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Operation of Turbine-Electric and Turbine-Gear Drive Ships

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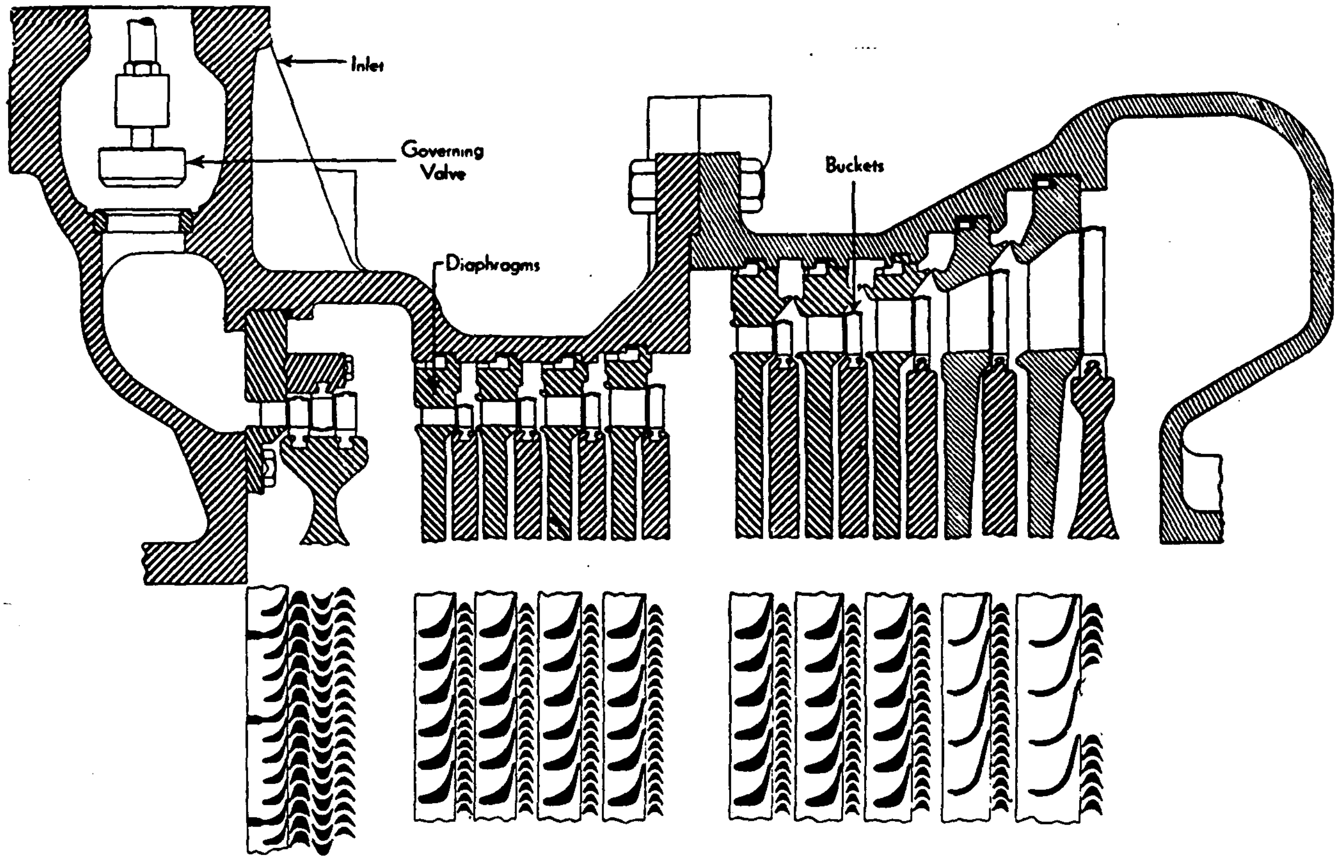
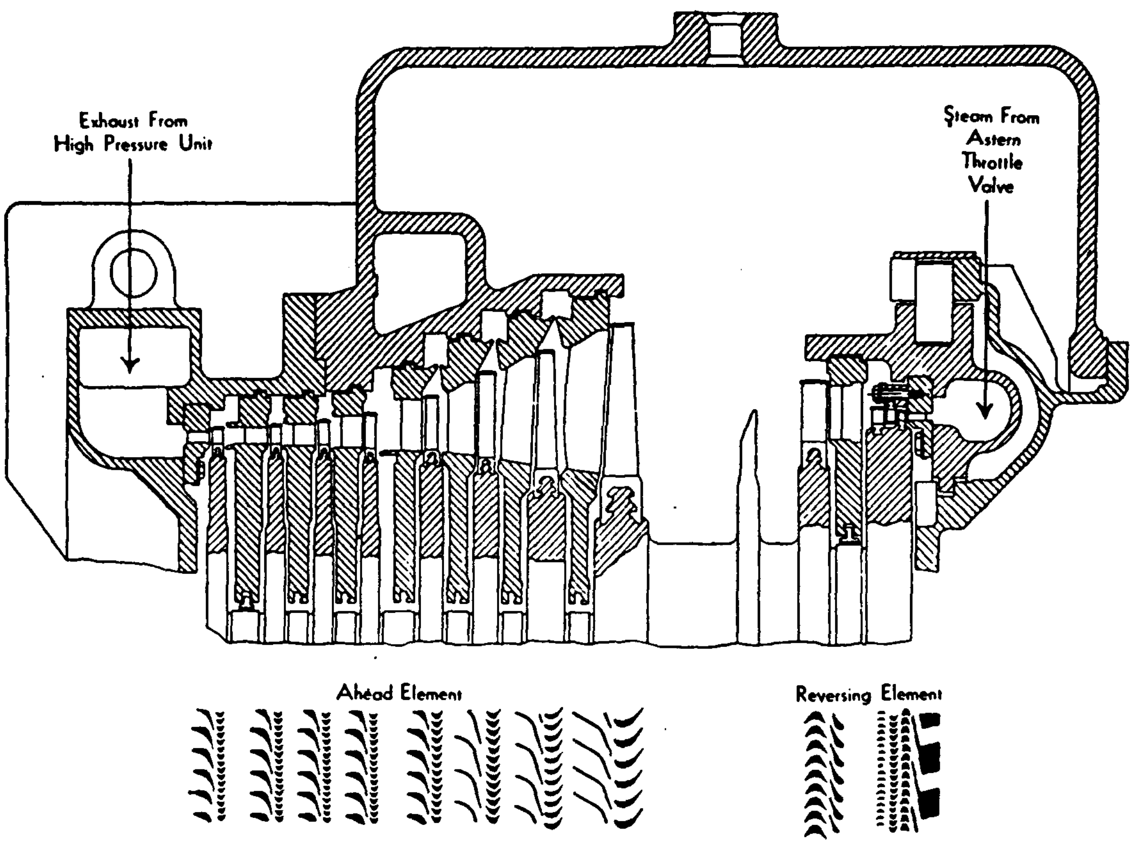


Type of turbine used on electric-drive ships



Low-pressure turbine used on turbine-gear drive ships

FIG. 1—SECTIONS OF TURBINES USED WITH ELECTRIC AND TURBINE-GEAR DRIVE. PLAN VIEW OF NOZZLES AND BUCKETS IS SHOWN BELOW EACH TURBINE. FLOW OF STEAM IS FROM LEFT TO RIGHT

Operation of Turbine-Electric and Turbine-Gear Drive Ships

By Frank V. Smith[1]

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Looking at a steam turbine from an elementary point of view, it is simply a machine that utilizes the velocity energy of steam to turn a wheel. In practice this is attained by two methods of design: First, the impulse type that allows a jet of steam to impinge against buckets placed around the rim of a wheel therby imparting motion to the wheel; and, second, the reaction type in which the backward pressure from the jet turns the wheel. The first might be likened to the playing of a stream of water on a paddle wheel; and the second to a rotating type of lawn sprinkler.

