



CANDU Safety

#1 - CANDU Nuclear Power Plant Design

Dr. V.G. Snell
Director
Safety & Licensing



What Accident is This?



28 killed, 36
injured, 1821
homes and
167 buildings
destroyed



Or this?

“It could take months to determine what caused an explosion early Wednesday at Hawthorn power plant. The generating plant, which produces 15 percent of Kansas City Power & Light's electricity, will be out of operation for an extended period of time”



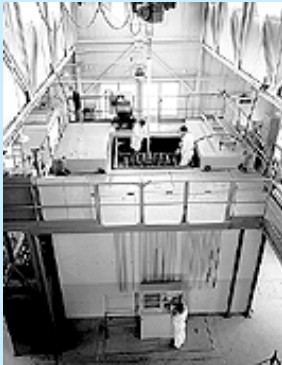


What is CANDU?

- λ CANada Deuterium Uranium - the name gives the design
- λ started as the Canadian contribution to the War effort: to produce plutonium using natural uranium and heavy water
- λ the first reactor to go critical outside the U.S. was ZEEP in 1945 - too late for the War but started the Canadian nuclear civilian power programme



ZEEP - Canada's First Reactor

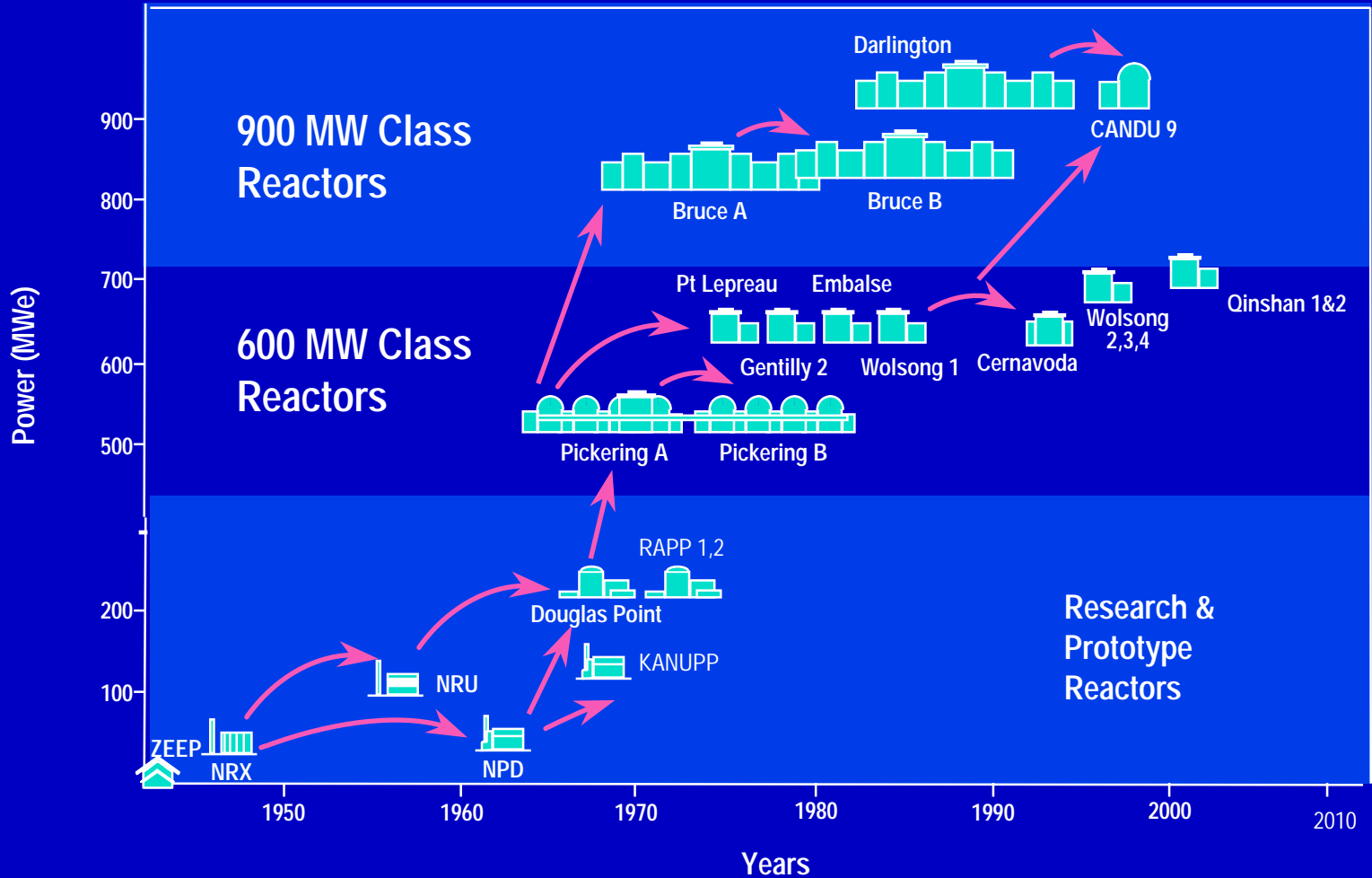


Right - ZEEP building at Chalk River Laboratories near Chalk River, Ontario, as it appeared around the time of the first startup in 1945.

Left - ZEEP taken during the 1950s. Experiments were conducted on fuel for early CANDU designs, including NPD and Douglas Point



