CANDU Safety
#8 - Containment

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What's Special About CANDU Containment?

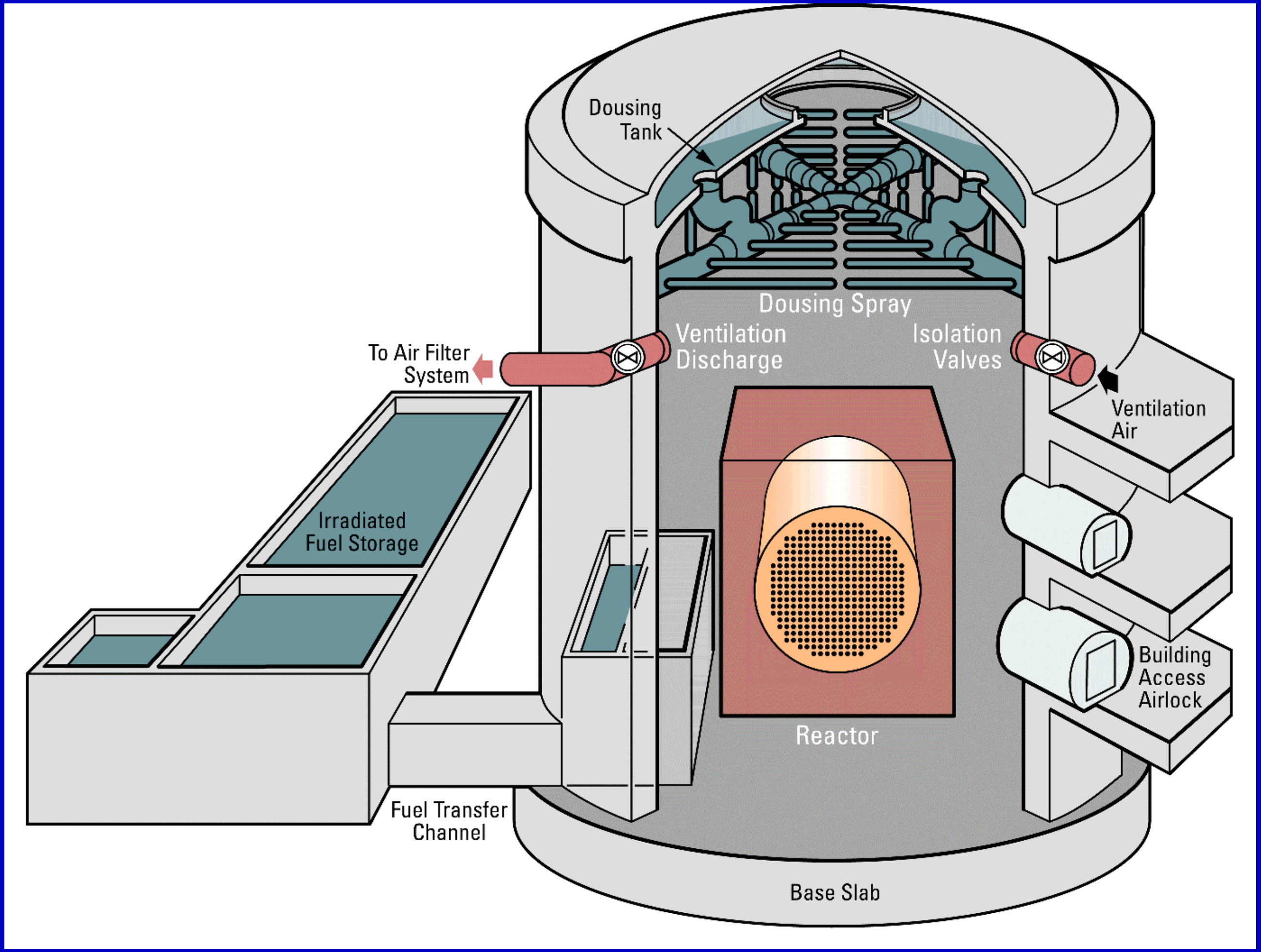
- not much
- containment type is not tied to the CANDU design:
  - single unit pressure suppression (CANDU 6)
  - multi-unit vacuum pressure suppression (Ontario Hydro)
  - double containment with suppression pool (recent Indian HWRs)
  - single-unit dry (CANDU 9)

