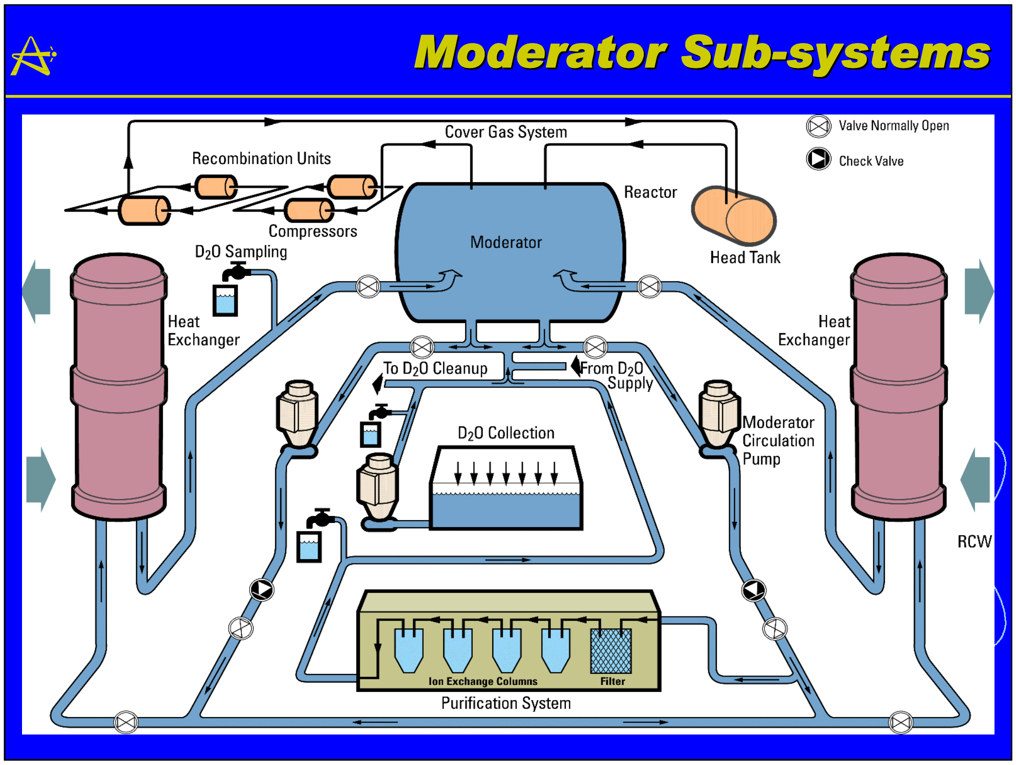
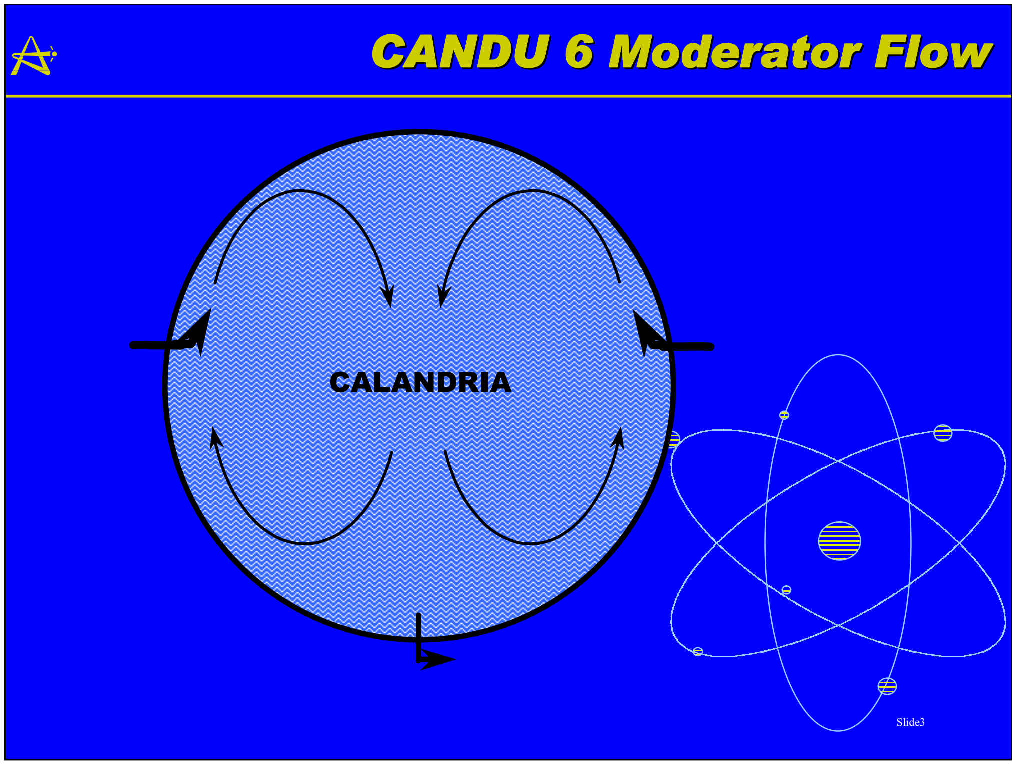
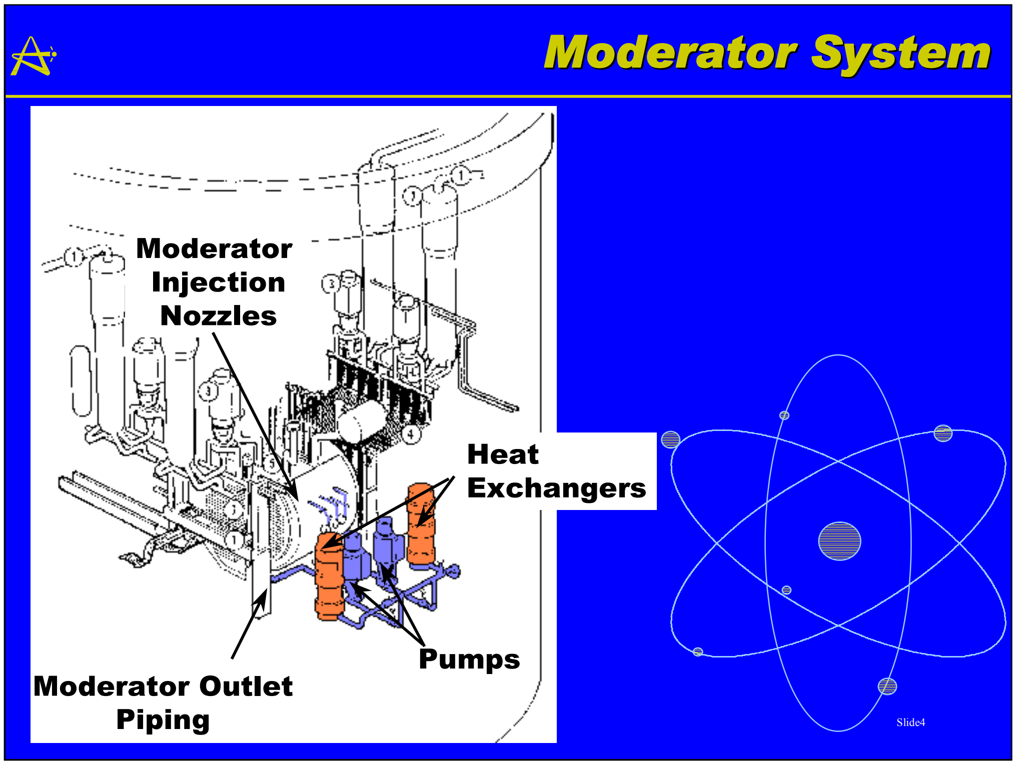
- This photograph shows the Wolsong Unit 2 calandria on its way from the Canada-Korea shipping dock to the site, a few years ago. The Wolsong Unit 4 calandria was manufactured in Korea.
- This large tank is not very heavy because it is only thin-walled, unlike a PWR pressure vessel. Also, it is quite easy to manufacture except for the requirement for a large-diameter boring tool