CHAPTER 5

STEAM, TURBINE AND FEEDWATER

CHAPTER OBJECTIVES:

At the end of this chapter, you will be able to describe the following features
of the steam, turbine and feedwater systems used in CANDU generating
stations:

1. How steam is produced, transfered to the turbine, condensed, and returned
   to the boilers;
2. The reasons for the main design and operating features of the Turbine;
3. The process of optimizing the thermodynamics of the steam and feedwater
   cycle;
4. The use of three element control to minimize fluctuations of steam
   generator level;
5. The use of standby equipment to ensure that the boliers are maintain their
   role as heat sinks;
6. The steam flows during 'Poison Prevent' Operation, regulation of steam
   generator pressure and protection against overpressure.

The steam and feedwater system performs the following functions:

a) Provides the means for the transfer of heat energy from the primary heat transport system,
   and for the production of steam.

b) Conveys the steam produced in the steam generators to the high pressure turbine and other
   balance of plant loads.

c) Provides for overpressure protection of the steam generator secondary side.

d) Provides instrumentation for steam generator level and pressure control.

e) Provides for a crash cool of the steam generators on a loss-of-coolant.

f) Enables testing of one turbine stop valve at a time without interruption to the unit and
   without causing problems in control of steam generator water levels.

g) Provides feedwater to each steam generator and maintains steam generator secondary side
   water levels.

h) Provides for cooldown of the heat transport system following a design basis earthquake.

i) Provides for a remote manual isolation of each pair of steam generators from the steam
   system (as may be required in the event of a tube leak).

The simplified flowsheet of the 'secondary' side of a nuclear generating station that includes the steam, turbine-generator and feedwater systems is shown in Figure 5.1. The values of pressure, temperature, etc., quoted in the text refer to full power operation and are approximate. Real values differ slightly from station to station. The systems we will consider in some detail are the Steam Generator, Main Steam, Turbine, Condenser, Feedheating and Feedwater, including the major process, control and protective systems.

Figure 5.1. Simplified Diagram of Balance of Plant Systems, including Steam Generator, Main Steam, Turbine, Generator, Condenser and Feedwater Systems.

5.1 STEAM GENERATOR (BOILER)

During normal operation, the heat transport system transfers heat from the reactor to the secondary coolant by way of the boilers. The boilers thus act as the principal heat sink for the reactor. Reactor heat is transferred from the heat transport system to the boiler feedwater. As a result, the boiler produces steam to drive the turbine.

Figure 5.2 shows a boiler typical of those used in large nuclear generating stations. Hot, pressurized heavy water enters the boiler and passes through the tube bundle. The heavy water inside the tube is hotter than the feedwater around the tubes. This allows heat transfer from the heavy water to the feedwater, causing the feedwater to boil.

The steam leaving the top of the tube bundle is about 90% water. To prevent damage to the steam piping, valves and (most important) the turbine, only dry steam must leave the boiler. Cyclone separators, located above the tube-bundle, dry the steam by giving the steam/water mixture a swirling centrifugal motion. The water, being denser than steam, moves to the outside area of the separator and is drained off. The steam that leaves the top of the cyclone separators has low moisture content but is still unacceptable for use in the turbine. The steam scrubbers, located above the cyclone separators, remove the last traces of moisture.

Water separated from the steam in the cyclone separator and steam scrubber drains to the outside of the boiler's tube shroud. The water flows down to the bottom of the boiler through the downcomer annulus and re-enters the tube bundle area enabling it to generate more steam. The amount of water cycling through the tube bundle, through the downcomer, is typically ten times as much as feedwater entering the boiler.

The water in the boiler moves through natural circulation without the use of pumps. The water and steam in the tube bundle move upward because of the decrease in density due to the addition of heat. The water that comes out from the cyclone separators is relatively dense, because it has no steam bubbles, and falls down the downcomer to begin the cycle again.

The feedwater flow in the boiler starts from the preheater. The preheater heats the feedwater to near saturation temperature. Inside the boiler the feedwater circulates up around the tube bundle and down the downcomer many times while acquiring the latent heat of vaporization, and finally leaves the boiler as nearly saturated steam.
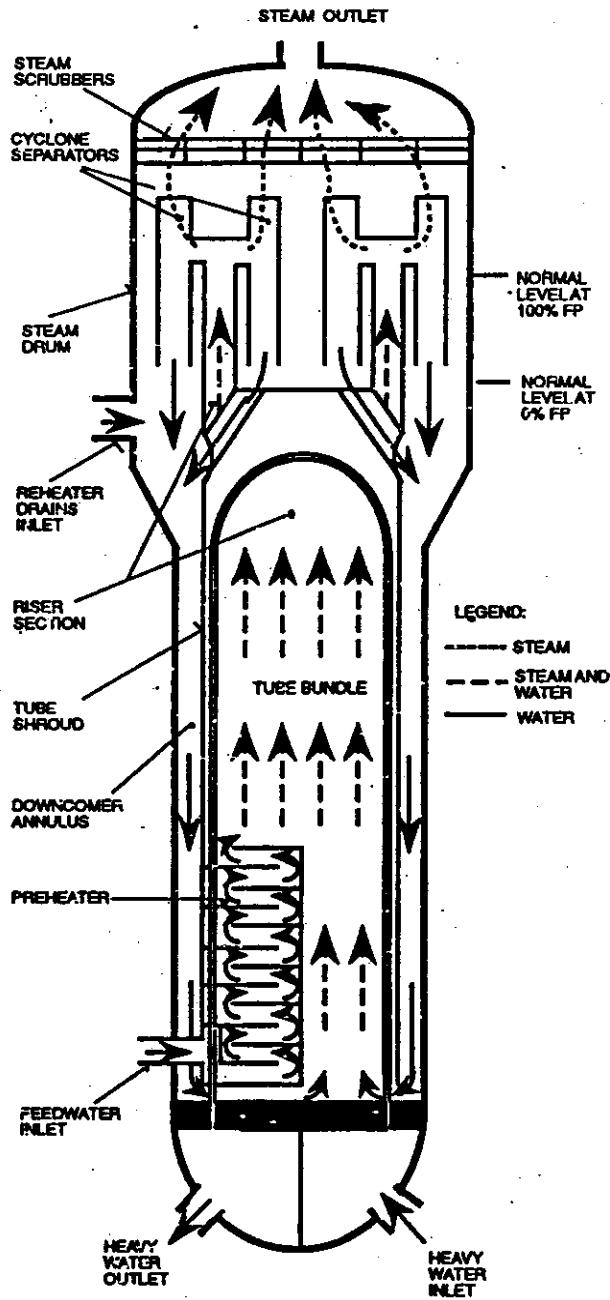
Figure 5.2. Typical Steam Generator or Boiler used in CANDU stations.

