CANDU Safety
#25 - CANDU 9 Safety & Licensability

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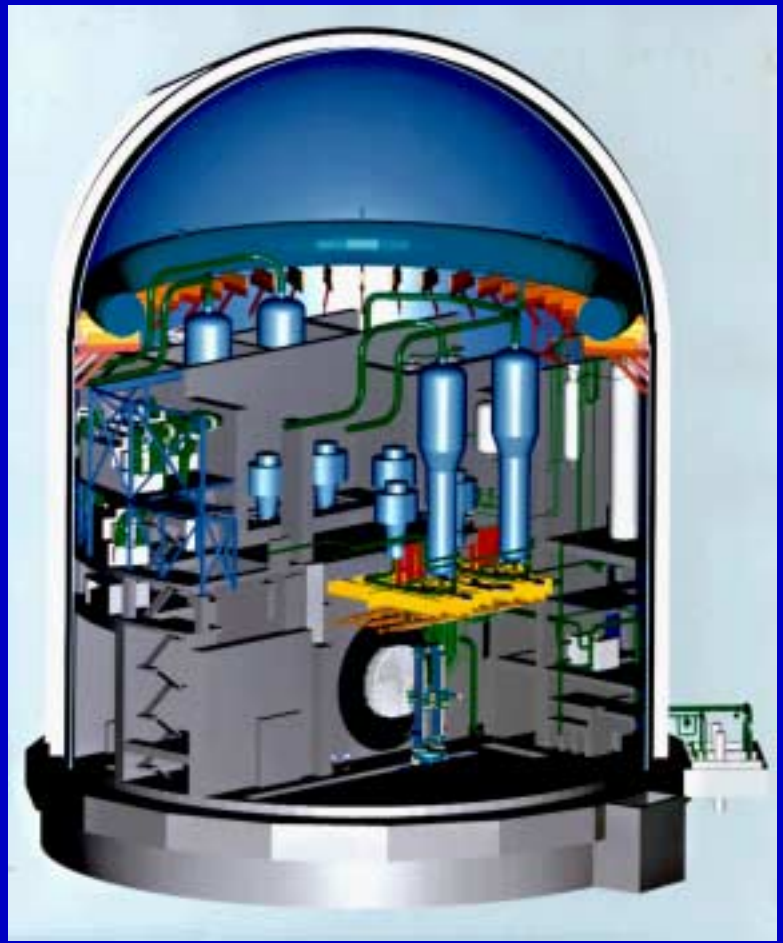
Safety & Licensing

