Turbine, Generator & Auxiliaries - Course 334

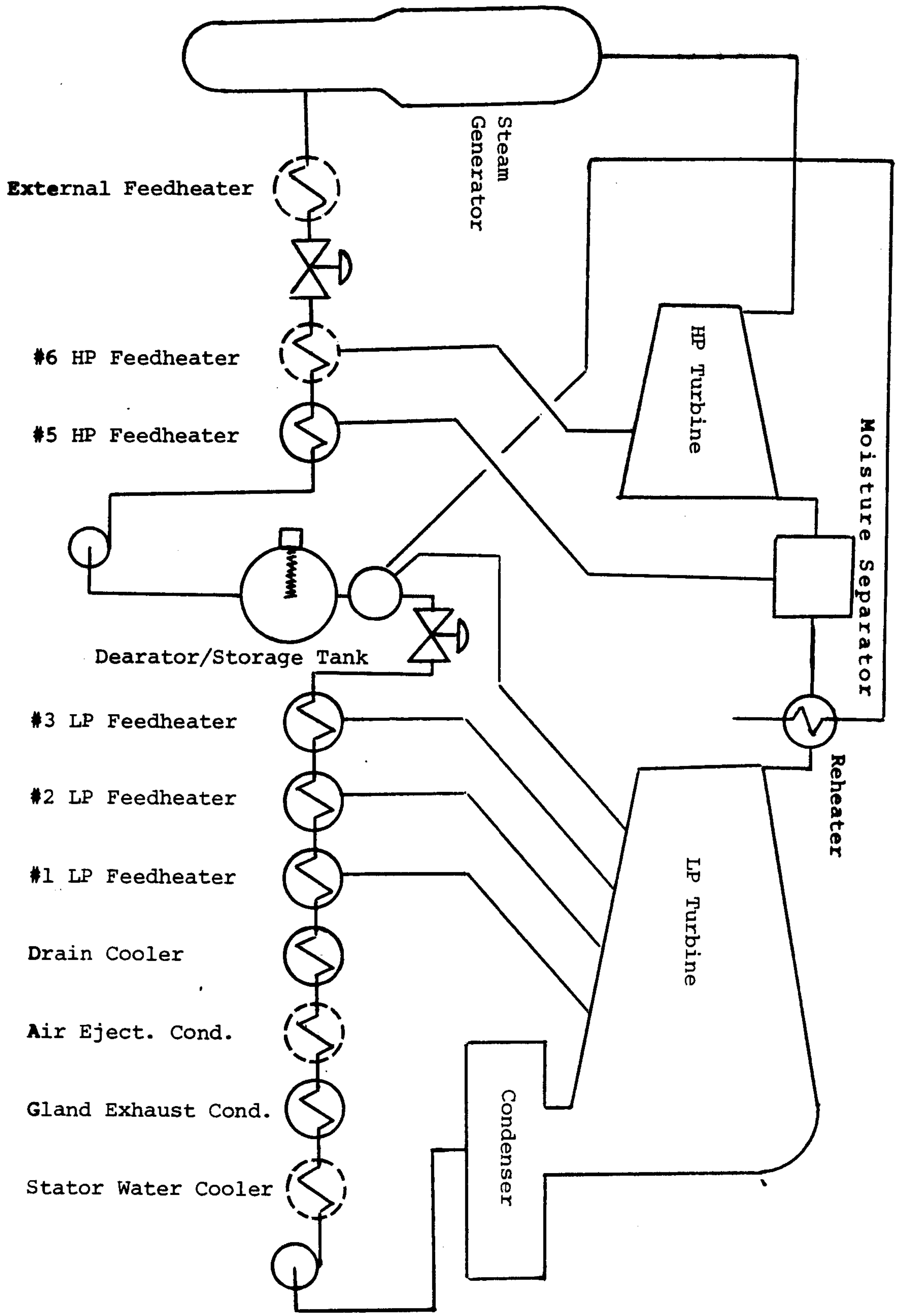
FEEDWATER HEATING SYSTEM - II

Figure 9.1 shows the feedheaters of a typical CANDU generating station. Depending on plant configuration and temperatures, the exact number of feedheaters and the sources of heat energy varies from station to station. The purpose of this lesson is to examine the sources of heat energy available for feedheating and discuss why they are used or not used in particular stations.