5.2 STEAM SYSTEM

Figure 5.3 shows a simplified schematic of the steam system and components typical of a large turbine unit. Safety valves installed on top of the boiler protect the steam system components from over pressure. The pressure from the boilers drives the steam to the high pressure (HP) turbine. On route to the turbine the steam travels through several valves. Two of interest are the emergency stop valves and the governor valves. The governor valve controls the quantity of steam flowing to the turbine, and therefore controls the speed of the turbine when not connected to the grid, and when the generator is synchronized to the grid, it determines the electrical output of the unit. Before reaching the governor valve the steam passes through the emergency stop valve. The emergency stop valve quickly stops the steam flow to the turbine in the event of an emergency that could damage the turbine.
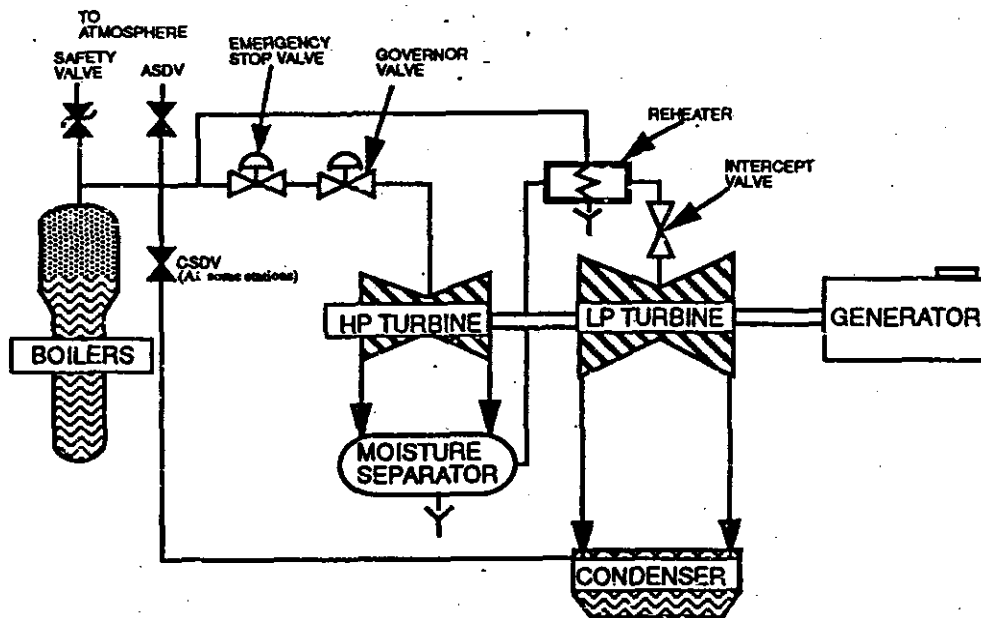

Figure 5.3. Simplified Steam System.

From the governor valve the steam passes through the HP turbine. The HP turbine converts the latent heat of the steam to mechanical energy. As the HP turbine uses the latent heat in the steam, the steam becomes wet (moist). Moisture content of more than 10% will cause excessive erosion on the turbine blades. Removing the moisture in the steam allows further conversion of the remaining available energy. The HP/LP arrangement of the turbine provides an opportunity at this stage to improve the quality of the steam to allow more energy to be converted with risk of damage to the turbine.

Steam leaves the high pressure turbine at approximately 900 kPa and 170°C at 10% moisture. It passes to the moisture separator which removes the moisture in the steam. Steam leaving the moisture separator has the same temperature and pressure as that at the turbine outlet but without moisture. It then passes through a reheater to heat the steam. This increases the work that the steam can do in the Low Pressure (LP) turbine. The reheater uses steam directly from the boiler to heat the steam from the moisture separator. The steam leaves the

reheater in a superheated condition at about 230°C and 900 kPa. Before entering the LP turbine, the steam passes through intercept valves. In a fashion similar to the emergency stop valves, these valves shut off steam to the LP turbine in an emergency. Steam passes through the normally open intercept valves, passes through the low pressure turbine, and is then exhausted to the condenser at approximately 5 kPa(a), 35°C and 10% moisture.