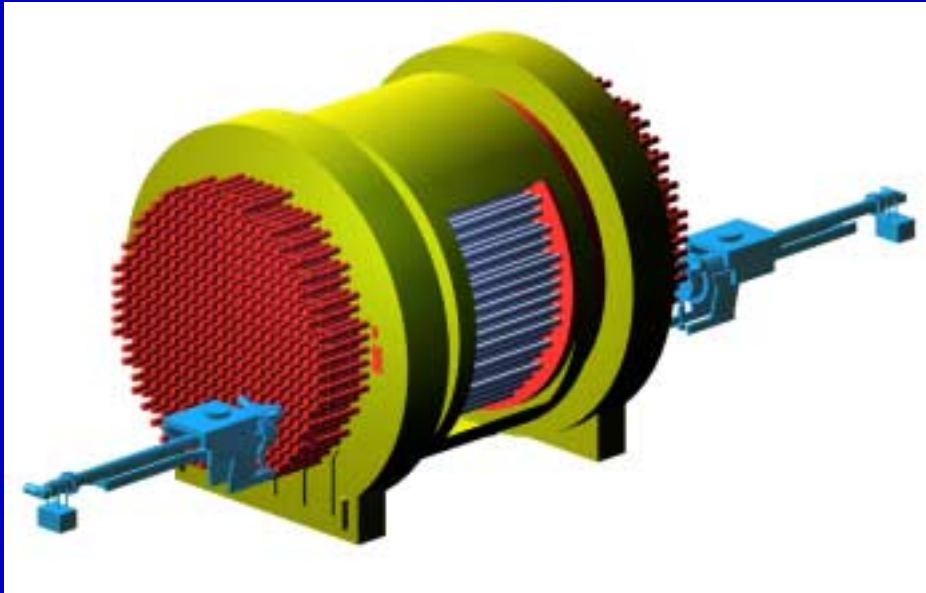
CANDU Genealogy



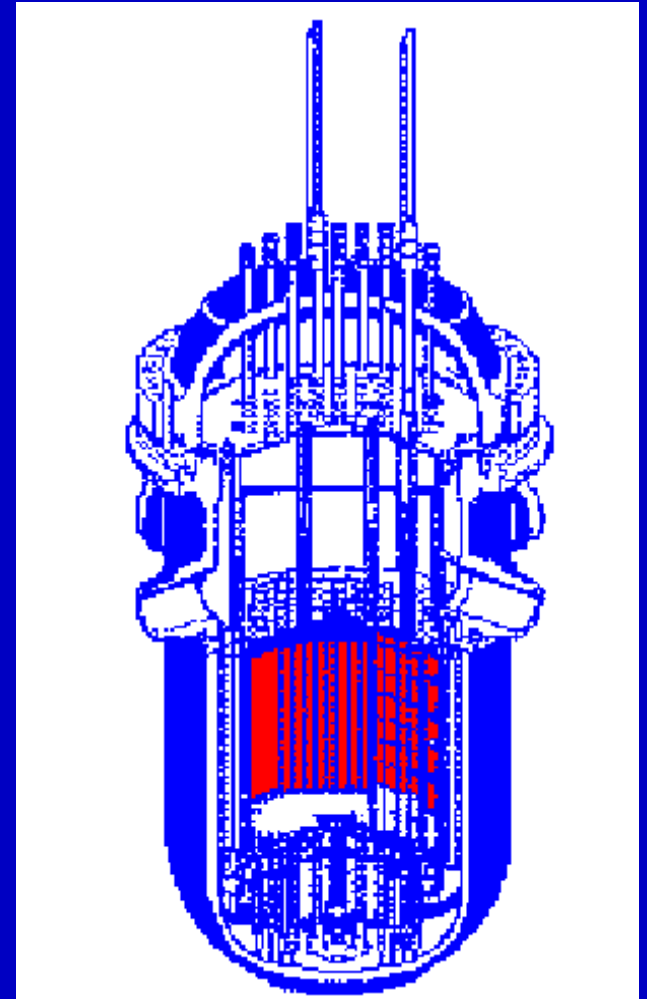


Reactor

CANDU



PWR





Reactor

λ CANDU

- 380 small diameter (10 cm), thin (4.2 mm) pressure tubes
- horizontal orientation
- heavy water coolant (312°C)
- separate heavy water moderator (65°C)
- reactivity devices in low pressure moderator
- large core, low energy density (11 MW / m³)

λ PWR

- 1 large diameter, thick pressure vessel
- vertical orientation
- light water coolant (329°C)
- coolant is the same as the moderator, both hot
- reactivity devices in high pressure coolant / moderator
- small core, high energy density (60 MW / m³)



Fuel

CANDU



PWR





Fuel

λ CANDU

- natural uranium
- low burnup
- short bundles (0.5 metres)
- on-power refuelling
- remove defected fuel during operation

λ PWR

- enriched uranium
- high burnup
- long bundles (3.8 metres)
- shut down to refuel
- remove defective fuel only when shut down to refuel



