Turbine, Generator and Auxiliaries - Course 134

TURBINE START-UP

This lesson will discuss the general operation of a steam turbine unit during start-up from a cold condition. It should be appreciated that no two turbines have identical operating characteristics, even when they are of identical design. This is due to differences in material, clearances, auxiliary systems, age and general condition. Thus while it is possible to outline a starting procedure in general terms, this must be adapted in detail to suit the particular machine under consideration. In all cases, the manufacturer's instructions should be followed with variations introduced as a result of experience where necessary.

Figure 4.1 shows graphically the major steps required for the start-up of a large turbine unit.

CHECK STATE OF PLANT

The plant should be checked both visually and administratively to ensure that all system maintenance is complete and the plant is physically ready for start-up. During the last few days prior to a start-up, the operator should continually review the status of systems to ensure no surprises are encountered when each system needs to be started up. A review should be made of all tests which will be called up for this start-up and necessary equipment and personnel made available. Following system maintenance, the actual position of valves should be checked against the flow diagram. This valve lineup verification may involve only a small portion of a single system or, in the case of an extended shutdown, all plant systems. The fact that a valve is supposed to be open and is shown as open on a flow diagram does not mean the valve is open.

SYSTEM START-UP PRIOR TO PLACING TURBINE ON TURNING GEAR

Prior to placing the unit on the turning gear the following auxiliary systems will be placed in operation:

(1) all electrical supplies
(2) low pressure service water
(3) low pressure instrument air
(4) high pressure instrument air
(5) condenser cooling water.

The inventory of makeup water should be checked and the water treatment plant placed in service if necessary. The temper-

