following systems of piping, together with such others as may be necessary to complete the machinery in accordance with the specifications and plans, viz.:

"Main steam and exhaust piping; auxiliary steam and exhaust piping, with branches to all auxiliary and special steam machinery in the vessel; bleeder pipes; live-steam pipes to intermediate and low-pressure receivers; dynamo steam and exhaust piping; main-feed suction and discharge piping; auxiliary-feed suction and discharge piping; bilge suction and discharge piping; sea suction and discharge piping; fresh-water suction piping and discharge pipes to reserve-feed water tanks; discharge piping from pumps to fire mains and sanitary system; water-service piping; boiler blow, pumping-out, and internal piping; distiller and evaporator piping; vapor, escape, drain, indicator, radiator, and fire-extinguishing piping, and steam piping to sea valves, refrigerator piping complete.

"Each system will be complete in itself, and all piping, together with valves, fittings and connections, will be shown on the working drawings."

Piping Systems. — The following systems are met with in the Navy.

Main Steam-Pipes are made of seamless drawn steel, with male and female flanges, and with gaskets of corrugated copper. The main steam line is arranged symmetrically in two systems, one on each side of the vessel. The branches from the boilers connect to the main steam pipe, which is successfully enlarged till it connects to the after boilers, which size is then carried to engine room. Stop valves are fitted near the forward bulkhead of each boiler compartment for the purpose of cutting out any boiler room. Cross-connections between the two systems are made generally at two joints; these are fitted with valves so that each system can be kept separate.

Inside the engine-room bulkhead there is another cross-connection. A separator is fitted for each engine, also a bleeder connection to condenser, a connection to the auxiliary exhaust line, a branch for live steam to receivers, and the branch leading to the throttle valve in which the main-engine stop valve is located.

Expansion joints are fitted generally between each bulkhead, and there should be such a joint between each point of anchorage.

Drains are fitted to all places where water may collect, and these are usually connected to traps, which discharge to the feed tanks.

Auxiliary Steam Pipes are of seamless-drawn steel, with male and female flanges, and gaskets of corrugated copper, except for pipes of small diameter where rubber insertion of strengthened asbestos packing is used.

In the latest practice the auxiliary steam pipe takes steam from the nozzle at the cross connection between the main steam pipes in engine room. The pipes pass along outboard sides of engine room and form a connecting loop. A branch pipe leads aft to supply steam to the after auxiliaries, expansion joints or expansion bends are fitted at intervals; drains and separators are fitted where pockets are formed.

From the forward cross-connection of main steam pipe in boiler rooms there is a branch pipe to supply steam to forward auxiliaries.

Branch Steam and Exhaust Pipes. — The general requirements for these may be seen from an extract of latest machinery specifications:

"BRANCH STEAM AND EXHAUST PIPES AND VALVES

"The size and lead of branch pipes to parts of ship outside of the machinery spaces will be subject to the approval of the Bureau of Steam Engineering. Such branches will always have stop valves in the engine or firerooms.

"1-inch branches from the auxiliary steam pipes will lead to the bottoms of main, auxiliary and dynamo condensers for cleaning the tubes by boiling.

"Connections will be made to the auxiliary steam pipe for supplying steam to sinks, steam table in pantries and crew's lavatories.

"Steam for galleys will be taken from the auxiliary steam pipe. through a separate pipe with reducing valves, steam gage, relief valve and stop valves, where approved.

"Each sea injection valve will have a steam connection of approved size for cleaning the strainer. This steam connection will be a branch pipe, with a valve at each end, leading from the auxiliary steam pipe to the injection pipe outside of the injection valve but inboard of the sea chest proper.

"Steam pipes to sea valves will be of the following sizes:

SIZE OF SEA VALVES	STEAM CONNECTIONS
6 inches and less	¾ inch
Above 6 inches and including 9 inches	1 inch
Above 9 inches and including 12 inches	1¼ inches
Above 12 inches	1½ inches

"All branches leading from the auxiliary steam pipe to crank engines will lead from the top or side of the pipe and in no case from the bottom. When the branch leads to a lower level the stop valve on the branch will be placed as high as possible, so that with the engine standing idle there will be no opportunity for water to collect in the vertical pipe leading to it.

"All branches leading from the auxiliary steam pipe to direct-acting pumps will lead from the bottom of the pipes.

"All auxiliary machinery will take steam from the auxiliary steam pipe and exhaust into the auxiliary exhaust pipe, except as follows:

ENGINE	TAKES STEAM FROM	EXHAUSTS INTO THE
Main circulating pumps, fire and bilge pumps, reversing engines.	Cross-connection pipe between the main and auxiliary steam pipes.	Auxiliary exhaust pipe.
Main air pumps	Cross-connection pipe between the main and auxiliary steam pipes.	Do.
Brine pump	Auxiliary steam pipe, also from evaporator tubes near discharge to traps, or from top of traps, to prevent the evaporators from becoming air bound.	Do.

"All branches and sub-branches of auxiliary steam and exhaust pipes must (unless excepted) have valves at junctions and ends.

"Each auxiliary engine will have stop valves in both steam and exhaust pipes, as close to the cylinder as possible.

"When a pump or an engine, connected with the auxiliary exhaust pipe, lies below the pipe, the stop valve next the pipe will have a spindle of sufficient length to be worked from below.

"All exhaust pipes leading to the condenser from engines above the protective deck will be fitted with valves below the protective deck."

Further Details. — Such auxiliaries as require it have their branch steam lines fitted with reducing valves.

The former practice was to have the auxiliary steam pipe connected to all the main stop valves, and a connection from auxiliary steam line to main steam line in each boiler room. This is the system installed on most vessels now in commission (January, 1906).

Auxiliary Exhaust Pipes are of copper, having flanges faced and grooved, steel bolts, composition nuts, copper gaskets, except for small pipes where strengthened rubber packing is used.

The auxiliary exhaust line forms a loop throughout the machinery compartments. All of the auxiliary engines have connections to it.

The auxiliary exhaust has connections so that it can be turned into either main or auxiliary condenser, into either L.P. receivers, into either feed-water heater or into the atmosphere through the after escape pipe.

At the connections to the condensers there is a stop valve and a spring relief valve opening toward the condensers for the purpose of regulating the pressure in the exhaust line when the exhaust is turned into the feed heater or L.P. receivers. At the connection to the escape pipe two valves are generally fitted to minimize the chance of air leaks.

On older vessels, especially where no feed-water heaters are installed, spring relief valves are not fitted on the connection to the condensers.

Dynamo steam and exhaust pipes are of same material as auxiliary steam and exhaust pipes.

The latest practice is to have two dynamo rooms, one forward and one aft. The steam is then taken from the forward cross-connection of main steam line and from a connection in after boiler room. The control valves are in the dynamo rooms. Separators and reducing valves are fitted in dynamo room, and drain pipes and traps supplied. The pipes are so arranged that in case of break at least one-half of the dynamo engines in each room may be operated.

The exhaust from the dynamo engines can be directed to the dynamo condenser or to the auxiliary exhaust pipe.

In older vessels there are often fitted on boilers, separate dynamo stop valves with a special system of piping. Separate dynamo condensers are only fitted on the latest vessels.

Steam Piping to Receivers. — This is taken from the main steam pipe and has branches leading to the L.P. and I.P. receivers. Stop valves are fitted close to main steam pipe and at each receiver, where the valve is operated by rod or lever from the starting platform.

Bleeder Pipes. — Bleeder pipes lead from the main steam pipe, forward of separator, to each main condenser. A stop valve is fitted at the connection to the main steam pipe, and there is another valve close to the condenser. One of these valves is fitted to be operated from or near the starting platform.

Escape Pipes are fitted abaft of each smoke stack and have branches leading to the safety valves of the boilers connected to their respective smoke stacks. The after escape pipe has a connection to the auxiliary exhaust line.

Vapor pipes are led from the feed and filter tanks and connect to the after escape pipe. The purpose of these pipes is to ensure an atmospheric pressure in feed tanks and to allow escape of air.

Pipes to Whistle and Siren. — These are branch pipes leading from the main or auxiliary steam pipes in the boiler room from some point that is likely to be always under steam.

Fire-Extinguishing Pipes to Bunkers. — These pipes lead from the main or auxiliary steam line to the bunkers and have valves at the bunker bulkheads. Bunkers above the protective deck sometimes have valves worked from the deck above by gearing. The pipes in the bunkers are fitted with special nozzles for distributing steam throughout the coal. In the latest practice this system is not fitted, and dependence is placed on fire hose or special water-sprinkling pipes.

Automatic System of Closing Valves. — On some late vessels the stop valves of boilers are closed by steam operating a piston connected to the valve; the system of piping for operating these valves takes steam from the main steam line. The control valves are located so that they are operated from the adjacent boiler compartment or from a station above the boiler.

This system or variations of it have in some cases been of questionable utility and reliability. Direct mechanical control is generally regarded with more favor by the operating personnel.

Fire-Extinguishers on Grates. — This system of piping is fitted on recent vessels. Nozzles are fitted for the furnaces, and the piping is either connected to the fire main or from the auxiliary pumps in adjacent boiler compartment. In some vessels these extinguishers take their water from the sea valve.

Separators. — The object of the separator is to extract the moisture contained in the steam. This is generally accomplished by an enlargement of the volume and a sharp turn around a baffle plate. Other types of separators give the steam a whirling motion, and the particles of water are thrown out by centrifugal force. In practice the simple separator gives about as great satisfaction as the more complicated ones fitted with elaborate baffling systems.

Separators must be frequently drained and the interior should be examined from time to time and have the grease deposits removed.

Expansion Joints. — To allow for expansion and contraction in piping due to change of temperature, and also for movement of the structure of the ship, vibrations, etc., expansion joints are fitted. The joints are packed with metallic packing, or with strengthened

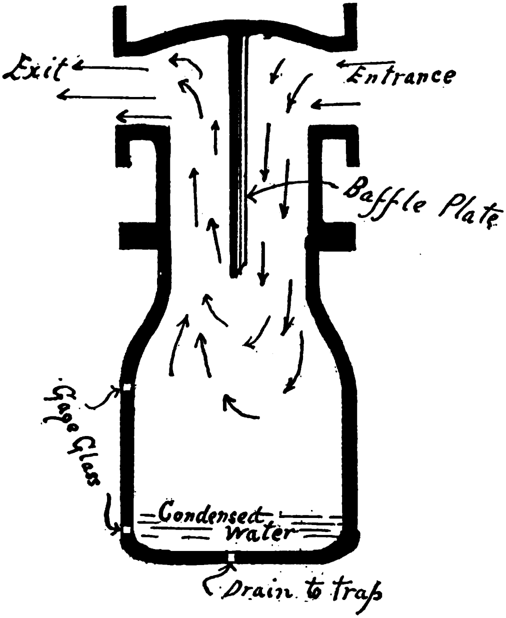


FIG. 63. — Separator for Steam Pipe.

woven asbestos packing. For small pipes and in feed lines bends instead of expansion joints are introduced to allow for the movement of pipes. By use of bends no danger of leakage is introduced and there is a saving of weight. Expansion joints will generally be found only on the larger piping.

Packing for Expansion Joints.—This is usually metallic, reinforced by asbestos woven rings. Specially prepared asbestos woven rings are also used without metallic packing.

Feed Piping. — Feed pipes are made of copper with composition flanges, steel bolts, and composition nuts, and packed with copper gaskets, wire gauze and red lead, or with thin wire insertion packing.

The auxiliary feed suction pipes take their suction from the feed-tank connecting pipe, or directly from feed tank, and lead forward to the boiler compartments. They have suction connections to all the auxiliary feed pumps in the boiler rooms.

The main feed suction pipe takes its suction from the cross-

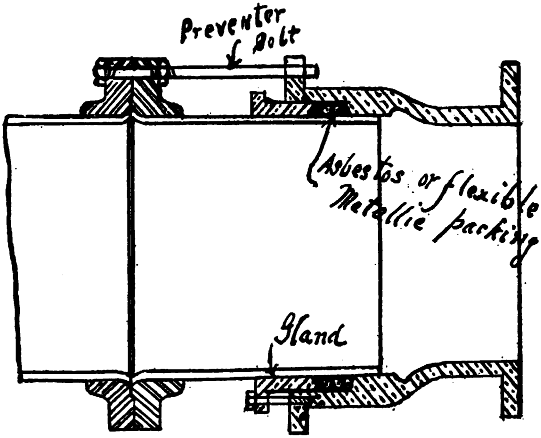


FIG. 64. — Expansion Joint.

connecting pipe of the feed tank or from the feed tank direct, and leads to the suction of main feed pump.

Feed discharge pipes lead from discharge side of main feed pump (through feed heater if fitted on suction side of pump) and then to the boiler compartment, having branches to discharge to boilers on its own side of the ship and a cross-connection to the opposite side. Gate valves are fitted to cut out portions of piping not in use.

On many vessels there is only one main feed line which supplies both sides.

The auxiliary feed pumps discharge into a fore-and-aft delivery pipe having branches so that all boilers on that side of the ship can be fed.

The lead of piping differs for nearly every vessel; both main and auxiliary feed systems are, however, installed in nearly all cases.

The cut-out valves in the main feed line are usually gate valves, to give a clear opening and reduce friction. The branches to the boilers have either stop valves or gate valves.

Feed pipes are fitted with bends to allow for expansion. Feed pipes should be covered with non-conducting material and are, as much as possible, carried above the floor plates.

Bottom and Surface Blow Pipes. — The bottom and surface blows of boilers are connected with a system of piping which connects to the overboard discharge valve in its own or adjacent compartment. This system of piping is connected to the fresh-water manifold of the auxiliary feed pump in the boiler compartment. This connection is for use in pumping out boilers.

In the latest vessels contracted for the auxiliary feed pumps have no salt-water connections whatever. This is to effectually guard against the possibility of salt entering the boiler feed.

Hot-well and Fresh-water Pumping System. — Where hot-well pumps are fitted they have a suction to the cross-connection pipes between the feed tanks and to a cross-connection between the two air-pump suction pipes, to suctions on ship's side for taking on board fresh water, and to reserve tanks for the purpose of distributing fresh water. These pipes are of copper, flanges faced and grooved, and packed with approved rubber packing.

The hot-well pump has discharge piping to the reserve tanks by means of a combination manifold where one pipe can be used for either suction or discharge.

The hot-well pump discharge to feed pump suction is arranged so as to pump through or by-pass the heater, if suction heater is fitted, and then to feed suction pipe. Where pressure heaters are fitted, the hot-well pump simply discharges into the feed suction, its object being to enable the main feed pump to obtain a good suction. A great many vessels have no hot-well pump, but there is usually a fresh-water pump for handling fresh water in reserve tanks and for pumping fresh water on board.

The piping to and from the reserve-feed tanks in the latest vessels is of wrought iron or steel, galvanized, the same as bilge and drainage piping.

Air-Pump Piping. — This consists of (1) a suction pipe from condenser to air pump. 2. A discharge from air pump to feed and filter tank, and a connection running across the ship, connecting the two air-pump suction pipes. By means of this cross-connection either air pump can work on either condenser. This cross pipe also has connections to the hot-well pump or to some of the feed pumps, so that these pumps can pump direct from the condenser. Such a connection would enable the condenser to be used, although the air pump should be broken down.

The exact arrangement of air-pump piping can be understood only by an examination of the piping plans for a vessel.

Salt-Water Suction and Discharge Piping. — Pipes for circulating water for main, auxiliary and dynamo condensers.

These pipes are of copper, have composition flanges packed with rubber packing.

Zinc protectors are fitted in standard zinc boxes for preventing corrosion of the pipes. Joints in such piping are made in accordance with Standard No. 86, issued by the Navy Department.

Drainage Systems. — *Drainage Piping.* — The drainage piping of large vessels consists of a main and a secondary drain with their suctions, a double-bottom pumping system for the inner-bottom compartments other than the reserve feed tanks, the connections from these systems to the pumps, and the discharge pipes from the pumps overboard.

Main Drain. — The main drain is a pipe made of steel; for large vessels it is about fifteen inches in diameter. This drain extends throughout the machinery spaces and has a suction in each boiler and engine compartment. Each suction valve is fitted with gear for operating from above the protective deck.

The main drain has pumping connections to the bilge pumps in the engine rooms and to the auxiliary feed pumps in the fire rooms, on all but latest vessels, those contracted for after 1904. These connections are either direct or through the drainage manifold, which in late vessels is separate from the engineering manifolds at pumps, having connections to main drain, secondary drain, and double bottoms.

The main drain also has connections to each main circulating pump in the engine room.

On the latest vessels the connections from the drain to fire room, fire and bilge pumps have been omitted.

Secondary Drain. — This is a pipe varying in diameter from five to seven inches, and is located along the center line of the ship on the side opposite from the main drain. This drain is connected, in forward boiler room, to a manifold which has valves controlling the suctions to the forward parts of the vessel outside of the engine-room compartments. In the after part of the engine room it connects to a similar manifold which controls the suctions to the after compartments of the vessel. The secondary drain has suctions in each engine and boiler compartment with valves worked from above the floor plates, and on many vessels arranged to be worked from deck as well.

The secondary drain has pumping connections to the fire and bilge pumps and to the auxiliary feed pumps. These connections are either direct to the pumps or through the drainage manifolds. In the latest vessels contracted for after 1904 auxiliary feed pumps are not so connected. Secondary drain is sometimes called auxiliary drain.

Independent Bilge Suctions. — The bilge pumps in engine rooms have an independent bilge suction pipe, which has suctions to engine bilge, crank shaft, and, in latest practice, to shaft alley. Additional branch suctions are sometimes fitted to this pipe for the purpose of pumping out pockets difficult to keep dry.

The auxiliary feed pumps or boiler-room fire and bilge pumps have an independent bilge suction to the bilges of their own boiler compartments.

Strainers are fitted in all suction pipes for the purpose of collecting dirt from the bilge and preventing it from clogging pipes and pumps.

Valves and Manifolds. — The valves in manifolds at pumps are usually check valves arranged so that they can be raised off their seats by an extreme movement of the valve spindle, usually called stop-lift check valves.

In order to pump a compartment through the secondary drain it is necessary to open the suction valve for the compartment, the valve in the drainage manifold which controls secondary drain suction, and the stop valve separating drainage manifold from the pump manifold.

Double-Bottom Piping. — The double bottoms are connected to a double-bottom main, which is arranged so that the fire and bilge pumps or auxiliary feed pumps can pump on them either by a direct connection to the pump manifold or through the drainage manifold. Valves controlling the suctions to the compartments are located above each compartment and are arranged to be operated from above the floor plates.

On other vessels the system is arranged so that independent pipes, one from each compartment, lead to double-bottom manifolds located in the boiler and engine rooms.

The system of double-bottom piping with its manifold and valves is under the cognizance of the Bureau of Construction and Repair.

Water Service Piping. — The water-service piping consists of brass piping for conveying the water to various engine and thrust bearings.

On some vessels the water service takes its water from the discharge of main circulating pump, and the water, after leaving the bearing or guide, instead of going to the bilge is allowed to discharge to main circulating-pump suction, thus avoiding a very large amount of water in the bilges and crank pits.

Flushing System. — Material of pipe, copper. This system consists of a main supplied by a connection from the distiller circulating pump and also usually by a connection from the fire main. This pipe has branches supplying water to water closets, urinals, wash rooms, shower baths, laundry, pantry, and galleys. Relief valves are fitted to prevent an excessive pressure coming upon the pipe.

This pipe, from a flange located near the distillers, is under the cognizance of the Bureau of Construction and Repair.

Fire Main. — Copper. This system, on large vessels, consists of two large mains, one on each side of vessel, directly underneath the protective deck within the machinery spaces. These two systems are cross-connected and are connected by pump risers with the fire and bilge pumps in engine rooms, the fire and bilge or auxiliary feed pumps in boiler rooms and, in some vessels, with the distiller circulating pumps.

The risers from the pump are fitted with cut-out valves near the main. From the main on each side risers are taken, usually through some of the machinery hatches, and have plugs and short branches on the various decks.

Each riser is fitted with a cut-out valve below the protective deck close to the main. These valves are arranged to be worked from above the protective decks. By this arrangement it is possible to cut out any riser when damaged, without impairing the rest of the fire main.

The fire main has connections for flooding the magazines above the lower platform. There are also connections to each ash chute for flushing same. These last should more properly be connected with flushing system.

Plugs are arranged so that any part of vessel can be reached with a fifty-foot hose from two plugs.

All valves in fire main are composition gate valves. Chapman valves are largely used. The relief valves on fire main are set at one hundred pounds pressure.

Zinc boxes are fitted in the fire main to prevent corrosion.

The principal difficulty experienced with fire mains is the corrosion of pipes due to the action of salt water, and leaky valves. Of late most gate valves are fitted with removable seats which can be taken out and faced off in a lathe when the seat becomes rough.

All fire-main plugs are either 2½-inch or 1½-inch Navy standard.

The fire main and all risers from it are under the cognizance of the Bureau of Construction and Repair. The risers from the steam pumps to the fire main are under the cognizance of the Bureau of Steam Engineering.

The division of cognizance between the two Bureaus is at the flange on the main between the riser and the main.

Remarks on Erecting Piping on Board Ship. — *Steam Piping.* — A great deal of the trouble experienced with steam piping is due to want of alignment. This want of alignment operates to throw excessive strains on the flanges of stop valves, anchorages, separators and expansion joints. These strains are brought about by reason of the flanges being brought together by forcing on the connecting bolts instead of the joints coming fair without this outside assistance. Any joint that requires outside pressure to make the parts come together will cause trouble. When the flanges do not come together fairly they should be taken down and refaced, and, if necessary, a thin steel distance piece put in to make the required length. When erecting heavy pipes, every length should be placed in position and properly supported and aligned in its own brackets and hangers, before being permanently secured. It will usually be found that various lengths will have to be altered slightly before proper alignment is obtained.

Expansion and contraction due to change in temperature, to vibration and to slight movement of the structure of the vessel must be properly allowed for. To this cause most leakage in joints is due. The positions of anchorages, bends, valves, and branch connections will materially affect the ability of the piping to accommodate itself to the changes.

When certain joints are continually leaking, the connections should be carefully studied; often some slight alteration can be made in the anchorage, connections, hangers or lead of pipe that will allow for the necessary movement and prevent the strain which causes the leak coming on the joint.

Vibration is a prolific cause of leakage, especially in small steam piping. Vibration of pipes can often be largely stopped by placing bands or guys on the pipes that will stop the vibrating movement, but which will not prevent expansion or contraction due to temperature or to regular movement of the vessel. Often the pipe can be prevented from vibrating by taking a turn of wire around it and securing the wire to some part of the ship's structure.

Position for Drainage. — Steam pipes should be erected so that they will naturally drain themselves and so that pockets, where condensed water can accumulate, may be avoided. The danger from the accumulation of water is twofold: (1) water ram; (2) injury to packing. The pipe lines should be run so that the water of condensation will drain either back to the boilers or to the separator. Where the piping is long and complicated, drains should be fitted at frequent intervals.

Pockets where water collects are often formed by stop valves being placed so that their bodies form a water trap. An example is shown in cuts (Lunkenheimer Co.'s catalogue), Fig. 65. In the first figure the arrangement permits the accumulation of condensed water above the valve when it is closed, and by careless opening water hammer may result. In the second figure the forming of a water pocket is avoided. In any case where such pockets are unavoidable a drain should be fitted, and this drain should be open before the large valve is opened.

Care in Fitting. — The greatest care should be exercised in fitting pipes to see that all dirt, grease, parts of gaskets, scale or little pieces of metal are not left in the piping, since this foreign matter is liable to get into the valves and cause them to leak. In smearing flanges with grease care should be taken that this does not get into the piping and valve castings, since it will be carried to the bearing parts of the valve, and there, owing to its sticky nature, it will hold grit and scale on the seats and cause them to become scored.

Corrosion of Piping. — Internal pitting, due to air, is liable to be met with, and the interior of pipes should occasionally be examined to see if any is present. External corrosion is also liable to result from the combined action of the heat and moisture on asbestos pipe covering, causing pitting. This outside corrosion can be guarded against by giving the pipe a good coat of graphite paint before the covering is put on.

Repairing Leaks. — Leaks in copper piping are permanently

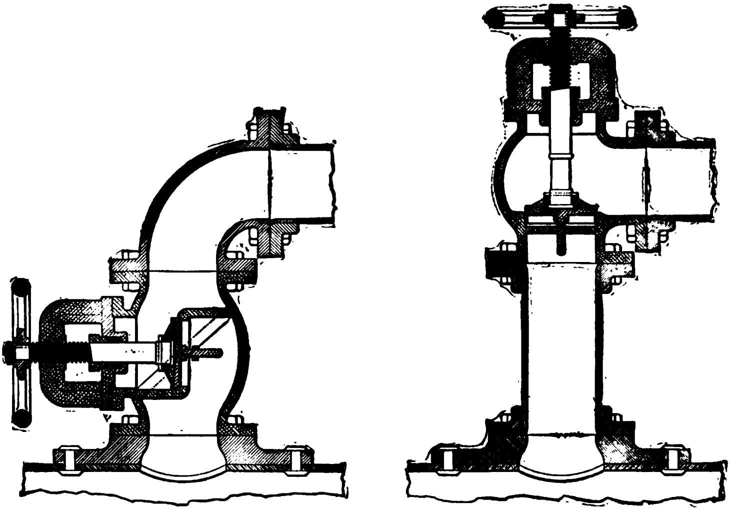


FIG. 65.

repaired by rebrazing the seam or by brazing on a patch. To braze on a patch, clean the metal carefully with file, emery cloth and hydrochloric acid. Cut out a piece of copper of suitable thickness and shape it carefully to the pipe, cleaning thoroughly the surface next to the pipe. The patching piece is securely wired in place. The pipe is then heated in a forge with a charcoal or coke fire. Spelter or hard solder, with borax as a flux, is placed over the hole on the inside and the whole heated, the pipe is moved and turned about to keep the brazing matter from running away from the patch. As the brazing mixture melts, it runs between patch and surface of pipe and makes a joint between the two. If the hole is very small, the brazing mixture may have to be put on the outside and caused to run in from one side of the patch. Great care must be exercised to prevent the pipe from burning. By the use of loam the heat may be directed to any one position and protect the other parts from injury.

A patch may be welded, riveted, or bolted on a steel pipe. If the leak is a small one on a thick pipe, the hole may be rounded out and a rivet put in from the inside and hammered over from the outside. Or the hole may be tapped out and a small plug screwed in and riveted over on the outside. It is, however, very difficult to make a permanent repair with the pipe in place, though often there is not sufficient time to take pipes down, and a temporary measure must be adopted.

Some Methods of Temporary Repair. — Place a putty made of red lead and oil, sometimes mixed with pieces of hemp to give strength over the leak, wrap with canvas, and then serve the pipe with marline. Or place a piece of packing over the putty and then serve with wire. Another way is to put on the putty and then serve the pipe with wire, and solder the wire on as it is being served. Clamps made of iron or brass and drawn up with bolts are often useful in holding the patch over the leak. A very secure patch can be made by shaping a piece of copper to the leak, then put a piece of soft packing coated with red lead between the pipe and copper and draw the piece of copper up with several bolted clamps. Pine plugs driven into holes form a ready means of stopping a leak in low-pressure water piping. After the plug is driven, the moisture will cause it to swell and continue to make it tighter. Pin holes may be closed by the use of soft solder. Portland and Smooth-on cements are also very useful in repairing leaks. Smooth-on cement is especially good for cracks in metal piping or castings.

Brass and copper piping in bilges should be kept well covered with paint. If there are bare places and the bilge water is brought into contact, galvanic action is liable to be set up.

Copper water piping is peculiarly liable to electric corrosive action. The use of zincs acts in some manner as a preventative, but where there is a continual flow of salt water it appears to be impossible to prevent the corrosive action. Tinning the pipes also acts as a preventative to some extent, but it does not stop the action. In order that the various sections of piping may not be insulated from each other by rubber gaskets at flanges, the flanges can be connected by short pieces of copper.

Drains. — Places where condensed steam can accummulate are provided with drain pipes with or without traps for conducting such water to the feed tanks or condensers.

The parts usually fitted with drains are as in the accompanying table:

MACHINERY DRAINS

PARTS DRAINED	DRAINS THROUGH —	DRAINS TO —
Main steam separators . . .	Approved automatic "float trap" with by-pass.	Main condenser, feed tank near bottom.
Dynamo steam separators.	Do.	Dynamo condenser.
Exhaust to low-pressure receiver (separator if directed.)	Do.	Main condenser.
Dynamo exhaust pipes (separator if directed).	Trap with by-pass and pumps (if directed).	Exhaust to dynamo condenser, above valve at condenser.
Aux. steam separator, steam pipes and valves.	Approved automatic "float trap" with by-pass.	Main condenser, aux. con., feed tank near bottom.
Whistle pipe and separator.	Do.	Feed tank near bottom.
Low-pressure jacket drain ($\frac{3}{4}$-inch diameter).	Approved automatic "float trap" with blow through, or "expansion trap."	Lower part of feed tank.
High-pres. evap. coils	Do.	Feed tank, main and aux. cond.
Low-pres. evap. coils	Do.	Same, with branch of dis. fresh-water pump suction.
Heater drains (each man).	Do.	Feed tank, main and aux. cond.
Galley steam drains	Do.	Feed tank, aux. cond.
Cylinder drains, main engine.	No trap, unite in pipe.	Top main cond. and to bilge.
Cylinder drains, aux. eng.	No trap	As approved.
Cylind. drains, dyn. eng.	No trap	Dyn. cond. above valve.
Cylinder relief valves	No trap. Drain pipes.	Bilge.
Valve-chest drains	Do.	Main cond. and bilge.
Feed-water heaters	Trap if required	Feed tank, main and aux. cond.
Where hot water passes . .	Float traps *must* be used.	As approved.

PARTS DRAINED	DRAINS THROUGH —	DRAINS TO —
Where warm water passes.	Float or expansion traps.	Do.
Bath heaters............	No trap.............	Most convenient aux. exhaust in continuous operation.

Drain pipes are of copper, and are fitted with unions where necessary so that the pipes can be readily disconnected for overhauling.

Steam Traps. — Steam traps are now fitted of many different kinds. They are of two general types: (1) the float trap, (2) the expansion trap.

The following extracts from an article by Lieutenant H. T. Winston, U. S. Navy, show the results of recent experience with steam traps in the U. S. Navy:

"*Types of Traps.* — The open-bucket float type, though bulky and somewhat affected by the ship's motion in a seaway, has given the most general satisfaction. It will take care of a sudden gush of water and requires no adjustment for varying pressures and temperatures.

"The hollow-ball float type has given some trouble on account of the ball corroding through, getting punctured or becoming detached. This type should give satisfaction if proper provision has been made to insure water-tightness of the float and if the float is securely attached to its lever.

"The expansion type of trap is superior to the float type in that it is not bulky, has few parts and lasts well. It does not work well where there are wide variations in the temperature or in the amount of water to be handled. Under such conditions trouble has been experienced with the frequent adjustments, irregular working of the trap and the leakage of steam.

"The following traps are largely used in the Navy: (float type) Dinkel, Nason, McKellar and Kieley; (expansion type) Geipel.

"*Requirements of a Good Trap.* — The best trap is the one that will discharge the water which collects without wasting steam and at the same time requires little attention. Other qualities to be considered are durability, simplicity, facility of overhauling, weight, size and cost.