Stopping the flow of steam to the turbine results in increased boiler pressure. This can happen on a turbine trip. Reducing reactor power and getting rid of the steam prevents excessive boiler pressure build up. Adjusting the reactor power level too low can poison out the reactor. However, if the power level is kept above 60% full power, the reactor can keep operating. Providing an alternative heat sink, while operating at this power level, will prevent a boiler pressure increase. The alternate heat sink can be provided by blowing the steam to atmosphere or directly to the condenser. All CANDU units have large steam reject valves able to discharge steam either to the atmosphere or to the condenser with the reactor at 60% FP They are also equipped with smaller steam reject valves that are able to discharge steam to the atmosphere at the decay heat power level, if the condenser is unavailable.
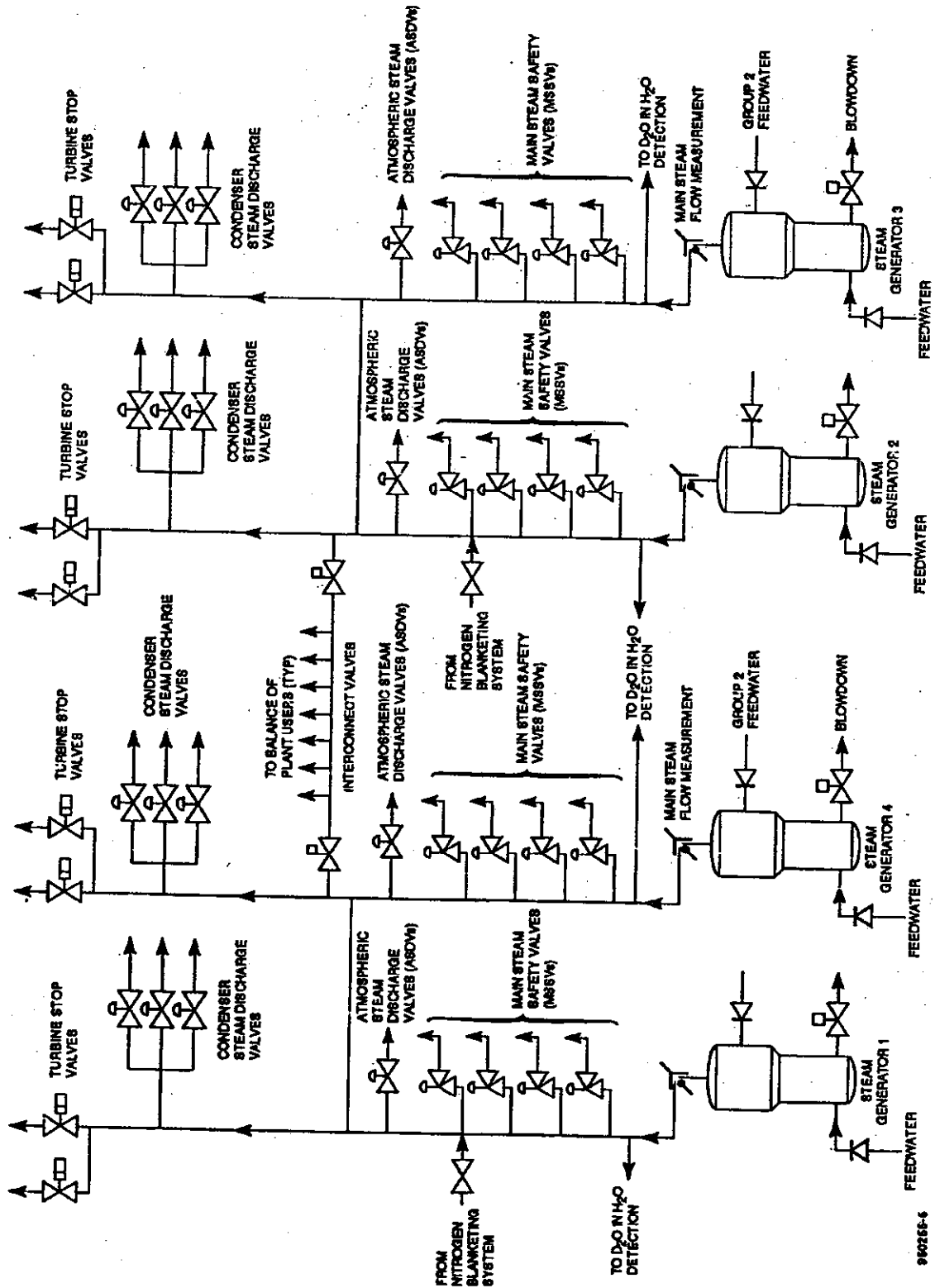
Main Steam

The steam system of a typical CANDU unit is shown on Figure 5.4. All the valves and other major equipment shown on the previous simplified diagrams can be identified, and the ones of particular relevance to the operation of the Main Steam system are discussed in the following sections.

Main steam safety valves are provided on each steam main to protect the steam system and the steam generators from overpressure.

Provision is made to detect heavy water in the steam. Connections from each steam line to the D_2O in light water detection system provide a continuous on-line measurement capability. Each sampling line also has a low pressure low temperature grab sample valve for periodic assessment of steam chemistry and tritium content.

It may be desirable to isolate any one pair of steam generators following a steam generator tube rupture, or a process failure while operating with a steam generator tube leak. This is accomplished by closing the appropriate turbine stop valves on the steam lines from two steam generators (the steam generator with the tube leak and its companion) and the appropriate steam main interconnect valves by remote manual operation from the main control room. Steam supply to balance of plant steam loads are provided by connections between the steam main interconnect valves. Closure of both steam main interconnect valves also isolates these steam loads.

Figure 5.4. Typical CANDU Main Steam system.

Steam Generator Blowdown

The steam generator blowdown system is provided to limit impurities in the steam generator. To accomplish this, provision has been made for a continuous blowdown, from the secondary side, at a mass flowrate equal to 0.1 percent of the steaming rate. In the event that the feedwater quality becomes poor, the blowdown rate can be increased to 0.3% of the steaming rate. Blowdown flow is taken from the downcomer area and the tube free lane. Shutoff valves are provided to close off flow from either of these areas. The blowdown rate is controlled by a control valve located in the turbine building. Environmentally and seismically qualified isolation valves are provided in each blowdown line to prevent draining of the steam generators, in the unlikely event of a line break. These valves automatically close on initiation of Group 2 feedwater. The steam generator blowdown discharges into tanks which reduce the temperature and pressure of the blowdown water and provide an effective separation of flashed steam from the water.