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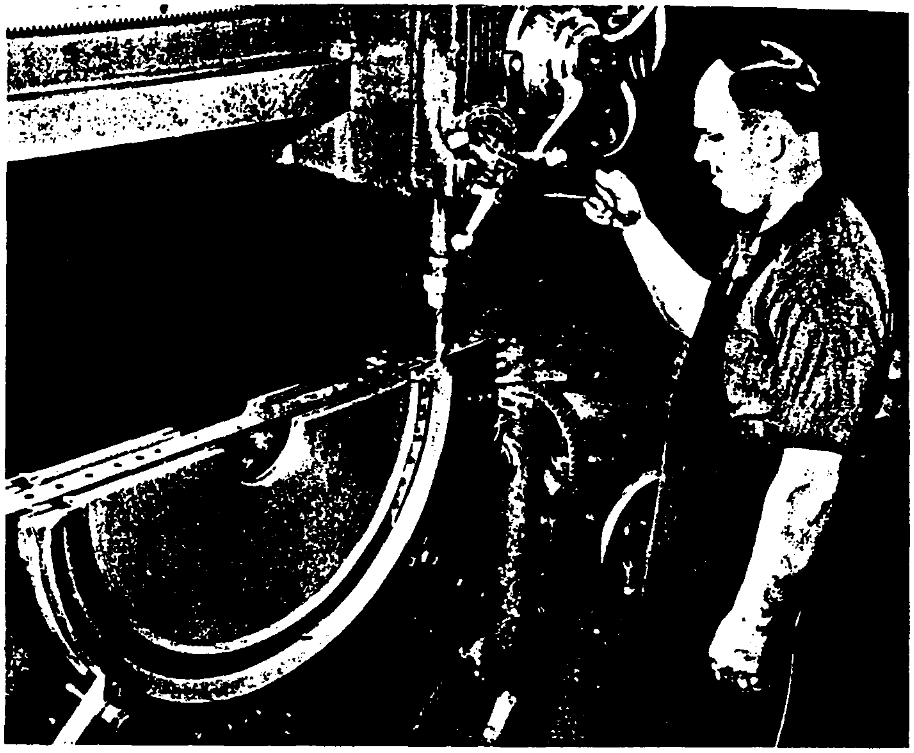

FIG. 2.—(RIGHT) DRILLING DIAPHRAGM FOR STEAM TURBINE. (BELOW) ROTOR OF CONDENSING TURBINE

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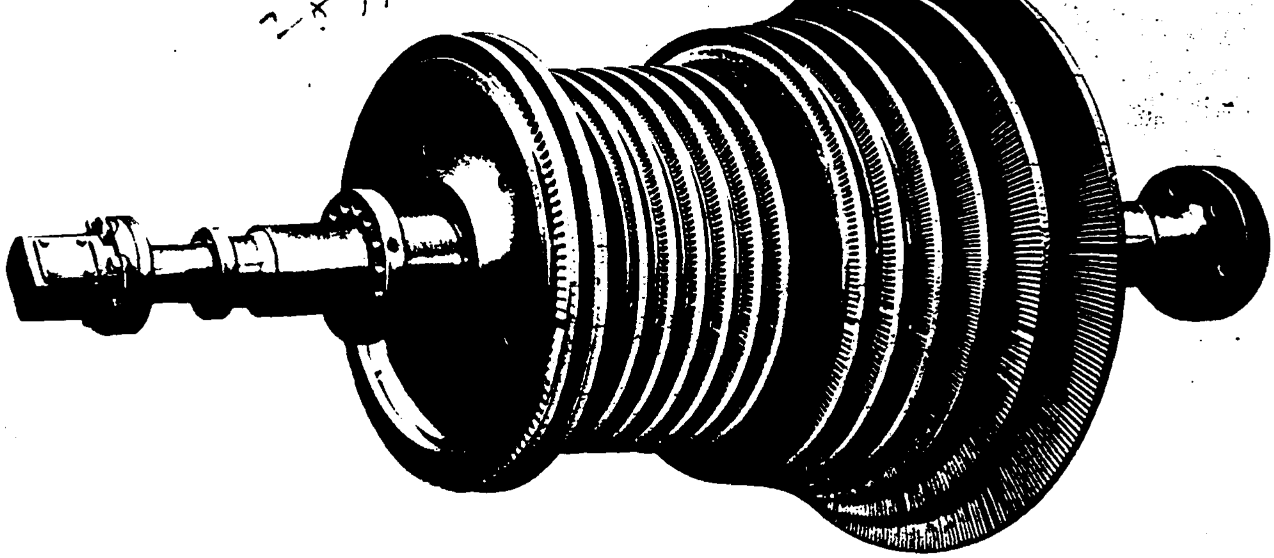

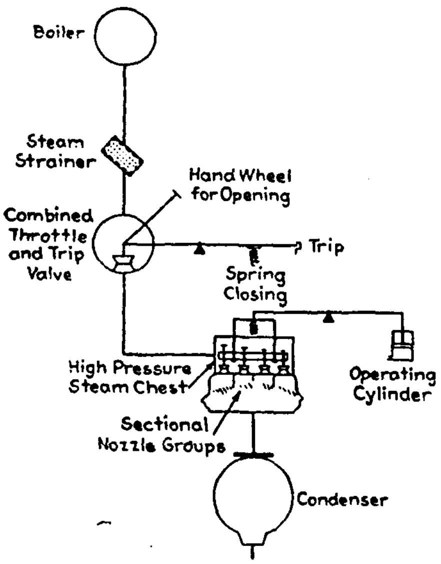

FIG. 3.—CONTROL OF STEAM FLOW TO TURBINE ON ELECTRICALLY PROPELLED SHIPS (SECTIONAL VALVE GEAR PLAN)

THROTTLE AND TRIP VALVE

1. Used as a throttle valve when warming up turbine only.
2. Emergency Trip
   (a) Trips automatically in case of loss of lubricating oil supply.
   (b) Trips automatically in case of turbine overspeed.
   (c) Hand trips provided at turbine and at central panel.

GOVERNING VALVES

1. Regulate the steam flow to the first stage nozzles. Operated in proper sequence they reduce the steam flow by closing the entrance to nozzle groups thus preventing throttling losses.
2. Operated by means of oil pressure within a cylinder.
3. Speed adjustment made by combination of flyball governor and pilot valve which regulates oil pressure to cylinder.

Modern turbines utilize steam over very great pressure ranges, and the high velocities that would attain between such pressure ranges makes it impractical to design a turbine with a single wheel and a single jet. To do a more efficient job the steam pressure is reduced and permitted to expand and gain velocity in graduated steps. In an impulse type of turbine the pressure drop and expansion of the steam take place within the nozzles and remain constant across the path of the buckets. In the reaction type the nozzles are replaced by stationary blading similar to the ones on the wheel, that permit the steam pressure drop and expansion to take place between such stationary blading and moving blading. In both types of turbines it is essential that the steam be kept in well-directed paths so that the velocity attained may be directly applied to the rotating part of the turbine.

In an impulse type of turbine the steam jets or nozzles are placed in partitions with bucketed wheels intervening. Each of these consecutive pressure drops is known as a stage. The assembled bucketed wheels with shaft is called the rotor, and the partition with nozzles the diaphragm.

Years of patient research have been spent in perfecting turbines. The steam velocities through the nozzles approach several thousand feet per second, and it takes less than one-half second for the steam to pass through as many as ten stages. Smooth and almost frictionless passages for the steam is a primary requirement.

The main propulsion turbines installed on both turbine-electric drive ships, and turbine-gear drive ships follow the same basic principle of design. The principal difference is the number of casings involved.

In turbine-electric drive ships, the turbine drives a generator through a single shaft, and therefore all divisional stages can be housed in one casing. In turbine-gear drive ships the divisional stages are usually divided between two or more casings, so that the power can

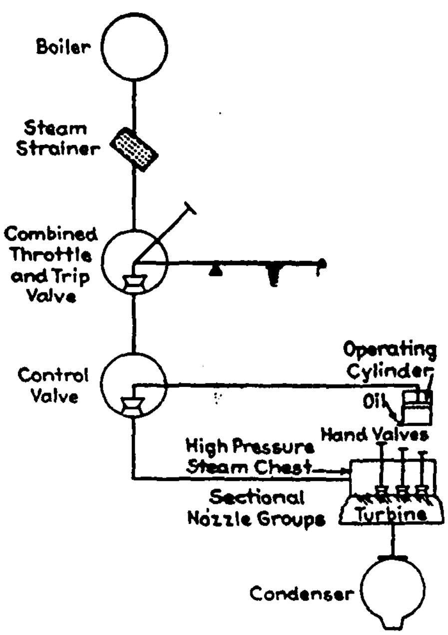

FIG. 4.—CONTROL OF STEAM FLOW TO TURBINE ON ELECTRICALLY PROPELLED SHIPS (CONTROL VALVE AND HAND VALVE COMBINATION)

THROTTLE AND TRIP VALVE

1. Used as a throttle valve when warming up turbine preparatory to getting underway.
2. Emergency Trip
   (a) Trips automatically in case of low lubricating-oil pressure.
   (b) Overspeed.
   (c) Hand trips provided
      (1) At turbine.
      (2) At control panel.

CONTROL VALVE

1. Controls steam flow to one sectionalized nozzle group for attainment of very slow speeds.
2. Gives close adjustment of speed between hand valve settings.

HAND VALVES

1. Manually operated to maintain speed desired and still maintain maximum pressure in high-pressure steam chest.

be divided between several pinions that drive the gears.

The steam flow through the two types is shown in Fig. 1, and a view of a turbine rotor, and a diaphragm with nozzles in Fig. 2.

Operating Requirements.—Turbines are high-speed machines often designed for operating speeds above 5000 revolutions per minute and producing many thousand horsepower in a relatively small casing. The rotors of such machines are scientifically balanced to avoid vibration, and the running clearances between the moving and stationary parts are but a few thousandths of an inch. The initial steam pressures now used in modern marine power plants are above 400 pounds per square inch and the steam temperatures above 700 degrees F. At the exhaust end of the turbine the absolute pressure may be as low as 0.5 pound, and the temperature but 79 degrees F. Metals expand when heated, and shrink when cooled. And this, taken in connection with the small running clearances, calls for special care in warming up the turbine prior to operation, and special care in cooling off the turbine after operation.