"It is better to have the drain valve of a trap at the top of the chamber rather than at the bottom, where sediment collects. It is also an advantage to have valves outside the float chamber, where they may be cleaned and overhauled without breaking a joint.

"The bonnet of a float trap should be secured with studs, or if through bolts are used, the heads should be so fitted as to prevent turning. The facility for overhauling might be still further increased by the use of hinged bolts.

"The piping for all traps should be fitted with union couplings to facilitate the removal of trap for examination or repair. In case of an expansion trap, the discharge should be fitted with a by-pass to the bilge, by means of which it could be determined whether the trap was working properly.

"*Traps for Special Use.* — Where the quantity of water is subject to sudden variations, as in steam pipe and separator drains, the float type should be used. Where there is a slow, regular and continuous condensation at a practically constant temperature, the expansion type is satisfactory and often desirable.

"For cylinder jackets of main engines an arrangement similar to that on vessels of recent designs seems best; *i.e.*, steam goes from the H.P. jacket to the I.P. jacket through a reducing valve from the I.P. jacket to the L.P. jacket, through another reducing valve, and then drains through the I.P. jacket trap; one trap taking care of the water for the whole system.

"The following easily improvised substitute for a jacket trap has been used with success: a small cast cylinder, fitted with a drain valve and a gage glass, is placed in the jacket drain-pipe line. When in operation, the drain valve is opened just enough to keep the water in gage glass at a fixed height, the whole arrangement being near the starting platform, and readily seen.

"For steam radiators the bucket type generally gives the best results. Expansion traps when used should be placed close to the radiators and each trap should not drain more than two or three coils; they have been found to give considerable trouble when required to drain more than one heating circuit.

"For evaporators and feed heaters bucket traps have been extensively used. It is probable that an extension trap, carefully installed, would work efficiently on evaporator coils.

"Drains for feed-water heaters when discharging to condensers do not require traps, but if the heater drains discharge to the feed tank traps may be necessary.

"For steam separators and steam lines bucket traps must be used.

"*Location of Traps.* — A trap must be located below the lowest part of the vessel or pipe to be drained, and, if practicable, above the level of the tank into which it discharges, in order to prevent water backing up when the trap is not in operation. This applies particularly in the case of the expansion trap, which has given trouble in discharging against a head of water. Under certain conditions it may be necessary to fit a non-return valve in the discharge line.

"All traps, and particularly those which will need frequent overhauling, should be so placed as to be easily overhauled and examined. If a trap cannot be installed where it is fairly accessible for overhauling it should be omitted and a drain valve fitted instead.

"*Operation and Overhauling.* — Many traps are of no value on account of lack of care and attention.

"A float trap can be heard 'dumping' when in order, and may work satisfactorily for months without overhauling. Whenever the sound of dumping is not heard at intervals the trap should be examined at once. Less trouble is experienced with a large trap than a small one, as in the latter case valves are more easily clogged, thus causing a failure to discharge, or if not entirely stopped will permit a leakage of steam. This is particularly the case where there is likely to be sediment in the water.

"While experience is necessary to judge in each particular case the period a trap may be left without examination, it may be said in general that a large trap should never go more than three months or a small trap more than two months without examination and cleaning.

"By opening the expansion-trap discharge by-pass to bilge it may be seen whether the trap discharges water properly, and if it leaks steam. The trap should be tested frequently when in use, and adjusted and cleaned out if necessary."

Draining Steam Lines. — Steam lines and separators are fitted with drains usually led to traps, the discharge from the trap being led to the feed tank or the auxiliary condenser.

On some vessels main separators are also drained by leading a pipe from the bottom of the separator for operating some reciprocating pump, such as a hot-well pump. Dynamo separators are sometimes drained by leading a pipe from bottom for operating dynamo condenser pumps. By this system the separators are being drained continuously.

Draining Jackets. — In order that steam jackets may work efficiently they must be kept constantly drained. If jackets fill with water they do not impart any heat to the steam in the cylinder.

In the Navy there are two different systems for draining jackets. On late vessels, steam first enters the H.P. jacket, the discharge leads through a reducing valve to the I.P. jacket, then through another reducing valve to the L.P. jacket. The discharge from the L.P. jacket leads to a trap. The reducing valves placed between the jackets can be set to regulate the pressure in each of the jackets. Sometimes additional drain cocks are fitted at the bottom of each cylinder jacket to allow any water condensed in the jacket to be drawn off.

The other system is to have each jacket have its own independent steam connection, reducing valve, and trap.

While jackets are being used the traps should be occasionally by-passed to ensure that water is drawn off.

Cylinder Drains. — The cylinders and valve chest of the main engines are fitted with drain cocks at the bottom. These cocks are arranged so as to be operated by shafts and levers from the working platform; one lever being arranged to move all the cocks of each cylinder and its valve chest.

The drain cocks are high-pressure packed cocks.

The discharge from cylinder drains leads to a pipe which leads to condenser, and is usually fitted with branch to bilge.

The drains are led to the condenser to ensure thorough draining. To avoid blowing through to the condenser it is most important to see that the drain cocks are tight.

Particular attention must also be paid to see that the valves in branches to the bilge are absolutely tight.

Cylinder drains of auxiliary engines are either led to traps or to bilge. The large auxiliaries, such as dynamo engines and circulating pumps, usually have their drains led to traps. For the purpose of saving fresh water it would seem advisable to lead the drains of the various auxiliaries now going to the bilge, to the auxiliary exhaust. This has been done on some vessels.

Heater Drains. — Heater drains are led to traps which discharge to the feed tank or to the auxiliary condenser. In order to ensure pipes being thoroughly drained these traps should be ocasionally by-passed. If heaters are not properly drained they fill up with water and there is no proper heating effect. Drains from the galley and pantries are led to traps.

Bath-heater drains are led to the auxiliary exhaust line. At first these drains were led to traps, but as there was not a steady drain the heaters did not work well. When connected to auxiliary exhaust there is always a thorough draining.

The principal repairs to drains consist in tightening up on leaky joints, nipples, and unions, repairing split pipes, overhauling traps and grinding in and packing valves.

The principal cause for leaks is the accumulation of water in the pipes.

Valves are generally caused to leak by having their seats scored from dirt or scale in the piping, or by the valve disc and seat corroding from the action of salt, acid, or alkali in the drain water.

CHAPTER XXIII

Valves and Cocks — General Requirements Bureau Steam Engineering — General Remarks on Valves — Stop Valves — Check Valves — Gate Valves — Throttle Valves — Care and Overhaul of Valves.

Valves and Cocks. — Valves and cocks are fitted to regulate and distribute, open up and cut off the supply of steam, water, or other fluid contained in the piping and cylinders connected with the machinery and other parts of the engineering plant.

The general requirements of the Bureau of Steam Engineering relating to cocks and valves are as follows:

"*Valves and Cocks.* — The dimensions of all valves, unless otherwise directed, will be in accordance with the Bureau of Steam Engineering table of standard valves.

"Valves of approved pattern will be supplied wherever necessary to complete the various pipe systems, whether specified or not.

"The size of a valve, when given in these specifications, refers to the diameter of the equivalent clear opening.

"Gate valves will not be used on steam or exhaust pipes, except where approved.

"All valves in feed suction and discharge pipes, except boiler or other check valves, will be gate valves, of approved design, unless otherwise directed.

"Draincocks will be fitted on all cylinders, boilers, pipes, and other parts of machinery where required.

"*Material and Fittings of Valves and Cocks.* — All valves subject to superheated steam will be as follows:

Bodies, cast steel, "Class B." Valves, cast steel, "Class B." Valve seats, nickel. Valve stems, "Class B" forgings. Handwheels, composition N-c. Glands, composition G.	Letters refer to specifications for material issued by Bureau of Steam Engineering.

"All other valves and cocks and their fittings, except as otherwise specified or approved, will be of composition G.

"Valve stems will be of composition P, T-r, or Mn-r.

"All valve stems will be so threaded as to turn right-handed to close.

"The valve stems of all steam valves larger than ¾ inch and of all other valves larger than 1 inch will have outside square or "Acme" threads.

9	25 1/2	10 1/8	11 1/4	5 1/2	15 3/8	15	10	11	11 1/8	1 7/8	1/8	1 3/8	1/4	15/16	2 1/2	1 7/8	3 1/2	1/2	1/16	2 5/8	10	20	1/2	7/16	2 1/8	13/16	13 5/8	14	3/4	4	1/2	3	1/2	1 1/8	5/8	3/4	5/8	3 3/4	2 7/8
9 1/2	26 3/4	10 3/4	11 5/8	5 7/8	16	15 3/4	10 1/2	11 1/2	11 3/4	1 7/8	1/8	1 7/16	1/4	15/16	2 3/4	2	3 3/4	1/2	1/16	2 3/4	10 1/2	21	1/2	7/16	2 3/8	13/16	14 1/8	16	3/4	4	1/2	3	1/2	1 1/2	3/4	7/8	3/4	4 1/4	3 1/8
10	28	11 1/4	12	6 1/8	16 5/8	16 1/2	11	12	12 1/8	2	1/8	1 1/2	1/4	15/16	2 3/4	2	3 3/4	5/8	1/16	2 3/4	11	22	1/2	7/16	2 3/8	7/8	14 7/8	16	3/4	4	1/2	3	5/8	1 1/2	3/4	7/8	3/4	4 1/4	3 1/8
10 1/2	29 1/4	11 3/4	12 1/2	6 3/8	17 1/2	17 1/4	11 1/2	12 1/2	12 7/8	2	1/8	1 1/2	1/4	15/16	2 7/8	2	3 7/8	5/8	1/16	2 7/8	11 1/2	23	1/2	7/16	2 3/8	7/8	15 3/4	18	3/4	4	1/2	3	5/8	1 1/2	3/4	7/8	3/4	4 3/8	3 1/8
11	30 1/2	12 1/8	13	6 5/8	17 3/4	18	12	13	13 1/4	2	1/8	1 1/2	1/4	1	2 7/8	2 1/4	3 7/8	5/8	1/16	2 7/8	12	24	1/2	1/2	2 3/8	7/8	16	18	3/4	4	1/2	3	5/8	1 1/2	3/4	7/8	3/4	4 3/8	3 1/4
11 1/2	31 3/4	12 5/8	13 1/4	6 7/8	19	18 3/4	12 1/2	13 5/8	13 3/4	2 1/8	1/8	1 5/8	1/4	1	3	2 1/4	4	5/8	1/16	3	12 1/2	25	1/2	1/2	2 5/8	7/8	17	18	7/8	4	1/2	3	5/8	1 5/8	3/4	7/8	3/4	4 1/2	3 3/8
12	33	13	13 5/8	7 1/8	19 5/8	19 1/2	13 1/8	14 1/4	14 3/8	2 1/8	1/8	1 5/8	1/4	1	3	2 1/2	4	11/16	1/16	3	13	26 1/2	1/2	1/2	2 5/8	7/8	17 5/8	18	7/8	4	5/8	4	5/8	1 5/8	3/4	7/8	3/4	4 1/2	3 3/8
12 1/2	34 1/2	13 3/8	14 1/4	7 1/2	20 1/8	20 1/4	13 5/8	14 3/4	14 7/8	2 1/8	1/8	1 5/8	1/4	1	3 1/4	2 1/2	4 1/2	11/16	1/16	3 1/8	13 1/2	28	1/2	1/2	2 5/8	7/8	18 1/8	20	7/8	4	5/8	4	5/8	1 5/8	3/4	7/8	3/4	4 5/8	3 5/8
13	36	13 3/4	14 3/4	7 3/4	20 5/8	21	14 1/8	15 1/4	15 3/8	2 1/4	1/8	1 3/4	1/4	1	3 3/8	2 3/4	4 5/8	11/16	1/16	3 1/4	14	28 1/2	1/2	9/16	2 5/8	7/8	18 5/8	20	7/8	4	5/8	4	5/8	1 5/8	7/8	1	7/8	5 1/8	3 3/4
13 1/2	37 1/2	14 1/8	15 1/4	8	21 1/8	21 3/4	14 5/8	15 3/4	15 7/8	2 1/4	1/8	1 3/4	1/4	1	3 1/2	2 3/4	4 3/4	3/4	1/16	3 3/8	14 1/2	29	1/2	9/16	2 5/8	7/8	19 1/8	20	7/8	4	3/4	4	5/8	1 5/8	7/8	1	7/8	5 1/4	3 7/8
14	39	14 1/2	15 3/4	8 3/8	21 7/8	22 1/2	15 1/4	16 3/8	16 5/8	2 1/4	1/8	1 3/4	1/4	1	3 1/2	3	4 3/4	3/4	1/16	3 3/8	15	31	1/2	5/8	2 3/4	7/8	19 7/8	20	7/8	4	3/4	4	5/8	1 5/8	7/8	1	7/8	5 1/4	3 7/8
14 1/2	40 1/2	15	16 1/4	8 5/8	22 3/8	23 1/4	15 3/4	16 7/8	17 1/8	2 1/4	1/8	1 3/4	1/4	1	3 5/8	3	4 7/8	3/4	1/16	3 1/2	15 1/2	32	1/2	5/8	2 3/4	7/8	20 3/8	20	7/8	4	3/4	4	5/8	1 5/8	7/8	1	7/8	5 3/8	4
15	42	15 1/2	16 3/4	9	22 3/4	24	16 1/4	17 3/8	17 1/2	2 1/4	1/8	1 3/4	1/4	1	3 5/8	3	4 7/8	3/4	1/16	3 1/2	16	33	1/2	5/8	2 3/4	7/8	20 3/4	22	7/8	4	3/4	4	5/8	1 5/8	7/8	1	7/8	5 3/8	4

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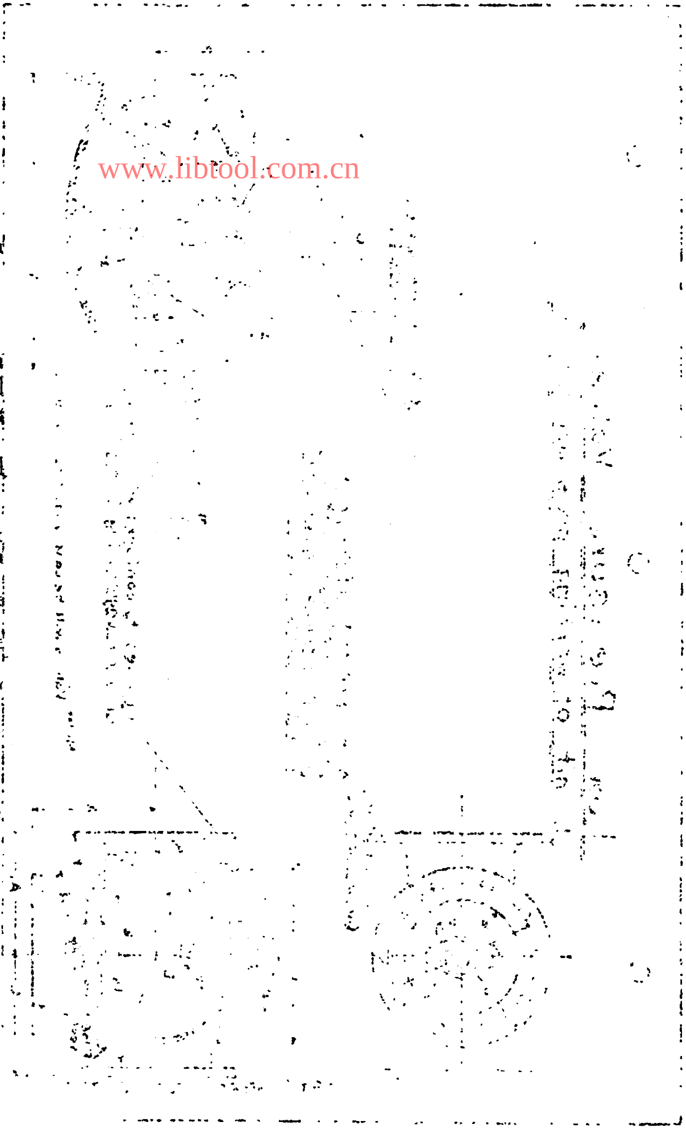

"All sea valves and all high-pressure valves, except gate valves, will have the threaded part of valve stem work in a forged-steel crosshead, supported by forged-steel standards.

"The valve stems of sea valves will be in a vertical position if possible.

"The stems of valves should not point below the horizontal except where required for convenience in working from below.

"Handwheels, unless otherwise directed, will be composition N–c. All handwheels, conspicuously located in the engine rooms, will be finished all over; other handwheels, unless otherwise directed, will have rims and faces of bosses finished.

"All handwheels will be at least one and one-half times as great in diameter as their valves.

"All gate valves will be fitted with indices to show whether they are open or closed.

"All valves and cocks underneath the floor plates will have their wheels or handles easily accessible.

"Valves and cocks will have, where directed, removable box or socket wrenches in lieu of handwheels or permanent handles. These wrenches will be so fitted that they can be removed only when the valves are closed, and they will be marked and stowed in convenient racks.

"The handles of all draincocks will point downward when closed. All cocks communicating with vacuum spaces will have bottoms of shell cast in, and will have packed plugs. All cocks over 1 inch in diameter will have packed plugs. Plug cocks will not be used on pipes more than 2 inches in diameter.

"All valves will be so fitted as to be easily ground in, and where required there will be grinding in guides and handles.

"No conical-faced valve will have a bearing on its seat of more than $\frac{3}{16}$ inch in width.

"All valve chambers will be so placed that their discs may be readily withdrawn.

"All steam valves $\frac{3}{4}$ inch and above, and all exhaust valves 1 inch and above, will be flanged.

"All steam valves above 8 inches diameter will have by-pass valves 1 inch diameter.

"All valves 3 inches and above will have bolted covers.

"All gate valves $1\frac{1}{4}$ inches diameter and above will have removable seats.

"All gate valves above 5 inches in diameter, subjected to a pressure above 50 pounds per square inch, will have by-pass valves to relieve the valves when jammed on their seats. For gate valves above 5 and to 8 inches in diameter, the by-pass valves will be 1 inch in diameter; from 8 to 12 inches, $1\frac{1}{2}$ inches in diameter, and above this, 2 inches in diameter.

"All cocks and valves on boiler drums, unless fitted on pads or in other approved manner, will have spigots, or nipples passing through the boiler plates."

The schedules of standard valves for various pressures issued by the Bureau of Steam Engineering are shown abreast pages 187, 188, 190, 192.

Cocks. — Cocks are made in the shape of a section of a cone and depend on the wedging effect of this coned surface to keep them tight. A cock gives a clean straight through opening, which a stop valve will not give. Cocks are generally handier than valves, especially since they can be very quickly thrown open or closed. They are also, in some cases, cheaper, since one cock can in many cases take the place of several valves. They are, however, less reliable and the liability of making mistakes in opening wrong connections is much greater. Cocks are rather hard to keep tight and are harder to grind in than valves. For naval purposes valves are fitted in place of cocks wherever this is feasible; but where a full unrestricted opening is desired and where it is desired that opening and closing be accomplished quickly, cocks are used. Thus for cylinder drains, indicator connections, shut-off and drain cocks in connections to gages and instruments, cocks are used.

In order to be tight, the cock and its seat must be truly circular in section and the surface must be perfectly smooth. These parts are turned smooth in a lathe and after that the cock can be ground in on its seat with the use of emery or ground glass. This is done by coating the surface with the glass or emery, mixed with oil; then the cock is put in place and turned back and forth. The glass will grind the two surfaces till they are smooth and will make the surfaces fit together tightly. The character of the fit can be told by feeling how the cock turns. To actually locate the loose places the cock can be spotted. The surface of the cock is chalked or rubbed over with a very light coat of red lead. The cock is then inserted in its seat and turned. At places where the surfaces touch the chalk or red lead will be rubbed off. If the entire surface is rubbed it shows that the surfaces touch all over and that the cock is properly ground in. If the coating is only rubbed off in spots, additional grinding in will be necessary.

Small cocks and those not subjected to great pressure do not have a packed gland, but only some provision for holding the cock in place. Cocks, other than small ones subject to high pressure, have a gland. Steam cocks are usually packed with asbestos packing.

General Remarks on Valves. — Screw down valves may in general be divided into two classes, disc or stop valves and gate valves; both are extensively used in the engineer department of vessels. Some of the matters that determine whether a disc or a gate valve is to be used are the following:

"Space available. The gate valve, especially for large valves, requires less space.

"The desirability of having a clear through opening and thus avoiding excessive friction.

"The necessity for securing great tightness against heavy pressures. Gate valves are more difficult to keep tight.

"Corrosive action of the seats. A disc valve is much easier to grind in than is a gate valve, hence where the necessity of grinding in frequently appears, disc valves will be in favor. Nearly all valves handling sea water are disc valves.

"A disc stop valve is considered more reliable and positive in action than a gate valve, so it is used on the more important places where tightness is specially required.

9	1 15/16	1 3/4	1/2	10 1/2	1 1/8	11/16	1/2	4 1/2	3 1/2	2 15/16	12	1 3/8	7/16	–	–	–	–	9	2 7/8	11/16	2 3/8	1 1/8	2	1 5/8	7/8	4	1/2	9/16	5/32	1	5 1/8	2 3/4	8 5/8	1/2	5/8	2 3/4	2 1/4	4 3/4	2 1/2	2 1/2	1 5/16	14
9 1/2	2	1 3/4	1/2	11	1 1/4	3/4	1/2	4 5/8	3 5/8	3 1/8	12	1 1/2	1/2	–	–	–	–	9 1/2	3	11/16	2 5/8	1 1/4	2 1/4	1 3/4	7/8	4	1/2	9/16	5/32	1	5 3/8	3	9 1/8	1/2	5/8	3	2 3/8	5 1/8	2 3/4	2 3/4	1 7/16	16
10	2 1/8	1 7/8	1/2	11 1/2	1 1/4	3/4	1/2	4 3/4	3 3/4	3 1/8	12	1 1/2	1/2	–	–	–	–	10	3	3/4	2 5/8	1 1/4	2 1/4	1 3/4	7/8	4	1/2	9/16	5/32	1	5 1/2	3	9 1/2	5/8	3/4	3	2 1/2	5 1/4	2 3/4	2 3/4	1 7/16	16
10 1/2	2 1/4	1 7/8	1/2	12	1 1/4	13/16	1/2	4 7/8	3 7/8	3 1/8	12	1 5/8	1/2	–	–	–	–	10 1/2	3 1/4	3/4	2 3/4	1 3/8	2 1/2	1 7/8	1	4	1/2	5/8	3/16	1 3/16	5 5/8	3 1/4	10	5/8	3/4	3 1/4	2 5/8	5 5/8	2 3/4	2 3/4	1 7/16	16
11	2 1/4	2	1/2	12 1/2	1 1/4	13/16	9/16	4 7/8	3 7/8	3 1/8	12	1 5/8	9/16	–	–	–	–	11	3 3/8	3/4	2 3/4	1 3/8	2 1/2	1 7/8	1	4	1/2	5/8	3/16	1 3/16	5 3/4	3 1/4	10 1/2	5/8	3/4	3 1/4	2 3/4	5 3/4	3	3	1 5/8	18
11 1/2	2 3/8	2	1/2	13	1 3/8	13/16	9/16	5	4	3 1/8	10	1 3/4	9/16	–	–	–	–	11 1/2	3 1/2	13/16	2 7/8	1 1/2	2 3/4	2	1	4	1/2	5/8	3/16	1 3/16	5 7/8	3 3/8	10 7/8	5/8	3/4	3 1/2	3	6 1/8	3 1/4	3 1/4	1 5/8	18
12	2 1/2	2	1/2	13 1/2	1 3/8	7/8	5/8	5	4	3 1/8	10	1 7/8	5/8	–	–	–	–	12	3 5/8	13/16	2 7/8	1 1/2	2 3/4	2	1	4	1/2	5/8	3/16	1 3/16	6	3 3/8	11 3/8	5/8	3/4	3 1/2	3 1/8	6 1/4	3 1/4	3 1/4	1 5/8	18
12 1/2	2 5/8	2	1/2	14 1/8	1 3/8	7/8	5/8	5 1/8	4 1/8	3 1/2	10	1 7/8	11/16	–	–	–	–	12 1/2	3 3/4	13/16	3 1/8	1 1/2	2 3/4	2 1/8	1 1/8	4	1/2	3/4	3/16	1 3/8	6 1/16	3 5/8	11 3/4	5/8	3/4	3 3/4	3 1/4	6 5/8	3 1/2	3 1/2	1 7/8	21
13	2 3/4	2 1/8	1/2	14 5/8	1 3/8	7/8	5/8	5 1/4	4 1/4	3 1/2	10	2	3/4	–	–	–	–	13	3 7/8	7/8	3 1/4	1 1/2	2 3/4	2 1/4	1 1/8	4	1/2	3/4	3/16	1 3/8	6 1/8	3 5/8	12 1/4	5/8	3/4	4	3 3/8	6 7/8	3 3/4	3 3/4	1 7/8	21
13 1/2	2 7/8	2 1/8	1/2	15 1/8	1 3/8	7/8	11/16	5 3/8	4 3/8	3 1/2	10	2	3/4	–	–	–	–	13 1/2	4 1/8	7/8	3 3/8	1 1/2	2 3/4	2 3/8	1 1/4	4	1/2	13/16	3/16	1 1/2	6 1/4	3 3/4	12 5/8	5/8	3/4	4 1/4	3 3/4	7 1/4	4	4	1 7/8	21
14	3	2 1/8	1/2	15 3/4	1 1/2	7/8	11/16	5 3/8	4 3/8	3 1/2	10	2 1/8	3/4	–	–	–	–	14	4 1/4	7/8	3 3/8	1 5/8	3	2 3/8	1 1/4	4	1/2	13/16	3/16	1 1/2	6 1/4	3 3/4	13 1/8	5/8	3/4	4 1/4	4	7 1/2	4 1/8	4 1/8	1 7/8	21
14 1/2	3 1/8	2 1/4	1/2	16 1/4	1 1/2	7/8	11/16	5 1/2	4 1/2	3 7/8	10	2 1/8	3/4	–	–	–	–	14 1/2	4 3/8	15/16	3 1/2	1 5/8	3	2 1/2	1 1/4	4	1/2	13/16	3/16	1 1/2	6 3/8	4	13 1/2	5/8	3/4	4 1/2	4	7 3/4	4 1/8	4 1/8	1 7/8	21
15	3 1/8	2 1/4	1/2	16 3/4	1 1/2	7/8	11/16	5 1/2	4 1/2	3 7/8	10	2 1/4	3/4	–	–	–	–	15	4 1/2	15/16	3 1/2	1 5/8	3	2 1/2	1 1/4	4	1/2	13/16	3/16	1 1/2	6 3/8	4	14	5/8	3/4	4 1/2	4	7 3/4	4 1/4	4 1/4	2 1/16	24

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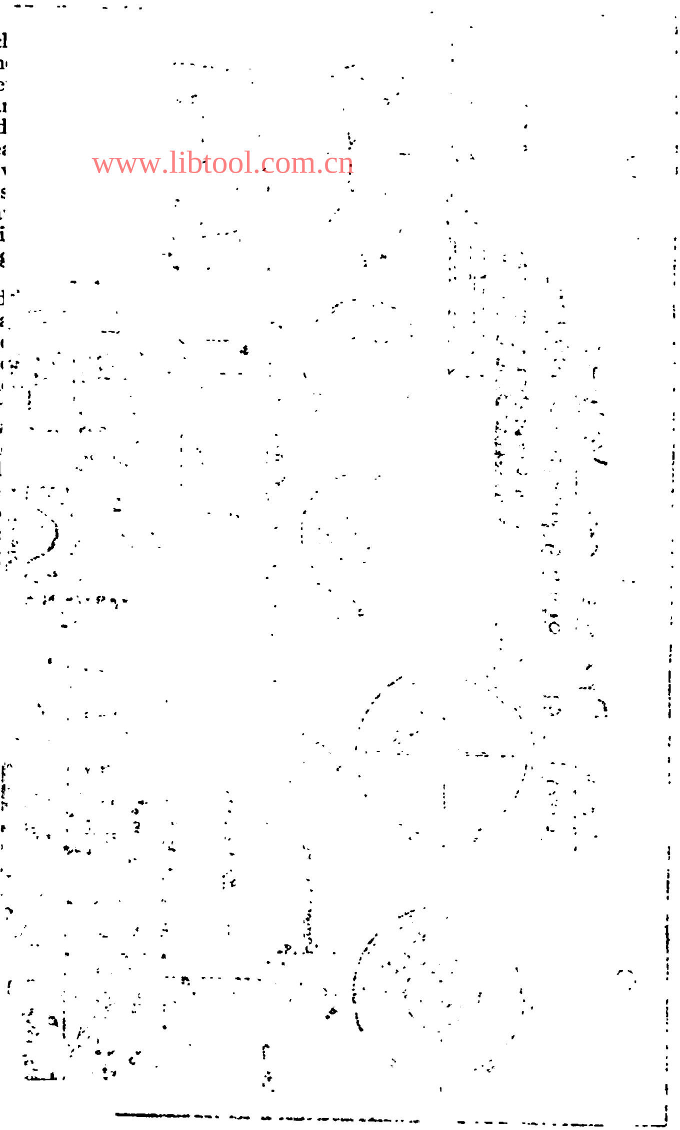


"*Stop Valves.* — These are the most common type of valve used. The general arrangement of globe and angle valves can be seen from the schedule

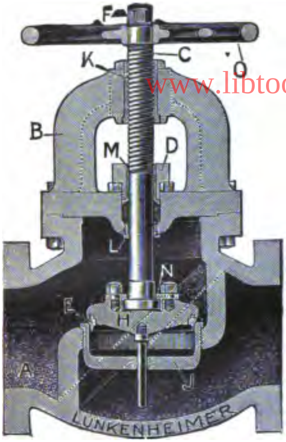


FIG. 66. — Sectional View of Extra Heavy Pattern Globe Valve.

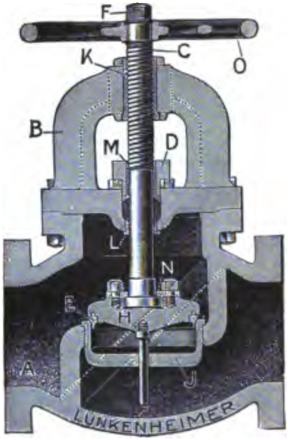


FIG. 66a.—Lukenheimer Heavy Screw-down Globe Stop Valve.

of standard valves. Other types of valves of commercial design are shown in the figures 66–67a. Inside screw valves are only used for the smaller sizes. The valve seats and discs are usually ground to an angle of 45 degrees. All large valves have spindle or wing guides to keep them from becoming cock-billed or thrown out of position. For small valves the stem furnishes sufficient guide. Seats are made removable so that they can be taken out and carefully ground when their surfaces become worn or damaged.

"*Stop-lift Check Valves.* — These valves are arranged so that they act as a check valve when the stem is partly screwed back, but an extreme movement of the stem will

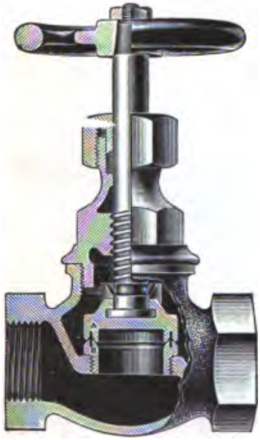


FIG. 67. — Crosby Spring Seat Stop Valve.

