The Westinghouse-Parsons Steam Turbine

A description,
with suggestions and instructions
for its

INSTALLATION CARE AND OPERATION

ENGINEER'S REFERENCE BOOK

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Instruction Book WM 103 April 1910

The Westinghouse Machine Company

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INSTALLATION
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OPERATION

EAST PITTSBURG, PA.

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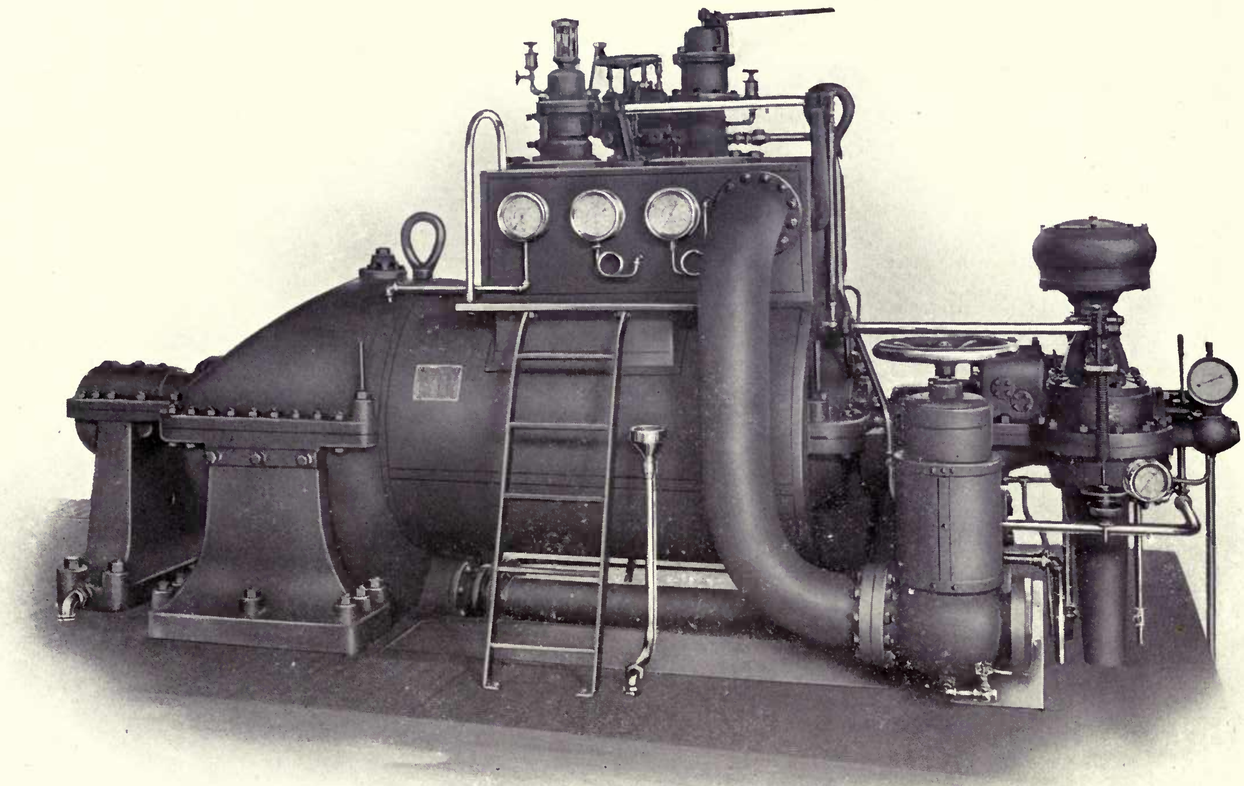
INTRODUCTION

While the turbine is simple in design and construction, and does not require constant tinkering and adjustment of valve gears, or taking up of wear in the running parts, it is like any other piece of fine machinery, in that it should receive intelligent and careful attention from the operator by inspection of the working parts that are not at all times in plain view. Any piece of machinery, no matter how simple and durable, if neglected or abused, will in time come to grief, and the higher the class of the machine, the more is this true.

The experienced engineer understands, in a general way, the principles and operation of almost any piece of apparatus that he may come across in the power house. At the same time there are points about any new machine that he has to learn, either from his own experience or the previous experience of others, and the latter supplemented and confirmed by the former, is perhaps apt to be the least costly. In the case of the ordinary large size reciprocating engine, where it is almost never run and sometimes not even assembled in the shop, the operating engineer can often tell the builders more about the care and operation of the engine than they are able to tell him; but in the case of the turbine, which is not only assembled but is thoroughly tested and operated for some time in the shop, the builders have had continued and varied experience under all sorts of conditions, and are, therefore, in a position to give advice in regard to its operation and maintenance.

The object of this pamphlet is to cover in a general manner the principal features of construction and methods of operation common to all Westinghouse turbines, the details occasionally met with in special types being described in a separate pamphlet covering each particular case.



1000 K. W. WESTINGHOUSE-PARSONS STEAM TURBINE

II.

Fundamental Principles of a Steam Turbine.

Any steam turbine depends for its operation upon the effect of steam being caused to expand through suitably formed passages, thereby attaining a velocity. The steam then impinging upon suitable buckets gives up the energy due to velocity and thus gives motion to the rotating element of the turbine. In some cases the steam expands through passages which are themselves capable of movement, in which case the effect of velocity is to give motion to the rotating element by reason of reaction.

In the Westinghouse-Parsons turbine use is made of each of the two effects. A general idea of the turbine blades may be gathered from the diagram, Fig. 1, in which both stationary and moving blades are shown in their respective location to one another.

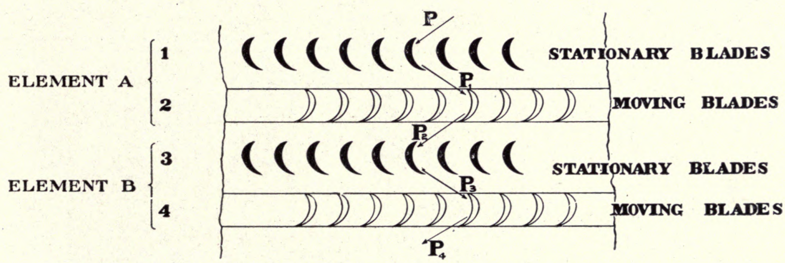


Fig. 1

The steam in passing through row 1, falls from pressure P to pressure P_1. In thus expanding it does work upon itself and attains a velocity, the energy of which is given up on the moving blades, row 2. Again, in the passage of steam through the blades of row 2, the pressure falls from P_1 to P_2. This expansion again produces a velocity, but this time its effect is to react on row 2. This cycle is repeated a number of times until exhaust pressure is reached.

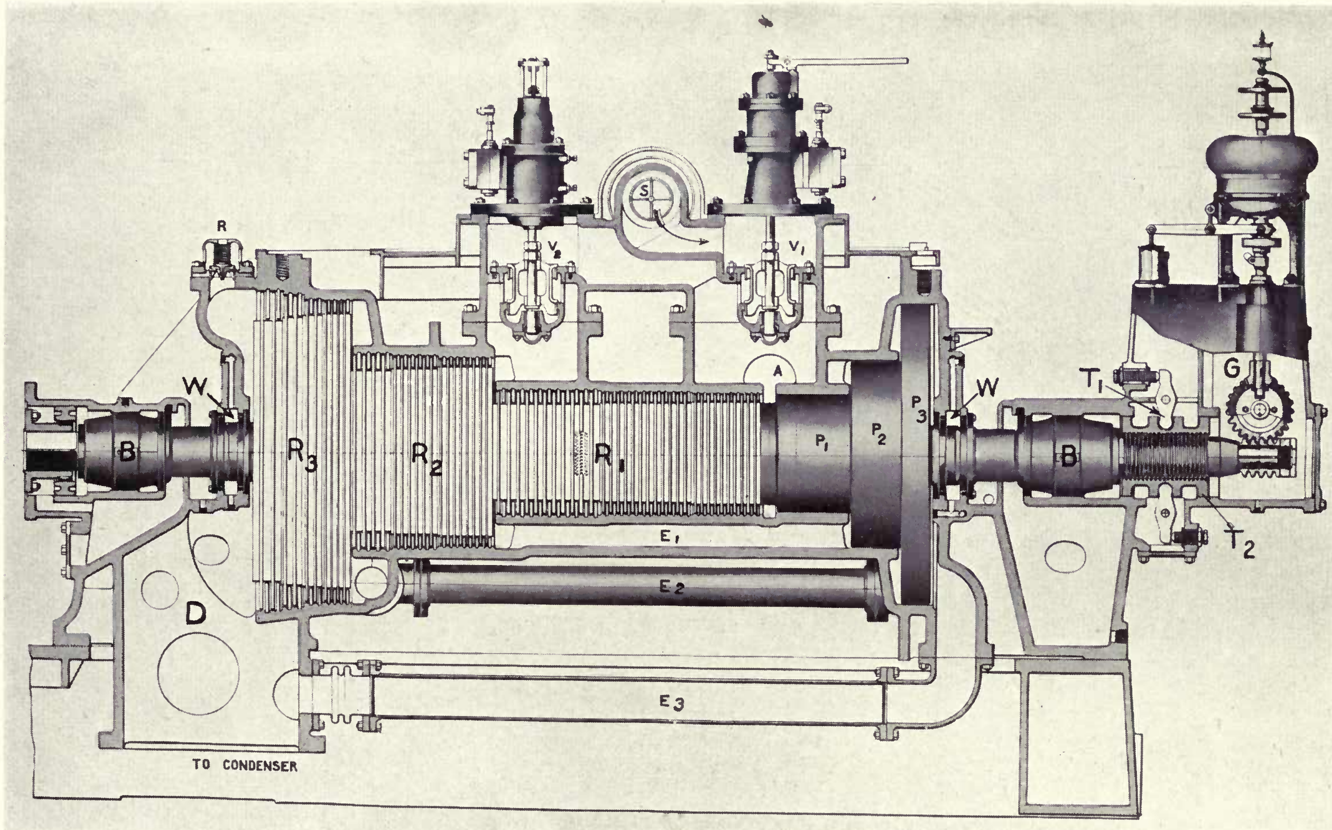


Fig. 2—LONGITUDINAL SECTION OF A TYPICAL WESTINGHOUSE-PARSONS STEAM TURBINE

III.

The Westinghouse-Parsons Steam Turbine.

Figure 2 is a sectional view showing the construction of the Westinghouse-Parsons straight parallel flow steam turbine. While the different types vary somewhat in minor details, the principle of operation remains the same. Steam enters through the strainer S, passes through the main admission valve, into the turbine at A. After expanding through the cylinders R_1, R_2, R_3, it passes down the exhaust chamber D to the condenser. The admission of steam is regulated by the valve V actuated by the governor G, driven by the worm wheel at the end of turbine rotor.

There are two distinct types of steam turbines built by the Westinghouse Machine Company—the straight parallel flow Westinghouse-Parsons steam turbine as shown in Figure 2, and the Double Flow Westinghouse steam turbine, Figure 3. As the latter is a development of the former, especially suited for handling large volumes of steam, but having the same elements of construction such as rotor, cylinder, governor, etc., and is operated in practically the same manner, it is treated as a special case and the details of design such as direction and regulation of flow of steam are discussed in a separate pamphlet.

The principal elements of construction are taken up as follows:

Rotor:

This is shown at R, P, Figure 2. The parts R_1, R_2, R_3, consist of steel drums mounted upon a spindle, in which are inserted rows of blades or vanes, by means of which the rotative effort imparted by the steam is received and transmitted to the rotor. On the opposite end of the spindle and corresponding to each diameter, R, are balance pistons P_1, P_2, P_3, of such diameter as to exactly balance the axial pressure on the drums R_1, R_2, R_3, the different pressures at either end of the respective drum diameter being communicated to the corre-

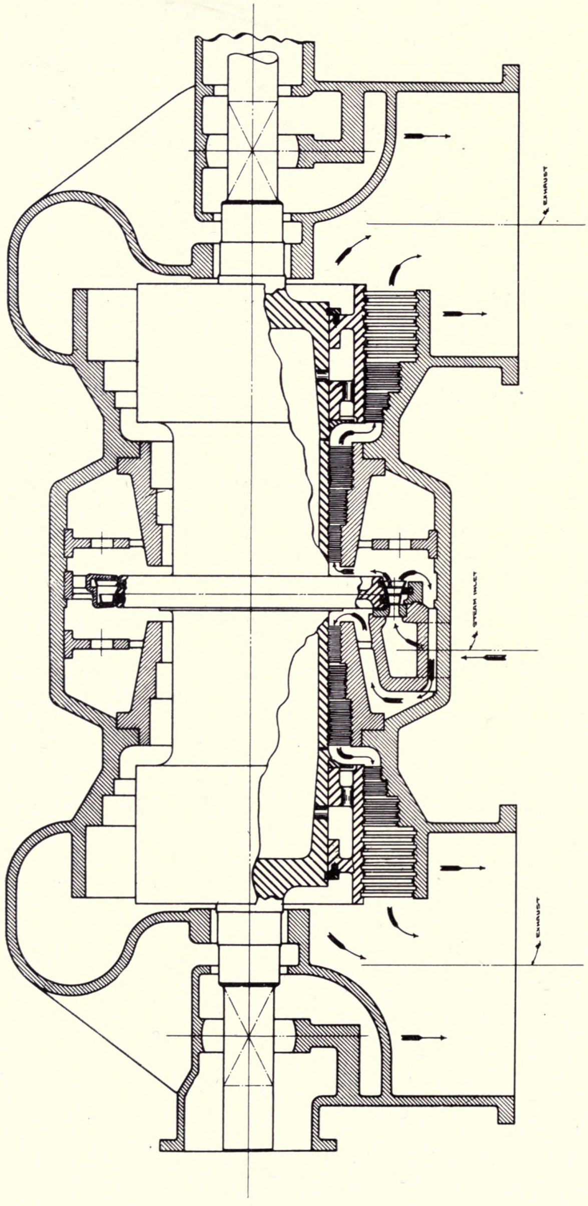


Fig. 3

sponding piston faces by means of the passages E_1, E_2, E_3, as shown. These balance pistons have a number of grooves cut in their faces, into which mesh corresponding collars in the cylinder, thereby effectively preventing leakage, although they run without actual metallic contact.

Cylinder:

The rotor revolves in the stator or stationary cylinder, which has rows of guide blades corresponding to those in the spindle, but set in reverse position. (See Fig. 1.) Also placed in the cylinder, at the section occupied by the balance piston, are collars or strips, which fit into the grooves in the balance pistons on the spindle as referred to above. By means of aligning bearings, T_1, T_2, Figure 2, the spindle is held in such a position that the sides of the grooves in the balance piston are close to the strips in the cylinder, but not close enough to touch them, thus preventing the passage of any appreciable amount of steam without rubbing contact between the adjacent surfaces.

