

**Westinghouse Technology Systems Manual**

**Section 7.3**

**Westinghouse Turbine and Auxiliaries**

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## **7.3 WESTINGHOUSE TURBINE AND AUXILIARIES**

### **Learning Objectives:**

1. State the purposes of the turbine and turbine auxiliaries.
2. Identify the sources of heating steam to the moisture separator reheaters (MSRs).
3. State the purposes of the following turbine valves:
  - a. Throttle (stop) valves,
  - b. Governor (control) valves,
  - c. Reheat stop valves, and
  - d. Intercept valves.

### **7.3.1 Introduction**

The purposes of the turbine and turbine auxiliaries are as follows:

1. To convert the thermal energy of steam to mechanical energy to turn the main generator,
2. To provide turbine shaft sealing,
3. To provide turbine generator lubricating oil and auto-stop oil for the turbine trip system, and
4. To provide dry, superheated steam to the low pressure turbines to reduce moisture erosion and to increase plant efficiency.

### **7.3.2 Main Turbine**

#### **7.3.2.1 System Description**

The main turbine consists of one high pressure turbine and three low pressure turbines coupled to a single shaft. The four turbines that comprise the main turbine are coupled to the generator and exciter; they serve as the prime mover for these components. A cross section of the turbine is shown in Figure 7.3-1. Steam enters the main turbine at the high pressure turbine through the turbine throttle (stop) and governor (control) valves.

The thermal energy of the steam is converted to mechanical energy in the high pressure turbine, and the steam is exhausted to the moisture separator reheaters. In each MSR the steam is dried, reheated, and superheated prior to its entry into the low pressure turbines. The superheated steam is routed through the reheat stop and intercept valves as it travels from the MSRs to the low pressure turbines. Energy conversion occurs again in the low pressure turbines as the steam expands into the vacuum of the main condenser.

## **7.3.2.2 Component Descriptions**

### **High Pressure Turbine**

The high pressure turbine is a double-flow turbine with a rateau (impulse) stage followed by several stages of reaction blading in each end of the turbine. Main steam enters the high pressure turbine through two steam chests (Figure 7.3-2). The steam chest outlets are connected to the high pressure casing through four inlet points; steam from the steam chest flows to each end of the high pressure turbine. Extraction steam exits the turbine via interstage outlets. The high pressure turbine exhaust outlets direct steam to the MSRs.

The high pressure turbine rotor is supported by two bearings, and one end is coupled to the low pressure turbines. An auxiliary shaft coupled to the opposite end of the high pressure turbine is used to drive the impeller of a shaft-driven oil pump.

### **Throttle Valves**

The turbine throttle valves (sometimes referred to as stop valves), located in throttle valve/steam chest assemblies, serve two functions: the control of turbine speed when in the full arc steam admission mode during heatup of the turbine, and rapid closure (tripping shut) to isolate steam flow to the high pressure turbine upon a turbine trip.

During the first steps of the turbine startup, steam is admitted to the turbine through all four governor (control) valves with the speed of the turbine being controlled by the throttle (stop) valves. This mode of operation (full arc admission) allows even heating of turbine components. Speed control is accomplished by small internal poppet valves built into the main discs of the throttle valves. The speed error signal from the electro hydraulic control (EHC) system controls the positions of the internal poppets.

During the final stages of the turbine startup, the throttle valves are wide open. In this mode of operation (partial arc admission), the governor valves control speed and/or load. If a turbine trip signal is present, the high pressure hydraulic fluid will be dumped from the throttle valves. The dumping of the high pressure fluid allows spring force to rapidly close the throttle valves. Since all turbine valves close on a turbine trip, the throttle valves and governor valves provide redundant isolation of steam flow to the high pressure turbine.

### **Governor Valves**

The governor valves (sometimes referred to as control valves) function to regulate the speed of the turbine during partial arc admission (during the last stages of heatup) and to control load when the unit is supplying power to the grid. These valves control turbine speed when a load rejection occurs and isolate steam flow to the high pressure turbine when the turbine trips. The governor valves are located in the steam chest assemblies and are shown in Figure 7.3-2.

During partial arc admission, the speed error signal positions the governor valves by controlling the EHC fluid supply to the valves. When the main generator is on line, the positions of the governor valves are controlled as a function of reference load, impulse pressure feedback, and speed error. The trip function of the governor valves is accomplished through the dumping of high pressure oil from the valve operators, thus allowing spring force to close the valves.

When a load rejection occurs, speed control is achieved through the dumping of high pressure oil from the governor valves, which are then closed by spring force. This action isolates the flow of steam to the high pressure turbine and prevents a turbine overspeed trip (the intercept valves simultaneously isolate steam from the MSR to the low pressure turbines).

### **Low Pressure Turbines**

Each of the three low pressure turbines is a dual-flow, reaction, condensing turbine. Steam from the moisture separator reheaters enters the low pressure turbines after passing through the reheat stop and intercept valves. In the low pressure turbines, steam is expanded through several reaction stages before it is exhausted to the condenser. Interstage extraction points provide steam for feedwater heating. Each low pressure turbine is supported by two journal bearings. Condenser overpressure protection is provided by rupture discs in the low pressure turbine casings.