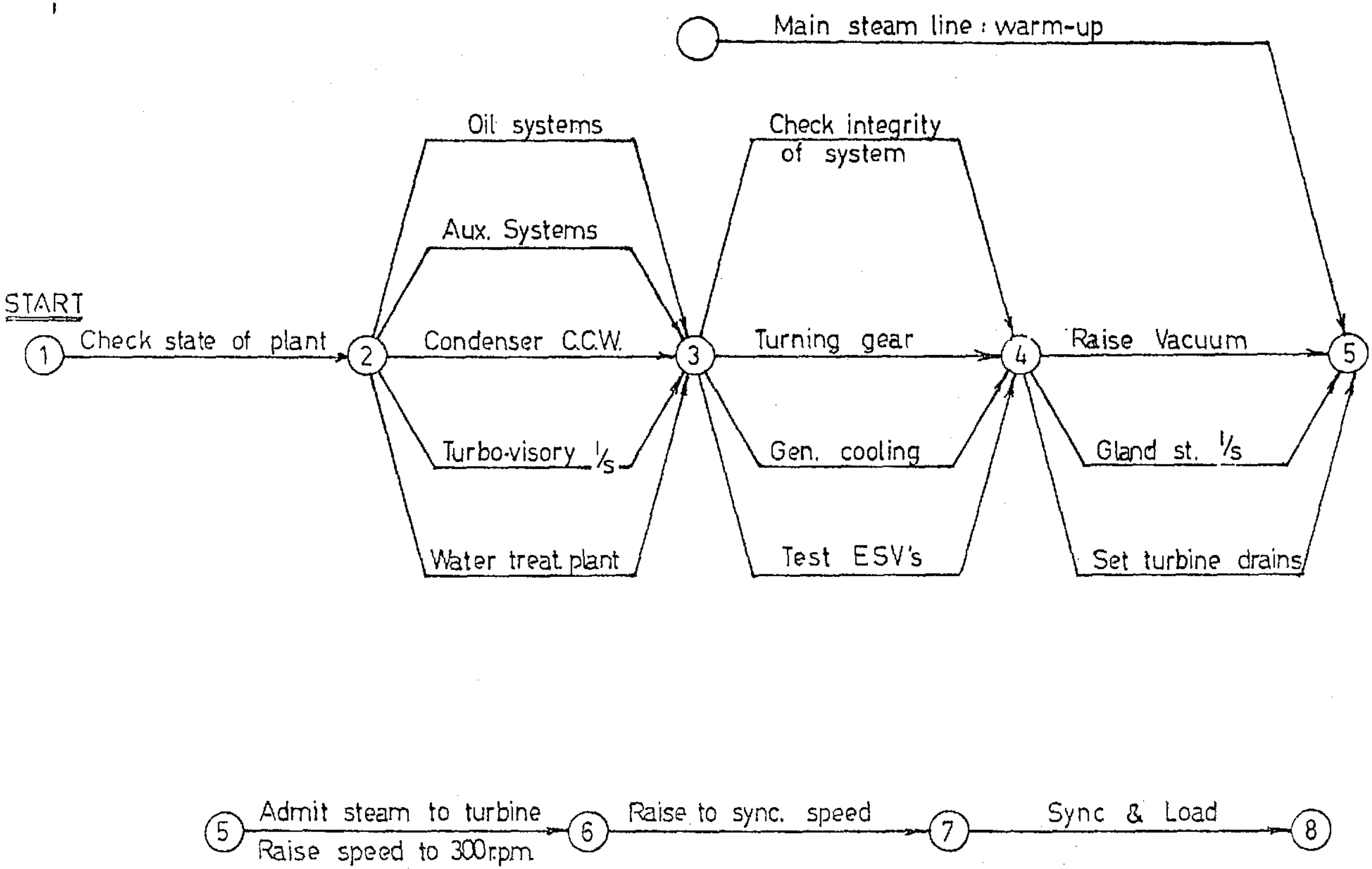

Figure 4.1

Turbine Unit Start-Up

ature of the deaerator should be sufficiently high to allow the addition of water to the steam generators. The warmup of the deaerator takes approximately 36 hours.

The generator seal oil system should already be in operation if the generator is pressurized with hydrogen. However, even if the generator is not pressurized with hydrogen, seal oil must be supplied to the seals prior to placing the unit on the turning gear as the oil lubricates and cools the seals.

The lubricating oil system is started and tested. The turning gear lube oil pump or auxiliary lube oil pump will be supplying oil to the bearings and the proper pressure should be checked. The jacking oil pump is placed in service and its discharge pressure to the bearings is checked. The differential pressure across the lube oil filters should be checked. Following maintenance, the lube oil flow to each bearing should be checked prior to starting the turning gear.

The turbovisory system is energized to provide the following indication:

(a) shaft eccentricity
(b) differential expansion
(c) casing expansion
(d) shaft position
(e) shaft rotational speed
(f) emergency stop valve position
(g) governor steam valve position
(h) bearing vibration
(i) thrust bearing temperature
(j) journal bearing temperatures
(k) lube oil temperatures
(l) generator hydrogen gas pressure and temperature
(m) generator hydrogen purity
(n) generator hydrogen seal oil differential pressure
(o) generator hydrogen-to-stator water differential pressure
(p) generator stator coolant pressure, temperature and conductivity.

TURNING GEAR OPERATION

The turbine should be placed on the turning gear some time prior to steam admission. Twenty-four hours would be typical. This allows time to roll out minor shaft eccentricities, warm up the lube oil and flush any impurities from the lube oil system. Since the lube oil purifier will be operating during turning gear operation, this time will allow for removal of impurities in the oil. During this turning gear operation prior to rolling with steam, shaft eccentricity and lube oil filter and strainer differential pressure should be checked.

The generator cooling system is put in operation and the hydrogen purity and pressure checked. Hydrogen pressure must be maintained above stator cooling water pressure to prevent leakage of water into the generator. The stator cooling system is put in operation and the conductivity of the water checked. Prior to rolling the turbine with steam, service water is supplied to both the hydrogen and stator water coolers.

If it is not already running the auxiliary oil pump would be started to supply oil to the control oil system. In the case of an electrical-hydraulic governing system using FRF, the FRF system would be placed in operation.

At this time the emergency stop valves would be tested to insure they functioned properly. The boiler stop valves will be shut; the governor steam valves will be fully open with the speeder gear wound to the lower stop which corresponds to about 1650 rpm. This insures that during the start-up, the turbine will come on the governor at as low a speed as possible. After the emergency stop valves are tested, they are fully shut. At this point the governing and control systems are ready for operation.