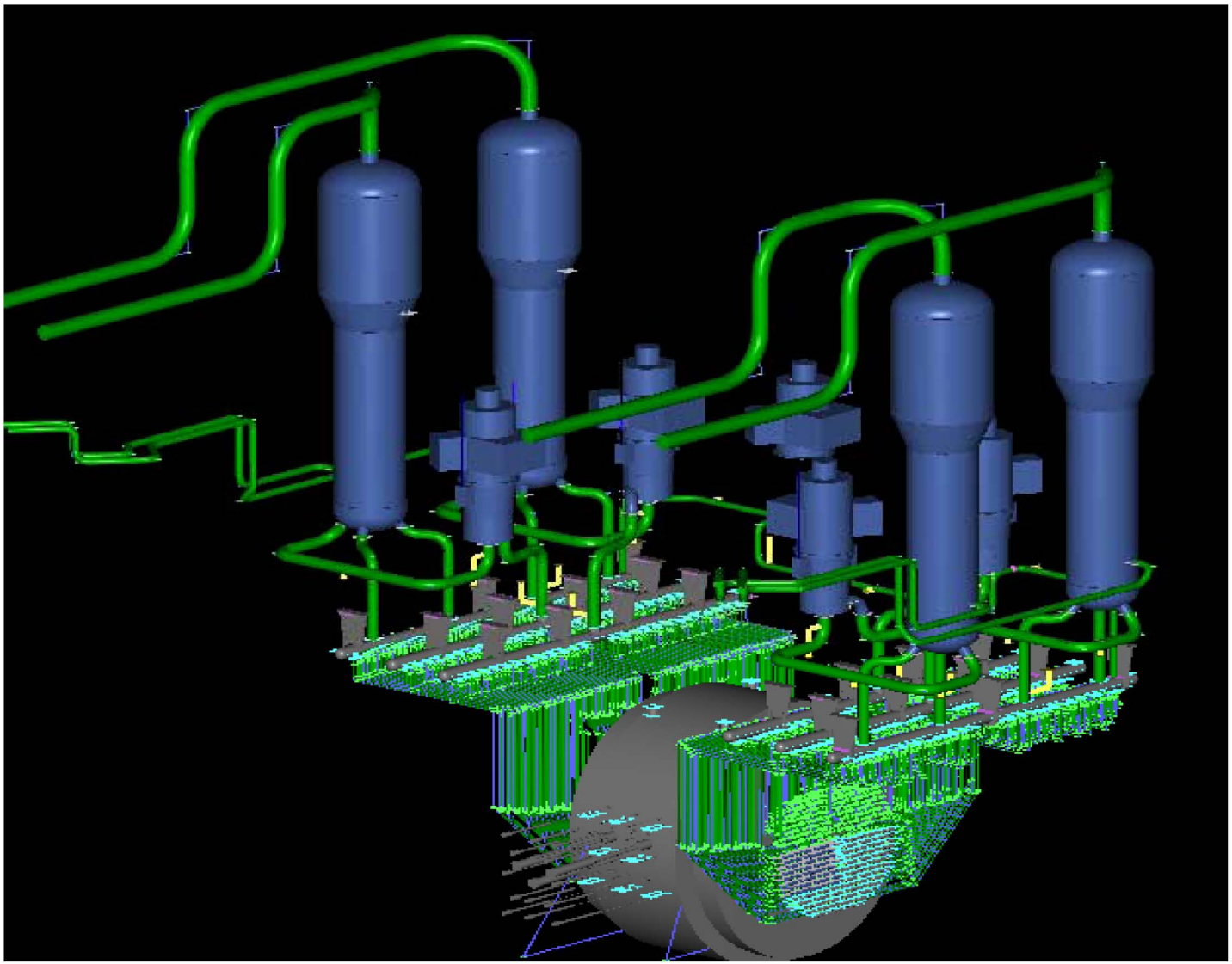
CANDU 9 Safety & Licensing Requirements



- licensable in Canada
  - "up-front" review by the AECB to ensure no fundamental barriers
- licensable in customer's country
  - example of dual licensability: desire for Exclusion Area Boundary <500m led to dry high-pressure steel-lined containment *and* two independent ventilation isolation systems
- meet IAEA Standards and Guides
- meet utility requirements for modern evolutionary plant
- enhanced safety