### **Reheat Stop Valves**

A large quantity of steam is available in the shell side of the moisture separator reheaters. Therefore, the steam supply from the moisture separator reheaters to the low pressure turbines must be isolated on a turbine trip; otherwise, turbine damage from overspeeding will occur. The reheat stop valves isolate the moisture separator reheaters from the low pressure turbines. Each reheat stop valve is a butterfly valve held in the open position by high pressure oil. When the turbine is tripped, the oil is dumped from the valve operators, allowing spring force to close the valves.

### **Intercept Valves**

The purpose of the intercept valves is to isolate the flow of steam from the moisture separator reheaters during a turbine trip or load rejection. The intercept valves are identical in construction to the reheat stop valves and provide redundant isolation on a turbine trip.

The closure of the intercept valves on a load rejection prevents the steam contained in the moisture separator reheaters from overspeeding the main turbine and thereby causing a turbine trip.

## **7.3.3 Gland Steam System**

### **7.3.3.1 System Description**

During plant operation the entry of air into and the exit of steam from the turbine are prevented at those points where the rotor penetrates the turbine casings. These functions are accomplished through the design of the rotor/casing penetrations (glands) and through the operation of the gland steam system.

The gland steam system (Figure 7.3-3) has two sources of steam supply: the auxiliary boiler and the main steam system. In the initial phases of a startup from cold shutdown, gland steam is supplied from the auxiliary boiler. Once the plant is heated up, the gland steam requirements are supplied by the main steam system.

Either of the two supplies provides steam through a seal supply regulator which, in turn, supplies a sealing steam distribution header. The high pressure turbine glands are supplied through a common regulating valve, while each low pressure turbine gland is supplied through an individual regulator. The distribution header also supplies sealing steam to the main feed pump turbines. Each feed pump turbine has its own seal steam regulating valve.

At higher plant powers (greater than approximately 40%), steam from inside the high pressure turbine casing will leak past the inner turbine glands to supply gland sealing steam. The direction of steam flow through the gland seal supply piping is thus reversed from that at low powers. Seal steam to the low pressure turbine glands is always provided by the gland seal steam supply header.

Each turbine gland is a labyrinth-type seal consisting of seal strips mounted in the turbine casing. The seal strips clear the rotor surface with just enough margin to prevent rubbing during operation. Gland seal supply and exhaust piping is connected to each gland.

The gland exhaust portion of the system consists of the gland steam condenser, gland steam condenser exhausters, and associated piping. A slight vacuum is created in the gland steam condenser by the gland steam condenser exhausters. This vacuum is felt at the turbine glands; the differential pressure between the glands and the condenser causes the flow of excess gland steam and air to the gland steam condenser.

Condensate system flow condenses the gland exhaust steam, and the exhausters remove noncondensable gases from the condenser. The condensed steam drains to a collecting tank, and the air is exhausted to the atmosphere. The gland steam condenser also receives turbine valve steam leakage.

### **7.3.3.2 Component Descriptions**

#### **Main Seal Supply Regulator**

This regulator reduces the steam inlet pressure to a value of 140 psig. The valve capacity is such that sufficient gland steam flow can be supplied with an inlet pressure as low as 185 psig. A motor-operated inlet valve is provided for regulator isolation.

A motor-operated bypass valve is installed for use in the event of a regulator failure. Both of the motor-operated valves are controlled from the control room. Control

room pressure indication is supplied from a pressure transmitter located downstream of the main supply regulator. The relief valve located downstream of the main seal supply regulator protects against over pressurization and lifts at 315 psig.

### **Turbine Seal Regulators**

The turbine seal regulators reduce seal steam pressure to 16 psia and supply steam to the turbine glands. Each of the regulator valves is a pneumatically operated, diaphragm-controlled globe valve. The valves modulate to maintain the downstream pressure. Manually operated inlet, outlet, and bypass valves are installed to provide regulator maintenance capability while maintaining the seal steam supply. A locally mounted pressure gage provides indication of the supply pressure for each gland.

### **Spillover Valve**

The spillover valve maintains the correct steam pressure at the high pressure turbine glands when the high pressure turbine exhaust pressure exceeds the gland steam supply pressure. The valve dumps excess steam to the first-stage feedwater heater shells. Motor-operated inlet isolation and bypass valves are installed so that gland pressure can be maintained in the event of regulator failure. These valves are controlled from the control room. Overpressure protection is provided by a relief valve set at 105 psig.

### **Gland Steam Condenser**

The gland steam condenser is a tube-and-shell heat exchanger. Condensate flow through the heat exchanger tubes serves as the heat exchange medium. The condensed gland exhaust steam drains to a collecting tank and eventually returns to the condensate system. Noncondensable gases are removed from the shell side of the heat exchanger by the gland steam condenser exhausters.