Referring again to Figure 2, which represents the typical Westinghouse-Parsons turbine in sizes from 300 to 3000 Kw., it will be noticed that there are three large changes in the diameter of the working portions of the spindle and cylinder. These are commonly referred to as the different cylinders of the turbine, being respectively the high pressure, the intermediate pressure and the low pressure cylinders, starting with the smallest diameter at R_1, R_2 being the intermediate and R_3 the low pressure cylinder. It will be noticed that each cylinder is further divided into small steps, each one of these latter having blade rows of the same height. Each of these steps is known as a barrel, there being usually three to five of these in each of the cylinders, and anywhere from one to twenty rows in each of these barrels. In the event of any correspondence relating to blading, it is customary to refer to any particular row of blades as the 1st, 2d, 3d, or otherwise row in the 1st, 2d, 3d or otherwise barrel in the high pressure, intermediate or low pressure cylinder of the spindle or cylinder, as the case may be, counting from the high pressure end.

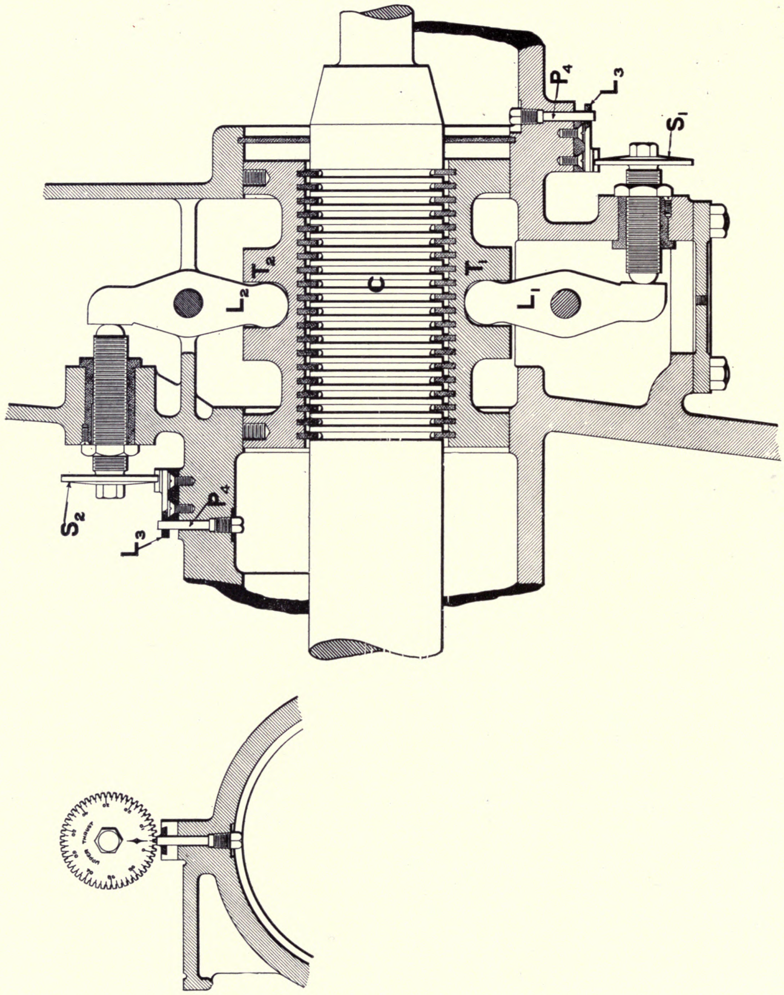


Fig. 4

Thrust Bearing:

The aligning or thrust bearing is made up of two parts T_1, T_2, each consisting of a cast iron body in which are placed brass collars. (See Fig. 4.) These collars fit in grooves C, cut in the shaft as shown. The halves of the block are brought into position by means of screws S_1, S_2, acting on levers L_1, L_2, mounted in the bearing pedestal and cover. It will be seen that, by turning the screw inwards, the half of the block that it acts on is moved in the opposite direction, and that the spindle cannot move beyond that point.

The screws are provided with graduated heads, which permit the position of the respective halves of the thrust bearing to be set to one-thousandth of an inch. The arrangement of each screw is similar to the familiar micrometer.

The upper screw S_2, is set so that when the rotor exerts a light pressure against it, the grooves in the balance pistons just escape coming in contact with the strips in the cylinder. The lower screw S_1, is adjusted to permit about eight one-thousandths to ten one-thousandths of an inch freedom for the collars C, between the thrust bearings.

The alignment bearings are carefully adjusted before the machine leaves the shop and, to prevent either accidental or unauthorized changes of their adjustment, the adjusting screw heads are locked by the method shown in Figure 4. It will be observed that the screw cannot be revolved without sliding back the latch L_3. To do this the pin P_4, must be withdrawn, for which purpose the bearing cover must be removed.

In general, this adjustment should not be changed except in some special case where there has been wear of the collars in the alignment bearings. Nevertheless, it is a wise precaution to go over the adjustment at intervals. The method of doing this is usually as follows: The machine should have been in operation for some time so as to be well and evenly heated and should be run at a reduced speed, say 10% of the normal speed, during the actual operation of making the adjustment. Adjust the screw, which, if tightened, would push the spindle away from the thrust bearing towards the exhaust. This, in some type of machines might be the upper screw and in others the lower screw; as shown in Figure 4 it is the upper screw. Find a position for this, such that, when the lower screw is tightened, thus drawing the spindle towards the governor end, the balance pistons can just be heard coming in contact, and such that the least change of position inwards of the upper screw will cause the contact to cease by forcing the spindle towards the exhaust end as evident from Figure 2. To hear if the balance pistons are in contact, a short piece of hard wood should be placed against the cylinder casing near the balance pistons. If one's ear is applied to the other end of the piece of wood, the balance pistons can be heard when in contact with the strips in the cylinder. The lower screw should then be loosened and the upper screw advanced six one-thousandths, at which position the latter may be considered to be set. The lower screw should then be advanced until one-half of the thrust pushes the rotor against the other half of the thrust bearing, and from this position it should be slacked back ten one-thousandths to give freedom for the rotor between the thrusts and locked.

Great care must be exercised in this operation, in determining when the collars of the balance pistons are just in contact. Gentle pressures only must be exerted in adjusting these screws or the parts will be strained, giving an erroneous setting. This contact should be only momentary, and the screw should be released just as soon as the rubbing is heard.

The above mentioned dimensions of clearance apply only to turbines up to 1000 Kw. Special settings are generally used in larger sizes.

The object in view is to have the grooves of the balance pistons running as close as possible to the collars in the cylinder, but without danger of their coming in actual contact and to allow as little freedom as possible in the thrust bearing itself, but enough to be sure that it will not heat. The turbine rotor itself has scarcely any end thrust, so that all the thrust bearing has to do is to maintain the above described adjustment.

Some machines are provided with a thrust-bearing, having both adjusting screws on the upper cap, facilitating the operation of adjusting the thrust blocks. However, the same precautions and directions given in connection with Figure 4, apply to this bearing, as it differs only in arrangement of details.

The principal feature wherein it differs from Figure 4 is the position of lever for adjusting the lower half of the bearing. Instead of engaging in the bottom of the bearing and requiring adjustment in the lower part of the pedestal, the lever consists of two arms which span the upper bearing and engage in recesses at the side of the lower bearing so that it is adjusted from above. The two adjustment screws are so located that both may be conveniently regulated at the same time, by adjusting one with either hand. In most cases the inner adjustment screw, that is the one nearer to the turbine casing, controls the upper thrust block, while the outer regulates the lower block.

The lock slide (L_3) is held in place by a screw which in turn is prevented from becoming loose by being drilled to receive two cotter pins, one on each side of the slide.

Main Bearings:

The bearings which support the rotor of the smaller machines running at 3,600 r. p. m. are shown at B, B, Fig. 2, and in detail in Fig. 5. The bearing proper consists of a brass tube, B, Fig. 5, with suitable oil grooves. It has a dowel arm L, which fits into a corresponding recess in the bearing cover, to prevent the bearing from turning. Around this tube are three concentric tubes, C, D, E, each one fitting over the other with some clearance, so that the bearing itself is free to move slightly in any direction. These tubes are held in place by the nut F, and this nut in turn is held by the small set screw G. The bearing with the surrounding tubes is placed inside of the cast iron shell A, which rests in the bearing pedestal on the blocks and liners H. The packing ring M, prevents the leakage of oil past the bearing. Oil enters the chamber at one

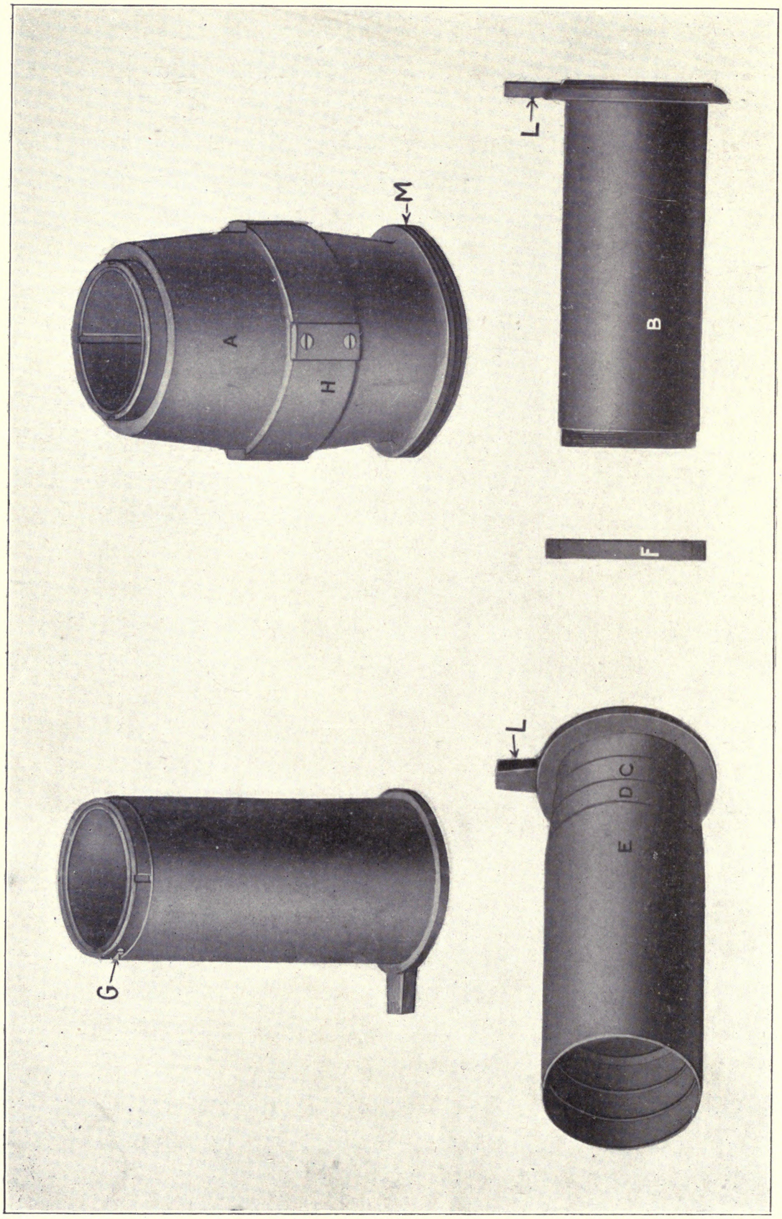


Fig. 5

end of the bearing and passes through the oil grooves lubricating the journal, and then out into the reservoir under the bearing. The oil also fills the clearance between the tubes and forms a cushion which dampens any slight vibrations. The bearings, therefore, absorb any vibration that might occur.

In some cases the bronze tube B is lined with babbitt, giving a babbitt bearing surface, while the rest of the bearing parts remain the same.

This type of bearing with its nest of tubes is required only in high speed machines where the bodies revolve above the critical speed, the tubes permitting the revolving element to tend to revolve about its gravity axis rather than about its geometric axis. The results are the same as were obtained later by Dr. De Laval by means of his flexible shaft.

In the larger machines running at 1,800 r. p. m. or less, a babbitted bearing is usually employed. This type of bearing is shown in Fig. 6, being divided longitudinally in the usual manner. It is also self-aligning, and is supplied with oil at the center through suitable passages, discharging at each end.

This bearing consists of two cast iron shells, A and B, Fig. 6, lined with babbitt and held together by the bolts C C and supported by the blocks and liners H. H. The babbitt is bored out slightly larger than the shaft, and further bored along the sides so that the horizontal dimension of the bore is somewhat greater than the vertical, thus giving close contact along only about two-thirds of the bottom half of the circumference, allowing ample room for oil to produce perfect lubrication. The oil enters at the point D and passes around the passages E, E, coming into the bearing at F.

The outer shells of both types of bearings are provided with four recesses, in which are fitted keys, as shown at H, upon which the bearing is carried in the pedestal. These keys have a number of sheet metal liners behind them by means of which accurate adjustment may be made of the bearings to give any desired adjustment of the revolving part with reference to the

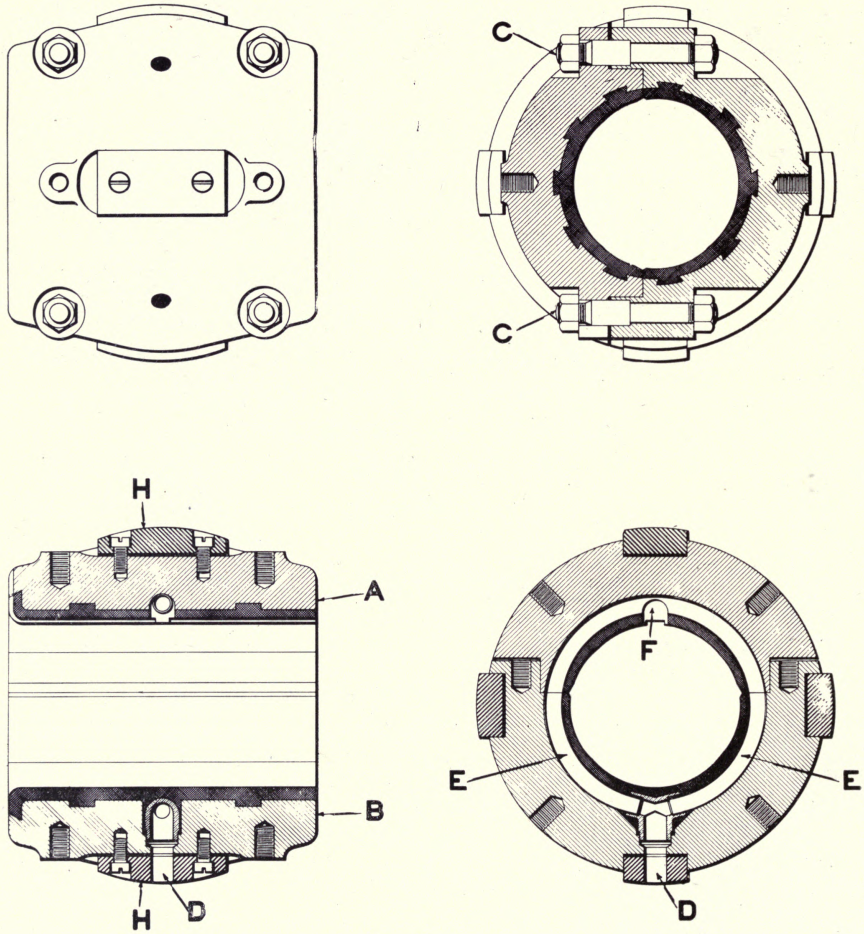


Fig. 6

stationary part. These liners are arranged in combinations to permit adjustments to be made in increments of five one-thousandths of an inch.