Marine power plants are subject to wide variations in both power and speed, and the steam supply must be accurately governed to accomplish this purpose. Such machines must be protected against overspeed should they lose their load, and must automatically shut down in case the lubricating-oil system should fail. The bore in the casing where the shaft passes through must be sealed against steam leakage on the high-pressure end of the casing, and against leakage of air into the casing at the low-pressure end.

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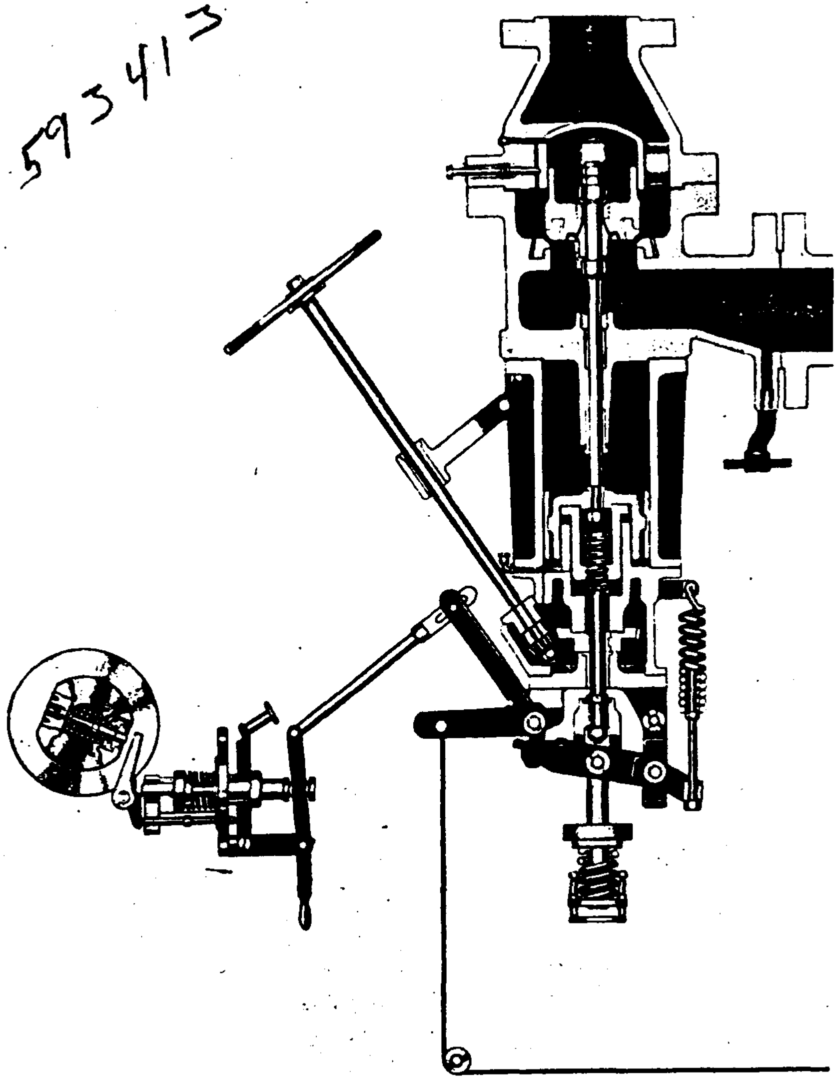


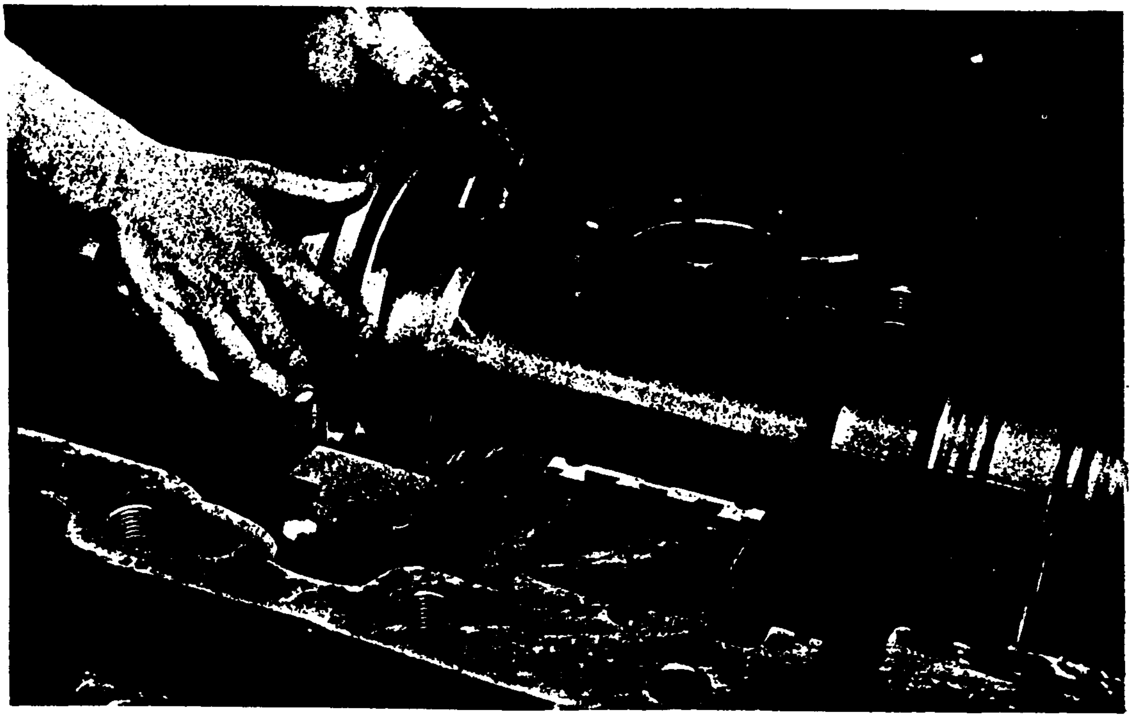
FIG. 5.—TYPICAL THROTTLE AND EMERGENCY TRIP VALVE

These are fundamental problems in turbine design for which there are many solutions. In all cases the operating engineer must familiarize himself with the extraneous devices used in connection with the turbine on the ship to which assigned before assuming responsibility for its care and operation.

Steam Governing Systems.—The control of the steam flow to turbines on electrically propelled ships differs from that on geared ships. On a turbine-electric drive ship we are dealing with a unidirectional turbine, built either in a single casing or as a tandem compound unit. A turbine for gear propulsion is usually built in two or more casings and, in addition, requires a reversing turbine. Another difference is that the turbine on an electrically propelled ship can be disconnected from its propeller load, whereas on turbine-gear ships the turbine is mechanically connected through gearing to the propeller shaft.

Diagrams showing the elemental valves used to control the steam flow in turbine-electric drive installations are shown in Fig. 3 and Fig. 4.

Throttle and Emergency Trip Valves.—Tracing the path of the steam in the electric-drive diagrams, steam from the boiler first passes through a steam strainer, and then through a combined throttle and trip valve. This valve serves two purposes: First, as a throttle valve when warming up the turbine preparatory to getting underway; and, second, as a trip valve. In modern installations this valve is opened by hand against a spring pressure which is maintained by means of a trip latch. The trip is actuated in any one of four ways: (1) by a plunger type of overspeed governor located on the end of the turbine shaft; (2) by a low oil-pressure trip valve; (3) by a lever situated at the forward end of the turbine; and (4) by a trip handle situated at the control panel. Although this valve must be opened by hand, it should be closed by means of one of the trip levers, the reason being that, if the valve was closed tight with the latch set, a great strain would be put on the valve stem when it cools and shrinks. Such strains are apt to ruin the valve. When underway, the throttle and trip valve remains wide open, as the steam flow is then regulated by means of the governing valves.