### **Gland Steam Condenser Exhausters**

These 480-Vac fans function to remove noncondensable gases from the shell side of the gland steam condenser and help maintain a slight negative pressure (approximately 14.6 psia) in the gland steam condenser. The gland steam condenser exhausters discharge to the turbine building roof.

#### **7.3.3.3 System Operation**

When the turbine is tripped or is very lightly loaded, gland steam is supplied to the high pressure and low pressure turbines via the main seal supply regulator and their individual gland regulators (Figure 7.3-4). A vacuum is present at the exhaust of both the high and low pressure turbines. In these situations, gland sealing steam flows through each labyrinth seal to the gland exhaust connection. This flow of steam creates a positive pressure at the gland, which prevents the entry of air into the turbine casing. At the gland exhaust connection, gland sealing steam combines with any air in-leakage, and this steam/air mixture flows to the gland steam

condenser due to the slight negative pressure maintained at the shell side of the heat exchanger.

As the turbine load increases, the high pressure turbine exhaust pressure becomes positive and overcomes the gland seal steam supply pressure. The flow of steam through the gland seal steam supply piping is reversed. The turbine exhaust pressure causes the spillover valve to open, relieving excess steam to the shell sides of the first-stage feedwater heaters. The combination of the spillover valve and the high pressure turbine seal supply regulator maintains the correct high pressure turbine gland seal pressure. Any steam that finds its way to the gland exhaust connection combines with air in-leakage and flows to the gland steam condenser.

### **7.3.4 Turbine Lubricating Oil System**

#### **7.3.4.1 System Description**

The turbine lubricating oil system, shown in Figure 7.3-5, provides lubricating oil for the turbine, generator, and exciter bearings; lift oil for turning gear operations; backup seal oil for the generator hydrogen seals; and auto-stop oil for the turbine trip system.

#### **Lubricating Oil**

The lubricating oil for the bearings (eight turbine bearings, two generator bearings, and one exciter bearing) is supplied by either of the motor-driven lube oil pumps or by the shaft-driven lube oil pump via the discharge of the ejector. When the turbine speed is below 90% of rated speed, lubricating oil is supplied by the ac lube oil pump, with the dc lube oil pump in standby. With turbine speeds greater than 90% of rated speed, the motor-driven pump(s) may be stopped, and the shaft-driven pump supplies the required lubricating oil. Regardless of the source of lubricating oil, bearing lubrication is supplied from the lube oil reservoir to each bearing via the lube oil coolers. The lube oil coolers cool the oil prior to its injection into the bearings. The bearing oil drains back to the reservoir through a basket strainer.

#### **Turning Gear System**

When the turbine comes to rest after shutdown, operators place the turning gear in service to prevent the turbine rotors from bowing. The turning gear is motor driven and is coupled to the turbine shaft between the generator and the last low pressure turbine. Bearing lift oil, supplied by the bearing lift oil pump, is injected at a high pressure to lift the turbine shaft. The speed of the shaft during turning gear operations is approximately 1.5 rpm.

#### **Backup Seal Oil Supply**

The application of hydrogen as a cooling medium for the main generator requires the use of oil-pressure floating ring seals to prevent hydrogen leakage where the shaft extends through the generator housing. The seal oil backup pump and/or the



shaft-driven pump provides a backup source of hydrogen seal oil to the generator seals. In addition, the seal oil backup pump is one of the two pumps which can supply auto-stop oil.

### **Auto-Stop Oil**

Auto-stop oil provides the interface between the high pressure electro hydraulic fluid and the turbine lubricating oil system. In addition to the interface function, the auto-stop oil system provides turbine trips on low lube oil pressure, low vacuum, thrust bearing wear, and overspeed. Solenoid trips are also provided through the auto-stop oil system. Auto-stop oil may be provided by the shaft-driven pump or the seal oil backup pump.

### **7.3.4.2 Component Descriptions**

#### **Shaft-Driven Lube Oil Pump**

The shaft-driven lube oil pump is a single-stage centrifugal pump driven by an extension shaft that is coupled to the high pressure turbine element. At normal operating speed (1800 rpm), the pump discharges oil at pressures between 320 and 380 psig when supplied with a suction pressure of 10-45 psig. The shaft-driven pump is not self priming.

During a turbine startup the pump is supplied with a suction from the motor-driven oil pumps. While operating at normal speeds, the shaft-driven oil pump suction is supplied by the ejector, which utilizes high pressure oil from the shaft-driven oil pump discharge as an operating medium.

The oil discharged by the shaft-driven pump during normal operation is used for the following purposes:

- Supplies bearing lubrication,
- Operates the ejector,
- Supplies auto-stop oil, and
- Supplies backup seal oil.

#### **Motor-Driven Lube Oil Pumps**

The motor-driven centrifugal oil pumps provide lubricating oil to the bearings and suction to the shaft-driven lube oil pump at turbine speeds less than 90% of rated speed. Either the ac motor-driven pump or the dc motor-driven pump can provide bearing oil at a supply pressure of 14 - 18 psig. The ac motor-driven pump, also called the bearing gear oil pump, is normally used during turbine startup and automatically starts when bearing oil pressure drops to 11 - 12 psig. The dc motor-driven oil pump is designed to provide bearing lubrication for the turbine/generator in the event of a loss of all ac power and automatically starts when bearing oil pressure drops to 10 - 11 psig.