Condenser Steam Discharge Valves

The main function of these valves is to discharge live steam to the condenser on loss of turbine so that the reactor can continue to operate at the power required to prevent a 'poison-out'. They are also used to discharge steam on a loss of line, or on a turbine trip, so that the main steam safety valves do not lift. The valves function as follows:

a. During normal operation they operate on the pressure control mode, with an offset to bias them closed.

b. During 'poison-prevent', their steady state opening is proportional to the power mismatch between the poison-prevent reactor power level and actual turbine steam consumption.

c. On a turbine trip, they are first opened fully and then returned to the pressure control mode.

d. During shutdown to provide a heat sink through the condenser for decay heat removal.

Operation of the condenser steam discharge valves is conditional on the maintenance of adequate condenser vacuum.

Atmospheric Steam Discharge Valves

These low capacity valves are used to control steam generator pressure via the steam pressure control program. They are opened in proportion to the pressure error, normally with an offset in the steam pressure setpoint. These valves may also be used to provide a heat sink during shutdown for decay heat removal when the main condenser is unavailable.

Steam Generator Pressure Control

During normal operation, steam pressure is primarily controlled by adjusting reactor power. If for some reason the reactor regulating system does not allow the reactor to respond to pressure controller demands, or if a reactor power reduction occurs because of a trip, a stepback, or a setback, the reactor setpoint is controlled directly by the respective reduction signal, and the 'normal' mode of control of steam generator secondary side pressure is interrupted. Steam pressure control switches to the 'alternate' mode of adjusting the plant loads.

Turbine Control

When the plant is in the 'normal' mode, the turbine governor valves are controlled through the unit power regulator program; i.e., the unit power regulator calculates what the valve setpoint should be and pulses to that position. If the plant is in the 'alternate' mode, the steam generator pressure control system controls the turbine in response to the steam pressure error, steam pressure error rate of change, and the rate of change of reactor power.

The turbine has a low steam pressure unloader external to the control computers. This overrides directly the turbine governor action including the steam generator pressure control signal, and causes a fast runback of the turbine.

5.3 TURBINE

The turbine converts the pressure of the steam to rotational energy. This conversion involves transformation of the heat energy into high velocity steam through fixed nozzles. The fixed nozzles form the turbine fixed blades. The high velocity steam directs its kinetic energy on to the moving blades forcing them to move (rotate).

From the first set of fixed and moving blades, the steam then moves through succeeding sets to repeat the process of energy conversions. A set of fixed blade nozzles and moving blade constitutes a turbine stage. It is common to use a number of stages in a turbine to convert the useful heat energy in the steam into mechanical energy. The moving blades are attached to a blade wheel and the blade wheel is mounted on the rotor shaft. The high velocity steam leaving the nozzle drives the wheel which in turn rotates the shaft.

The turbine wheels and casing get progressively larger as the steam goes from the high pressure end to the low pressure end. This is necessary to accommodate the expansion of the steam as a direct result of pressure and temperature reduction. Steam entering the high pressure end of a modern nuclear turbine set is typically around 250°C and 4000 kPa. At this temperature and pressure one kilogram of steam occupies 0.05 m^3. The steam leaving the turbine unit and entering the condenser is typically around 35°C and 5 kPa(a). At this temperature and pressure one kilogram of steam occupies 25.2 m^3. The steam expands roughly five hundred times from the inlet to the exhaust. In a large turbine generator set it is usually not possible to accommodate the large volume of steam in one turbine unit. Normally one high pressure turbine will exhaust to two or more low pressure turbines in combination with the double flow design.

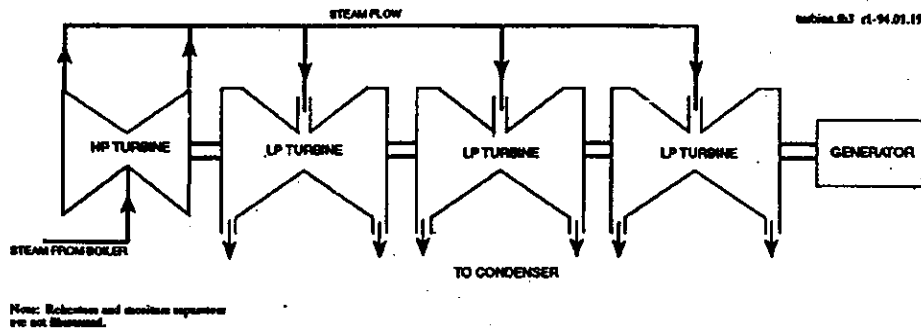Figure 5.5 shows a turbine unit typical of those installed at CANDU Generating Stations.

Figure 5.5. Typical Turbine Layout.

The double flow turbine design not only provides double the expansion volume within a common casing, it also balances the large pressure drop between the turbine steam inlet and exhaust which tends to force the blade wheels from the high pressure side towards the low pressure side.

Figure 5.6 shows a double flow turbine. Steam enters the turbine in the middle of the casing and expands outward in both directions before exhausting at the ends of the turbine. Turbine operational problems can still produce an imbalance in forces on the two sides. The resultant force will produce an axial thrust that is commonly dealt with by installing a thrust bearing.
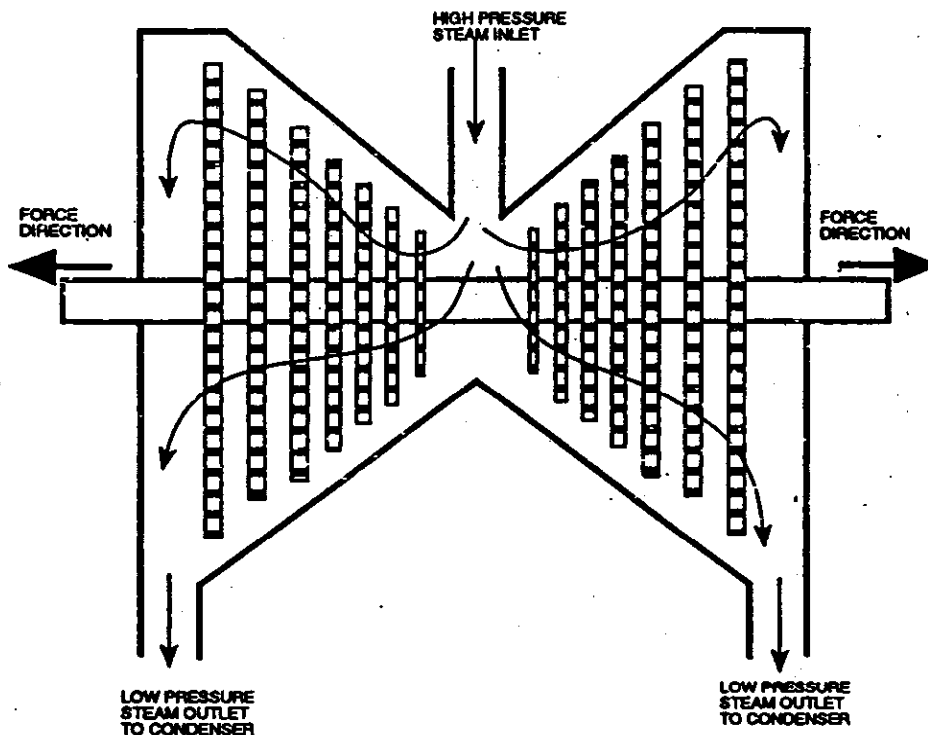