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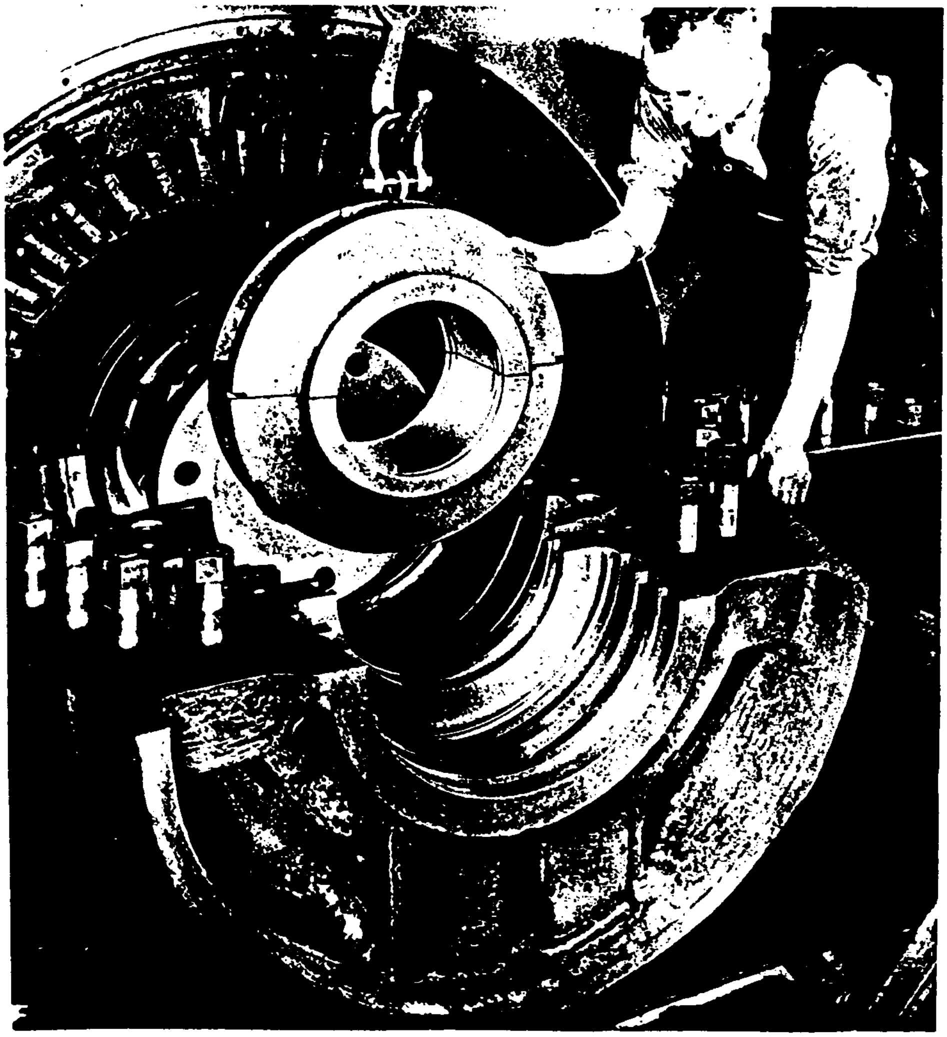

FIG. 6.—(TOP) JOURNAL AND THRUST BEARINGS IN STEAM TURBINE. (LEFT) MAIN BEARING LINING BEING LOWERED INTO PLACE IN A MARINE TURBO - GENERATOR SET

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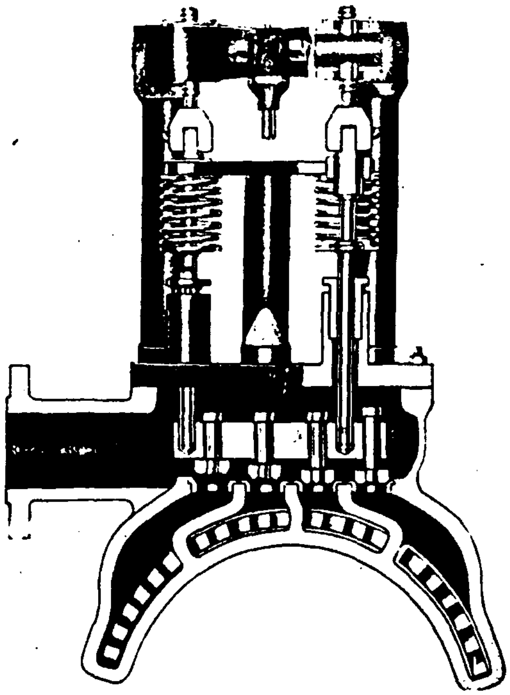


Sectional valve gear plan

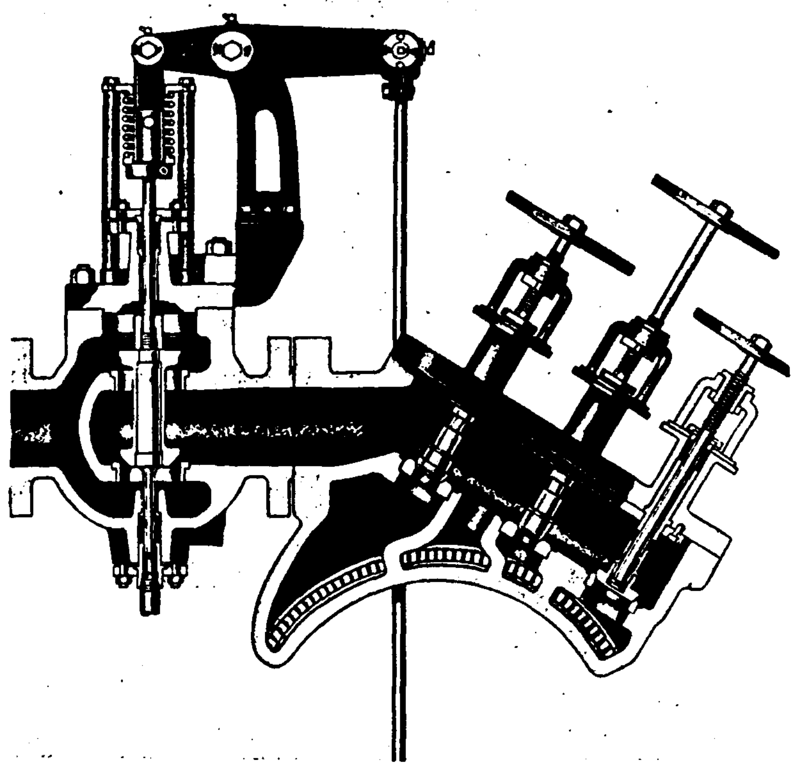


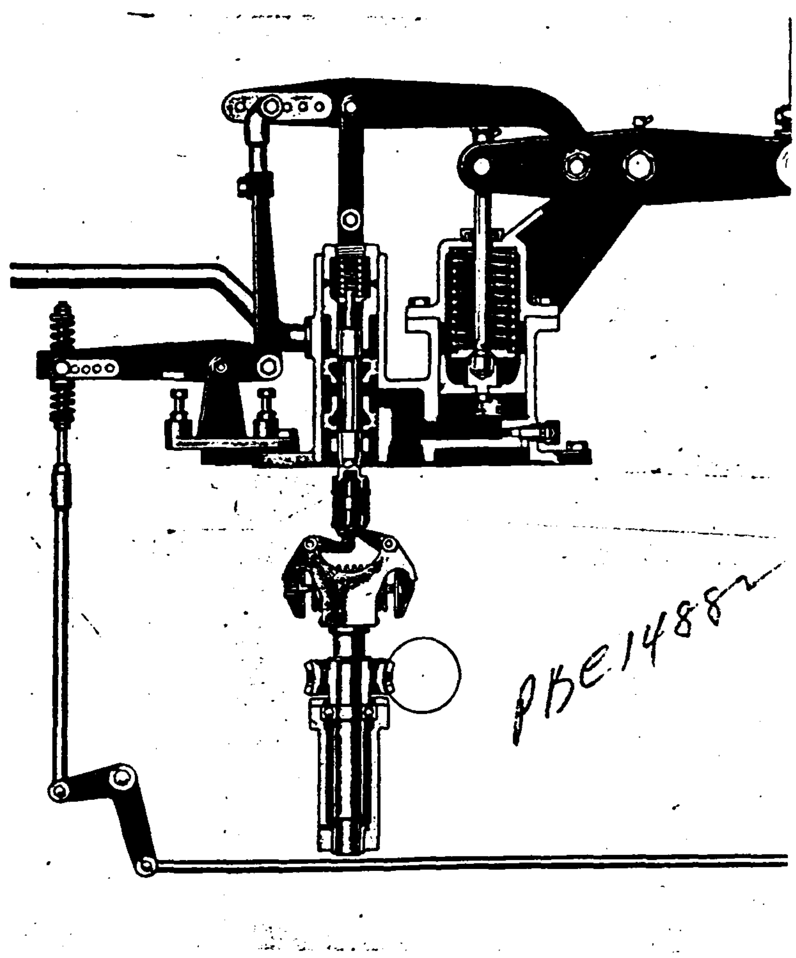
FIG. 7.—CONTROL-VALVE AND HAND VALVE COMBINATION

FIG. 8 (BELOW).—SPEED GOVERNING SYSTEM

A view of a typical throttle and trip valve is shown in Fig. 5. It will be noted that a small cylinder with piston is shown at the lower end of the valve stem. The purpose of this cylinder is to provide a cushion effect when the valve is tripped and to prevent peening of the valve seat.

Governing Valves.—There are two general systems for governing the steam flow to the sectionalized first-stage nozzle groups, both of which have the same objective—that of reducing the steam flow by closing off part of the discharge openings rather than by a reduction of the steam pressure. The efficiency of a turbine depends upon the expansion of steam between the greatest pressure limits.