Glands:

On either end of the turbine spindle at W W, Fig. 2, are located the water sealed glands to prevent air leaking into the turbine when running condensing and to prevent steam blowing out when operating with atmospheric or greater pressure at the exhaust.

Referring to Fig. 7, the sealing water is supplied to the glands through passage A in the turbine casing to chamber B, in which the runner C revolves with the turbine shaft. This runner is designed to be capable of pumping to a pressure of about thirty-five pounds if it were furnished with water at its inner radius, so that when water is supplied to its periphery at twenty pounds absolute, or say twenty pounds greater than the pressure within the turbine, this water is unable to flow into the turbine by reason of the pumping effect of the gland runner in the opposite direction. Thus there is maintained at the outer edge a solid annulus of water of a pressure greater than the pressure the gland has to pack against, producing a hermetic seal entirely precluding the passage of air.

The spindle gland sleeve E, which is shrunk on the shaft and doweled at H, consists of a bronze ring provided with grooves. This gland sleeve has a running clearance between it and the casing F, and acts as a labyrinth packing to prevent excessive leakage along the shaft while the turbine is operating slowly. What slight leakage there may be is taken care of by the drain pipe K. This should be a free drain, and at all times maintained clear, otherwise water may leak through the oil ring into the bearing chamber, and contaminate the oiling system.

A pipe G is provided at the inner side of the gland for the purpose of draining away any leakage to the exhaust pipe and preventing it from splashing on the revolving rings of the turbine.

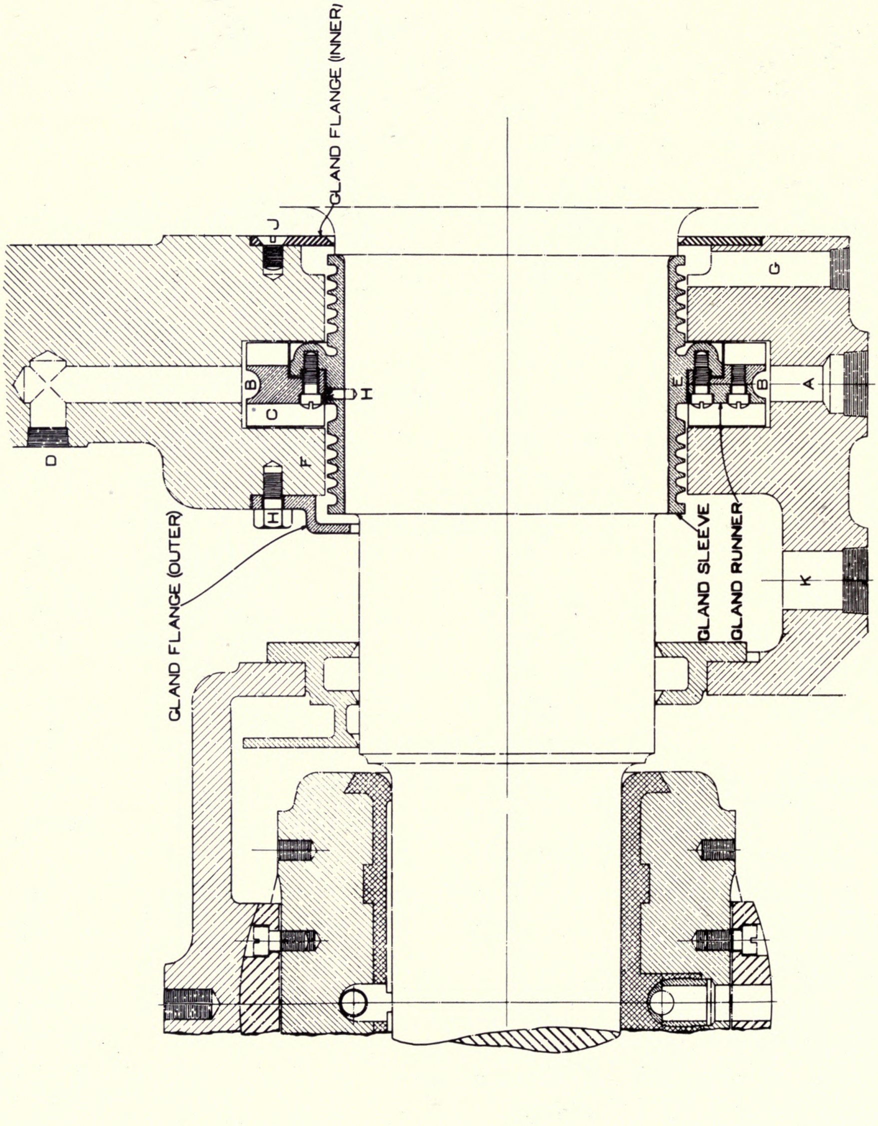

GLAND FLANGE (INNER)
GLAND FLANGE (OUTER)
GLAND SLEEVE
GLAND RUNNER
A
B
C
D
E
F
G
H
J
K

Fig. 7

The outer flange is to prevent any leakage from the shaft being thrown off into the engine room.

A gauge at D indicates the pressure at the outer edge of the glands, so that it may be known whether or not the water supply is being properly maintained.

Suggestions regarding various methods of connecting the water supply to these glands are given in the latter part of this pamphlet.

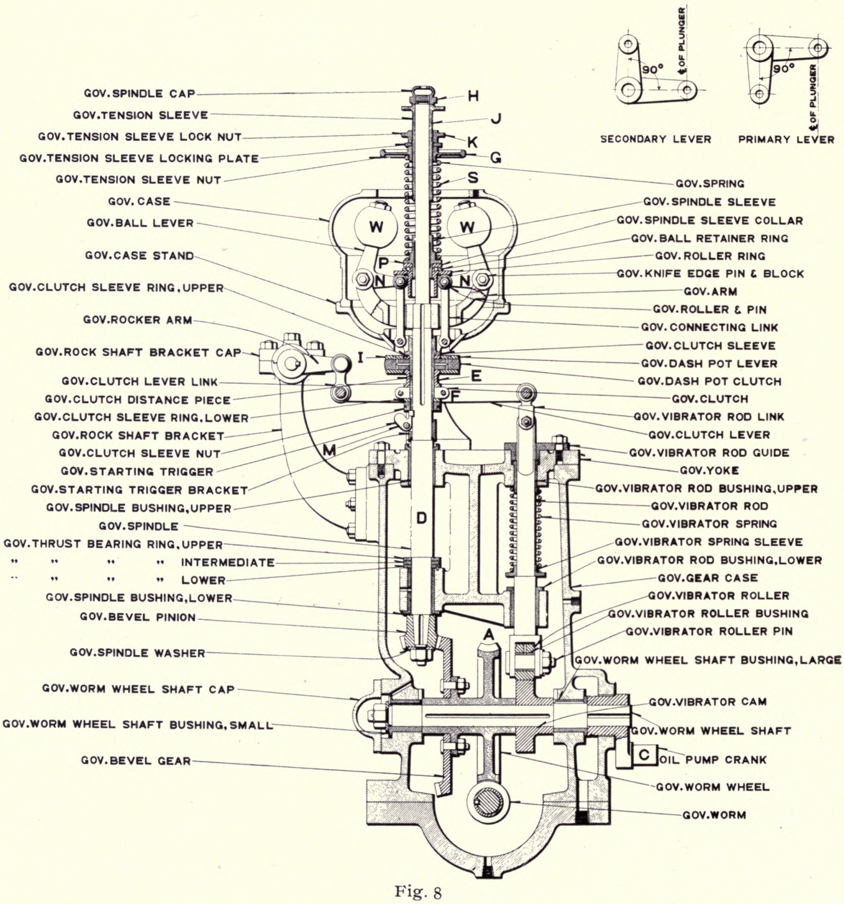
In the case of low pressure turbines where it is necessary to obtain a vacuum before the spindle is revolved, a special type of gland is furnished, as described elsewhere, in connection with low pressure turbines.

Governor:

Fig. 8 shows a section of the Westinghouse-Parsons flyball type of governor used in conjunction with poppet valves and steam relay mechanism for controlling the admission of steam.

Keyed on the end of the turbine shaft is a steel worm driving the bronze worm wheel A. This gear A drives the oil pump crank C and transmits its motion by means of a bevel gear and pinion to the governor spindle, D. On this spindle is keyed the governor arm which carries the balls W W, the levers N N being mounted on knife edge pins. On the ends of these levers are rollers which support a roller ring and ball race upon which the governor spring S acts. The object of this arrangement is to allow adjustment of the governor while the turbine is running; by lightly grasping the sleeve locking plate G, the tension sleeve, spring and spindle sleeve collar are brought to rest, and the governor balls are still free to revolve on the above mentioned ball thrust bearing.

Therefore, to vary the speed of the turbine, hold the tension sleeve nut G with one hand, and with the other loosen the locknut K a sufficient amount to disengage the pin in the locking plate from slot in G. Then adjust the sleeve nut until the speed has been changed the desired amount. In this manner adjustments of speed are made without interfering



GOV. SPINDLE CAP
GOV. TENSION SLEEVE
GOV. TENSION SLEEVE LOCK NUT
GOV. TENSION SLEEVE LOCKING PLATE
GOV. TENSION SLEEVE NUT
GOV. CASE
GOV. BALL LEVER
GOV. CASE STAND
GOV. CLUTCH SLEEVE RING, UPPER
GOV. ROCKER ARM
GOV. ROCK SHAFT BRACKET CAP
GOV. CLUTCH LEVER LINK
GOV. CLUTCH DISTANCE PIECE
GOV. CLUTCH SLEEVE RING, LOWER
GOV. ROCK SHAFT BRACKET
GOV. CLUTCH SLEEVE NUT
GOV. STARTING TRIGGER
GOV. STARTING TRIGGER BRACKET
GOV. SPINDLE BUSHING, UPPER
GOV. SPINDLE
GOV. THRUST BEARING RING, UPPER
" " " " INTERMEDIATE
" " " " LOWER
GOV. SPINDLE BUSHING, LOWER
GOV. BEVEL PINION
GOV. SPINDLE WASHER
GOV. WORM WHEEL SHAFT CAP
GOV. WORM WHEEL SHAFT BUSHING, SMALL
GOV. BEVEL GEAR
H
J
K
G
S
W
W
P
N
N
I
E
F
M
D
A
C
SECONDARY LEVER
PRIMARY LEVER
90°
90°
℄ OF PLUNGER
℄ OF PLUNGER
GOV. SPRING
GOV. SPINDLE SLEEVE
GOV. SPINDLE SLEEVE COLLAR
GOV. BALL RETAINER RING
GOV. ROLLER RING
GOV. KNIFE EDGE PIN & BLOCK
GOV. ARM
GOV. ROLLER & PIN
GOV. CONNECTING LINK
GOV. CLUTCH SLEEVE
GOV. DASH POT LEVER
GOV. DASH POT CLUTCH
GOV. CLUTCH
GOV. VIBRATOR ROD LINK
GOV. CLUTCH LEVER
GOV. VIBRATOR ROD GUIDE
GOV. YOKE
GOV. VIBRATOR ROD BUSHING, UPPER
GOV. VIBRATOR ROD
GOV. VIBRATOR SPRING
GOV. VIBRATOR SPRING SLEEVE
GOV. VIBRATOR ROD BUSHING, LOWER
GOV. GEAR CASE
GOV. VIBRATOR ROLLER
GOV. VIBRATOR ROLLER BUSHING
GOV. VIBRATOR ROLLER PIN
GOV. WORM WHEEL SHAFT BUSHING, LARGE
GOV. VIBRATOR CAM
GOV. WORM WHEEL SHAFT
OIL PUMP CRANK
GOV. WORM WHEEL
GOV. WORM

Fig. 8

with the operation of the turbine. This spring adjustment may be used if desired for bringing one machine into synchronism with another or for transferring the load to or from other turbines operating in parallel.

Of course the spring tension may be changed while the turbine is at rest, but it cannot be set at any definite speed unless the nuts have been previously marked for certain settings.

The oscillatory motion of the valves is derived from a cam or eccentric on the worm wheel shaft operating the vibrator rod which in turn actuates the clutch lever F, which is pivoted on the governor clutch. This clutch is free to travel on the spindle in response to different positions of the governor balls and levers. The effect of a change in the position of the governor weights is merely to change the plane of oscillation of the clutch lever, since the amplitude of the oscillations remains constant. The clutch lever is connected by means of suitable arms to the relay plunger which, while constantly oscillating, changes its mean position in accordance with changes in the position of the governor balls, or in other words, in accordance with the demands of the load. The operation of this relay plunger and manner in which it regulates the inlet of steam is explained on page 27 and following.

The motion of the clutch is dampened by means of a dash pot connected by levers pivoted at I.

The starting trigger M holds the lever in the position corresponding to normal speed, so that the relay plunger will allow the primary valve to open. It should fall out of place as soon as the turbine attains normal speed and the governor weights regulate the position of the valve mechanism.

Fig. 9 shows a sectional view of another type of governor.