FIG. 67a. — Crane Stop Valve.

cause it to lift the valve; then it acts as a stop valve. These valves are largely used in pump suction manifolds where a non-return valve is desired but where

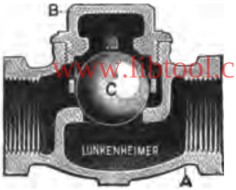


FIG. 68. — Horizontal Ball Check Valve.

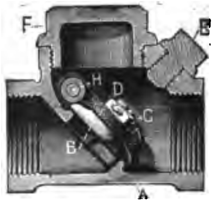
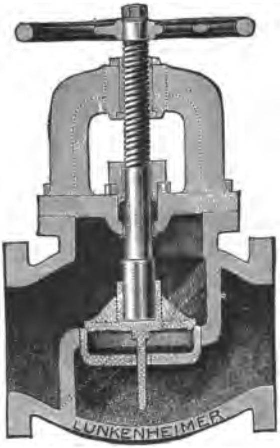


FIG. 69. — Horizontal Swinging Check Valve.

it is also desirable to be able to lift the valve. For low-pressure work ordinary check valves frequently become stuck on their seats, and in this case the advantage of being able to lift the valve off its seat is obvious.



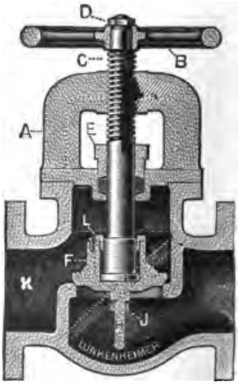


FIG. 70.

Sectional View of Screw-down Check Valve, Horizontal Pattern.

Sectional View of Screw-down and Lift-check Valve, Horizontal Pattern.

"*Check Valves.* — The check valve or non-return valve is arranged so that the contained fluid can only move in one direction; any tendency to change direction of flow will cause the valve to reseat itself and close. Check valves

9	25 1/2	10 1/8	11 1/4	6	16 1/2	15	10	11	11 1/8	1 7/8	1/8	1 3/8	13	3/16	1 1/4	3 5/8	3	4 7/8	15/16	1/8	3 1/2	12	20	1/4	3 1/4	3/4	2 1/8	1 3/4	7 3/4	1	14 1/4	14	1	4	5/8	3	5/8	1 1/2	7/8	1	7/8	5 3/8	4
9 1/2	26 3/4	10 3/4	11 5/8	6 1/4	17 1/2	15 3/4	10 1/2	11 1/2	11 3/4	1 7/8	1/8	1 7/16	13 5/8	3/16	1 3/8	3 7/8	3 1/4	5 1/8	15/16	1/8	3 5/8	12 1/4	21	1/4	3 1/4	3/4	2 3/8	1 3/4	8 1/4	1 1/8	15	14	1 1/8	4	5/8	3	5/8	1 5/8	7/8	1	7/8	5 3/4	4 1/4
10	28	11 1/4	12	6 1/2	18	16 1/2	11	12	12 1/8	2	3/16	1 1/2	14 1/8	3/16	1 3/8	3 7/8	3 3/8	5 1/8	1	1/8	3 5/8	12 3/4	22	-	3 1/2	13/16	2 3/8	1 7/8	9	1 1/8	15 1/2	14	1 1/8	4	5/8	3	3/4	1 5/8	7/8	1	7/8	5 3/4	4 1/4
10 1/2	29 1/4	11 3/4	12 1/2	6 3/4	18 3/4	17 1/4	11 1/2	12 1/2	12 7/8	2	3/16	1 1/2	14 7/8	3/16	1 3/8	4	3 1/2	5 3/8	1	1/8	3 7/8	13 1/2	23	-	3 3/4	13/16	2 3/8	2	9	1 1/8	16 1/4	16	1 1/8	4	3/4	3	3/4	1 5/8	1	1 1/8	1	5 7/8	4 3/8
11	30 1/2	12 1/8	13	7	19 1/2	18	12	13	13 1/4	2	3/16	1 1/2	15 1/2	3/16	1 3/8	4 1/8	3 1/2	5 1/2	1 1/16	1/8	4	14 1/4	24	-	3 3/4	7/8	2 3/8	2	9 1/4	1 1/8	17	16	1 1/8	4	3/4	3	3/4	1 3/4	1	1 1/8	1	6	4 1/2
11 1/2	31 3/4	12 5/8	13 1/4	7 1/4	20	18 3/4	12 1/2	13 5/8	13 3/4	2 1/8	3/16	1 5/8	16	3/16	1 3/8	4 3/8	3 3/4	5 7/8	1 1/16	1/8	4 1/4	14 3/4	25	-	4 1/4	7/8	2 5/8	2 1/4	10	1 3/16	17 1/2	16	1 1/8	4	3/4	3	3/4	1 3/4	1	1 1/8	1	6 1/4	4 3/4
12	33	13	13 5/8	7 1/2	20 1/2	19 1/2	13 1/8	14 1/4	14 3/8	2 1/8	3/16	1 5/8	16 5/8	3/16	1 3/8	4 1/2	3 3/4	6	1 1/16	1/8	4 3/8	15 3/8	26 1/2	-	4 1/4	15/16	2 5/8	2 1/4	10	1 3/16	18 1/8	16	1 1/8	4	3/4	4	3/4	1 3/4	1	1 1/8	1	6 3/8	4 7/8
12 1/2	34 1/2	13 3/8	14 1/4	7 3/4	21 1/2	20 1/4	13 5/8	14 3/4	14 7/8	2 1/8	1/4	1 5/8	17 1/8	3/16	1 1/2	4 5/8	3 3/4	6 1/8	1 1/8	1/8	4 1/2	15 3/4	28	-	4 1/4	1	2 5/8	2 1/4	10 1/2	1 3/16	18 3/4	18	1 1/4	4	3/4	4	3/4	1 3/4	1	1 1/8	1	6 5/8	5
13	36	13 3/4	14 3/4	8	22 1/4	21	14 1/8	15 1/4	15 3/8	2 1/4	1/4	1 3/4	17 7/8	3/16	1 1/2	4 5/8	4	6 1/4	1 1/8	1/8	4 5/8	16 1/2	28 1/2	-	4 3/4	1	2 5/8	2 1/2	11	1 1/4	19 1/2	18	1 1/4	4	3/4	4	3/4	1 7/8	1	1 1/8	1	6 5/8	5
13 1/2	37 1/2	14 1/8	15 1/4	8 1/4	23	21 3/4	14 5/8	15 3/4	15 7/8	2 1/4	1/4	1 3/4	18 5/8	3/16	1 1/2	4 3/4	4	6 3/8	1 3/16	1/8	4 3/4	17 1/4	29	-	4 3/4	1 1/16	2 5/8	2 1/2	11 1/4	1 1/4	20 1/4	18	1 1/4	4	3/4	4	3/4	1 7/8	1	1 1/8	1	6 3/4	5 1/8
14	39	14 1/2	15 3/4	8 5/8	23 3/4	22 1/2	15 1/4	16 3/8	16 5/8	2 1/4	1/4	1 3/4	19 3/8	3/16	1 1/2	5	4	6 5/8	1 3/16	1/8	4 7/8	18	31	-	4 3/4	1 1/16	2 3/4	2 1/2	11 1/2	1 3/8	21	18	1 1/4	4	3/4	4	3/4	1 7/8	1	1 1/8	1	6 7/8	5 3/8
14 1/2	40 1/2	15	16 1/4	8 7/8	24 1/4	23 1/4	15 3/4	16 7/8	17 1/8	2 1/4	1/4	1 3/4	19 7/8	3/16	1 1/2	5 1/8	4 1/4	6 7/8	1 3/16	1/8	5 1/8	18 1/2	32	-	5	1 1/8	2 3/4	2 3/4	12 1/4	1 3/8	21 1/2	18	1 1/4	4	3/4	4	3/4	2	1	1 1/8	1	7 1/8	5 1/2
15	42	15 1/2	16 3/4	9 1/4	24 3/4	24	16 1/4	17 3/8	17 1/2	2 1/4	1/4	1 3/4	20 3/8	3/16	1 1/2	5 1/4	4 1/4	7	1 1/4	1/8	5 1/4	19	33	-	5	1 1/8	2 3/4	2 3/4	13	1 1/2	22	18	1 1/4	4	3/4	4	3/4	2	1	1 1/8	1	7 1/4	5 3/4

used on board ship are of two general types, the swinging check and the stop or disc check. Disc check valves may or may not be spring loaded and they

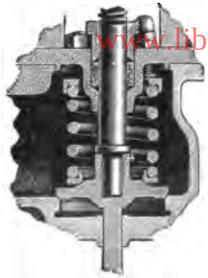


FIG. 71. — Detail Sectional View Showing Screw-down Check Valve with Spring.

FIG. 71a. — Crane Angle Check Valve.

may be screw-down valves or not. Different types are illustrated in the figures 68–71b. All pump suction valves are usually check valves. Swinging check valves are largely used in drain pipes from traps, steam lines, etc., in order to

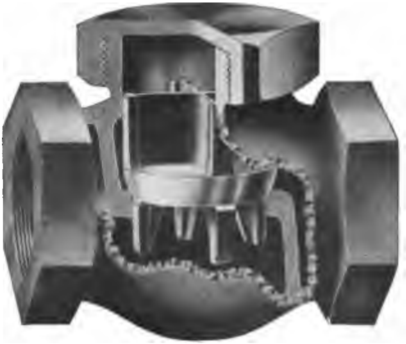


FIG. 71b. — Crane Check Valve.

keep water from backing up in a direction different from that in which it is intended to go.

"One of the most important applications of the check valve is the boiler feed check. This, in nearly all cases, is a spring-loaded, screw-down, disc-check valve. In order to prevent displacement of the check and to ensure the top of valve being covered with water, it is required that the valve cases be so made that the bottom of the outlet nozzle shall be at least one-half inch above the valve seat.

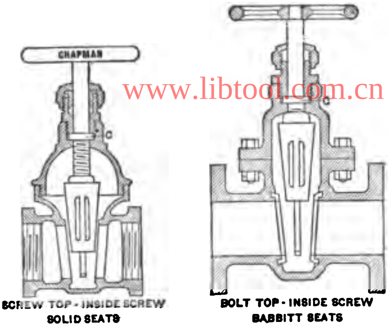


FIG. 72.—Screw Top, Inside Screw, Solid Seats; Bolt Top, Inside Screw, Babbitt Seats.

"*Gate Valves.*—Gate valves or straight-way valves are closed by having a gate moved from an offset at right angles to the line of valve. When a gate valve is used there is no change of direction and very little obstruction or irregularity caused to the flow of the fluid through it. Large gate valves are also more compact than stop valves of same size. The principal places where gate valves are used on naval vessels are, overboard discharge valves, air pump discharge to feed tank, valves in main exhaust to condenser, and feed lines. Gate valves are more difficult to keep tight under heavy pressures than are stop valves, hence in steam and feed lines with heavy pressures they are not used as the important cut-outs. Some types of gate valves are shown in cuts. (Figs. 72 to 73d.)

"Gate valves are made with inside and outside screw; the inside screw type usually have a non-rising stem. Small valves are usually made with inside screw and non-rising stem. In the rising stem, outside screw type the stem is securely threaded into the gate, and the hand wheel, whose boss forms a nut for the threads on the stem, in turning, causes the stem to raise or lower.

"Gate valves are made with and without removable seats. Removable seats are fitted to enable the seats to be removed for grinding them when their surfaces become damaged. The machinery specifications require

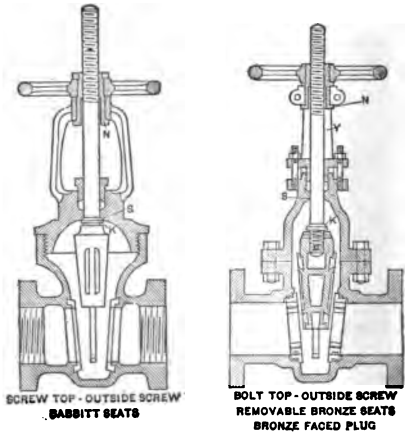
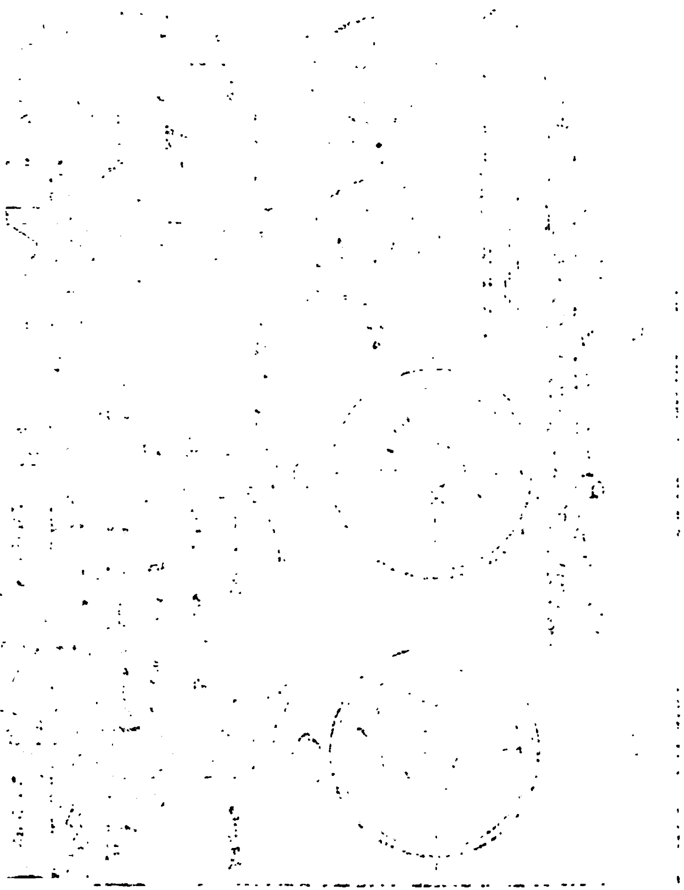


FIG. 73.—Screw Top, Outside Screw, Babbitt Seats; Bolt Top Outside Screw, Removable Bronze Seats, Bronze Faced Plug.

9½	2¼	1¾	½	11	1¼	15/16	11/16	5⅞	4⅞	3⅞	10	2	½	—	—	—	—	9½	2¼	3	15/16	3⅞	1¼	2⅞	2⅝	1½	18	⅞	7/32	1¾	4	2 3/16	1⅛	5⅝	4	1⅞	½	2 9/16	8¼	4⅝	1¾	1⅝	—	1 11/16
10	2⅜	1⅞	½	11½	1¼	1	¾	6⅛	5⅛	4¼	10	2	½	—	—	—	—	10	2⅜	3	1	3⅞	1¼	3	2⅝	1½	18	⅞	7/32	1¾	4	2¼	1¼	5¾	4	2	½	2¾	9	4⅝	1⅞	1⅝	2¼	1⅞
10½	2½	1⅞	½	12	1¼	1 1/16	¾	6⅜	5¼	4¼	10	2	½	—	—	—	—	10½	2½	3¼	1	4	1⅜	3	2¾	1½	18	⅞	7/32	1¾	4	2½	1⅜	6	4¼	2¼	⅝	2 13/16	9	5	2	1⅝	2⅜	1 15/16
11	2⅝	2	½	12½	1¼	1 1/16	13/16	6½	5½	4¼	10	2⅛	9/16	—	—	—	—	11	2½	3⅜	1 1/16	4⅛	1⅜	3⅛	2⅞	1⅝	21	15/16	7/32	1⅞	4	2½	1⅜	6¼	4½	2¼	⅝	2 15/16	9¼	5⅛	2	1⅞	2⅜	1 15/16
11½	2⅝	2	½	13	1⅜	1⅛	13/16	6⅞	5¾	4⅝	10	2⅛	9/16	—	—	—	—	11½	2¾	3½	1 1/16	4⅜	1½	3¼	3	1¾	21	1	7/32	2	4	2 13/16	1⅝	6½	4⅝	2½	¾	3⅛	10	5½	2¼	1⅞	2⅝	2⅛
12	2¾	2	½	13⅝	1⅜	1⅛	⅞	7	5⅞	5	10	2¼	⅝	—	—	—	—	12	2¾	3⅝	1 1/16	4½	1½	3⅜	3⅛	1¾	21	1	7/32	2	4	2 13/16	1⅝	6⅝	4¾	2½	¾	3⅛	10	5⅝	2¼	1⅞	2⅝	2⅛
12½	2⅞	2	½	14⅜	1⅜	1¼	⅞	7¼	6	5	10	2¼	11/16	—	—	—	—	12½	2¾	3¾	1⅛	4⅝	1½	3⅜	3¼	1¾	21	1	7/32	2	4	2 13/16	1⅝	6⅞	4⅞	2½	¾	3⅛	10½	6	2¼	1⅞	2⅝	2⅛
13	3	2⅛	½	14⅞	1⅜	1¼	15/16	7½	6¼	5	10	2⅜	¾	—	—	—	—	13	2¾	4	1⅛	4⅝	1½	3½	3¼	1¾	21	1	7/32	2	4	3⅛	1¾	7⅛	5	2¾	⅞	3½	11	6	2½	1⅞	3	2⅜
13½	3⅛	2⅛	½	15⅜	1⅜	1¼	15/16	7¾	6½	5⅜	10	2⅜	¾	—	—	—	—	13½	2¾	4⅛	1⅛	4¾	1½	3⅝	3⅜	2	24	1¼	7/32	2¼	4	3⅛	1¾	7¼	5⅛	2¾	⅞	3½	11¼	6⅜	2½	2 1/16	3	2⅜
14	3⅛	2⅛	⅝	16	1½	1⅜	15/16	8	6⅝	5¾	10	2⅜	¾	—	—	—	—	14	3	4¼	1 3/16	4⅞	1⅝	3¾	3½	2	24	1¼	7/32	2¼	4	3⅛	1¾	7½	5¼	2¾	⅞	3½	11½	6½	2½	2 1/16	3	2⅜
14½	3¼	2¼	⅝	16½	1½	1⅜	1	8¼	6¾	5¾	10	2½	¾	—	—	—	—	14½	3	4⅜	1 3/16	5	1⅝	3⅞	3⅝	2	24	1¼	7/32	2¼	4	3¼	2	7⅞	5⅜	3	1	3⅞	12¼	6⅞	2¾	2 1/16	3¼	2⅝
15	3⅜	2¼	¾	17	1½	1½	1	8½	7	5¾	10	2½	¾	—	—	—	—	15	3	4½	1¼	5¼	1⅝	4¼	3¾	2	24	1¼	7/32	2¼	4	3¼	2	8	5½	3	1	3⅞	13	7¼	2¾	2 1/16	3¼	2⅝



all gate valves above $1\frac{1}{4}$ inches in diameter to have removable seats. Special devices are often met with for enabling the surface of the gate to be pressed out securely against the seat. In some types, as the Ludlow valve, this is accom-

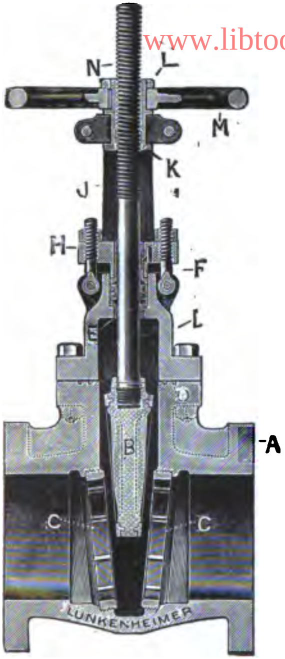


FIG. 73a. — Extra Heavy Gate Valve, Outside Screw and Yoke.

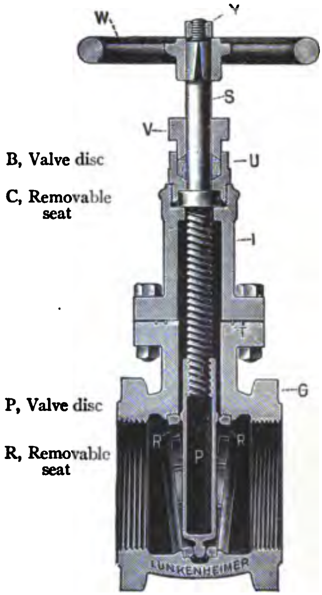


FIG. 73b. — Medium-pressure Gate Valve, Stationary Inside Stem.

plished by having the gate made in two halves so arranged that the extreme movement of the valve stem in closing will, by means of special wedged surfaces, cause the two parts of the gate to be pressed out sideways so that the edges of the gate bear tightly against the surface of the seat."

Throttle Valves. — The latest requirements of the machinery specifications for throttle valves are as follows:

"Each engine will have bolted to the high-pressure cylinder a throttle valve having a clear opening equal to 1.25, the area of the main steam pipe. The valve will be balanced by a piston which will work in a cylinder outside of the valve casing, steam being admitted to the back of the piston by means of a by-pass pipe and valve. The valves will be opened and closed by means of a system of levers which ensures quick working, or by a suitable arrangement

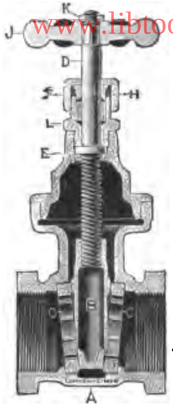


FIG. 73c. — Gate Valve, Inside Screw, Non-rising Stem.

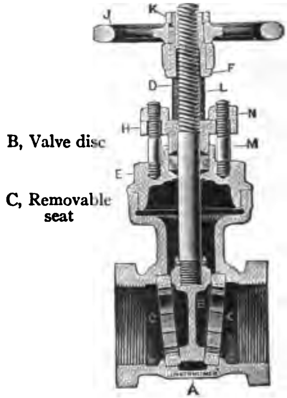


FIG. 73d. — Gate Valve, Outside Screw, Rising Stem.

of steam cocks. The amount of opening will be regulated or the valve firmly closed by means of hand wheel at the working platform. The stem of the valve will be vertical and an index will be provided to show the fractional valve openings in tenth parts of full opening. The throttle valves will be fitted with 2-inch by-pass valves, for warming up and slow running."

Besides the valves described above double balanced valves are largely used for throttle valves. An objection to the use of these valves for this purpose is that they cause a great disturbance in the flow of the steam, thus producing friction and causing a considerable drop in steam pressure.

Care and Overhaul of Valves. — The principal troubles that are met with are, (1) Leakage in valve, (2) packing of stuffing box, (3) valve stem sticking or coming loose.

Leakage. — Leakage is caused by the failure of the valve surfaces to come into actual contact all around the seat. Some of the numerous matters that may cause this are given below.

Bent Guide or Stem. — The valve guide, when a spindle guide, may be bent so as to prevent the valve from becoming properly centered. A bent stem may also cause this trouble.

Waste or Dirt on Seat. — Pieces of waste, scale, or dirt may get on the seat and prevent valve from seating. Such can often be dislodged by opening the valve and then moving it back and forth. If the obstruction cannot be removed in this way, the valve must be taken out and then the seat can be properly cleared. Care should be taken that the grease, etc., used for coating gaskets does not get inside of pipe or valve. Grease on seats will attract scale and dirt.

Valve or Seat Cut or Damaged. — This is generally caused by turning valve when some substance such as scale or dirt is on the surface of seat. Sometimes valve seats develop pit holes. Seats may also be damaged by trying to close valve when it is slightly cock-billed or out of line. To repair such damage the valve will have to be ground in or reseated. If the scoring is slight grinding in may be sufficient, if of considerable extent the valve will have to be reseated.

Valves are ground in by putting a coat of emery, or ground glass mixed with oil, on the surface of the seat, dropping the valve into place and turning it back and forth till a true surface is obtained. To reseat a valve a new cut is taken over the seat. This can be done in a lathe, but it may be done with a valve reseating machine with the valve in place.

Reseating Machine. — A cut of a large and a small "Morse and Dexter" valve reseating machine is shown. To reseat a valve the valve and valve bonnet are removed; a cutter of the required size is put on spindle of reseating machine. The machine is then attached and adjusted to the opening just inside of flange by the universal chuck, which has threaded adjusting jaws. The cutter is revolved by turning the upper hand wheel, for which a crank is supplied. Feed is adjusted by the second wheel; both flat and tapered seat cutters are supplied. By means of the Morse valve disc cutter attachment, shown on left, valve discs can be cut to a proper fit. The ring is held in a vise by a lug, the reseating machine being attached to the ring by the chuck jaws. The valve disc to be recut is securely fastened to the smaller chuck on machine spindle and is given a rotary motion by turning the crank, while the pointed tool is fed slowly over the valve disc to be redressed. (Figs. 74, 75, 76.)

Packing Stuffing Boxes. — When stuffing boxes leak the glands have to be set up or packed. Glands should not be set up so tightly as to cause stems to stick. Valves are often caused to turn very hard by reason of having the gland packed too tight.

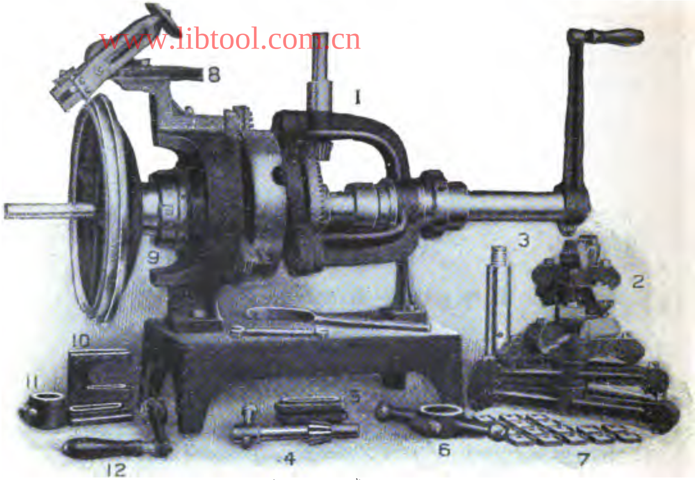


FIG. 74.

Valve Stems Sticking or Coming Loose. — When the valve stem is held to the disc by horse-shoe recess and split pin, the pin may sometimes come loose or break, thus allowing the valve to get adrift. When stems are secured by means of a screwed bushing, as on standard sheet, there is less likelihood of this getting loose. Such bushings should, however, be secured by set screws. Valve stems sometimes stick in the yoke through which they are threaded. This is often caused by dirt getting on the threads; sometimes threads are painted. The threads may become burred by rough handling and

FIG. 75.

this also may cause the stem to stick. On high-pressure valves where fine threads are used on stems and the metal of valve stem somewhat soft, the threads are caused to be turned over when a great pressure is brought on them in moving the valve. When a valve stem sticks it may sometimes be loosened by pouring on oil, or the

FIG. 76.

valve may be removed and a heavy turning force applied, which will enable the stem to be moved. If the stem cannot be moved, it will have to be cut out and a new one made.

Valve stems should be kept thoroughly clean and the threads oiled. Prohibitive measures must be taken to keep paint and rust off.

A great many valve troubles are due to the improper use of the cement used in making the joint. The cement should be put on the male part only. If put on the female part, it gets into the pipe and finally on some valve seat.

Valves are often sprung by the inconsiderate use of wrenches or by use of pipe wrenches, or by being squeezed out of shape in a vise. Sometimes the threads of the pipes attached to the valves are cut longer or smaller than standard, in which case, when the pipe is screwed into the valve, it is very likely to strike the partition and break or injure it.

PART IV

CARE AND PRESERVATION SUB-DIVISION OF HULL

CHAPTER XXIV

Cleaning, Painting, Points in Doing Work — Cleaning, Paint and Methods of Painting — Materials and Manner of Cleaning — Points in Doing Work — Mechanical Powers — Resistance of Sections of Metals — Resolution of Forces — Deformation of Metals — Wear of Metals on each Other — Expansion and Contraction of Metals.

Cleaning. — One of the most essential conditions to a thoroughly efficient Engineering Department is absolute thorough cleanliness.

A large part of the work in the engineer department consists in cleaning.

All machinery is more efficient by being clean, while dirt surely hurries along deterioration.

Cleanliness must, however, pervade to all the nooks and corners and to the out-of-the-way places not easily gotten at and which may, perhaps, be easily covered up.

It must not be confined to the conspicuous places, as is often the case, so as to have a very pleasing effect to the eye, while under cover in hidden places may be found alarming conditions of filth and deterioration.

Very often there is a great deal of unnecessary and unproductive work done in having a great deal of extra bright work so that the machinery compartments will appear well to the eye. Such clean, showy and bright appearance is very desirable, but when such extra bright appearance is secured at the expense of necessary repairs it is a very bad practice.

Cleanliness for the purpose of preventing deterioration is a prime necessity and this must especially apply to those parts not usually open to view. To be on the safe side there ought to be a rule that the hidden places and places hard to get at are the ones to receive the most attention. If the out-of-the-way parts are thoroughly clean, parts readily open will take care of themselves.

Paint and Methods of Painting. — The principal object of applying paint is to preserve the material from corrosion or other destroying influences; the improvement in appearance is only a secondary consideration and should not be the guiding one.

The different kinds of paints have different properties and suit themselves to different conditions. Paint is not all alike and should not be used indiscriminately on anything. In every case care should be taken to use only such paint as is actually suitable to conditions.

Color. — Engine room and parts of boiler room bulkheads are painted white in order to improve the light and also because white paint work shows up dirt more readily and is more likely to be kept clean. Wherever possible white should be used and is so directed by the Navy Regulations, Article 1617.

The lower portion of engine bulkheads and a large portion of boiler bulkheads are painted red or brown on account of wear on these parts and contact with dirt, etc.

Flanges are painted in accordance with the standard schedule of pipe colors issued by the Bureau of Steam Engineering. See Fig. 77.

Black is used on gratings, furnace fronts, and various metal parts. Green, vermilion, aluminum color, and bronze are used for ornamentations.

Preparation of Surfaces for painting. — The surface to be painted should be thoroughly cleaned before painting. If surfaces are very dirty, dirt can be most easily cleaned off by using a solution of hot water and washing soda, caustic soda or lye (lye is very likely to remove some of the paint). When such alkali is used the surface should afterwards be thoroughly rinsed off with clean fresh water. If there are any rust spots they should be scraped and touched up with red or white lead.

Surfaces must be perfectly dry before paint is put on; otherwise the moisture on being evaporated will form blisters. Each coat of paint should be thoroughly dry before another is applied.

In order to get a smooth coat, the surface should be smoothed down, using sand paper or a pumice stone. If old paint is blistered and rough it may be advisable to use steel scrapers to take off the blisters and rough places. But in scraping surfaces it is not advisable to scrape off good hard paint except where it is lumpy,

STANDARD COLORS OF PIPES

COLORS TO BE USED IN PAINTING THE SEVERAL *PIPES* FITTED ON BOARD *U.S. VESSELS*, AND ALSO IN REPRESENTING THEM ON THE DRAWINGS SUPPLIED FOR SHIP'S FILES.

A BLACK BAND OR COUPLING SIGNIFIES A LEADING SUPPLY OR SUCTION PIPE. A RED BAND OR COUPLING SIGNIFIES AN EXHAUST OR DELIVERY PIPE.