In one system the governing valves are operated automatically in sequence, and in the other such valves are manually controlled. When the valves are manually controlled, one nozzle group is left open, and the steam chest preceded by a control valve which permits throttling to attain very slow speeds. This valve is also used when warming up the turbine, and for attaining fine gradations in speed. In the latter case a speed governor of the flyball type actuates a pilot valve that in turn admits oil to or from a hydraulic cylinder which operates the control valve. Manufacturers generally designate these two systems by the names, (1) "Sectional Valve Gear Plan," and (2) "Control-valve and Hand Valve Combination." These systems are shown in Fig. 6 and Fig. 7.



The speed-governing device depends upon oil pressure from the lubricating-oil supply line to function, and should this pressure fall below normal it automatically closes the control valve in the hand valve combination, and the governing valves in the sectional valve gear plan. Speed settings are made at the operating panel by means of a speed lever. This lever controls the position of the ports that supply oil to the operating cylinder. A typical cutaway view of a speed governor and operating cylinder is shown in Fig. 8.

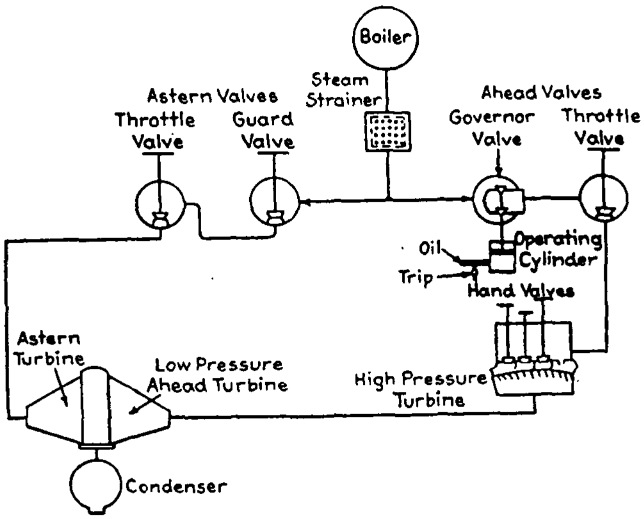


FIG. 9.—CONTROL OF STEAM FLOW TO TURBINES ON GEARED-TURBINE PROPELLED SHIPS

ASTERN

GUARD VALVE

Prevents steam leakage to astern turbine when ahead turbines are in operation.

THROTTLE VALVE

Regulates flow of steam to astern turbine.

AHEAD

1. GOVERNOR VALVE
   Shuts off steam in case of turbine overspeed or low-pressure lubricating-oil supply.
2. THROTTLE VALVE
   Used when warming up turbine and to obtain very low turbine speeds.
3. HAND VALVES
   Govern the steam flow to the first-stage nozzles.

On turbine-gear ships, control of the steam flow to the main turbines is entirely manual with the exception of the governor valve which is maintained in an open position by oil pressure from the lubricating-oil supply line. Should the oil pressure drop below normal, the valve will close. An oil pump which is geared to the turbine shaft reflects speeds above normal by increasing the oil pressure. Should such speeds exceed the maximum considered safe by the manufacturers, this excess oil pressure opens a valve that drains the operating cylinder of oil and closes the governor valve. By this method the turbine is protected from both loss of lubricating-oil supply, and from overspeeds. A hand trip for relieving the cylinder of oil pressure is also provided for emergency use.

Fig. 9 shows the path of the steam in a typical turbine-gear ship, and Fig. 10 a cutaway view of the valves and governing valve mechanism.

The needle valve adjusts the by-pass flow area of the drain from the governing valve mechanism and therefore predetermines the overspeed at which the valve will trip. As a general rule the needle valve is adjusted to trip the valve at approximately 115 percent maximum running speed and then padlocked in position.

Steam-Sealing Arrangements.—In order to confine the steam to its given path there are several items to be considered. It is obvious that the wheels and diaphragms must be enclosed in a steam-tight casing and steam leakage prevented at the high-pressure end where the shaft extends through the casing, and likewise that the low-pressure end be sealed against the admittance of air where the other end of the shaft extends through the casing. This is a universal requirement for turbines, and the measures taken to prevent this leakage is known as the "steam-sealing system."

There are two types of steam seal packings in use: First, the labyrinth type of packing with interlacing grooves that tend to wire draw the steam; and, second, the carbon type of packing. Both types depend upon a close running clearance to minimize leakage, and the stationary sections of such packings are backed by springs to maintain a moderate pressure. The rings are generally divided into three groups, arranged in such manner as to provide a space on each side of the center group. A pipe connects the inner space or chamber on the high-pressure end of the turbine to the inner chamber on the low-pressure end of the turbine, thus making use of the leakage of steam on one end to seal against air admittance on the other. The outer chambers are connected by pipe lines to an exhauster to prevent steam leakage into the engine room.

In the earlier designs it was the usual practice to control the steam pressure in the steam seal line manually. Valves were provided to by-pass a portion of the leakage steam from the high-pressure end when the pressure was too high, and to admit steam to the line when the pressure became too low. On modern ships the function of the steam-sealing arrangement is the same, except that the operation of the valves is made automatic by means of a steam-seal regulator.

One method of accomplishing this automatic regulation is to use a small diaphragm to reflect the pressure on the line, and let this in turn actuate the valves by means of a proper follow-up mechanism. A typical example of such a system is shown in Fig. 11. It is the duty of an operator aboard ship to familiarize himself with the construction of the steam-seal regulator and to see that the lever arms move freely, and that the device maintains the pressure specified by the manufacturer.

In an impulse turbine a steam pressure differential exists between the two sides of the diaphragms and it therefore becomes necessary to seal against steam leakage at the bore where the shaft passes through. This is accomplished by means of bronze grooved rings, backed by slight spring pressure to assure a close running fit.

Thrust Bearings.—The axial position of the turbine rotors is maintained by means of a thrust bearing situated on the forward end of the shaft. This bearing consists of a thrust collar rigidly connected to the turbine shaft, and babbitted thrust plates. The thrust plates are backed by shims so that they can be adjusted for a reasonable amount of wear when required. The usual allowable clearances on such bearings is between 0.005 and 0.010 inch.

For convenience, a thrust bearing indicator is generally mounted on the bearing shell from which readings can be taken. This indicator consists of a ball bearing roller which rides against the side of the thrust collar,

