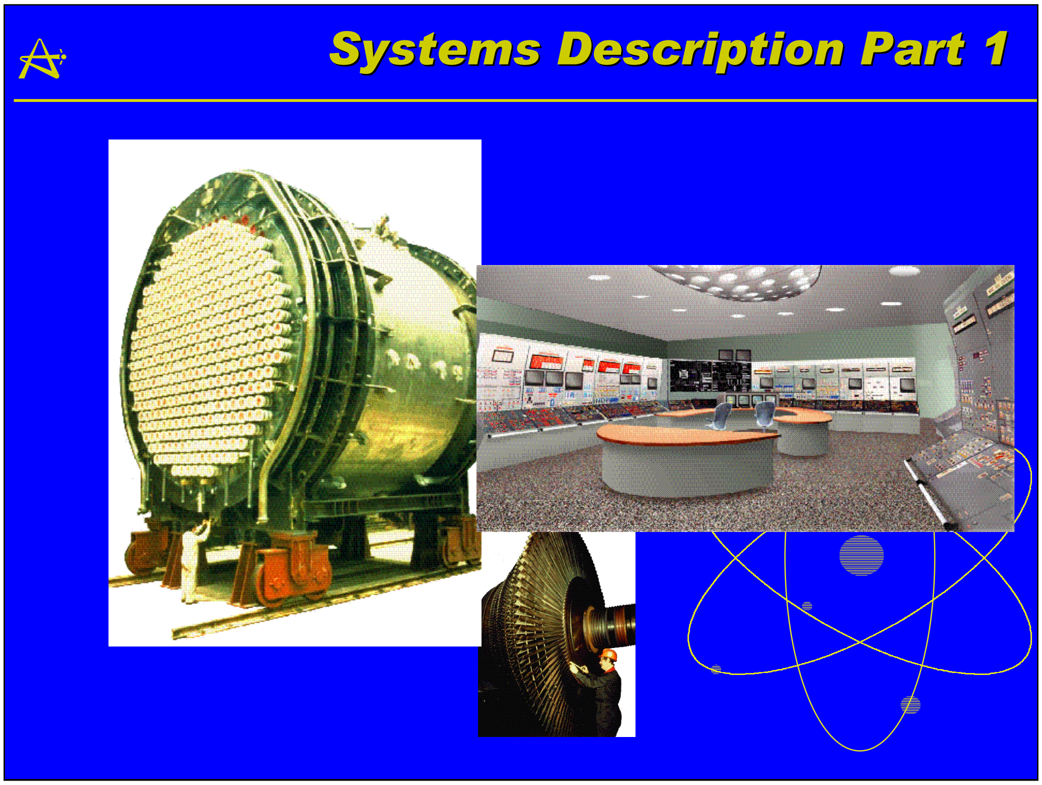
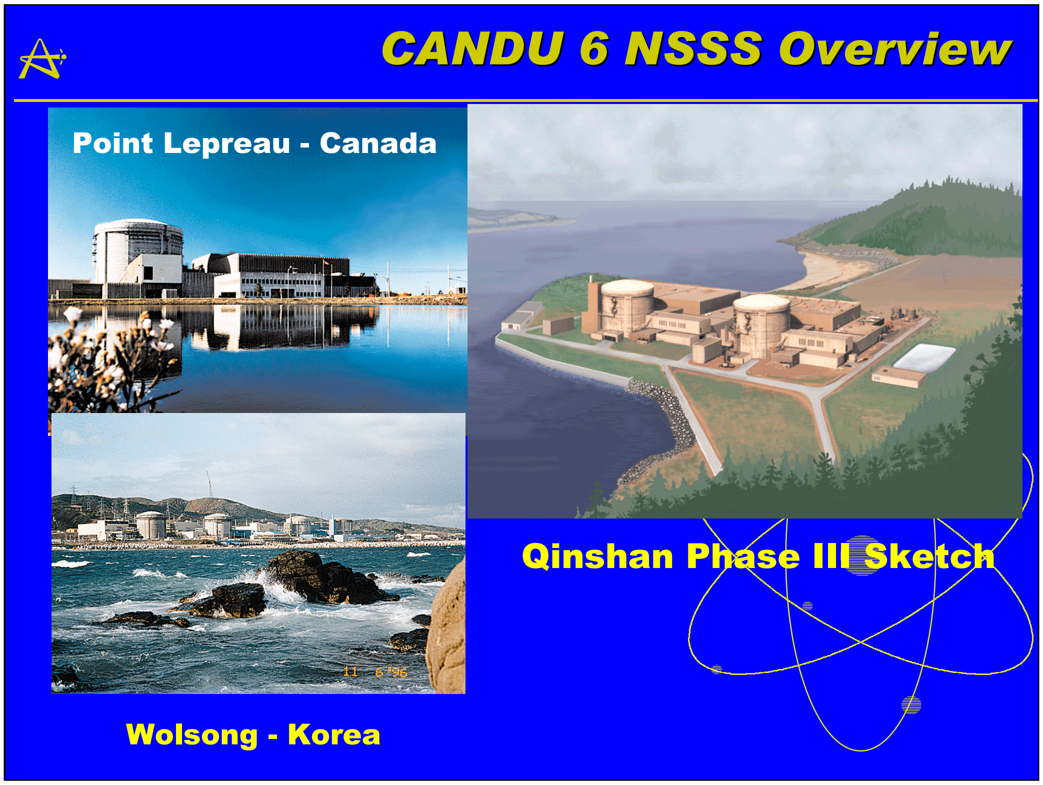
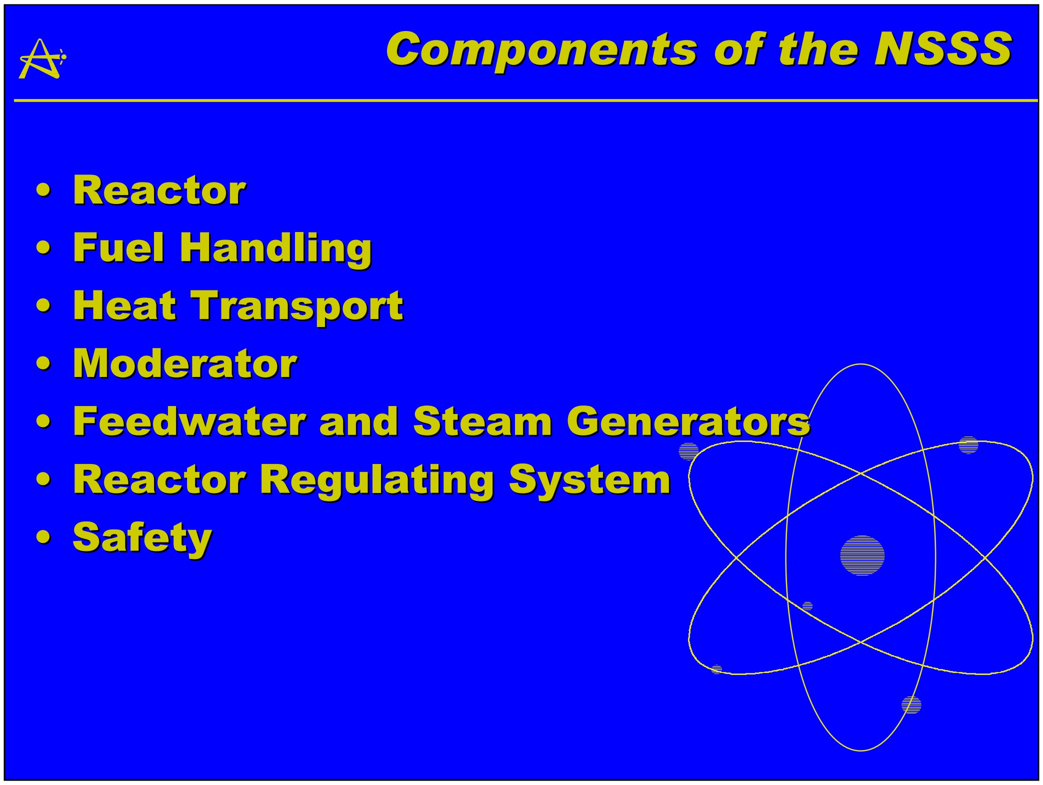


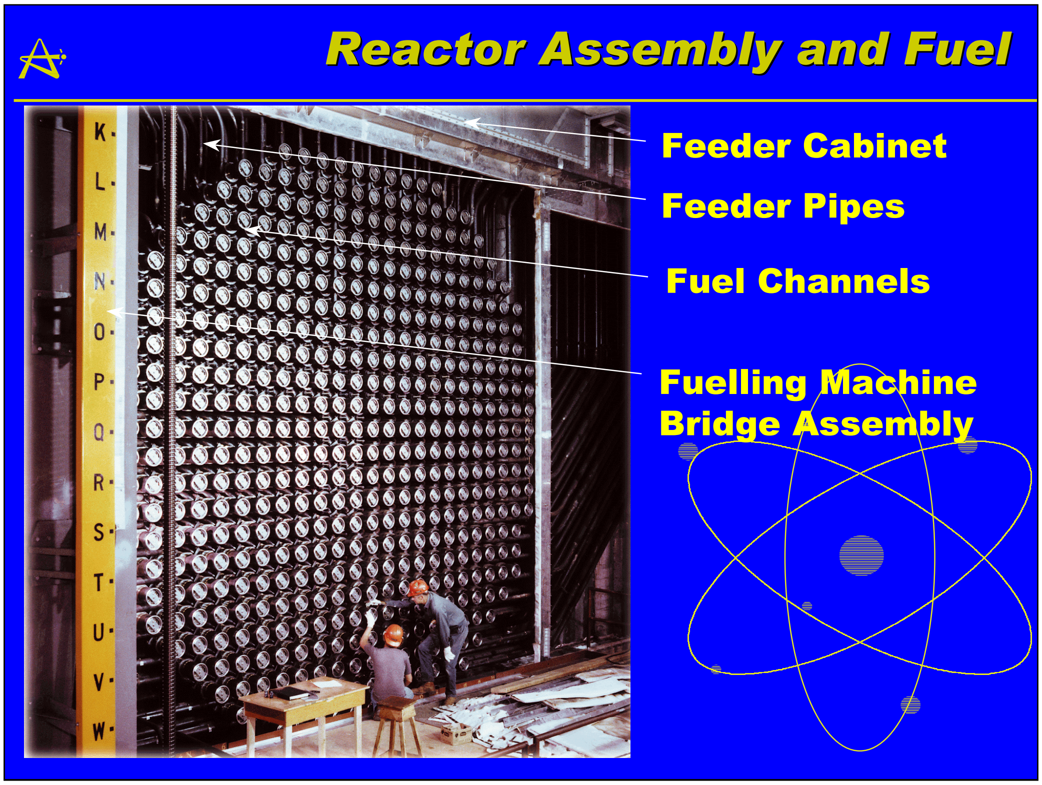
- The next four lectures, including this one, provide a discussion of the basic technical features of CANDU 6. The content and scope of these lectures follows the CANDU Technical Summary. Each of you has a copy of this document.