VACUUM RAISING

The reactor is brought to criticality and the temperature of the heat transport system is raised. As this occurs, steam generator and balance header pressure increases. Reactor power is established to increase heat transport system temperature at some rate (usually about 2-3°C per minute). As steam generator temperature and pressure increases, the steam reject valves (atmospheric steam reject vales), Figure 4.2, would open if pressure rose above the pressure determined by the reactor heat up ramp. During this heatup the steam generator and steam header pressure would be determined by the heat transport system temperature as it was raised by reactor power. The main steam header drains would be open to allow condensed water to drain from the lines as the steam lines are brought up to operating temperature.

The condensate system, Figure 4.3, is placed in an operating condition with one condensate extraction pump running, one pump in automatic (to start automatically at 60% power) and one pump in standby. The condensate system is lined up to deliver condensate through the low pressure feedheaters to the deaerator. The level in the deaerator is now being maintained by the level control valves which regulate the flow of condensate

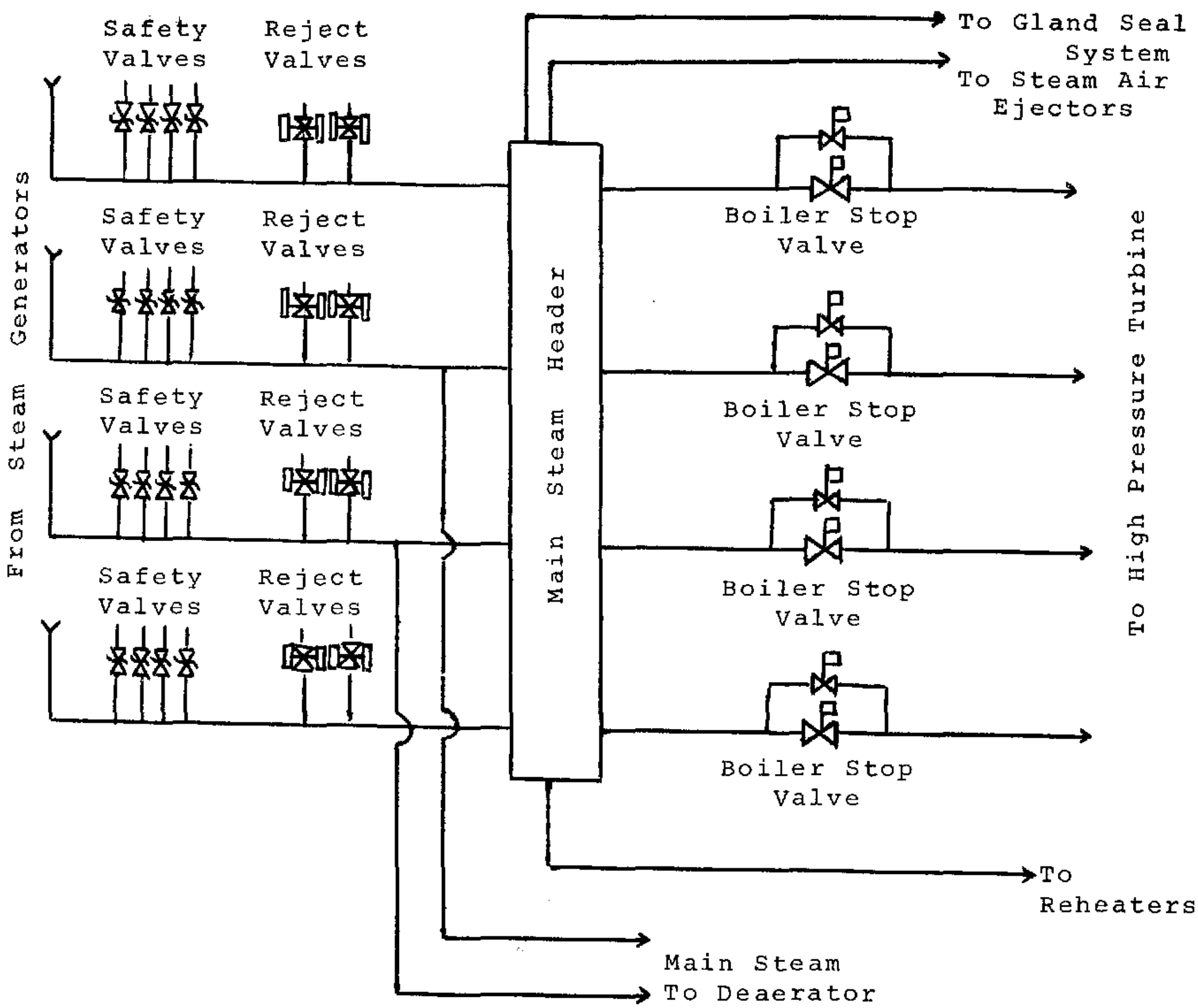

Figure 4.2

Steam System

to the deaerator. When little or no condensate is being passed to the deaerator, the condensate extraction pump recirculation line opens to allow sufficient flow through the condensate system to:

(1) insure adequate cooling to the gland exhaust condenser and, if applicable, the air ejector condenser (Bruce NGS, DPNGS) and stator water cooling heat exchanger (DPNGS);

(2) insure adequate flow exists through the condensate pump to keep it from overheating.