The governor spindle F is driven directly from the worm S on the end of the turbine shaft, meshing with the worm wheel V. This spindle carries the governor arm on which the weights, two cast iron blocks of rectangular cross section, are supported by means of levers and parallel guide

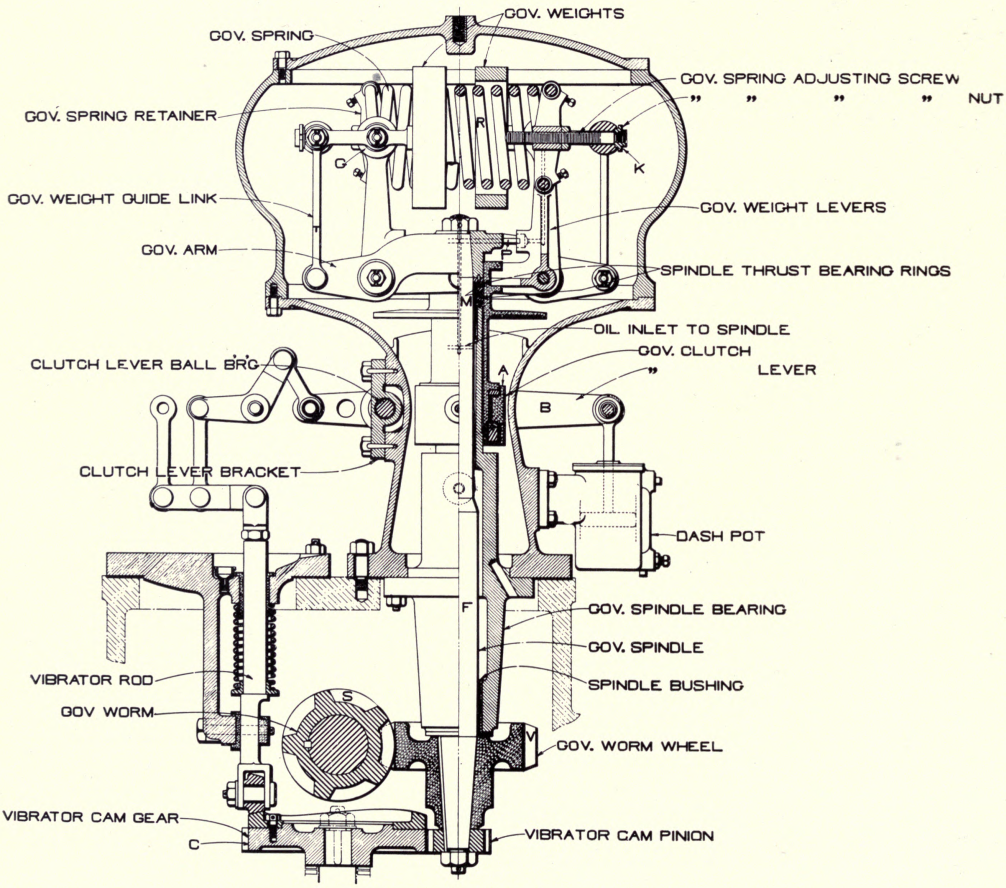

GOV. WEIGHTS
GOV. SPRING
GOV. SPRING ADJUSTING SCREW
" " " " NUT
GOV. SPRING RETAINER
R
G
K
GOV. WEIGHT GUIDE LINK
GOV. WEIGHT LEVERS
GOV. ARM
P
SPINDLE THRUST BEARING RINGS
M
OIL INLET TO SPINDLE
GOV. CLUTCH
" LEVER
CLUTCH LEVER BALL BRG
A
B
CLUTCH LEVER BRACKET
DASH POT
F
GOV. SPINDLE BEARING
GOV. SPINDLE
VIBRATOR ROD
SPINDLE BUSHING
S
GOV WORM
V
GOV. WORM WHEEL
VIBRATOR CAM GEAR
C
VIBRATOR CAM PINION

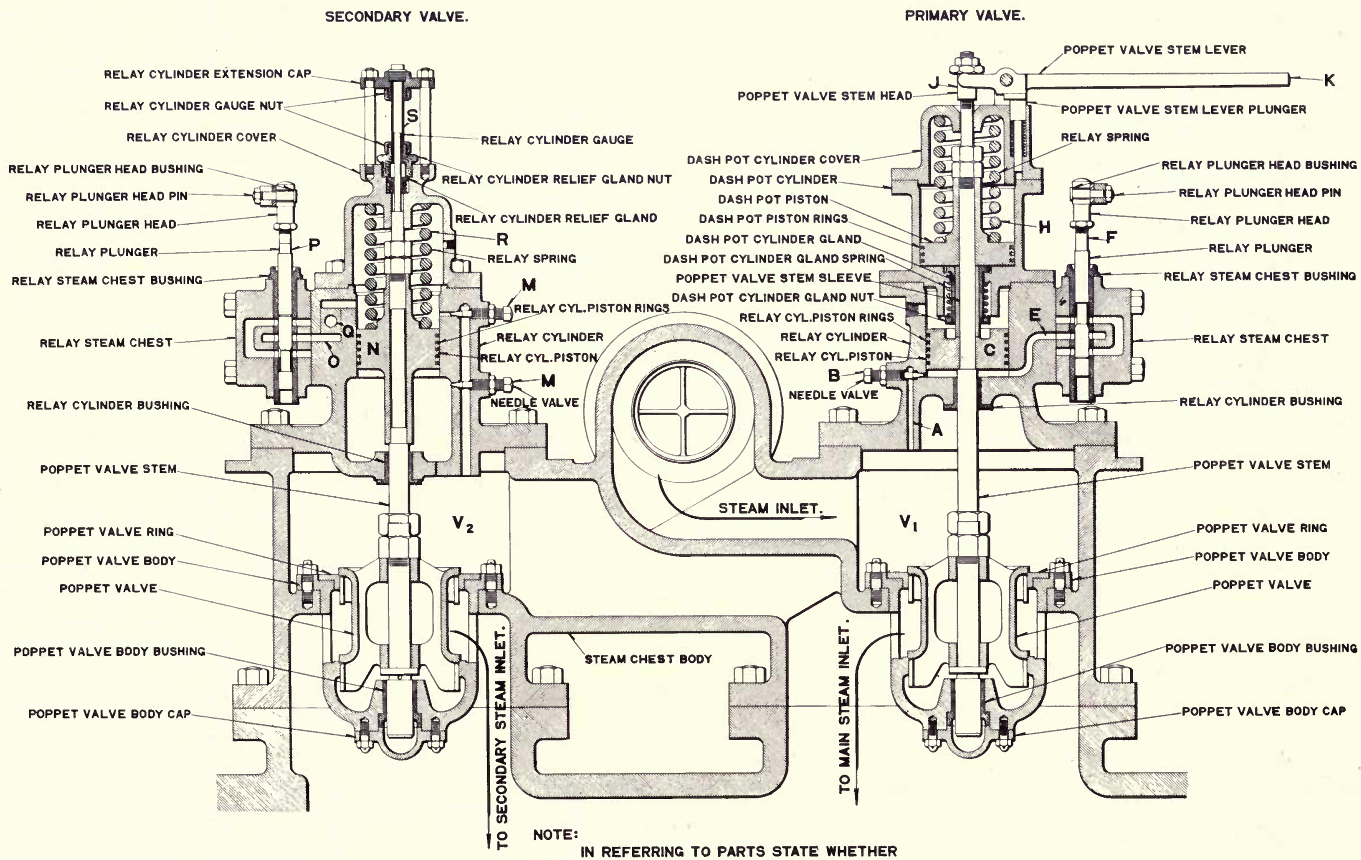
Fig. 9

links T. When the turbine is at rest the weights are in their innermost position and the clutch A at its lowest position, and therefore the relay plunger is raised to such a position as to admit steam to the turbine, as explained in the discussion of the valve setting. As the turbine is brought up to speed the centrifugal force of the weights is resisted by the spring R directly opposing this force through the axis, and thus no stresses are transmitted through the governor levers.

The lower end of the governor spindle carries a pinion, meshing into a larger gear C, which operates the oil pump below. The upper surface of this gear carries a cam, operating the vibrator rod, which is maintained against the face of the cam by means of the spring shown in the illustration.

The tension of the governor spring may be adjusted by means of the adjusting screw K, which acts on the spring shackles, the latter being constructed so that a number of coils of the spring may be thrown in, or out of action as desired. Thus, the speed at which the governor will regulate may be adjusted by the adjusting screws, and if it is desired to increase the speed variation between different loads, the spring may be shackled up, cutting coils out of action, or vice versa, to make the speed variation less with changes of load more coils may be thrown into action. Such adjustments, however, are always made at the time the turbines are tested, and no further adjustment should be necessary.

This governor differs from the one previously described in that the spring cannot be adjusted while the turbine is in operation, and hence, an auxiliary spring is required. The combined adjustment of the springs should permit the speed of the turbine to be lowered, say 5%, by means of the auxiliary spring, or enough so that the turbine may always be synchronized when being started up. Therefore, the main governor spring should have an adjustment such that with the machine shut down and the weights in their innermost position, the auxiliary spring having substantially no tension, the turbine will run with no load, and be under control of the governor at 5% below speed. Then, by means of the auxiliary



NOTE:
IN REFERRING TO PARTS STATE WHETHER FOR PRIMARY OR SECONDARY VALVE.

Fig. 10

spring, the speed may be brought up to normal, when the turbine should have a speed variation between no load and normal load, in accordance with the requirements of the particular service to which it is applied.

With this, as much as with any governor, it is always essential that the main valve shall come to its closed position before the governor weights are in their outermost position.

It is to be noted that oil from the main oiling system is admitted between the two spindle bushings, from which point suitable passages lead it to every part of the governor requiring lubrication. The weight of the governor is carried on the thrust bearing rings M. These rings receive a liberal supply of oil from the spindle bushing, the surplus passing on to the surface of the clutch A. Oil also passes to the interior of the spindle and out through the tubes P, lubricating the joints of the governor weight levers.

One feature of this governor is that the clutch sleeve revolves, being driven by the governor weight levers. It revolves, however, on a stationary portion, thus rendering it frictionless, in so far as any vertical sliding motion is concerned.

Valve Gear:

Figure 10 shows a section through the valve chamber of a Westinghouse-Parsons steam turbine fitted with its valves and relay plungers for governing the admission of steam.

By means of a rockshaft and system of levers connected to the governor clutch lever, an oscillatory motion is communicated to the relay plungers F and P, which operate the primary and secondary admission valves V_1 and V_2, Figure 2. The primary valve regulates between no load and slightly over full load, and then the secondary valve automatically comes into operation enabling the turbine to carry high overload with normal operating conditions, or full load without a vacuum.

The action of these relay plungers is shown in detail in Figure 10. If the throttle valve be opened with the relay plunger F in the position shown, steam will pass up through the small port A to the space beneath the piston C,—the amount of steam being regulated by the needle valve B. As the exhaust through the port E is closed by the relay plunger and the upper side of the piston C is subjected to atmospheric pressure only, the steam pressure beneath raises the piston compressing the spring H, thus lifting the valve from its seat, and admitting steam to the turbine at V. While the plunger is oscillating in this position, the oscillations are not great enough to uncover the port E. However, the outward motion of the governor weights will cause the plunger to move to a lower mean position such that the oscillations will uncover the port E and exhaust more or less of the steam from below the piston, and the valve will be closed correspondingly by the spring H. Violent closing of the valve is prevented by the dash pot piston.

While the plunger is oscillating with a constant amplitude the opening of the port E varies in accordance with the position of the governor. At light loads, no more pressure accumulates beneath the piston than is sufficient to just raise the valve V_1 off its seat at each oscillation. As the load increases the valve will have an increasing lift, admitting steam to the turbine in puffs,—until at maximum load these puffs merge into a continuous blast, and the valve is practically stationary in its wide open position.

There are several advantages arising from the use of this puff system of steam admission,—

1st. Inasmuch as the valve is continually moving it never can become stuck in one position,—any tendency to sticking will be apparent at once and may be rectified.

2nd. In effect this valve wiredraws the steam, and if it were in a fixed position the seats would cut out rapidly during times of light load. This wire drawing effect is practically eliminated because at reasonably fractional loads the valve virtually opens wide at its up stroke, when there is no wire drawing, and reaches its seat and is closed on the down position. It might be approximately said that at light loads the valve is closed the greater part of the time of an oscillation and open but a small part. At heavier loads it is open the greater part of the time and closed but a small portion. Hence the wiredrawing is much less than if the valve were in a fixed position.

3rd. Inasmuch as the valve admits puffs of high pressure steam, the walls of the cylinder assume temperatures corresponding to the higher pressures,—so an increase of load practically merely increasing the duration of the puffs will affect the temperature condition of the turbine cylinder less than if the increase of load required an increase of steam pressure as in the case of a wiredrawing method of steam admission.

It will be seen that the secondary valve is slightly different in its action. As this valve is in operation only when there is an overload on the turbine, it may not be brought into action for comparatively long periods. In order that the relay mechanism may not consume steam during such periods, it is so constructed that the relay plunger does not begin to exhaust steam until such time as the operation of the secondary valve is required. Steam is admitted to both sides of the piston N through the needle valves M M, and when on account of increased load the mean position of the relay plunger P is raised sufficiently by the governor, the port O is opened, exhausting the steam from the upper side of the piston, and the valve lifts by reason of the greater pressure beneath the piston N. The port O may be permanently closed by the hand valve Q, on the side of the secondary relay steam chest, thus cutting the secondary valve entirely out of action. The spring R acts in a similar way to H in the main valve. The end of the secondary valve stem shows in the gauge glass S, so that it can be readily seen whether or not the valve is operating properly, or that it remains shut all of the time when its operation is not required.

There are two needle valves for the purpose of regulating the action of the primary poppet valve. The one on the dash pot is merely for the purpose of checking the drop of the valve and needs no comment. The lower one, B, on the relay steam cylinder controls the inlet of the steam to the bottom of the piston. If this valve is not opened to pass sufficient steam, the result will be that the main valve will not be raised to its extreme lift and the machine will be unable to carry maximum load. If too wide open, the valve will operate with unnecessary violence, and if opened to admit an inordinate amount of steam, the valve will fail to close effectively when it is called upon to do so, because the volume of the steam will be so great that it cannot be completely exhausted by the relay plunger F.

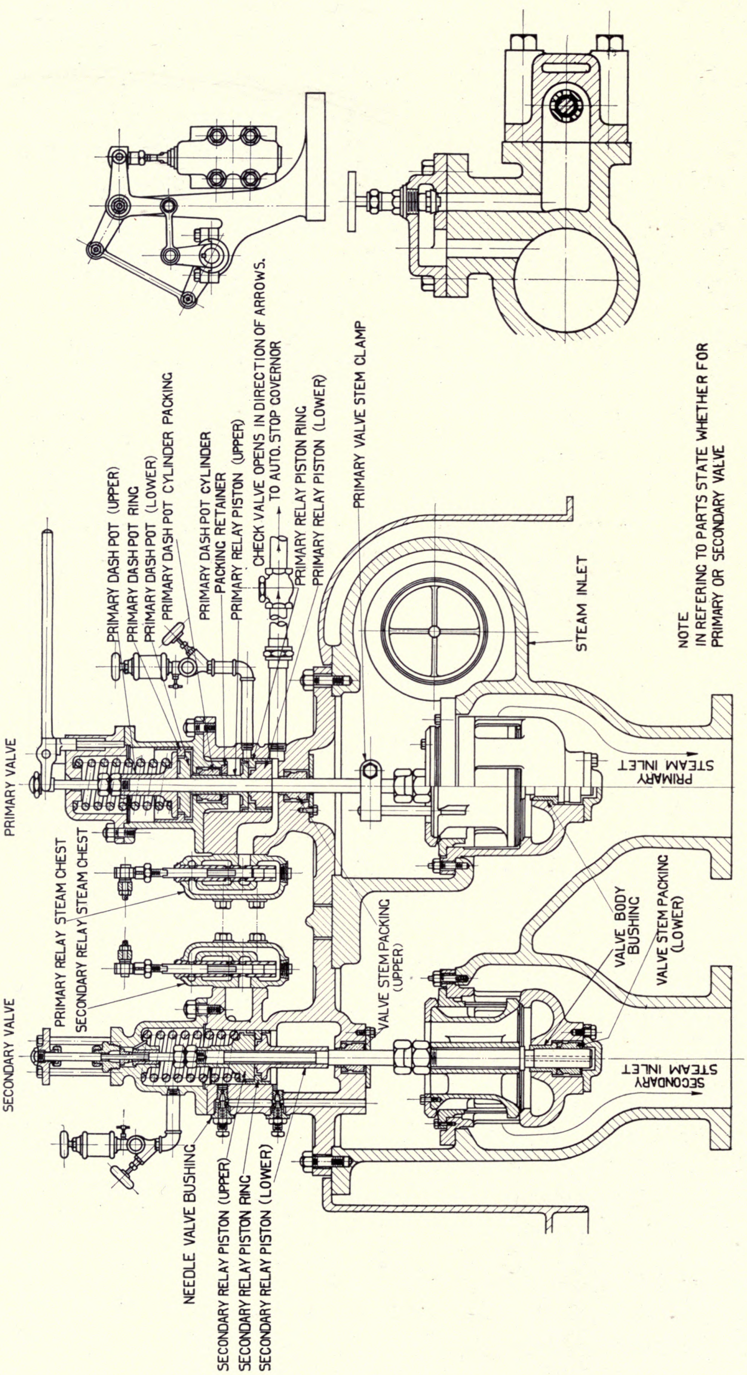
The functions of the needle valves M, M, on the secondary valve are somewhat different. The lower needle valve admits steam below and the upper one above the operating piston. The effect of the relay plunger is to release the pressure above the piston when the valve is required to open. The lower needle valve should be opened no wider than is just necessary to allow the secondary valve to open freely when the relay plunger releases the pressure above the piston. The upper needle valve should be open sufficiently to prevent the valve from being lifted from its seat at full load or less, by the puffs of steam within the turbine. At the same time this needle valve must not be opened too much, or steam will not be released freely enough by the relay plunger to permit the poppet valve to open when it is called upon to do so. The upper valve should not, however, be opened very much wider than the lower valve, as when the pressure drops with each impulse of steam admitted by the primary valve, the pressure on top of the piston will decrease faster than below, on account of the freer communication with the interior of the turbine, causing the valve to lift slightly. The bobbing of the valves on light loads may, therefore, usually be remedied by changing the relative opening of the two valves; and as a rule the upper valve should never be open more than a half turn to a turn more than the lower valve. In all the recent turbines the upper needle valve is supplied with steam at pressure in V_1 by a pipe tapped into the primary valve chamber, thus overcoming a tendency of the valves to operate at light loads. The secondary valve should begin to open when the pressure below the primary valve, that is the inlet pressure of the turbine, is within a few pounds of the throttle pressure.