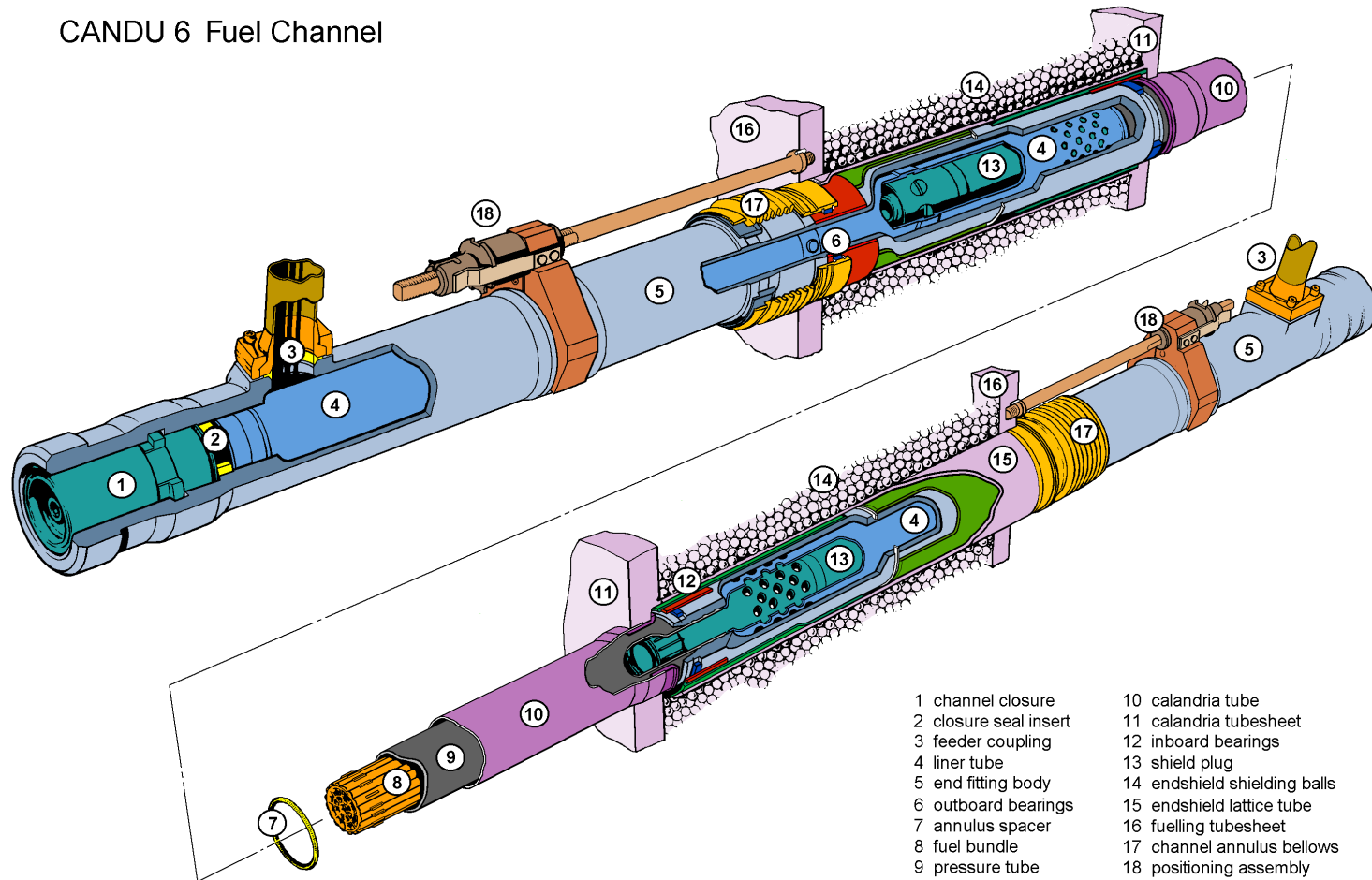
Fuel Channel

- λ CANDU fuel bundles lie inside the pressure tube
- λ a calandria tube separates the pressure tube from the moderator
- λ a gas gap between the pressure tube and the calandria tube provides thermal insulation