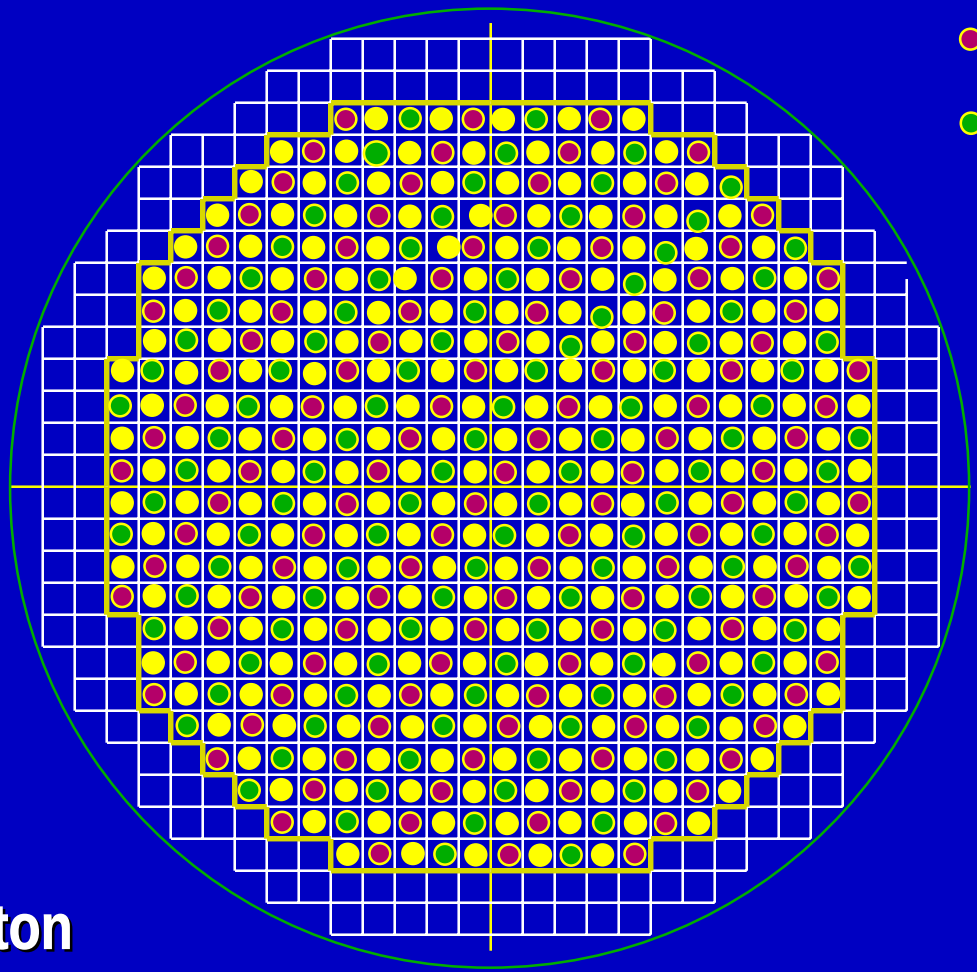
Heat Transport System

- one loop design (Bruce B) chosen for simplicity
- alternating channels connected to different inlet headers to increase margins for large LOCA power transient (interlacing)
- pressurizer volume handles change from zero power cold to full power hot
  - greater assurance of thermosyphoning in accidents



