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 m³ 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 m³ 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).

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*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