Figure 5.6. Double Flow Turbine

5.4 CONDENSER

The condenser is the final destination for most of the steam produced in the boiler, where it is turned back into water. The large decrease in volume creates a vacuum in the condenser. This permits steam flow from the high pressure boiler to the low pressure condenser so the turbine can extract mechanical energy efficiently.

Figure 5.7 shows a typical condenser used in most CANDU turbine units. The condenser cooling water (CCW) system supplies cooling water to the condenser. The water enters through the inlet water box, passes through the condenser tubes and discharges to the lake through the outlet water box. The turbine exhaust steam enters the condenser through the condenser exhaust trunk and reaches the outside surface of the condenser tubes. The large volume of CCW absorbs the latent heat of vaporization of the steam. The condensate falls into the bottom of the condenser and collects in the hotwell.
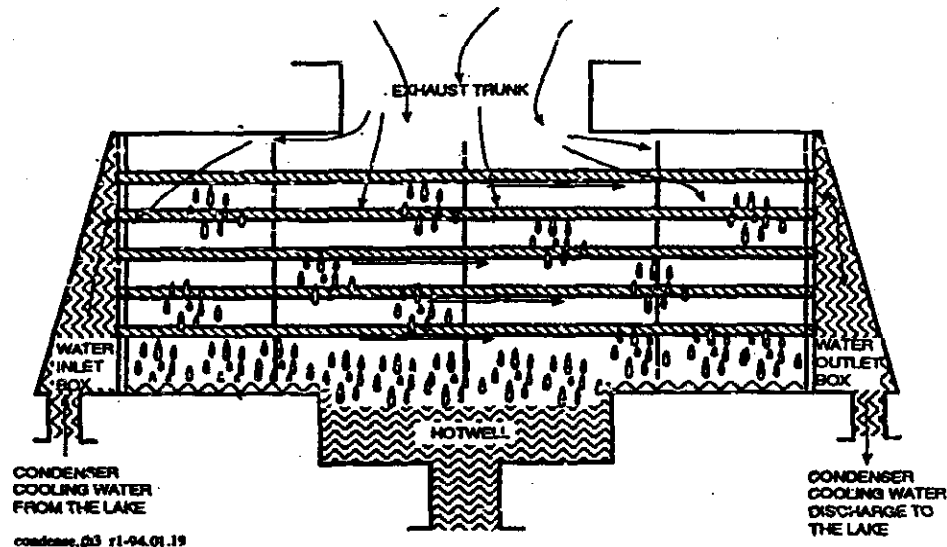

Figure 5.7. Typical Condenser used in CANDU stations.

The CCW flow maintains the saturation temperature of the condensate. This is achieved through proper adjustment of CCW flow. Maintaining the condensate temperature at its saturation point maximizes the retention of the condensate's heat. The lower the turbine exhaust temperature and pressure the greater the amount of steam energy that can be converted into mechanical energy in the turbine. As mentioned, steam leaves the turbine at about 35°C and 5 kPa absolute. This condition is near a perfect vacuum. This allows roughly 35% more energy extraction than if the steam is left at atmospheric pressure (101.3 kPa). The condenser provides the means of maintaining this low absolute pressure at the turbine exhaust through condensation of steam (the 25.2 m³ of steam reduces to 0.001 m³ of water or 25200 times volume reduction).

The steam/feedwater system is a closed loop because it would be wasteful and expensive to reject the clean, chemically treated, demineralized water after it has completed its work in the turbine. It would also be wasteful to throw away the heat held by the 35°C condensate, especially as the CCW flow is adjusted to keep the condensate at saturation temperature and not cool it more than necessary for condensation.

5.5 FEEDWATER SYSTEM

The feedwater system supplies normal feedwater to the steam generators. The feedwater system comprises the main feedwater pumps on Class IV power and a diesel-driven auxiliary feedwater pump. The feedwater is demineralized and preheated light water. The feedwater lines run from the feedwater regulating valve station in the turbine building to the reactor building and hence, to each steam generator.

Figure 5.1 shows a simplified steam system and boiler feedwater system. The feedwater system is generally divided into three parts:

- low pressure feedheating system;

- deaerator and storage tank;

- high pressure feedheating system.

The water leaving the condenser is at relatively low temperature and pressure. A series of heat exchangers raises the condensate temperature to 170°C. The preheaters then increase the temperature to 240°C (almost saturation temperature in the boiler). A set of pumps, known as boiler feed pumps (BFP), force the feedwater into the boilers operating at 4000 kPa.