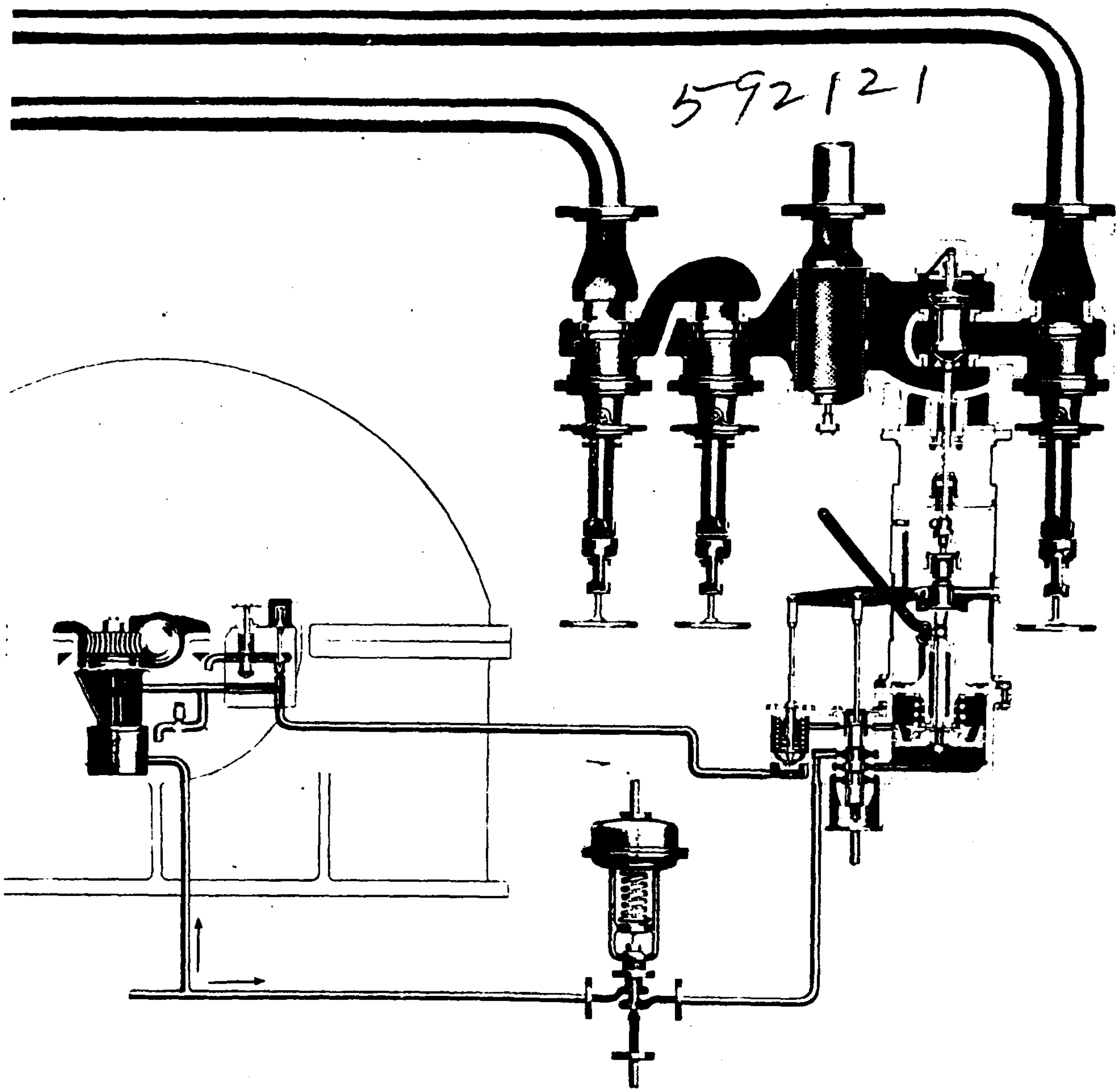


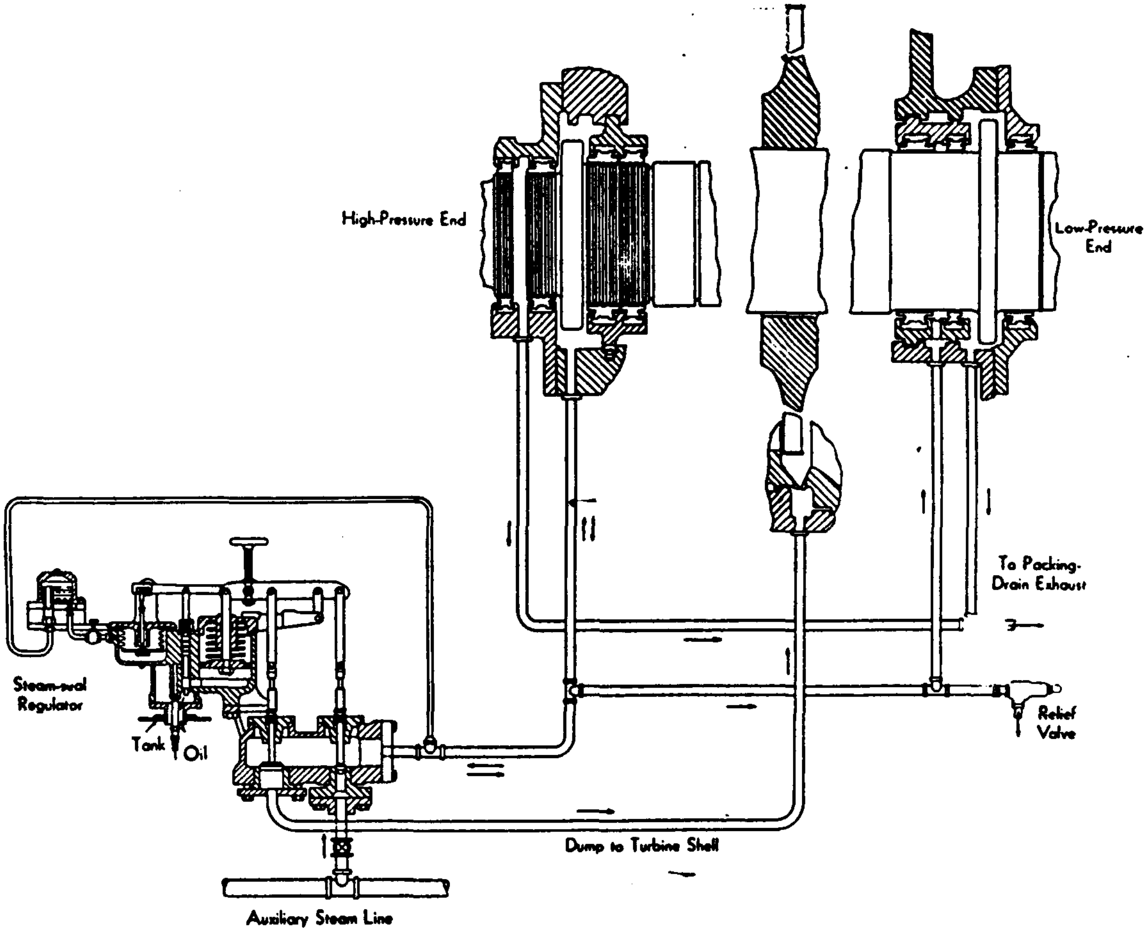
FIG. 10.—CONTROL OF STEAM FLOW TO TURBINES ON TURBINE-GEAR SHIPS

and a position indicator. In taking readings on an instrument of this type it is necessary for the rotor collar to be tightly up against the thrust plate that normally receives the thrust. In practically all turbines, the thrust is in the direction of steam flow.

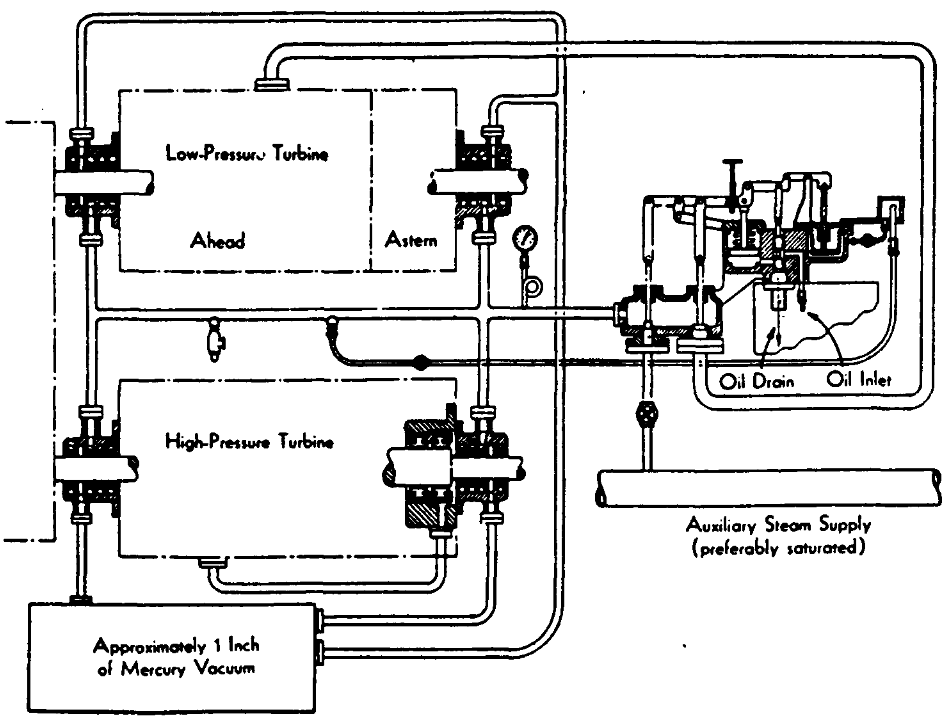
Main Bearings.—The main bearings on turbines consist of babbitt-faced steel liners mounted in holders having ball seats in the bearing brackets. This type of construction permits the bearing to aline itself with the shaft. The babbitted faces are chamfered slightly at the horizontal joint on the inlet side so that the oil is wedged between the shaft and bearing for lubricating purposes. Grooves in the upper part of the babbitted liners allow oil to flow for cooling purposes. The lubrication of turbines is one of the most important subjects in turbine operation, and one that requires exact knowledge on the part of the operator. The various types of lubricating oil systems are covered under a following heading.

Turbine Operation.—When a turbine is being warmed up prior to operation, and cooled down after operation, the rotor must be kept turning to prevent shaft distortion due to unequal heating or cooling.

On electrically propelled ships, the turbine rotor, together with its attached generator rotor, is free to turn without producing power as long as the generator field excitation is disconnected. This makes a turning-gear motor unnecessary during the warming-up period. During the cooling-down period, however, some method must be provided to turn the rotor. This will differ on various installations. On some ships a hand turning gear is provided, and on others a turning-gear motor. During the cooling-down period heat collects at the top of the casing, causing an unequal expansion between the top