The proper setting of the valves is not a difficult matter, as there may be quite a wide variation in adjustment without seriously affecting the economy of the machine. There are two things, however, which must be carefully looked out for. First, that when the governor is in its highest position the primary poppet valve will stop oscillating and remain solidly in its seat. Second, that the machine can readily carry the maximum load for which it will be called upon. The following adjustments should therefore be carefully made:

With the governor clutch resting on the starting trigger, or the mid-position of its travel, the turbine should be revolved with just enough steam pressure to keep the turbine at a sufficiently low speed to prevent the governor lifting off the trigger. The primary relay plunger should then be set so that the primary poppet valve tends to stay as far open as the steam pressure can keep it except when the plunger reaches its very lowest position, when the poppet valve should show a tendency to drop slightly. If the plunger were raised one-eighth of a turn in the plunger head, the primary valve would then tend to stay as wide open as possible during the complete oscillation of the plunger. The plunger, however, should be left in the first position so that whenever the turbine is started up it can be readily noticed that the valve setting is correct by the poppet valve having a slight tendency to drop when the plunger reaches its lowest position and the governor has not yet lifted off the trigger.

In the case of a turbine equipped with a governor of the type shown in Figure 9, which is not provided with a trigger, the preliminary setting is made when the turbine is tested, by blocking the governor weights to bring the levers in the position of mid-travel. After the turbine has attained speed, any further adjustment necessary may be made on the relay plungers in the manner described above.

Having made this adjustment of the primary relay plunger, the turbine should then be brought up to its full speed and in order to check up the setting the governor clutch should be deliberately forced into its highest position when the



PRIMARY VALVE
SECONDARY VALVE
PRIMARY RELAY STEAM CHEST
SECONDARY RELAY STEAM CHEST
PRIMARY DASH POT (UPPER)
PRIMARY DASH POT RING
PRIMARY DASH POT (LOWER)
PRIMARY DASH POT CYLINDER PACKING
PRIMARY DASH POT CYLINDER
PACKING RETAINER
PRIMARY RELAY PISTON (UPPER)
CHECK VALVE OPENS IN DIRECTION OF ARROWS.
TO AUTO. STOP GOVERNOR
PRIMARY RELAY PISTON RING
PRIMARY RELAY PISTON (LOWER)
PRIMARY VALVE STEM CLAMP
NEEDLE VALVE BUSHING
SECONDARY RELAY PISTON (UPPER)
SECONDARY RELAY PISTON RING
SECONDARY RELAY PISTON (LOWER)
VALVE STEM PACKING (UPPER)
STEAM INLET
PRIMARY STEAM INLET
SECONDARY STEAM INLET
VALVE BODY BUSHING
VALVE STEM PACKING (LOWER)
NOTE
IN REFERING TO PARTS STATE WHETHER FOR PRIMARY OR SECONDARY VALVE

Fig. 11

primary poppet valve should stop beating and remain tight shut.

The secondary relay plunger is adjusted so that the secondary poppet valve will admit steam to the intermediate cylinder of the turbine when the average pressure below the primary valve has reached nearly the pressure at the throttle. This is of course the point when the turbine is doing all the work possible with the primary valve open, and any further opening of the primary valve alone could not admit any more steam to the machine. The secondary valve should open soon enough so that there will not be too great a drop in speed before it comes into play, the allowable drop, of course, depending entirely on the nature of the service. Care should be taken in this setting to prevent the valve from opening too soon as the economy of the machine will be impaired if this valve comes into operation before the turbine is carrying the maximum load possible with the primary valve alone.

Figure 11 shows a section of another steam chest having the same principle of operation as the arrangement shown in Figure 10, but differing in the following details:

The relay cylinder and dash pot pistons instead of being solid with split packing rings are made up of self-aligning sleeves accurately turned to the bore of the cylinder and provided with small grooves to form a labyrinth packing. By referring to the cut it will be seen that on either side of this sleeve or ring are two centering pieces called the upper and lower dash pot pistons, fitted on the valve stem, so as to allow a small clearance vertically as well as sidewise, thus avoiding the liability of valves sticking or binding should the stem be slightly out of true, due to carelessness in assembling.

Self-aligning packing is also provided for bushing the valve stem both below the relay cylinder and at the bottom of the poppet valve cage. This bushing is made up of two pieces, the lower one fitting the valve stem with no more than working clearance, and held against a ground bevel seat on the upper section by means of two springs. This provides very nicely for a steam tight seal and still permits of a slight misalignment of the valve stem, without resultant binding or sticking of the valves.

The needle valves in place of having the seats bored in the relay cylinder casting are provided with bronze bushings having less tendency to cut from wiredrawing and may be easily renewed if cut by wet steam.

The poppet valve is provided with a removable upper disc and the upper valve seat is also a solid removable ring instead of being made in halves as formerly. To avoid any chance of the primary valve spinning, a block with a pin extending down between the webs of the valve is clamped on the valve stem.

There is a pipe leading from the chamber beneath the relay piston of the primary valve to the automatic stop governor valve. This is an additional overspeed safety device supplementing the automatic throttle valve, as whenever the stop governor operates, the chamber below the relay piston is opened to the atmosphere regardless of the position of the relay plunger, and whether the automatic throttle drops or not. In this manner the pressure is relieved from below the piston and the valve returned to its seat by the spring. It will be noted that there is a check valve in this exhaust pipe which should be kept tight so that line pressure steam may not get back to interfere with the regulation of the valve.

The relay steam chest cylinders are extended and provided with a port connecting the relay plunger bushing on either side of its working ports, so that any slight leakage may be entrapped and drained away rather than bubble over the steam chest.

Oiling System:

Mounted on the end of the bedplate is the oil pump connected to the turbine as previously explained. Around the bedplate are located the oil cooling coil, the oil strainer, the oil reservoir and the oil piping to the bearings, etc.

In some machines of the older types the oil pump draws the oil from the reservoir, sending it through the strainer, and thence through the oil cooling coil located on the side of the bedplate. It will be noted that there is a by-pass between the pipes leading to and from the strainer, and there are valves in these pipes so arranged that the strainer may be cut out of the system and taken apart and cleaned while the turbine is running A spring-loaded check valve in the by-pass automatically cuts out the strainer, in case it should clog up to such an extent as to interfere with the free circulation of the oil. The strainer itself consists of a cast iron case containing screens of varying fineness of mesh, the oil passing through the coarsest first.

In later type machines the strainer is located in one end of the reservoir. The oil returning from the bearings flows through this strainer into the reservoir and is then redistributed, as above. To clean this strainer while the turbine is running, it is only necessary to remove the cover plate above it and lift out the several portions.

From the cooling coil the oil enters the bearing supply pipes, whence it is led by branch pipes to the several bearings. The governor gear case acts as a reservoir to maintain the oil at a static head of from one to two feet. This is the only pressure under which the oil is supplied to the bearings. After the oil passes through the bearings it flows into small reservoirs immediately under them, and thence back to the main reservoir under the bedplate. The oil is thus used constantly over and over again and the only loss is by deterioration with time, and the very small loss due to leakage and spilling. A gauge glass is usually located in the governor gear case to indicate the level of the oil. In certain types of turbines a rotary pump is used in place of a plunger pump and the requisite pressure is maintained on the bearings without any oil reservoir in the governor gear case.

The oiling system is somewhat different in cases where an oil relay governor system is employed for operating the valve gear. In these cases the main oil pump is arranged to pump to a higher pressure and it delivers oil directly to the

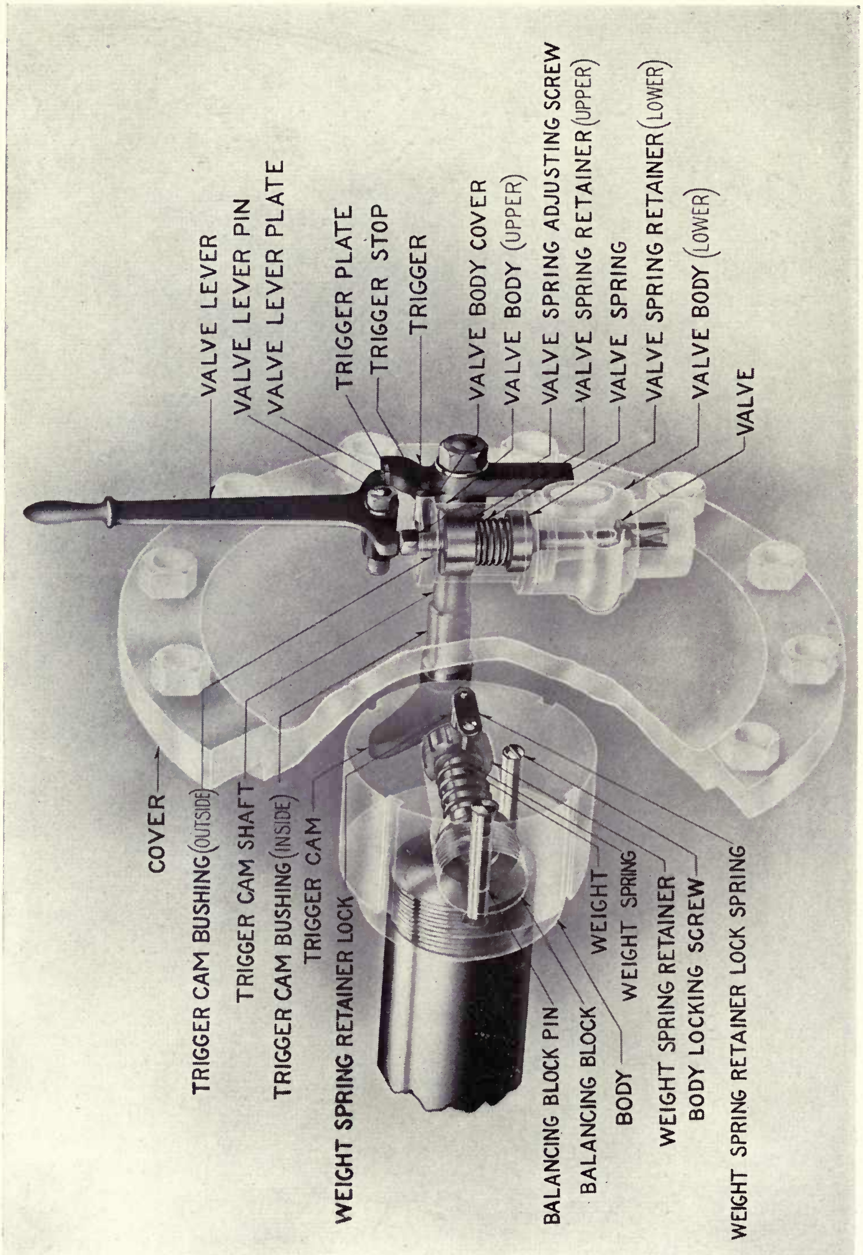

COVER
TRIGGER CAM BUSHING (OUTSIDE)
TRIGGER CAM SHAFT
TRIGGER CAM BUSHING (INSIDE)
TRIGGER CAM
WEIGHT SPRING RETAINER LOCK
VALVE LEVER
VALVE LEVER PIN
VALVE LEVER PLATE
TRIGGER PLATE
TRIGGER STOP
TRIGGER
VALVE BODY COVER
VALVE BODY (UPPER)
VALVE SPRING ADJUSTING SCREW
VALVE SPRING RETAINER (UPPER)
VALVE SPRING
VALVE SPRING RETAINER (LOWER)
VALVE BODY (LOWER)
VALVE
BALANCING BLOCK PIN
BALANCING BLOCK
BODY
WEIGHT
WEIGHT SPRING
WEIGHT SPRING RETAINER
BODY LOCKING SCREW
WEIGHT SPRING RETAINER LOCK SPRING

Fig. 12

valve operating gear whence it passes to the oil cooler. A spring loaded valve is provided which allows the oil not required by the governor to pass direct to the cooler; this valve at the same time maintains the pressure necessary for operating the governor gear.

In the larger machines an auxiliary oil pump is furnished. This pump is only for the purpose of establishing a circulation through the bearings with the turbine at rest, and should be cut out of service as soon as the turbine has reached speed and the main oil pump is maintaining the necessary oil pressure. After steam is shut off the turbine and the speed decreases, the auxiliary pump should be started to keep up the oil supply to the bearings until the turbine comes to rest.