needed to cut the holes in end-plates. There are a few places in the world where this equipment is available.



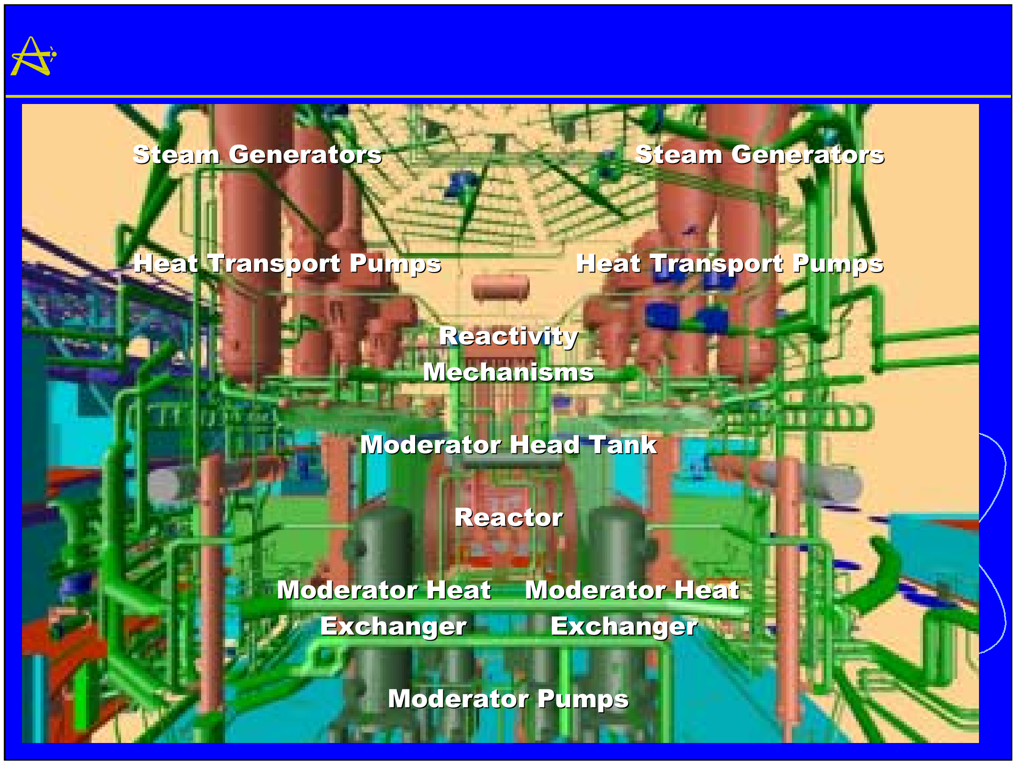
- The first requirement of these systems is to remove the heat generated in moderator water (about 78 MWt) by neutron capture, neutron slowing down, and gamma ray interactions.
- A small amount of this heat is due to losses through the pressure tube gas gap, captures in the in-core reactivity mechanism and flux measurement guides tubes, end shields, etc.
