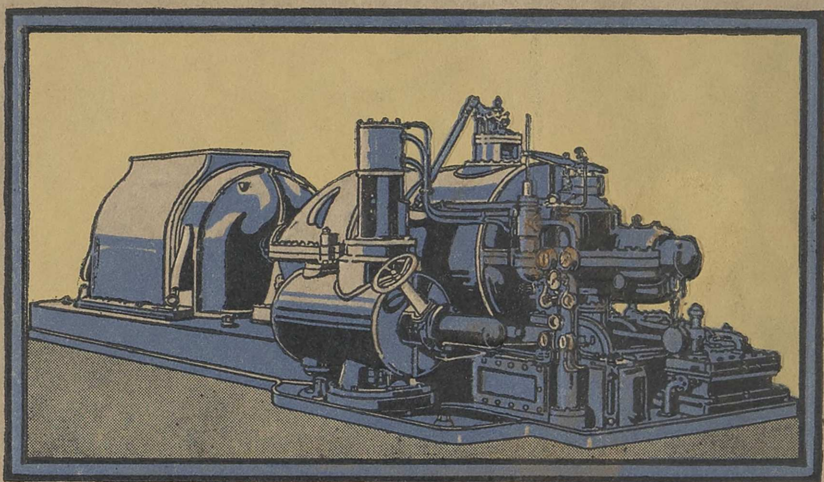
THE HORIZONTAL STEAM TURBINE



FOR STATIONARY PLANTS

The HORIZONTAL STEAM TURBINE

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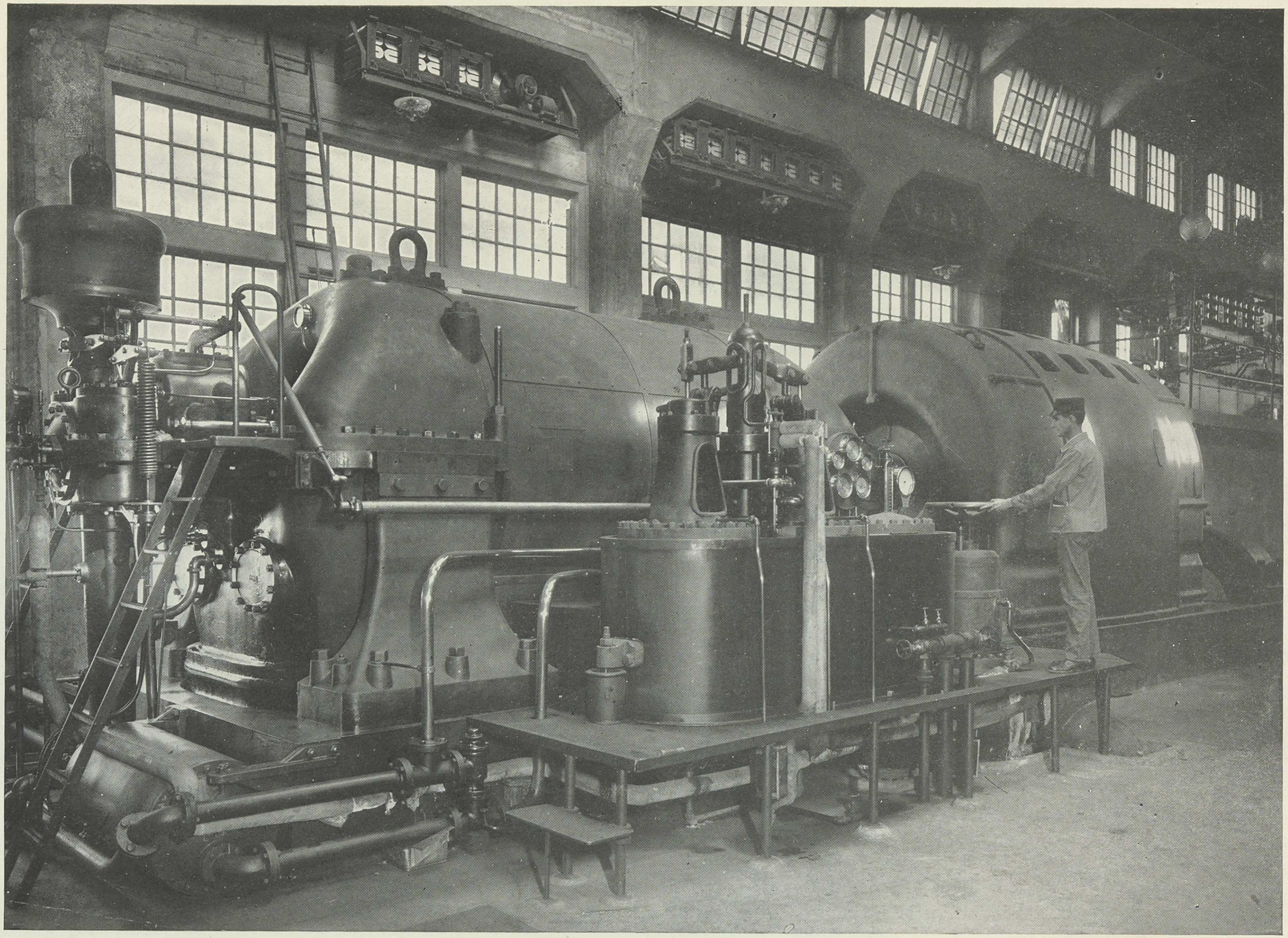


Reaction Type Turbine Direct-Connected to a 5000 KVA Alternating Current Generator

THE HORIZONTAL STEAM TURBINE *for* STATIONARY PLANTS

Field of Service; Classification; Types; Construction; Principle of Operation; Transmission of Power; Lubrication; Oil; Deposits

FIELD OF SERVICE

Horizontal steam turbines for stationary plants are built in a wide range of sizes.

Small turbines, up to 300 hp., running 30,000 to 3,000 revolutions per minute are used for operating high speed centrifugal pumps, for driving exhausters, exciter sets, small lighting plants, etc.

Turbines from 300 to 50,000 hp., running from 3,600 to 750 revolutions per minute, are used to drive electric generators furnishing power and light in collieries, steel works, paper mills, textile mills, street railway and industrial power stations.