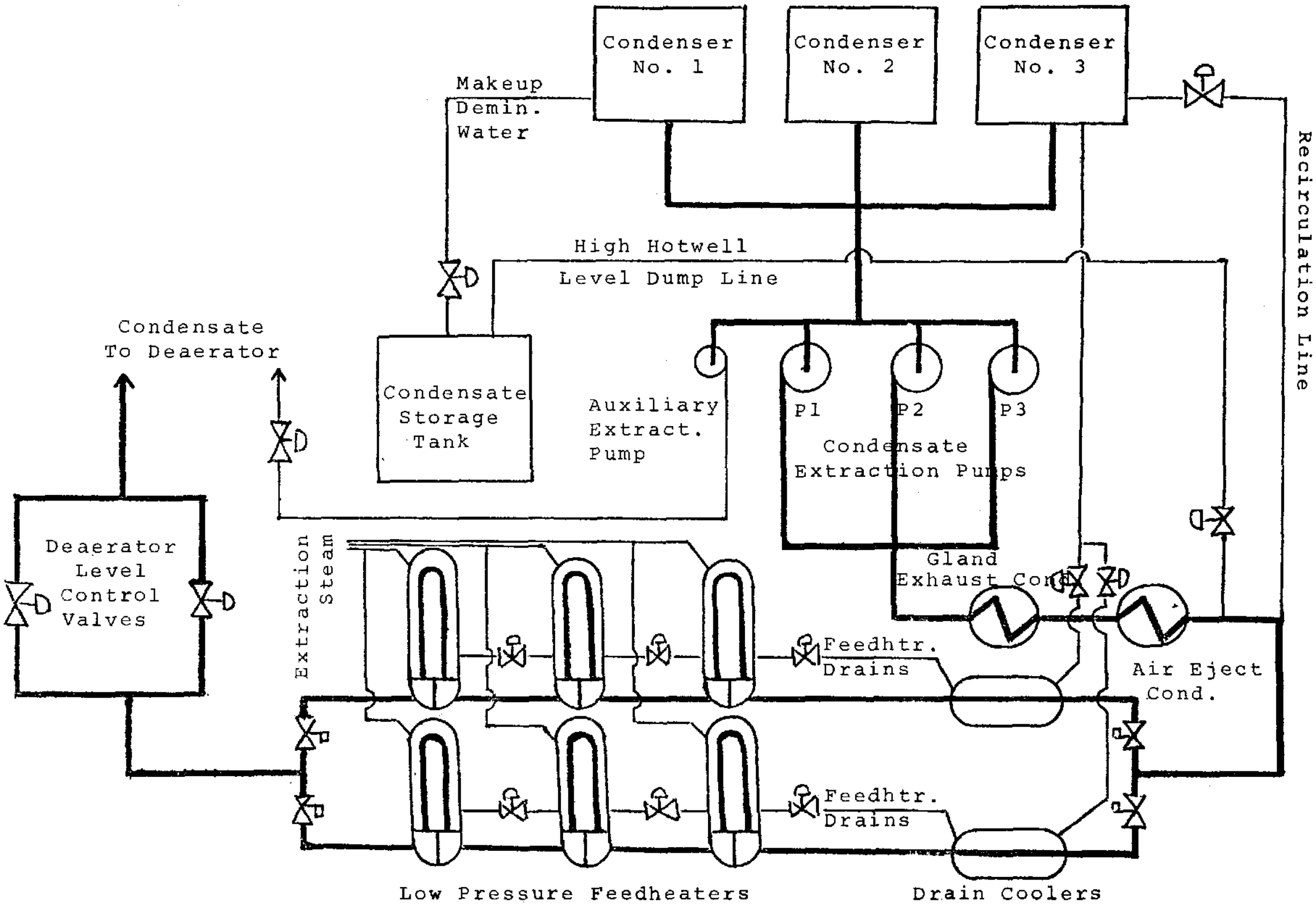

Figure 4.3

Condensate System

When the main steam header steam pressure is sufficiently high, the control valve which emits main steam to the deaerator will open to allow main steam to enter the deaerator for heating and deaerating incoming condensate (this valve will close automatically when extraction steam of sufficient pressure is available from the low pressure turbine). It should be noted that before steam is admitted to the turbine, no extraction steam is available for the low pressure feedheaters and condensate is entering the deaerator at essentially the same temperature it left the condenser hotwell. As part of the start-up of the condensate system the chemical feed system is placed in service.

After the condensate system is in operation, the feed system, Figure 4.4, is started up. The deaerator must be warm enough to prevent thermal shock to the steam generator before a feed pump is started. Typically this means the deaerator must be within 130° to 135°C of the steam generator temperature. One boiler feed pump is started, one pump is in automatic (to start automatically at about 50% power) and one pump is in standby. The feed system is lined up through the low pressure feedheaters to the steam generators. The levels in the steam generators are now being maintained by the feedwater regulating valves which regulate the flow of feedwater to the steam generators. To prevent the boiler feed pumps from overheating at low flows, each individual pump is fitted with a recirculation line.

At power levels below 25-50% of full power, the extraction steam available for the high pressure feedheaters may not be of sufficient temperature to provide any feedheating. For this reason, extraction steam which would normally go to the HP feedheaters is led to the condenser until sufficient power is reached to provide extraction steam heating in the HP feedheaters. The HP feedheaters are normally receiving extraction steam by 50% of full power. Until the turbine is above 25% of full power, the deaerator is providing virtually all of the feedheating.

The main steam pressure is allowed to rise as the heat transport system heats up. At approximately 1000 kPa(g) the gland seal system is placed in operation and the air extraction system is started to evacuate the condenser and turbine unit. The turbine and extraction steam drains are opened and then placed in automatic. By this time the condenser cooling water system, generator seal oil system, stator cooling system and generator hydrogen system should be in fully operating condition. As the gland seal steam heats up the rotor, differential expansion between the turbine rotors and casings is checked.

The main steam isolating valves (boiler stop valves) are opened to raise pressure in the steam lines up to the emergency stop valves. The reheater is placed in an operating condition.