- The pumps circulate moderator water through heat exchangers cooled by the Recirculating Water (RCW) System (a closed cooling water system which protects against leakage of heavy water to the environment.)
- The pumps discharge flow, through directed nozzles, into the moderator tank. These nozzles promote circulation inside the moderator tank.
- A head tank and heavy water makeup maintain the moderator level at the desired setpoint.
- The chemistry conditions in moderator water are controlled to minimize radiolytic production of deuterium gas as well as corrosion. Ion exchange columns are provided to maintain moderator water purity.
- Catalytic recombiners draw gases from the space above the moderator water to maintain the deuterium concentration below flammability limits.



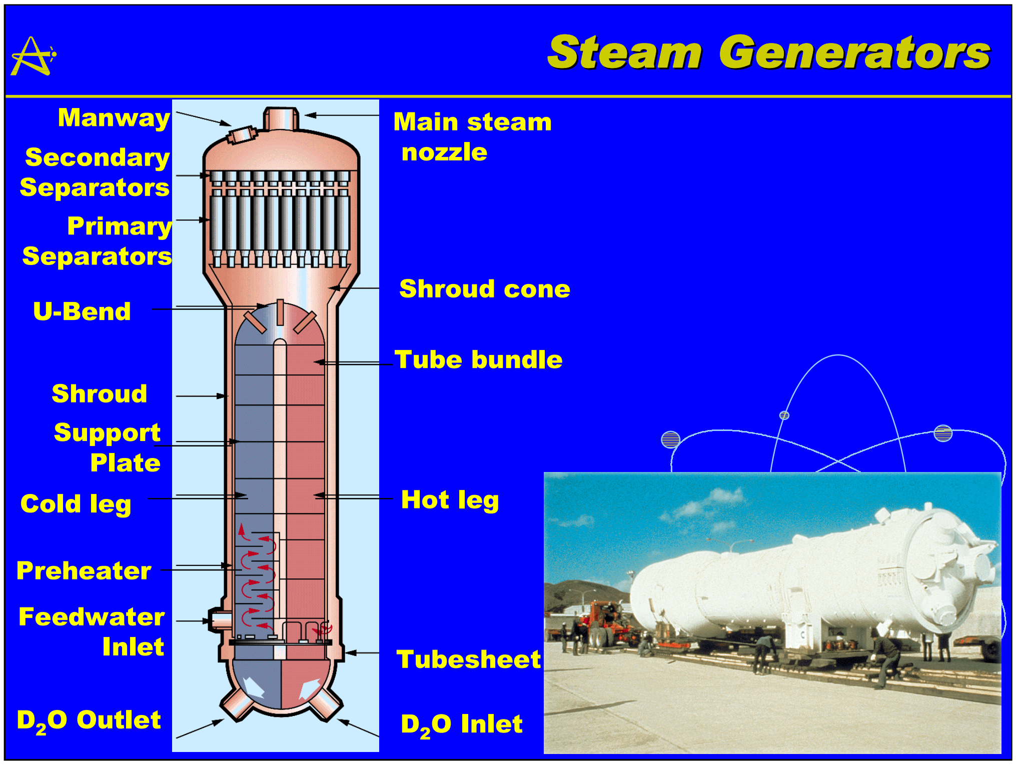
- General flow patterns inside the moderator are shown here. The objectives of this flow system is to cool the water and to maintain constant temperature
- Water from the main moderator pumps is directed to nozzles inside the tank, in the reflector region, and is withdrawn at the bottom of the calandria.
- Temperature is controlled by controlling the recirculating cooling water (RCW) flow in the heat exchanger secondary side.
- The majority of heat generated in the moderator water is deposited by neutron slowing down collisions and gamma rays. The moderator water also cools the calandria tubes, in-core detectors, reactivity mechanisms, and the calandria shell.



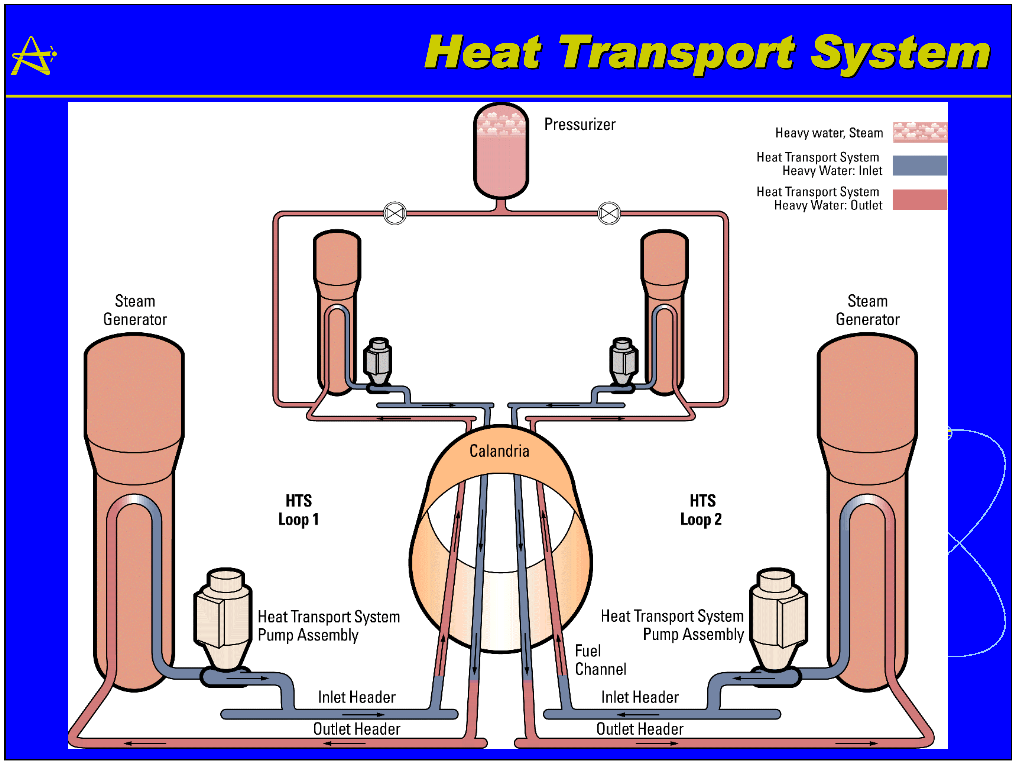
- This diagram shows the location of the moderator pumps and heat exchangers relative to the reactor. They are located on the ground level immediately next to the reactor. The large airlock and containment accessible area are located on the opposite side.