There are a number of sources of heat available for the feedheating system. In the general order they would appear in an <u>ideal</u> feedheating system, they are:

1. Heat from the generator hydrogen cooling system;
2. Heat from the generator stator water cooling system;
3. Heat from the steam pipe and turbine drains;
4. Exhaust steam from turbine glands;
5. Exhaust steam from steam control valve glands;
6. Exhaust steam from steam air ejectors;
7. Extraction steam from the low pressure turbine;
8. Main steam;
9. Electric heaters;
10. Drains and extraction steam from the main moisture separators;
11. Extraction steam from the high pressure turbine;
12. Reheater drains;
13. Heat transport system.

We will consider each of these heat sources and discuss where they are used in a typical feedheating system.



Typical Feedheating Chain

Figure 9.1

The Generator Hydrogen Cooling System

This system removes heat from the generator by circulating hydrogen over the rotor and through slots in the stator. Although the system rejects a reasonably large amount of heat (about 3 MW for a large unit), the temperature is quite low (35-40°C). With a condenser pressure of 4.5 to 5.0 kPa(a), the hotwell temperature is 31-33°C. This means that there is insufficient temperature difference between the generator hydrogen and the condensate to allow for efficient heat transfer.

Although generator hydrogen is being used for feedheating at various generating stations, it is not used at any NGD stations. The hydrogen is cooled in low pressure service water coolers.

The Generator Stator Water Cooling System

This system removes heat from the generator stator windings by pumping extremely pure water through the stator conductors. The stator water removes about 6 MW from the generator. The stator water temperature is about 50-60°C to the cooler and about 30-40°C from the cooler. For smaller units (DP NGS for example) this results in a high enough differential temperature for use to be made of the stator water cooling system in heating feedwater. On larger CANDU generating units, the differential temperature is too small when condensate temperature is near the upper end of its normal range. In these stations, heat is removed from the stator water cooling system in low pressure service water coolers.

Steam Pipe and Turbine Drains

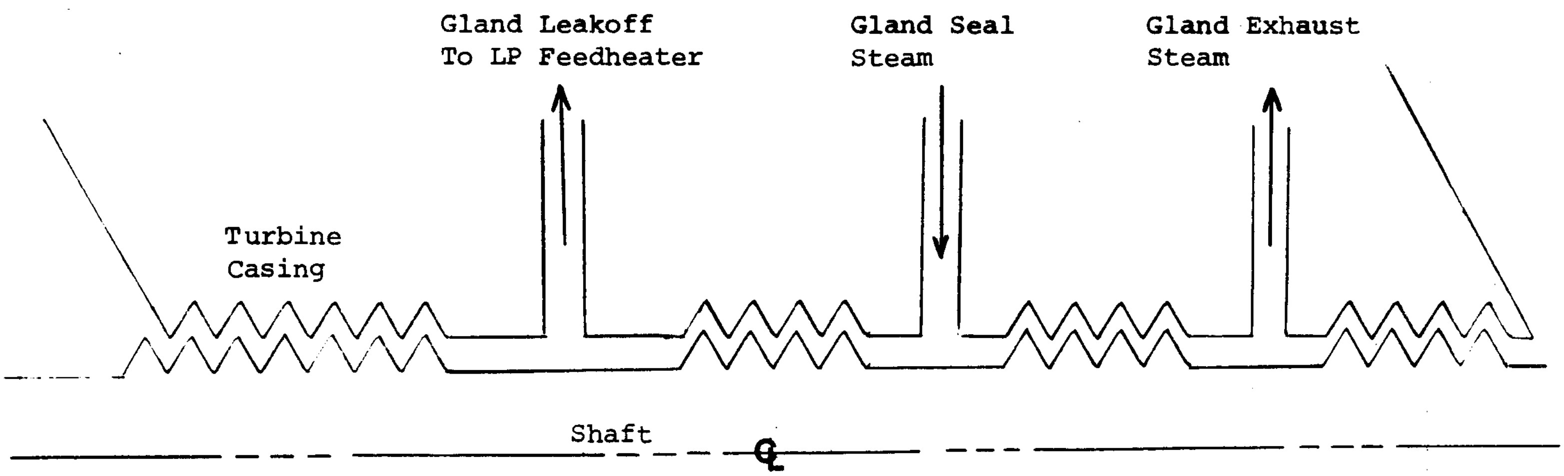
During system warmup and, to a lesser extent, during operation, condensation occurs in the steam piping and turbine. This water is removed by steam traps which allow water to escape but not steam. The normal operation of the trap is for water to collect until a certain amount accumulates. The water is then discharged from the trap.