Steam sealing arrangement on turbine-electric drive



Steam sealing arrangement on geared-turbine drive ships

FIG. 11.—SCHEMATIC DIAGRAM OF A STEAM-SEALING SYSTEM

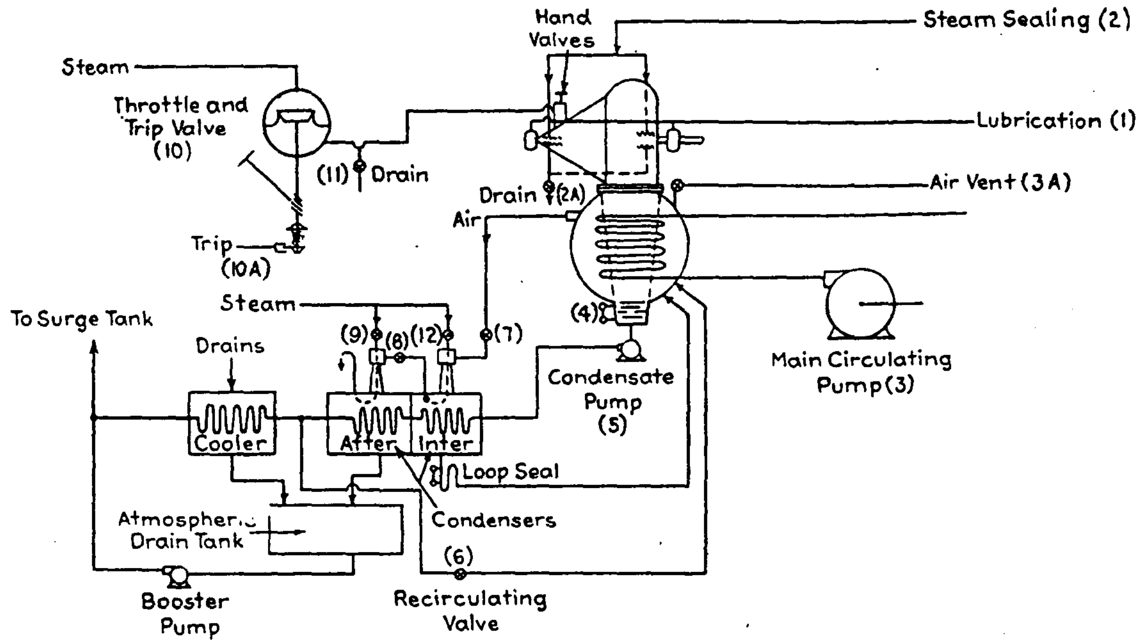


FIG. 12.—SEQUENCE OF VALVE OPERATION IN WARMING UP TURBINE ON ELECTRIC-DRIVE SHIP PRIOR TO GETTING UNDERWAY

(With Hand Valve Arrangement)

1. Start lubricating oil pumps and check pressure and temperature of oil.
2. Place steam sealing system in operation and open drain valve (2A).
3. Start main circulating pump and open air vent (3A).
4. Check water level in hotwell.
5. Start condensate pump.
6. Open re-circulating valve (6).
7. Open air valve only on first-stage air ejector (7).
8. Open air valve on second-stage air ejector (8).
9. Open steam valve on second-stage air ejector (9). Build up vacuum of about 15 inches.
10. Set trip (10A) on throttle and trip valve. Open valve a few turns, then trip to see that it works properly.
11. Open drain (11), also drains in turbine steam chest and in turbine casing. Re-open throttle valve (10) sufficiently to turn turbine over slowly.
12. After turbine has been warmed up, close drain valves and open steam valve on first-stage air ejector (12).

Note: On turbines using the automatically controlled sectional valve gear plan, the speed lever is placed in the maneuvering position and the load limit used for throttling during the warming up period.

and bottom half of the rotor. If a turning-gear motor is provided, the rotor is allowed to revolve slowly throughout the cooling-down period. When a hand-operated shaft turning gear is provided, the shaft is turned 180 degrees every few minutes during the cooling-down period.

On turbine-gear ships the turbines cannot be operated without turning the propeller shaft and this calls for a different procedure than with turbine-electric drive. In this case a motor-operated shaft turning gear is provided. This keeps the turbine turning over slowly without enough power to propel the boat during both the heating and cooling periods.

During the warming-up period with either type of drive, it is not good practice to maintain a high vacuum, the reason being that with the small energy required, the vacuum would extend well into the center stages of the turbine and defeat the purpose of preheating. Sufficient vacuum can be maintained with the second-stage air ejector in operation to serve the purpose during this period.

The exhaust steam from the air ejectors is condensed in the inter and after condensers by means of the condensate from the hotwell of the main condenser. To condense this steam it is necessary to provide a continuous flow of condensate, and as the quantity accumulating in the hotwell of the main condenser may be inadequate, it is necessary to provide a re-circulating line for the purpose. The valve in this line should be shut off as soon as the supply becomes sufficient.

In starting up the main circulating pump it is necessary to free the top of the water chests and upper tubes of the condenser of any air that may have accumulated. A valve is provided at the top of the condenser to discharge this air and it should be opened to expel such air and left slightly open during operation to expel any air that might be entrained in the circulating water. The inter condenser is provided with a loop seal and it is general practice to provide a gage glass on the loop to see that it contains water. If this loop is not sealed it permits the air that is being withdrawn from the steam side of the condenser to return to the condenser, thereby defeating the purpose of the air ejectors.

It is just a matter of good judgment that all drains should be opened during the warming-up period, as well as the cooling-down period. The turbine casing and rotor, and all valves and piping are cold when the steam is turned on. This causes condensation, and the accumulation of water in all low spots. It is very important that the engineer familiarize himself with the location of all of the drain valves before undertaking the responsibility for turbine operation. This information is given in the manufacturers' instruction books provided on each ship.

Fig. 12 shows the elements to be considered when starting a turbine from cold and at rest.

Lubrication.—The lubrication of high-speed turbine bearings and of gearing is a subject that must be thoroughly understood by the engineer before accepting operational responsibility.

The lubricating oil performs two general services on a turbine. First that of lubrication; and, second, that of carrying away heat so that the shaft temperatures may be maintained between certain predetermined limits.

Other very important services linked with the lubricating-oil system are automatic speed governing, automatic control of the steam sealing system if an oil-operated steam seal regulator is used, protection against overspeed, and protection of the equipment in case of loss of oil pressure.

High-speed turbine bearings and gears require a constant supply of lubricating oil of a given inlet temperature, and in such quantity as to limit its outlet temperature.

The working temperature range of lubricating oil on turbine-electric drive ships, and turbine-gear drive ships differ. On turbine-electric drive ships the bearings are all of the high-speed type and therefore can make use of an oil of lower viscosity than when gears are used. In the latter case it is generally necessary to work out a satisfactory compromise between the two uses.

Oil coolers are provided for maintaining the constant inlet temperatures recommended by the manufacturer, and the flow of water through the cooler tubes must be closely regulated to obtain the desired results. Thermometers and sight flow gages are also provided at each bearing for the engineer's guidance.

As there are several types of lubricating-oil systems in use to perform the various functions in connection with turbine lubrication and protection, it is suggested that the engineer make it a point to secure an instruction book from the manufacturer of the system in use on the ship to which he is assigned. Because of many variations found in practice, the following text has been prepared mainly to show the fundamental points involved:

Quality of Oil.—Lubricating oils for turbine use are "Mineral Base Oils" properly refined and free from alkali and acid. Such oils should have the quality of preventing rust and oxidation, and of ready separation from water should it become so contaminated. Lubricating oils that form emulsions, that decompose with age, or form sludges are dangerous from the standpoint of plugged pipe lines and passages in the bearings. Specifications covering oil for turbine lubrication also cover such qualities as flash point, fire test, pour point, demulsibility and viscosity. Oil companies manufacture lubricating oil especially for high-speed turbine and gear lubrication and no other type should be used under any circumstance.

Relation of Temperature, Viscosity, Fluidity.—Lubricating oils as well as other types of oil have the property of becoming more fluid as the temperature is increased.

Looking at the problem of lubrication from a practical standpoint, it is quite obvious that if a heavy, cold, viscous, slow-flowing oil is placed in a high-speed bearing, it is not likely that the oil would flow readily enough to either lubricate or carry away heat. The small amount of oil pressed under the journal would probably become overheated, leave carbon deposits, and do other damage.

In the case of the slow-speed shaft that turns so slowly that no wedge of oil is formed, heavier slow-flowing oils become necessary for proper lubrication. A heavy shaft turning at a low speed would in all likelihood press out a thin oil, causing excessive temperatures with danger of burn out.

From the foregoing it becomes quite clear that the higher the bearing speed, the lighter the oil that should be used, and the slower the bearing speed, the heavier the oil.

Lubrication of Turbine and Gear Bearings.—The generally accepted theory regarding the lubrication of bearings is that a boundary film of oil, only a few molecules thick, clings to both the bearing and journal, and that the continuous supply of oil fed to the bearing flows between the boundary films. A second accepted theory is that the frictional heat generated is that caused by the fluid friction between particles of the lubricant.

Irrespective of theories, however, common sense teaches us that there should be no metal to metal contact at any time on bearings, and that proper oil films must be maintained for efficient lubrication.

Upon starting, the friction at the bottom of shaft has a tendency to roll the shaft towards the side of the bearing in direction of rotation. This action is very momentary, however, as an oil wedge is quickly formed which forces the shaft away from the bearing side. When operating at high speed the wedge action is sufficient in many cases to give the shaft a tendency to favor the bearing side opposite to direction of rotation.

The problem that presents itself in turbine and gear lubrication revolves around the subject of temperature when starting, when warming up, and when running.

When first warming up a turbine from cold and st, the revolutions are kept down to a relatively slow speed for a given length of time. Because of this slow speed, the temperature of the oil may be slightly under that considered safe for running speed.