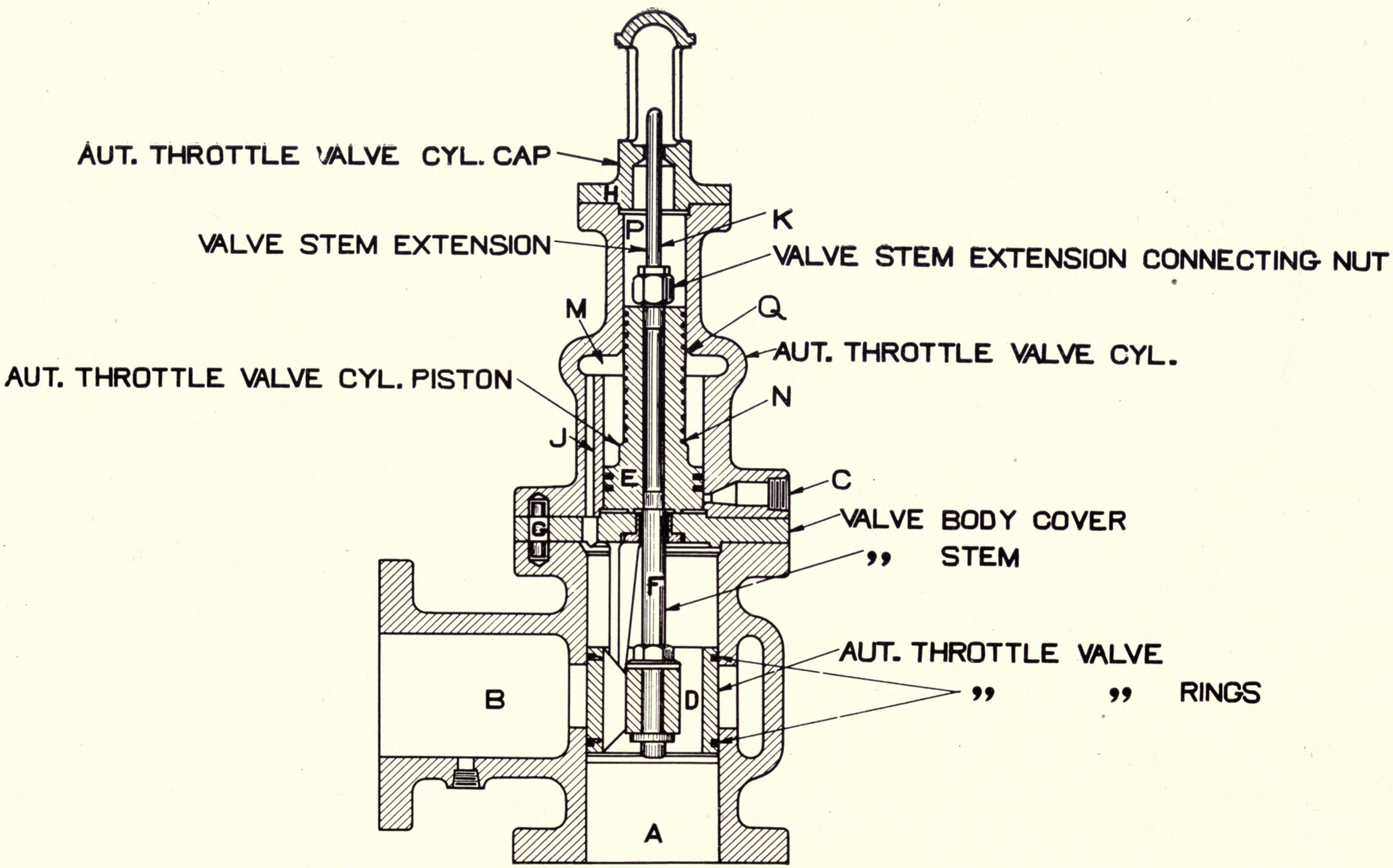
This pump should be located lower than the turbine so that the oil can run to it by gravity. Its throttle valve should be within easy reach of the operator starting or stopping the turbine.

The oiling systems in different types of machines vary in their detailed arrangements, but the general principles are as set forth above.

Automatic Safety Stop:

All turbines now built are equipped with automatic safety stop valves to shut down the turbine in case the normal speed is exceeded by a predetermined amount. This automatic stop valve is operated by a small valve actuated by an automatic stop governor. The general type of governor and governor valve is shown in Figure 12.

When the speed of the turbine for any reason rises above normal and reaches a predetermined limit, the governor weight is thrown out by centrifugal force. This limit is of course fixed or adjusted by the compression put on the governor spring. The weight on flying out comes in contact with a trigger cam, causing the trigger to disengage from the governor valve lever, relieving the compression on the governor valve spring, and allowing the governor valve to open freely. This exhausts the steam from the lower side of a differential


AUT. THROTTLE VALVE CYL. CAP
VALVE STEM EXTENSION
AUT. THROTTLE VALVE CYL. PISTON
K
VALVE STEM EXTENSION CONNECTING NUT
Q
AUT. THROTTLE VALVE CYL.
N
M
J
C
VALVE BODY COVER
" STEM
AUT. THROTTLE VALVE
" " RINGS
H
P
E
G
F
D
B
A
Fig. 13

piston on the automatic throttle stem, causing the throttle to close, and shut off the steam from the turbine.

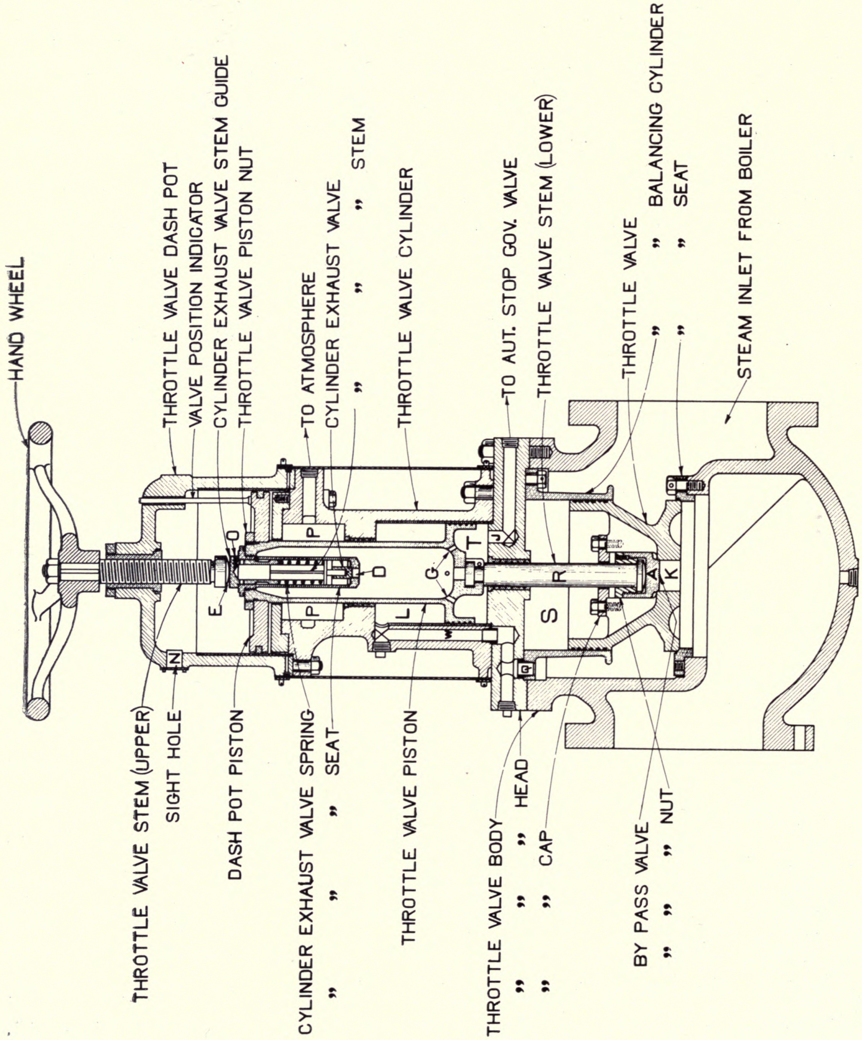
It should also be noted that the governor trigger may be disengaged by hand, and the turbine shut down when desired, by means of the automatic stop valve.

It is expected that the main turbine governor and inlet valve will be kept in such condition that the governor will control the speed at no load under all conditions of steam pressure and vacuum. Nevertheless, the automatic stop governor and throttle valve should be tested at frequent intervals to insure their always being operative. Where a reliable tachometer or frequency meter is used, it is well to shut down occasionally by raising the turbine speed 8% or 10% above normal, when the automatic stop governor should come into operation.

Automatic Throttle Valve:

Figure 13 shows a section of an automatic throttle valve, which is placed in the steam line, on the boiler side of the main throttle valve, and which is controlled by the automatic stop governor, just referred to.

Steam is shut off by the piston D, which is shown in the figure as being in the closed position. Steam from the main line passes up through the valve D, and freely enters the chamber M, above the operating piston, by means of the passage J. It also leaks in limited quantities past the piston and through the bushing around the stem F, and if prevented from escaping, accumulates a pressure under the piston E. The stem K passes up through the automatic throttle valve cylinder cap, and serves as an indicator to show the position of the valve. There is no packing at this point, so that the pressure at P always corresponds to that of the atmosphere. The opening C is connected to the automatic stop governor valve, which, when closed, causes the steam pressure to build up under the piston E, and the piston rises and opens the valve. Should the valve connected with C be released, steam will be exhausted from below the piston, and the pressure in the chamber M will force the valve to the closed position.



HAND WHEEL
THROTTLE VALVE DASH POT
VALVE POSITION INDICATOR
CYLINDER EXHAUST VALVE STEM GUIDE
THROTTLE VALVE PISTON NUT
TO ATMOSPHERE
CYLINDER EXHAUST VALVE
" " " STEM
THROTTLE VALVE CYLINDER
TO AUT. STOP GOV. VALVE
THROTTLE VALVE STEM (LOWER)
THROTTLE VALVE
" " BALANCING CYLINDER
" " SEAT
STEAM INLET FROM BOILER
THROTTLE VALVE STEM (UPPER)
SIGHT HOLE
DASH POT PISTON
CYLINDER EXHAUST VALVE SPRING
" " " SEAT
THROTTLE VALVE PISTON
THROTTLE VALVE BODY
" " HEAD
" " CAP
BY PASS VALVE
" " " NUT
E
O
P
D
G
T
J
L
W
R
S
A
K
N

Fig. 14

There are some packing rings on the small diameter of the operating piston. These are only useful when the valve is operating, or is in the closed position. When the valve is open, which is its normal position, these packing rings are of no value, as the steam-tightness of the parts is maintained by the ground seat on the piston N fitting against the ground seat Q. To ensure against leakage of steam, it is well to see that the piston has a steam tight ground fit against the shoulder of the valve stem.

The main valve D is provided with two packing rings, and in assembling, care should be taken that these packing rings are not caught in the ports of the valves. There is a projection on the valve cover to prevent the piston from revolving and getting the joints of the packing rings in an improper position. At G there is a dowel, the function of which is to prevent the valve from being assembled in such a manner that the steam may be cut off from the port J.

Sometimes, instead of the automatic throttle valve just described, a combination automatic and hand throttle, of the type shown in Figure 14, is employed. Steam is admitted at the upper side of the valve disc, filling the space above the valve. By reason of leakage past the balance-piston, immediately above the valve disc, the full pressure is established at S, in the balance cylinder, which so long as it is maintained, tends to hold the valve disc on its seat. On the pilot valve A being opened, the pressure in S is relieved, and the valve disc then becomes approximately balanced. The high pressure steam entering the valve, freely passes into the space L above the operating piston, through the ports Q and W. It also passes in limited quantities to the space T below the piston, both by leakage past the piston, and leakage around the stem R, so should there be no outlet for the steam at J, full pressure will be established at T, causing the valve to open as the hand wheel is raised, inasmuch as the upper portion of the operating piston, where it enters the dashpot, is exposed to atmospheric pressure only. On the other hand, should the pressure be relieved from T, the valve will be closed in a manner similar to the automatic throttle valve previously

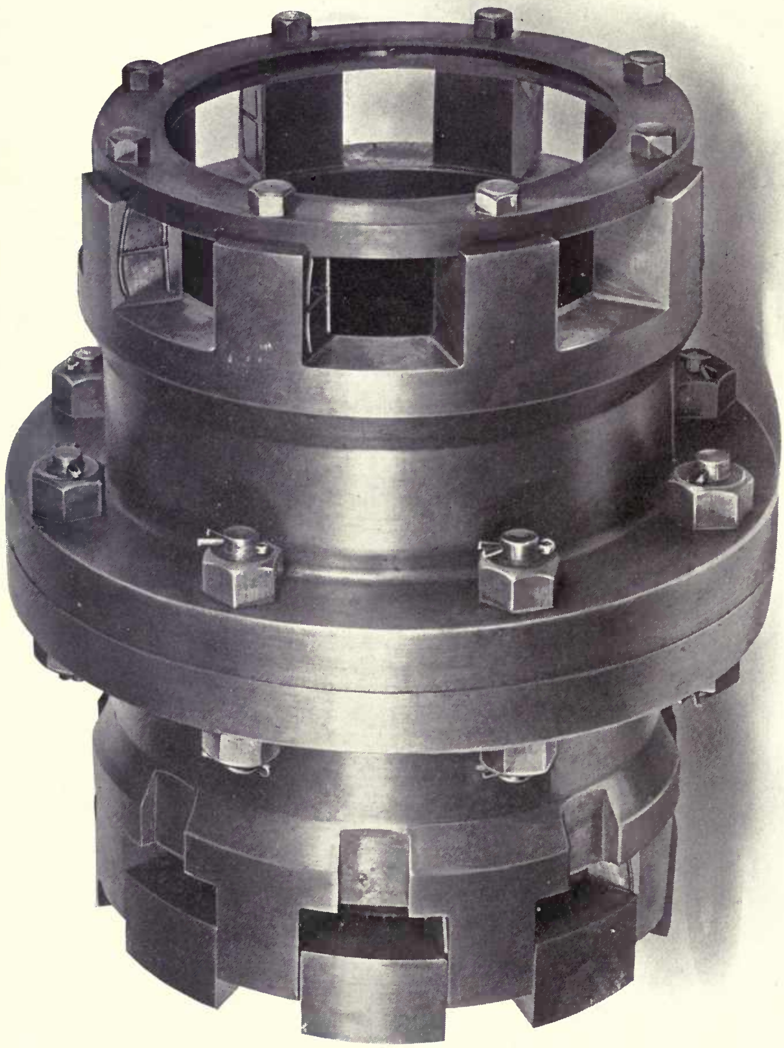


Fig. 15.—COUPLING

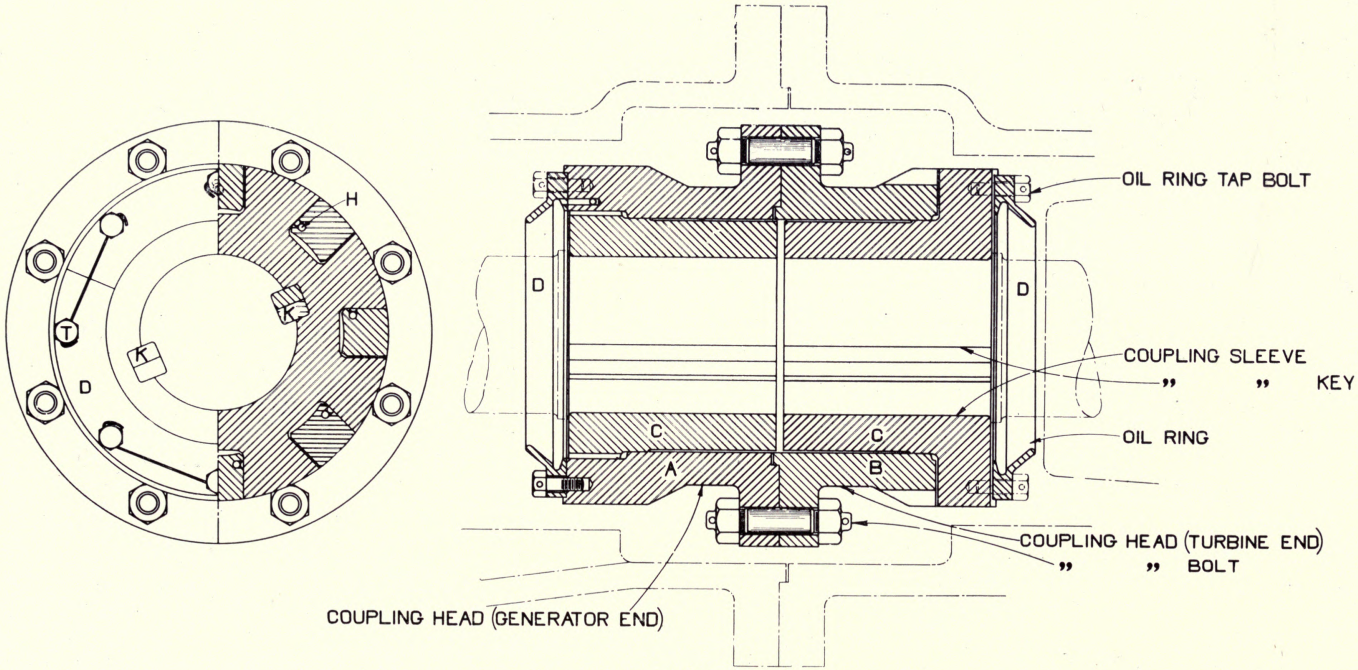
described, the port J, as in the other case, being connected to the automatic stop governor.

