Moderator, Heat Transport and Steam Systems

by

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Abstract

CANDU reactors, like other water-cooled reactors, utilize the heat released by the fission of uranium fuel in the reactor core to generate steam, which is subsequently used to drive a turbine-generator and produce electricity. Unlike Light Water Reactors (LWRs) in which the H2O contained in the Reactor Pressure Vessel serves as both moderator and coolant, the CANDU Pressurized Heavy Water Reactor (PHWR) incorporates two completely independent systems for the moderator and the coolant: the high pressure and high temperature heat transport system (reactor coolant system) that circulates D2O coolant through the fuel channels to remove the heat produced by fission in the fuel, and the cool low pressure moderator system that circulates the D2O moderator surrounding the fuel channels through heat exchangers to remove the heat generated in the moderator.

This paper provides a brief description of the moderator and moderator and auxiliary systems, the heat transport and heat transport auxiliary systems, and the steam system, which delivers steam from the steam generators to the turbine.

1. Background

Unlike Light Water Reactors (LWR), in which the H2O contained in the Reactor Pressure Vessel serves as both moderator and coolant, the CANDU Pressurized Heavy Water Reactors (PHWR) incorporates two completely independent systems for the moderator and for the coolant; the high pressure and high temperature heat transport system (reactor coolant system) that circulates D2O coolant through the fuel channels to remove the heat produced by fission in the fuel, and the cool low pressure moderator system that circulates the D2O moderator surrounding the fuel channels through heat exchangers to remove the heat generated in the moderator.

Typically, less than 2.5% of the neutron moderation (slowing down) is provided by the D2O coolant in the fuel channels; the remaining 97.5% is provided by the D2O moderator surrounding the fuel channels.

All reactivity control devices for both the reactor regulating system and the reactor shutdown systems are located in the cool low-pressure moderator; no reactivity control devices penetrate the heat transport system pressure boundary. In addition, no chemicals are added to the high-pressure heat transport system for reactivity control.

The following important CANDU design and operating characteristics result from the separation of the moderator and coolant;

- Changes in coolant temperature **do not** significantly affect reactivity; hence events such as a fast heat transport system cooldown or the injection of cold heavy water into the heat transport system do not result in a reactivity excursion.

- The cool moderator does not contribute energy to the containment during a loss of coolant accident. Instead, the moderator is an effective heat sink, and can remove decay heat from the fuel, in the unlikely event of a loss of coolant accident coincident with a loss of emergency core cooling, even if there is no coolant in the fuel channels.

- The relatively simple reactivity control devices (due to their location in the cool low pressure moderator) facilitate the economic provision of comprehensive neutronic measurement and reactivity control systems, and economically allows completely reactivity control devices to be used for the reactor regulating system and the two safety shutdown systems.

- The low pressure moderator environment inherently precludes the potential for the ejection of reactivity control devices (including the safety shutdown system devices) by pressure, or for the impediment of insertion of the reactivity control devices by pressure.

- Largely because the D2O moderator is not lost on a loss of coolant from the heat transport system, a loss of coolant does **not** tend to shut the reactor down, as is the case for LWRs. Reactivity instead increases with voiding of the fuel channels. CANDU plants accommodate the reactivity addition that results from voiding of the fuel channels by arranging the heat transport system to reduce the rate of void reactivity addition rate, and by providing two independent fully capable fast acting safety shutdown systems. In addition, the positive reactivity insertion resulting from the loss of coolant from the heat transport system facilitates the use of fast neutronic measurements to initiate a reactor trip, to complement the process trip measurements, and thereby enhance the high reliability of the two independent safety shutdown systems.

- The residence time of the heat transport D2O coolant in the fuel channels constitutes a small fraction of the time required for the coolant to complete one pass of the heat transport system circuit. Hence the heat transport system coolant provides a very small fraction of the neutron moderation in the reactor, oxygen levels in the coolant are readily limited to values acceptable for carbon steel, facilitating the use of carbon steel for all heat transport system piping.

As described above, CANDU reactors utilize heavy water (D_2O) for both moderator and coolant, and employ materials (principally zirconium and zirconium alloys) with very low neutron capture in the core (for example, for fuel channels and reactivity control device guide tubes). These features assure a very high level of neutron economy, and eliminate most of the parasitic neutron absorption that occurs in LWR reactor cores.

As a result of the neutron economy and efficient neutron moderation provided by the D2O coolant and moderator, CANDU reactors can operate on natural uranium fuel, or other fuels with low fissile material content, including spent fuel from light water reactors. The fissile U 235 content of irradiated (spent) fuel from CANDU is very low, generally below that of the tailings of enrichment plants producing enriched uranium for LWR fuel. In addition, the addition of light water to the CANDU core serves to shut the reactor down. Hence, the addition/removal of light water to compartments located in the core between columns of fuel channels is used for short-term reactor regulation. The addition of light water (without boron) by the emergency core cooling system following a loss of coolant accident adds negative reactivity, and serves to shut the reactor down.

Due to the low fissile content of both new and irradiated CANDU fuel, there is no potential for criticality for CANDU fuel stored in air or light water, regardless of the storage configuration. Boron addition to spent fuel storage bay water is not required.

2. Moderator Systems (Figure 1)

2.1 General

The principal function of the heavy water in the calandria is to moderate (slow) fast neutrons produced by the fission of the fissile fuel contained within the fuel bundles. In addition, the heavy water moderator in the calandria can cool the fuel in the fuel channels in the very unlikely event of a Loss of Coolant Accident (LOCA) during which coolant is lost from the heat transport system coincident with the failure of the Emergency Core Cooling System to operate. In this postulated event, heat is transferred to the pressure tube from the fuel by a combination of conduction and radiation, and is rejected to the surrounding moderator. The fuel cooling capability of this heat sink is assured by controlling the heavy water temperature in the calandria within specified limits.

During normal plant operation, most of heat generated in the heavy water moderator is by Gamma radiation produced by the fission process, a lessor amount is generated by the moderation (slowing) of the fast neutrons, and a small amount of heat is transferred to the moderator from the fuel channels. The total heat appearing in the heavy water moderator is about 4% of reactor thermal power.

The moderator system and the moderator auxiliary systems that provide a support function to the moderator system are described in sub-sections below.