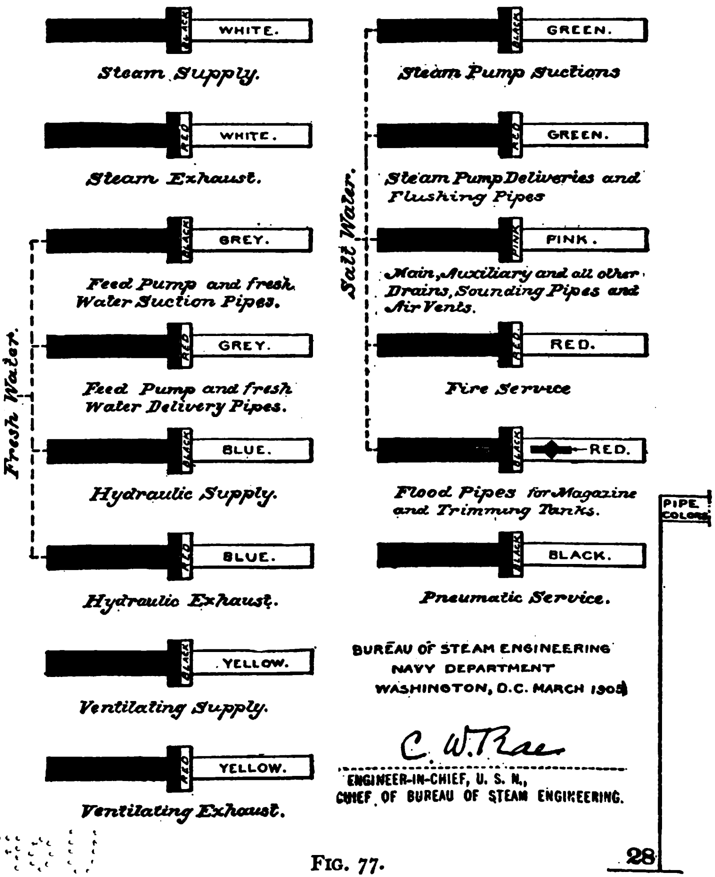


FIG. 77.

The various kinds of paints generally used, their general characteristics, etc., are given below:

White Paint. — White lead is carbonate of lead; it is used generally for bulkheads. It does not stand a high temperature, is cheaper than zinc white, has a very good covering power. Generally used for first coat on bulkheads or places not subjected to high temperatures.

Zinc White. — This is more expensive than white lead, resists heat and the action of the weather better. Zinc with a slight addition of varnish gives a very smooth and lasting surface and should be used for finishing coat for white paint work on bulkheads of machinery compartments.

Aluminum or pegmoid paint is a silvery lustrous paint which has the property of withstanding wear and heat to a high degree; it has a great covering power and its color does not change. There are various kinds, some mixed with alcohol and others mixed with turpentine or other oils. Various makes differ to a great extent in quality. Aluminum paint is very desirable for painting hot metal surfaces such as valve bodies, steam ends of auxiliaries, steam pipes, etc. It does not cling well to brass or copper surface; such surfaces should first be painted with other paint.

Yellow Paint. — This is used for sides of bulkheads, borders on white paint work, sides of ladders, etc. The usual base for yellow paint is yellow ochre or chrome yellow. For painting smoke stacks a wash of yellow ochre and kerosene is found to do well. The stack should first have a coat of red lead and linseed oil.

The following wash is used in English Navy:

17 pounds yellow ochre.
50 pounds whiting.
2 pounds glue.
1½ pints linseed oil.
Water as required for shade.

The following has also been successful:

Fire-proof buff (for 5 gallons): Take 2 gallons kerosene, 5 pounds Spanish whiting and 5 pounds dry yellow ochre; allow this to soak two days, then add 15 pounds white lead and 1 pound of Venetian red dry, beat well together and add turpentine to this. Lastly add one-half pint Japan drier.

Care of Bunkers. — Coal bunkers are required to have their paint work examined and touched up where necessary every quarter.

The bunkers are first swept down with wire brushes; blisters or bad places are scraped and red leaded, and if considered necessary, a new coat of red lead or of brown zinc is added.

Paint work in the vacinity of chutes and scuttles usually needs attention due to wear from the coal and leakage of water from the decks above.

Points in Doing Work, Mechanical Powers. — In working about machinery a practical knowledge of the mechanical powers is of great value and a knowledge of the application of a few simple principles of mechanics will be of great assistance to the workman.

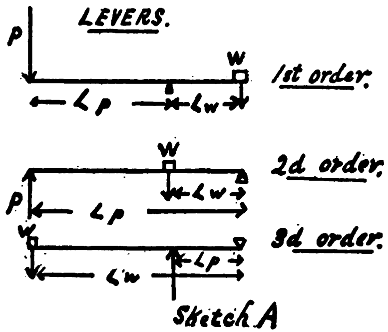


FIG. 78

The mechanical powers most used are the lever, the inclined plane, and the pulley.

The Lever. — Here the points to consider are (1) The point of application of the weight W to be moved. (2) The fulcrum or pivoting point. (3) The distance from fulcrum at which the power P is applied. (4) The distance from fulcrum at which the weight acts. The distance of W from fulcrum may be called the weight arm, and the distance of fulcrum from point of application of P may be called the power arm. The following rules will then apply to all levers:

W × weight arm equals P × power arm, provided the weight and power act at right angles to the length of arm. See sketch A, Fig. 78.

In a bent or curved lever the arm must be measured from the fulcrum in a direction at right angles to the direction in which the weight acts. This may be understood better by an examination of the diagrams.

It may be seen that the shorter the weight arm and the longer the power arm, the greater will be the mechanical advantage. By making the weight arm extremely short and the power arm extremely long, a power almost infinite can be obtained.

The fact that the power arm is measured by the distance from fulcrum at right angles to the direction in which the power is applied,

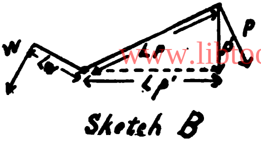


FIG. 79.

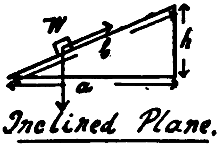


FIG. 80.

should always be taken into consideration, because if the power is not applied in the right direction the advantage is in a great measure lost.

In sketch B, Fig. 79, it can be seen that a force applied in the direction P is much more powerful than one applied in the direction P′.

The principle of the lever is applied in all wrenches. By holding the wrench near the end or by making a longer handle, as by slipping a piece of pipe over end of wrench, a much more powerful effect is produced. The mechanical advantage can also be very largely varied by adjusting the position of the fulcrum.

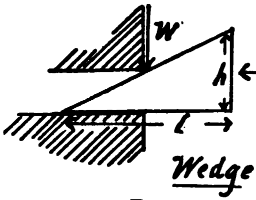


FIG. 81.

The Inclined Plane. — The inclined plane, Fig. 80, frequently offers means for moving or raising heavy weights which cannot be lifted directly. Here P, the force applied to move the weight W, is equal to $W \times \frac{h}{b}$; hence the smaller h is, the less power is necessary to move the weight.

The Wedge. — Fig. 81. The principles of the inclined plane also come into use with the wedge. The power of the wedge depends upon the acuteness of its angle. Here

$$W \times h \text{ equals } l \times P.$$

$$P \text{ equals } \frac{h}{l} \times W.$$

Hence the smaller h, the less power will be necessary to apply in order to move the weight W.

A fine wedge thus has more power but gives a slower movement, a thick wedge has less power but gives a faster movement.

The Screw Thread. — This is a revolving inclined plane or wedge, and the power is generally applied by means of an arm or lever; hence there will be a combination of these two mechanical powers and the mechanical advantage obtained may be very great.

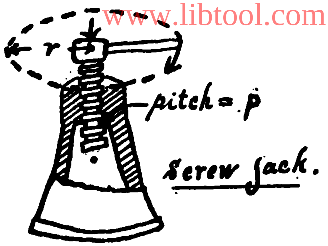


FIG. 82.

In Fig. 82, if p equals pitch of thread, that is, the distance that one complete revolution will move bolt or screw, P the force applied at a radius r, W the pressure exerted, then $W = \left(\frac{6.2832\ r}{p}\right) P$.

Hence the finer the pitch or the larger the radius, the greater will be the force exerted.

The use of the screw thread as a mechanical power is well shown in the screw jack.

The use of the screw for bringing parts together is illustrated in screw clamps, lifting jacks, etc. Temporary rigs may often be devised by using ordinary bolts and making special nuts and attachments, which will very greatly facilitate the work of forcing into place or withdrawing parts that have become jammed or frozen in. The use of a screw bolt threaded at each end in opposite directions is frequently very useful in withdrawing parts.

Wheel and Axle, Windlass. — This is really a modification of the lever. In the case of the windlass the crank is the power arm and the radius of barrel the weight arm. In the case of a pulley driving a shaft the radius of the pulley is the power arm and the weight arm will depend on the arrangement of the machine. By always bearing in mind that the moment of the force is the force multiplied by the arm, advantageous arrangements can be rigged that will help very materially in handling various parts of machinery.

Gearing. — By means of gearing power can be transmitted, increased, or decreased and the speeds altered. The increase in speed and the decrease in power is found by dividing the diameter of driving wheel by the diameter of the wheel that is driven. Thus where a wheel 6 inches diameter is driving a wheel 12 inches diameter, $\frac{6}{12}$ equals $\frac{1}{2}$. The speed is here reduced by one half and the power doubled.

Block and Tackle. — A block and tackle are frequently used. The power obtained depends on the number of parts at the moving end. By intelligently hooking the tackle a very considerable advantage may often be obtained. In order to obtain the greatest mechanical advantage the block having the greatest number of parts of line should be the moving one. However, a better lead may sometimes be obtained by hooking the tackle the other way.

To increase the power largely, put one tackle on to the hauling part of another; each tackle will then multiply the power separately.

Differential Pulley. — It would hardly be possible to handle heavy machinery weights without the use of the differential pulley. The advantage in power that can be obtained by the differential pulley is very great. The pulley has two sheaves at top fastened together or made in one piece, and a single block below to which the weight is attached. The falls are of chain and the links fit into recesses on the sheaves. The power obtained is as follows:

R = radius of large sheave.
r = radius of small sheave.

$$\text{Then } \frac{W}{P} = \frac{2R}{R - r} \text{ or } W = \left(\frac{2R}{R - r}\right) P.$$

By making the difference between R and r very small, the power gained is enormous, but the speed is of course correspondingly reduced.

Resistance of Section to Bending. — The relative value of a section to resist bending depends upon the area of the cross-section and on the mean distance of the metal of cross-section from the neutral axis. The neutral axis may be taken to be along the center line of the section. While the ability to resist bending depends in direct proportion to the amount of section, it also varies as the square of the distance of the mass of the cross-section from the neutral axis. Hence, to resist bending, the metal should be at the greatest distance from the axis. For this reason the H bar and the channel bar are very efficient to resist bending, since here the mass of the metal of the section is at a considerable distance from the neutral axis.

A flat bar is much better able to resist bending when placed on edge than when flat. See sketch, Fig. 83.

This is also illustrated by the greater resisting power of a hollow over a solid rod or column of the same weight.

Character of Different Stresses. — The various stresses that a load or force will produce in a machine are shear, bending, tension, compression, and torsion.

The resistance to shear depends upon the area of the section subject to the shearing load.

Bending will depend upon the area of the section and also on the distribution of the metal with reference to the neutral axis.

Torsion will depend upon the area and the distribution of the metal (it varies as the square of the distance from the neutral axis).

The greater the amount of the metal and the greater its distance from the center of section the greater its ability to resist torsion. Hence the hollow cylinder is a very good section to resist torsion.

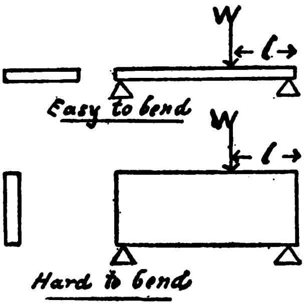


FIG. 83.

Ability to resist tension and compression depends on the area of cross-section directly. Thus a one square inch cross-section will stand one half of what a two square inch cross-section will.

Relative Position of Supports. — The bending effect or moment causing the bar to bend is proportional to $l \times W$. If l, the distance of W from the point of support, is decreased the bending effect is decreased. Hence the closer W is to a support the more easily can it be carried. (Fig. 83.)

Resolution of Forces. — A proper consideration for the resolution of forces is very useful in mechanical work.

The efficiency of a force depends upon its position, direction, and amount. By an intelligent arrangement of position and direction much mechanical advantage may often be gained. Unless a force is acting exactly opposite in direction to the direction in which the resistance to be overcome is acting, it can be resolved into two forces having different directions. This can be shown graphically by means of the force triangle. (Fig. 84.)

Deformation of Metals. — Different metals vary in their power to resist hammering, bending, or any other shock, and a due consideration for these properties will very often avoid a serious breakage.

Cast Iron. — This should never be subjected to heavy blows as it is brittle and will readily crack. It cannot be bent and if sufficient force is applied it will break. It can stand a crushing stress very well but no sudden shocks. Cast iron will also crack when subjected to sudden changes in temperature.

Cast Steel. — This will stand sudden blows and hammering and can also be bent to some extent, but is not easily deformed. It has very little flow under stress. It is more brittle and less liable to deformity and bending when subjected to blows than forged steel. Cast steel is very liable to crack when subjected to sudden changes of temperature.

Forged Steel. — This is tough and elastic and will withstand sudden shocks very well and it can be bent without any great danger of cracking. It will not crack as readily as cast metal when subjected to changes in temperature.

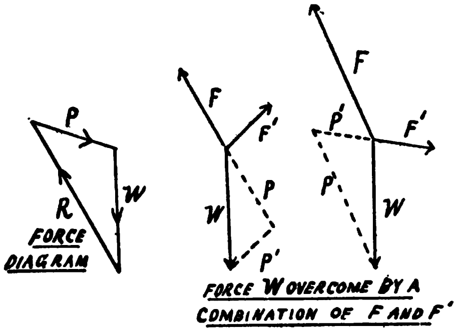


FIG. 84.

Forged Iron. — This is tough and is softer than steel, but not as strong. It can be bent without danger of cracking. Hammering will not cause it to crack but will easily force it out of shape. Changes in temperature will not cause it to crack readily.

Cast Brass or Composition. — This, like other cast metal, is somewhat brittle. The larger the percentage of copper the less brittle will brass be, and the more will it be able to withstand hammering and bending. It will expand more when the temperature is raised, but will not crack as easily as cast iron when its temperature is suddenly changed.

It will be noticed that cast iron should not be struck by blows, nor should there be any endeavor to bend it or to bring it into shape by hammering. Cast steel can be bent but should not be struck with a blow, as it may crack; the same may be said of composition.

In striking parts of metal that are likely to be deformed by the process, use a soft copper maul and never a hammer of any material harder than that which is struck, since in that case the material struck will be deformed and the hammer retain its shape. When a soft hammer is used it will be knocked out of shape, but the part on which it is used will not be deformed.

To prevent edges burring or causing deformity, place pieces of wood against the part struck. The blow will then be distributed over a greater area and the part struck will not be deformed. In handling a delicate piece in a vise, strips of wood or cloth should be used to protect the surface which might be otherwise dented or grooved by the vise jaws.

Wear of Metals on Each Other. — Whenever metal works on metal, nearly all the wear will take place on the softer metal of the two; the softer will thus be worn away and the harder will retain its shape. This fact is often considered in arranging the various parts of machines so that the softer part can be renewed and replaced. As a rule for wearing surfaces two different kinds of metals are used. Cast iron will wear well on itself, but cast steel and forged iron will not. Brass will wear well on steel or cast iron.

Expansion and Contraction of Metals. — All metals in general contract with cold and enlarge when heated, but the relative amount of this extension differs widely for different materials.

The extension per linear foot in inches for each 100 degrees in temperature F. of metals ordinarily met with is as follows:

Brass	.0125	Steel rod	.00763
Cast iron	.0074	Steel cast	.0072
Copper from 0°–212°	.0115	Steel tempered	.00826
Copper from 32°–212°	.0114	Steel not tempered	.00719
Gun metal	.0127	Zinc forged	.0207
Iron forged	.00814	Zinc sheet	.0196
Iron forged 0°–212°	.00788	Zinc composition {8 zinc, 1 tin}	.0179

This property of expansion can often be made use of in loosening nuts that are frozen, which when heated expand and can then be moved. In connection with this it is well to note the different coefficients of expansion as shown above.

The property of metals contracting when cooling can be made use of in bringing parts together with great force. If an iron clamp or ring is put on while hot, on cooling it will contract and grip tightly, and a rivet put in hot will draw the plates together by contraction in cooling. Collars and jackets are often shrunken by being thus heated and then allowed to cool after being put in place.

Water in freezing expands with great force and will cause the containing vessel to be fractured. Hollow shells have been broken in this way.

CHAPTER XXV

Care and Sub-Division of Hull — Sub-Division of Hull — Water-Tight Doors — Long Arm System — Dry-docking — Propellers.

Water-Tight Sub-division. — To guard against the danger of sinking in case of damage to any portion of the hull of a naval vessel, the vessel is divided into a great number of water-tight compartments.

This system of water-tight sub-division depends primarily on the following principal devices:

1. A water-tight double bottom.
2. A heavy water-tight protective deck.
3. A system of water-tight compartments outside of the double bottoms above and below the protective deck. These compartments being formed by longitudinal and transverse water-tight bulkheads.

The double bottom in the armored vessels of the U. S. Navy usually extends to the armor shelf on each side.

In small vessels it usually extends to the turn of the bilge.

The protective deck is a curved deck over the entire vessel and about at the level of the water line.

The principal transverse bulkheads are located at each end of the engine and boiler compartments, with one or more forward or aft of the machinery spaces.

These bulkheads extend from the inner bottom to the protective deck, where they have openings for access; they are fitted with water-tight doors actuated by power.

On large vessels of late designs no doors are to be fitted in the athwart-ship bulkheads which divide the machinery compartments.

Such unpierced bulkheads will serve to isolate in a fore and aft direction any local damage to the hull of vessel and will prevent a great or dangerous change of trim. They will, however, on the other hand, make the machinery very hard of access and the supervision and care of machinery both while in operation and when under repairs much more difficult than when water-tight doors are provided.

The principal longitudinal bulkheads are the center line bulkheads separating the two engine rooms and the port and starboard boiler rooms, and the longitudinal bulkheads separating the coal bunkers from the machinery spaces.

These bulkheads extend from the double bottoms to the protective deck and are pierced with openings fitted with water-tight doors operated by power.

The center line bulkhead, though fitted on most of the U. S. large armored vessels, is considered by many of the best informed experts to be a real menace instead of a measure of safety to the ship. Its presence does not enable the vessel to keep on an even keel in case one of the large compartments is penetrated and flooded.

All water-tight compartments are numbered on the following system:

The vessel is divided into three sections by four principal transverse bulkheads. The forward one just forward of the boiler compartments, the second dividing the engine and boiler compartments, and the third just abaft the engine compartments.

All compartments forward of the first mentioned bulkhead have A prefixed to their numbers, thus A-1, A-2, etc.

All compartments between the first and second of the above bulkheads, that is, in the boiler rooms and adjacent spaces, have B prefixed to their number.

All compartments between second and third of the above bulkheads, that is, the engine rooms and adjacent spaces, have a C prefixed to their number.

All compartments aft of the third bulkhead, that is, aft of the engine rooms, have a D prefixed to their numbers.

Starboard compartments have odd numbers.

Port compartments have even numbers.

The double compartments in each division are numbered downwards from aft forward, beginning with 99.

Compartments above the inner bottom and below the protective deck are numbered from forward, beginning with 1.

The large compartments such as boiler and engine rooms have numbers 1 to 10.

Coal bunkers, storerooms, and small wing compartments have numbers 11 to 40.

Magazines and shell rooms have an M after their numbers, thus, A-6-M, D-7-M.

Above the protective deck the compartments are numbered from forward aft, beginning with 100.

It can thus be seen that the number of any compartment will at once indicate its position in the ship.

The frames of a ship are numbered from forward aft, beginning with 1. The distance between frames varies with the size of vessel; on the later large vessels it is 4 feet.

Nomenclature of Decks. — The deck on or immediately above the protective deck, is called the berth deck. The lower platform is the first deck above the double bottom. The upper platform is the first deck below the protective deck.

The highest deck extending from stem to stern is the main deck. A deck between the main deck and berth deck is called the gun deck.

A deck above the main deck and extending over a portion of the ship is called the bridge deck.

Water-tight Doors. — All openings cut into the water-tight partitions of the ship for access are fitted with water-tight doors or scuttles.

The principal doors below the protective deck are operated by power.

Openings into double-bottom escape doors from bunkers, and other small doors below the water line, and all doors in water-tight bulkheads above the water line are closed with hinged doors of elliptical shape. These doors are fitted with a rubber gasket fitted into a groove and are set up tightly by means of lugs, or for small doors, as for double-bottom compartments, with hinged screw bolts and butter-fly nuts.

Care of Water-tight Doors. — For doors fitted with gaskets and not actuated by power.

Gaskets must be kept clear of all paint, varnish, or shellac. Paint can be removed by rubbing with turpentine. The dogs must be adjusted so that they all come up tight when turned to close.

If lightly built, doors may have the frames sprung. This defect can sometimes be remedied by additional stiffening.

If gaskets become soft and mushy, or hard, dry, and cracked, so as to become inefficient, they should be replaced with new one.

The edge of the angle iron which takes up on the gaskets should not be painted and should be free from nicks, hollows or any irregularities. If burrs are formed they should be smoothed down.

Power Doors.—Power doors are operated by electric or pneumatic power. They are either vertical or horizontal sliding doors, and the latest type are those supplied by the Long-Arm System Co., of Cleveland, Ohio. This company also publishes detailed description of its system.

Long-arm System. — Cuts of doors are shown, and description of system taken from bulletin 10 of Long-Arm System is given. A more detailed description can be had by obtaining pamphlets furnished by the company.

The principal features of the "Long-Arm" system are:

1. *The Central Emergency Station* for quickly closing all the doors at need; located on the bridge; connected with each door by electric wires; thrown into action by releasing a hand wheel; and embodying indicator lamps which show at any time when each door is closed, or in case of local obstruction point out the door to be cleared.

2. *The Liberty Action* at each door, whereby a man on either side of any door can open it at any time during an emergency period for duties or escape, the door immediately closing after such action or any number of them, without further manipulation either locally or from the emergency station.

3. *The Automatic Cut-out* at each door, whereby the power is continually weighed during operation, shutting off the current when an obstruction stops the doors, and automatically closing the circuit and so resuming action the moment the obstruction is removed. Thus the danger of the apparatus being rendered inoperative by a burnt-out fuse is avoided.

4. *Water-tight Doors.* — The doors themselves are of the most improved type for effective operation and water-tightness, each being provided with a specially designed electric motor and safety controller whereby the door may be closed from the bridge or operated locally from either side at any time.

Wiring. — The wiring required for a complete installation of the system is as follows:

First. The emergency station is connected with the ship's mains by one twin conductor.

Second. The emergency station is connected with the controller on each door and hatch gear by means of one twin conductor.

Third. The controller on each door or hatch gear is connected with the ship's mains by one twin conductor.

FIG. 85. — Emergency Station.

Emergency Station. — The working parts of the emergency station are contained within a water-tight brass case arranged to be supported by the side wall of the pilot house or other convenient fixture at a suitable distance above the deck. The apparatus is divided into three parts:

First. *The mechanism for controlling the circuits running to each door or hatch gear for closing the door hatch.*

Second. *The lamps to indicate the closure of each door or hatch.*

Third. *The fuse box in which each entering wire is supplied with a proper fuse.*

The operation of the emergency station is as follows: When the officer in charge is cognizant of an approaching danger, he operates a latch which releases the gearing driven by a large spring and controlled by a suitable escapement. This gearing automatically closes the circuits for operating the emergency switches located in the controller of each door and hatch gear, and, in performing this function, does not start all motors at the same instant, as in a large installation this would demand an enormous supply of current from the generator, but starts them one after another at about a three-second interval, so that with the usual time of closing these doors and hatches it is seldom that more than four motors are in operation at any one time, yet the entire closure of twenty-five doors and hatch gears operated by one emergency station would be accomplished in about one minute and fifteen seconds.

As each door is locked it automatically closes a circuit running to the emergency station and connected with a small incandescent lamp located therein. Over each lamp and forming part of the case is a small translucent disc bearing the number of the corresponding door, so that the officer in charge by merely pressing a button will cause the indicator lamp of every closed door and hatch to glow, thereby assuring himself of the successful operation of the emergency closure; in the event of any door being prevented from closing by material left in its path, it is at once apparent to the officer in charge, who can have an investigation made and such material removed so that the desired closure will be effected.

Each "Long-Arm" power door and hatch gear is supplied with a most ingenious Controller containing three independent switch mechanisms, as follows:

FIG. 86. — Controller.

First. The switch by means of which the man at the door (who may be on either side of the bulkhead) can open and close it at will.

Second. The switch, operated from the emergency station, by which the door is closed in event of danger. This emergency switch, although absolute in its final control, may have its operation temporarily suspended by the man at the door who may wish to open the door for some useful purpose. In the condition just referred to the switch will close the door as soon as the handle of the controller is released.

FIG. 87. — Motor.

Third. The limit switch, by which the current supplying the motor is cut off when the door has been properly seated or has struck any obstruction, such as large lumps of hard coal, timbers or other material, left in the clear opening. This switch is operated by mechanical connection with the door or hatch plate in such a way that should its closure be prevented by an obstacle offering great resistance, this switch will cut off current from the motor and prevent blowing of the fuses.

Should the obstruction be removed (as in the case of coal being washed away by the flood of water passing through the clear opening) this switch will again close the circuit to the motor and the door will be automatically started to continue its closure.

The Motor is direct current, reversible, compound wound, iron clad, bi-polar, of a light, compact construction for intermittent ser-

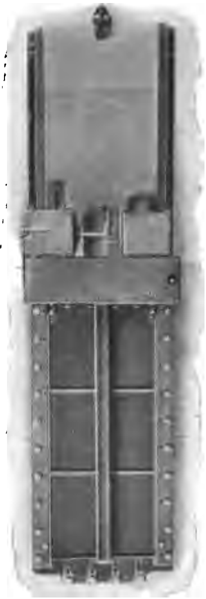


FIG. 88.—Sliding Door, Closed.

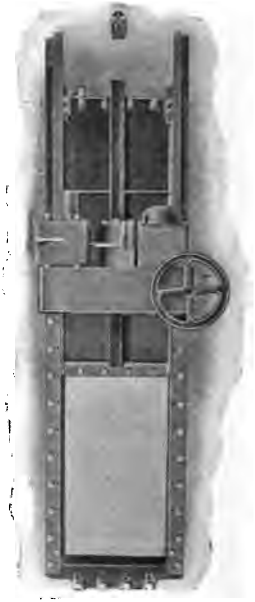


FIG. 89.—Sliding Door, Partly Open.

vice; entirely enclosed within a water-tight case and capable of a normal output of 1 B. H. P. at 1200 r. p. m. and 125 volts; and capable of carrying 50 per cent overload five minutes, and four times its rated input for ten seconds, without heating or injury to any part.

Each "Long-Arm" power door and hatch gear is supplied with one of these motors.

Hand Gear. — Each power door and hatch gear is supplied with two removable hand wheels, so that in case of failure of the power the device may be operated by hand (from either side of the bulkhead in the case of a power door, and either above or below the protective deck in the case of a hatch). These hand wheels are designed to be stowed in the immediate vicinity ready for use at any time.

The operation by hand does not in any way interfere with the power operation, and it is not necessary to throw out any clutches or disengage any of the working parts in making use of the hand gear.

The Power Door. — These doors are made of two distinct types, viz.: those sliding *vertically* and those sliding *horizontally*, but the general principles underlying the operation are identically the same, and they will be described together. Such features as apply solely to one or the other will be noted as they are described.

FIG. 90. — Horizontal Door.

The Bulkhead Frame is a heavy steel casting, securely fastened to the bulkhead and completely surrounding the clear opening; it forms the foundation for the entire power door, and no reverse frame or additional stiffening of bulkhead is necessary. This frame is made sufficiently stiff and heavy to prevent any distortion due to irregularity of bulkheads and to secure at all times a perfectly rigid, flat face against which the door plate can seat with uniform tightness. This construction makes the "Long-Arm" power door entirely independent of surrounding conditions as far as alignment and adjustment are concerned, and also enables shipment of these doors as a unit fully adjusted, tested, and ready to set up and operate on board.

The Door Plate is made of cast steel, suitably ribbed, as light as possible and somewhat flexible. The face of the door plate engaging the bulkhead frame is provided with brass seating strips to avoid corrosion and preserve good, working faces. When unlocked the plate rides freely in its guides with about $\frac{1}{8}$-inch clearance in all directions.

Guides secured to the bulkhead frame direct the door plate in its movement, and, to facilitate inspection of the contact between the door plate and the bulkhead frame, also the action of the tightening gear, these guides are of an open-work construction. This particular form has an additional advantage in that it entirely prevents coal or other material from lodging in the guides and thus interfering with the proper movement of the door plate.

To guide the door plate as it passes beyond the bulkhead frame, extension guides of a somewhat different form are furnished, which are secured to the bulkhead.

The Tightening Gear of a power door is of the most vital importance, for when the door plate is closed and locked it must be held against the bulkhead frame with sufficient force and at a sufficient number of points to prevent an unreasonable escape of water under pressure equivalent to a head of 35 feet. Although this extreme tightness is essential when the door plate is closed, it is equally necessary that it should ride freely between the guides in all directions when opening and closing.

The Power Hatch Gear, for Raising, Lowering and Locking Armored Hatches

The "Long-Arm" power hatch gear is divided into two parts:

First. *The Hatch Lift*, which is a substantial, rectangular enclosed frame carrying the motor and controller, and having on one end a massive projecting crank, driven through gearing from either the motor or the hand wheel.

The train of gearing is provided with the worm and wheel feature embodying the automatic cut-out device described as part of the power doors, and by means of this device the pressure with which the hatch plate is drawn against its seat is a predetermined and constant amount.

Through ingenious features in design this hatch lift is so arranged that the crank, referred to above, may project on either end of the lift, and also that the lift may be fastened either on the under side of the protective deck or against a nearby bulkhead; also that it may be so placed as to have its *least dimension vertical, giving the* *maximum headroom*, or, its *least dimension horizontal, covering the minimum horizontal area.*

Second. *The Lever System for Connecting the Hatch Lift with the Hatch Plate* and by means of which the projecting crank on the hatch lift raises, lowers, and locks the hatch plate.

This lever system is made in several forms, so that the hatch lift may be conveniently located with reference to local conditions surrounding the hatch. The arrangement of the apparatus is as follows:

Secured to the under side of the protective deck and almost directly below the hinges for the hatch plate are two heavy bearings supporting a shaft driven by the crank on the hatch lift. This shaft carries two bent levers extending out beneath the hatch plate and attached to it by suitable links. These levers are placed so that when the hatch is open they occupy a very little of the clear space, being in the corners of the clear opening nearest the hinges.

FIG. 91. — Hatch Gear.

The links through which the bent levers are attached to the hatch plate serve to operate a most ingenious tightening and locking mechanism (secured to the under side of hatch plate), which operates after the hatch plate is closed. This locking action is, therefore, performed by the hatch lift after lowering the plate, and does not require any manual operation. The principle of the wedge and roller tightener, so successfully used on the power doors, is here applied, and each hatch is firmly secured at its four corners.

The hatch gear is so designed that it may be operated by power or hand either from the deck or platform below the hatch or from the protective deck.

Dry-docking. — When a vessel is dry-docked all the underwater fittings should be overhauled and examined. This includes the sea valves, the propellers and their shafting.