CLASSIFICATION

Steam turbines are classified according to the way in which steam is used:

High Pressure Turbines
Exhaust Turbines
Mixed Pressure Turbines

High Pressure Turbines

High pressure turbines use steam at a boiler pressure of from 160 lbs. to 200 lbs. per square inch. The steam, before it leaves the boiler, is sometimes further heated, as a result of which its maximum value in heat units is utilized. The resultant dry steam is called superheated steam.

Exhaust Turbines

Exhaust turbines use the exhaust steam from reciprocating engines, *i.e.*, plant engines, steam hammers, rolling mill engines, colliery winding engines, etc. The pressure of exhaust steam is low, only a few pounds per square inch.

Before entering the turbine, the steam passes through an accumulator or receiver (a large enclosed reservoir) which establishes a regular flow of steam from the reciprocating engines to the turbine.

Where exhaust steam from large reciprocating engines is used, it is necessary that impurities in the steam, carried over from the boilers, and the excess oil used in steam cylinder lubrication, be thoroughly separated from the steam. Otherwise the turbine blades will become coated and the power of the turbine diminished.

Exhaust steam is always very moist, and carries fine particles of water in suspension. The steam usually is cleaned by means of separators placed in the exhaust steam lines between the engine and the turbine.

Mixed Pressure Turbines

Mixed pressure turbines are designed to operate with two sources of steam supply, a low pressure source and a high pressure source. They may be low pressure turbines with additional blading to utilize high pressure steam in case the supply of exhaust steam is not sufficient for the load required; or they may be high pressure turbines specially designed to make additional use of a supply of low pressure steam.

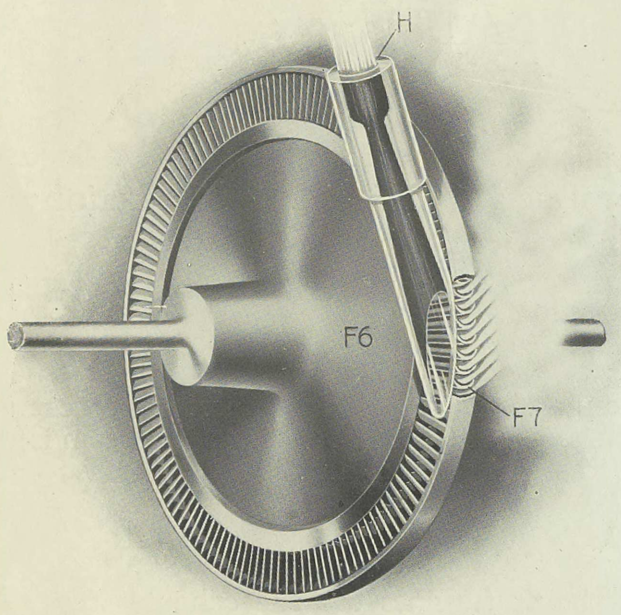


Fig. 1. The Principle of the Impulse Type Turbine.

TYPES

Horizontal type turbines are of the impulse type, the reaction type, or combine the features of both.

The Impulse Type Turbine

All expansion of steam takes place in stationary nozzles or steam delivery pipes and the velocity energy thus produced acts directly on the blades of the revolving disk.

The principle of the impulse type turbine is illustrated in Fig. 1.

The high velocity steam from the nozzle (H) impinges on the buckets (F7) of the wheel (F6) revolving it at high speed. Steam economy is secured with high velocity of the turbine wheel.

The capacity of this type of turbine is increased either by repassing the steam through another and larger set of buckets arranged in a circular section inside the row of buckets on the edge of the turbine wheel, or by the addition of one or more bucket wheels, which utilize the steam flow after it has passed through the set of buckets fixed in the rim of the first wheel.

Single-stage impulse type turbines are built in sizes below 600 hp.

Multi-stage impulse type turbines are built in sizes from 500 hp. to 6,000 hp.

The Reaction Type Turbine

The steam acts both on the moving and the stationary buckets or blades. As it passes through the turbine the steam imparts a small part of velocity energy by impulse at entrance and the greater part by the reactive thrust of expansion, on the blades fixed in the periphery of the revolving rotor.

The pressure of steam expansion is more effective than the velocity flow at which it impinges on the blades.

The larger size turbines are of the reaction type and operate at speeds as high as 3,600 revolutions per minute.

The De Laval, Kerr, Terry, Moore, Parsons, Curtis, Zoelly, Riedler-Stumpf, Brown, Bovery, A. E. G., M. A. N., Allis-Chalmers-Rateau, etc., are adaptations or combinations of the impulse or reaction types.

Curtis turbines are both vertical and horizontal.

The differences in design of all horizontal turbines affect only the arrangement of the revolving and stationary disks, the blading and the steam distribution to the disks; they do not influence the construction of the main bearings nor the methods of lubrication.

CONSTRUCTION

The Impulse Type of Turbine

The impulse type of turbine consists of a wheel case of iron (A, Fig. 3), cast in two parts, and a rotor (Fig. 2).

The Rotor

The turbine spindle or shaft is short and of relatively small diameter, but stiff enough to insure quiet running. It is made of forged, open hearth steel perfectly ground and finished.

It is carried in two bearings: (aF2) of the ring-oiled type and (bF8) a ring-oiled thrust bearing designed to prevent endwise movement and to hold the bucket wheels (aF6 and bF6) in the correct position relative to the vertical plane of the nozzles (H, Fig. 3) and the stationary guide vanes (A1).

The wheels (aF6 and bF6, Fig. 2) keyed to the shaft are forged steel circular disks. A separate wheel is provided for each row of buckets.

The buckets are made of nickel bronze and are securely fixed to the rim of the wheel.

Metallic ring packing (A3, Fig. 2) is fitted to the shaft to prevent leakage of steam from the wheel case (A, Fig. 3) outward, or of air inward.

In the multi-stage construction of the impulse type turbine, the steam leakage from stage to stage is prevented by the use of a labyrinth packing (Fig. 6). Carbon packing (Fig. 5) is also employed.