Low Pressure Feedheating System

The first stage in the boiler feedwater heating is through the LP feedheating system. The condensate extraction pump (CEP) delivers the condensate from the condenser hotwell to the LP feedheaters. The low pressure feedheating system gets its name from the low pressure condition of the feedwater, at about 1400 kPa, compared to the 4000 kPa in the boiler.

The LP feedheaters use extraction steam (wet steam removed from the turbine before it reaches the exhaust end) from the LP turbines as their heating medium. The extraction steam transfers its latent heat of vaporization to the feedwater through a process similar to that in the condenser. A series of low pressure feedheaters heat the feedwater. The extraction steam condenses in the shell of the heater. A separate pump recovers this condensate by pumping it to the condenser hotwell. The feedwater leaves the last LP feedheater at approximately 80°C to 100°C. The heated feedwater then goes to the next stage of the feedheating process.

Deaerator and Storage Tank

The deaerator is the next stage in the feedwater heating process. This is the highest vessel in the system. The deaerator adds heat to and removes non-condensable gases from the feedwater. Some of these gases can increase the corrosion rate of the metals in the high pressure feedheating system and boiler. All non-condensable gases will take-up space in the steam system we wish to occupy with steam.

Figure 5.8 shows a typical deaerator and its associated storage tank. The incoming feedwater enters the deaerator near the top and sprays downward over cascade trays. Extraction steam from the LP turbine enters the deaerator near the bottom and passes upward. As a result the feedwater heats up to about 125°C. The steam passing over the water droplets scrubs the non-condensable gases off their surface. As the extraction steam condenses, the water droplets release the noncondensable gases which are vented to the atmosphere. The deaerated feedwater and condensed steam drain from the deaerator into a storage tank. The storage tank supplies water for boiler operation.
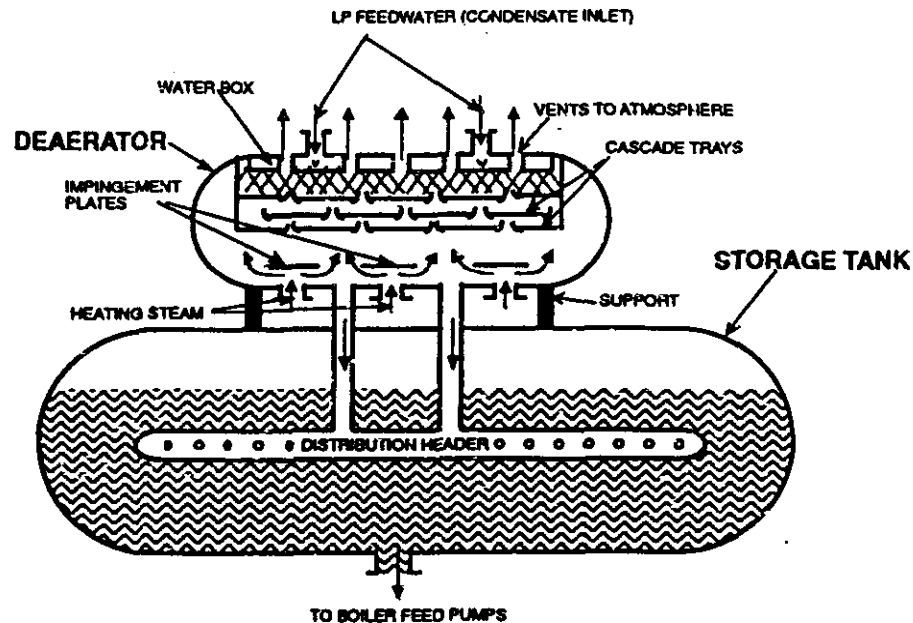

Figure 5.8. Simplified Deaerator and Storage Tank Assembly

High Pressure Feedheating System

From the deaerator storage tank, the feedwater undergoes one more stage of having its temperature and pressure raised. The boiler feed pumps (BFP) take suction from the deaerator storage tank and raise the feedwater pressure to between 4 and 7 MPa. The pump discharges the high pressure feedwater to the high pressure (HP) feedheaters. The HP feedheaters heat the feedwater to about 170°C. HP feedheater operation and construction are similar to that of the LP feedheaters. Extraction steam from the HP turbine normally supplies the heating medium.

The feedwater regulating valve controls the flow of feedwater into the boiler. This valve allows sufficient feedwater to enter the boiler to match the steam flow leaving it, so as to maintain a constant water mass in the boiler. To do this, the controller for the valve compares steam flow out of the boiler with feedwater flow into the boiler and positions the valve to make the two equal. It also compares the actual boiler water level with a predetermined programmed level and positions the valve to make these two equal.

It is critical to maintain a proper boiler level. If the boiler water level is too high, the cyclone separators and scrubbers will not operate properly. This results in wet steam being delivered to the turbine which could lead to damage to the turbine blades. If water level is too low, there would not be enough inventory to cool the heat transport coolant.

CANDU Boiler Feed Pumps and Level Control

Figure 5.9 shows the boiler feed pumps, associated valves, the two high pressure heaters and the steam generator level control valves as configured for a typical CANDU generating station.

Three main boiler feed pumps are required to supply the necessary flow, and one additional pump is on standby. Two auxiliary pumps are also provided, these are sized so that either one can supply the flow to remove decay heat in case of a loss of class IV supply to the main pumps. Connections to the Condensate system allow for recirculating flow when the pumps are operating but the level control valves are closed.

The level in each steam generator is controlled individually. Since the measured level in a boiler is higher for a given mass of inventory as the power level increases due to the expansion of the water with increased boiling, the level setpoint as well as alarm and trip settings are increased automatically as a function of reactor power.

Because of safety, range of control and maintenance considerations, each steam generator has a set of three control valves for feedwater control connected in parallel: one small valve to control feedwater during shutdown, startup, and low power operation, and two larger valves to control feedwater for on-power conditions. Each of the two large valves can handle the full power flow requirements. Isolating valves are provided for each control valve.

The steam generator level control system balances feedwater to steam flow for all operating conditions: fast reactor runup, reactor setback, turbine trip and 'poison-prevent' mode. The water level setpoint is automatically programmed over a set range as a function of load.