- We do not have time, of course, for a detailed description of each system. That would need about 10 weeks of lectures. But we can look at the whole CANDU 6 station in summary form, so that when detailed lectures start the ideas of CANDU will be more familiar.
- The pictures on this slide show a CANDU 6 reactor during shipping to site, with a worker standing next to it to show its size. The weight of this assembly is about 275 Mg.
- At the upper right is a Computer Aided Drafting and Design (CADD) sketch of the new CANDU 6 control room to be installed in Qinshan Phase III. Functionally, this room is identical to those in earlier stations - the differences are modernization and “face lift” to make the system easier to operate.
- The picture at the bottom shows the last stage of a typical CANDU 6 low-pressure steam turbine. Each turbine-generator set of Qinshan Phase III generates about 720 MWe of electrical power.



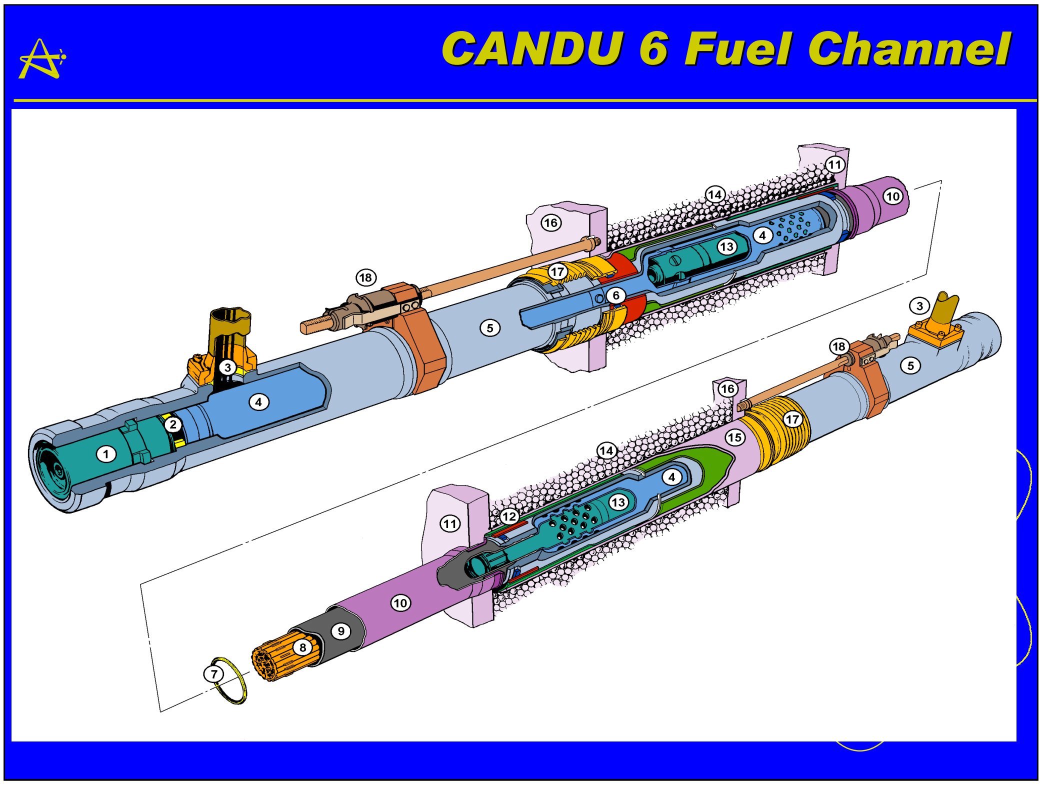
- Even through they all have the same identifier, the details of each CANDU 6 station are slightly different, for two reasons. One reason is time - the Point Lepreau unit shown at the top left was designed before 1983, as was the Wolsong 1 unit which is furthest in the distance in the bottom-left picture. Each station reflects the latest available technology and concepts of design and safety. These concepts change slowly over the years, especially with the lessons learned from operating experience.
- The second reason the stations are different is location -- each station uses some equipment specific to the construction contract and agreements on the localization of manufacture. A good example is the turbine-generator. Each manufacturer offers a unique design to meet the given specification.
- The Qinshan Phase III station, shown in the sketch at the right, includes the latest refinements of CANDU 6 based on over 15 years of successful operation. The existing CANDU 6 stations are the best possible locations for learning how these plants operate. In addition, an electronic information exchange system, called CANNET, gives the operating staff at each station a way to share detailed questions and answers about their own equipment with operators of all other CANDU stations around the world. TQNPC is a member of the CANDU Owners' Group (COG), which operates this system.