The Turbine Casing

Fig. 3 illustrates a view from above of an impulse type turbine with the top half of the

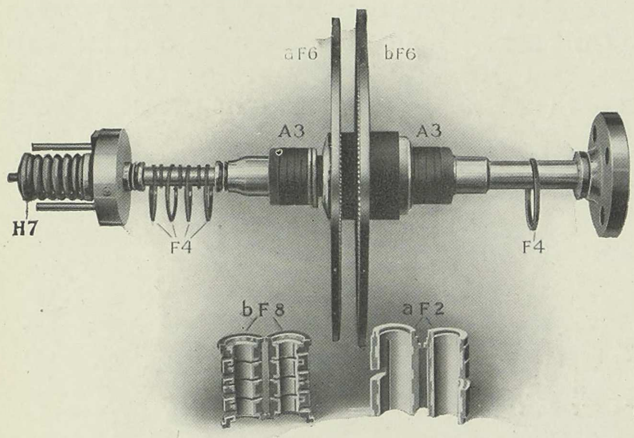


Fig. 2. Two disk rotor, bearings and governor

wheel case (A) lifted off and the rotating parts and bearings (shown in Fig. 2) removed.

The individual steam nozzles (H, Fig. 3) by which the steam is directed upon the first row of moving buckets on the wheel (aF6, Fig. 2) are also shown.

Inasmuch as full steam expansion takes place in the nozzles, the only parts of the turbine which come in contact with steam at boiler pressure and temperature are the governor valve (H5, Fig. 3), the steam chest

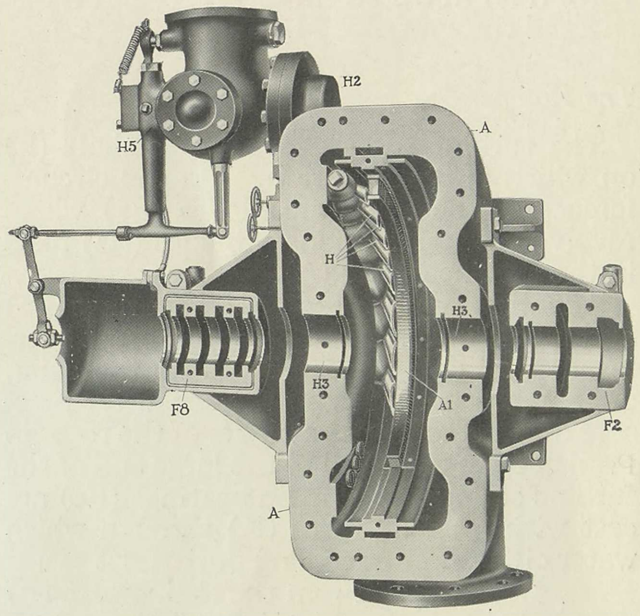


Fig. 3. Interior of lower half of casing

(H2) and the inlet ends (not shown) of the nozzles (H).

No internal parts (Fig. 2) are subjected to temperature of steam higher than that corresponding to the pressure of the expanded steam from the nozzles (H, Fig. 3).

The intermediate guide vanes (A1, Fig. 3) re-direct the steam from the moving buckets of the first wheel (aF6, Fig. 2) to the moving buckets of the second wheel (bF6).

The bearing brackets (F2, F8, Fig. 3) are supported directly upon the turbine casing and are quite separate from the stuffing boxes (H3), which prevent the leakage of steam or water from the casing (A) into the bearings or oil reservoirs (F2, F8).

The Reaction Type Turbine (Fig. 4)

The Turbine Casing

The turbine casing (A) is built of cast iron in two parts, bolted together in the horizontal plane of the center of the turbine shaft. It is a steam-tight cylinder in which are fixed the stationary blades (A2) used for re-directing the steam from one set to the succeeding set of moving blades (F7) of the turbine rotor.

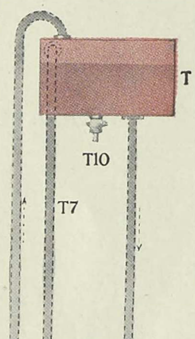
The upper half of the casing may be removed, for the examination of the rotor and blades and to facilitate repairs to the blading.

The steam enters the turbine at the stop valve (H5) in the steam line (H3) and is discharged through pipe H4.

The Rotor

The turbine rotor consists of a shaft (F) on which is fixed a drum. On the circumference of the drum are blades (F7) which revolve between stationary blades (A2) fixed in the turbine casing (A).

The shaft (F) is supported by bearings (F2) and is held in correct position by thrust bearing (F8). This bearing takes up the axial, or end thrust, caused by the expansive pressure of the steam on the blades of the rotor in passing from the small to the large end of the turbine casing. The main bearings (F2) are cast with inside cavities (K) through which water circulates for cooling purposes.



From the main shaft (F) is driven a vertical shaft (H6) on which is mounted the governor (H7), which automatically maintains the speed of the turbine by the control of the requisite amount of steam.

At each end of the turbine casing (A) are the gland packings (A3 and A4). Gland packing (A3) prevents steam leakage outward. Gland packing (A4) prevents air leakage inward when operating condensing or prevents steam leakage outward when operating non-condensing.

The exhaust steam from a non-condensing turbine is discharged to the atmosphere or is sometimes used for heating purposes.

The exhaust steam from a condensing turbine is discharged into a condenser where it is cooled and condensed in a vacuum. Highest steam efficiency is thus obtained.

The temperature at the exhaust end of a non-condensing turbine is raised by the temperature of the exhaust steam; whereas the vacuum utilized in a condensing turbine insures much lower operating temperatures at the exhaust end.