Single Unit Pressure Suppression (CANDU 6)

Fundamental Requirements

- **design pressure set above pressure reached in large LOCA**
- **leak rate at design pressure set to ensure the dose to the public in an accident is less than the regulatory limit**
- **note that the dose is *calculated* from:**
  - **release to containment using physically-based models of reactor physics, fuel, reactor thermohydraulics, etc.**
  - **containment pressure transient using physically-based models of containment thermohydraulics**
  - **atmospheric dispersion models**

Single-Unit Pressure Suppression

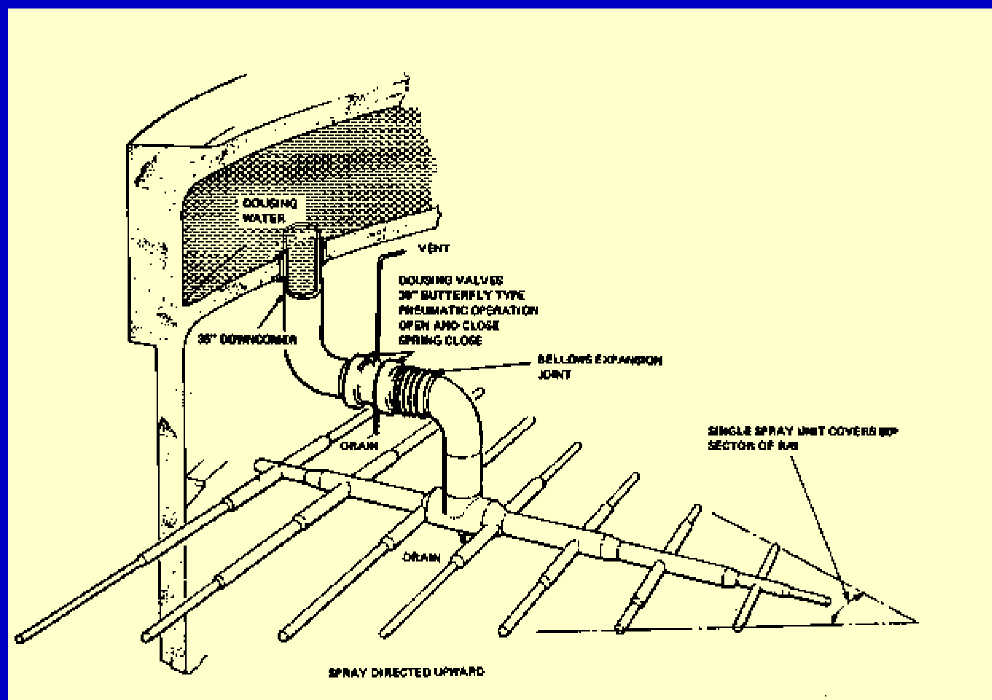


Design Summary - CANDU 6

- **prestressed, post-tensioned concrete structure**
  - **keeps the building in compression**
- **relatively *large***
  - **41 metres ID × 44 metres high; 48,000 m^3 net volume**
  - **diameter required for fuelling machines**
  - **large volume per unit energy allows lower design pressure (124 kPa (g))**
- **wall thickness: 1.1 metres**
- **walls lined with epoxy for leak-tightness**
- **design leakrate: 0.5% / day at design pressure**

Dousing

- powerful pressure suppression, *not* like LWR sprays
- in elevated tank around building dome
- capacity 1560 m^3, flowrate 4500 kg/sec for 4 out of 6 headers