Sea Valves. — The zinc rings should be examined and, if there are any signs of wear, should be renewed. All sea valves should be ground in. If valves are damaged, they should be repaired.

Propellers and Shafting. — Whenever a vessel is docked the outboard shafting should be carefully examined for any corrosion.

The shafts of many of the older vessels are fitted with a composition casing, and if there is any indication of the joints in this casing opening or leaking, they should be calked or made tight by other means.

Where the shafting is only cased at the bearings, it should be scraped clean and carefully examined for any signs of pitting or corrosion. If any pit holes are found they should be cleaned out and given a coat of red lead, the whole shaft should also be given a good coat of red lead and afterwards the anti-fouling paint should be put on.

All zinc plates should be examined and those that show any signs of considerable wear should be renewed.

The latest practice is to fit a wrought-iron ring around the shaft at the end of the bearing bushings. If these rings are badly corroded, they should be replaced.

The amount of wear that has taken place on stern tube and strut bearings is measured by inserting wooden wedges between the top of the shaft and the lignum-vitæ. These wedges should then be kept as a record for future examination.

At the same time the thickness of lignum-vitæ to be worn down before the shaft touches the brass bushing should be measured and recorded.

If the clearance between shaft and lignum-vitæ is over $\frac{1}{8}$ inch for smaller vessels, $\frac{1}{4}$ inch for larger ones, the bearings should be lined up. It is possible to turn the bearing around, that is, to put the top piece on the bottom and the bottom piece on the top, and bring the shaft up, but there will still be too much vertical clearance. It is better to renew the lignum-vitæ strips. The lignum-vitæ should be put in so as to wear on end of grain, should be well water-soaked and bored out to perfect alignment and to a loose fit on the shaft bearing.

The lignum-vitæ bushings for bearings are made in halves, the joints being nearly horizontal, there being a slight inclination fore and aft so as to facilitate the withdrawal of the lower half of bearing. They are held in place by flat rings secured to the bearing boss. The bearings can thus be examined and renewed without disturbing the shaft. To examine the bearings the fair waters must be removed.

The casings over couplings and propeller nut should be examined, and if there is any water seen running out it shows that there is leakage. The spaces inside casings are filled with melted pitch and tallow. The plugs should be removed and spaces should be completely filled. The cone casing over propeller nut may be taken off and nut and key examined.

Zincs are usually fitted to the fair waters, around the rudder and on the struts.

Propellers. — The surface of the blades and nut should be thoroughly cleaned of all marine growth.

A material increase in speed can be obtained by carefully smoothing up and polishing the surfaces of the propeller.

Blades should not be painted. Any pitting of the surfaces should be noted.

Friction Test. — If desirable, a friction test of shaft may be made. This will determine the amount of friction that must be overcome to turn the shaft.

The bolts of after coupling are taken out, the packing may be left in or taken out of the stern gland as desired. One blade is placed horizontally and a weight is hung from a shackle secured to the blade. The weight is increased till the shaft is just made to turn. Knowing the weight and the radius from center at which the shackle was placed, the force necessary for turning the shaft can be calculated.

Measuring the Pitch of Propellers. — It may sometimes happen that it is desirable to measure the pitch of propeller blades. There are times when the blades are slightly bent by striking some object and in other cases it may be desired to change the pitch.

In measuring the pitch an instrument called a pitchometer is used. This consists of a circular dial graduated in degrees and a brass or wooden radial arm, having holes at regular graduated intervals through which graduated distance rods are passed. The bar is pivoted over the center of the graduated dial. To measure the pitch with propeller in place the cap over the end of the hub is taken off and the plate of pitchometer secured in place so that the center of the graduated dial is in the center line of shaft and that the radial arm will rotate exactly at right angles to the line of shaft. The holes through which the distance rods are run must be exactly parallel to the line of shaft. The bar must swing on its pivot with out any lost motion and must be sufficiently stiff so as not to be easily bent or pushed out of shape. If the bar is at all inclined to wabble the readings will be inaccurate.

The pitch at any point is obtained as follows: Assume a radius r, 4 feet on bar, insert distance rod so that it just touches the driving surface of blade. Read distance rod, call this A, say 20 inches, swing bar through an angle θ, say 20 degrees, adjust distance rod so that it touches the blade at B, reading say 5 inches. Then the difference of reading on distance rod, A — B, will represent the same proportion of the pitch that the angle θ represents of the entire 360 degrees of circumference. Hence Pitch $= \frac{360}{20}(20\text{-}5) = 270$ inches or 22.5 feet. If the radius at which pitch is taken is r, D C is the corresponding fraction subtending arc θ. B D, the arc subtended by θ, equals

$$\sqrt{\overline{BC}^2 - \overline{CD}^2} \text{ and pitch} = \frac{2\pi r \times CD}{\sqrt{\overline{BD}^2 - \overline{CD}^2}}$$

In order to get an accurate record, the pitch should be measured at a number of different radii and at all portions of the blade. A

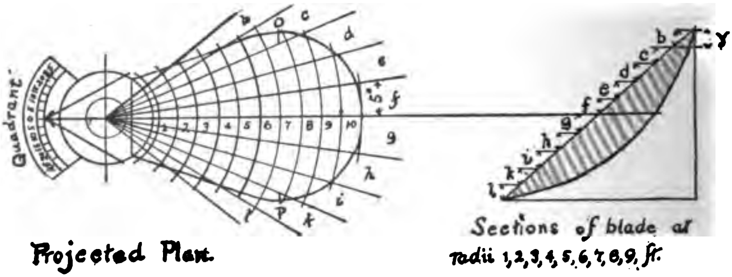


FIG. 92.

convenient method is to set the bar opposite one edge of the blade, take readings at several different radii, swing the bar through an angle θ, take readings at same radii as before, then again through θ and so on till the whole surface has been covered.

A copy of the instructions for taking propeller measurements, issued by the Bureau of Steam Engineering, is here given.

"*Instructions for Measurements.*—The form on this sheet will be filled out in accordance with the following instructions whenever propeller measurements are taken:

"Propellers with adjustable blades for altering pitch should have a graduated arc on hub and a suitable mark on blade, so that the position of blade for each set of measurements may be recorded. Measurements for pitch should be made with the blades set in at least three positions and must include the mean and two extreme positions; this will enable the blades to be set at any time in positions corresponding to previous measurements.

"Place the propeller on a horizontal face-plate, the after end of hub uppermost and the blades secured to hub in desired position, set the pitchometer true with the axis of hub, place radial arm over center line of blade, which should be located by laying a steel tape across the broadest part of blade, as at O P and center punching at middle. With vertical measuring rod of arm on this center mark, and radial arm index set to zero on pitchometer quadrant, secure quadrant in position. Proceed by measuring the pitch Y for each 5 degrees and record same in its proper column.

"It should be noted that the pitch measurement entered under column *f* is for the 5-degree angle immediately to the left of center line of blade, and likewise under column headed *g* for the 5-degree angle immediately to the right of center line; by remembering this no difficulty should arise in entering data in proper columns.

"In the column headed y_1 enter the sum of the y's for each radius, the mean pitch is obtained by the formulæ $\frac{360}{\theta_1} \times \frac{y_1}{12}$ where y_1 is in inches and θ_1 = total arc for that radius, or the number of measurements taken at that radius $\times$ 5 degrees.

"*Projected Area.* — Place under each blade a sheet of paper and project on same the outline of blade with a square or other suitable instrument; with axis of hub as a center trace a circle with diameter equal to that of the hub, then area enclosed is the desired projected area. Draw in arcs with radii equal to those at which pitch measurements were taken; note on same actual measurements of these arcs from edge to edge of blade as taken by steel tape; have reduced drawing of propeller projections with measurements thereon made to scale and forward same to Bureau of Steam Engineering with record sheet. Indicate on opposite sheet whether propeller is right- or left-handed, Starboard, Center, or Port; and whether original or spare blades are measured."

"With blades adjustable, note setting of blades on hub."

In order to discover any slight variations in the pitch, it can be

Record Sheet.

Propeller Measurements U. S. S. ....

Measured at ....

.... 190..

Right hand. Starboard. Original Blades.
Center.
Left hand. Port. Spare Blades.

Material. ....

Item	Designed	Measured
Diameter		
Pitch		
Hel: Area		
Proj: Area		
$\frac{P}{D}$		

	Weights
Hub	
Blades	
Propeller	

Measured by..............
Computed by.............
Checked by..............

Blade No. 1 Mean Pitch............ Hel: Area........ ⌀. Proj: Area............ ⌀.

Radius	b	c	d	e	f	g	h	i	k	l	y_1	Mean Pitch
1												
2												
3												
4												
5												
6												
7												
8												
9												

Blade No. 2 Mean Pitch............. Hel: Area....... ⌀. Proj: Area........... ⌀.

Radius	b	c	d	e	f	g	h	i	k	l	y_1	Mean Pitch
1												
2												
3												
4												
5												
6												
7												
8												
9												

Blade No. 3 Mean Pitch............... Hel: Area......... ⌀ Proj: Area........... ⌀.

Radius	b	c	d	e	f	g	h	i	k	l	y_1	Mean Pitch
1												
2												
3												
4												
5												
6												
7												
8												
9												

figured out for each observation and the results placed in appropriate columns and averages made each way, both for the mean pitch at any of radii and the mean pitch at any angle of observation.

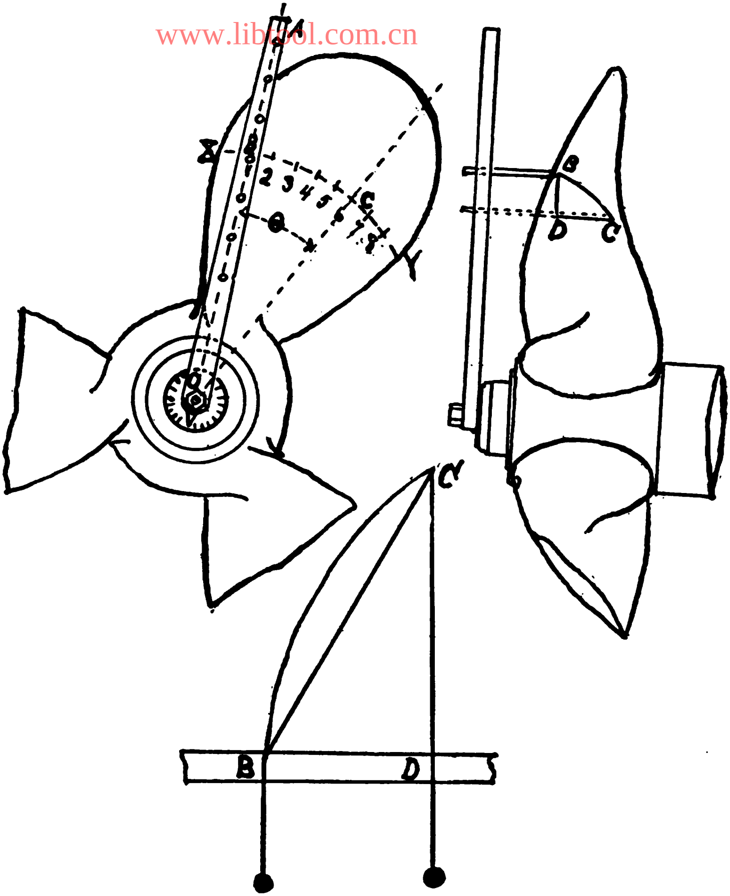


FIG. 94.

If the pitch is a true screw the individual results should be all alike. If the pitch varies with the diameter or between leaving or entering edges the gradual changes in the values will show this. Any warping or irregularity of the surface will be shown by irregular changes in the pitch at any portion of blade.

Other methods of measuring pitch are as follows (from Barton's "Naval Engines and Boilers"):

Take the blade where the inclination to the face is 45 degrees to the axis of the shaft, then the pitch will be equal to the circumference due to that radial distance.

Divide the arc X Y in Fig. 94 into a number of equal parts, 1, 2, 3, 4, etc. Measure off the same number of intervals upon a base line X′ Y′ equal in length to the developed arcs, Fig. 95. Measure the ordinates at such intervals on the arc from the batten on a plane perpendicular to the axis and lay off the ordinates 1–1′, 2–2′, 3–3′, etc., at the corresponding intervals on the base line. Through the points 1′, 2′, 3′, etc., draw the line A B, produced to cut the base line at A. With a uniform pitch, A B will be a straight line. From A lay off A C, equal to the circumference of a circle at the radius from which measurements are taken, then the perpendicular D C, on A C, will give the pitch of the screw. With a variable pitch, the points 1′, 2′, 3′, will lie in a curve Fig. 95. To find the mean pitch in this case, draw a tangent to the extremities of the curve and take the arithmetical mean of the two pitches obtained.

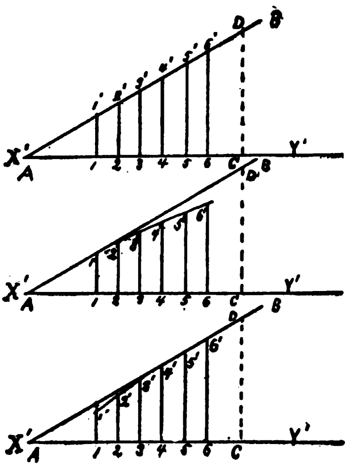


FIG. 95.

If a pitchometer is not available the pitch may be measured by a very simple method described in Durand's[1] "Practical Marine Engineering."

Bring the blade so that it is horizontal, take any point in the blade and hang over the blade a cord having a weight at each end as shown in Fig. 94. The points B and C must be the same distance from

[1] *Practical Marine Engineering*, published by International Marine Engineering.

the center, and the line B C parallel to the line of shafting. It will be seen that the points B, C, and D correspond to the same lettered points in the other figure where the pitchometer was used. Measure the distances B C and C D, then the pitch will be found by formula:

$$\text{Pitch} = \frac{2\pi r \times CD}{\sqrt{\overline{BC}^2 - \overline{CD}^2}}$$

or

$$\text{Pitch} = \frac{6.2832 \times R \times BD}{DC}$$

R = radius at point pitch is taken.

PART V

SPECIAL AUXILIARY ENGINES

CHAPTER XXVI

Steam Steering Gear — Williamson Engine — Forbes Engine — Rudder Mechanism — Telemotor — Other Systems — Care and Operation.

Steam Steering Apparatus. — Nearly all the U. S. Naval vessels are fitted with steam steering gear. The location of the engine is generally in the steering compartment, located just forward of the rudder.

The steering gear is arranged so that the engine can be operated from the bridge, chart house, conning tower and at the engine. Sometimes the engine can be operated from the quarterdeck. The gear is also arranged so that it can be operated by hand at the steering engine compartment and, in numerous cases on older vessels, from the quarterdeck. On late vessels the hand steering wheels are located only in the steering engine room.

The steering gear may be divided into three divisions as follows:

1. The controlling gear worked by the helmsman at any of the several points of operation in the vessel, which transmits the movement of the steering wheel to the steering engine.

2. The steering engine which, being governed by the controlling gear, furnishes the power for moving the rudder by means of the rudder mechanism.

3. The rudder mechanism which conveys the power of the engine to the rudder head or tiller.

On naval vessels where the steering engine is located in the compartment just forward of the rudder head, the control from the wheel to the steering compartment is transmitted by shafting or by means of wire wheel ropes which operate a drum in the steering compartment. Wire rope is used in preference to shafting owing to the objection of the great lengths of shafting that would be required on large vessels.

The steering wheel is mounted on a brass column or pedestal. On this column is also mounted the small drum on which the wire wheel ropes wind. Pedestals are fitted one above the other in the conning tower, pilot house, and bridge, all connected to the same wheel ropes and each can be thrown in or out of operation. On the top of the pedestal is fitted a tell-tale to show the position of the rudder by showing the angle through which the quadrant of the rudder has moved. Wheels are arranged to move in the same direction as the bow of the vessel does when it responds to the movement of the rudder. The number of turns of the wheel necessary from hard a-port to hard a-starboard varies from six to ten, depending on the size of the vessel.

The Williamson engine consists of a two-cylinder horizontal engine driving a crank shaft H, which by means of the gear wheels, S and T, transmits the motion to the tiller shaft C. The large spur gear wheel S is loose on the shaft but is fitted with a clutch M, by means of which the engine can be connected or disconnected from the tiller shaft. The engine is fitted with the ordinary cranks, connecting rod and eccentrics, and is mounted on a bed plate secured to the ship's frames. The shaft C is connected by means of a clutch to the hand steering wheel just forward of the engine. When steering by hand the engine is disconnected by clutch M and the hand wheel put in gear. The shafting at the engine operated by the wheel-rope drum, or by the wheel direct, transmits motion through the automatic control shaft E to the differential valve which controls the movement of the engine. This shaft is fitted with a clutch so that it can be thrown out of gear from the wheel-rope drum.

On the shaft E there is a sleeve L with internal threads fitting into corresponding threads on the shaft E. A groove is cut into sleeve L in which is fitted a loose collar or strap which, in connection with a series of bell crank levers F, moves the reversing valve in one direction or the other according to the direction in which the control shaft E is turned by means of the wheel rope or hand wheel I attached to the end of the shaft and by means of which the engine can be operated from the steering engine room. The differential valve A can, by its position, cause the engine slide valve VV to take steam either inside or outside. Its movement from one position to the other causes the steam and exhaust ports to be interchanged and the engine

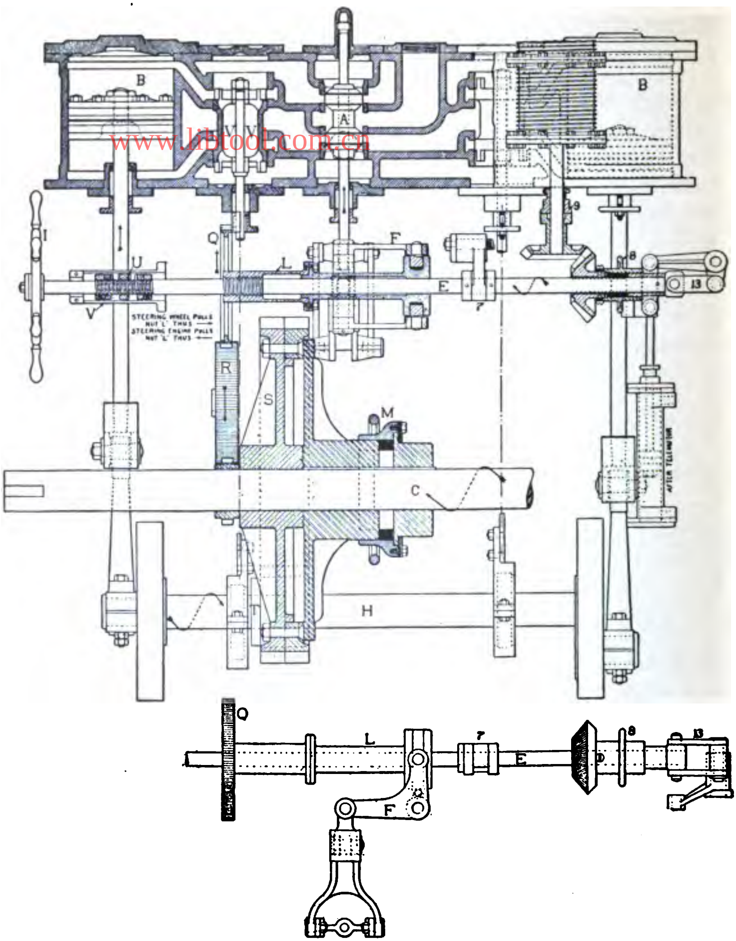


FIG. 96. — Williamson Steam Steering Engine.

to be run in either direction or, when valve is on center, as shown in cut, to be stopped. If the valve is moved in the direction of the arrow (steam being on the outside of this valve), the steam will enter through the lower port of the differential valve and will go to the inside of the engine slide valve which will admit steam to the lower side of the piston and cause the engine to run in the direction of the arrow. If the differential valve is moved in the opposite direction steam will enter on outside of engine slide valve and the engine will work in the opposite direction.

The gear wheel R is attached to the shaft C. The wheel Q gears into this and is also secured to the sleeve L. When the engine is set in motion by the movement of the shaft E, the pinion Q is caused to revolve and the threads on L are so cut that the movement of L will cause the lever F to be moved in a direction opposite from the movement imparted to it by the movement of E. The movement of Q will thus cause the differential valve to be brought to its center and stop the engine. A continuous movement of the shaft E by means of the wheel ropes will, however, counteract the movement of Q, and keep the engine going. Hence as long as the steering wheel is being moved the engine will operate, but when the steering wheel is stopped the motion of Q will stop the engine. The movement of the steering wheel in the opposite direction will reverse the engine, but the movement of Q will tend to stop the engine no matter in what direction it may be going.

To prevent the engine from going too far in one direction and jamming the gear, stops are arranged by means of a traveling nut U, with a projecting lug engaging in the slot in the bearing V. A connection is made through this lug to a pointer on a graduated rudder tell-tale on the pedestal of the steering wheel previously mentioned.

Another type of steering engine is the "Forbes." The details of this are as follows (information taken from catalogue of Forbes' Company) (Figs. 97 and 98a):

In Fig. 1 steam enters at 1, as shown by the arrow and circles around the hollow piston valve V, and when in the position shown is prevented from entering either of the ports P or P′.

Now if the valve V is moved down say $\frac{1}{16}$ the port P will open at its top the same amount, allowing the live steam to enter the chamber A, the port P′ will open a like amount, allowing the exhaust steam to flow out as shown by the arrow, down through the center of the valve V to the exhaust pipe or opening X. If this movement of the valve V is reversed, the steam will, of course, pass through the port P′ and the port P will open, allowing the exhaust steam to pass below the valve V into the exhaust pipe.

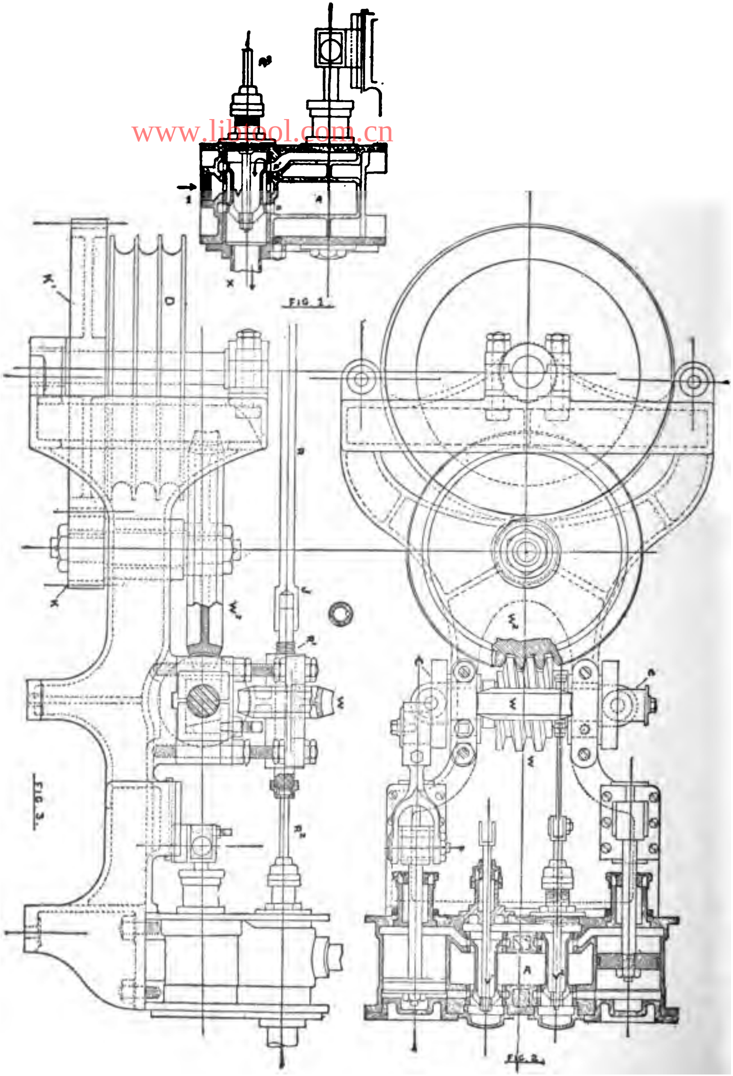


FIG. 97. — Forbes Steering Engine.

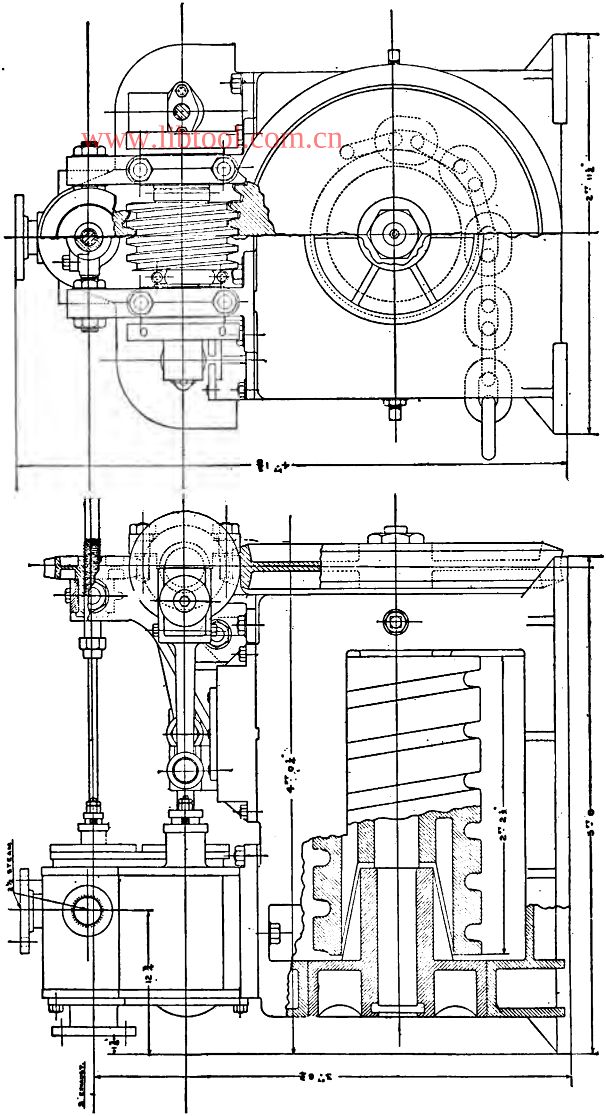


Fig. 98. — Forbes Steering Engine.

When the steam enters either of these ports or passages, P or P′ it reaches the two valves V^1 and V^2, Fig. 2, and is controlled by them as in any engine.

In Fig. 3 there will be noticed a rod R. This is led to the pilot house and to it is geared the steering wheel, so that when it is turned the rod R also turns and with it the screw R^1.

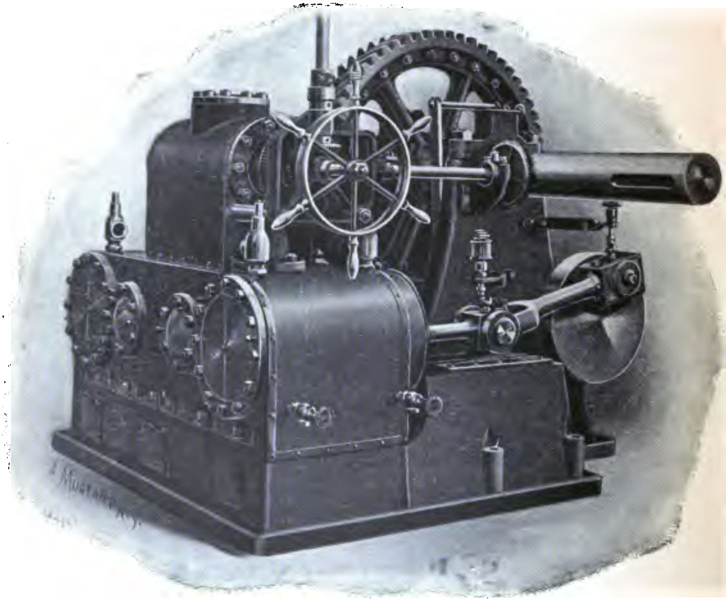


FIG. 98a. — Forbes Steering Engine.

The worm wheel W through which the screw R^1 passes, is threaded in its hub to meet it. It will be seen at once if the screw R^2 is turned it must rise or fall, which motion is provided for by the slip joint J as shown.

In Fig. 2 it must be noticed that the crank shaft C has cut on it the worm W^1 and this worm must turn when the engine turns. Into this worm W^1 meshes the worm wheel W as well as the large worm heel W^2, Fig. 3. When the rod R is turned by the pilot and with it the screw R^1, the worm wheel W acts as a nut, and the floating valve V is lifted or lowered by the valve stem R^1 Fig. 3, thus allowing the steam to enter either the port P or P′, Fig. 1, which results in the engine starting.

If the rod R is turned to the left, the valve V is lifted and the engine will start, which will cause the worm wheel W to turn also, as its hub is a nut for the screw R^1. When the rod R ceases to turn, the engine will make a few revolutions, which will continue to turn W until the movement of W causes the valve rod R to be pushed back till the valve is brought on its center, when the engine will stop and hold the rudder in that position. If R is turned to the right the operation is similar, except that the engine will move in the opposite direction.

To Set the Floating Valve. — A double-pointed wire gage will be found on the small brass worm wheel bracket, and when the gear is set up and all connections to the steering column are made, the wheel must be set with the King spoke central and one point of the gage placed in the center punch mark in the above-named bracket and the floating valve stem adjusted until the center punch mark on it can be entered by the second point of the gage; the gear will then be central. It must, of course, be understood in making this adjustment, some key in a bevel gear is taken out until the adjustment is made, which is done by turning the rod R. The key can then be put in the gear selected.

For the large horizontal type the follow-up motion is obtained from the tiller shaft by means of a bevel gear and shaft.

Rudder Mechanism. — For large vessels of the U. S. Navy the differential screw gear type is almost exclusively used. This is illustrated in Fig. 99. C is the rudder shaft as before mentioned; on this shaft are cut two series of square threads, one right-handed and the other left-handed. Each series of threads works in a composition driving nut N N which slides on and is supported by the side-rod guides. The driving nuts are connected by means of the connecting rods R R to a yoke or crosshead, fitted on the rudder head.

When the shaft C is turned the driving nuts are, owing to the opposing direction of the threads, caused to come together or to separate, and this motion, by means of the connecting rods, causes the rudder head to be turned.