Steam leakage out of, or air leakage into, the turbine would greatly decrease its efficiency, hence the adoption of gland packing. There are three types of gland packing as follows:

Carbon packing
Labyrinth packing
Water seal

Carbon Packing (Fig. 5)

The carbon packing rings (1), made in several parts, are usually held in their places by means of helical springs (2) and fit into casing (3). The carbon rings (1) fit the shaft (F) closely, under slight pressure from

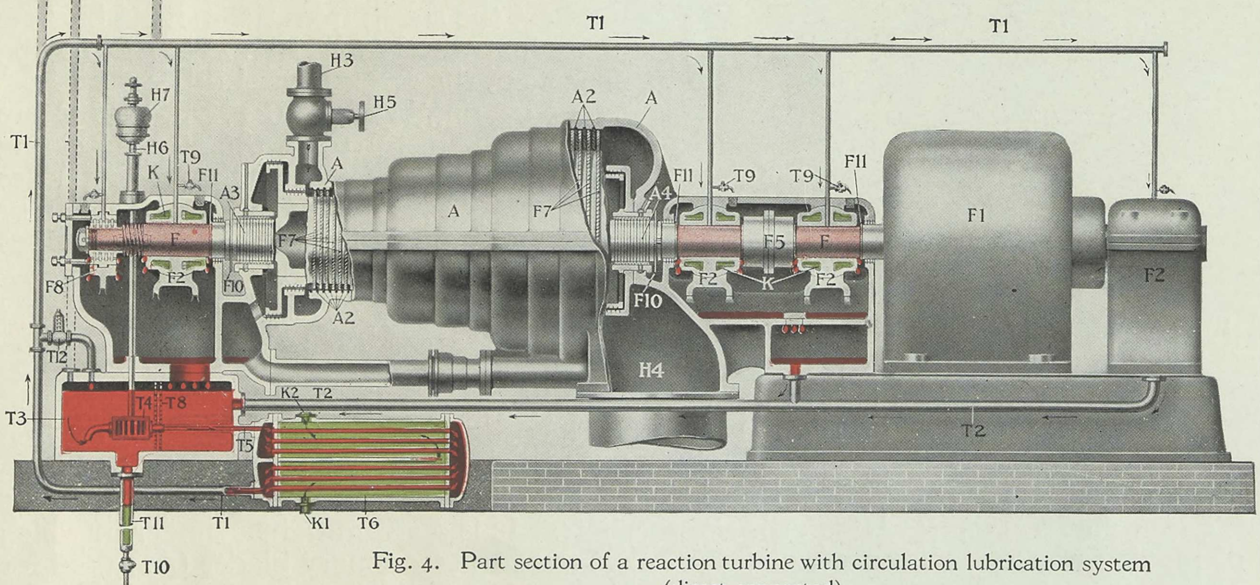


Fig. 4. Part section of a reaction turbine with circulation lubrication system (direct connected)

the springs (2). The pipe (5) is a steam connection permitting the employment of live steam for sealing purposes. A small

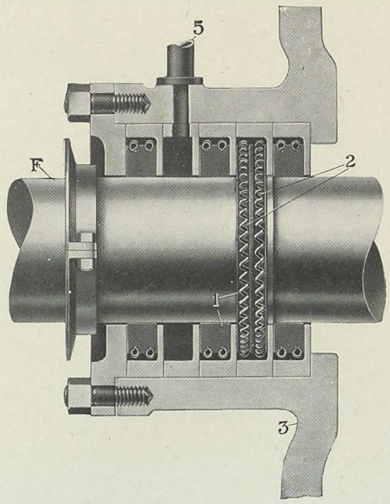


Fig. 5. Carbon packing

amount of cylinder oil is introduced into this gland to prevent wear of the shaft and to improve the sealing effect of the packing.

Labyrinth Packing (Fig. 6)

There is a labyrinth packing at the high pressure and another at the low pressure or exhaust end of the turbine.

Labyrinth packing consists of rings (1) on the shaft (F), which alternate with stationary rings (2) fixed in the surrounding

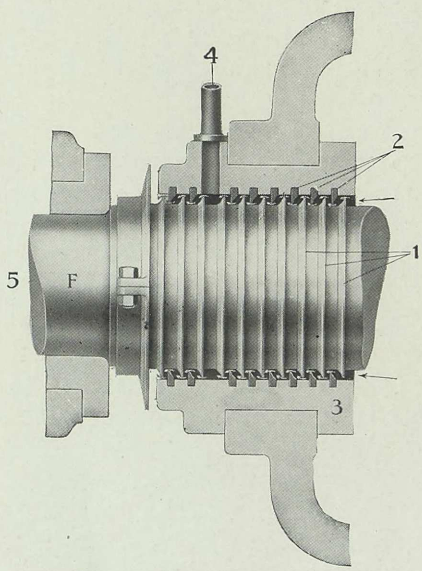


Fig. 6. Labyrinth packing

casing (3). The clearance is small between the stationary rings and the shaft.

Leakage is prevented by the small spaces (clearances) between the rings, which makes it difficult for leaking steam from the turbine to pass all the rings in a zigzag way. The high pressure steam that leaks past the rings as far as the pipe (4) is led away through that pipe connection to the condenser, or to an intermediate stage of the turbine. Any of the condensed steam in the form of water that passes the packing is deflected by the baffle ring (F10, Fig. 4), which throws it by centrifugal force from the revolving shaft. Water is thus prevented from working into the bearings, where it would mix with the oil.

In a condensing turbine the pipe (4) is used for introducing steam at low pressure into the low pressure packing. This is to prevent the leakage of air into the turbine. Air leakage into the turbine greatly decreases its operating efficiency.

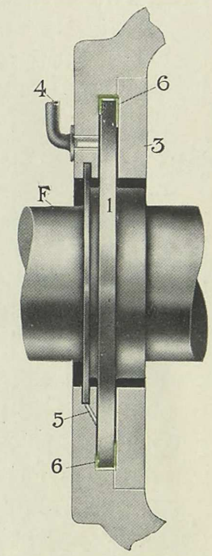


Fig. 7. Water seal packing

Water Seal (Fig. 7)

The disk (1) is fixed on the shaft (F) and revolves inside the casing (3) into which a constant supply of water is admitted by means of a pipe connection (4). Due to the centrifugal force of the revolving disk the water is thrown to the outside of the circular chamber and forms a water seal (6) making it impossible for steam or air to pass from one side of the disk to the other side.

PRINCIPLE OF OPERATION

Steam is admitted through the stop valve (H5, Fig. 4) and passes into the turbine at the high pressure end.