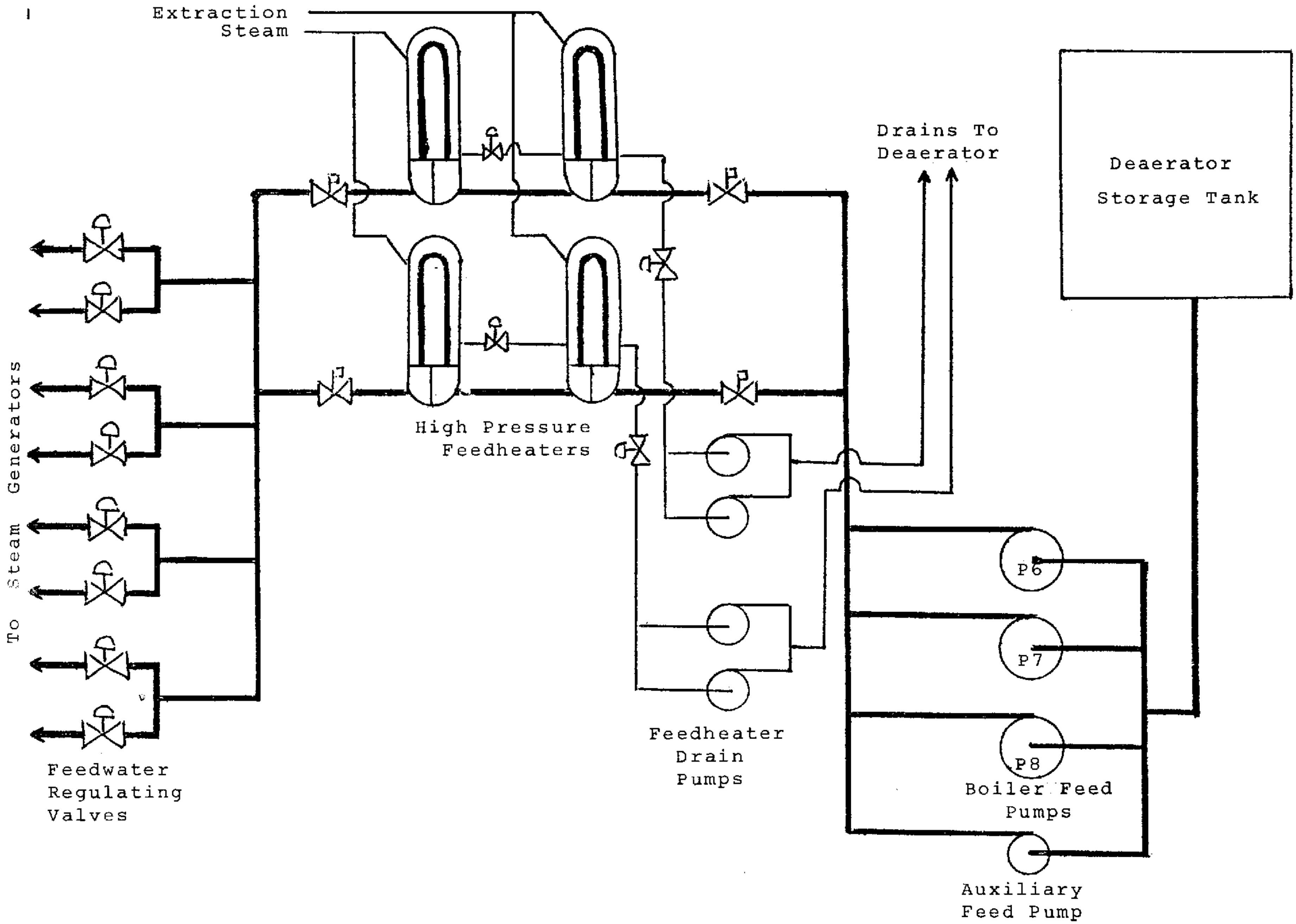

Figure 4.4

Feed System

STEAM ADMISSION TO THE TURBINE

Prior to admitting steam to the turbine the shaft eccentricity is checked within limits. The generator field is energized and the steam pressure at the emergency stop valve is determined to be satisfactory. Provided condenser vacuum is greater than approximately 380 mm mercury [50 kPa(a)], steam is admitted to the turbine by cracking open the emergency stop valves, Figure 4.5. Of the four emergency stop valves, generally only two valves - master ESV's - are used for turbine runup. The other two ESV's - slave ESV's - are not utilized until after the unit has attained operating speed. The slave ESV's will begin to open automatically after the master ESV's are 50% open. The turbine is brought up to 300 rpm. The turning gear will disengage automatically as speed increases above turning gear speed. The turning gear and jacking oil pump will both shut down at some preset speed typically between 100 and 250 rpm. Turbovisory parameters are checked within the limits of Figure 4.6.and speed is either held constant or the unit tripped depending on the values.