#### **Lube Oil Reservoir**

This 15,000-gal tank serves as a storage and supply tank for the lubricating oil system. The ejector, seal oil backup pump, and motor-driven lube oil pumps are located within the lube oil reservoir. Oil drains from the bearings are returned to the reservoir through a removable strainer.

### **Lube Oil Coolers**

These tube-and-shell heat exchangers cool the bearing lube oil supply. Oil flows on the shell side and raw cooling water flows through the tube side. Oil flow to and from the coolers is controlled by three-way valves.

### **Bearing Lift Oil Pump**

The positive displacement bearing lift oil pump supplies high pressure oil (1200-1500 psig) to the undersides of the bearings to lift the turbine rotor for turning gear operations. The motor is interlocked with turbine speed; it automatically stops and starts with a turbine speed of approximately 600 rpm.

### **Turning Gear**

The turning gear motor drives a pinion that engages a bull gear located on the turbine rotor. A bearing oil pressure of 3-5 psig and a lift oil pressure of at least 850 psig are required for turning gear operation. A low speed switch allows automatic starting of the turning gear when the turbine speed decreases to less than 1.5 rpm. A high speed switch prevents the operator from inadvertently starting the turning gear with a turbine speed of greater than 100 rpm.

### **Seal Oil Backup Pump**

The seal oil backup pump is an ac electrically driven centrifugal pump. The seal oil backup pump supplies backup oil to the generator hydrogen seals and supplies auto-stop oil when the turbine speed is below 90% of rated speed. The pump discharges oil at pressures between 115 and 125 psig and must be in service to latch the turbine. The seal oil backup pump will automatically start if the bearing oil pressure decreases to 11-12 psig.

### **Ejector**

The ejector, located in the lube oil reservoir, provides bearing oil and the shaft-driven lube oil pump suction when the turbine is at normal operating speed. The discharge of oil from the shaft-driven lube oil pump flows through the "throat" of the ejector, which causes oil to flow from the lube oil reservoir to the ejector discharge. From the ejector discharge, oil flows to the shaft-driven pump suction and to the bearings.

### **Turbine Bearings**

Eleven journal bearings and a thrust bearing, located on the generator end of the middle low pressure turbine, are installed in the turbine/generator unit.

The journal bearings are constructed of steel and have babbit faces. Each bearing sits in a pedestal and consists of two semicircular halves. A bearing pedestal cap, bolted to the pedestal, completes the bearing assembly. Drilled passages through the upper and lower halves of the bearing supply lubricating and lift oil, respectively.

The thrust bearing accepts axial loads developed by the main turbine. The thrust bearing assembly is of the leveling plate design, which automatically distributes the load equally on the thrust shoes. The leveling plates allow the thrust shoes to take positions such that the centers of loading of the faces are all in the same plane. Consequently, each shoe takes an equal share of the load. The thrust of the rotor is transmitted to the shoes by a collar machined integrally with the turbine rotor shaft.

### **7.3.5 Moisture Separator Reheaters**

#### **7.3.5.1 System Description**

The moisture separator reheaters provide dry, superheated steam to the low pressure turbines. Low pressure steam to the main feed pump turbines is also supplied by the moisture separator reheaters. The MSR's improve secondary system efficiency and minimize moisture erosion of the low pressure turbine blading.

The exhaust steam from the high pressure turbine is routed to the shell side of each moisture separator reheater, where moisture is removed by chevron separators. The steam then flows past two reheating tube bundles. The first of these bundles, called first-stage reheat, receives turbine extraction steam from the high pressure turbine. The second bundle, or second-stage reheat, receives steam from the main steam system. The steam exiting the moisture separator reheaters is piped to the low pressure turbines via the reheat and intercept valves. Reheated steam from the moisture separator reheaters is also supplied to the main feed pump turbines. The supply lines connect to the main feed pump turbine low pressure stop valves.

#### **7.3.5.2 Component Descriptions**

##### **Moisture Separator Reheater Shell**

The exhaust steam from the high pressure turbine enters each moisture separator reheater via the shell end (Figure 7.3-6). The steam is directed up through the chevron separators to the reheat tube bundles. The separated moisture from the turbine exhaust is directed to a heater drain tank. The shell is constructed of carbon steel. Relief valves mounted on the shell provide overpressure protection.

##### **First-Stage Reheat Bundle**

The first-stage reheat tube bundle receives high pressure turbine extraction steam. The flow of steam through the bundle adds energy to the high pressure turbine exhaust steam. The flow of steam to the first-stage reheat tube bundle is controlled

by a pneumatic control valve that receives signals from the reheater control system (see Section 11.4). The condensate that results from the heat transfer across the first-stage tube bundle is drained to the next-to-last-stage feedwater heater shells.