It first passes through the blades (A2) of the first *stationary disks*—the set of smallest diameter—and impinges on the blades (F7) of the first set of *revolving disks*; it then passes to the second set of *stationary disks* which directs the flow of steam to the second set of *revolving disks*—and so on throughout the whole series of blades.

In its passage through the turbine the flow of expanding steam loses its pressure and the successive sets of blading are gradually increased in size, being greatest at the exhaust end of the turbine.

After the steam has passed through the last set of blades it leaves the turbine casing through the exhaust pipe (H4).

Maximum efficiency of the turbine is secured with the use of superheated steam and a high vacuum. To secure the highest operating efficiency it is necessary to remove the slight amount of air in the steam by means of a dry vacuum pump which may be independently steam driven or operated by an electric motor. The air, which enters the boilers with the feed water, expands into a great volume in passing with the steam through the turbine.

Small turbines are not usually provided with an independent condensing apparatus.

Large turbines usually employ an independent condensing apparatus, where the steam, after it has passed through the last set of revolving disks, is condensed. The condensed steam is pumped from the condenser to the boilers which convert it again into high pressure steam required for the operation of the turbine.

Sometimes a turbine equipped with condensing apparatus operates non-condensing, the exhaust steam being used for commercial heating. In this event, the steam is exhausted into the heating line instead of passing through the condensing apparatus.

TRANSMISSION OF POWER

Direct Connected Turbines (Fig. 4)

The power of a direct connected steam turbine is transmitted through a flexible coupling (F5) to an electric generator (F1) or a fan, pulley, pump, etc., or to a shaft upon which a driving pulley is mounted. In the latter case the pulley transmits the turbine power indirectly by belt to shafting or machines.

Geared Turbines

Turbines with bucket wheels of small diameter run at high velocity—as high as 30,000 r.p.m.

High turbine speeds must be reduced to enable the machinery to which the turbine is coupled to operate.

Fig. 8 illustrates a set of reduction gears.

On the end of pinion shaft (A) is a flexible coupling (C) to which is coupled the end of the turbine rotor shaft (not shown). Gears (B) are cut on the pinion shaft (A) which is lubricated by ring-oiled bearings (D) at each end of the shaft.

In mesh with the teeth of pinions (B) are the teeth of gears (F) mounted upon the gear shaft (E). To the end of the gear shaft

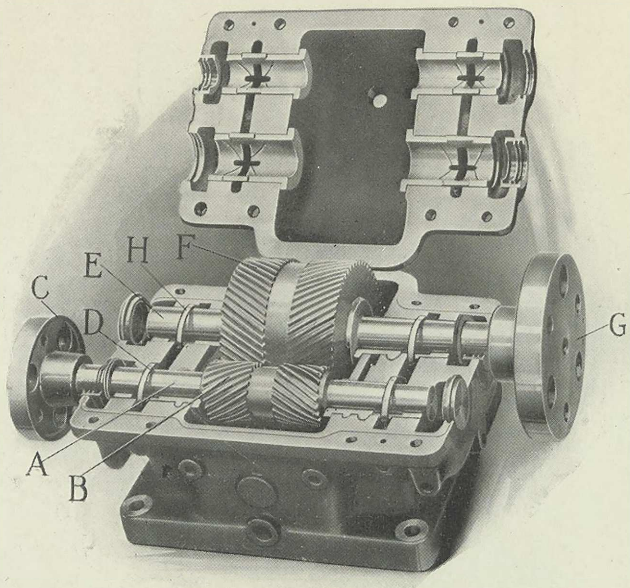


Fig. 8. Speed reduction gear

(E) is fixed a flexible coupling (G) to which is coupled a generator shaft (not shown). The gear shaft (E) is supported by ring-oiled bearings (H).

Fig. 9 represents a geared turbine connected to an electric generator. The covers of the turbine and gear casing are lifted, showing the relative position of the turbine rotor (L), the pinion shaft (A) and the gear shaft (E), with their respective gears (B and F).

The coupling of the pinion shaft is in a housing (at C) while the coupling (G) of the gear shaft (E) is shown connected to a similar coupling on the end of the generator shaft (J).

Bearings are shown at F2.

The high speed of the turbine is thus reduced, by means of the difference in size of the respective gears, to the relatively low speed of the generator.

For example, a turbine speed of 3,600 r.p.m. may be reduced to a driving shaft speed of 450 r.p.m.

LUBRICATION

There are two principal methods of turbine lubrication.

Oil Circulation System—for the large sized turbines of 300 horse power and over.

Ring-oiled bearings.

These are usually employed on the smaller turbines up to 300 horse power in size; sometimes ring-oiled bearings are employed on the largest sized turbines.

Oil Circulation System (Fig. 4)

From the lower portion of the governor spindle (H6, Fig. 4) is driven the rotary oil pump (T4), which takes oil from the oil tank (T3) and delivers it, through the oil cooler (T6), directly to the bearings (F2) through oil supply pipes (T1), or to the elevated tank (T).

Generally the oil passes from the oil cooler directly into the distributing pipe (T1); it then becomes necessary to have a spring-loaded relief valve (T12) in the delivery pipe, near the bottom oil tank, in order to maintain an adequate oil supply at a steady pressure. The surplus is returned to the bottom oil tank (T3).

From the bearings the oil returns through return pipes (T2) to the bottom oil tank (T3) through the strainer (T8). Oil throwers (F11) prevent the oil from creeping out along the shaft from the bearings.

If more oil is delivered to the elevated tank (T) than is required for the bearings, the surplus oil overflows through the pipe (T7) into the bottom oil tank (T3). The elevated tank (T) is nearly always omitted except in very large installations.

From an elevated tank (T) the oil is fed through the distributing pipe (T1) into the various bearings of the turbine.

It is good practice to have inserted in the return oil pipes (T2), sight feed arrangements by which the actual flow of oil from each particular bearing can be examined. Frequently test cocks (T9) are fitted in the middle of the bearing tops, which, when opened, will show whether the bearing is being adequately supplied with oil.

In both the elevated oil tank (T) and the bottom oil tank (T3) are fitted drain cocks (T10), through which water and sludge can be drained away.