While this water is hot enough for effective feedheating, the quantity during normal operation is relatively small and in almost all turbine units, this water is passed directly to the condenser.

Gland Exhaust Steam

The normal leakoff of steam and air from the turbine and control valve glands is exhausted to a gland exhaust condenser. The steam condenses and the air is removed by a gland exhaust fan. The gland exhaust condenser is cooled by condensate. With the exception of those station with stator water heating of feedwater, the gland exhaust condenser is normally the first heater in the feedwater system.

It was mentioned in the lesson on turbine construction that the high pressure turbine glands are self sealing at power. The outward leakage of steam is more than sufficient to seal the gland. This excess steam is supplied to a low pressure feedheater. The general arrangement of the HP turbine gland is shown in Figure 9.2.



HP Turbine Gland

Figure 9.2

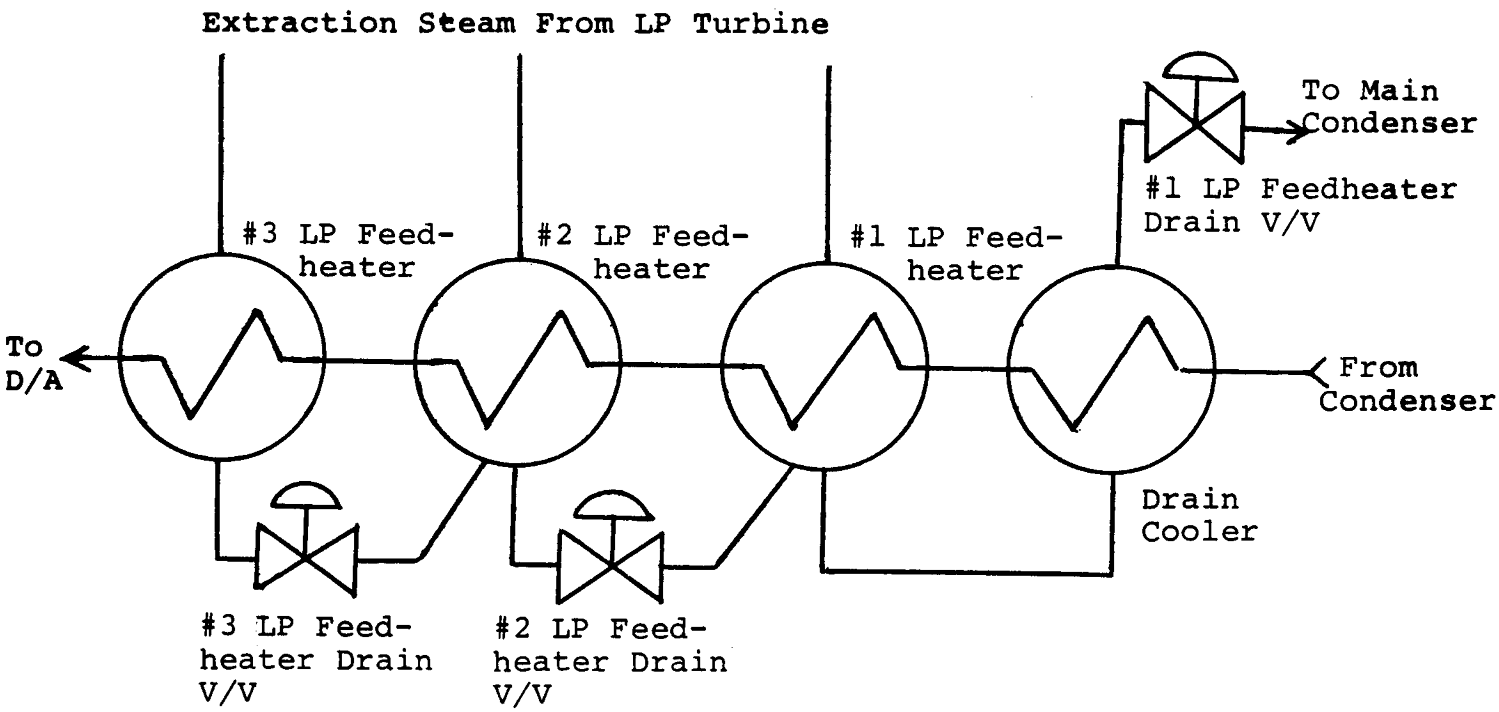
Steam Air Ejector Exhaust

The air extraction system is used to remove air and other non-condensible gases from the main condenser. On those plants with steam air ejectors, the steam exhausting from the ejectors is cooled in an intercondenser and an aftercondenser. The inter and after condensers are cooled by feedwater.

Low Pressure Turbine Extraction Steam

The majority of the feedheating in the low pressure feedheating system and deaerator is done with extraction steam. For a large CANDU generating station about 20% of the steam entering the low pressure turbine is bled off as extraction steam. Roughly 1/3 of this steam goes to the deaerator; the remaining 2/3 goes to the three LP feedheaters.