### **Second-Stage Reheat Bundle**

Steam from the main steam system is supplied to the second-stage reheat tube bundle via a pneumatic valve controlled by the reheater control system. Condensate from the second stage of reheat is drained to the last-stage feedwater heater shells.

### **Main Feed Pump Supply**

The MSR's supply low pressure steam to the main feed pump turbines. The MSR's usually supply the pump turbines when secondary power has increased to 35% of rated load. With this alignment, the high pressure steam supply from the main steam system to the pump turbines is secured.

### **7.3.6 Summary**

The nuclear steam supply system supplies steam to the main turbine. The main turbine consists of one high pressure turbine and three low pressure turbines coupled to the main generator. Hydraulically controlled governor valves regulate the flow of steam to the turbine, thereby maintaining a desired speed or electric load for the grid.

Dry, superheated steam is supplied to the low pressure turbines by the moisture separator reheaters. The MSR's improve secondary cycle efficiency and minimize low pressure turbine blade erosion. In addition, the MSR's supply dry, superheated steam to the main feed pump turbines.

The gland steam system is designed to prevent air entry into the turbine or steam leakage out of the turbine. The turbine lubricating oil system provides all required lubrication for the turbine bearings. In addition, the turbine lubricating oil system provides backup seal oil to the generator and auto-stop oil to the turbine trip system.