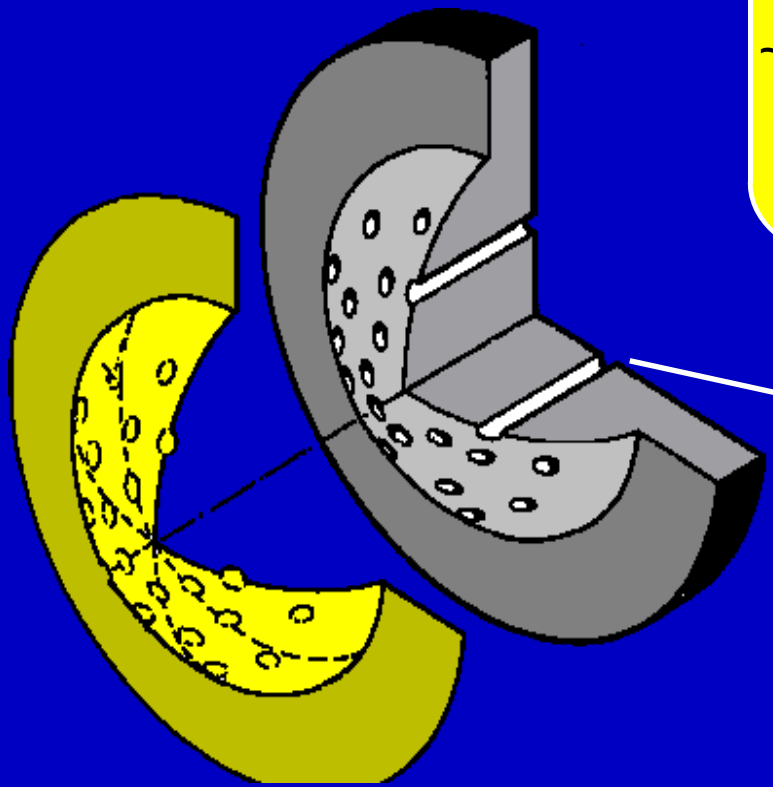
Feeder Connections

- To outlet header
- To inlet header 1
- To inlet header 2



Same
480 channel
core as Darlington

ECC System



Gas

~8MPa

Gas

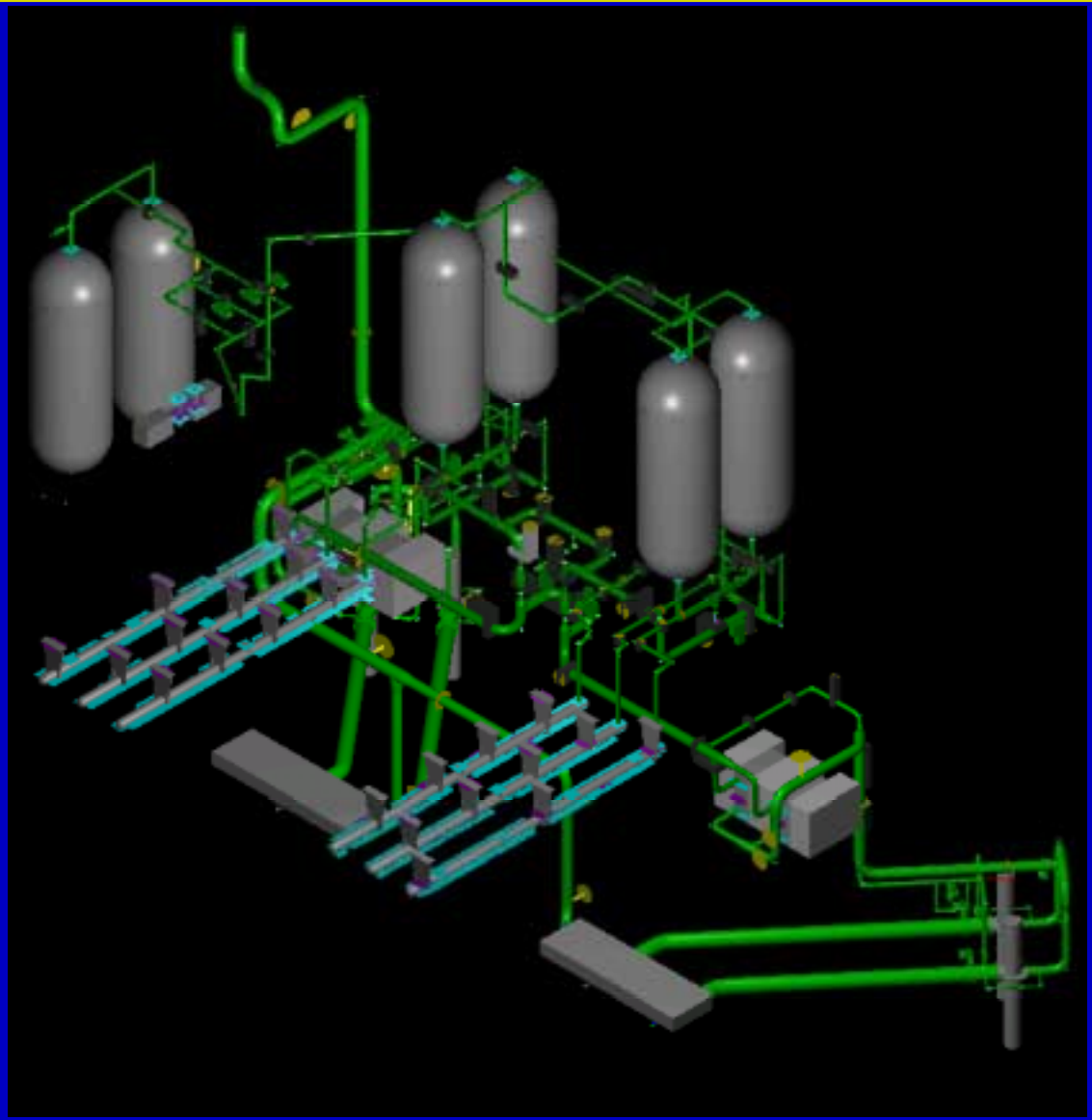
Water

Floating Ball Shut-Off

One-Way Rupture Disc

Heat Transport System

ECC System



Grouping & Separation

- defence against common cause & external events
- each group must on its own:
  - shutdown the reactor
  - remove decay heat & contain radioactivity
  - monitor state of the plant
- *either* Main Control Room (MCR) *or* Secondary Control Area (SCA) can perform the above safety functions including earthquakes
- SCA needed only for major fire in MCR or hostile takeover

Calandria Tubes

- increased heat transfer under accident conditions
- shot-peening of the outside surface, for Qinshan project
- black oxide on the inside surface, added for CANDU 9
- reduces required moderator subcooling, and therefore the size of moderator heat-exchangers or risk of summer derating