Frequently the oil is also used for operating the governor gear (not shown). For this purpose oil is introduced into the various parts of the governor gear operated by the oil at a pressure of from 25 lbs. to 80 lbs. per square inch.

Occasionally one oil pump is used for supplying oil for bearing lubrication and another pump for supplying small quantities of oil under high pressure, for the governor

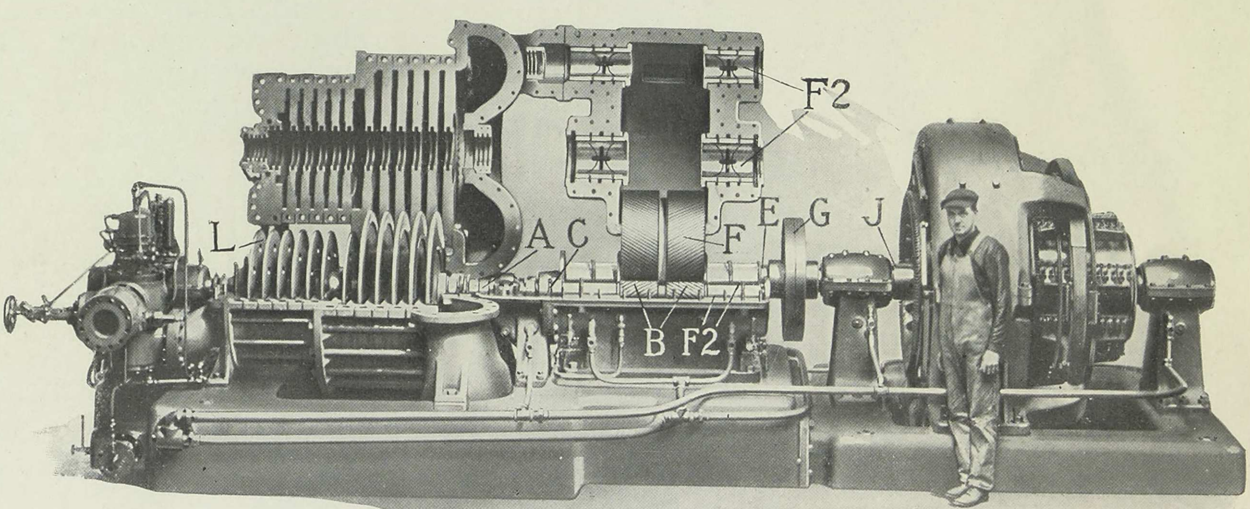


Fig. 9. Turbine connected to generator through a reduction gear (turbine and gear cover removed)

gear. Usually, however, in a direct pressure feed system, only one pump is employed and this pump must deliver all the oil under sufficiently high pressure to work the governor gear.

If, for any reason, the oil pressure falls below that required, a piston in the governor gear, held up by the oil pressure, falls and causes the steam supply to be shut off. The turbine will usually come to a stop before the oil supply to the bearing is sufficiently reduced to cause damage.

Where an elevated tank is employed, sufficient oil is usually assured to lubricate the turbine for at least thirty minutes, should the oil pump fail to work.

When starting up a turbine, where there is no elevated tank, the oil supply to the bearings will not be adequate until the tur-

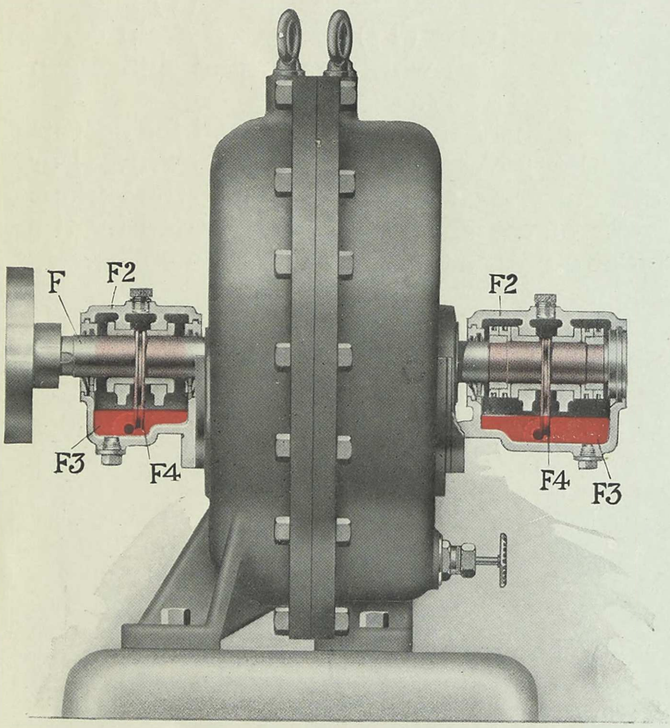


Fig. 10. Ring oiled turbine bearings

bine is running at about one-quarter normal speed. Therefore, before starting up a turbine, it is necessary to apply oil to the bearings by means of a hand or an auxiliary power-driven oil pump.

An auxiliary steam-driven or electrically-operated oil pump is employed for large turbines. As soon as the turbine reaches normal speed the auxiliary oil supply should be cut off, after which the oil pump, automatically operated by the turbine, will supply the requisite quantity of oil.

Ring Oiled Bearings (Fig. 10)

The bearings (F2) have oil reservoirs (F3) from which the rings (F4) suspended on the shaft (F) continuously carry oil to the shaft, distributing it through a longitudinal groove over the entire bearing surfaces. The oil, as it leaves the ends of the bearings, drops back into the oil reservoir.

Occasionally the bearings (F2) are fitted with Sight Feed Drop Oilers, which feed a certain number of drops per minute into the bearings. In such cases the oil, when leaving the bearings, is caught in "save-alls," filtered and used again.

This system, however, is obsolete and has been superseded by the ring-oiled bearings, which are now generally used on small turbines.

OIL

Oil Qualifications

Correct high grade oils, specially manufactured for turbine lubrication, are least affected by the presence of air, water and other impurities.

The use of the correct oil will eliminate wear and manifest efficient lubrication in terms of low bearing temperatures.