On the upper portion of the valve are the dashpot and piston, for preventing the valve from slamming violently on its seat. There is also a valve position indicator, to show the position of the valve with reference to its seat.

At P is a metallic packing with a connection to the atmosphere, to carry away any leakage.

Provision is made for locking the valve disc when it is in its wide open position, so that it may not vibrate or rattle in the steam current. There is also a device to prevent the sudden opening of the valve after it has automatically closed, should the operator reset the automatic stop governor, without first closing down the throttle valve hand wheel. It is thus possible to readmit steam to the turbine with proper judgment, instead of instantaneously turning on the full head of steam. It is, of course, presupposed that there is some derangement of the governing gear, which has caused the turbine to speed up, and trip the safety stop mechanism, so that in starting the turbine again care must be taken to see that the governor is in proper control. Hence the desirability of speeding up the turbine somewhat slowly and not exposing it instantaneously to the full head of steam.

This is accomplished by holes through the operating piston at G, and a spring loaded valve called the cylinder exhaust valve, located in the upper portion of the operating piston. The lower side of this valve is exposed to the full pressure, which, however, is insufficient to compress the spring. On the valve being opened, the valve disc fetches up against the body head. The upper stem, however, has a little further to travel before the head on the lower end of it is stopped against the bushing on the upper pcrtion of the dashpot. This permits the cylinder exhaust valve spring to expand a trifle, but still not sufficient for the steam pressure to force open the valve D; this feature of the valve disc, being held by the operating piston tightly against the valve body head, is what prevents the valve from rattling in the current of steam.


OIL RING TAP BOLT
COUPLING SLEEVE
" " KEY
OIL RING
COUPLING HEAD (TURBINE END)
" " BOLT
COUPLING HEAD (GENERATOR END)
A
B
C
C
D
D
D
H
K
K
T
Fig. 16

Should the valve close automatically, the operating piston with the cylinder exhaust valve, will descend leaving the upper throttle valve stem, when the spring will be entirely released, and the valve D will be free to open. Then, should the automatic stop governor valve be closed at this time, thus preventing egress of steam at J, it will be impossible for the steam pressure to build up at T, because the steam will be free to escape through the holes G, the valve D, and the sight hole N. Hence the valve will be unable to open until the hand wheel has been screwed down, forcing the cylinder exhaust valve D to the seat.

In opening the valve, the upper valve stem on being raised, permits the operating piston to first open the pilot valve A, relieving the steam in S, thus practically balancing the throttle valve itself, after which the operating piston is capable of opening the main valve in the manner before described.

Coupling:

The coupling between the turbine rotor and the generator field shaft is either of the sleeve type or of the claw type.

The former is used on turbines of small capacity and high speed. In this case the coupling ends of the turbine and generator shafts are machined square, and the coupling is a steel cylinder slotted out to fit with sufficient clearance to allow it to slide freely on the squares. This coupling should be free to slide easily on the shafts, both when turbine is cold and when it is heated to operating conditions.

The claw coupling employed on the larger machines is shown in Figs. 15 and 16. The sleeves are pressed on the ends of the shafts, and secured by the keys K K. They are then turned true, a narrow shoulder being left near the fingers on which the coupling head fits freely with a slight clearance. The smaller diameter at the ends of sleeves C C allows some flexibility.

Oil grooves H are cut in the driving faces of the fingers on the coupling head and are supplied with oil thrown off the shaft and caught in the retaining ring D. This is a split oil ring held on the head by bolts T and has oil holes which register with the grooves on the coupling fingers. On assembling, care should be taken that the rings are placed so that the oil holes correspond to the grooves in the fingers, and that they are free from foreign matter that might restrict the oil passages.

The retainer rings also serve to restrict the end motion of the revolving field and prevent the shoulders on the shaft from coming in contact with the ends of the bearings.

IV.

Operating Suggestions.

Before putting the turbine into operation for the first time, it should be completely dismantled and the spindle removed so that an inspection may be made of all of the parts, to insure that they have suffered no injury in transit. The bearings, valve gear and governor parts should be carefully inspected and cleaned. The oil tanks and pedestal reservoirs should be thoroughly cleaned, and particular care should be taken that the gland overflow drain is clear, as should this become clogged, any water that might leak through the glands would pass into the oiling system. The pilot valves should be removed and the bushings cleaned.

After the turbine has been reassembled, the oiling system should be filled either by pouring the oil into the governor gear case G, Fig. 2—if this type of governor is used—or by means of the pipe and funnel provided in connection with the oil reservoir. Enough oil should be provided so that when the turbine is running at full speed, the suction to the pump is covered, and no air is drawn into the system. Although there is a strainer in the oiling system, it is well, as a matter of precaution, to strain the oil either before putting it into the turbine, or to pour it into the reservoir through a fine mesh screen or cloth.

Before connecting the steam line to the turbine inlet, the whole line clear back to the boilers should be blown out with live steam to remove all scale from the pipe, as well as any other foreign matter that might have been left in the piping during erection. There is a steam strainer in the inlet at S, Fig. 2, but fine sand and particles of gasket might pass through and choke up the first row of blades, restricting the steam passage to some extent.

Care and judgment must be exercised in the warming up of the turbine before starting, as it is quite possible to over do it, particularly where steam is superheated. If it were possible to warm the turbine evenly all over, it could not become overheated before starting, but so long as the turbine is standing still, this is impossible. With small quantities of steam passing through the turbine, the hottest steam will remain above, falling to the lower portion as it is cooled, with the natural result that neither the spindle nor the cylinder will be straight, the former running out of true as soon as it is revolved. It is, therefore, the better practice to warm the turbine only moderately and get it revolving as quickly as possible, and really do the latter part of the warming up after the machine is in motion. The higher the superheat the more important it is that the machine be not allowed to stand for a long time with steam blowing through it.

The turbine should be started up non-condensing and not subjected to vacuum until it has attained sufficient speed to allow the water glands to effectively seal. The reason for this precaution is that if a vacuum were established in the condenser or even the air pump operated with the turbine at rest, or before the glands were packed, a certain amount of air would be drawn into the casing at both ends of the spindle, which would result in some distortion of the spindle, causing it to run out of true until such time as it had become evenly heated throughout its length. When there is no gate valve between the turbine and condenser, some means of forced injection must be provided so that the turbine can be started non-condensing and the vacuum established afterwards.

This general rule, of course, does not apply to low pressure turbines, which are treated of in a special pamphlet.

After the turbine is up to speed and under control of the governor, it is well to make sure that the speed is correct, either by counting the strokes of the governor vibrator, or by noting the tachometer, if there is one, as it is possible that the adjustment of the governor may have been interfered with while the machine was standing idle. It is also well at this time, while there is no load on the turbine, to be sure that the governor controls the machine with a high vacuum and the throttle wide open. It might be that the main poppet valve was leaking or that it had sustained some injury not evident when the inspection was made. The action of the valve and the control of the governor should be noted each time the turbine is started or shut down, and should there be any such defect, steps should be taken to regrind the valve to its seat at the first opportunity, as a small leak will rapidly become serious through wiredrawing the steam.

Where conditions will permit, it is better to build up the load gradually so that there may be no sudden heavy demand upon the boilers with the possibility of water being drawn over into the turbine. While there is no danger of the serious results that are almost certain to occur in a reciprocating engine, a slug of water is by no means desirable, as it will cause the turbine speed to decrease considerably and impose undue strains on the machine. Care should be taken both in the arrangement of the piping and in the method of operation to avoid any sudden rush of water to the turbine, especially in case superheated steam is used.

It should hardly be necessary to state that while the turbine is running it should be given the same careful and systematic attention demanded by any high class engine. That is, at regular intervals the engineer should inspect and note the temperature of bearings and oiling system, the water pressure on the glands, pressure of steam and action of governor and valves. Should any irregularity be detected, such as loss of gland water or insufficient oil supply, he should immediately locate the cause and correct it.

No alarm should be felt if the turbine bearings are very warm, as there is no danger as long as the hand can be borne on them even momentarily. However, should a bearing show signs of distress, as evidenced by smoke or burning oil, the trouble should be investigated immediately without attempting to nurse it back into condition. These bearings are subject to a continuous circulation of oil, and should give no trouble, and if a bearing starts to burn, there is some definite cause for it, such as a stoppage of oil supply, foreign matter in the oil, or a tight bearing cap, and the cause should be removed without delay. In case superheated steam is used, the thermometer should be read at intervals in order to make sure that the turbine is not being subjected to excessive variations of temperature.

While accidents to blading are of infrequent occurrence and not to be expected under normal operating conditions, should any sound of rubbing or grinding be detected, the turbine should be shut down immediately, and the trouble located and rectified before any serious damage results. The engineer should not be misled by thinking any unusual sound too trivial to warrant investigation. Every irregularity should be looked into at once and in this way serious results may be averted. It is possible that after inspection, the bearing alignment may have been changed inadvertently, and the blade clearance decreased. Should any blades be damaged, and should there be insufficient time to make a proper repair, the turbine may be put back into service if the damaged blades are removed. If any considerable portion of any blade row is damaged, the entire row should be removed. As the blade rows are in pairs—one stationary and one moving—not only must the damaged row be removed, but also the corresponding moving or stationary row that in connection with the damaged row makes a complete pair—unless a complete pair of rows is removed, the end thrust of the rotor will be unbalanced. The turbine will operate at some small sacrifice of economy until such time as it is convenient to make a proper repair.

When a turbine is first put into service the oil strainers should be removed after a few hours' run and cleaned of any foreign matter that may have found its way into the oiling system. After the first few days' run, when the oil circulation has washed out the system, as it were, such frequent cleanings of this strainer should not be necessary, and the amount of dirt found will indicate how often it is advisable to take care of it. The strainer may be removed while the turbine is in operation, as explained in the description of the oiling system.

Frequent and sudden changes from condensing to non-condensing operation with the turbine under load should be avoided. Should it be necessary to cut out the condenser, the vacuum should be reduced as slowly as the existing conditions will allow, so that no stresses may be set up in the turbine casing, by reason of sudden changes of temperature in the exhaust end.

In shutting down the turbine, the vacuum should be broken as soon as the turbine throttle is closed so that as the turbine comes to rest, cold air will not be drawn in through the glands on the heated spindle. Also do not leave the gland water running, as it may leak over into the bearing and pedestal reservoirs.

As is customary with engines of any type, the turbine should be completely dismantled and inspected every year. The word *dismantled* is used in its fullest sense, and means that the rotor, valves, bearings, oil cooling coil, etc., should all be removed. If the valves show any sign of cutting they should be ground to their seats. The cooling coil may show a deposit from the oil on one side or water on the other side, thus interfering with the circulation of the oil and effectiveness of the cooling surface. If the bearings or coils show an excessive oil deposit, the brand of oil should be looked into, as in time the piping may become clogged up, imperiling the safety of bearings by restricting the oil supply.

The governor should be cleaned and inspected and the knife edge pins examined to make sure that no grit has found its way to them, causing wear which would injuriously affect the sensitive action of the governor.

The glands and balance pistons should be examined for any deposit of lime from hard water, as discussed later in the explanation of the several methods of gland piping. Also the blading should be carefully inspected, and in case there is any deposit of mud or scale from the boilers, it should be cleaned out and steps taken to prevent a renewal of this condition.

During an inspection it is always desirable to check up the clearance over the tips of the blades. This is accomplished by removing liners one by one from behind the keys on the under side of the main bearings, (see H, Fig. 6.) This allows the spindle to be lowered in the cylinder, a distance equal to the thickness of the liners removed. Several trials should be made, removing additional liners at each trial, and revolving the spindle by hand until the tips of the blades just begin to rub. As the liners are of known thickness expressed in thousandths of an inch, the clearance can be obtained with great exactness.

In a similar manner the spindle may be raised above its original position, and the top clearance determined; it may then be moved sidewise in either direction and the side clearances measured.

From the measurement of liner thicknesses, the spindle may readily be set in any desired position in the cylinder. It is customary to set it some few thousandths above the central position, the exact amount differing somewhat according to the size and type of the machine. It is always desirable to have the clearances such that the spindle blades will rub on the walls of the cylinder before the cylinder blades rub on the surfaces of the spindle, as in the event of blades striking while the turbine is running the rubbing is less harmful.

V.

Condensers.

While the choice of the condenser is a matter of special engineering and hardly within the province of this pamphlet, the economy of the turbine is so dependent on the condenser performance, that a few remarks on this subject will not be out of place.

So far as the turbine is concerned, one type of condenser is as good as another. The condenser which will give the best performance, regarded from the standpoint of condenser performance only, is the best one to use. The condenser should be such that it will carry the highest vacuum consistent with the temperature and volume of cooling water available, and the choice of type depends largely upon the individual conditions of the plant.

Where a condenser capable of giving the highest vacuum is installed, the need of utilizing this capability to the utmost, can hardly be emphasized too strongly. A high vacuum will, of course, entail special care and attention and constant guarding against air leaks in the exhaust piping, but it will result in the most economical operation of the turbine. It must not be inferred that a high vacuum is essential to successful operation of the turbine, for most satisfactory results are obtained with low vacuum and even without any at all. However, as it is a well known fact that the steam economy of a turbine with high vacuum increases in greater proportion than that of a reciprocating engine, the condenser should be kept at its highest efficiency, in order that full advantage may be taken of this feature.

VI.

Oils.

There are several oils on the market that are suitable for use in the turbine oiling system, but great care must be taken to select a proper one. In the first place, the oil must be pure mineral, unadulterated with either animal or vegetable oils, and must have been washed free from acid. Certain brands of oil require the use of sulphuric acid in their manufacture and are apt to contain varying degrees of free acid in the finished product. A sample from one lot may have almost no acid, while one from another lot may contain a dangerous amount.