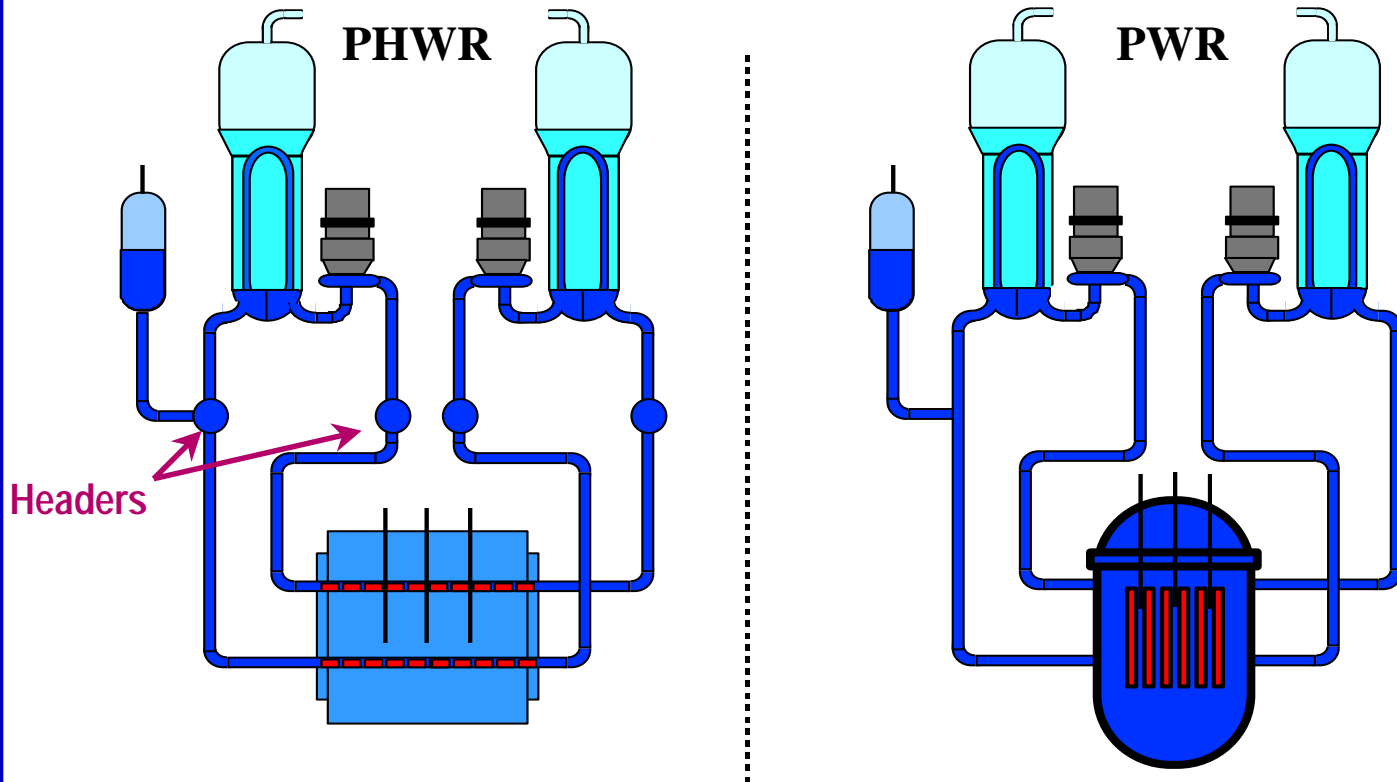
Fuel channel

CANDU 6 Fuel Channel





Heat Transport System





Heat Transport System

λ CANDU

- each channel is individually connected to collectors (headers) above the core
- pumps, steam generators above the core
- each particle of fluid goes through the core twice before it gets back to where it started
- one or two loops
- operating pressure ~10 MPa