- This system is shielded to reduce gamma fields produced mostly by the short-lived nitrogen-16 isotope.



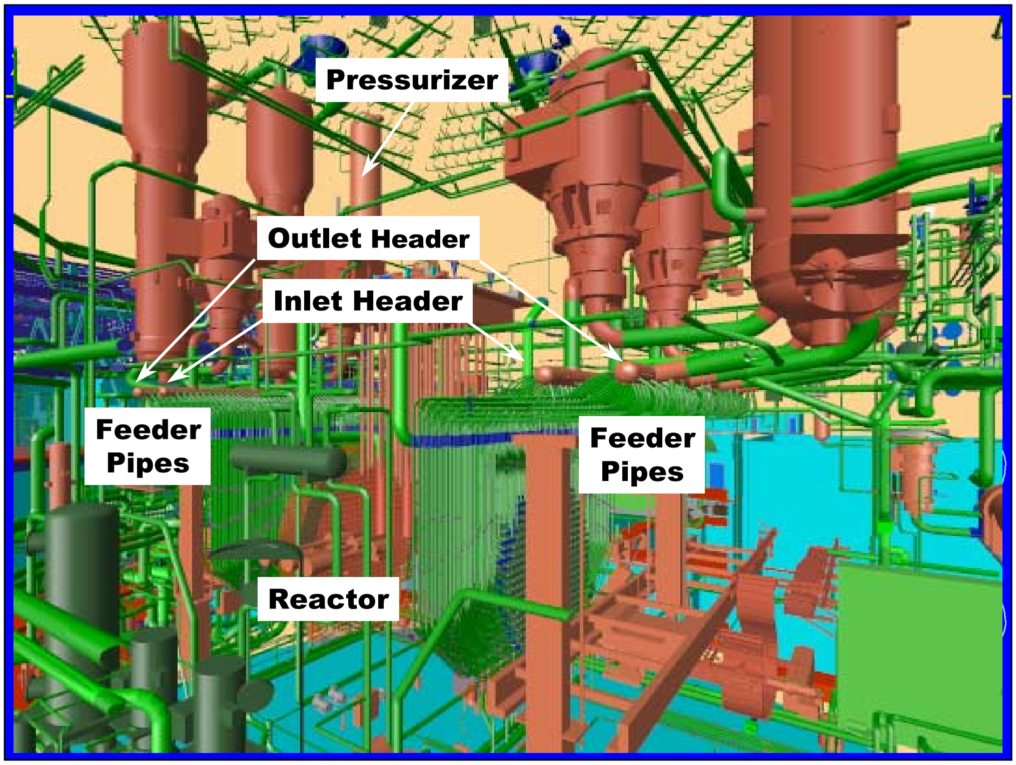
- This diagram was produced from the high-precision 3-dimensional CADD system in which all important CANDU 6 systems are modelled. Concrete has been deleted temporarily from this view to improve the visibility.
- The CADD model can be viewed from any angle to give the impression that the viewer is "flying" around the station. This gives a chance to see the real position of all equipment and systems. At the same time, the model can be used to specify components and piping, analyze stresses, check interferences, and finally to prepare a bill of materials for purchasing.
- The diagram shows the moderator systems position relative to the reactor and other plant systems, especially the reactor reactivity mechanisms, heat transport pumps, and steam generators.
- There are four moderator injection nozzles and a set of three ion chamber housings on this side of the reactor.
- The lattice-work piping which can be seen above the steam generators is the dousing spray system, which is important to safety. That system takes water from the storage tank at the top of the reactor building and sprays the containment space to condense steam produced in an accident.