With an incorrect grade of oil, the bearing temperatures are always extremely high. The rate of oil oxidization—generated by the great heat—is thus increased, so that frequently the life of an ordinary oil in a turbine is only a few months.

Circulation oils have been specially treated to produce ready separation, and to withstand contamination with impurities under the severe conditions of continued service. When the operating conditions are extreme and impurities collect in the system, the oil in its circulation conducts to the journals and bearing metals those impurities, which may cause their corrosion.

The most prominent failures of oil in circulation systems have been in turbines where the surface speed of the journals was high, the oil circulation rapid, with a practical certainty of water collecting in the system and where insufficient time was allowed for the separation of impurities from the oil.

Oil Temperatures

After a turbine starts running, the temperature of the oil gradually increases and finally becomes constant—in a small turbine, after four hours' continuous running, and in a large turbine after almost a whole day's continuous running.

The shaft (F, Fig. 4) becomes hot because of the high temperature within the steam casing of the turbine. Therefore, the frictional heat of the bearings and contact with the heated turbine shaft raise the temperature of the oil.

Most of the heat absorbed by the oil is removed by means of an oil cooler. The resultant temperature of the oil depends partly upon the temperature of the cooling water used, but principally upon the capacity and size of the coils in the oil cooler. The larger the size and capacity of the cooling coils, the lower will be the temperature of the oil.

The cooling water should be pumped through the cooler at low pressure and should be as clean as possible. Otherwise, deposits will form on the cooler pipes and the oil will not be cooled sufficiently.

In order to control the lubrication of the various bearings thermometers should be fitted in the return oil pipes from each bearing. The temperature of the oil returning from the bearings should be not more than 130 degrees F. Occasionally records have shown a temperature as high as 170 degrees F. This indicates insufficient cooling capacity.

In some types of turbines experience has shown that the normal oil temperatures are very high. This usually results from too small an oil capacity for the work required and may be influenced by the location of the oil tank adjacent to the steam chest through which high temperature steam is supplied to the turbine.

Where the main bearings are water cooled, the temperatures are lowered about 10 degrees F.

In rare cases the main bearings are oil cooled, the oil passing through the cavities in the main bearings before entering the bearing surfaces.

The oil or bearing temperatures are important factors in judging the efficiency of the lubrication and cooling, and it is an advisable precaution to take temperature records every hour, as follows:

Temperature of each main bearing or of the oil return from each main bearing.

Temperature of oil return from the gear case of a reduction geared turbine.

If abnormally high temperatures are recorded, the following additional temperature readings should immediately indicate the source of trouble.

Temperature of the oil before entering oil cooler.

Temperature of the oil after leaving oil cooler.

Temperature of the cooling water entering oil cooler.

Temperature of the cooling water leaving oil cooler.

Oil Vapor and Foaming

On occasion, atomized oil or oil vapor comes from the bearings and oil tanks, notwithstanding the fact that the bearing temperatures are quite normal.

The cause of the vapor is the heavy charging of the oil with tiny air bubbles, due to the high speed at which the oil is circulated through the bearings and oil pipes. When the air bubbles burst in the bearings or in the oil tanks, the resultant very fine spray of oil produces the vapor.

Atomized oil drawn into the electric generator from the bearings may necessitate costly repairs. The oil will also deposit over the outside of the main bearings and the turbine frame.

The oil return pipes from the bearings or gear case must be large enough to carry away the oil, the oil foam and the oil vapor.

If the oil return pipes from the bearings are not large enough for this purpose, a positive remedy for the escape of oil vapor from the bearings is secured by the addition of a pipe, venting the oil reservoir of the bearing at a higher level than the original pipe. The additional pipe will return the oil foam and vapor which the first pipes are unable to handle.

Where too great a percentage of make-up oil is added to the system, excessive foaming sometimes occurs. This condition should become normal after a few hours' operation and will not have any detrimental effect on the service of the circulating oil. Continued excessive foaming is evidence that air is being drawn into the suction pipe by the oil pump. Air leaks should not be allowed to exist.

DEPOSITS

As has been shown the oil used in horizontal steam turbines is subjected to severe strain. The general belief among engineers in the past has been that petroleum lubricating oils are indestructible. This is very nearly true in practice, where the older methods of lubrication are employed, as in the case of drop feed oilers for reciprocating engines.

However, where the turbine is lubricated by means of an oil circulating system, in which the oil is forced to the bearings under pressure, then collected, filtered, cooled and repeatedly returned to undergo the same severe service, deposits may form, due to the breaking down of some portions of the oil from the following causes:

Air and heat
Solid impurities
Water
Broken down oil
Foreign substances
Adding new oil

Air and Heat

The circulating oil always contains more or less air, and when the temperature of the oil is above normal—say more than 140 degrees F.—the air has a strong tendency to oxidize the oil. This will be realized when it is remembered that the oil film in the bearings is very thin and that the air is present in very fine bubbles, which are intimately mixed with the oil.

The result is that the oil darkens considerably in color. In extreme cases, a very dangerous black carbon deposit develops, which may choke the oil inlets to the bearings and cause the oil-worked piston in the governor gear to stick.

Solid Impurities

Due to the high temperature at which the oil passes through the circulating system, the oxidizing effect of impurities—such as iron oxides, dust and dirt, etc.—is very considerable, particularly where ordinary oils are in use.

The effects produced are the quick darkening of the color of the oil, a considerable increase in viscosity, the production of a large percentage of petroleum acids and the breaking down of the oil from oxidation.

The oil in this condition smells burnt and throws down a slimy deposit which lodges in the system, particularly in the oil cooler.

In addition, if there is even a slight leakage of water into the system, the oil will emulsify badly, owing to its already weakened condition from the oxidizing effect of the air and solid impurities.

This will explain why, when starting up a new turbine for the first time, emulsification of the oil may occur as a result of the combined effects of the water, air and dirt present, even though the oil may be of high quality.

Water

Water has an emulsifying effect on the oil, particularly if the water contains impurities.

Where considerable quantities of water leak into the system and emulsification takes place, the mixture becomes yellow or brownish-yellow in color. If a sample is taken out and heated, it will separate into clean oil at the top (Fig. 11), more or less milky water at the bottom and a spongy sludge separating the two.