2.2 Moderator System (Figure 2)

The Moderator System consists of a closed recirculating heavy water circuit. The moderator system circulates the heavy water moderator through the calandria to remove moderator heat during reactor operation; moderator heat is rejected to the Recirculated Cooling Water System. The location of the moderator inlet nozzles and outlet nozzles on the sides of the calandria ensures a relatively uniform moderator temperature distribution within the calandria, and assures that the heavy water temperature in the calandria is maintained within a range that is satisfactory for both normal operation and safety functions. The operating pressure at the moderator free surface, which is maintained within a specified range above the top row of fuel channels, is slightly above atmospheric.

The low-pressure moderator system is fully independent of the heat transport system. The moderator system includes two 100 percent capacity pumps and two 50 percent capacity heat exchangers. The materials in the calandria and moderator system, which contact the heavy water moderator, are either stainless steel or zirconium alloys. These materials are compatible with the low temperature and slightly acidic moderator heavy water chemistry conditions. The reliability of the moderator system is ensured by careful design and appropriate component, instrument, and power supply redundancies.

The moderator system head tank maintains the moderator level in the calandria within the required range by accommodating moderator swell and shrinkage resulting from temperature fluctuations.

Potential heavy water leak sources in the moderator and moderator auxiliary systems are minimized by using welded construction, seal welding and bellows seals wherever practical. All potential leak sources in the moderator system are connected to the moderator D_2O collection system.

2.3 Moderator Auxiliary Systems (Figure 1)

The moderator system is complemented by several auxiliary systems, described below; the moderator auxiliary systems serve to maintain the operating parameters of the moderator system within the specified operating ranges.

- The **moderator purification system** maintains the purity of the heavy water moderator and minimizes corrosion of components and crud activation by controlling the pD (pH) and by removing impurities present in the D_2O. The moderator purification system is also used to adjust the concentration of poisons, and to remove the soluble gadolinium poison following the operation Shutdown System 2 (SDS2). The moderator purification system consists of the moderator purification heat exchanger, a filter, and 5 ion exchange columns.

  The moderator purification system is a closed loop. Flow is taken from the discharge line from the moderator pumps; the flow then passes through the moderator purification heat exchanger (cooled by recirculated cooling water) to lower its temperature and thereby extend resin life, through the filter for the removal of suspended solids, and finally through one or more of the ion exchange columns. Flow is then returned to the suction of the moderator pumps. Resins in the ion exchange columns are periodically exchanged using a slurry process. A Deuteration system is provided to displace ordinary water from fresh resins prior to their introduction into the moderator purification system ion exchange columns, and a dedeuteration system is provided to displace the D2O from the spent resins prior to their transfer to the spent resin storage facility. The heavy water recovered is transferred to the heavy water upgrading facility.

- The **moderator cover gas system**, consisting of a closed recirculating circuit, controls the concentration of deuterium gas in the moderator cover gas by catalytically recombining deuterium and oxygen gases that are produced by the radiolysis of the heavy water moderator in the calandria, to re-form heavy water. Helium, which is chemically inert and not activated by neutron irradiation, is used as the cover gas for the moderator system.

  The moderator cover gas system includes two 100% capacity compressors, each powered by electric induction motors provided with Class III power; one compressor is normally in operation, with the other on standby.

  A helium supply, from a helium bottle station, provides makeup helium to the cover gas system as required. A small amount of oxygen, from standard oxygen cylinders, is provided to the recombination units to assure that an excess of deuterium does not persist in the cover gas.

- The **Moderator liquid poison system** adds negative reactivity to the reactor through the addition of a solution of neutron absorbers in heavy water to the moderator when required for reactivity adjustments. The moderator liquid poison system is also utilized to add sufficient soluble neutron absorbers to the moderator to preclude criticality during guaranteed reactor shutdown conditions. The liquid neutron absorbers employed are boron as boric anhydride, and gadolinium as gadolinium nitrate, dissolved in D_2O.
- The **moderator D_2O collection system** facilitates the draining of moderator system components for maintenance, and collects heavy water leakage from anticipated leakage sources in the moderator and moderator auxiliary systems. Moderator heavy water

collected is transferred to the heavy water management systems for cleanup and upgrading.

3. Heat Transport Systems (HTS)

3.1 General

The heat transport system circulates pressurized heavy water through the fuel channels to remove heat produced by the fission of uranium fuel. The heavy water coolant carries the heat to the steam generators where it is transferred to ordinary water to produce steam. The ordinary steam produced in the steam generators subsequently drives the turbine generator or, alternatively, may be provided to process users. The heat transport auxiliary systems support the operation of the heat transport system, and maintain the operating parameters within specified limits. The principal advantages of using heavy water as the coolant in CANDU include its very low neutron absorption and high heat capacity

CANDU heat transport systems make extensive use of carbon steel, which is ductile, and relatively easy to weld and easy to inspect. Specific requirements are imposed on heat transport system materials to limit corrosion (minimum limit for the chromium content, for example) and minimize reactivity production and transport (low cobalt content in materials for example). There are two major HTS coolant chemistry control requirements; the first is the maintenance of low concentrations of dissolved oxygen, which ensures low rates of zirconium alloy and carbon steel corrosion; the second is appropriate alkalinity, to ensure acceptable low rates of carbon steel corrosion.

The principal performance features for the heat transport system and the heat transport auxiliary systems are as follows:

- Reactor coolant circulates through the fuel channels at all times during reactor operation, shutdown and maintenance.
- HTS pressure is controlled for all normal modes of operation by the pressure and inventory control system.
- The HTS is protected from overpressure by instrumented relief valves and by the reactor regulating and safety shutdown systems.
- HTS coolant inventory is controlled for all normal modes of operation by the pressure and inventory control system.
- The shutdown cooling system, capable of operation at full HTS temperature and pressure, can remove decay heat following reactor shutdown, and lower the HTS temperature to facilitate maintenance. This system also permits draining the D2O coolant from the HTS pumps and steam generators for inspection and/or maintenance, while maintaining fuel cooling.

- Purification by filtering, ion exchange and degassing, and chemical addition maintains the chemistry and purity of the HTS coolant.
- The Emergency Core Cooling (ECC) system supplies light water to the HTS in the event that reactor coolant is lost from the HTS.
- Heavy water leak sources are minimized by using welded construction and bellows-sealed valves where practical. Components that require draining for maintenance and/or inspection and potential leak sources are connected to the heat transport D_2O collection system.