With the quality of oil generally specified to the purpose the minimum temperature considered safe during the warming-up period is 90 degrees F. Should the lubricating oil in the lubricating-oil drain tank be less than 90 degrees F, it becomes necessary to heat the oil in the tank by means of steam heating coils.

As the oil is circulated in the bearings during the warming-up period, the temperature will gradually increase and this should be allowed to continue until the recommended operating temperature is reached. The inlet operating temperature usually recommended varies from 110 to 120 degrees F and the satisfactory outlet temperature 160 degrees F. As soon as the correct operating inlet temperature has been reached, the oil cooler must be placed in operation and regulated to maintain this temperature irrespective of the outlet temperature.

High-speed turbine bearings are lined with babbitt and split along the horizontal joint for ease in assembly and disassembly.

The babbitt material is chamfered at the horizontal joint so that the turning shaft has a tendency to wedge the oil under the lower half for efficient lubrication where it is most needed.

The upper half of the babbitted bearing, which is not called upon to sustain the weight of the rotor shaft, is furnished with grooves of liberal width and depth to permit the passage of sufficient lubricating oil to carry away the heat which creeps along the shaft from the inner part of the turbine.

When a turbine is at rest the turbine shaft presses directly downward thus squeezing out any excessive thickness of oil. During this time the boundary films of oil on the journal and bearing prevent actual contact of the two metals.

Care of Oil.—Practically all turbine lubricating-oil systems contain two tanks of liberal size. One of these tanks is known as the service tank, and the other as the settling tank. The emulsions, water, or settlings are removed from the settling tanks.

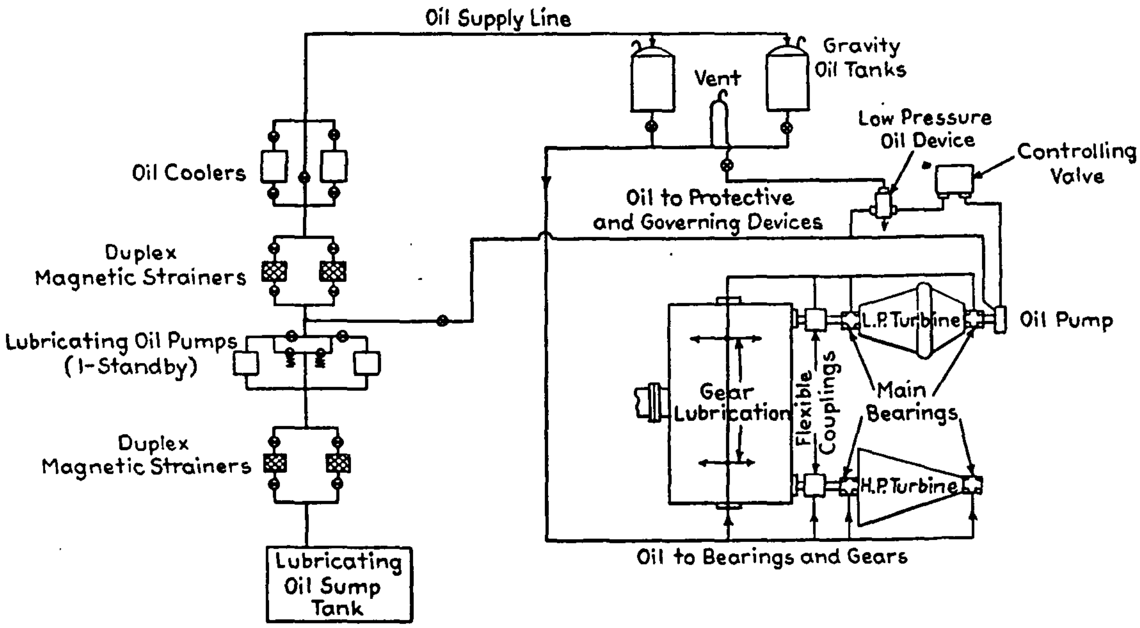


FIG. 13.—TYPICAL LUBRICATING-OIL SYSTEM, GRAVITY TYPE, USED WITH GEARED-TURBINE DRIVE

Oils sustain water in suspension in decreasing quantities as temperatures are increased, the amount being negligible at 130 degrees F. For this reason it is advisable to maintain the foregoing temperature in the tank so that water will be precipitated to the bottom of the tank where it can be withdrawn.

Oil levels should be maintained in the tanks and reserve supplies checked to make certain that oil is available for contingencies.

Lubricating oils should not foam, evaporate, break down, or form emulsions. If they do, an immediate investigation must be made of the cause, clean oil supplied to the system, and the old oil either reprocessed by centrifuging or discarded.

If water is mixed with the oil, the oil should be centrifuged.

If operating conditions are constant and oil inlet and outlet temperatures to and from the cooler constant, with a given amount of circulating water it is a fair indication that lubrication is normal. If such conditions have prevailed and then for some unaccountable reason temperatures rise, it shows something is wrong.

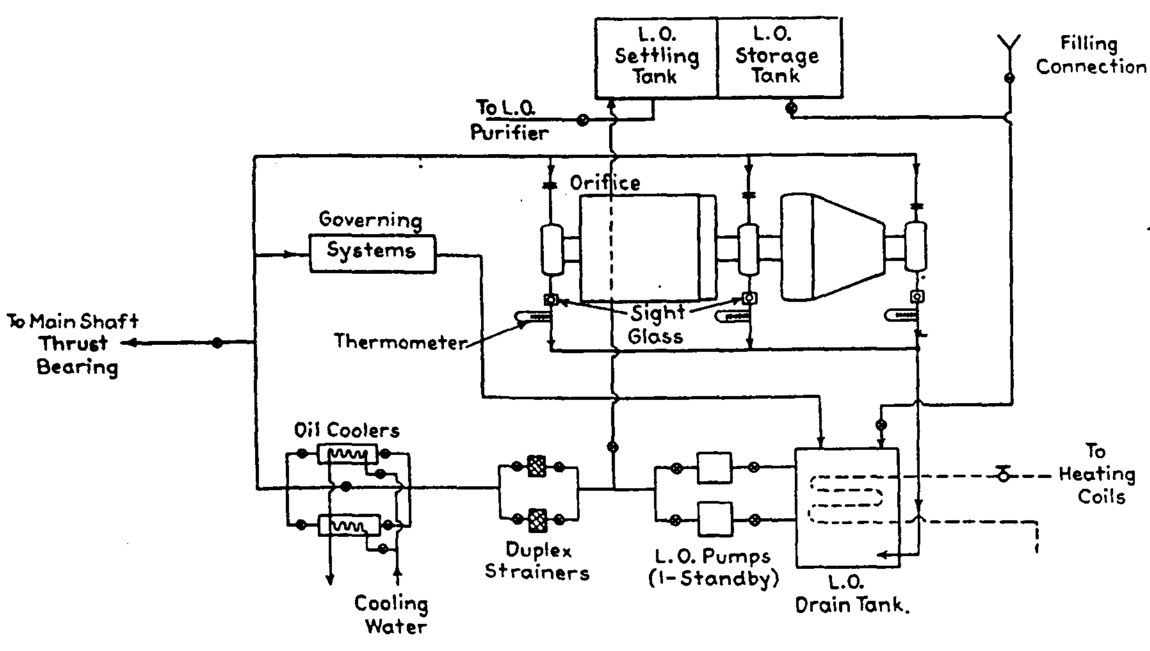


FIG. 14.—DIRECT-PRESSURE TYPE LUBRICATING-OIL SYSTEM

A few possible causes might be grip, oil fatigue, or plugged lines.

Pumps, coolers and strainers should be kept clean and no chances taken on contamination of lubricating oil from any source whatsoever.

Cautions.—An efficient engineer is not apt to wipe off oil-covered inner surfaces with waste or linty substances, but one can never tell what the greenhorn will do. Lint and waste plug up oil drain holes and can cause a lot of trouble. Their use is prohibited where it can do damage.

The use of gasoline as a cleaning agent of oiled parts is strictly against the rules. Kerosene is permissible but not gasoline.

The use of an open light around oil tank openings where there are fumes is dangerous, and to the item of open lights should be added lighted cigarettes or smokes of any kind.

Systems of Lubrication.—There are two general systems of lubrication in use: First, the gravity system, and, second, the direct-pressure system. Both of these systems incorporate the means for operating the protective and governing devices when used in connection with turbines.

The gravity system is inherently a low-pressure system and can be used in the majority of installations. In high-temperature installations, however, it is often desirable to use the direct-pressure system.

The oil pumps used for lubrication are always furnished in duplicate—one being used as a standby. In many installations, an automatic throw-over device is installed to start the standby pump in case the other one fails. Alarm signals are also provided to warn the engineer in case of trouble.

Two typical lubricating-oil systems are shown in Figs. 13 and 14. Fig. 13 shows a typical gravity system for use with turbine-gear drive, and Fig. 14 a typical direct-pressure system, used in some cases with turbine-electric drive. There may be many variations to these systems and in any case the engineer should refer to the manufacturer's instruction books for detailed information. The two diagran . do, however, show the elements that must be considered.