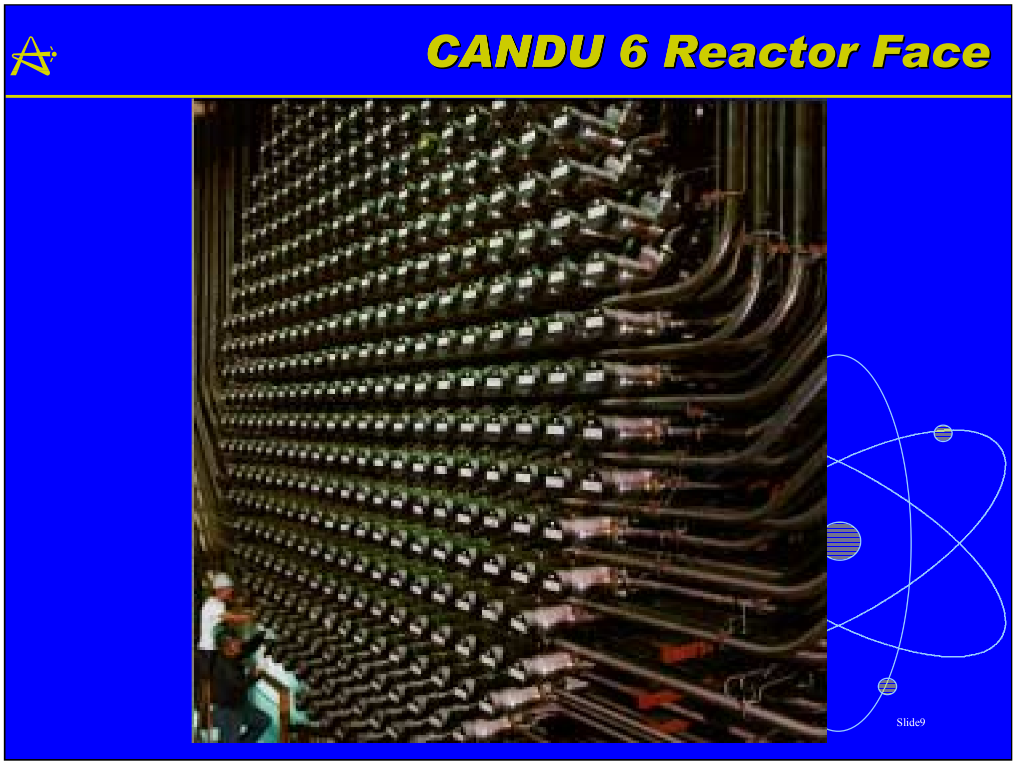
- One of the most important components of a CANDU nuclear plant is the steam generator. Many difficult aspects of thermal and mechanical design are combined here.
- The primary side of the steam generator consists of several thousand small diameter Incolloy-800 tubes bent into an inverted U-shape. Each end of this array is welded into a thick steel tubesheet.
- The bottom hemispherical vessel head is split by a divider plate to separate the incoming hot D_2O from the outgoing cool D_2O.
- Heavy water enters the vessel head with about 4 percent steam quality. This steam is condensed rapidly as it transfers its heat to the secondary water. The remaining portion of the U-tubes contains liquid heavy water.
- The secondary side of the steam generator contains ordinary water.
- Subcooled feedwater enters at the bottom of the secondary side shell and is passed through a preheater which raises it to saturation temperature before it joins the main boiling flow.
- The boiling water on the secondary side rises by natural convection until it meets the primary cyclone separators, which remove the bulk of the water from the steam. The water spills over into the annular region formed by the outer shell and the shroud, through which it is returned to the bottom of the tube bundle.
- The ratio of the mass of recirculated water to the mass of steam leaving the steam generator is about seven. This is a high recirculation ratio; this feature greatly improves heat transfer through the steam generator tubing.
- Secondary steam separators increase the exit quality to stem to 99.75% or greater.
- Pressure and effective level on the secondary side of the steam generator are carefully controlled.



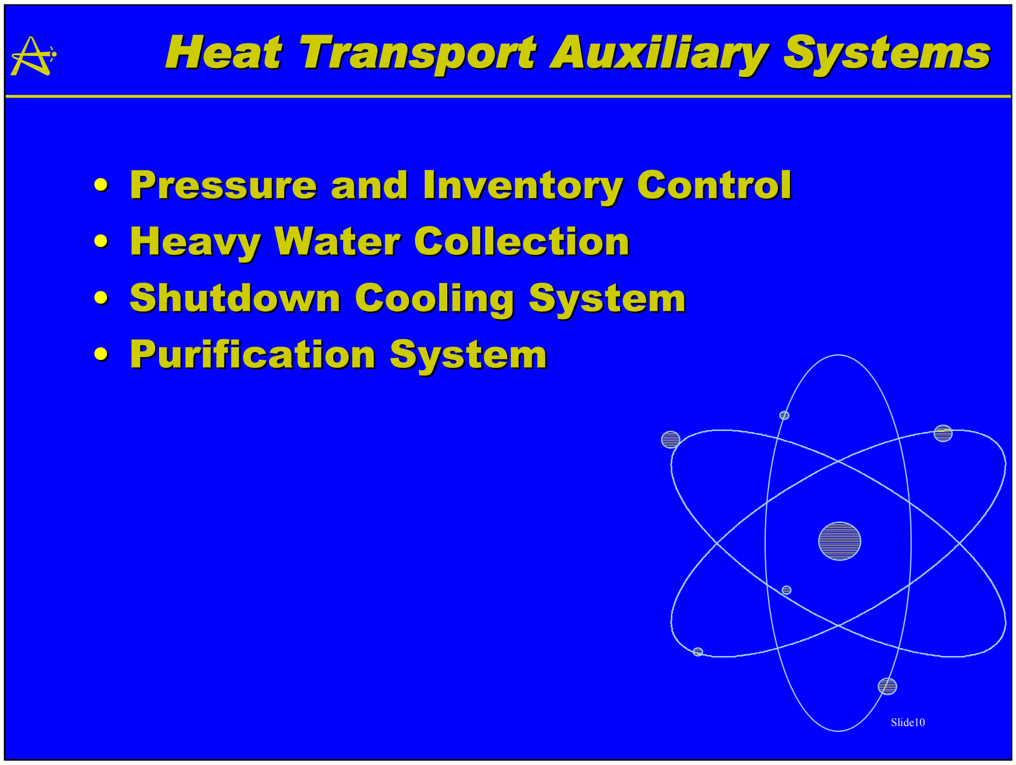
- The Heat Transport System, as the name implies, transfers heat from the fuel to the steam generators. It is a high-flow, high-pressure, high-temperature system which also has a vital safety significance -- no serious release of radioactive materials from the plant can occur unless this system fails in one way or the other.