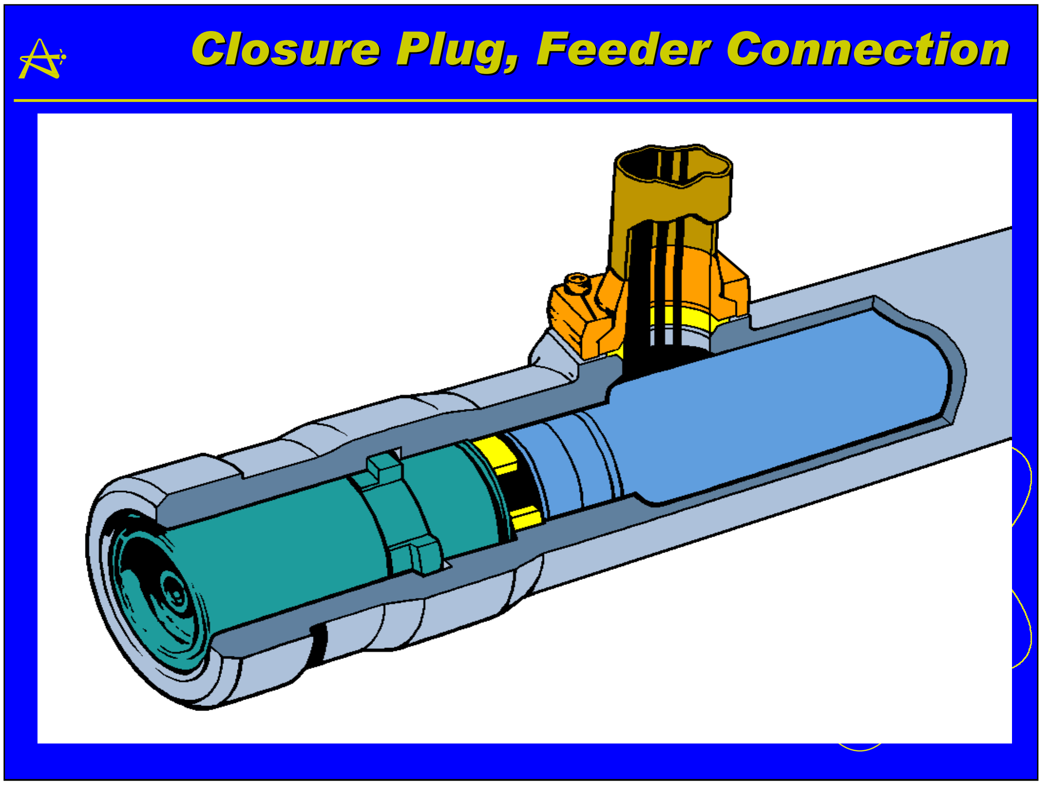
- These are the topics to be discussed in this lecture



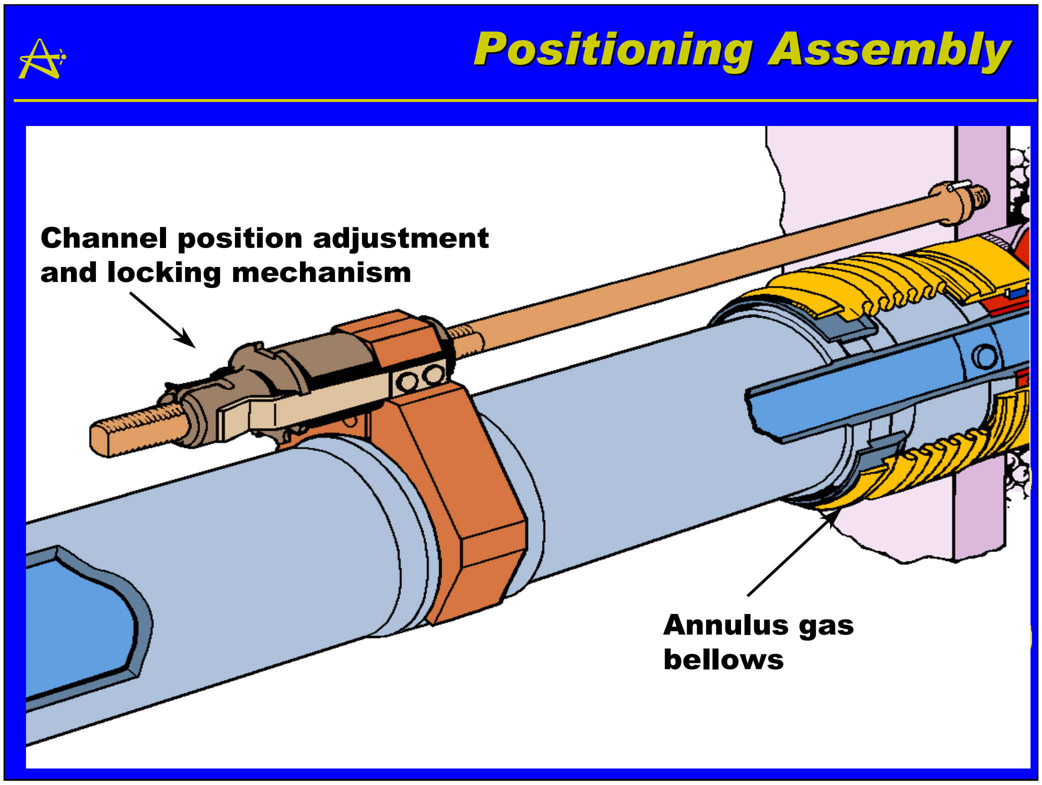
- This picture shows one end of a CANDU 6 reactor during construction.