On some naval vessels and on most colliers, transports, and other auxiliaries, the motion from the steering engine is transmitted to

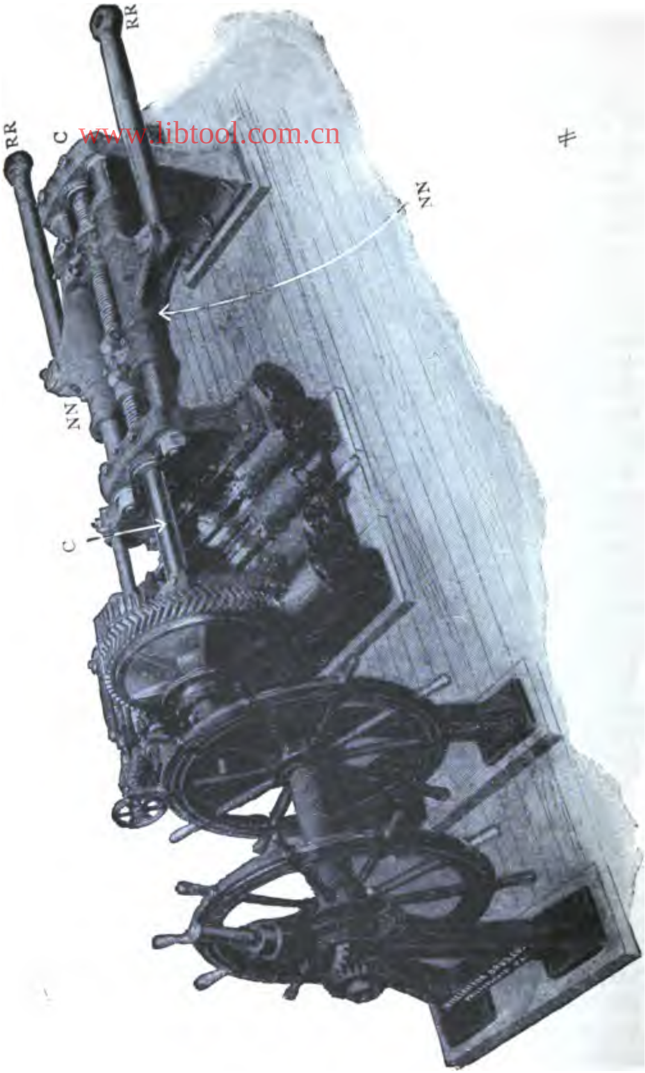


FIG. 99. — Rudder Mechanism with Williamson Steering Engine.

the rudder by means of chains or wire cable. The steering engine shaft in this case operates a drum upon which the chain is wound. The ends of the chain are attached directly to the tiller and move it to one side or the other. The tiller is usually fitted as a quadrant to guide the ends of the chain.

The Telemotor.—This control may be used in place of the wheel ropes or direct shafting control. The parts of the telemotor are shown in Fig. 100. The pedestal of the steering wheel contains a cogged rack which is moved by means of gear from the steering wheel. This rack operates by means of a system of levers and rods, a piston in the transmitting cylinder, usually located under the steering wheel and below the protective deck. This piston is packed with double-cup leathers and when in the middle of its stroke allows communication between the two ends of the transmitting cylinder. The ends of the transmitting cylinder are connected by means of small copper pipes to the ends of an operating cylinder, as shown in Fig. 100, located at the steering engine. The piston of the operating cylinder is connected by means of levers to the controlling shaft of the steering engine, see Fig. 96, so that this piston can move the shaft E horizontally. When the telemotor is to be used the shaft and wheel rope control are thrown out and the guide clutch 7 must be shifted to allow for the lateral movement of the shaft E.

The telemotor system is kept filled with fresh water mixed with 30 per cent glycerine to prevent freezing. The reservoir tank shown, by its connection, keeps the system completely filled at all times. When the steering wheel is moved the rack moves the transmitting piston; this forces the fluid through the connecting pipe and causes the operating piston to be moved. This piston, by means of its attached levers, operates the differential valve of the engine. The water expelled from the operating cylinder is returned to the transmitting cylinder through the return pipe. When the steering wheel is put amidships, communication is opened between the ends of the transmitting cylinder and the piston of the operating cylinder is returned to the central position by the springs shown, either one of which is compressed when the piston is moved from its center. Thus whenever the steering wheel passes the midship position both pistons are automatically brought back to the central position.

Electric telemotors have also been experimented with but are not used to any great extent.

Another system lately installed on large passenger vessels is shown in Fig. 101. Here there are two engines, either of which can be used. This ensures greater safety and in case of any break-down to one

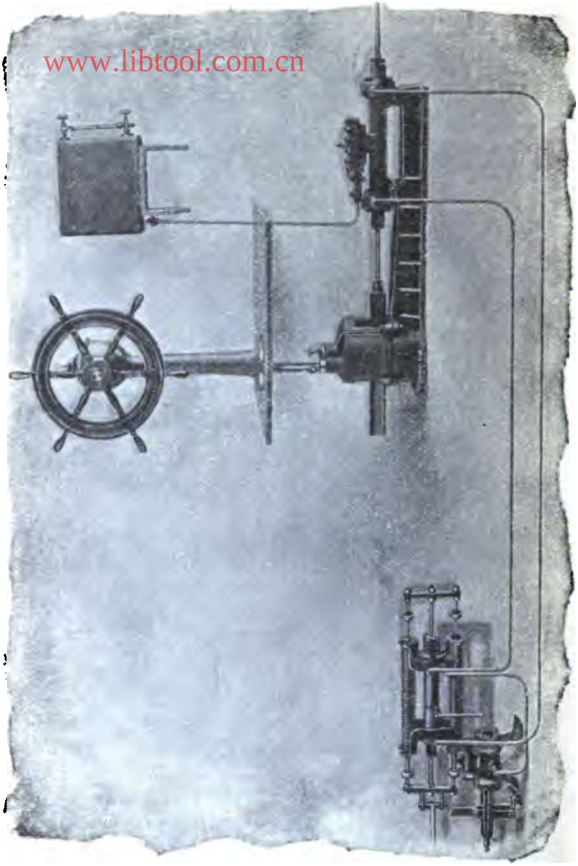


Fig. 100. — Hydraulic Telemotor.

of the engines the other will be available. As shown, the gearing on the engine gears in to a geared quadrant secured to the rudder head.

Various foreign naval vessels are fitted with electric steering gear.

The arrangement of a combined steam and electric steering gear, designed by Williamson Bros., is shown in Fig. 102.

Care and Operation. — Engines are usually arranged to operate

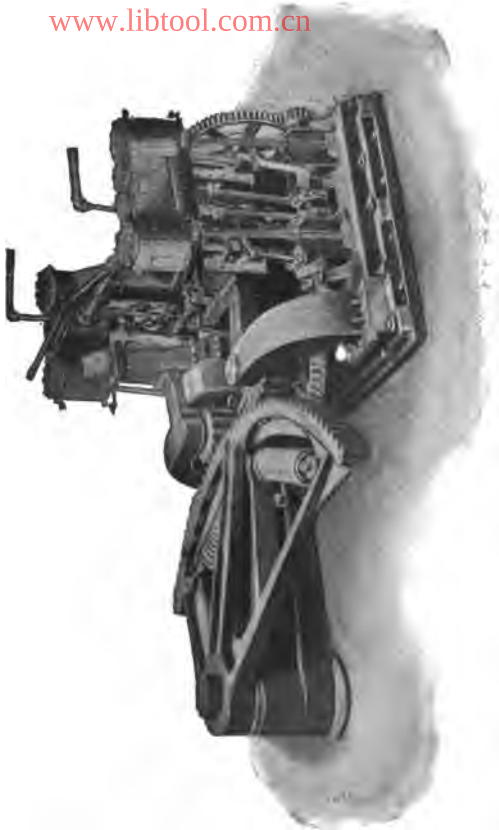


FIG. 101. — Williamson Twin Steering Engine as Applied in Merchant Vessels.

with about 100 pounds steam pressure. The reducing valves should be adjusted to furnish this pressure. Steam should be turned on a large engine at least 15 minutes before it is used, in order that the pipe and engine may have a chance to warm up. The exhaust pipe

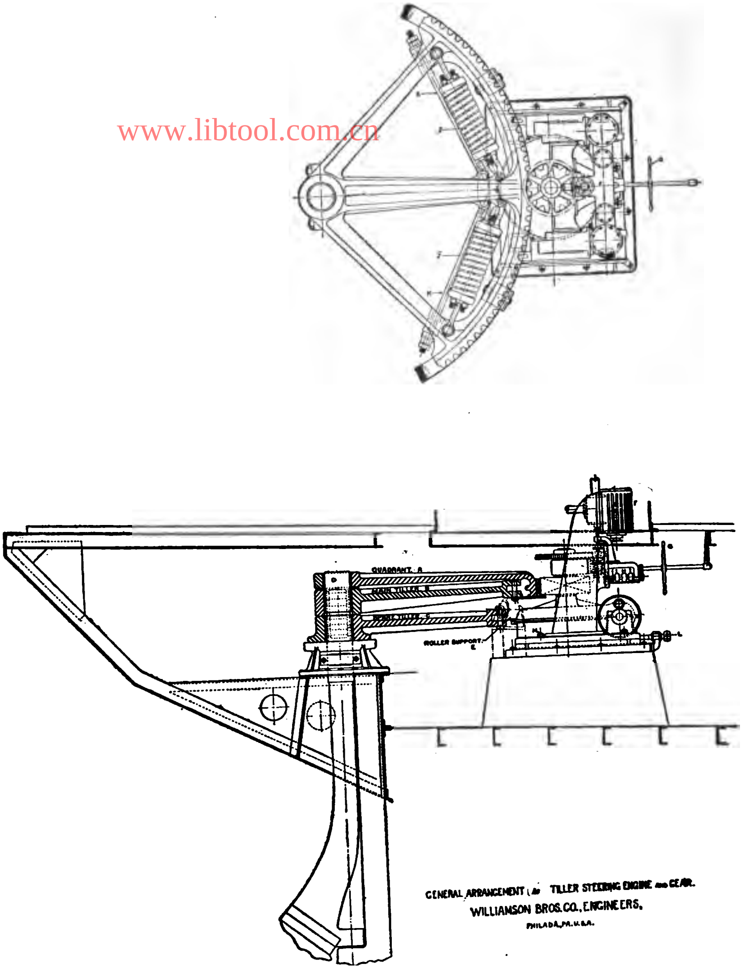


FIG. 101A. — Tiller Steering Engine.

should be drained thoroughly before the engine is operated. Before starting engine care should be taken to see that all the proper clutches

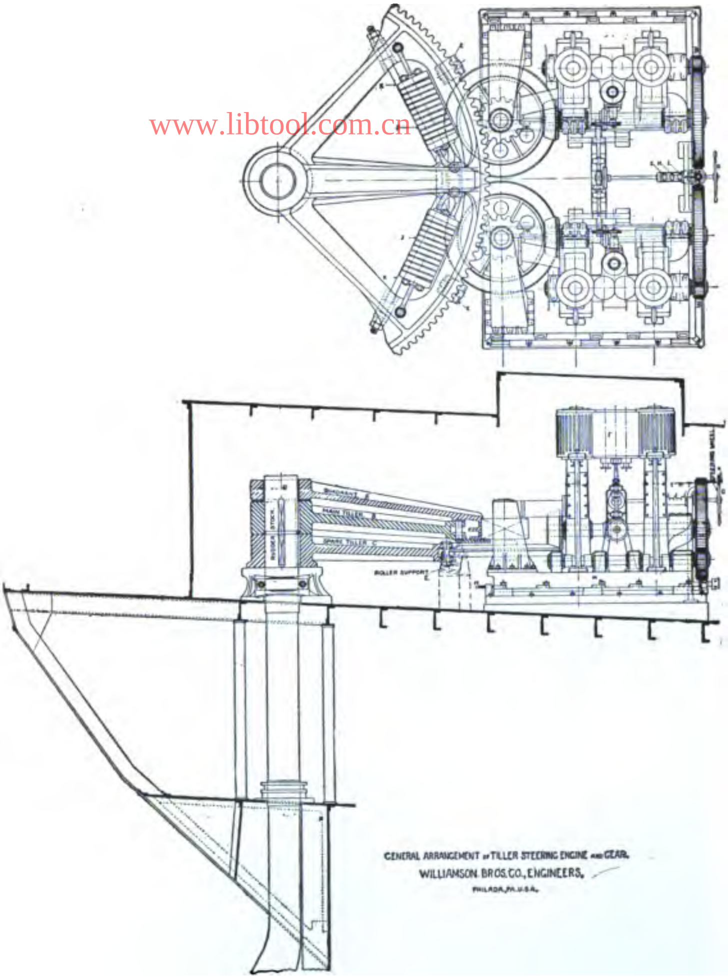


FIG. 101b. — Diagram Gear Shown in Fig. 101.

are in or out. In changing from steam to hand gear or from wheel rope to telemotor control great care must be exercised to see that all

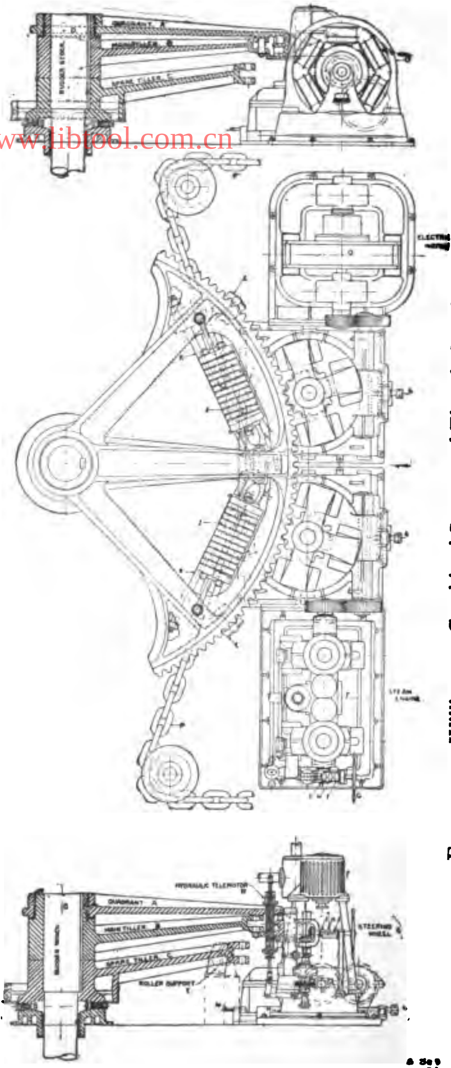


FIG. 102. — Williamson Combined Steam and Electric Steering Gear.

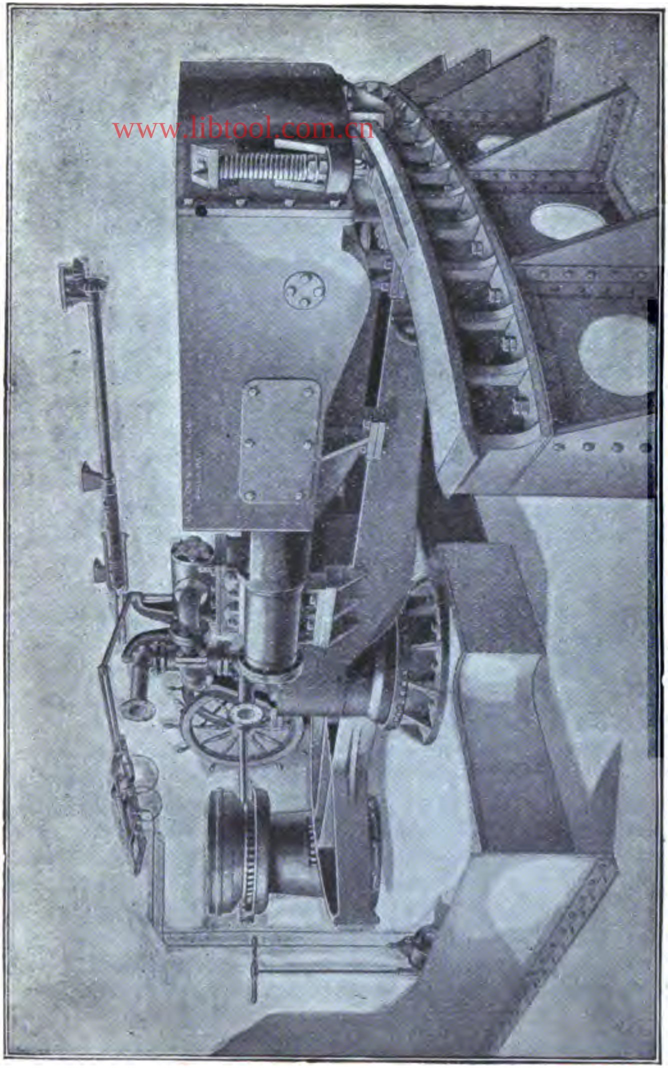


FIG. 102a. — Late Type Williamson Steering Gear.

the proper connections are made and that the various clutches are placed securely in their proper positions. On starting the engine the drains should be opened, and the engine should be gradually warmed up by moving slowly each way. While in operation the wheel should not be turned too quickly or its direction of motion suddenly reversed or stopped, as these sudden changes are liable to bring the engine up so quickly that there is danger of breaking something. The oil cups on the engine and rudder gear should be kept properly filled and the gearing should be lubricated. The separator in steam and exhaust line should be kept drained.

Overhaul. — Cylinders and valves should be examined and wiped out each quarter. Lost motion in bearings should be taken up when noticed. The clutches should be frequently cleaned and oiled so that they may be easily moved and have no tendency to jam.

CHAPTER XXVII

Air Compressors — Westinghouse Compressors — Christensen Compressors

Air Compressors.*— On all large vessels air compressors are fitted for the several purposes of (1) Supplying air for the smoke ejecting system for the large guns of the battery. (2) For furnishing air to operate pneumatic tools. (3) To supply connections for blowing the soot off the boiler tubes, an air main is run through the boiler compartments with a connection abreast each boiler. On vessels having Niclausse boilers the air system is used for blowing out the water left in the back ends of tubes when boiler is drained.

Other uses that this compressed-air service can be put to are: To furnish air for blacksmith's forge for heavy work where the hand blower does not give sufficient air. To furnish air for plumbers or coppersmiths' blow pipe. To furnish power for operating boiler tube cleaners. To furnish an air-cleaning blast for sweeping out bunkers, double bottoms and bilges.

Westinghouse Compressor. — The most common type of air compressor met with is the Westinghouse, vertical, steam-driven machine. It is of the same general type as that supplied on locomotives for furnishing air for the air brakes.

A detailed description and rules for the care and operation of this type of machine, as given by the manufacturers, is as follows (Fig. 103):

Operation of 8-inch, 9½-inch and 11-inch Compressors. — The following description applies to either the Standard or "Right and Left-hand" Compressor, the only difference between the two being in the arrangement of the steam and exhaust connections. All parts of compressors of the same size are interchangeable.

As will be seen by examining Figs. 2 and 3, the compressor has two cylinders connected by a center piece; the upper is the steam cylinder, and the lower the air cylinder; the steam admission and

* Machines described are exclusive of those furnished to supply air to torpedo tubes.

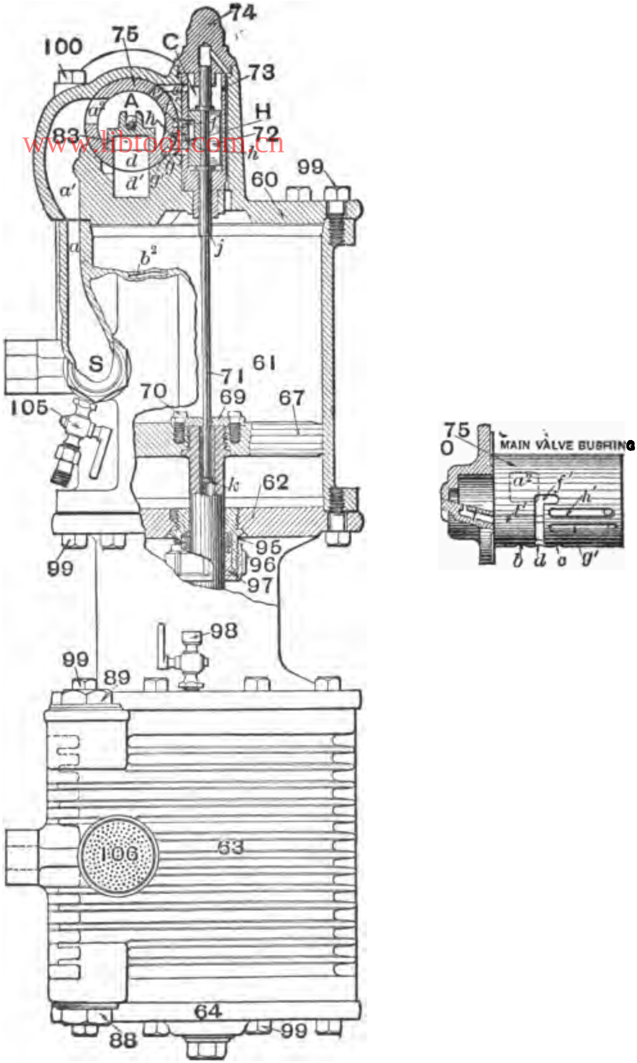


FIG. 103. — Westinghouse Air Compressor.

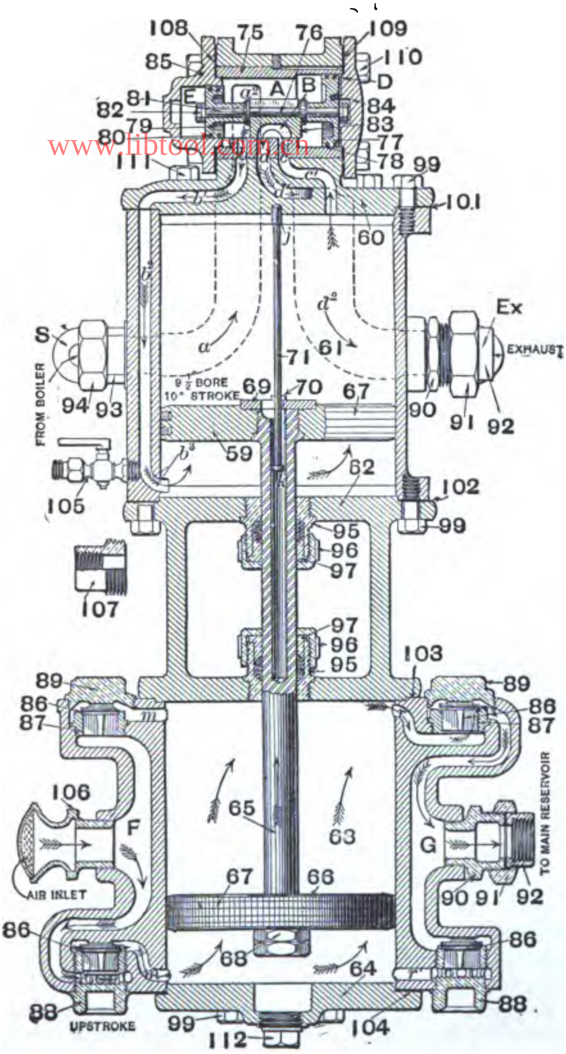


FIG. 103. — Westinghouse Air Compressor.

exhaust are controlled by a steam-actuated valve gear in the top (steam) cylinder head; both cylinders are double acting; there are two admission air valves (shown on the left in Fig. 3) and two discharge valves (shown on the right), one of each for each end of the air cylinder. These four air valves are alike, and each has a lift of $\frac{3}{32}$ inch. Chambers A and C are always in free communication through port e, e^1. Chamber E, at the left of piston 79, always communicates, by means of port t, shown in the main-valve bushing, Fig. 4, directly to main exhaust port d, so that chamber E is always free from pressure.

When reversing slide, valve 72 is in the position shown, chamber D is connected, through ports h^1, h, reversing-valve cavity H, and ports f and f^1, with main exhaust passage d, d^1, d^2, and there is no pressure at the right of piston 77.

As steam enters the compressor at S, it passes through passage a, a^1, a^2, into chamber A, between pistons 77 and 79. Since the area of piston 77 is greater than that of piston 79, it is forced to the right, drawing with it piston 79 and slide valve 83, to the position shown in Fig. 3, thus admitting steam below piston 59, through port b, b^1, b^2, b^3. Piston 65 is thereby forced upward, and the steam above piston 65 passes through port c^1, c, cavity B of slide valve 83, port d, and passage d^1, d^2, to connection E X, and discharges into the atmosphere through the exhaust pipe.

When piston 59 reaches the upper end of its stroke, reversing plate 69 strikes shoulder j on rod 71, forcing it and reversing slide valve 72 upward sufficiently to expose port g. Steam from chamber C then enters chamber D through port g and port g^1 of the bushing (Fig. 4). The pressures upon the two faces of piston 77 are thus equalized, and the piston is balanced. The pressure in chamber A, acting upon small piston 79, therefore forces it to the left, drawing with it piston 77 and slide valve 83.

With slide valve 83 in its extreme position at the left, steam from chamber A is admitted, through port c^1, c, above piston 59, forcing it down; at the same time, the steam below the piston is discharged to the atmosphere through port b^3, b^2, b^1, b, chamber B of the slide valve, port d, d^1, d^2, and the exhaust pipe connected at E X.

When piston 59 reaches the lower end of its stroke, reversing plate 69 engages reversing button k, drawing it and reversing slide valve 72 down to the positions shown, and one double stroke of the steam end of the compressor has been traced.

The movement of steam piston 59 is imparted to air piston 66 by means of the piston rod. As piston 66 is raised, the air above it is compressed, and air from the atmosphere is drawn in beneath it; the reverse is true in the downward stroke.

As piston 66 is raised, the air above it is compressed and passes through port *r*, lifts the upper discharge valve from its seat, as soon as the pressure below the valve is greater than the main-reservoir pressure above it, passes down into chamber G, and thence into the main reservoir through the pipe connection to main reservoir. The upward movement of the air piston produces a suction which causes the lower receiving valve to lift from its seat, and atmospheric air to enter through strainer 106, passing through chamber F to the port below receiving valve, thence past that valve into port m^1 and into the lower end of the air cylinder, filling the cylinder. In the downward stroke of the compressor, the effect just described is produced upon the opposite corresponding receiving and discharging valves.

The oil cup, 98, furnishes lubrication for the air cylinder.

General Instructions for Installation and Care of Westinghouse Steam-Driven Air Compressors

Installation. — Select a location easily accessible for inspection and repairs, and fasten compressor securely to heavy machinery or a solid wall by means of substantial brackets; otherwise pounding will result. Run the compressor suction to a point where clean, cool, dry air can be obtained. Provide a main reservoir of ample capacity, located at the lowest point in the piping system, and see that it is drained every day. The use of a discharge pipe of considerable length between the compressor and reservoir will tend to cool the air and prevent harmful moisture from being carried beyond the reservoir.

Piping. — All pipes should be hammered to loosen scale and dirt, have fins removed, and be thoroughly blown out with steam before erecting; bends should be used wherever possible instead of ells, and all sags avoided. Shellac or Japan varnish should be applied on the male threaded portion only, and never in the socket. Do not use red or white lead. Place substantial globe valves in steam-admission pipe, and air-discharge pipe about 12 inches from pump connection. Also put drain cock in steam admission pipe about

6 inches from pump connection. This latter is important; and failure to comply with these directions may result in the compressor stopping at critical times. Put a good sight-feed lubricator in the steam-admission pipe between boiler and steam valve.

To Start Compressor. — Fill the oil cup on the air cylinder with valve oil and set it to feed so that one filling will last about twelve hours of continuous service. Put about a teaspoonful of valve oil on the piston swab. Start the sight-feed lubricator to work; open the steam valve gradually, permitting steam-pipe condensation to pass out at the drain cock. Do not allow this condensation to pass through the compressor. Close the drain cocks when all condensation has passed off, but continue to run compressor very slowly until sufficient pressure is obtained to furnish a cushion for the air piston. Adjust the sight-feed lubricator to feed about one drop every ten seconds, until the compressor has been gradually brought up to speed, then regulate to two drops per minute.

To Stop Compressor. — Close the feed and steam valves on the sight-feed lubricator; the steam valve; the globe valve in air-discharge pipe; and open all drain cocks.

Disorders, Causes and Remedies

Compressor Refuses to Start. — Cause 1. Drain cocks have not been used as directed, allowing leaky globe valves to pass steam from the supply pipe into the compressor, where it condenses and rusts the pistons and valves. Remedy 1: Tap cap nut 74 smartly with light hammer or wrench. Shut off globe valve in steam pipe (open all drain cocks), remove cap nut 74, dose reversing valve 72 liberally with valve oil; let the oil soak down past the parts, lubricating them and cutting the rust, then proceed as per directions "To start the compressor." Cause 2. Insufficient oil reached the wearing surfaces of the compressor during the last time it was used. Remedy 2. Same as in preceding case.

Compressor Groans. — Cause 1. Steam cylinder needs oil. Remedy 1. Increase lubricator feed. Cause 2. Air cylinder needs oil. Remedy 2. Put some valve oil in air cylinder and saturate piston swab in valve oil, then replace it on the rod.

Uneven Strokes of Compressor. — Cause: Probably improper condition of air valves. Remedy: Close globe valve in air-discharge pipe, remove and clean the valves and valve chambers.

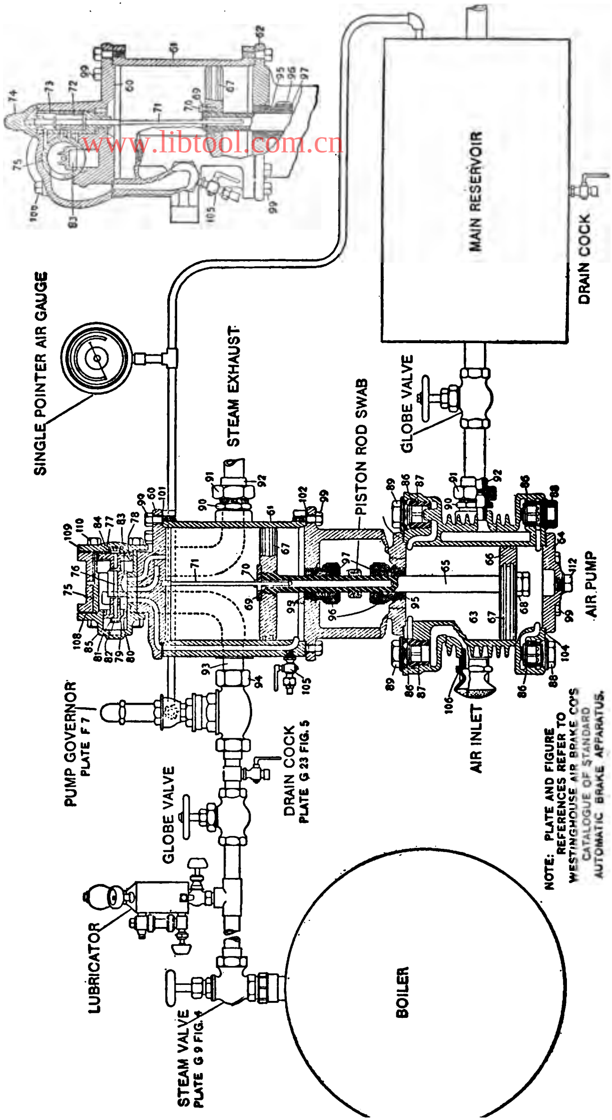


FIG. 104. — Westinghouse Air Compressor with Connections.

Compressor Compresses Air Slowly. — Cause: (1) Air piston rings a poor fit in cylinder; (2) Cylinder may be worn; or (3) Valves dirty. To determine this, place hand over suction and note whether air is drawn in during only a portion of each stroke; if so, air piston rings or cylinder are at fault. If this occurs on but one stroke, the air valves need cleaning.

Compressor Erratic in Action. — Cause: Poor condition of packing rings in valve motion. Remedy: Remove and renew same.

Compressor Heats. — Cause: (1) Air passages are clogged with burnt oil; (2) Air-piston packing rings are loose fit in cylinder; or (3) The discharge valves have insufficient lift. Remedy: (1) Clean air passages; (2) Renew air-piston rings; (3) Regulate lift of discharge valves.