- The system is arranged in two flow loops which are arranged in a "Figure of Eight". That is, there are two pumps and two steam generators connected in series in each loop. Each pump-steam generator pair is located at the opposite end of the reactor.
- Ninety five fuel channels are connected by feeders, in parallel, to one pair of reactor headers. The pressure drop, header-to-header, is about 1 Mpa. Each channel is flow-matched for equal enthalpy rise; the maximum channel mass flow is approximately 25 kg/s.
- Pumps are of the centrifugal, single suction, single-volute, double discharge type, each with an operating power of about 7.5 MW. They are driven at constant speed by squirrel-cage induction motors. The shaft seals are high efficiency multi-component seals cooled and lubricated with heavy water.
- The two heat transport loops are connected by way of piping connected from outlet headers to a single pressurizer, which is placed at one end of the reactor. Each loop is capable of independent pressure and inventory control when the pressurizer is isolated.
- By design, the coolant has a steam quality of about 2 percent at the outlet header. In order to balance potential flow oscillations in the loops (each of which has two liquid flow sections and two 2-phase flow sections), the outlet headers at each end of the reactor are connected by a pressure balance pipe.
- Coolant at the reactor exit is in two-phase conditions, so the outlet temperature detector cannot be used as an indicator of flow. Flow is checked periodically be lowering reactor power to about 85% periodically, and then recording a full scan of these detectors.



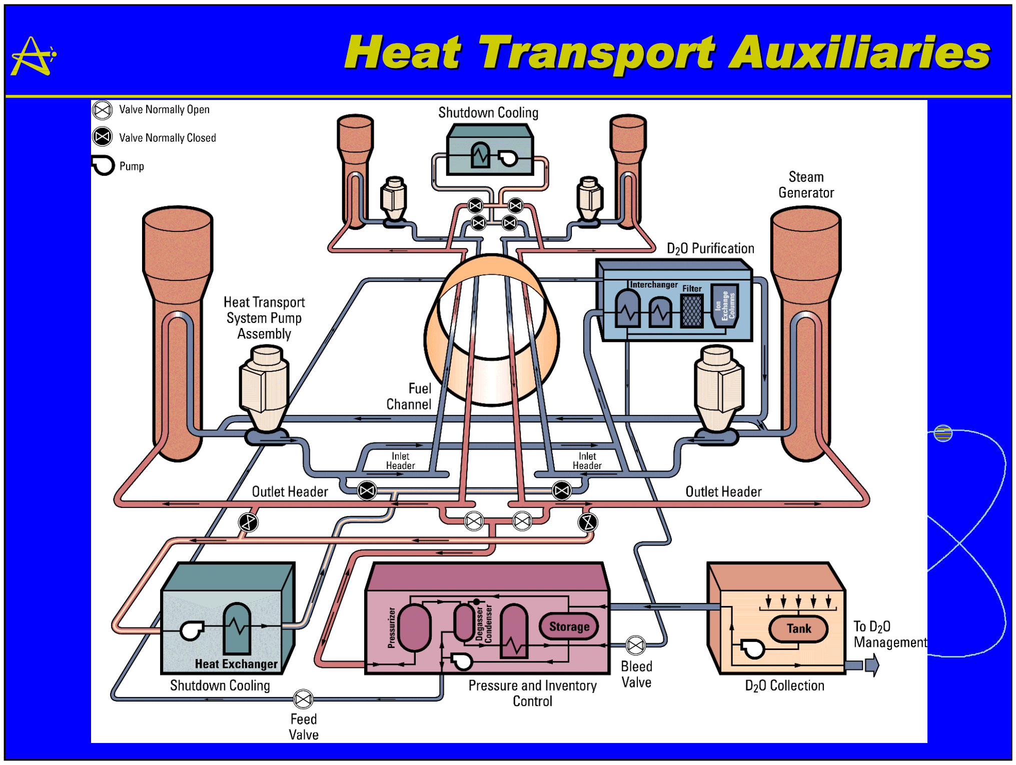
- This is another CADD-generated view of the CANDU 6 systems. It is possible to "fly" around these systems using the CADD modelling tool, in order to get a clear idea the systems size, position, and relation to other systems.
- This view shows the geometry of inlet and outlet headers, steam generator piping, feeder pipes, and reactor. Also, the pressurizer can be seen here in its actual position.
- All HT piping except steam generator tubes and pressure tubes is manufactured of carbon steel to achieve the best possible cost, good corrosion resistance, and toughness over the life of the station.
- The position of the fuelling machine relative to the reactor face can be seen in the right foreground of this picture.