3.2 Heat Transport System (HTS) (Figure 3)

The heat transport systems in CANDU plants are configured to limit the rate of positive void reactivity insertion into the reactor in the unlikely event of a loss of coolant from the transport system. The particular heat transport system arrangement selected is dependent on the size of the reactor. The CANDU 6 heat transport system arrangement, which is effective for small and medium sized CANDU reactors, comprises two loops. Each loop circulates pressurized heavy water coolant through the 190 of the fuel channels located to one side of the vertical centre-plane of the reactor. Hence, the immediate effects of a LOCA are limited to the loop experiencing the LOCA, thereby reducing the rate of positive reactivity insertion and increasing shutdown system margins.

Each loop contains 2 pumps, 2 steam generators, 2 inlet headers and 2 outlet headers, and connecting piping, in a 'figure-of-eight'; in this arrangement, the pumps and steam generators of each HTS loop are connected in series. Feeders connect the inlet and outlet ends of the fuel channels to the inlet and outlet headers, respectively.

The flow through the fuel channels is bi-directional (i.e. in opposite directions in adjacent channels). The feeders are sized such that the coolant flow to each channel is proportional to time averaged channel power. The time averaged enthalpy increase of the coolant is therefore about the same for each fuel channel.

The steam generators, HTS pumps and headers are located above the reactor to facilitate circulation of the coolant by thermosyphoning (natural circulation), thereby assuring fuel cooling following reactor shutdown in the event that the HTS pumps are unavailable. This configuration also permits the HTS coolant to be drained to a level just above the headers to facilitate the inspection and/or maintenance of the HTS pumps and steam generators.

The heat transport system operating pressure is one of the key elements in optimizing the specific capital cost of CANDU power plants; high HTS pressure permits high coolant operating temperature and, hence increased steam pressure and increased thermal efficiency. However, increased HTS pressure requires the pressure tube wall thickness to be increased, which incurs a fuel burnup penalty. The CANDU 6 heat transport system (outlet header) operating pressure of 9.9 MPa(g) represents a good economic balance. In order to enhance overall plant economics by reducing steam generator size and by reducing the steam generator D2O hold-up, boiling in the outer portion of the fuel channels at high power is permitted; the maximum outlet header steam quality is 4% at full power.

An overview of CANDU heat transport system design parameters is provided in Table 1.

The heat transport pump is driven by a vertical, totally enclosed, air-water cooled squirrel cage induction motor. The pump/motor unit has sufficient rotational inertia so that, on loss of electrical power to the motor, the rate of coolant flow reduction matches the reactor power decrease following a reactor trip. Natural circulation maintains fuel cooling after the pumps stop; the shutdown cooling system can subsequently be brought into operation.

The steam generator is illustrated in Figure 4. The steam generators transfer heat from the reactor coolant, which flows within the steam generator tubes, to ordinary water surrounding the steam generator tubes on the secondary side to produce steam. CANDU steam generators consist of an inverted vertical U-tube bundle in a cylindrical shell. Steam separating equipment is provided in the steam drum in the upper part of the shell.

Feedwater enters the baffled preheater section of the steam generator secondary side, and flows over the outlet end of the U-tube bundle. Water at saturated temperature from the preheater mixes with recirculated water flowing over the hot leg section of the tube bundle.

The steam-water mixture rising from the upper end of the U-tube bundle passes through cyclone steam separators. The separated water recirculates to the tube bundle through a shrouded annulus, and the steam, with less than 0.25 percent moisture by weight, leaves the steam generator through the steam generator steam outlet nozzle.

Feedwater flow control valves in the supply lines to each steam generator control the water level in the steam generators within the defined operating limits based on steam generator level measurement, steam flow measurement, and feedwater flow measurement.

The prevention of steam generator tube failures is important in all indirect-cycle nuclear power plants. Thus, careful consideration is given to secondary side chemistry and to the control of inadvertent additions of undesirable chemical species to the secondary side of the steam generators through steam and feedwater systems leakage. CANDU secondary side systems use All Volatile Treatment (AVT) and high quality makeup water, exclude alloys containing copper as a major constituent, have leak tight titanium condensers and optimize operating chemistry to minimize the transfer of corrosion products into the steam generators.

High recirculation ratios and relatively low heat flux, in combination with comprehensive chemistry control, material specifications and detailed attention to design, assure long life and relatively low maintenance requirements for CANDU steam generators.

Each steam generator is supported from the fuelling machine vault floor by a cylindrical column, which connects to the steam generator head. A backup support system consisting of four cables (normally unloaded), connect to the steam generator at about the vertical mid-point of the steam generator shell, and attach to embedded parts in upper level of the steam generator enclosure structure.

3.3 Key Heat Transport Auxiliary Systems

The heat transport system is complemented by auxiliary systems that support its operation and maintain operating parameters within specified operating ranges. These systems are discussed below.

The **pressure and inventory control system** (Figure 5) provides pressure and inventory control and overpressure protection for the HTS. The principal system components are the pressurizer, the degasser-condenser, the D_2O feed pumps and associated control and safety valves and instrumentation. The principal system functions are to:

- Control HTS pressure over the design range of HTS and reactor operating modes.
- Control HTS inventory over the design range of HTS and reactor operating modes.
- Limit HTS pressure increases or decreases caused by transients to acceptable values.
- Accommodate HTS coolant thermal expansion and contraction associated with warm-up, start-up, power maneuvering, shutdown, and, cool-down.
- Provide degassing of the HTS coolant.

A common pressurizer connects to both heat transport system loops; fast acting isolation valves, which close on a Loss Of Coolant Accident signal, are provided in the lines connecting the pressurizer to each loop. The pressurizer, which contains liquid D2O and D2O steam at all times, serves to reduce the severity of HTS pressure transients (increases or decreases) during plant operation. During normal operation at power, the pressure in the heat transport system is maintained by the pressurizer; energy is added to the pressurizer by electric heaters located in the bottom section of the pressurizer when an increase in pressure is required, and energy is rejected from the pressurizer by discharging steam from the steam volume in the upper section of the pressurizer via the steam bleed valves.

The heat transport system heavy water inventory is maintained within defined operating limits by feeding heavy water into the heat transport system from one of the two 100% capacity D2O feedpumps, or by bleeding heavy water from the heat transport system via the D2O feed valves. Inventory control is based on pressurizer level, which is specified as a function of reactor power. The pressurizer accommodates heat transport system swell between zero power hot and full power hot; pressurizer level therefore increases with increasing reactor power.