Compressor Pounds. — Cause: (1) Air or steam pistons are loose; (2) Air valves have too much lift; (3) The reversing plate, 69, is loose; or, (4) The reversing rod or plate may be so worn that the motion of compressor is not reversed at the proper time. Remedy: Repair and renew worn parts.

Care of Air Compressor

1. Keep the sight-feed lubricator filled and feeding while the compressor is running.
2. Keep piston-rod swab saturated with cylinder oil.
3. Keep the piston rod neatly but loosely packed.
4. Keep globe valves closed and drain cocks open when compressor is not working.
5. Cleanse the compressor thoroughly once every six months with hot lye water, whether compressor heats or not.

Christensen Air Compressors. — This type is largely used. It is manufactured by the National Electric Company, Milwaukee, Wisconsin. The following illustrations and descriptions are furnished by the manufacturers.

Types "H" and "L" Compressors. (For Intermittent and Continuous Service)

General Description. — The general appearance of this type machine is illustrated. They are built for intermittent or continuous service in capacities from seven and one-half to fifty cubic feet of free air per minute.

The motors driving these compressors are of the series type. All coils are form wound by automatic machinery, and are thoroughly insulated. The gear and pinion are of the herring-bone type with teeth cut by special machinery, thereby reducing the noise.

The compressor has two cylinders, each being fitted with a single acting piston, with improved form of packing rings. The connecting rods are operated by a steel crank shaft with cranks set at such an angle as to give the best balance to moving parts.

FIG. 105. — Christensen Air Compressor.

The base of the motor forms the top of the compressor, and the gear, keyed on the crank shaft, is enclosed in a suitable cast-iron casing. It will thus be seen that the interior of the compressor is entirely enclosed. The space in the compressor base is partly filled with oil through an oil-filling elbow and ensures a very thorough lubrication of all moving parts. The oil chamber in the pump base communicates with the gear case, which carries oil up to the pinion on the armature shaft.

FIG. 106. — Motor and Base.

Seamless cold drawn steel suction and discharge valves are conveniently arranged in the cylinder head, each working independently of the other, with access to either. No springs are used with these valves, they being seated by gravity, and may be interchanged providing the seats have worn equally.

Type "L" Waterjacketed

These compressors are identical in every respect with the compressor just described, except that provision is made for a circulation of water around the cylinders and heads, keeping these parts at a minimum temperature and permitting these machines to be operated continuously.

Nearly all working parts of the compressors operate in a bath of oil. Other parts are automatically and continuously lubricated in a most thorough manner.

With the water-jacketed types is furnished a water governor

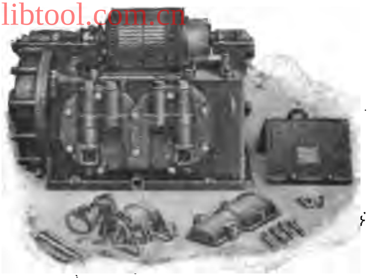


FIG. 107. — Showing Field and Bearing Caps Removed.

which automatically cuts off the circulation of water as soon as the compressor has been shut down. These governors are very simple and reliable in operating and eliminate the possible neglect to turn

FIG. 108. — Pump Base.

the water off after stopping the machine, and in a like manner the water is admitted to the cylinders and heads when the compressor is started up.

The compressor operates only when air is being used. The automatic governor described on this page stops the motor as soon as the pressure reaches a predetermined maximum and starts it again when the pressure is reduced to a minimum.

The Automatic Governor

For intermittent service, an automatic governor shown below starts and stops the compressor at the desired minimum and maximum pressures. It is a very simple piece of apparatus, consisting

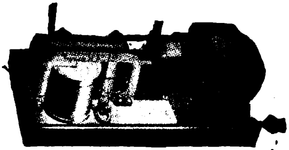


FIG. 109. — Compressor Governor.

of an ordinary pressure gage mechanism with a special hand, which upon coming in contact with a conducting stud at the position of minimum pressure allows current to flow through magnet coil. This

FIG. 110. — Motor Complete.

coil operates a plunger to which the contact pieces for the motor circuit are attached, thereby closing the circuit and starting the motor.

As soon as the pressure reaches the desired maximum, the hand strikes another stud and current passes through a second solenoid magnet, thereby pulling the plunger in the opposite direction and opening the motor circuit. By this mechanism it is possible to get a close margin between maximum and minimum pressures. This margin is readily adjusted by moving the contact studs.

FIG. 111. — Pump Base.

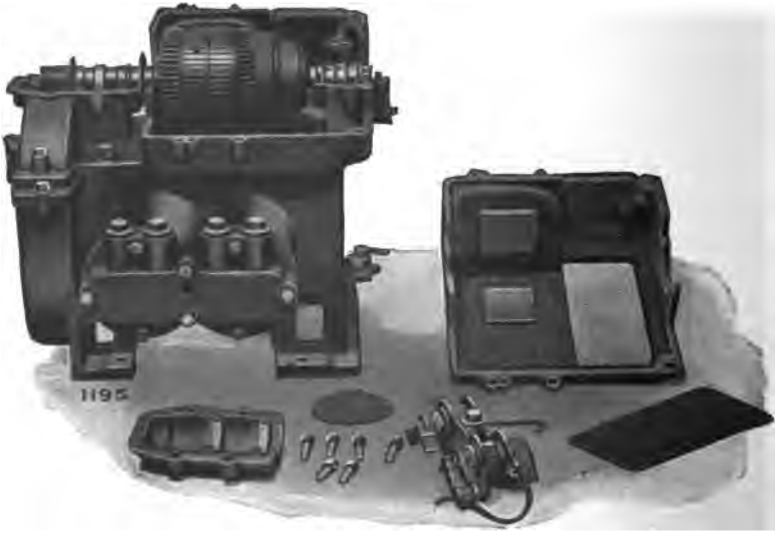


FIG. 112. — Covers Removed.

The governor is provided with a magnetic blow-out for extinguishing the arc and preventing the burning of the contact pieces.

The National Brake and Electric Co. are now furnishing the National Standard Electric Air Compressor which is a development and improvement of the Christensen Air Compressor. The

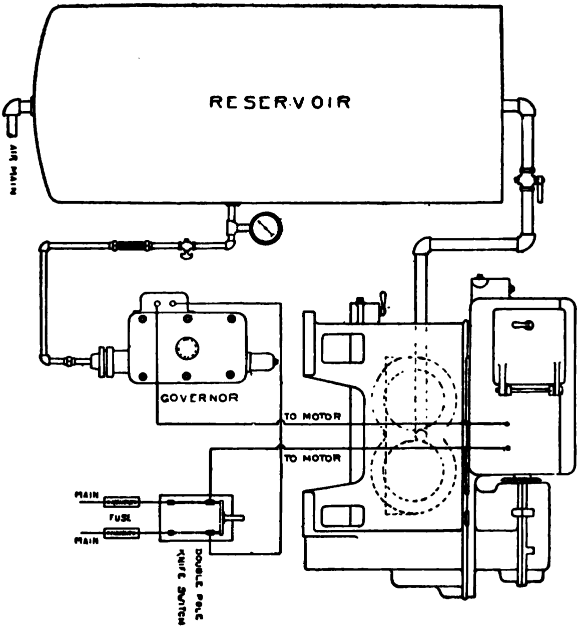


FIG. 113. — Connections for Christensen Air Compressor.

general appearance and important details of this compressor are shown by the figures taken from Bulletin 374, published by the National Brake and Electric Co. Figure 110, Motor Complete, (119ZB) Fig. 111, Pump Base Complete (1191A), Fig. 112, Covers Removed, showing simplicity and accessibility (1195).

Wiring and piping connections for compressor plant are shown in the accompanying diagram. (Fig. 113.)

CHAPTER XXVIII

Blowers and Blower Engines.

Blowers and Blower Engines. — Blowers are installed on board ship for purposes of furnishing forced draft for the boiler plant and for ventilation.

The system of forced draft almost exclusively installed is the closed fire-room system. On some small vessels and on the armored cruisers *California* and *South Dakota* the closed ash-pit system is installed.

FIG. 114. — Straight Blade Centrifugal Fan.

The blowers are installed in the fire rooms, generally suspended from the protective deck, or they are located on the protective or splinter deck above the boiler rooms, where they have a more substantial support and are not so liable to shock and vibration.

When they are above the boiler rooms the engines can be much easier kept clean, they are more accessible for overhauling and attendance, and they are not required to work in such a high temperature. They can also be repaired without interfering with the operation of boilers.

Two blowers are usually fitted for each boiler compartment, so that if one should break down the other will be available. In order that the pressure may not be lost through the opening to a disabled blower, air-tight doors or shutters are fitted on the blower ducts.

Types of fans adaptable for naval service are as follows:

Peripheral-Discharge, Straight-Blade, Centrifugal Fan. — Fig.

114. This is the type most largely encountered, and is specifically suited to the conditions for producing forced draft on naval vessels. The hub is of cast iron and fitted to the steel shaft. It has steel T arms rigidly cast into place; in other types the hub and T arms are

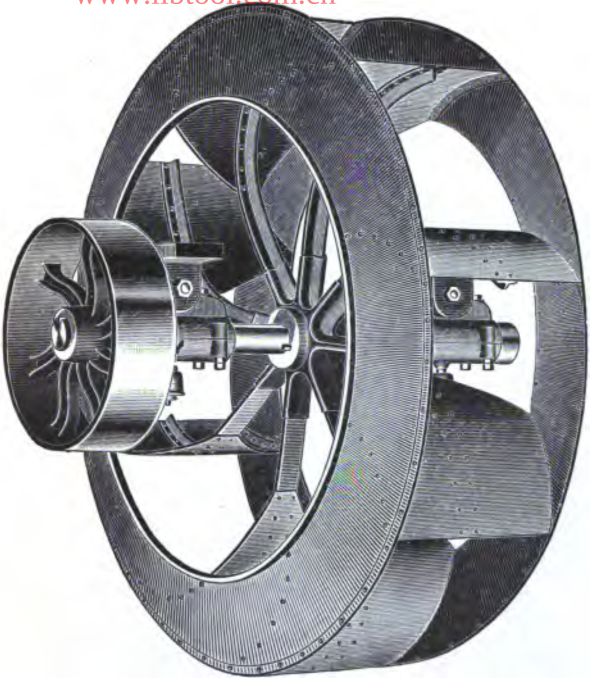
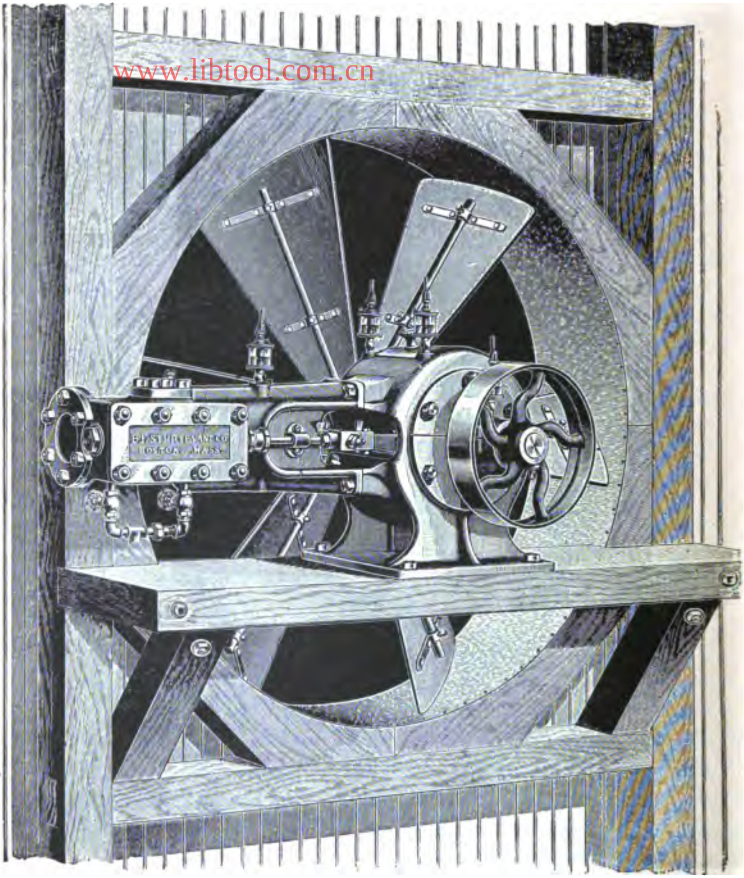


FIG. 115. — Curved Blade Centrifugal Fan.

cast in one. The steel plates are riveted to the arms, and the plates, in turn, are bolted to the conical side plates.

Curved-Blade Peripheral-Discharge Fan. — For heating and ventilating fans the blades are sometimes turned backward to secure an easier escape of the air and to reduce the noise of the fan. (Fig. 115.) This type is used largely for forced draft.

Cone Ventilating Wheel. — This type secures very great efficiency and is especially suited to places where air is drawn from one compartment without ducts to an adjoining one. It is usually installed



THE STURTEVANT DISC WHEEL
WITH
DIRECT CONNECTED HORIZONTAL ENGINE.

FIG. 116.—The Sturtevant Disc Wheel with Direct Connected Horizontal Engine.

without a casing. At the center of the wheel, forming its hub, is a conoidal casting with its apex toward the inlet side of the wheel, so that the entering air is gradually deflected in its course. By this means all unnecessary friction and loss of head, due to change of direction, are avoided.

Attached to the circumference of the casting is the steel back plate of the wheel which carries the numerous curved blades. This back plate is stiffened by steel **T** arms radiating from an auxiliary hub. This type is used on torpedo boats for forced draft.

Disc Wheels.—Fig. 116. For moving large volumes of air under low pressure with a minimum expenditure of power, disc wheels are very efficient. They are especially applicable to exhaust ventilation. The fan consists of a hub to which are cast or otherwise secured radial arms to which the steel plate blades are attached. The blades, acting as inclined planes, force the air through and beyond in a direction parallel to the shaft.

FIG. 117.—Propeller Fan.

Propeller Fans.—Fig. 117. Fans having their blades curved to a regular pitch, like a propeller, are also used. An increase in the number of blades does not add to the capacity of the fan, but secures smoother working.

The Sirocco Blower.—Fig. 118. This type of fan is, like the others, based on centrifugal action, but in this blower the blades are arranged in a different way. The blades are long and narrow, and curved forward in the direction of rotation and mounted parallel to the shaft. The length of blades is about $\frac{3}{8}$ of the diameter, and the height, radially, is about $\frac{1}{16}$ the diameter of the fan. The blades are set closely together and are riveted to an iron ring at the back, which is attached to a cast-iron conical hub, the front ends of blades being riveted to an iron ring. The suction is at the center and discharge at periphery, as on other centrifugal types.

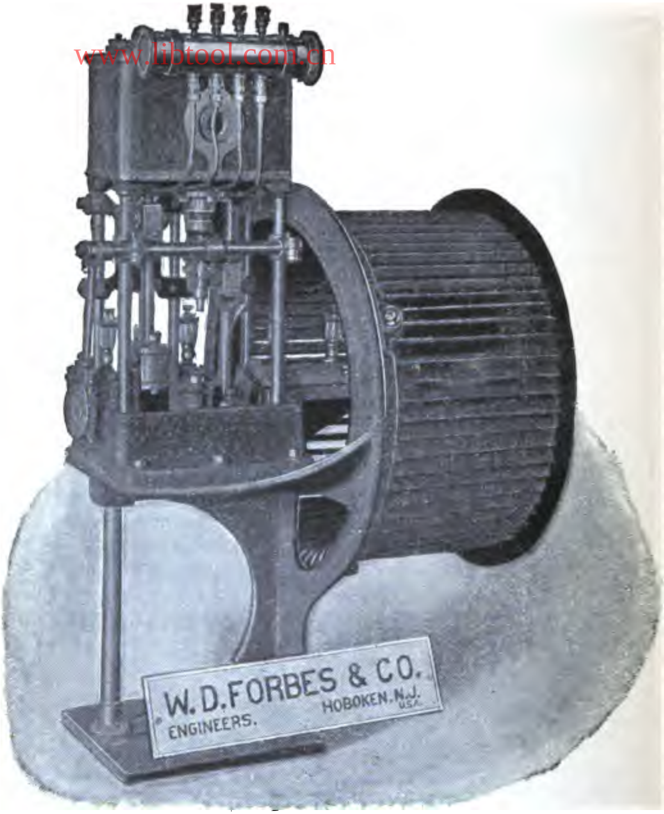


FIG. 118. — Sirocco Blower.

The Sirocco blower is a late development, and an increase in efficiency of about ten per cent over the ordinary type is claimed for it.

The ventilating blowers on board naval vessels are now operated entirely by electric motors and require the usual care of such electric apparatus. The fans are usually peripheral discharge wheels with curved blades.

Forced-Draft Blower Engines. — Force-draft blowers are operated by fast moving steam engines. They are usually two-cylinder simple or two-cylinder compound engines. On torpedo boats, yachts and small vessels horizontal engines are used. Turbine engines may also be used. The speed of these reciprocating engines is 250 to 700 revolutions per minute. On the latest vessels force-draft blowers are to be electrically driven.

Blowers and blower engines are usually of special make. Forbes, Sturtevant, and Buffalo Forge Co. are makes very generally used. Figs. 119, 120, 121 show applications of blowers for F. D.

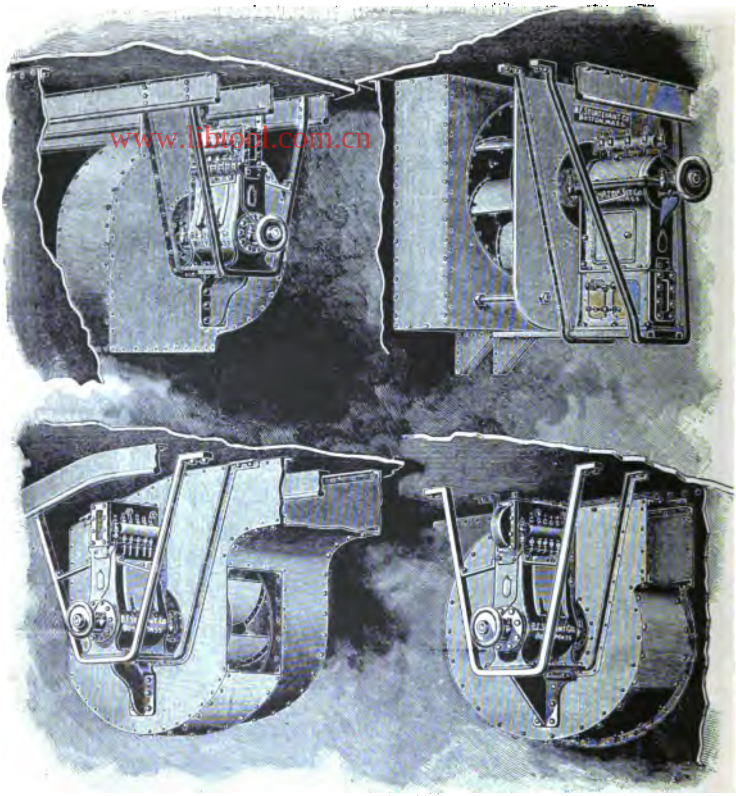
One of the most important matters in installing blower engines is to secure sufficiently rigid supports to check vibrations at high speed. Supports to suspend engines are usually too light, and they are not sufficiently rigid. These faults can often be remedied by installing additional braces.

Operation. — The principal thing to look out for is to keep a proper supply of oil. Blowers are usually fitted with closed automatic sight-feed oil boxes, and some have forced lubrication, similar to that of the latest dynamo engines. To maintain a certain air pressure the speed necessary will depend in a large measure on the tightness of the forced-draft doors. If there is much leakage the blower engines must be run faster.

The speed at which the blower is to be run is regulated by the water tender in charge of the fire room, who is governed by the air pressure that he wishes to maintain. On vessels where blowers are above the protective deck the admission of steam is often controlled from the fire room by means of an extension stem from the blower branch steam pipe.

Care and Overhauling. — Blower engines require periodically a general adjustment of working parts and an examination of cylinders and valves. With well-designed and well-balanced engines little trouble is met with.

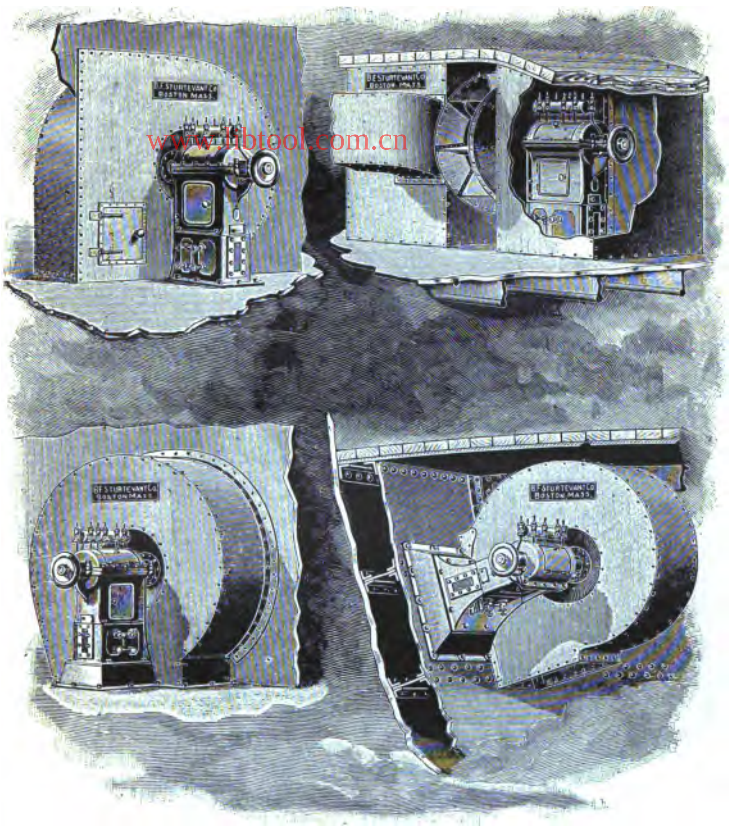
One of the principal troubles with blower engines is dirt and grit, dust, etc., getting into some of the bearings. Special care should be taken to see that the doors of casings, oil service, etc., is absolutely dust-tight. The space surrounding the blowers should be kept clear of dust especially at the times that the engines are being overhauled.



TYPES OF STURTEVANT SPECIAL STEAM FANS

APPLIED FOR FORCED DRAFT ON VESSELS OF U. S. NAVY.

FIG. 119 — Types of Sturtevant Special Steam Fans applied for Forced Draft on Vessels of U. S. Navy.



TYPES OF STURTEVANT SPECIAL STEAM FANS

APPLIED FOR FORCED DRAFT ON VESSELS OF U.S. NAVY.

FIG. 120. — Types of Sturtevant Special Steam Fans Applied for Forced Draft on Vessels of U. S. Navy.

Additional dust guards can often be fitted over bearings and oil service.

In order to insure blowers being ready they should be tried at least once a month under steam. Forced-draft doors, etc., must be frequently overhauled, as they often warp out of shape from heat.

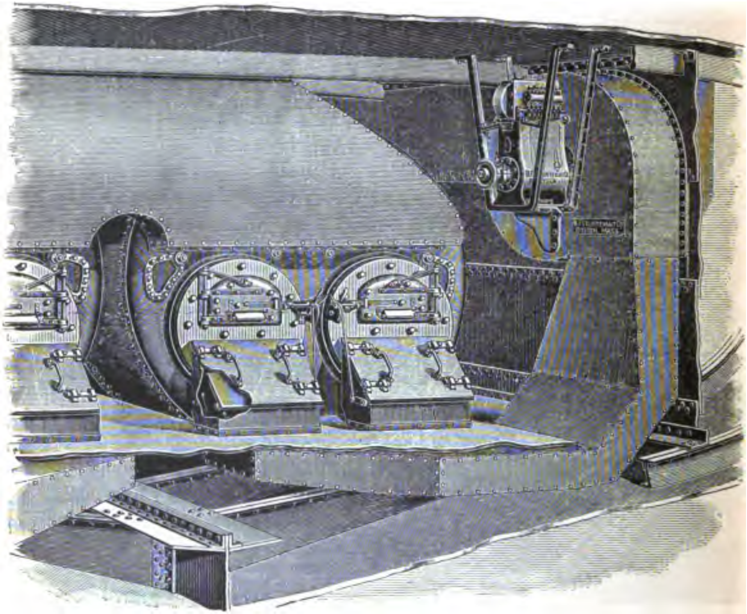


FIG. 121. — Closed Ashpit Draft.

CHAPTER XXIX

Hoists and Ejectors.

Ash Hoists and Ejectors. — Ashes are usually disposed of by hoisting them to the main or gun deck and dumping them in the ash chute.

Fire-room ventilators are used for the hoists, and rails are fitted for the purpose of guiding the ash buckets. The engines are usually

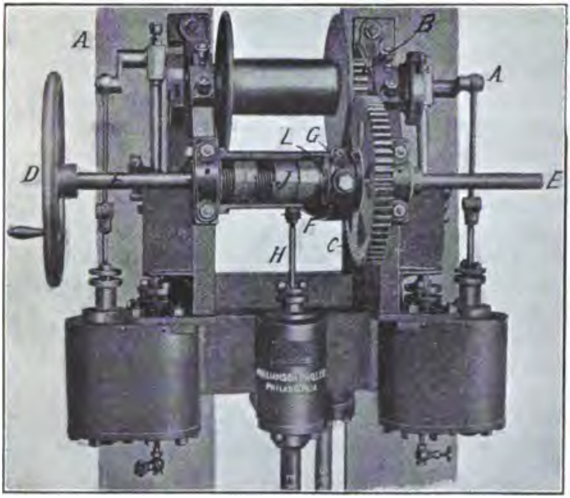


FIG. 122. — Williamson Ash Hoist Engine.

located in the fire-room hatch at the level of the gun deck. One engine is employed for a hoist at each side. The engine is put in gear with either side by means of a shifting clutch. A general type of ash hoisting engine is that shown in Fig. 122.

Operation. — Steam should be turned on slowly and cylinders drained. The control wheel should be turned uniformly and not by jerks. Control wheel should not be suddenly reversed. Great care is to be taken that the change clutch is properly in gear, and that it is in gear on only one side.

The detail method of operation is as follows: A A are single eccentric cranks, which operate the main valve on each cylinder. B is a gear wheel fixed to the drum and gearing into a spur wheel C, cast on a sleeve, L, with an internal thread to correspond to the external thread on shaft E. A groove is cut in the sleeve fitted with a loose collar, G, which, through a bell-crank lever, F, moves the reversing valve by means of the valve stem H when spur wheel C moves to the right or left.

Turning the starting wheel, D, to the right, the spur wheel, C, moves to the left, the differential valve moves downward and the engine turns, moving the drum shaft to the left; the spur wheel, C, will then have a right-handed motion, pushing the sleeve to the right, and closing the differential valve, with the result that if the hand wheel is stopped the engine stops, or if the hand wheel is turned in the opposite direction a reverse movement is given.

The thread shown on the shaft carries a nut, J, which is prevented from turning, but has a certain lateral motion, between the safety stops, to give a proper amount of hoist. On bringing up on the stops the engine is stopped. This prevents over-winding and the breaking of cable, and stops the ash bucket as it reaches the fire-room floor. The stops can be adjusted to the desired hoist.

To Overhaul. — It often happens that parts of these engines are out of line. In some cases the stuffing boxes when packed tight may throw valve stems to one side. Parts of clutches are often made of cast iron, and sometimes break from jar. When made of composition they will stand wear and jar much better.

The wire hoisting cable should be kept clear of paint and occasionally wiped over with graphite and tallow.

Cylinders and valve chests should be periodically overhauled and coated with graphite. When drains of ash hoists lead to open air special care should be taken to see that they are closed while engine is standing idle.

Electric Ash Hoist. — Fig. 123. This type of ash hoist has been used in some foreign vessels. The electric hoist is heavier and more costly than the steam engine, and there are other disadvantages to ·use its non-adoption for general service.

Ash hoists are located near boiler rooms so that steam leads are always short and direct.

The lift ash hoist, consisting of a long steam cylinder whose piston operates a multiple pulley, is used on some vessels, and these are often met with in the merchant service. The noise encountered

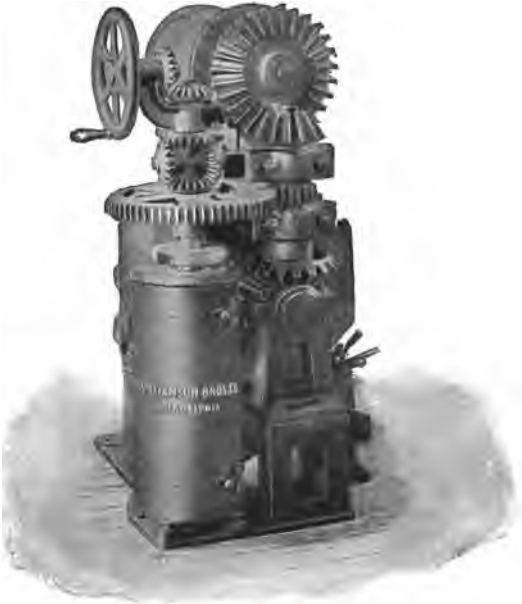


FIG. 123. — Electric Ash Hoist.

with the usual type of reciprocating engine is avoided and the space occupied is very small.

NOTE.—The illustration, Fig. 123, shows an Electric Ash Hoisting Engine in which the motor is controlled automatically; the operator applying the current for starting, and the action of the motor itself following up automatically and closing the current. The brake illustrated is applied by a spring weight when the current is open, and is held off by electro-magnets when the motor is hoisting or lowering. Capacity of hoist, 400 pounds.

Ash Ejectors.—Fig. 124. Some naval vessels, especially torpedo boats, destroyers, and scout cruisers, which are likely to be under heavy forced draft for long periods, are fitted with ash ejectors for removing ashes from the fire rooms. A connecting pipe leads through side of the ship several feet above the water line. The connection at the bottom of the hopper is led to the discharge of a pump.

FIG. 124. — See Ash Ejector.

The operation is as follows: The lid of the hopper is closed and the jet cock and drain cock are closed. First drain the water from the discharge pipe by opening the drain cock, and start pump. When a good pressure has been obtained, open the jet cock quickly. The water issues from the jet nozzle at a high velocity and discharges at the upper end of the pipe. It creates a suction in the hopper, and if this is now opened and the ashes shoveled in they will be sucked in and then carried up with the water and ejected from the ship's side. When all ashes are in, the hopper is secured and pump stopped.

The base of hoppers is fitted with a grating to prevent large lumps coming in and clogging the pipe.

Difficulties with ejectors arise from opening the hopper before a proper jet suction is secured, or by stopping or slowing the pump before closing the hopper. If this is done the water will back into the fire room.

The pump for operating must be sufficiently large to maintain a constant pressure at the jet. Duplex pumps are considered more desirable for this purpose, but simplex pumps are also used. The connection from the pump should be short and direct, and the pump should be in the same compartment as the ejector. Where ejectors are less than 4-inch diameter, considerable trouble is experienced by pipes clogging. The bent part of pipe is subject to considerable wear from the action of ashes and clinkers. This is often made up with a specially thick cast-iron piece that can be renewed when worn.

CHAPTER XXX

Workshop Machinery — General Workshop — Other Accessories — Material for Workshop.

General Workshop. — The general workshop on large vessels contains the following machine tools:

Large lathe.
Small tool-room lathe.
Shaper.
Milling machine.
Drill press.
Sensitive drill.