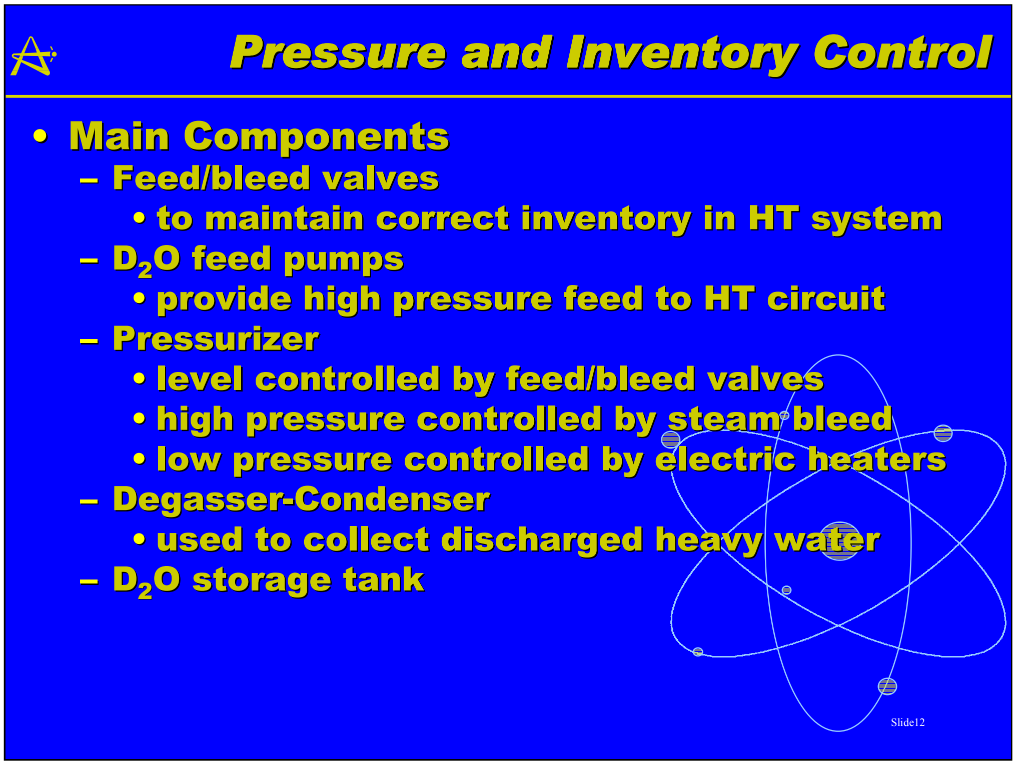
- The feeder pipes are connected to the fuel channels as seen in this photograph. Half of the channels are connected to each HT loop.
- The flow in alternate channels (in a "checkerboard" pattern) is in the opposite direction, so that inlet and outlet feeders alternate in the feeder bank.
- Feeder supports can be seen in the photograph. These are arranged to allow for axial channel movement and thermal expansion.
- Resistance temperature detectors, failed-fuel monitoring tubes, and flow measurement Venturi meters also are located here.



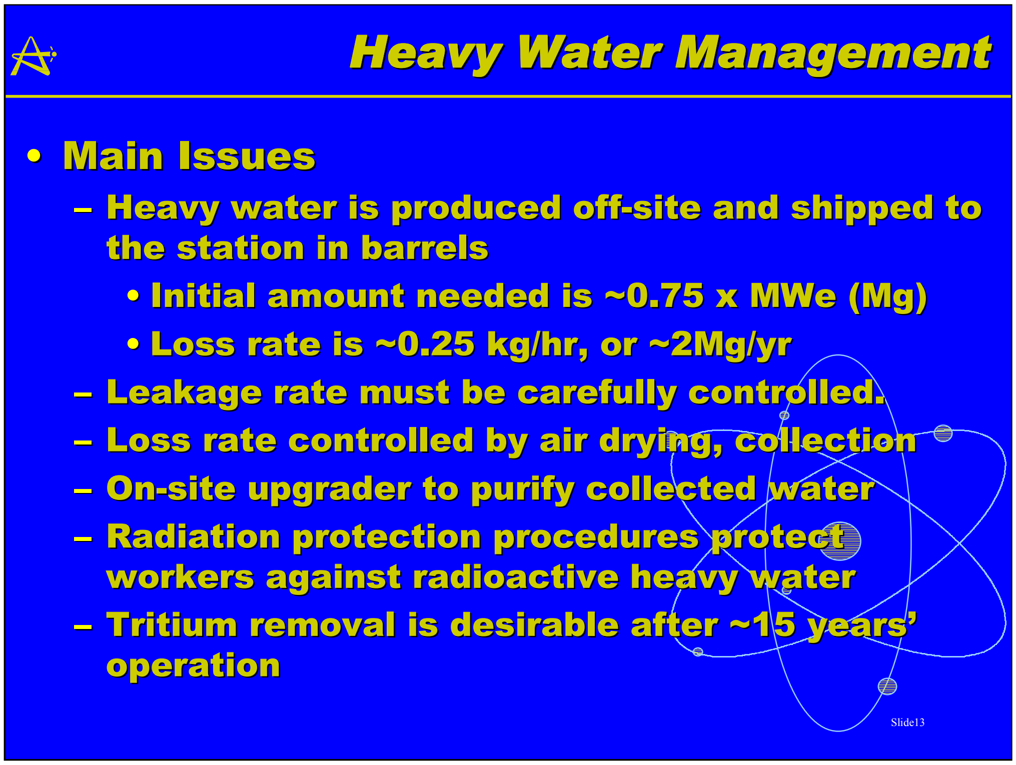
- This is a list of the most important subsystems that support operation of the heat transport system. The pressure and inventory control system is of most direct interest here.
- The shutdown cooling system is important to safety, even though it is classified as a process system. It is designed to remove decay heat (up to more than 1 percent of full power) from the Heat Transport System (HTS) at full pressure, and at full temperature in special circumstances.
- This system is normally isolated from the HTS but can be opened by remote-manual operation. The main HT pumps are shut down before this system is started.
- Heavy water collection systems are always important to CANDU operation because of the high price of heavy water. This high price brings, however, a strong motive to control leakage. As a result, any change in leakage rate is noticed immediately (usually by monitoring the level in the heavy water storage tank) -- a factor which may be important to safety.
- In order to protect the HT piping, pressure tubes, steam generator tubes, feeders, and fuel it is required that the HT water should have a pH above 10 and a very low oxidation potential. In addition, it must have a slight overpressure of deuterium to help the recombination of deuterium and oxygen in the irradiated water.