The clean oil will be found darker in color and heavier in body than the original and will have a strong characteristic odor.

When subjected to rapid circulation, especially in small systems, the oil and water forms an objectionable mixture, which clogs the screens, forms a slime on the cooling coils, and accumulates in the clearance spaces throughout the system.

This mixture will generally become hard, and in some instances cause partial stoppage in the oil pipes. In such cases, the increasing temperature of the bearings indicates insufficient supply of oil; and this in turn demands an immediate shutdown of the turbine to thoroughly cleanse the system.

One source of water accumulation in the oil is the steam leakage of the gland packing (A3, Fig. 4). The steam blows past the packings into the housings of the main bearings (F2) and condenses.

Water may also leak into the oil from the water cooling coils in the oil cooler (T6), or from the water jackets (K) in the housings of the main bearings.

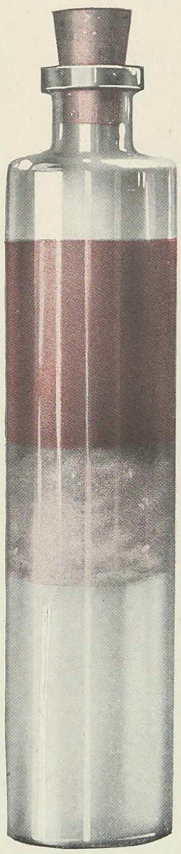


Fig. 11. "Broken down" oil

Where leakage of water into the oil system cannot be avoided, a water trap (T11), fitted in a vertical position, to the bottom of the oil tank, has been found of great service. The water, circulating with the oil, will separate and drain into the trap. Once there, it cannot mix with the oil again. This water trap should be drained every twenty-four hours, letting the water and sludge run until clear oil appears.

The drain cocks on the oil tanks should be opened before starting up the turbine, and at least once every twenty-four hours to remove water and impurities.

The suction of the oil pump should be from 2 to 4 inches above the bottom of the oil tanks, as otherwise any separated water will be taken up by the pump, churned with the oil, and passed into the oil system.

In view of the unfavorable influence of water upon the oil, it is well to remove each day, from the bottom of the oil tank, 3 to 6 gallons of oil for treatment in a steam-heated separating tank and later in a good filter.

The purified oil should be returned to the circulating system at the same time that a corresponding quantity is drawn off for treatment. In this way the vitality of the oil can be maintained at a high standard.

If the oil capacity of the system is small, it is particularly desirable to follow this treatment.

It is good practice to have a large quantity of oil in circulation, with large oil tanks in which the oil has time to rest and separate from the air, water, dirt and other impurities it collects in the system.

Broken Down Oil

The length of service of an oil is dependent upon the quality of the oil. An unsuitable oil breaks down quickly and "goes to pieces" badly. The correct high-grade oil, under normal conditions, will give good service for 10,000 working hours at least; and under severe and very unfavorable working conditions, for 3,000 working hours at most.

Fig. 11 is a photograph of an actual sample of broken down oil. The original oil has separated into three distinct bodies.

At the top is clear oil; at the bottom is clear or somewhat cloudy water; between the two is a slimy mixture, a large portion of which is water intimately mixed with less than 5 per cent of oil.

This slime represents the broken down oil and may be due to unsuitability, incorrect manufacture, or to some chemical action on the oil in the service.

Broken down oil accumulates in the most dangerous places, namely, the oil pipes which lead the oil from the distributing pipe (T1, Fig. 4) into the main bearings (F2). Partial stoppage of the pipes may result.

Broken down oil also accumulates, as a slime, on the water cooling coils in the oil cooler, thereby decreasing the efficiency of the cooler. The circulating oil assumes a temperature higher than normal which, in extreme cases, greatly impairs the life of the oil.

If broken down oil forms in the oil pipe leading to the governor, or inside of the governor gear, the governor may stick and fail to act. In consequence, the turbine either will gradually slow down or gradually increase in speed much above the normal.

The parts of the governor gear with which the oil comes in contact are very sensitive, and the oil must be absolutely clean and of high quality to guarantee smooth working of the parts.

Foreign Substances

Because of the penetrating and cleansing effect of oil in a circulation system, every oil circulation system must be thoroughly cleaned after an initial run of 150 hours.

When starting up a new turbine for the first time, there are always present in the circulating system impurities of many kinds, such as core sand, scale, cotton waste, etc.

It is, therefore, good practice after running the turbine for two or three weeks, to remove the entire supply of oil from the system and recharge it with new oil.

The oil taken out should be allowed to rest in a large tank, or in barrels, to separate it from the impurities. The separated good oil can then be used as "make up" for the turbine.

Should the charge of oil first removed from the turbine be badly affected by abnormal quantities of impurities, the oil should be heated and, after separation from the bulk of impurities, passed through a good filter before use.

Adding New Oil

Where little or no water enters the circulation system and where there is practically no waste or leakage of oil, so that the amount of new oil added to the system per week is very small, the oil will gradually become darker in color.

Where incorrect oils are in use, a dark deposit will be thrown down throughout the system, upon the addition of a new charge of oil, due to the action of the old oil on the new; and more particularly is this the case with heavy oils than with light oils.

A correct high grade oil, when used in the circulation system of a steam turbine under normal conditions of operation, will demand only small additional quantities of "make up" oil to insure economical and continuous service.

The correct high grade oils separate quickly from impurities and will not break down under normal working conditions. They will reduce friction to a minimum, prevent high bearing temperatures and provide a greater margin of safety.

The "make up" for lost oil, due to leakage and vaporization, will vary according to the size and operating conditions of the turbine; and when correct oils are used this replacement is usually sufficient to keep the oil in satisfactory working condition for a long time.

When, however, the limit of the oil's capability has been reached, entire replacement with fresh oil is recommended.

In reviewing the various causes of the formation of deposit, it will be observed that decomposition of the oil is invariably followed by a darkening in color and an increase in the percentage of acidity.

Therefore, both these features can be taken as standards by which to judge the service value of the oil.

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