On the smaller vessels the milling machine and sensitive drill are omitted.

The following are the specifications for the machine tools for the latest battleships.

MACHINE TOOLS

There will be provided and installed in the general workshop the following machine tools, viz:

One screw-cutting, back-geared, extension gap lathe, to swing at least 28 inches over the upper and 48 inches over the lower ways, with not less than ten feet between the centers, when extended.

To have hollow spindle, compound rest, steady and follow rests, power cross feed, taper attachment, countershaft, 2 face plates, 1 large and 1 small chuck, 1 drill chuck and a complete set of at least 16 lathe tools and 7 lathe dogs.

One screw-cutting, back-geared tool-room lathe to swing at least 14 inches over the ways and not less than 4 feet between the centers.

To have quick-change feed gear, power cross feed, hollow spindle, taper attachment, oil can, 1 large and 1 small face plate, counter shaft, 1 large and 1 small chuck and drill chuck, drawing-in attachment, with complete set of chucks, a set of at least 12 lathe tools and 6 lathe dogs.

One column tool-room shaper of at least 15-inch stroke and not less than 15-inch traverse; to have automatic stop, adjustable table, and graduated swivel vise with jaws for taper work, 24-inch graduated index center and a set of at least 12 shaper tools.

One upright drill, to drill up to 1½ inches, to have at least 14 inches from edge of work, to have not less than 14 inches of traverse of spindle, to be fitted for No. 4 Morse taper, with requisite number of sockets.

To have a complete set of twist drills from $\frac{1}{4}$ to $\frac{5}{8}$ inch by 32ds, and from $\frac{11}{16}$ to $1\frac{1}{2}$ inches by 16ths. To have automatic and hand feed, sliding head, counterbalanced spindle, circular table, revolvable by gear and adjustable vertically by gear, automatic stop, tapping attachment, countershaft, and a small drill chuck fitted.

One 16-inch sensitive drill, to have a counterbalanced spindle fitted for No. 1 Morse taper, sliding head; table to have vertical adjustable movement, to drill holes up to $\frac{5}{8}$ inch, with drill chuck and complete set of drills from $\frac{1}{16}$ to $\frac{5}{8}$ inch by 32ds.

One universal milling machine with overhanging arm; to have at least 18-inch longitudinal feed of table, 13-inch vertical movement, and $4\frac{1}{2}$-inch traverse. Spindle to be fitted for No. 9 B. & S. taper. To have automatic cross-feed, universal chuck, arbor, index, swivel, vise, spiral cutting attachment, countershaft, 3 milling cutters, 2 side millers, 6 metal slit saws, 3 angular cutters, 4 end mills and 2 collets.

One combined hand-punch and shears with 6-inch shear blades, to cut $\frac{3}{4}$-inch round iron, shear $\frac{3}{8}$-inch steel plate, and punch $\frac{3}{8}$-inch holes in $\frac{3}{8}$-inch mild-steel plates 4 inches from edge.

One double emery grinder on column, with carborundum wheels, 12-inch diameter by 2-inch face, with countershaft and attachment for surface grinding and with 2 spare wheels.

One portable cylinder-boring machine, with latest attachments for boring cylinders in place. To bore from 6 to 24 inches diameter and to have at least 30 inches travel.

Six machinist's swivel bottom vises, with jaws at least $5\frac{1}{4}$ inches wide, opening 8 inches, with pipe vise jaws and copper vise lips.

One approved steel blacksmith's forge, of the portable folding type, with all the necessary tools and fixtures. The blast wheel to be about 12 inches diameter, turned by a crank. The gearing enclosed in a dust-proof case. When set up, the pan to be about 24 inches square. The pan and hood to form a case which, when the forge is dismantled and the parts placed inside, will be a strong, impact, steel box, provided with handles for carrying. This forge will be supplied with a set of tools of assorted sizes, consisting of the following: 6 pairs tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets swages, 6 sets of fullers, 1 flatter, 1 hardy, and 1 set hammers.

There will be provided and set in the blacksmith shop an approved blacksmith's forge, about 42 inches square by about 25 inches high. Forge to be complete with tuyere, blast gate, pipe connecting as directed, etc., and with a set of tools of assorted sizes consisting of the following: 6 pairs of tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets of swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set of hammers.

One steel blacksmith's anvil of 140 pounds weight, face 14 inches by 4 inches, horn $8\frac{1}{2}$ inches long, with a cutter hole $\frac{7}{8}$-inch square.

All tools to be the best design, material, quality, and workmanship, to have the latest improvements and all necessary attachments, wrenches and countershafts, and, when required, provision will be made for working them by hand.

The lathes to have a complete set of change gears for cutting U. S. N. standard screw-threads, including $11\frac{1}{2}$ threads per inch.

When submitted for approval there must be furnished full descriptions, cuts or drawings showing details of the machine, also the name of the maker, the net weight, the space occupied, and a list of the tools and attachments.

All machines to be furnished complete with a full set of cutting tools and all necessary attachments for miscellaneous work.

The machine tools will be driven by one or more inclosed motors, either directly or through the medium of line and countershafting as approved.

All of the above tools will be subject to the approval of the Bureau of Steam Engineering.

The following are the specifications for the machine tools for the scout cruisers.

MACHINE TOOLS

There will be provided and installed in the general workshop the following machine tools, viz.:

One screw-cutting, back-geared, extension-gap lathe, to swing at least 28 inches over the upper and 48 inches over the lower ways, with not less than 10 feet between the centers, when extended. To have hollow spindle compound rest, steady and follow rests, power cross feed, taper attachment, countershaft, 2 face plates, 1 large and 1 small chuck, 1 drill chuck and a complete set of at least 16 lathe tools and 7 lathe dogs.

One screw-cutting, back-geared tool-room lathe, to swing at least 14 inches over the ways and not less than 4 feet between the centers. To have quick-change feed gear, power cross feed, hollow-spindle taper attachment, oil pan, 1 large and 1 small face plate, counter shaft, 1 large and 1 small chuck and drill chuck, drawing-in attachment, with complete set of chucks, a set of at least 12 lathe tools and 6 lathe dogs.

One column tool-room shaper of at least 15-inch stroke and not less than 15-inch traverse. To have automatic stop, adjustable table, and graduated swivel vise with jaws for taper work, 24-inch graduated index center and a set of at least 12 shaper tools.

One upright drill, to drill up to $1\frac{1}{2}$ inches, to have at least 14 inches from edge of work, to have not less than 14 inches of traverse of spindle, to be fitted for No. 4 Morse taper, with requisite number of sockets. To have a complete set of twist drills from $\frac{1}{4}$ to $\frac{5}{8}$ inch by 32ds, and from $\frac{11}{16}$ to $1\frac{1}{2}$ inches by 16ths. To have automatic and hand feed, sliding head, counterbalanced spindle, circular table, revolvable by gear and adjustable vertically by gear, automatic stop, tapping attachment, countershaft and a small drill chuck fitted.

One 16-inch sensitive drill, to have a counterbalanced spindle fitted for No. 1 Morse paper, sliding head, table, to have vertical atjustable movement, to drill holes up to $\frac{5}{8}$-inch with drill chuck and complete set of drills from $\frac{1}{16}$ to $\frac{5}{8}$ inch by 32ds.

One universal milling machine with overhanging arm; to have at least 18-inch longitudinal feed of table, 13-inch vertical movement, and $4\frac{1}{2}$-inch traverse. Spindle to be fitted for No. 9 B. & S. taper. To have automatic cross feed, universal chuck, arbor, index, swivel vise, spiral cutting attachment, countershaft, 3 milling cutters, 2 side millers, 6 metal slit saws, 3 angular cutters, 4 end mills and 2 collets.

One combined hand punch and shears with 6-inch shear blades, to cut $\frac{3}{4}$-inch round iron, shear $\frac{3}{8}$-inch steel plate, and punch $\frac{3}{8}$-inch holes in $\frac{3}{8}$-inch mild-steel plates 4 inches from edge.

One double emery grinder on column, with carborundum wheels, 12-inch diameter by 2-inch face, with countershaft and attachment for surface grinding and with 2 spare wheels.

One portable cylinder-boring machine with latest attachments for boring cylinders in place. To bore from 6 to 24 inches diameter and to have at least 30 inches travel.

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One approved steel blacksmith's forge, of the portable folding type, with all the necessary tools and fixtures. The blast wheel to be about 12 inches diameter turned by a crank. The gearing enclosed in a dust-proof case. When set up, the pan to be about 24 inches square. The pan and hood to form a case which, when the forge is dismantled and the parts placed inside, will be a strong, impact, steel box, provided with handles for carrying. This forge will be supplied with a set of tools of assorted sizes, consisting of the following: 6 pairs tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set hammers.

There will be provided and set in the blacksmith-shop an approved blacksmith's forge about 42 inches square by about 25 inches high. Forge to be complete with tuyere, blast gate, pipe connecting as directed, etc. And with a set of tools of assorted sizes consisting of the following: 6 pairs of tongs, 4 chisels, 6 punches, 4 hammers, 3 sledges, 6 sets of swages, 6 sets of fullers, 1 flatter, 1 hardy and 1 set hammers.

In addition to the accessories enumerated above the following are desirable:

For large lathe: Pipe center to fit tail stock, to be used in turning pipe.

Bell center for centering pipes.

Two centering tools, same size as pipe center.

One center grinder to fit tool post head.

Additional lathe tools for special work.

For small lathe: One steady rest.

One follower set.

Pipe center to fit tail stock.

Bell center, same as pipe center.

Armstrong tool holder.

One center grinder.

Two centering tools, the same size as the pipe centers.

For drill press: One boring bar complete with tapered shank.

Machine tools on board ship are driven by independent electric motors, by a motor which drives shafting from which each tool is operated by a belt, and by a small steam engine driving shafting.

The most approved system is considered to be that where each tool is driven by its own motor. This dispenses with the use of shafting and belts, and thus gives greater space and facilities for handling work about the machines.

The following is a list of material for use in work shop:

Castings: Hard cast iron, hollow, of various diameters, for making packing rings, valve chest liners, etc.

Steel billets: For making crosshead and crank pins of auxiliaries, especially for blowers, ice machines, and ash hoists.

Iron bar: Round and flat, of various sizes, for brackets, ties, supports, etc.

Steel bars: For making extension spindles, valve stems and piston rods of auxiliaries.

Tool steel: For making chisels, tools and special wearing parts.

Brass castings, various sizes: For making brass fittings of different kinds.

Brass and Manganese-bronze rods, round and hexagonal: For making brass valve stems, valves, bushings and other fittings.

Sheet brass, assorted sizes: For liners, shims, distance pieces and pipe covering.

Sheet copper: For gaskets and pipe covering.

Spring steel and brass: For springs.

Sheet iron, plain and galvanized: For making covers, tanks, shelves, etc.

Brass, iron and copper piping of various sizes.

Copper tubing: For small steam pipe and gage connections.

Other accessories to the machine shop are surface plates, usually a small and a large one, plate gages, sets of taps and dies for bolts and nuts, sets of pipe taps and dies, pipe cutters, pipe wrenches, corrugating machine for corrugating copper gaskets, electric and pneumatic drills and hammers, buffing wheel to be used on emery grinder spindle for polishing.

PART VI

SPARE PARTS AND TESTS

CHAPTER XXXI

Outfit of Tools and Spare Parts — Tools and Stores — Spare Parts.

Outfit of Tools and Spare Parts. — On commissioning, vessels are furnished with an outfit of special tools and spare parts by the builders. These may be considered to be the permanent outfit; additional tools, gear and supplies are furnished from the General Storekeeper of the Navy Yard in accordance with the regular allowance list for a vessel.

The following are the latest requirements of the machinery specifications for the permanent outfit of tools and spare parts.

Tools and Stores. — The following tools will be provided for the engine and fire rooms, viz.:

Two ratchets for turning gear.

One wrench for propeller-blade nuts.

One wrench for propeller-shaft nuts.

One set of case-hardened wrenches with racks, for each auxiliary engine, to be secured to the bulkhead near its engine.

One set of wrenches complete for each engine and fire room, fitted for all nuts in the respective compartment, plainly marked as to size and any special use, and fitted in iron racks of approved pattern. The set will include duplicates of all special wrenches found to be necessary in erecting and installing the machinery.

Wrenches for nuts of bolts less than 1 inch in diameter will be finished. For sizes over 2 inches they will be box wrenches, where such can be used. Socket wrenches will be furnished where required. Open-end wrenches will be of forged steel with case-hardened jaws; all others will be of forged or cast steel.

A fixed trammel for setting the main valves without removing the covers. The valve stems will be properly marked for this purpose.

Fixed trammels or gages for aligning crank shafts.

Two tube expanders for evaporating tubes.

One tube expander for feed-heater tubes.

One tube expander for distiller tubes.

A hydraulic jack of approved pattern for withdrawing the bolts of the main-shaft couplings.

One boiler-test pump, with gage, to test up to 500 pounds; to be fitted with 10 feet suction and 24 feet pressure hose of sizes to suit pump, with couplings and connections complete.

Steel templets, $\frac{1}{8}$ inch thick, of the bore in propeller hubs.

One hundred condenser-tube plugs, brass, hollow, threaded same as ferrules.

One hundred feed-heater-tube plugs, cast iron, slightly tapered.

Scrapers for brasses, of various sizes and shapes.

Three portable work benches for fire rooms, to be easily taken apart or bolted together. Each to be fitted with Parker's combination vise or equivalent, for holding 3-inch pipe or under; to be 2 feet 6 inches high, 2 feet 6 inches wide, and 4 feet long.

Planks of suitable lengths and dimensions, properly shaped for use as staging about crank pits.

Boxes for cleaning gear, 12 by 6 by 5 inches, to be strongly made of galvanized iron, with vertical partition in middle and with handle in end to draw from shelf; this end stamped "U. S. S. Engineer Dept."

Pigeonhole cabinet shelves for stowing the above boxes, to be strongly made of galvanized iron and placed where directed.

Brass lamp trays, about 4 feet by 27 inches, to be about 4 inches deep and provided with perforated division plates in three sections, so as to be easily lifted out. To have draincock and to be secured in shaft alley as directed.

Flanges, for copper steam pipes, of brazing material, as per sketches to be furnished. These flanges to be faced, grooved, and ready for use, except that bolt holes are not to be drilled.

Any special or unusual gear for engine-room telegraphs.

Any special or unusual gear, knuckle joints, bevel gears, etc., for revolution indicator.

Dies for making copper gaskets.

There will be the following tools and stores for the boiler rooms:

Two sets of fire tools for each fire room. A set of fire tools will comprise two long and two medium-length slice bars, two long and two medium-length fire hoes, one long and one medium-length ash hoe (each hoe with one spare blade), two devil's claws, two pricker bars, two soot hoes, four coal buckets, and two ash buckets.

Racks will be fitted in the fire rooms, in convenient places, for holding the fire tools.

Wrenches for boiler hand-hole nuts, two for each boiler.

Wrenches for superheater hand-hole nuts, one for each boiler.

Wrenches for boiler manhole nuts, one for each boiler.

Suitable wire and bristle brushes for cleaning soot from exterior of tubes.

Tube scrapers with handles, two for each boiler.

Six tube expanders and mandrels, complete, for each size of generating tube.

Four tube expanders and mandrels, complete for each of the other sizes used in assembling boilers.

Twenty-four plugs for each size of tubes used.

Four plug extractors.

Eight safety-valve gags.

All special tools used in assembling, repair, and cleaning of boilers, as directed.

One turbine tube cleaner for each two boilers, for each size of generating tube, all to be provided with flexible hose.

Four patterns for grate bars.

One pattern for furnace dead plates.

One pattern for fire-door lining.

One pattern for each special form of zinc protector used in boilers.

One set of steel templets, $\frac{1}{16}$ inch thick, for all manhole and hand-hole plate gaskets, each plainly marked to show for which gasket.

Other tools, etc., as may be directed, depending on the type of boiler adopted.

All tools will be conveniently stowed and trammels and gages will have protecting cases.

Fire brick must be of commercial size.

Spare Parts. — Spare parts will be furnished in accordance with the following tables.

Where machinery not here mentioned or auxiliaries of a different type are installed, spare parts will be furnished in accordance with lists prepared or approved by the Bureau of Steam Engineering.

Spare Parts for Main Engines. — The following spare parts for main engines will be furnished and carried on board:

PART	NUMBER TO BE FURNISHED
Piston rods	1 of each size and pattern.
Valve stems	1 of each size and pattern.
Crosshead slippers	1 of each size and pattern.
Metallic packing, piston rods	All for both engines.
Metallic packing, valve stems	All for both engines.
Eccentric straps, bolts and liners, complete	1 set of each pattern.
Crank-pin brasses, top	1 of each pattern.
Crank-pin brasses, bottom	1 of each pattern.
Liners for crank-pin brasses	2 of each pattern.
Bolts for crank-pin brasses	2 of each pattern.
Crosshead-pin brasses, top	2 of each pattern.
Crosshead-pin brasses, bottom	2 of each pattern.
Liners for crosshead-pin brasses	4 of each pattern.
Bolts for crosshead-pin brasses	4 of each pattern.
Eccentric-rod brasses, top	2 of each pattern.
Eccentric-rod brasses, bottom	2 of each pattern.
Liners for eccentric-rod brasses	4 of each pattern.
Main-bearing brasses, top if fitted	1 of each pattern.
Main-bearing brasses, bottom	1 of each pattern.
Liners for main bearings	2 of each pattern.
Bolts for main bearings	4 of each pattern.
Valve-gear brasses, bushings, etc., not specifically mentioned above.	1 of each size and pattern.
Piston-rings, complete	1 for each piston.
Piston-ring springs	All for each piston.
Piston-follower bolts and nuts	25 of each size and pattern.
Cylinder head bolts	25 of each size and pattern.
Coupling bolts and nuts	3 of each size and pattern.
Split pins, special	2 of each size and pattern.

Boiler Spares. — The following spare parts will be furnished and carried on board:

PART	NUMBER TO BE FURNISHED
Grate bars	Complete for 3 boilers.
Bearers	Complete for 3 boilers.
Dead plates	Complete for 3 boilers.
Furnace-door frames, complete	Complete for 3 boilers.
Furnace-door linings	Complete for 3 boilers.
Ash-pit doors	Complete for 2 boilers.
Boiler-manhole plates, with bolts, nuts and dogs	Complete for 2 boilers.

PART	NUMBER TO BE FURNISHED
Gage cocks	Complete for 2 boilers.
Water gages, complete	Complete for 2 boilers.
Feed check valves	2 to each hand.
Surface blow valves	1 to each hand.
Bottom blow valves	1 to each hand.
Hand-hole plates with bolts, nuts, and dogs	5 per cent of all including superheater.
Special fire brick	10 per cent of all.
Special fittings	As may be directed.
All tubes of each size and shape, including superheater.	8 per cent.
Springs for boiler safety valves	2 of each size.

Miscellaneous Spare Parts. — The following miscellaneous spare parts will be furnished and carried on board:

PART	QUANTITY TO BE FURNISHED
Condenser tubes of each length	5 per cent.
Feed-water heater tubes	10 per cent.
Distiller tubes	100 per cent.
Evaporator tubes	25 per cent.
Condenser-tube ferrules	10 per cent.
Springs for all safety valves except boiler safety valves	1 of each size, pressure and type.
Springs for all relief valves	1 of each size, pressure and type.
Springs for all reducing valves	1 of each size, pressure and type.
Diaphragms for reducing valves	2 of each size, pressure and type.
Removable seats for all gate valves	2 of each size and type.
Nozzles and flexible metallic tubing of steam tube cleaners	50 per cent.
Zincs not made from standard plates	100 per cent.
Thrust-bearing horseshoes	All, for either bearing.
Baskets for bilge strainers	100 per cent.
Collar bolts for condenser heads	25.

Spare Parts for Auxiliary Engines. — The following spare parts for auxiliary engines will be furnished and carried on board:

PART	Circulating-pump engines	Turning engines	Workshop engine, if fitted	Reversing engines	Forced-draft blower engines, if fitted
Connecting rods, of each size and pattern fitted	1	......	......	......	6
Eccentric rods, straps, bolts, and nuts, of each size and pattern fitted	1	1	......	......	6
Piston rods and nuts, complete with cross-heads and slippers, of each size and type fitted	1	1	......	......	6
Valve stems and nuts, complete, of each size and pattern fitted	1	1	......	......	6
Brasses and bushings, for each one fitted	1	1	1	1	1
Bolts and nuts of crank-pin and cross-head brasses, of each size and pattern fitted......sets	1	1	1	......	6
Metallic packing for all glands, for each size and pattern fitted......sets	4	1	1	1	12
Cup leathers......sets	......	......	......	2	......
Packing rings for pistons and piston valves, for each size and pattern fitted	1	......	......	......	6
Springs for pistons and all other parts, for each size and pattern fitted...... sets	1	......	......	......	12

Spare Parts for Pumps. — The following spare parts will be furnished and carried on board (see next page):

Part	Main air pumps	Auxiliary and dynamo air and circulating pumps	Feed pumps, main and auxiliary	Fire and bilge pumps	Distiller circulating pumps	Evaporator feed pumps	Distiller fresh-water pumps	Oil pumps	Shaft pumps	Other pumps
Steam piston rods and nuts, complete, for each size and pattern fitted	1	1	1	1	1	1	1	....	....	1
Pump rods and nuts, complete, for each size and pattern fitted	1	1	1	1	1	1	1	....	....	1
Valve stems and nuts, complete, for each size and pattern fitted	1	1	1	1	1	1	1	....	....	1
Pump valves, with guards, guard bolts, and springs	All	All	All	All	All	All	All	All	All	All
Metallic packing, for glands, for each size and pattern fitted ...... sets ...	2	2	2	2	2	1	1	1	1	1
Packing rings for steam pistons and piston valves, for each size and pattern fitted	1	1	1	1	1	1	1	....	....	1
Packing rings for water pistons, for each size and pattern fitted	1	1	1	1	1	1	1	....	....	1
Springs for pistons and all other parts, for each size and pattern fitted ..... sets	1	1	1	1	1	1	1	....	....	1
Brasses and bushings for every purpose, for each one or pair, of each size or pattern	1	1	1	1	1	1	1	1	1	1

Spare Parts for Electric Motors under Steam Engineering. — The following spare parts will be furnished, and carried on board, for each motor:

1 armature, complete with shaft.
1 field coil.

1 set of bearing bushes or linings, complete.
1 set of brush studs, with insulation.
½ set of brush holders.
6 sets of carbon brushes.
1 set of carbon breaks.
2 oil-gage glasses.
1 set of contacts.
1 set of resistances, completely assembled.
10 inclosed fuses.

Armatures over 120 pounds in weight are to be stowed by supporting the shafts on brackets, secured to the bulkhead, the armature to be incased in a protecting casing of No. 18 U. S. S. G. galvanized steel, in halves, secured by hooks. The journals to be neatly covered with tarred canvas.

Armatures under 120 pounds in weight are to be stowed in plain wooden boxes with hinged covers, hinged hasp, and lock, the armature to be mounted on chocks in such a manner that it can be revolved by hand to permit inspection of all parts. The chocks should be so fitted that the armature can be removed or replaced without damage to it.

Field coils may be stowed in the same box with the armature but in a separate compartment. When the armatures are stowed on brackets, the field coils must be stowed in boxes.

Spare Parts for Air Compressors.

Spare parts for air compressors will be furnished and carried on board. These spare parts will depend upon the type of machine adopted, and a list will be submitted to the Bureau for approval when drawings of air compressor are submitted.

Spare Parts for Ice Machines. — The following spare parts will be furnished, and carried on board, for each ice machine:

PART	NUMBER TO BE FURNISHED
Valve stems for steam valve, compressor distributing valve, compressor cut-off valve, expander distributing valve, expander cut-off valve.............	1 of each size and pattern.
Piston rods for steam, compressor, and expander cylinders..................................	1 of each size and pattern.
Eccentric rods	1 of each size and type.
Crank-pin brasses for steam, compressor and expander cylinders.	1 set for each, of each size and pattern.

PART	NUMBER TO BE FURNISHED
Crosshead brasses for steam, compressor and expander cylinders.	1 set for each, of each size and pattern.
Rock-shaft bearing brasses	4 sets.
Valve-rod bushings	10.
Valves with guards and springs for circulating pump and primer pump.	1 set of each, of each size and pattern.
Springs for steam pistons	$\frac{1}{2}$ set for each.
Cooling coil	1.
Packing for piston rods and valve stems	1 set for each set fitted.
Packing leather	6 sets for each set fitted.
Thermometers	1 for each fitted.
Wrenches	1 set complete.

Spare Parts not carried on Board.—The following spare parts, not carried on board and not included in the penalty weight, will be furnished:

PART	NUMBER TO BE FURNISHED
Main propeller shaft	1.
Main-engine crank shaft	1 of each pattern.
Propeller blades	All.
Evaporator steam heads	All.
Boiler tubes of each size and shape	$\frac{1}{4}$ of total number fitted.
Boiler-tube nipples	$\frac{1}{4}$ of total number fitted.

The packings for compressor and expander cylinders of ice machines will be securely and separately packed in tight boxes with covers and filled with castor oil.

All spare parts will be finished and fitted ready for use, as specified above, and stowed in an approved manner.

Boiler tubes will be securely stowed in racks, or as directed.

Condenser tubes will be packed in boxes. All brass pieces will be stamped with name, and finished pieces, liable to corrode, will be painted with three coats of white lead and oil, and well lashed in tarred canvas, with the name painted on outside.

The spare propeller blades will be of such pattern as may be directed after trial of vessel.

The spare shafts, propeller blades, and such other spares as may be directed, will be packed for storage at a Navy Yard.

Additional Spares.—The following not included above may be desirable:

Main engine, 2 packing rings for each size of balance piston, 1 packing ring and follower for each size of piston valve.

Boilers (B. and W.), 2 side boxes, 1 cross box.

Ice machines, 200 feet of galvanized iron cooling pipe.

The following additional tools will also be of use: Set of star wrenches, clamp for turning out bottom main bearing brasses.

CHAPTER XXXII

Tests of Machinery and Piping. — Requirements of machinery specifications.

As a guide to tell what pressures may safely be allowed to be put on various parts of machinery and piping, the following tables giving the latest requirements of the machinery specifications will be valuable. Practically all the piping and parts of machinery subject to pressure are fitted with relief valves designed to operate at pressures considerably below that of the test pressure. It is, however, often desirable to test certain parts for strength after being repaired. It is also convenient to know what pressures certain parts are likely to stand.

Tests of Boilers and Machinery. — The following parts of machinery will be tested *before being placed on board the vessel:*

PART	Test pressure per square inch above atmosphere	Test
	POUNDS	
Main boilers	450	By the application of heat to fresh water in the boilers, boilers being quite full. This test optional.
Circulating-pump casings	30	Water pressure.
Condenser shells and water chambers	30	Do.
Cylinders and all parts of auxiliary machinery subject to boiler pressure	450	Do.
Cylinders, H. P., valve chests and connections	450	Do.
Cylinders, I. P., valve chests and connections	200	Do.
Cylinders, L. P., valve chests and connections	100	Do.
Distiller heads, shells, and tubes	50	Do.
Evaporator shells	50	Do.
Evaporator steam heads and tubes	450	Do.

Feed-water heaters when on suction side of pumps	100	Water pressure.
Feed-water heaters when on discharge side of pumps	500	Do.
Fittings and connections subject to boiler pressure	450	Do.
Pumps, feed, water cylinders, valve chests, and air vessels	500	Do.
Pumps, fire and bilge, water cylinders, valve chests, and air vessels	225	Do.
Shaft casings after being fitted on shafts	30	With boiled linseed oil.
Tanks, air compressor	150	Water pressure.
Tanks, feed, filter, hot-well, distiller, reservoir, soda, oil, tallow, waste, store, etc.	10	Do.
Other parts and tests	As directed.	As directed.

Parts to be tested will be so placed that all parts are accessible for examination by the Inspector during the tests.

Pipes will be tested, by water pressure, before being placed on board, as follows:

PIPES	TEST PRESSURE *Pounds*
Air pump, main and auxiliary, suction and discharge	50
Bilge discharge	150
Bilge suction	100
Bleeder	450
Blow, boiler	450
Blow, evaporator	100
Boiling-out condensers	450
Circulating pumps, main and auxiliary, suction and discharge	100
Distiller, circulating	100
Distiller, fresh water	100
Drains, crank pit	50
Drains to traps	450
Drains, separator	450
Drainage suction	100
Escape	30
Exhaust, auxiliary	50
Exhaust, branch	50
Exhaust, dynamo	50
Exhaust, to atmosphere	50
Exhaust, to feed heater	50
Exhaust, main	50
Feed, discharge	450
Feed, evaporator	100
Feed, suction	100

PIPES	TEST PRESSURE *Pounds*
Fire extinguishing on grates	100
Fire-main supply connections	225
Fire main to stern tubes	225
Fireroom hydrants	100
Fresh water from ship's side	100
Fresh-water pumping system	100
Indicator	450
Jacket steam	450
Overboard discharge	150
Overflow from feed tanks	30
Pneumatic main	150
Pumping-out boilers	450
Receiver, L. P.	200
Receiver, L. P.	100
Refrigerating plant, air pipes	250
Reserve feed-tank connections	100
Sanitary connections	100
Sea suctions	100
Shaft bilge-pump discharges	150
Shaft bilge-pump suctions	100
Steam, auxiliary	450
Steam, branch	450
Steam, galley	450
Steam, dynamo	450
Steam, main	450
Steam, radiators	150
Steam, from evaporators	100
Steam, to evaporators	450
Steam, to I. P. receiver	450
Steam, to L. P. receiver	450
Steam, to sea valves	450
Vapor	30
Water service	50
Whistle and siren	450
Other pipes	As directed

Valves, manifolds, and castings for pipes will be tested, by water pressure, before being placed on board, as follows:

VALVES, MANIFOLDS, AND CASTINGS	TEST PRESSURE *Pounds*
Feed valves and castings	500
Steam valves	450
Exhaust valves	100
Water vaves, low pressure	100
Composition castings for feed	500
Steel castings for steam	450
Composition castings for low pressure	100

The following parts of machinery will be tested *after being placed on board the vessel:*

	Test pressure per square inch above atmosphere	Test
	POUNDS	
Main boilers	450	By the application of heat to fresh water in the boilers, the boilers being quite full.
Main boilers and pipe connections ...	375	By steam, and all leaks to be made tight before parts are clothed and lagged.
Main and auxiliary feed systems as a whole, installed and connected, from and including the pressure parts of the pumps up to the valves on the boilers	500	Water pressure.
All parts after being secured on board	Working pressures.	Under working conditions.
Other parts and tests	As required.	As directed.

The circulating pumps will be tested by discharging water under a head of 25 feet, 5 feet of which will be suction.

The suction and discharge pipes, during the test, will be the same size as the nozzles on the pumps.

A four-hour test of evaporating and distilling plant will be made under service conditions, using sea-water feed, and maintaining a density of $\frac{3}{32}$ in the evaporators.

No lagging or covering will be on cylinders, pipes or condensers during the tests.

If India-rubber valves are used, they will be taken at random and must stand a dry-heat test of 270° F. for one hour and a moist heat test of 400° F. for three hours without injury.

Steam will not be raised in the boilers until after the water test of boilers on board, unless desired for drying or testing joints, for which purpose the pressure will not exceed 10 pounds per square inch.

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