All valves that can discharge heavy water from the heat transport system and the pressure and inventory control system (for example, pressurizer relief valves, HTS liquid relief valves, and D2O bleed valves) connect to the degasser condenser. The degasser condenser relief valves are set above the operating pressure of the heat transport system; hence, the failure of a valve connecting the heat transport system to the degasser condenser in the open position does not result in heavy water being lost from the heat transport systems. The degasser condenser relief valves are sized to provide overpressure protection to the heat transport system when operating in series with the heat transport system liquid relief valves.

The **shutdown cooling system** (Figure 6) is designed to remove decay heat following a reactor shutdown, and to cool the HTS to a temperature suitable for maintenance of heat transport and auxiliary systems components. The shutdown cooling system can be brought into operation at full heat transport system temperature and pressure to assure fuel cooling in the event that the steam generator heat sink is unavailable. In normal operation, if heat transport system cooldown is required, the heat transport system is partially cooled via steam discharge from the steam generators; the shutdown cooling system is then utilized to cool the heat transport system to the desired temperature, and to maintain it that temperature for an indefinite period of time. The shutdown cooling system is also capable of providing fuel cooling with the heat transport system heavy water coolant drained to just above header level, to facilitate maintenance and inspection of steam generators and/or heat transport pump internals.

The shutdown cooling system consists of two separate circuits, one located at each end of the reactor. Each circuit includes a shutdown cooling pump and a shutdown cooling heat exchanger. The shutdown cooling system circuits connect to the inlet and outlet headers. In each circuit, one at each end of the reactor, the pump takes coolant from the reactor outlet header and returns it to the reactor inlet header via the heat exchangers. The pumps and heat exchangers are located below the reactor headers so that a net positive suction head is available for the pumps when the HTS drains to the headers.

The shutdown cooling system is normally cold, depressurized, and isolated from the HTS by valves during reactor operation. The shutdown cooling pumps are provided with backup power from the Class III power supply. During normal operation, the shutdown coolers are cooled by the recirculated cooling water system.

The **D_2O collection system** collects any heavy water leakage from mechanical components, and receives heavy water drained from equipment prior to maintenance. The collected heavy water is returned to the heat transport heavy water storage tank.

The **heat transport purification system** minimizes the accumulation of active deposits within the heat transport system.

The production of radioactive materials in the main HTS is very low. This is due to restrictions placed on materials used in the system (for example, very low cobalt contents are permitted in system materials), and to the absence of failed fuel during reactor operation (if a fuel failure occurs, it is detected and promptly removed by the on-power refuelling system).

The coolant is continuously filtered and purified by the purification system. Purification flow is provided from the discharge of one HTS pump in each loop; the flow passes through an interchanger and a cooler prior to passage through filters and ion exchange columns. The flow is then returned to the suction lines of the same HTS pumps via the interchanger.

4. Steam System (Figure 7)

The steam produced by the steam generators is fed by four separate steam mains to the turbine balance header, located adjacent to the turbine.

The steam pressure is controlled at a constant value during reactor operation by matching the reactor output and turbine-generator demand. This is most commonly accomplished by varying reactor power to match the turbine-generator demand, but alternatively, the turbine generator demand can be varied to match reactor power.

Four Main Steam Safety Valves (MSSVs) are provided on each steam main to protect the steam generators and steam system from overpressure. The MSSVs provide the overpressure function via spring action; the MSSVs are equipped with power actuators that are used to open the valves on a LOCA signal and thereby cool the steam generator secondary side and the heat transport system.

The turbine bypass system allows steam to bypass the turbine, and flow directly from the balance header to the condenser via the Condenser Steam Discharge Valves (CSDVs). The turbine bypass system and condensers are designed to permit 100% of full power steam flow to the condenser for a short period (typically 5 minutes), and up to 60% of full power steam flow continuously. The CSDVs operate in the event of a turbine trip or loss of line, and facilitate continued operation of the reactor (at reduced power) under these conditions. Operation of the CSDVs is sufficiently fast to prevent the MSSVs opening on a turbine trip. Isolation valves are provide upstream of each CSDV.

Atmospheric Steam Discharge Valves (ASDVs) are provided on each steam main to allow steam to be discharged to the atmosphere. The ASDVs maintain the steam generator heat sink in the event that the condenser is unavailable.

Steam flow measurements (elbow taps) are provided on each steam main downstream of the steam generators.

A Steam Main Isolation Valve (MSIVs) is provided in each steam main downstream from the MSSVs. One or more of these valves can be closed by the operator in the event of a significant steam generator tube leak.

A steam sampling line is provided on each steam main to obtain representative samples of the steam. The samples are used for chemical analysis, and for the detection of D2O in H2O; the latter provides a fast and accurate indication of any D2O leakage from the steam generator tubes. Connections to the nitrogen supply system are also provided to each steam line. These lines are used to “blanket” the steam generator secondary side and the steam mains with nitrogen during an outage when the steam generator is cooled and depressurized to prevent corrosion.

Key steam system parameters for a typical CANDU 6 are provided in Table 2.

Table 1
Overview of CANDU Heat Transport System Parameters

	Fuel Channels		Heat Transport System Conditions				
	Electrical Power Output (MW) Gross/Net	No. of Fuel Channels	No. of Elements in Fuel Bundle	No. of Loops	Reactor Outlet Header Pressure (MPa)	Maximum Channel Flow (kg/s)	Reactor Outlet Header Quality (%)
CURRENT STATIONS							
Pickering A	542/515	390	28	2	8.7	23.0	0
Pickering B	540/516	380	28	2	8.7	23.0	0
Bruce A	904/840	480	37	1	9.1	24.0	0.7
Bruce B	915/860	480	37	1	9.1	24.0	0.7
CANDU 6	715/668	380	37	2	9.9	24.0	4
Darlington	936/881	480	37	2	9.9	25.2	2
NEW STATIONS							
CANDU 9 480/NU	925/870*	480	37	1	9.9	25.2	2.0

	Heat Transport Pumps			Steam Generators			
	Total	Operating	Motor Rating per Pump (kW)	No.	Area (m^2) per Steam Generator	Integral Preheater	Steam Pressure (MPa)
CURRENT STATIONS							
Pickering A	16	12	1420	12	1850	Yes	4.1
Pickering B	16	12	1420	12	1850	Yes	4.1
Bruce A	4	4	8200	8	2400	No	4.4
Bruce B	4	4	8200	8	2400	No	4.7
CANDU 6	4	4	6700	4	3200	Yes	4.7
Darlington	4	4	9600	4	4900	Yes	5.1
NEW STATIONS							
CANDU 9 480/NU	4	4	9600	4	4900	Yes	5.1

* Output is dependent on condenser cooling water temperature and turbine design.