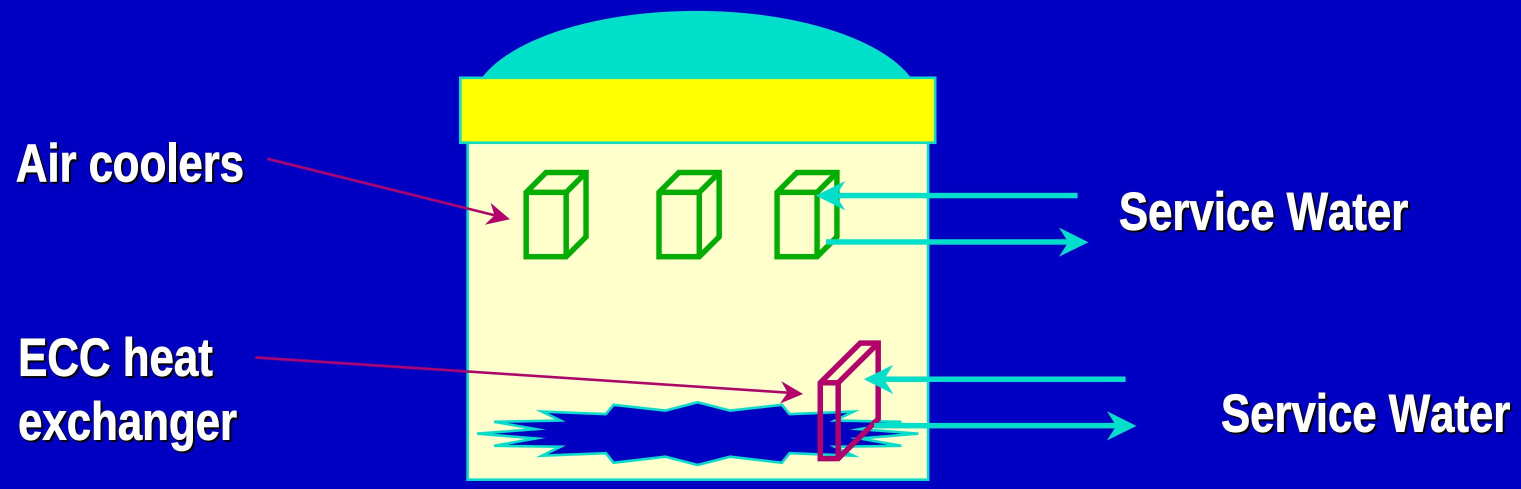


Dousing Operation

- 6 spray headers, each with 2 valves in series (to avoid inadvertent douse, which is costly)
- dousing turns on when building pressure reaches 14 kPa (g) and off if it falls to 7 kPa (g)
  - always on for large LOCA until dousing water is all used
  - cycles on & off for small LOCA
- dousing connections above bottom of tank so 500 m^3 of water is reserved for medium-pressure ECC
- assists in fission product washout
- no effect in long-term containment pressure control

Long-Term Cooling

- 16 local air coolers
- condensation on structures and equipment
- for LOCA, emergency core cooling system heat exchangers



Ventilation

- in operation, most of the containment building is accessible, unlike most LWRs
- ventilation is needed for working conditions and to control and condense heavy water vapour
- on a containment isolation signal (high pressure or high radiation), redundant valves in each ventilation line to the atmosphere are closed - but *not* major process lines
- unavailability of ventilation valve closure must be < 10^{-3} as with other safety systems
- tested during operation to show the unavailability target is not exceeded

Hydrogen Control

- hydrogen can build up:
  - in the short term, from clad oxidation, in a severe accident such as a LOCA + Loss of Emergency Core Cooling
  - in the long term, after a LOCA, due to radiolysis
- natural circulation in containment and the size of the building reduces the hydrogen concentration for LOCA + LOECC
- forced flow from Local Air Coolers mixes hydrogen
- supplemented by 44 igniters to ignite local concentrations
- for "worst" LOCA + LOECC, maximum room hydrogen concentration is 7%; building average is 3.5%

Acceptance Criteria

- peak pressures must be less than design pressure for:
  1. LOCA
  2. LOCA with loss of emergency core cooling
  3. LOCA with loss of all dousing
- there must be no structural failure which could damage the reactor systems for:
  4. steam or feedwater line break
  5. steam or feedwater line break with loss of all dousing
- there must be no damage to the containment structure for items 1 to 4