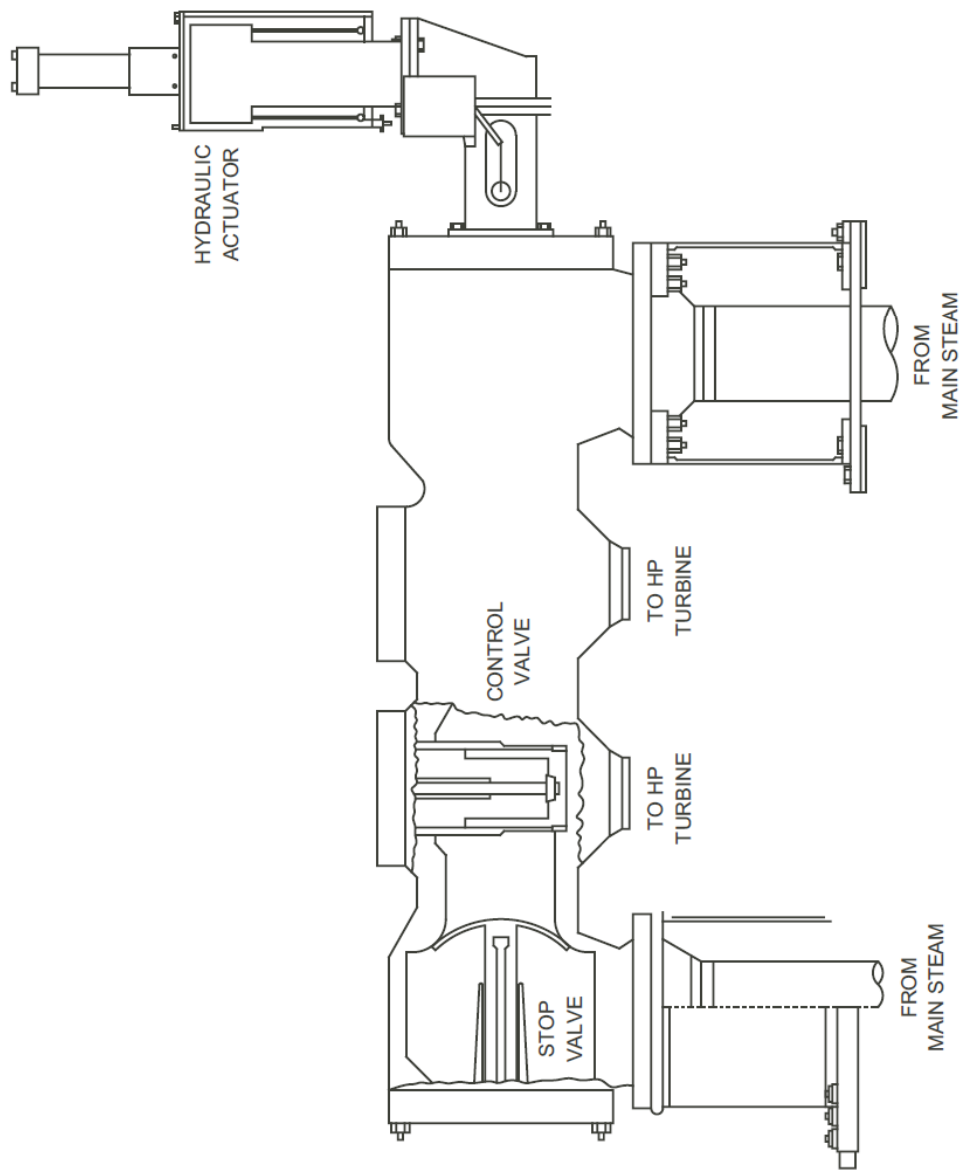


Figure 7.3-2 Stop and Control Valves

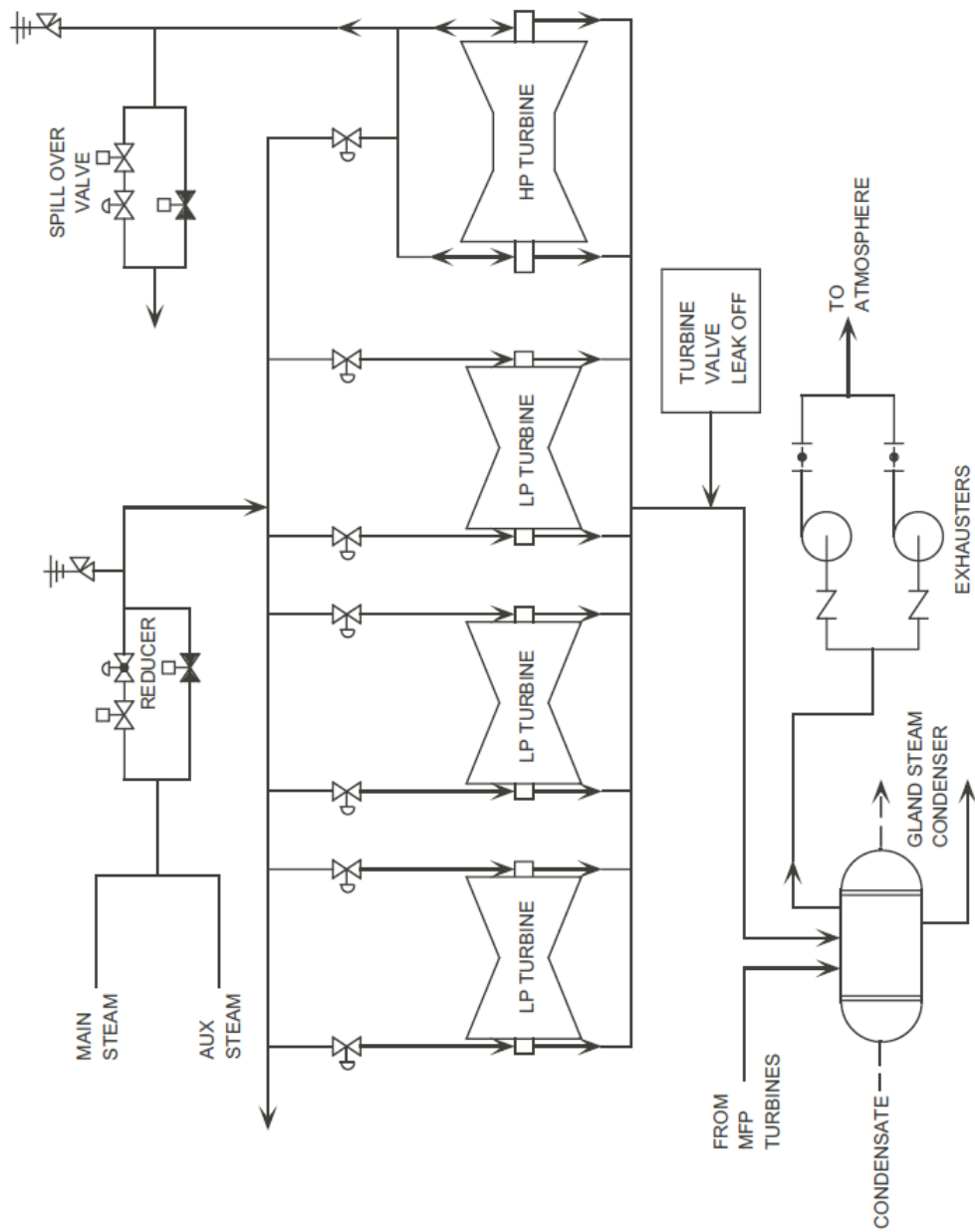