Table 2
Key Steam System Parameters

• Net steam flow rate		1033 kg/sec
• Pressure at Drum Nozzle (CANDU 6)		4.7 MPa(a)
• Steam Temperature at Drum Nozzle		260 C
• Main Steam Isolation Valves		4 (electric motorized)
• MSSVs	- number	16
	- capacity (each)	99 kg/sec
• ASDVs	- number	4
	- capacity (each)	26.4 kg/sec
• CSDVs	- number	12
	- capacity (each)	91 kg/sec

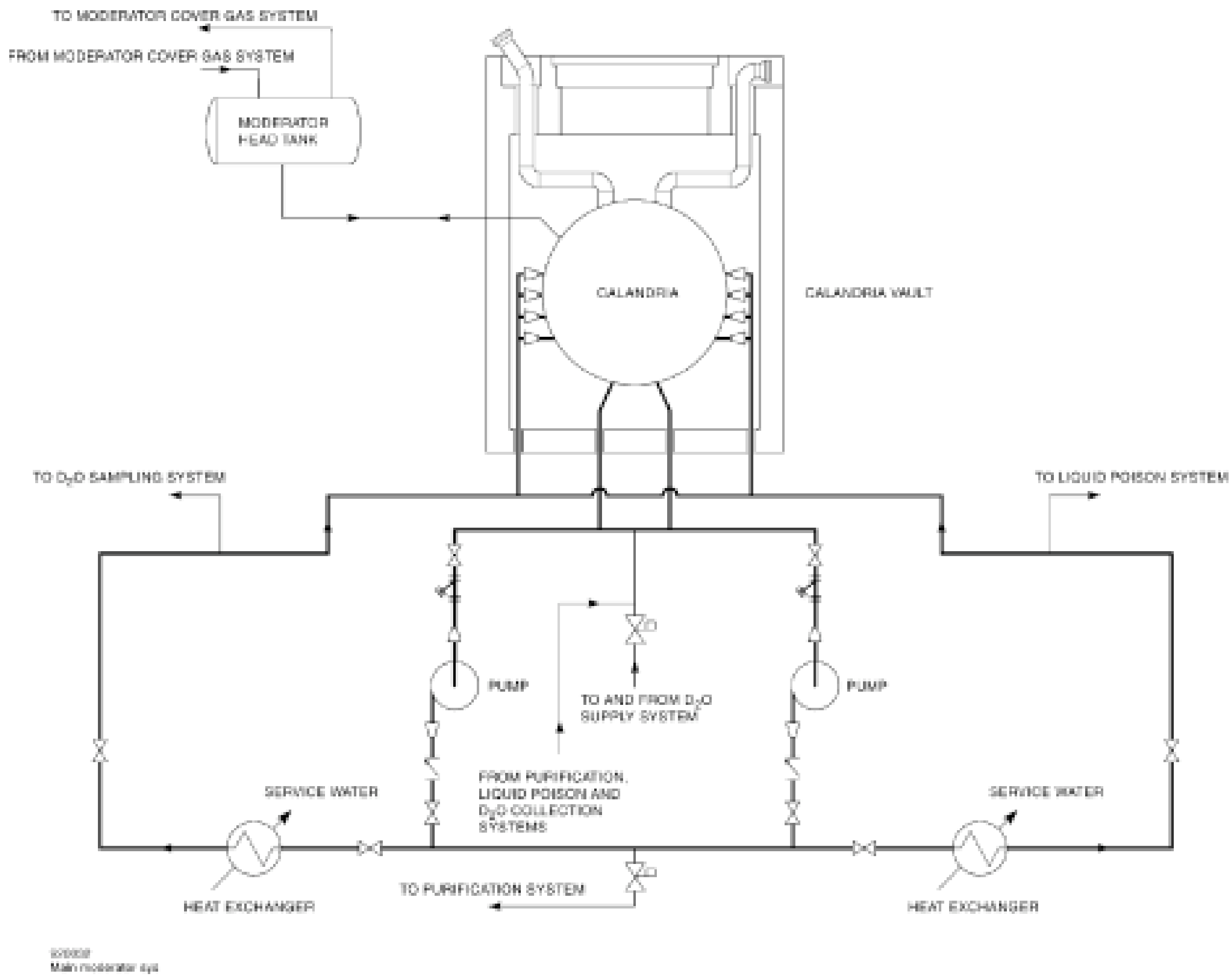

Figure 1 Moderator System