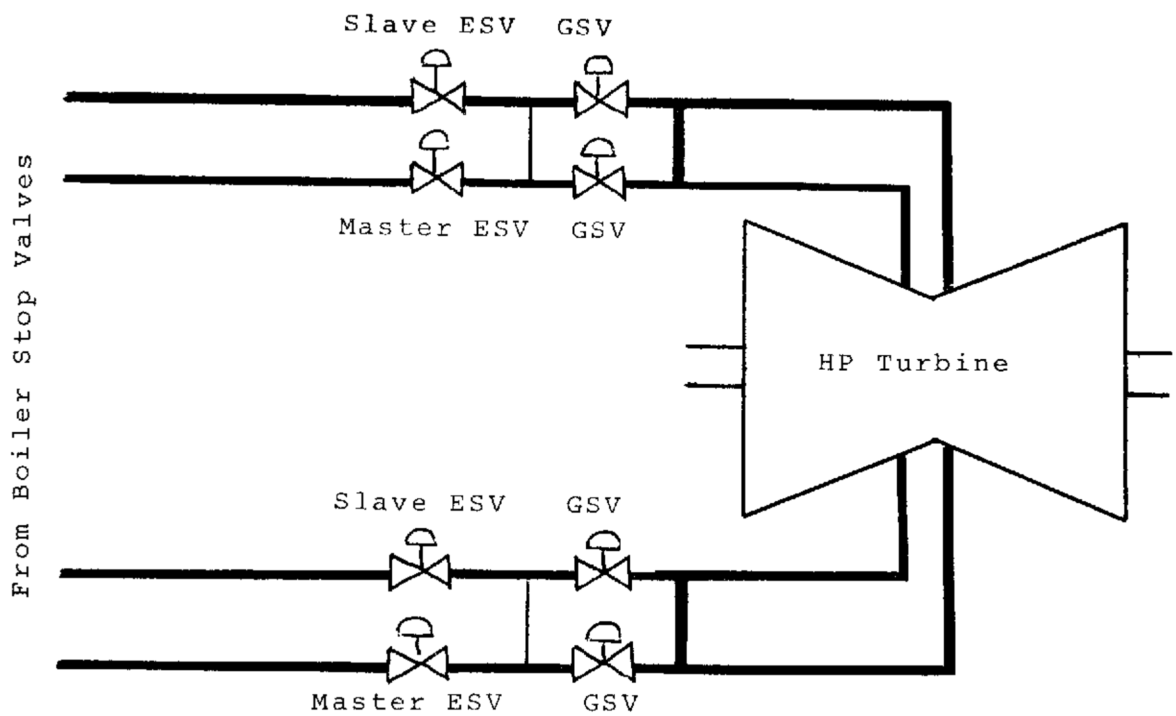

Figure 4.5

Steam Control

Parameter	Parameter Value	Action
Bearing Vibrations	A = 0.003" B = 0.002"	TRIP at any speed. If speed >300 <600 reduce speed and hold at 300 rpm.
H.P. Differential Expansion	>+0.100" <-0.100" >+0.050" <-0.050"	TRIP HOLD
L.P. 1 Differential Expansion	>+0.150" <-0.300" >+0.100" <-0.250"	TRIP HOLD
L.P. 2 Differential Expansion	>+0.150" <-0.600" >+0.100" <-0.050"	TRIP HOLD
L.P. 3 Differential Expansion	>+0.150" <-0.900" >+0.100" <-0.850"	TRIP HOLD
H.P. Shaft Eccentricity	0.008" 0.006"	TRIP HOLD
Lub. oil temp. Gen. rotor temp.	<39°C <20°C	Reduce & hold speed at 1200 rpm Reduce & hold speed at 1200 rpm

Figure 4.6

Turbovisory Parameters For Start-Up

If condenser pressure is below 33 kPa(a) and turbovisory parameters within specified limits, speed is increased to 600 rmp. Steam-to-metal differential temperature is checked to insure steam temperature remains above metal temperature, but that metal temperature does not increase more than about 250°C/hour. In addition, the trend of turbovisory parameters is checked. At this point the unit speed is held constant, reduced, or the unit tripped depending on the value and the trend of these parameters. The speed would be held constant at 600 rpm until:

(a) all turbovisory parameters are below the HOLD value and have an acceptable trend, and

(b) condenser pressure is below 18 kPa(a).