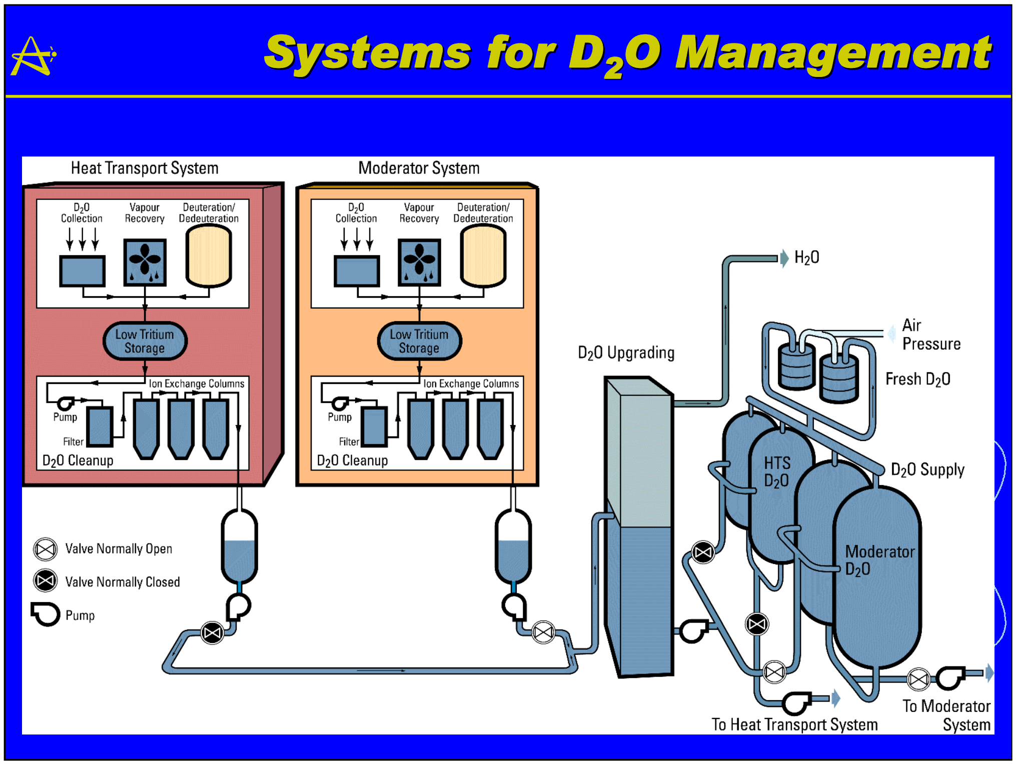
- The pressure and inventory control system is controlled by the station control computer, based on measurements of pressure, temperature, reactor power, and pressurizer level.
- In normal operation the pressurizer is connected to both HT loops. (It may be isolated during reactor startup or emergency conditions.) Notes below.
- The pressurizer is large enough to accept the heat transport system liquid expansion from zero power hot conditions to full power, as well as the heavy water vapor volume produced at the channel outlet between 86% and 100% reactor power. The RRS computer calculates the appropriate pressurizer level setpoint for each reactor power level.
- When the pressurizer is isolated the HT system the power is lowered so that each loop contains only liquid heavy water. Under these conditions, pressure in each loop is controlled directly by the feed/bleed valves.



- The Pressure and Inventory Control System (PICS) acts to control HT pressure by a combination of electric heaters inside the pressurizer, which are turned on in succession by the RRS program if HT pressure is low, and heavy water steam is discharged through valves at the top of the pressurizer, which are opened if the HT pressure is high.
- The PICS controls HT inventory by first calculating the correct level setpoint for the measured reactor power, and comparing the measured actual pressurizer with this setpoint. (This calculation includes a calculation of the coolant exit quality). Heavy water feed and bleed valves are adjusted to match the actual level to the setpoint.
- The degasser-condenser receives steam from the steam bleed piping, from any liquid relief flow out of the pressurizer, and liquid relief from the heat transport system. (It also feeds the required spring-loaded code valves). Spray cooling and electric heating control the pressure in this vessel; water is transferred to the heavy water storage tank as required after being cooled in the bleed cooler.



- The essential features of heavy water from the point of view of Operations are its high value and its radioactivity.
- To the highest degree, the control of heavy water leakage and especially losses are absolutely essential for both of these reasons..
- Water collection from pump seals, fuelling vault and several other sources is directed to the collection system. Air dryers are located in spaces containing heavy water and in the reactor building ventilation ducts.



- Water from the HT system and moderator system are managed separately, because the moderator water contains much higher tritium levels.
- Heat transport system water passes through the reactor core rapidly in relatively small quantity. Production of tritium is proportional to (neutron flux x time) so that the moderator water, which spends much more time inside the core, has a higher level of tritium contained in it.
- Because the spaces which contain heavy water also receive some ordinary water in-leakage, heavy water collection tanks are downgraded. For this reason the station design incorporates a small distillation column to separate the light water. The purified heavy water then is returned to the storage tanks for further use.

- Fresh heavy water at about 99.75% purity (or higher)is shipped form production facilities to the generating station, to makes up annual losses of about 2 Mg.
- Reserve inventory is stored in drums at the station, and is added to the system manually when required.
- Tritiated heavy water may be shipped to tritium removal facilities if and when the need arises. In the future, a small catalytic exchange unit may be installed at the station to provide on-site tritium removal as well as heavy water upgrading.