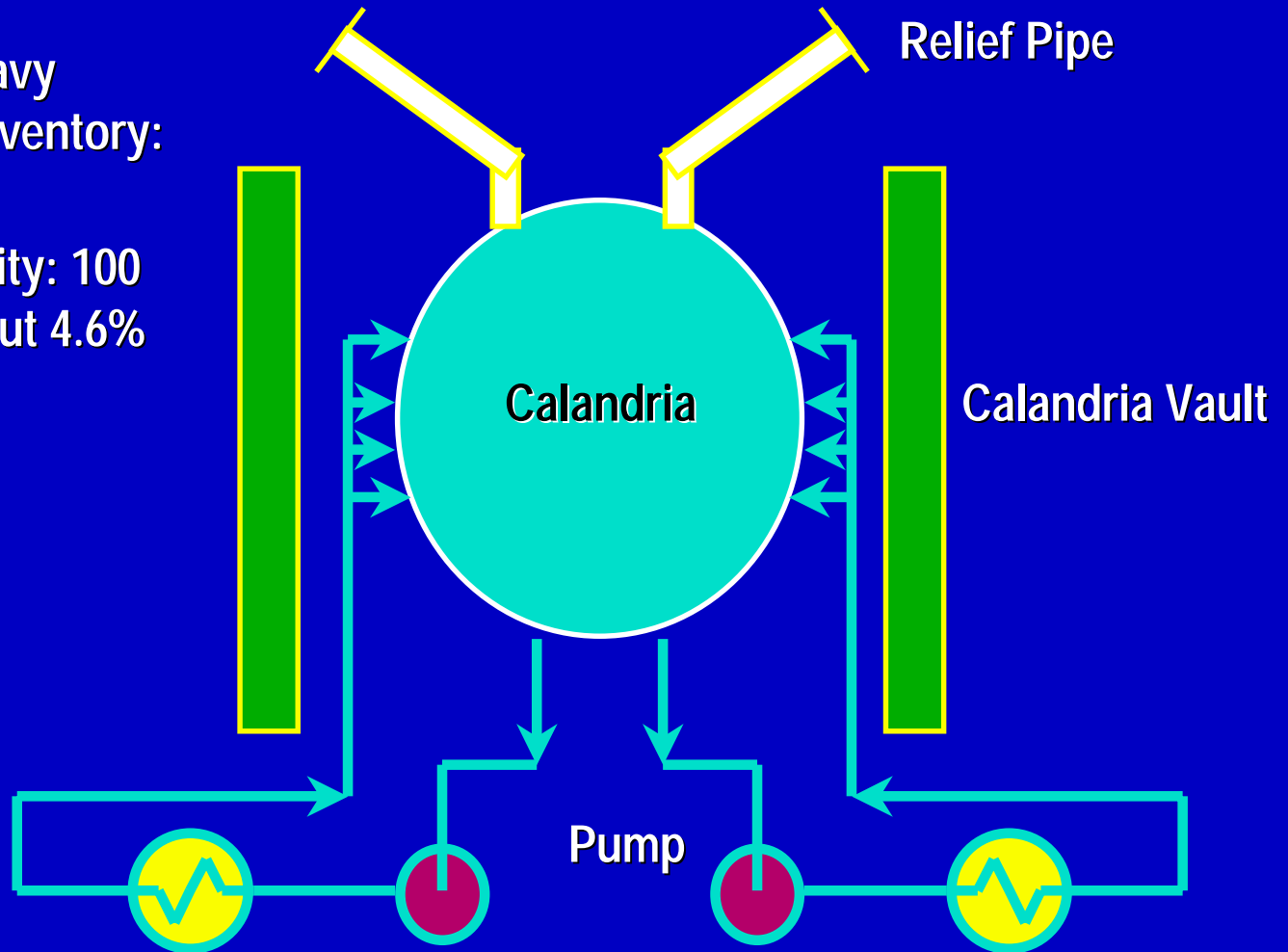
λ PWR

- the pressure vessel is a large pot containing all the core water in one place
- pumps, steam generators above the core
- each particle of fluid goes through the core once before it gets back to where it started
- two, three or four loops
- operating pressure ~15.5 MPa



Moderator

- λ cold: 65°C heavy water, large inventory: ~260 Mg
- λ cooling capacity: 100 MW(th) or about 4.6% of full power