Figure 7.3-3 Gland Steam and Exhaust System

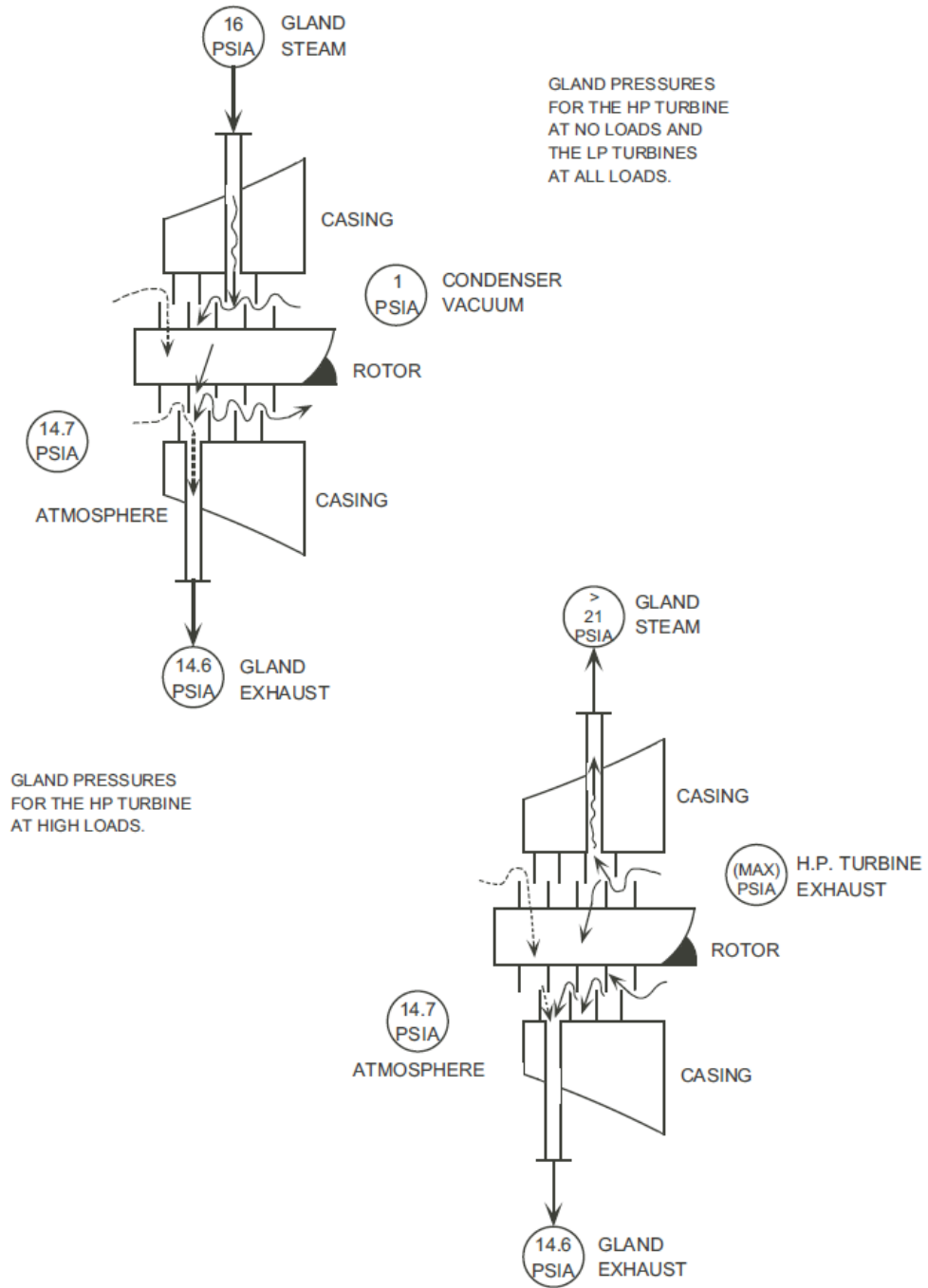


Figure 7.3-4 Gland Steam / Exhaust Pressures



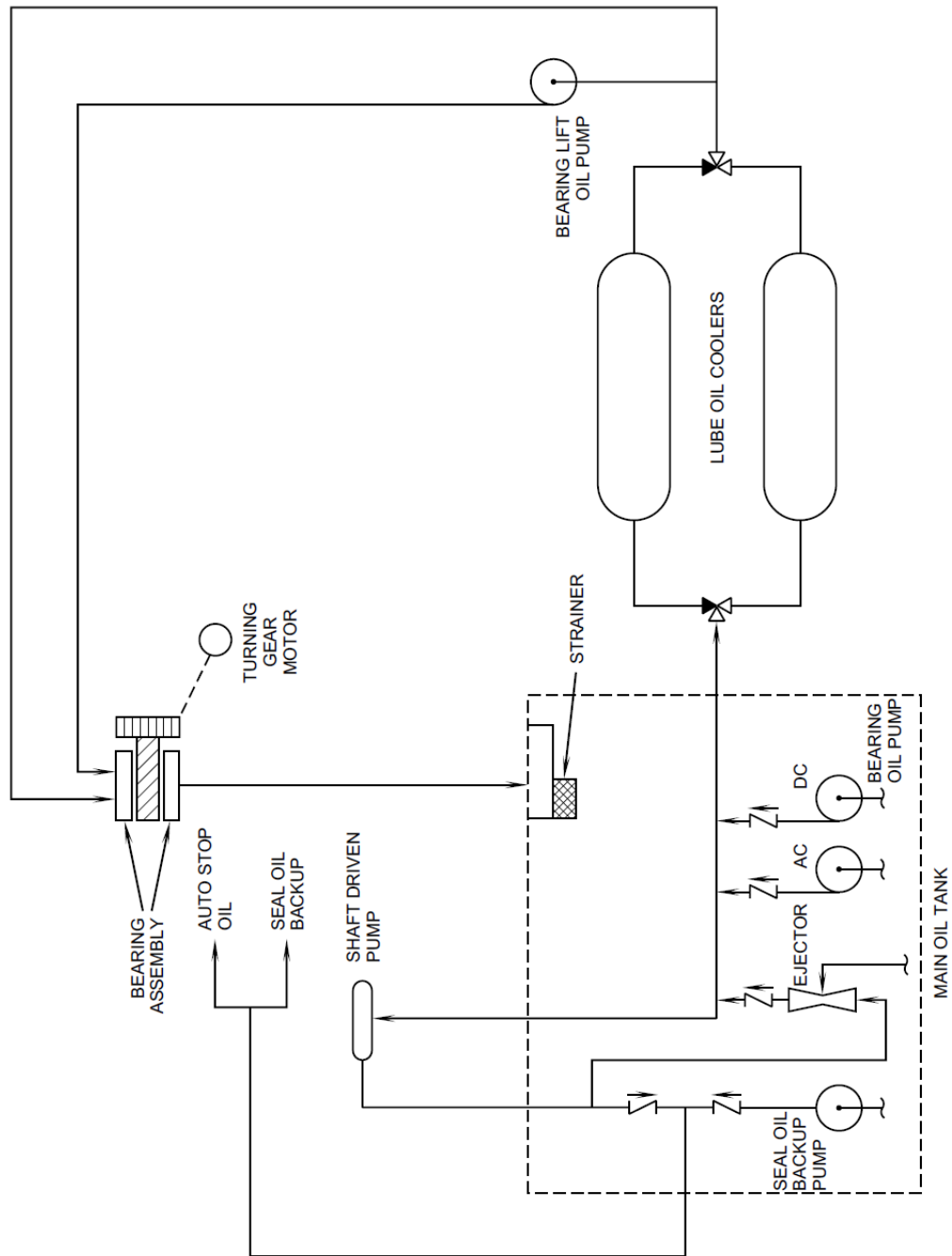