Discussion of Design Pressure

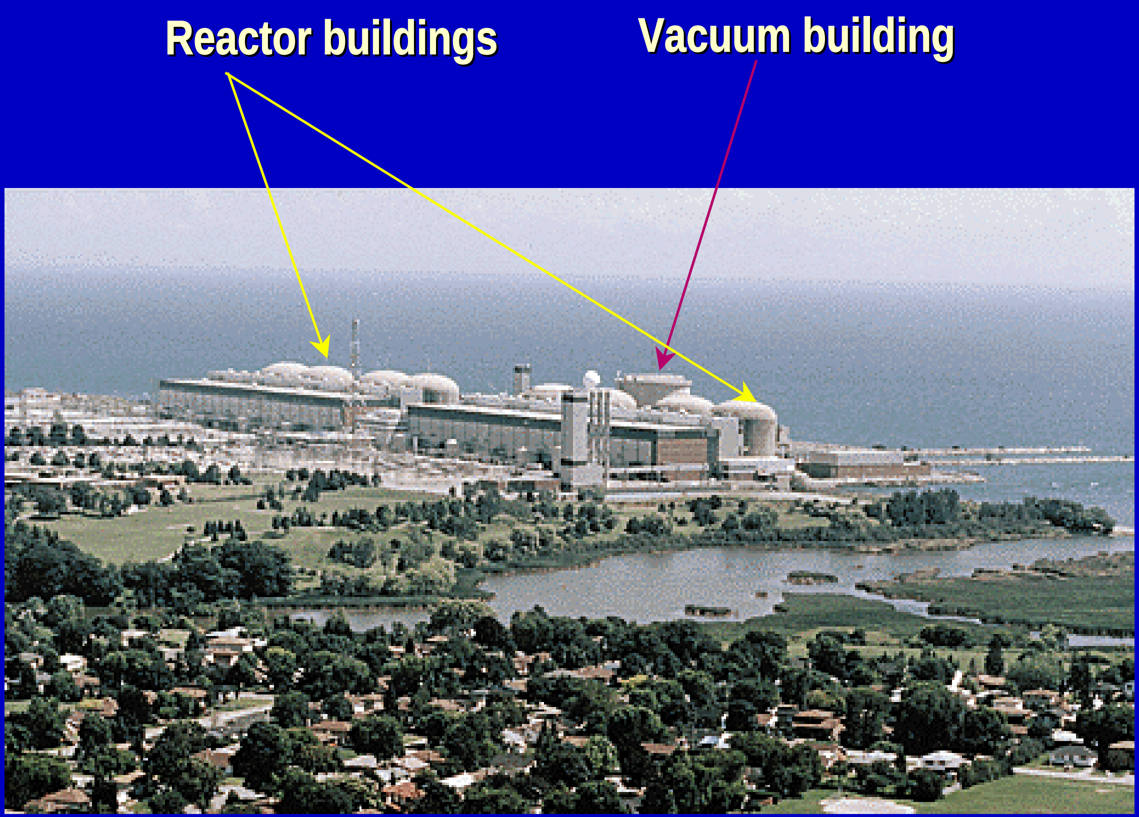
- containment pressure must be less than design for accidents which can release fission products
- this includes some *severe accidents* such as LOCA + LOECC
- containment leakage is not as important for accidents which do not release much radioactivity (and steam line breaks cause a power reduction, not an increase)
- the structural integrity of the building must be maintained even for some multiple failures

Overpressure Behaviour

- **in severe accidents which increase pressure far beyond design pressure, failure mode is "graceful"**
  - **increasing leakage through cracks**
  - **no massive failure**
- **AECB tests on scaled model CANDU 6 containment**
  - **through-wall cracks at 2.7 times design pressure, negligible leakage**
  - **failure at 4.3 times design pressure *if* pressure could be maintained**
  - **leakage rate increases rapidly and prevents failure**

Multi-Unit Vacuum Containment

- each reactor containment is connected by a large duct to a common vacuum building
- water sprays in vacuum building condense steam
- containment stays subatmospheric for days after an accident so the leakage is inward
- very powerful and allowed siting of CANDUs near major city (Toronto)



Pickering 8-Unit CANDU, near Toronto

Single Unit Dry Containment

- **CANDU 9**
- **dousing has been removed**
- **higher containment design pressure**
- **steel-lined for increased leak-tightness**