Mineral oils that have been adulterated will, when heated up, partially decompose, forming acid. These oils may be very good lubricants when first put into use, but after a while they lose all their good qualities and become harmful to the machine by corroding the journals in which they are used. These oils must be very carefully avoided in the turbine, as the cheapness of their first cost will in no way pay for the damage they may do. A very good and simple way to test for such adulterations is to shake up a quantity of the oil in a test tube with a solution of borax and water. If there is any animal or vegetable adulterant present it will appear as a white, milk-like emulsion, which will not separate out when allowed to stand. The pure mineral oil will appear at the top as a clear liquid, and the excess of the borax solution at the bottom, the emulsion being in between. A number of oils also contain a considerable amount of paraffine which is deposited in the oil cooling coil, preventing the oil from being cooled properly, and in the pipes and bearings, choking the oil passages and preventing the proper circulation of the oil and the cushioning effect in the bearing tubes. This is not entirely a prohibitive drawback, the chief objection being that it necessitates an unduly frequent cleaning of the cooling coil, oil piping and bearings.

Some high class mineral oils of high viscosity are inclined to emulsify with water, the emulsion appearing as a jelly-like substance. It might be added that oils having a high viscosity are not the most suitable for turbine use.

Since the consumption of oil in a turbine is so very small, being practically only that due to leakage or spilling, the price paid for it should be of secondary importance; the prime consideration should be its suitability for the purpose.

In some cases a central gravity system will be employed, instead of the oil system furnished with the turbine, which, of course, will be a special consideration.

For large installations a central gravity oiling system has much to recommend it, but as it performs such an important function in the power plant and its failure would be the cause of so much damage, every detail in connection with it should be most carefully thought out, and designed with a view that under no combination of circumstances would it be possible for the system to become inoperative. One of the great advantages of such a system is that it can be designed to contain very large quantities of oil in the settling tanks, and the oil will thus have quite a long rest between the times of its being used in the turbine, a circumstance which seems to be very helpful in extending the life of the oil. We furthermore believe that where the oil can have a long rest for settling, an inferior grade of oil may be used, providing, however, that it is absolutely free from acid.

We will at all times be glad to co-operate with engineers installing our turbines and consult with them as to the design of oiling systems.

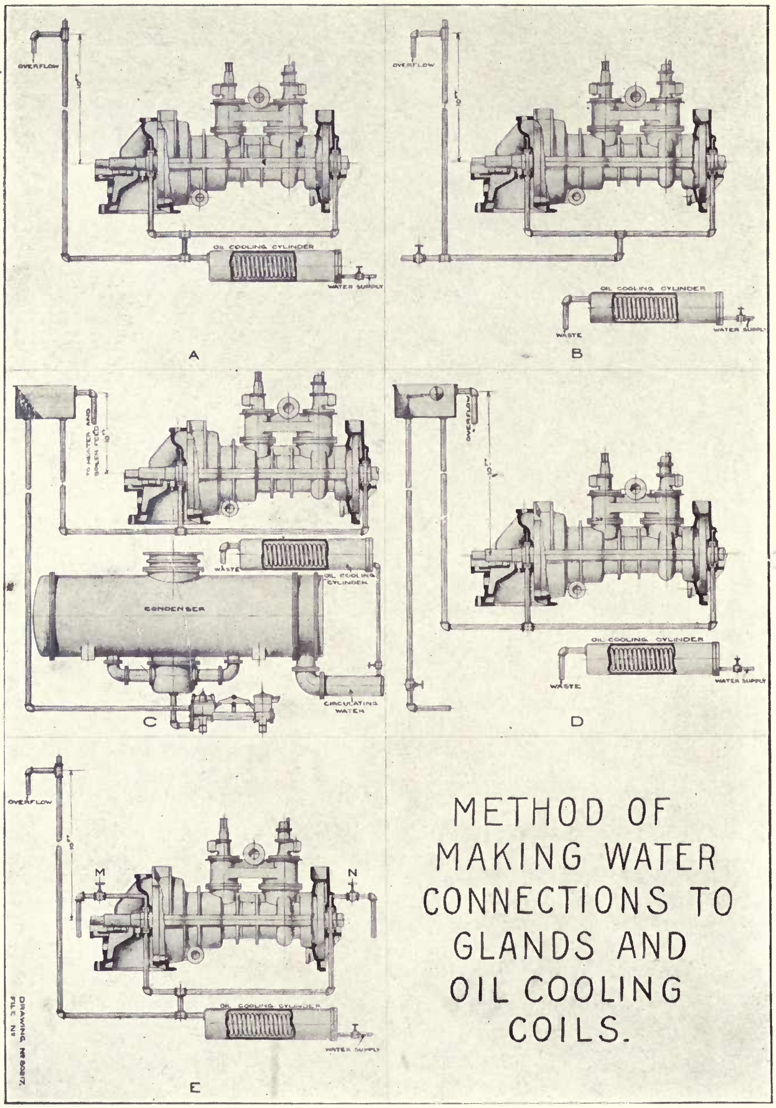

OVERFLOW
OIL COOLING CYLINDER
WATER SUPPLY
A
WASTE
B
CONDENSER
CIRCULATING WATER
C
D
M
N
E
METHOD OF
MAKING WATER
CONNECTIONS TO
GLANDS AND
OIL COOLING
COILS.

Fig. 17

VII.

Methods of Connecting up Glands and Oil Cooling Coils.

There are several satisfactory plans of connecting the water supply to the glands and oil cooler, the choice of any certain one depending upon the particular conditions existing in the power house.

The temperature of the water for the gland supply must be lower than the temperature of the steam, due to the vacuum in the turbine, or it will evaporate rapidly and find its way into the turbine in the form of steam.

In any case, a small amount of the sealing water will pass by the gland collars into the turbine so that, if the condensed steam be returned to the boilers, the water used in the glands must be of such character that it will not be injurious to the boilers. Whether the water so used is returned to the boilers or not, it should never contain an excessive amount of lime or solid matter, as some evaporation is continually going on in the glands which will cause the deposit of scale, and necessitate frequent disassembling for cleaning. If the scale is allowed to form, it will be deposited on the back of the balance piston, throwing the machine out of balance. There is also danger of its filling up the space in which the gland runners work to such an extent as to cause mechanical contact which may produce serious vibrations.

In the following pages are described various plans for supplying water to the glands and oil cooler, and it is believed these cover all of the conditions that are ordinarily met with.

First:

Where there is a cheap supply of good pure water, the same water that is used in cooling the oil may be utilized for the glands. The discharge from the cooling chamber is run to a stand pipe with a height of 10 feet above the axis of the glands and the supply to the glands is taken through a T just outside of the cooling chamber, as shown diagrammatically at A, Figure 17. This is the method generally employed.

The quantity of water required for the oil cooler is always more than sufficient for the glands.

Second:

Where there is a limited supply of proper water for the glands and a large and cheap supply of poorer water which may be readily used in the oil cooling chamber, the cooling chamber and the glands will be piped up separately, each to its own supply, the oil cooling supply discharging through the cooler, direct into the sewer or similar waste. The glands will then be supplied from a pure water supply, this supply pipe having a branch to the glands and being led to a stand pipe, the overflow from which discharges into the hot well, serving, if desired, for "make up feed," as in B, Figure 17. In this case it is possible to take the water for the glands from the feed line at a point between the pump and the feed heater, and discharge it from the gland overflow into the tank to which the suction of the feed pumps is connected.

Third:

When the only available supply of pure water is that for the boiler feed and the condensed steam is pumped directly back to the boiler, as is shown at C, Fig. 17, then the delivery from the condensed water pump may deliver to an elevation 10 feet above the axis of the glands, where a tank should be furnished of sufficient capacity that the water may have time to cool considerably before being delivered to the glands.

In most of these cases, if desired, the oil cooling water may come from the circulating pump for the condenser, providing there is sufficient pressure to produce circulation.

Fourth:

The arrangement B may be somewhat costly if the water fed to the glands has to be brought from the city water mains and cannot, after service in the glands, be made good use of, as opening the supply too wide will allow most of the water to go into the overflow which, in some cases, may exceed the quantity necessary for make-up boiler feed, and is, therefore, liable to be wasted. The arrangement shown diagrammatically at D admits just enough and no more water than is necessary for sealing the glands. This method is probably the one which is the most economical of water. One tank can obviously furnish required water pressure to any number of tanks in the same station. This type of tank is one which can be bought in plumbers' stores, and is such as is used for toilet rooms, etc.

Fifth:

In certain cases the turbine is required to exhaust against a back pressure of one or two pounds, when a slightly different arrangement of piping must be made. The sealing water in this case must be allowed to circulate through the glands in order to keep the temperature that is within, below 212 degrees Fahrenheit. If this is not done the water in the glands will become heated from the main castings of the machine and will evaporate. This evaporation will make the glands appear as though they were leaking badly. In reality it is nothing more than the boiling of water in the glands, but it is, nevertheless, equally objectionable.

E, Fig. 17, illustrates a method of overcoming this objectionable feature where the general arrangement may be the same as any one of the several methods proposed, except that two connections and valves are furnished at M and N, which drain away to any suitable tank or sewer. These valves are open just enough to keep sufficient circulation to keep the temperature of the gland water below the boiling point, boiling being evidenced by steam coming out of the glands as though they were leaking.

In case the turbine is operating against back pressure the water pressure on the glands must be raised above the standard of five pounds by the amount that the back pressure exceeds the pressure of the atmosphere. That is to say, in case a back pressure of five pounds gauge is maintained, a gland pressure of ten pounds or a standpipe about twenty feet above the axis would be required.

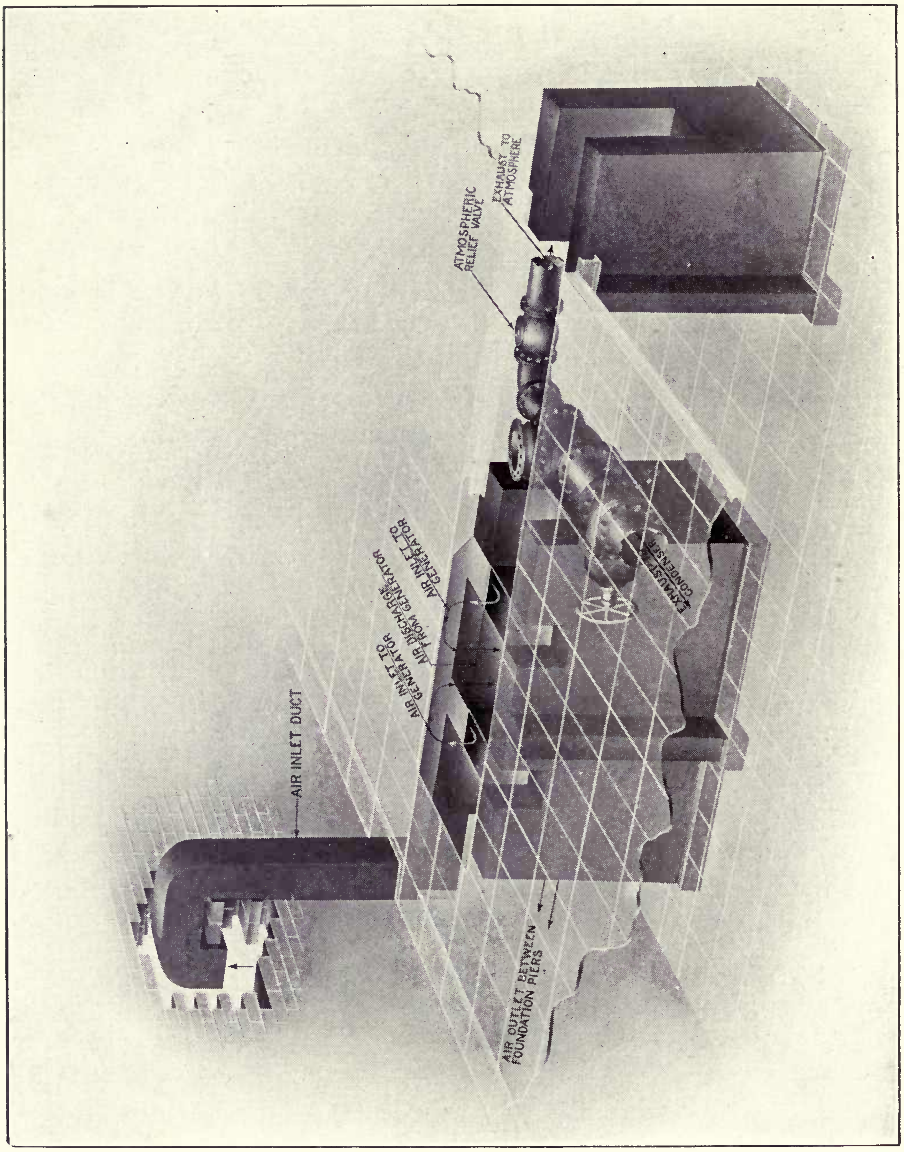

AIR INLET DUCT
AIR INLET TO GENERATOR
AIR DISCHARGE FROM GENERATOR
AIR INLET TO GENERATOR
EXHAUST TO CONDENSER
ATMOSPHERIC RELIEF VALVE
EXHAUST TO ATMOSPHERE
AIR OUTLET BETWEEN FOUNDATION PIERS

Fig. 18

VIII.

Foundations.

The foundations should be built in accordance with the requirements called for in the official foundation plans.

These drawings, however, are not intended to give the actual design of the foundation, as this must be made to suit the particular conditions of the individual power house. Its design is not limited like that for a reciprocating engine, and hence can be made in many ways, to suit the arrangement of condensers and auxiliary apparatus in the basement, as well as any peculiarities of building, etc. As the motion of the turbine is rotary, it is not necessary to provide heavy foundations or any foundation bolts, but at the same time it is necessary to provide a foundation such that any part of it will support its share of the weight of the turbine and generator without sinking, and consequently disturbing the alignment of the machine.

In designing the foundation, provision should be made for the necessary air ducts for ventilating the generator, and one inch of grout should always be allowed for on top of the foundation.

While concrete is to be preferred wherever practicable it is often convenient to install the turbine on a structural steel floor because of the greater amount of space left in the basement for auxiliary apparatus. In order that such a floor may be sufficiently rigid, and to avoid the location of beams in positions where they would interfere with proper access to the turbine, we show on our foundation plan a desirable arrangement of beams. We also specify the size of beams required for various spans in order that the deflection may be kept down to .020, which is considered to be as great a deflection as should be allowed. In using a structural steel floor, it is very convenient to run in one-half to one inch of lead between the turbine bedplate and the steel work, so that the turbine may be properly leveled with the weight evenly distributed on all beams, as there is liable to be some slight misalignment in the steel work. This lead pad also tends to absorb any slight vibration that may exist. With either a structural steel or concrete foundation the final leveling should not be done until the entire weight of the turbine and generator is in place, after which the lead or grout may be poured.

As before stated the concrete foundation is more desirable, as any vibration tends to be intensified if the turbine is mounted on structural steel, and especially is this the case if any members form a harmonic with the turbine vibration. A desirable and convenient form of foundation is shown in Fig. 18.

The Westinghouse Machine Co.

General Offices and Works

East Pittsburg, Pa.

SALES OFFICES

New York	165 Broadway
Atlanta	Candler Building
Boston	131 State Street
Chicago	171 La Salle Street
Cincinnati	1102 Traction Building
Cleveland	New England Building
San Francisco	Hunt, Mirk & Co., 141 Second Street
Denver	512 McPhee Building
Pittsburg	Westinghouse Building
Philadelphia	1003 North American Building
St. Louis	Chemical Building
City of Mexico	G. and O. Braniff & Co.