Figure 7.3-5 Turbine Lube Oil System

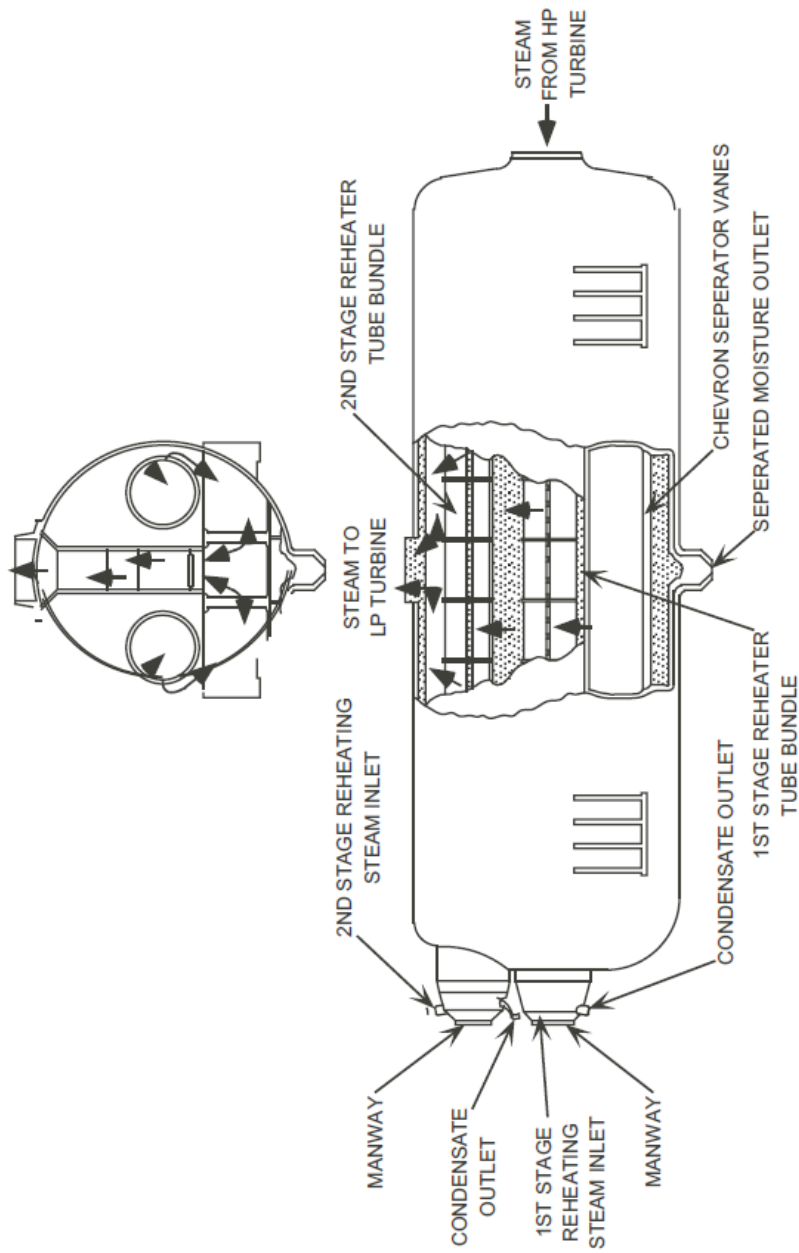


Figure 7.3-6 Moisture Separator Reheater