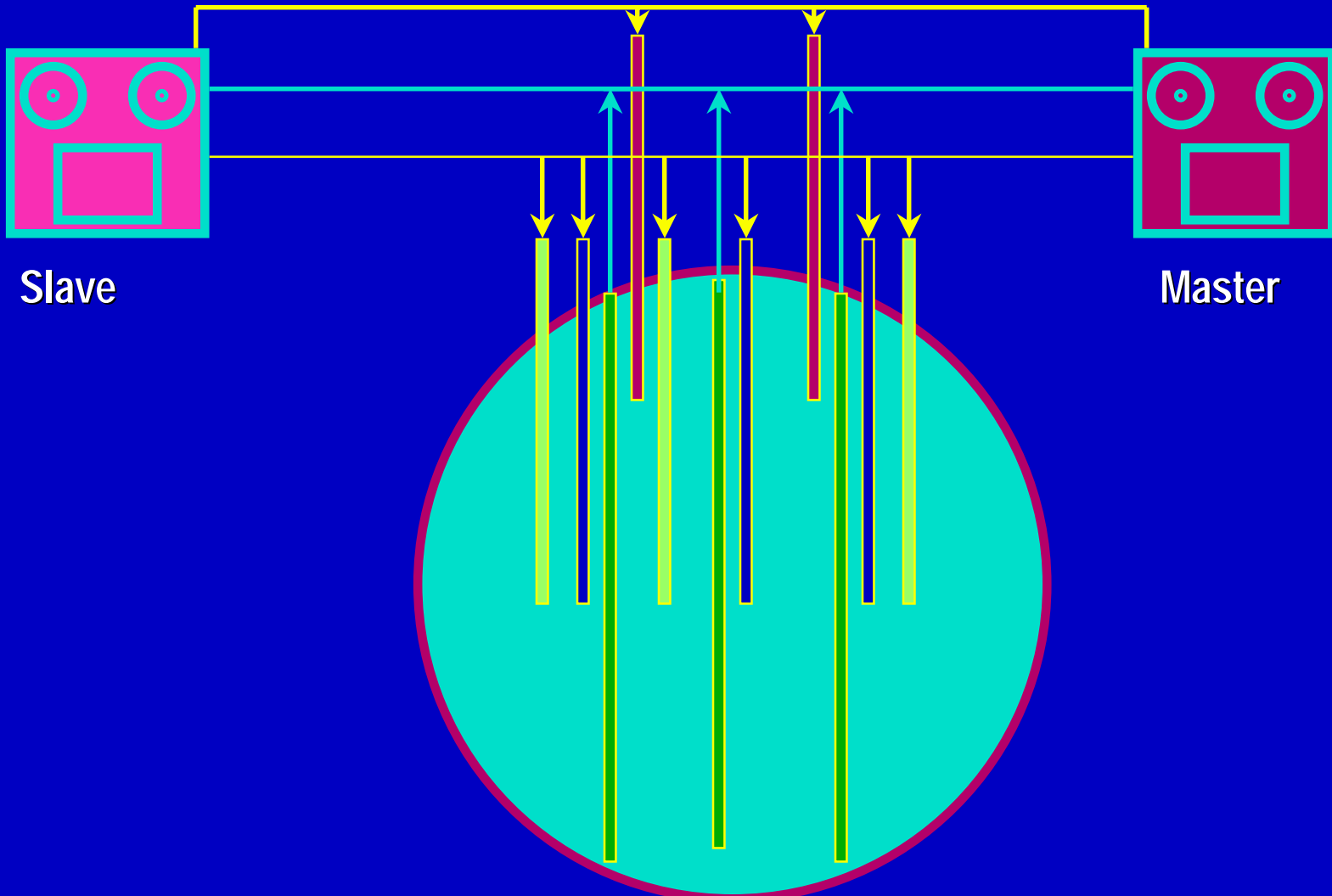


Reactivity Control

- λ short-term: in-core devices (absorber & adjuster rods, light water)
- λ long-term: on-power refuelling
- λ no absorber in coolant
- λ little absorber in moderator except during startup after a long shutdown
- λ routine control: dual redundant digital computers