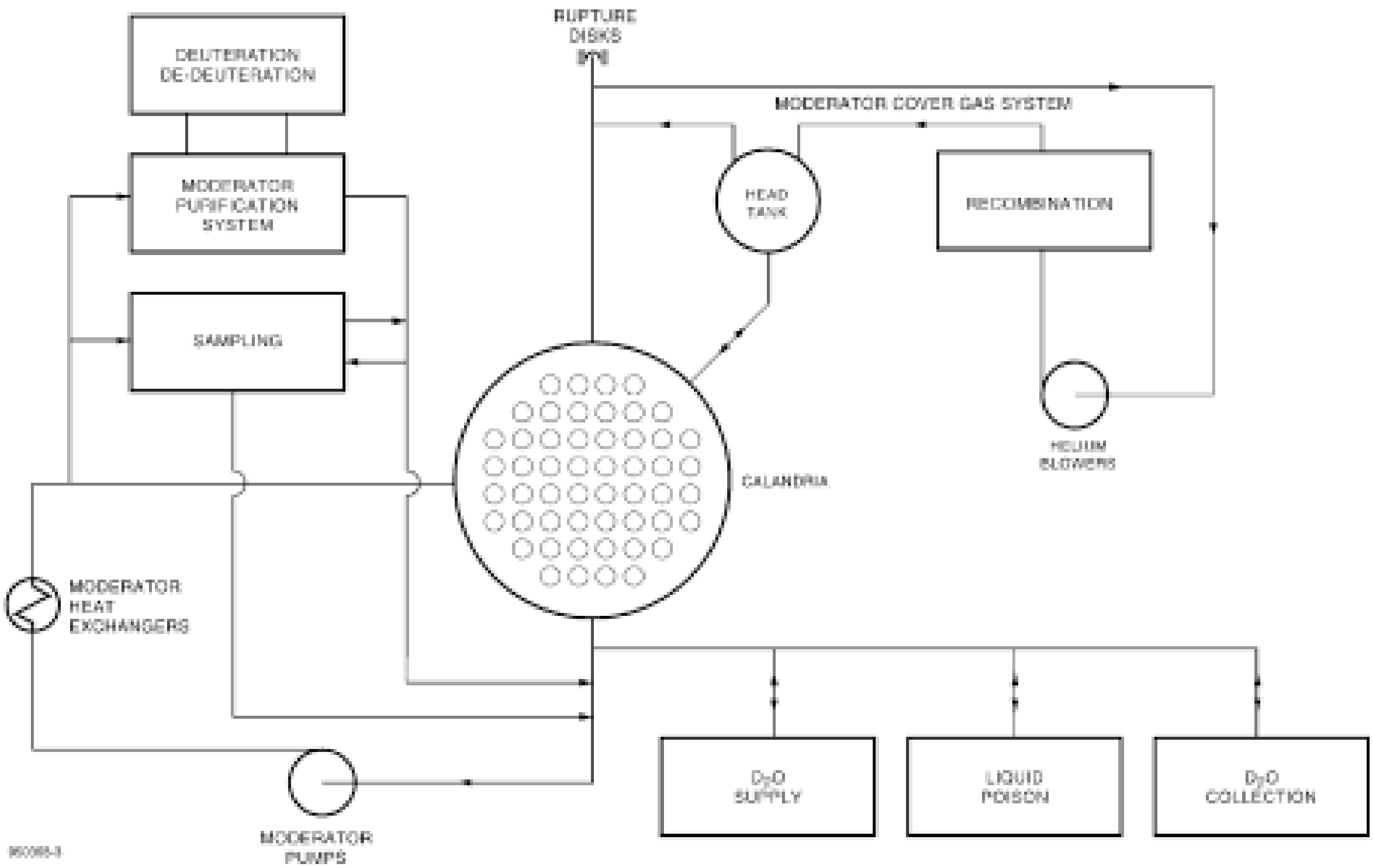

Figure 2: Moderator Auxiliary Systems

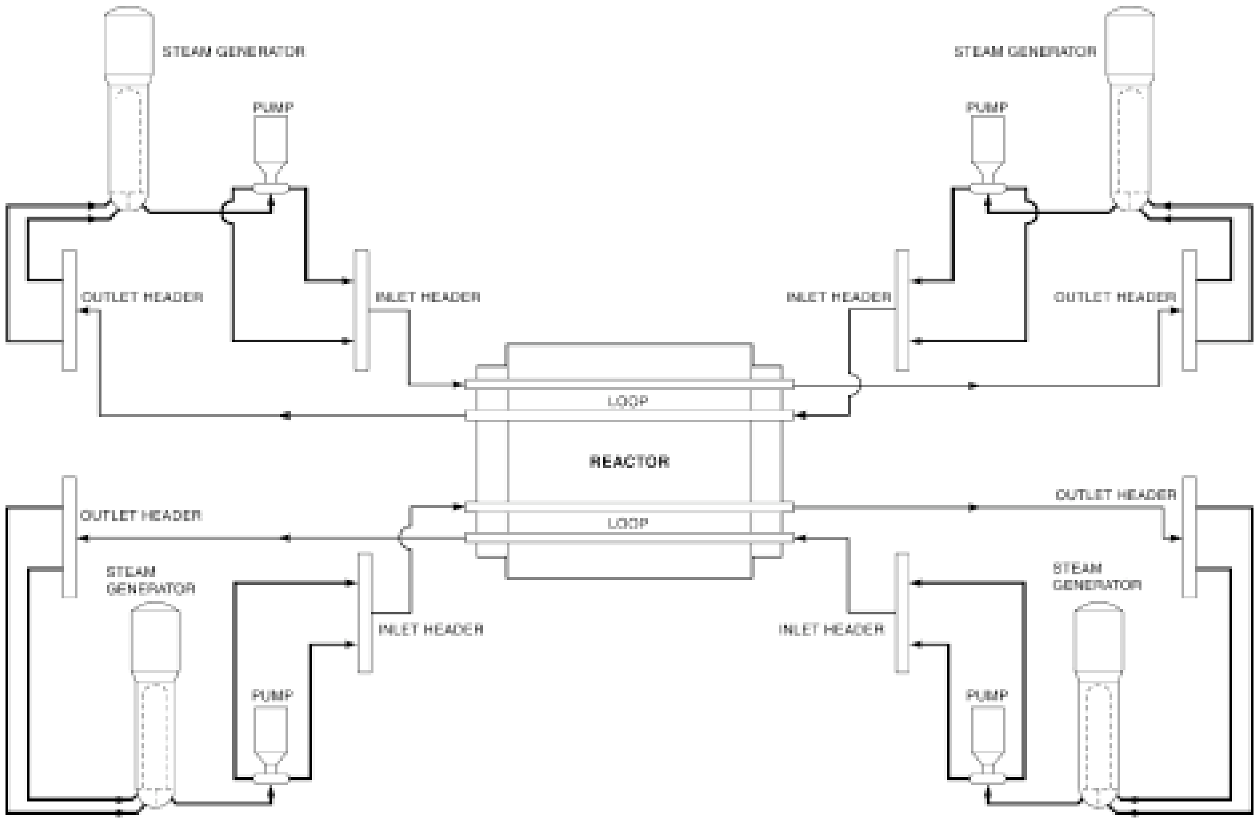

Figure 3: Heat Transport system

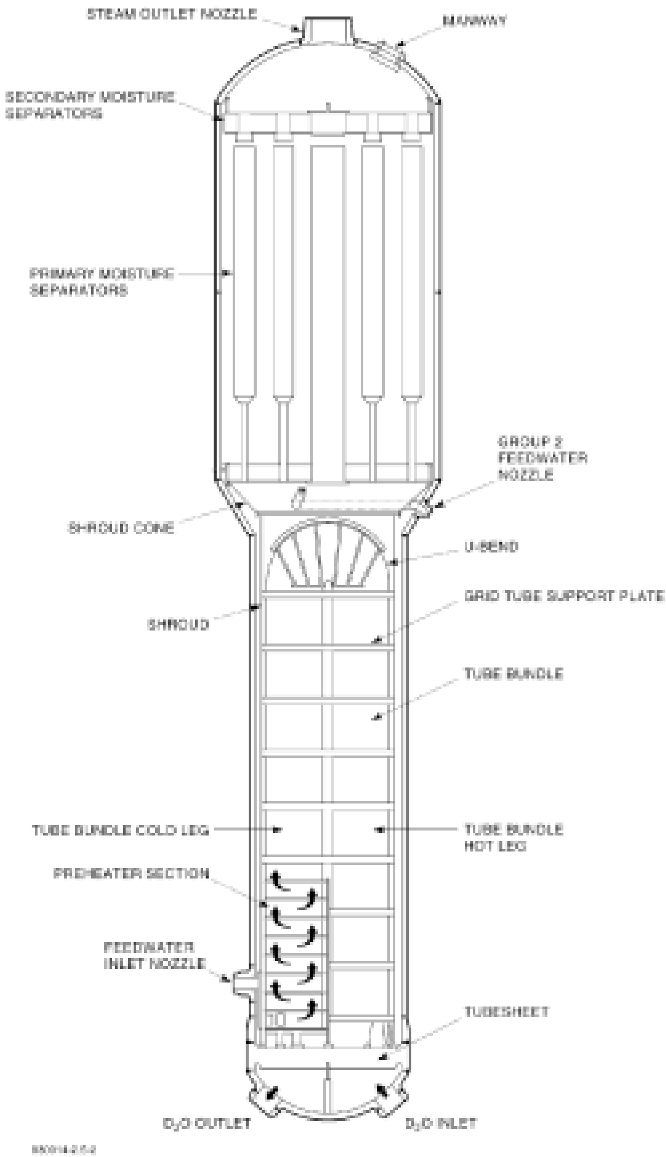

Figure 4: Steam Generator