- Feeder pipes carry cooling water from the inlet header to each fuel channel. Outlet feeder pipes carry heater water from each channel to the outlet header and then to the steam generator.
- During operation, the feeder cabinets (used for thermal insulation) will cover all except the ends of the fuel channels.
- To change fuel, one fuelling machine attaches and seals to each end of the chosen fuel channel. The inside of each fuelling machine is then pressurized to the heat transport system pressure and plugs are removed to allow the fresh fuel to be added to the channel and the used fuel to be removed. Fuelling machines are raised into position automatically by one fuelling machine bridge assembly located at each end of the reactor.
- At the outlet end, each fuel channel includes a coolant temperature monitor and a tube for sampling the coolant. These samples are analyzed regularly, by an automatic system, to detect any fuel failure in the channel. When delayed neutrons are detected in the coolant, fuel can be discharged from the channel to avoid contamination of the heat transport coolant.
- Twenty two fuel channels are fully instrumented for coolant flow measurement.
- If a fuel channel must be inspected or removed for any reason, operators can enter this area during reactor shutdown, to carry out the necessary operations. Semi-automatic channel inspection and replacement tools are available.



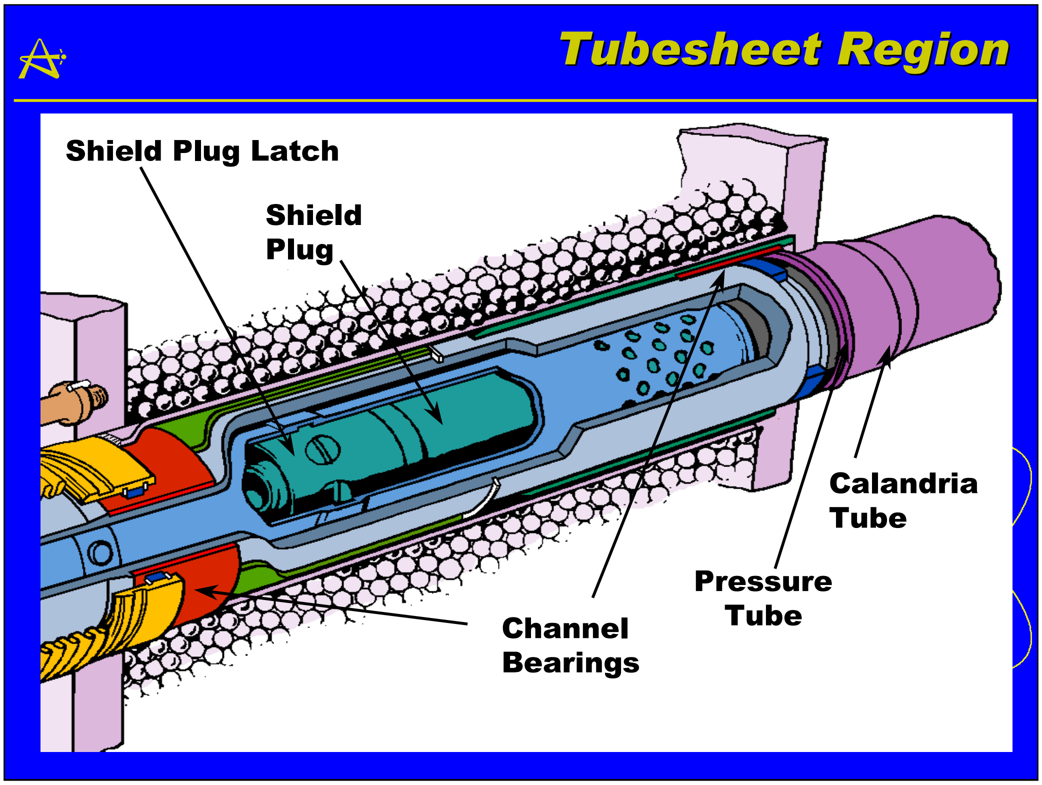
1. Channel closure - removable plug
2. Closure seal insert - metal seal face for sealing the plug
3. Feeder coupling - Grayloc seal, removable for channel replacement
4. Liner tube - to guide fuel and shield plug into channel
5. End fitting body - steel support tube for channel components
6. Outboard bearings - end fitting assembly slides axially at one end, to allow for expansion
7. Annulus spacer - separates pressure tube and calandria tube.
8. Fuel bundle - slides inside pressure tube, on bearing pads mounted on each bundle
9. Pressure tube - holds pressurized coolant, and contains fuel bundles. (30-40 year life)
10. Calandria tube - supports the pressure tube, separates the moderator water from the pressure tube. Annulus between P/T and C/T contains low-pressure CO_2