Chemical Control

Boiler steam and feedwater system construction in almost all CANDU stations uses carbon steel, copper alloys and nickel alloys. Each metal is susceptible to corrosion at a different pH level. A compromise pH of 8.8 to 9.3 is relatively safe for all metals involved. Chemical addition at the discharge of the condensate extraction pump ensures the appropriate pH level.
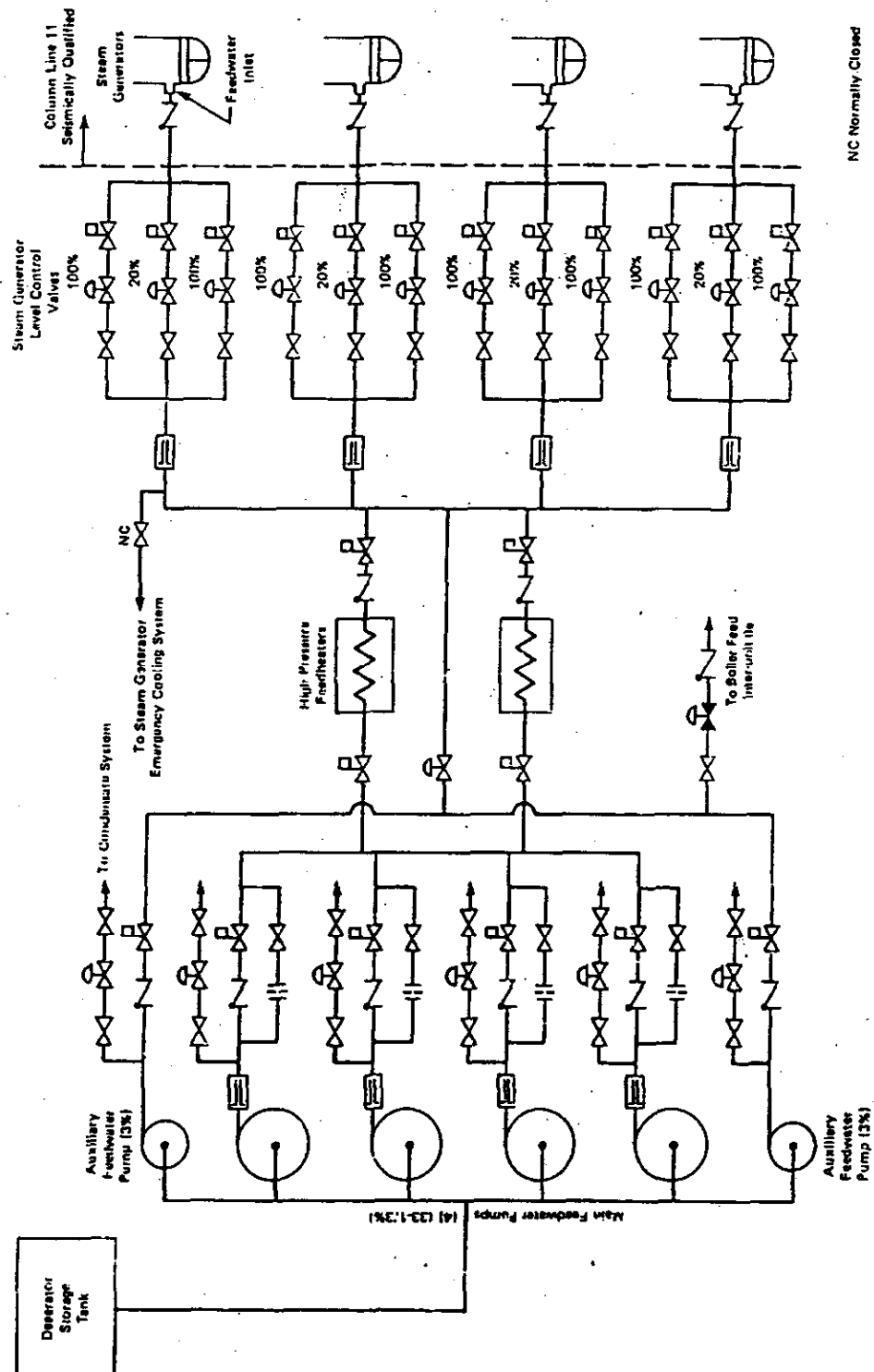
Figure 5.9. Typical CANDU Boiler Feed and Level Control System.

Other methods used to prevent corrosion are:

- oxygen removal from the system,

- chemical addition to react with oxygen.

Most oxygen is removed from the system by the scrubbing action of the deaerator. Hydrazine addition to the feedwater, after the deaerator, removes the remaining oxygen. Its reaction with oxygen produces noncorrosive nitrogen gas and water. Unfortunately, hydrazine also produces ammonia which attacks copper alloys.

High quality feedwater and makeup water is vital as low quality will produce deposits in the boiler and turbine causing:

- reduced heat transfer because of an insulating scale layer on the boiler tube surface;

- increased risk of stress corrosion cracking;

- corrosion of tubes and other components.

All will shorten the life of the boilers and turbines. Demineralization, deaeration, oxygen removal and pH control ensure that we have good quality boiler water. A blowdown system in each boiler allows removal of any impurities that collect in the boilers. This system minimizes accumulation of impurities by draining the contaminated water out of the boiler. Blowdown can be intermittent or continuous, depending on the water condition.

5.6 GENERATOR

Figure 5.10 shows a simplified arrangement of a generator coupled to a steam turbine drive. The stationary conductors (coils) and the associated iron cores are referred to as a stator. Conductors (coils) and the associate iron core mounted on the shaft are referred to as a rotor.

Insulated slip rings on the shaft transfer DC current to create a magnetic field in the rotor. The stator windings act as the conductors for the main generator current while the turbine provides the mechanical torque on the shaft of the generator. The rotating motion provided by the shaft produces the relative motion between the rotor magnetic field and the stator conductors. As a result, a voltage is induced in the stator conductors and transferred to the transmission lines through a step-up transformer.