The low pressure feedheater drains are <u>cascaded</u> from higher to lower temperature feedheaters. The drains from the number one low pressure feedheater is passed through a separate drain cooler prior to flowing back to the condens-er. The arrangement of low pressure feedheaters is shown in Figure 9.3. The feedheating in the low pressure feedheating system is done by a combination of extraction steam from the turbine and cascaded drains from the next higher low pressure feedheater.



Cascade LP Feedheaters

Figure 9.3

The contribution of extraction steam to feedheating can be seen by the temperature rise through the low pressure feedheating system. The feedheating prior to the drain cooler raises the feedwater temperature from 29°C to about 31°C. The drain cooler and three low pressure feedheaters raise the temperature from 31°C to about 120°C.

The low pressure extraction steam to the deaerator accomplishes two functions:

1. heat the feedwater by direct contact with the incoming feedwater, and

2. deaerate the incoming feedwater.

The extraction steam raises the temperature of the incoming feedwater to the range of 125-150°C depending on the individual unit design. This temperature corresponds to the boiling temperature at the deaerator pressure of 250-450 kPa(a).

The deaeration of feedwater must take place above atmospheric pressure [101.3 kPa(a)] to prevent air re-entering the system after deaeration. On the other hand, the deaerator cannot be operated at too high a pressure since the cost and size of a large, high pressure vessel would be prohibitive.

Since the deaerator is a direct contact feedheater, it is more efficient than closed feedheaters where the steam and feedwater do not mix. The closed feedheaters, however, do not require a separate pump after each feedheater.