Effect of Increased Heat Transfer in Accidents

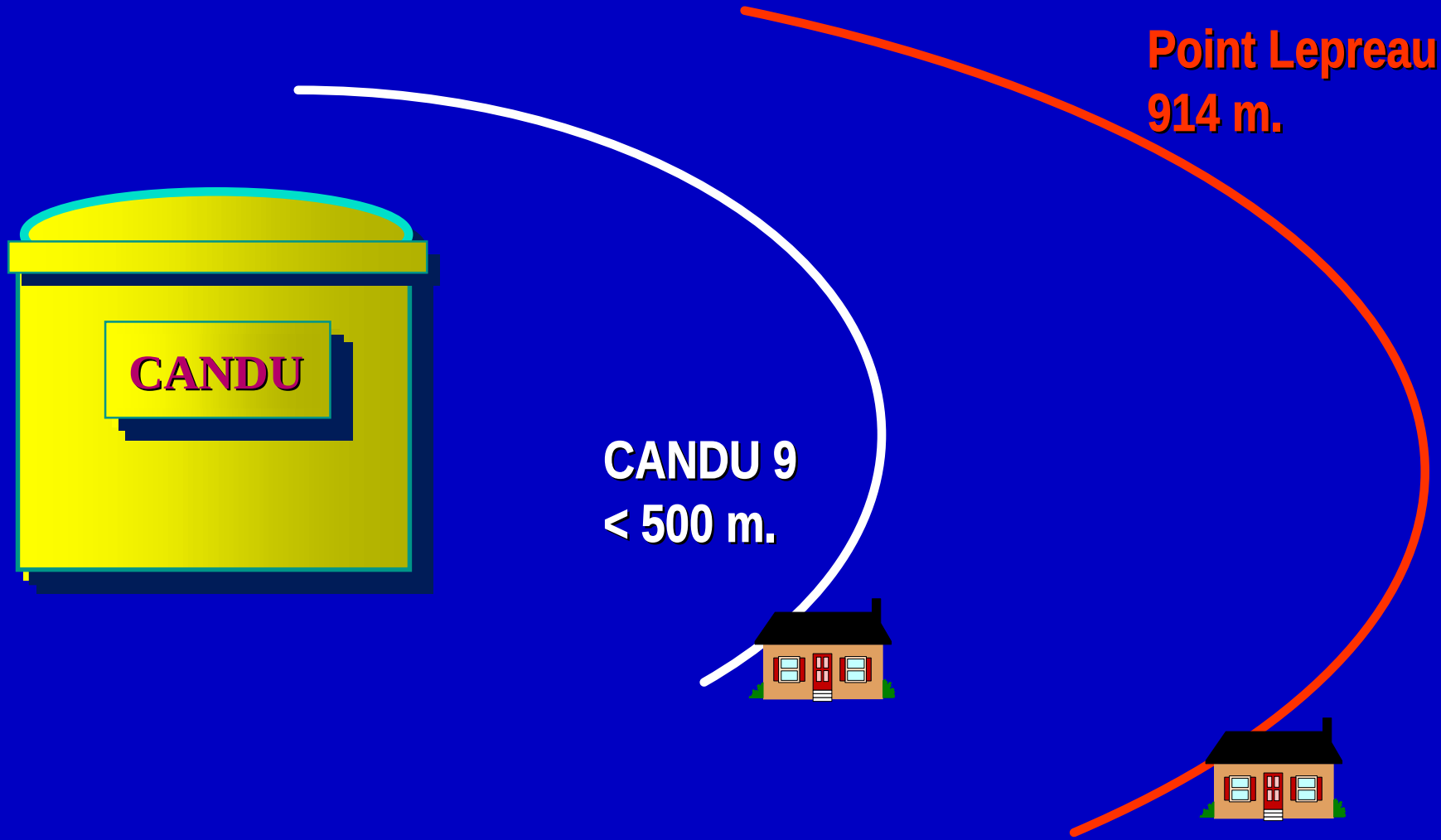
Reserve Water Tank

- large high-elevation tank similar to CANDU 6 dousing tank supplying:
  - ECC water, directly to sumps
  - steam generator emergency feedwater
- for severe accident mitigation
  - makeup to shield tank (added)
  - makeup to moderator (added)
  - makeup to heat transport system