11. Calandria tubesheet - supports and seals each calandria tube
12. Inboard bearings - second of the two bearings which support the end fitting
13. Shield plug - to reduce axial gamma and neutron streaming from the channel.
14. Endshield shielding balls - carbon steel balls and water for axial radiation shielding
15. Endshield lattice tube - separates shield balls and water from end fitting, and carries annulus gas
16. Fuelling tubesheet - supports end fittings, positioning assembly, bellows, and lattice tubes
17. Channel annulus bellows - seals CO_2 gas in annulus, allows for channel expansion
18. Positioning assembly - holds one end of each channel in a fixed position. Position is adjustable.



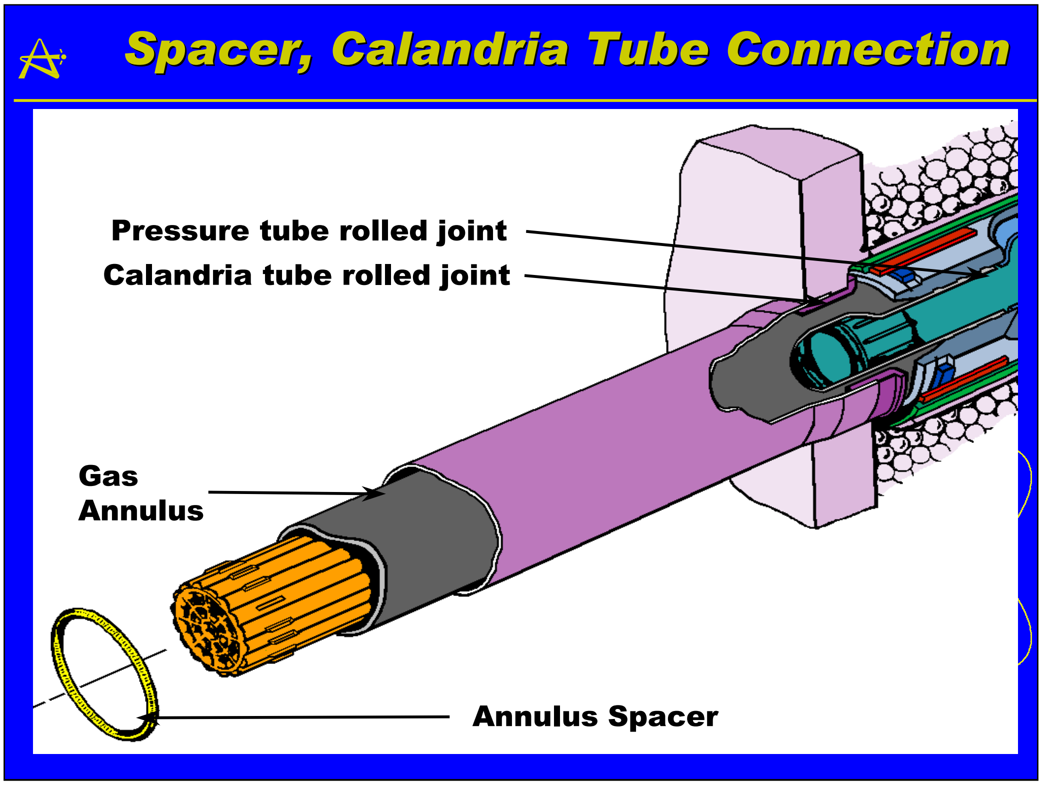
- The steel closure plug is held in place by lugs which fit into slots on the inside diameter of the end fitting body. The plug is sealed by a metal face seal (shown here in yellow).
- The fuelling machine takes out the plug by first latching to the inside diameter and then pushing on the central rod. This action releases the closure lugs.
- This plug is stored in one of the fuelling machine magazine positions during fuelling.
- The end fitting is attached to the end fitting body by a standard Grayloc connector and seal. To remove a channel, the feeder is first plugged by freezing the heavy water using a jacket surrounding the feeder at each end of the channel. This connection is then detached.



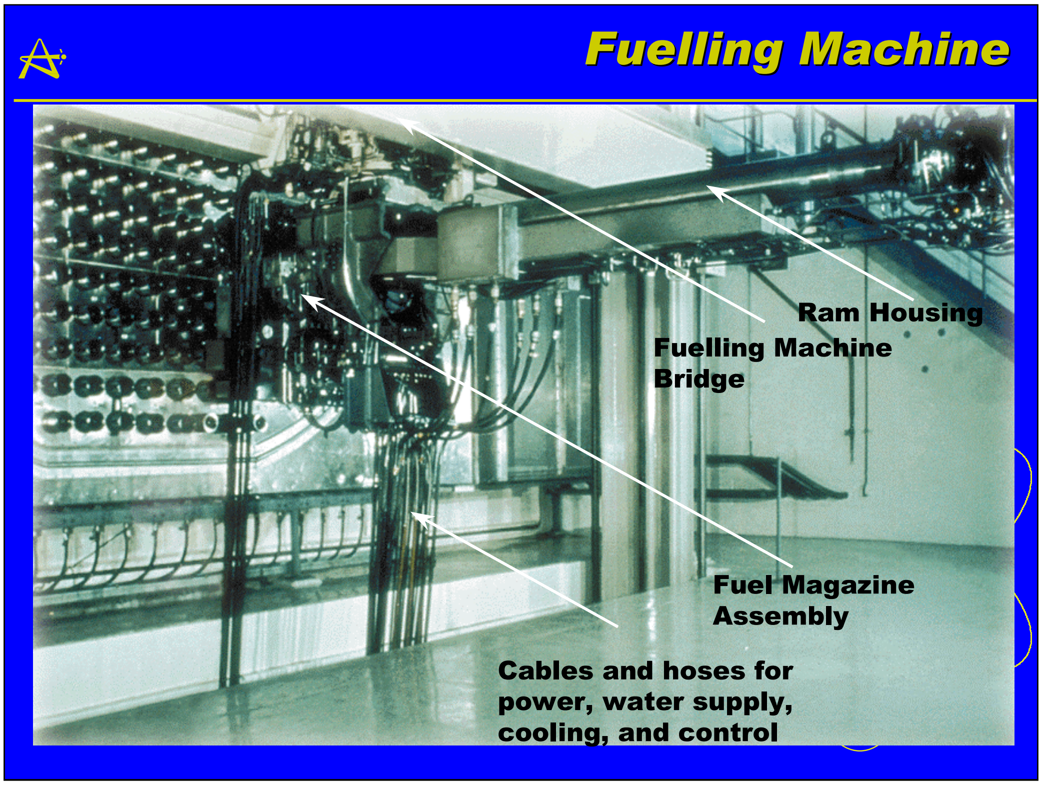
- Only one end of each channel is fixed in position, allowing the other end to move by thermal expansion and radiation growth.