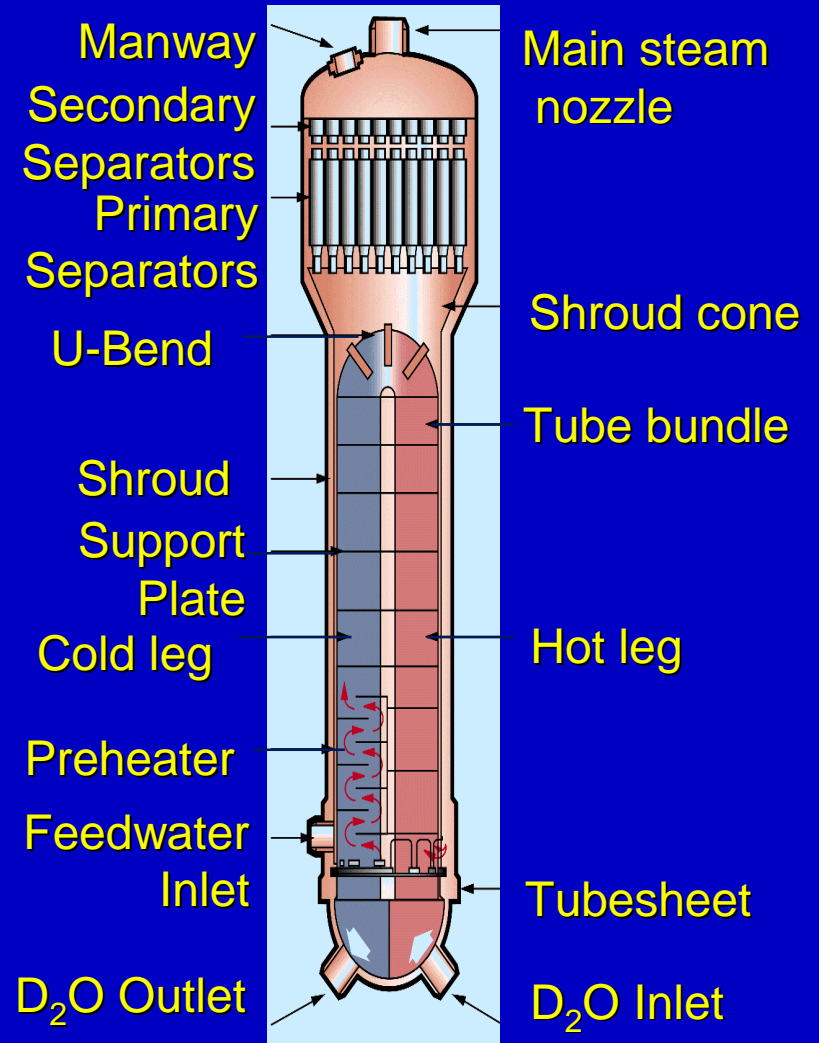
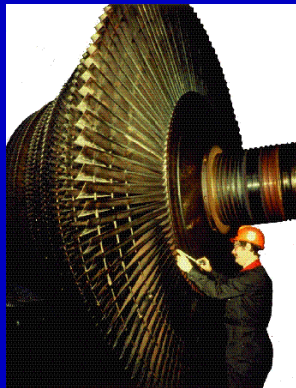
Reactivity Control





Secondary Side

- λ conventional nuclear steam generators and turbine / generator
- λ the steam generators have heavy water on the primary side
- λ steam conditions: 4.7 MPa and 260°C





Auxiliary Systems

- λ CANDU has systems not found in PWRs
 - automated refuelling & fuel handling system
 - annulus gas system (leak-before-break)
 - shield cooling system
 - heavy water vapour and liquid recovery
- λ and systems that are found in PWRs
 - primary pressure & inventory control
 - shutdown cooling system
 - shutdown systems, Emergency Core Cooling, containment, emergency power etc.



Systems CANDU Does Not Need

- λ Some PWR systems are not needed in CANDU or are much simpler
 - no boron control system in the coolant
 - no boron addition to ECC water
 - no criticality concerns outside the reactor for new or used fuel
 - simpler core, reactivity devices



Summary