In a generator, the rotor velocity determines the frequency. When the generator is connected to the grid the frequency is fixed at 50 or 60 Hz depending on the bulk electric system. Since the frequency for the Grid is controlled at a fixed value, the velocity of the rotor is kept constant.
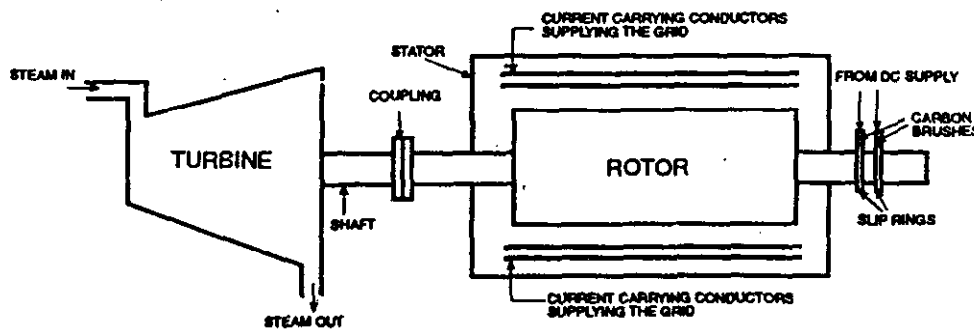
Figure 5.10. Simplified Arrangement of a Generator Coupled to a Turbine Drive.

As electrical consumers use electricity they create a load current on the Grid thereby increasing counter torque to the turbine shaft. The tendency of the turbine is to slow down as counter torque is increased which would decrease the frequency. The governing system senses the decrease in rotational velocity and produces an increased counter torque by admitting more steam to the turbine, thereby producing more shaft mechanical power and maintain the generator speed. In practice, nuclear power plants are seldom used to control Grid frequency, hydraulics and thermal plants with governing systems specifically designed for this purpose would normally have that role. As we have seen in Chapter 1, the Unit Power Regulator would monitor generator output and maintain it at the setpoint by varying the amount of steam flow to the turbine via the governing system, in a manner analogous to that described above, but without any change in generator frequency.

Generator Cooling

The modern electric generator for a steam power station is an extremely efficient machine. Approximately 98% of the mechanical power delivered on the shaft from the turbine is converted to electrical power. The remaining 2% appears as heat in various places in the generator. Two percent does not appear to be very much until you consider that 2% of a 900 MW machine is equal to 18 MW. Since all of this 18 MW is converted to heat, it is like putting a heater of this size inside the generator.

The heat that is produced in a generator comes from several sources including windage (gas friction) between the rotor and the circulating cooling gas, the electrical heating due to the current resistance in the windings of both the rotor and stator, and the electrical heating due to current induced in the structural material of the rotor and stator.

Even small increases in the operating temperature of a generator will lead to rapid deterioration of the insulation on the windings. For this reason, two systems are provided to cool the generator. One system uses hydrogen circulated through the generator. Hydrogen has the advantages of:

• better thermal conductivity than air;

• less damaging to insulation than air;

• less dense than air so less heat is produced from windage.

The disadvantage is that it is explosive when mixed with air. To avoid this hazard, the generator requires very good seals to prevent air inleakage or leakage of hydrogen out of the generator.

By itself, the hydrogen cooling system is inadequate. To complement it, a stator cooling water system is also provided. The conductors in the stator are hollow and water is circulated through them. This water has to be exceptionally pure to prevent leakage of current from the stator conductors to ground through the coolant.

Turning Gear

When a turbine comes to rest, after operating, the cooler and denser steam tends to collect in the lower half of the cylinder and makes the lower half of the rotor cool quicker than the upper half. This causes the shaft to 'hog' (bend upwards). When at rest and cool, the shaft will begin to 'sag' under its own weight. If the turbine shaft is not rotated, hogging, especially above a critical temperature, can become permanent and the shaft would have to be sent to the manufacturer for heat treatment and straightening. Sagging does not usually become permanent but it takes time to recover the sag. To prevent a bent shaft due to sag or hog the shaft is rotated by a turning gear which is a motor driven gear train mechanism on the turbine generator shaft.

Lubrication System

Each unit of the turbine and the generator has its own rotor/shaft that is supported at each end by journal bearings. Journal bearings get hot due to friction and heat conduction along the shaft from hot parts of the turbine. The journal bearings are normally lined with white metal known as antifriction metal or babbitt, which is a lead-tin alloy with a melting point that can be as low as 182°C. A centralized lubricating system is employed to protect the bearings from damage due to metal to metal contact and high temperature. This extends the life of the bearings and reduces the chance of failure. A bearing failure is a very serious incident as far as the turbine-generator is concerned and would cause extensive damage. For this reason it is always important to have sufficient oil flow through the bearings for lubrication and cooling purposes.

5.7 CONVENTIONAL PLANT SERVICES

Conventional plant services include water supply, heating, ventilation, air conditioning, chlorinating, fire protection, compressed gases and electric power systems.

The water supply systems provide cooling water, demineralized water and domestic water to station users.

Heating, ventilation and air conditioning is provided to ensure a controlled environment during winter and summer.

Chlorination systems are used for treatment of domestic water, fresh water supply to the pre-treatment plant, condenser cooling water and raw service water. Separate chlorination systems are provided, in the water treatment plant, in the Group 1 pumphouse, and the Group 2 pumphouse.

Compressed gas systems supply compressed air, helium, nitrogen and carbon dioxide gases, and vacuum to all plant systems as required.

Provision is made to detect heavy water in the steam. Connection from each steam line to the D_2O in light water detection system provide a continuous on-line measurement capability. Each sampling line also has a low pressure low temperature grab sample valve for periodic assessment of steam chemistry and tritium content.