- Approximately at channel mid-life (15-20 years) the channel is repositioned, and the opposite end is locked. This is to allow shorter bearing and feeder clearance allowances.



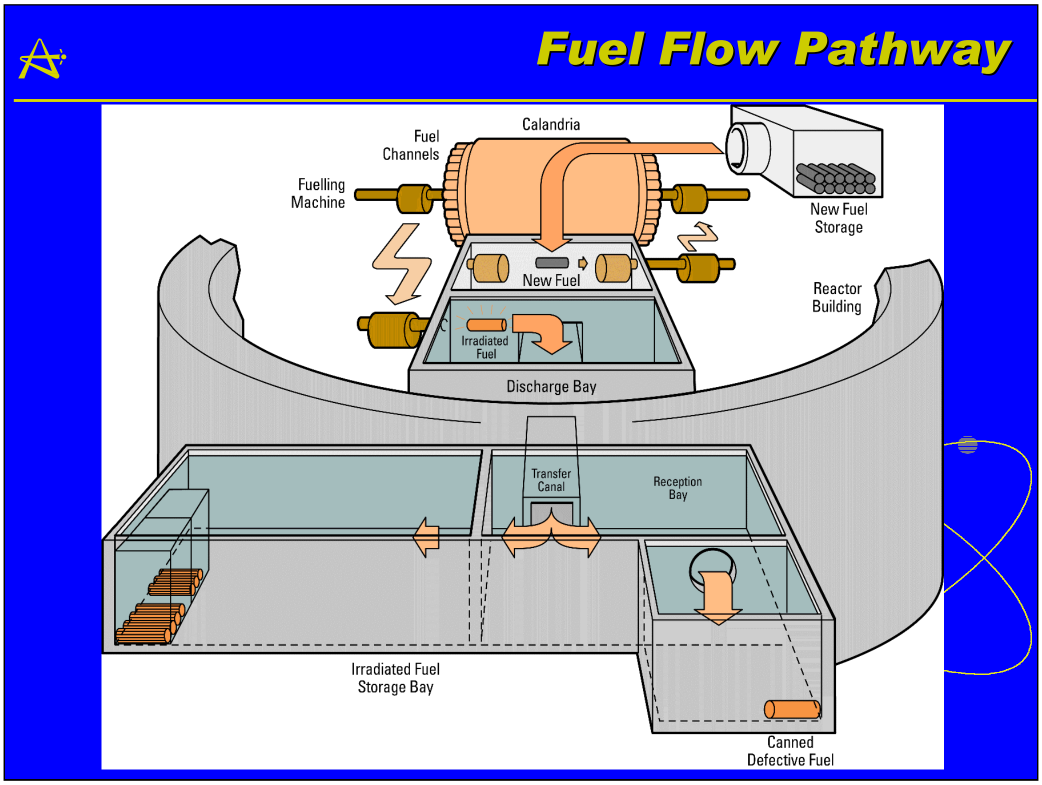
- The shield plug is latched in position as shown, and carries the load of the 12-bundle fuel string onto the liner tube. This latch is opened by the fuelling machine in the same way as is the latch on the closure plug.
- The fuelled region of the channel is located at the inboard side of the inboard tubesheet.