Containment

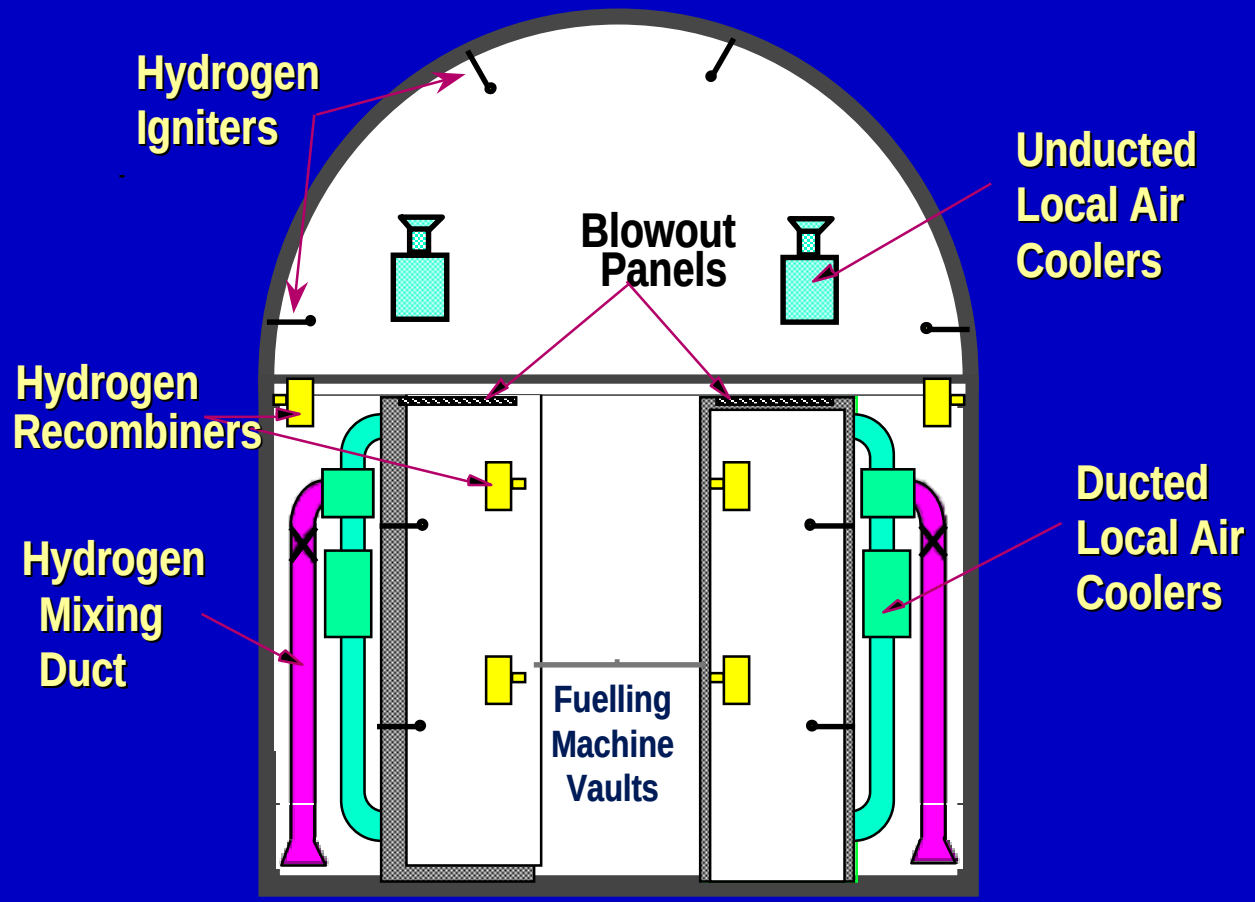
- prestressed concrete with steel liner for increased leaktightness & robust severe accident performance
  - design leakrate 0.2%/day at design pressure
- *no* pressure suppression via dousing (simplification)
- two redundant, separated, fully independent ventilation isolation systems
- reduced exclusion area boundary (less than 500m.)
- hydrogen mitigation for severe accidents