Speed would then be increased to 900 rpm. This speed is held until lube oil is above 39°C, generator rotor temperature is above 20°C, condenser pressure is below 9 kPa(a), and turbovisory parameters are acceptable. Speed is then increased to 1200 rpm and conditions checked again. At this point, the low condenser vacuum trip is placed in operation. (Up until this point the low vacuum trip has been disabled to allow opening of the ESV's at below the minimum acceptable operating vacuum.)

Turbine speed is now ready to be increased through the critical speed range of the turbine and generator. In this speed range (typically 1225 to 1400 for the turbine; 1550 to 1650 for the generator) the rotational frequency of the unit, matches the natural frequency of the rotor. Prolonged operation in this region could destroy the turbine and/or generator through amplification of vibration. For this reason the speed is brought up rapidly through the critical speed range to about 1700 rpm. If the turbovisory parameters develop HOLD values while in the critical speed range, the speed is lowered to 1200 rpm. By the time speed reaches 1700 rpm the auxiliary oil pump should have shut down (main oil pump providing sufficient discharge pressure) and the governor should have taken control of the turbine. The ESV's can now be fully opened.

SYNCHRONIZING AND LOADING

The turbine speed is now raised to 1800 rpm with the speeder gear controlling the position of the governor steam valves. Excitation is adjusted to provide a terminal voltage equal to grid voltage and the generator is synchronized with the grid. The unit is now ready for loading.

Up until the time that loading of the generator commences the steam reject valves (atmospheric steam reject valves) have been controlling steam generator pressure. When loading of the generator is to begin, steam generator pressure control is transferred to the governor speeder gear. In this mode of pressure control, the speeder gear is under computer control and will open the governor steam valves to reduce steam generator pressure to the desired setpoint. Loading is thereby accomplished by raising reactor power which in turn raises heat transport system temperature and steam generator pressure. This causes the speeder gear to open the governor steam valves and thereby return steam generator pressure to the desired setpoint. If the turbine is unable to accept the additional steam (HOLD turbovisory parameter, exceeds maximum loading rate, etc), the reject system will operate to maintain the desired steam pressure.

The value and trend of turbovisory parameters are checked within limits as the turbine increases load and warms up to operating temperatures. By this time the turbine and extraction steam drains should be shut. The maximum rates of loading specified in Figure 4.7 are followed.

As turbine/generator power increases the operator will check to ensure that:

(1) the deaerator transfers from main steam to extraction steam

(2) the extraction steam flow to the HP feedheaters is established

(3) AUTO feed pump starts

(4) AUTO condensate extraction pump starts.

The unit is now in an operating state and loading would continue to 100% power or whatever value is desired.

ASSIGNMENT

1. Using Figure 4.1 as a guide, discuss the major steps involved in starting up a large turbine unit.

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TYPE OF START	COLD TURBINE	WARM TURBINE		HOT TURBINE	
Period of shut down Hrs.	-	36	12	6	1
Estimated metal temperature °C	21	116	188	216	243
Maximum Condenser Back Pressure kPa(a)	50	30	13.5	8.5	6.5
Time from turning gear to full speed Mins.	40	20	10	5	3
Block load on synchronizing. MW	-	-	50	100	140
Load 0-50 MW @	2½ MW/MIN.	5 MW/MIN.	-	-	-
50-150 MW @	10 MW/MIN.	12½ MW/MIN.	20 MW/MIN.	50 MW/MIN.	100 MW/MIN
150-300 MW @	15 MW/MIN.	20 MW/MIN.	25 MW/MIN.	50 MW/MIN.	100 MW/MIN
300-540 MW @	15 MW/MIN.	20 MW/MIN.	35 MW/MIN.	35 MW/MIN.	100 MW/MIN
Time from synchronizing to full load. Mins.	56	32	18	11	4

Figure 4.7

Rates Of Loading