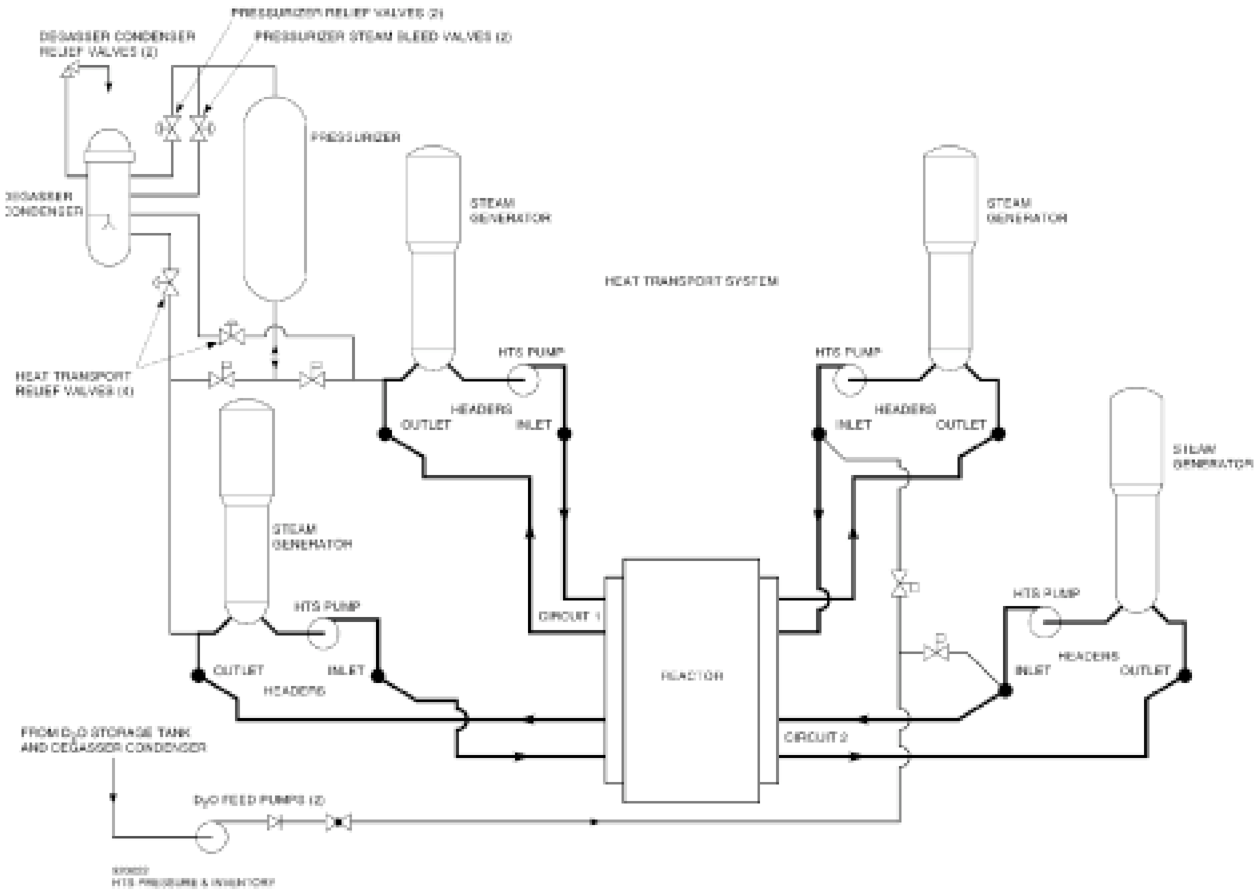

Figure 5: Heat Transport Pressure and Inventory Control System

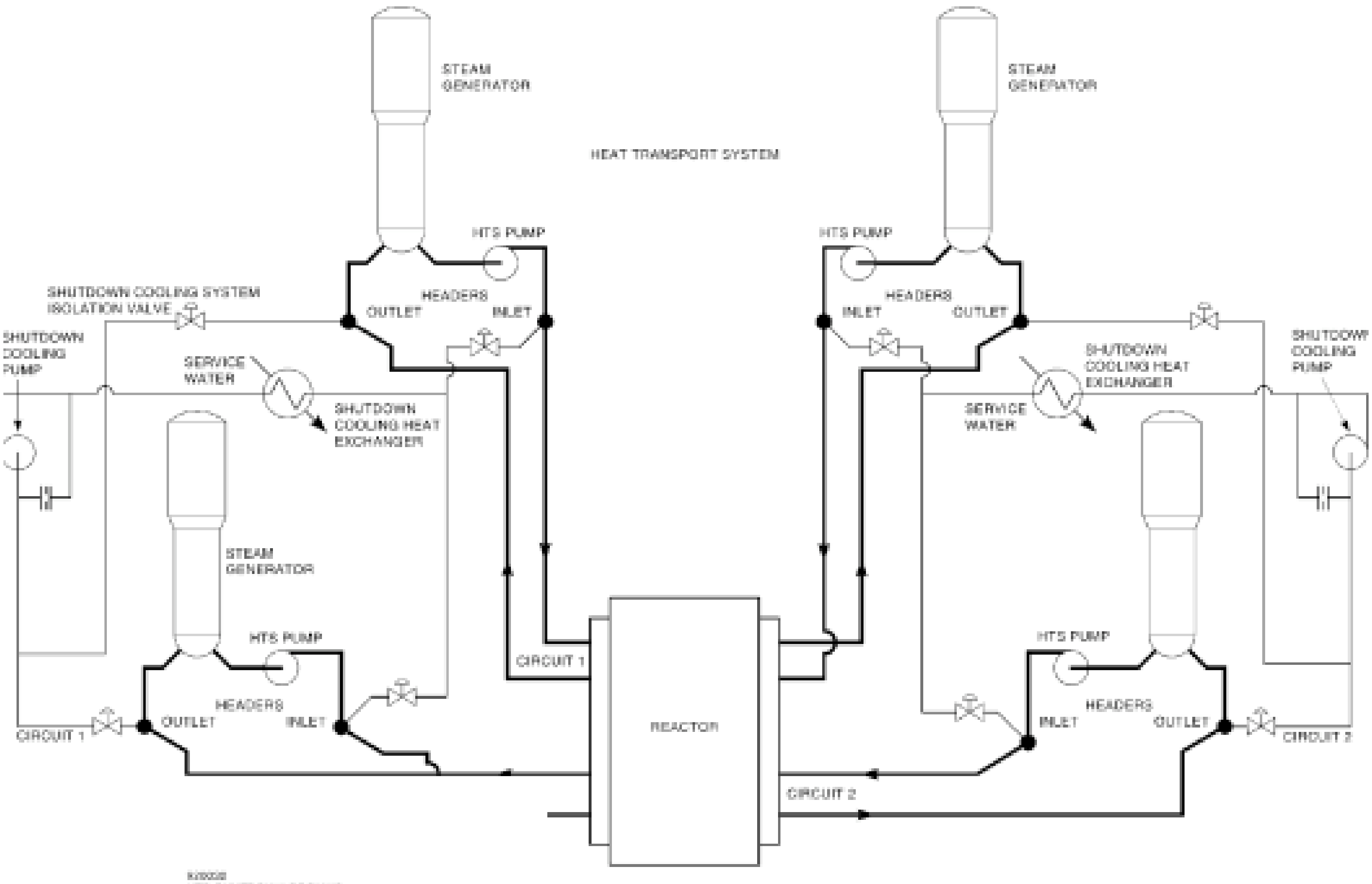

Figure 6: Shutdown Cooling System

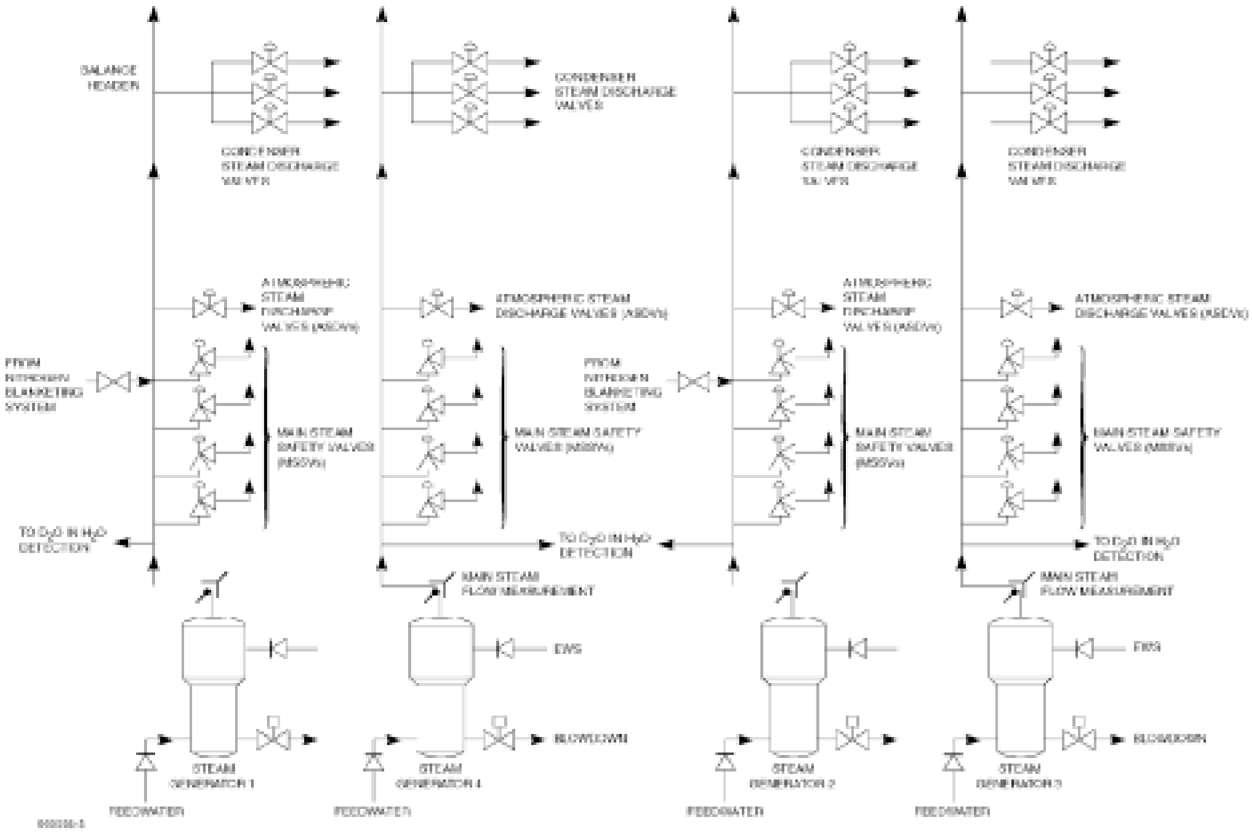

Figure 7: Steam System