Exclusion Area Boundary

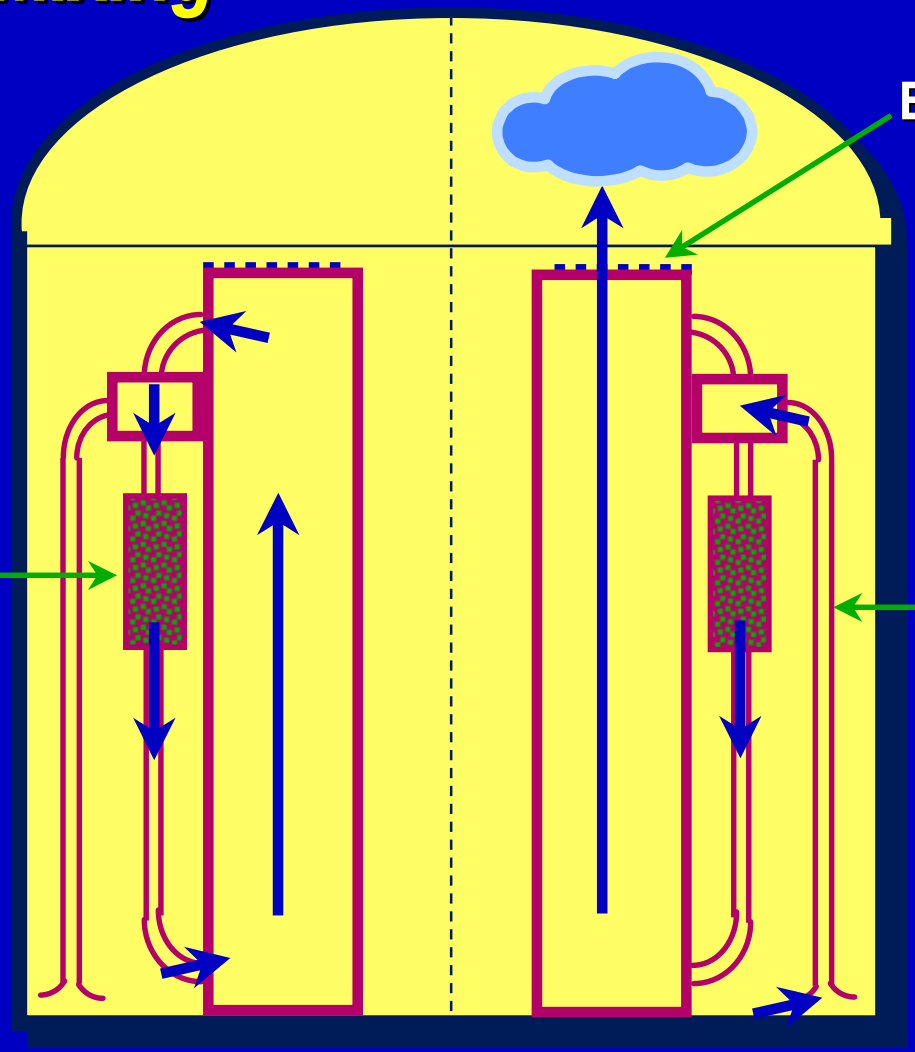


Hydrogen Control

- small hydrogen source term (cool moderator)
- natural convection flow patterns
- no hydrogen traps
- large containment volume
- dispersed igniters
- passive recombiners