Main Steam

By far the majority of feedheating prior to the steam generator (or more precisely prior to the preheater) is done with extraction steam. During normal operation, roughly 99% of the feedheating comes from turbine extraction steam. When the turbine extraction steam is at low temperature (startup) or unavailable (turbine trip, poison prevent), there is essentially no normal feedheating capability. However, to prevent excessive thermal shock to the steam generators, the feedwater must be heated to within about 125°C of boiler temperature. This necessary feedheating is accomplished by taking main steam from the boiler outlet and dumping it through a control valve into the deaerator.

The amount of main steam required is considerably less during startup (when feedwater flow is relatively low) than during poison prevent (when feedwater flow is roughly 70% of full power). For this reason, there are normally two control valves: a large one for poison prevent, and a smaller one for start up.

As the turbine becomes available to provide extraction steam to the deaerator, the supply of main steam is automatically shut off.

Electric Heaters

In large turbine units thermostatically controlled electric heaters are used in the deaerator storage tank to maintain the temperature during off load and low load periods. The heaters are also used to warm up the deaerator prior to startup if the deaerator has been cooled off for maintenance.

It is desirable to keep the deaerator warm during shutdown periods to minimize the amount of air entering the system. In addition, when shutdown or at low power levels, the supply of hot water in the deaerator can be used for adding feedwater to the steam generator. The electric heaters are of relatively small capacity and can do no appreciable feedheating when the turbine is at power. As an example of this, it requires about 36 hours for the heaters to bring the 240,000 kg of water in a deaerator from room temperature to 125°C. At 100% power, this mass of water passes through a typical deaerator every seven minutes.

Main Moisture Separator Extraction Steam and Drains

The drains from the main moisture separator are sent to the high pressure feedheater immediately after the deaerator. Since the quantity and heat content of these drains are insufficient to provide the required amount of feedheating, they are supplemented by extraction steam from the main moisture separator.

High Pressure Turbine Extraction Steam

The feedwater enters the preheater at about 170-175°C. If the crossover between the HP and LP turbine is at a high enough pressure, the high pressure feedheater using moisture separator extraction steam will be the last feedheater. If the crossover pressure is lower, there will be a second high pressure feedheater which uses extraction steam from the HP turbine.

If there is more than one HP feedheater, the drains are cascaded in a manner similar to the LP feedheaters. However, because of the small pressure differential and large elevation difference between the first HP feedheater and deaerator, the HP feedheater drains are pumped back to the deaerator.

Reheater Drains

Having given up only the latent heat of vapourization, the reheater drains are at the same temperature as the steam generator. They are too hot to be efficiently used in a feedheater and are pumped directly back to the steam generator.

Heat Transport System

The feedwater leaves the last stage of feedheating at about 170-175°C. The heat transport system is used to convert this subcooled water into saturated steam at 250°C. Roughly 80% of the heat energy required to raise condenser water to saturated steam comes directly from the heat transport system in the preheaters and steam generators.

The function of the preheater is prevention of thermal shock by raising the temperature of the feedwater to steam generator temperature before releasing it into the steam generator shell. Whether the preheater is located internal or external to the steam generator, it is really just an extension of the steam generator. From the standpoint of the feedheating system, it makes little difference whether the preheater is internal or external to the steam generator. At Bruce NGS-A, the location of the preheater external to the steam generator was done for heat transport system considerations. It was desired to create cooler heat transport fluid for the central fuel channels. This was achieved by cooling some of the heat transport fluid with feedwater in an external preheater.

Figures 9.4 and 9.5 show the arrangement of a typical feedheating system for a large CANDU generating station. The drawing is a composite of the various stations and does not contain the exact arrangement of any one station.

ASSIGNMENT

1. List the available sources of heat for a feedheating system. For each source, list the feedsystem components in which the particular source is used.

2. The deaerator - storage tank has three sources of heat available. Under what circumstances is each used?

3. Why might some stations not use a high pressure feedheater using HP turbine extraction steam?

4. On large generating units, why is service water rather than feedwater used to cool the generator?

5. Why is the deaerator located near the center of the feedheating chain?

R.O. Schuelke