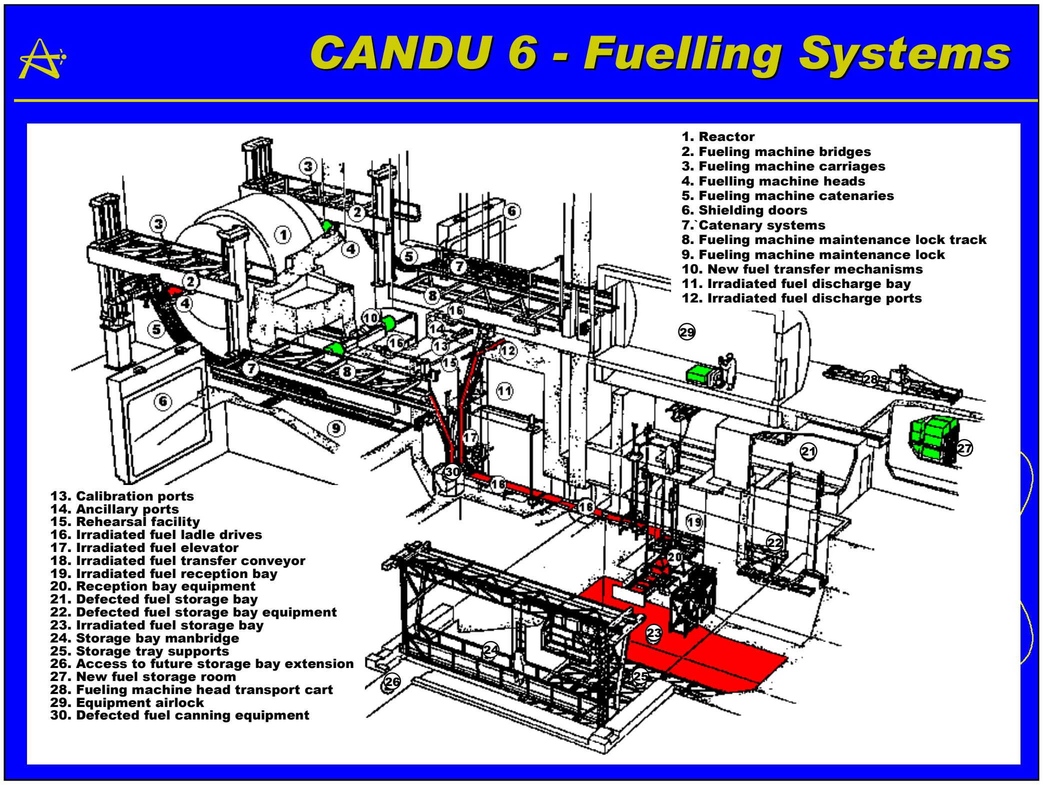
- The spacer consists of a coiled Inconel spring, welded at the ends. It fits tightly onto the pressure tube.
- The pressure tube rolled joint seals the pressure tube onto the inside diameter of the end fitting. It features three ring grooves which strengthen the bonding of the joint.
- The calandria tube rolled joint includes an inner sleeve, due to the thin section of this tube. The calandria tube is replaceable during plant life.



- This picture shows a Pickering A fuelling machine, photographed before plant startup. The CANDU 6 fuelling machines are almost identical except for improvements made on the basis of operating experience.
- The fuel magazine has 12 positions, each of which can carry two fuel bundles or one shield plug or one closure plug. Other positions are occupied by the fuelling machine snout plug, spare channel plugs and tools.
- Normally, 8 new fuel bundles are added to a channel by one of the machines at each visit, and eight used fuel bundles are removed by the machine at the other end of the channel. Eight fuel bundles add about 0.4 mk of reactivity - this change is controlled by the zone control system. The fuelling direction is the same as the direction of coolant flow.
- These machines operate 2-3 times per day on a 5-day, single-shift fuelling plan. Each complete fuelling cycle (from pickup of fresh fuel to discharge of used fuel) takes about 2 1/2 hours.
- Maintenance of these machines can be carried out in a separate room, with the reactor at full power.



- New fuel is brought into containment building through the large equipment airlock. It moves to the new fuel loading room for final inspection and manual loading into the transfer mechanism.
- Fuel is transferred to the fresh-fuel machine through a closed port. Fuelling is carried out, and then the used fuel bundles are transferred through the discharge port into the irradiated fuel discharge bay. From there, they are placed onto elevators which transfer them to the transfer canal.
- The transfer canal conveyor moves the fuel bundles to the reception bay where they are arranged on trays and inspected. If desired, fuel may be taken directly from this reception bay, placed into a shipping flask, and sent to a hot-cell laboratory for detailed inspection. Defected fuel (if any) is placed in sealed cans and stored in a separate water-filled bay.
- Full used fuel trays are transferred to the irradiated fuel storage bay, where they are stacked and remain for at least five years.
- When the fuel has cooled sufficiently, it normally is removed into a shielded flask and stored on-site in a dry storage facility. From this site it is planned to send the fuel either to a permanent repository or to a reprocessing facility.



• This General Arrangement Drawing shows additional details of the CANDU 6 fuel handling system. Green color indicates fresh fuel areas, and red indicates irradiated fuel areas.

1. Reactor
2. Fueling machine bridges
3. Fueling machine carriages
4. Fuelling machine heads
5. Fueling machine catenaries
6. Shielding doors
7. Catenary systems
8. Fueling machine maintenance lock track
9. Fueling machine maintenance lock
10. New fuel transfer mechanisms
11. Irradiated fuel discharge bay
12. Irradiated fuel discharge ports
13. Calibration ports
14. Ancillary ports
15. Rehearsal facility
16. Irradiated fuel ladle drives
17. Irradiated fuel elevator
18. Irradiated fuel transfer conveyor
19. Irradiated fuel reception bay
20. Reception bay equipment
21. Defected fuel storage bay
22. Defected fuel storage bay equipment
23. Irradiated fuel storage bay
24. Storage bay manbridge
25. Storage tray supports
26. Access to future storage bay extension
27. New fuel storage room
28. Fueling machine head transport cart
29. Equipment airlock
30. Defected fuel canning equipment