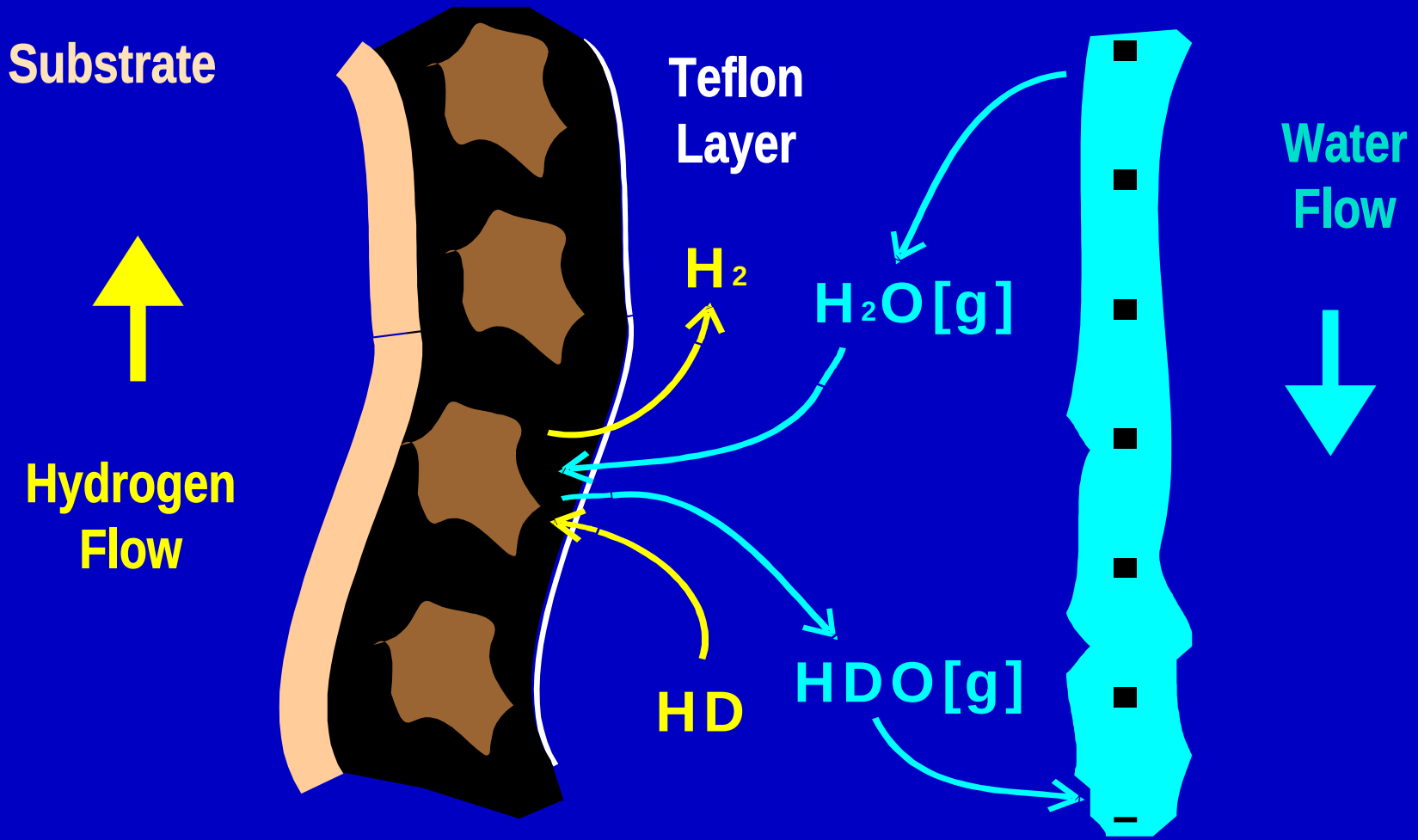


Hydrogen Mixing



Wetproofed Catalyst

Pt on Charcoal



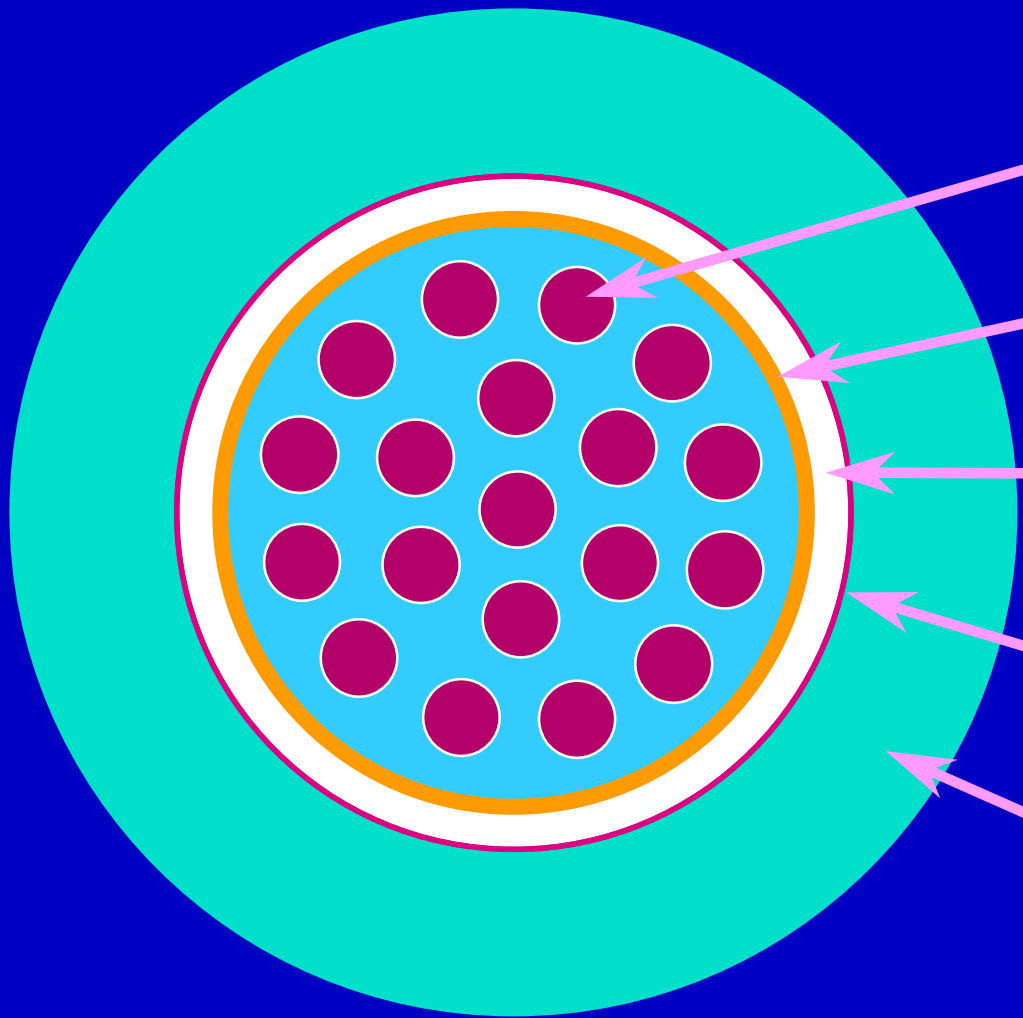
Severe Accident Goals

- stop severe accident at the channel boundary using the moderator (no fuel melting)
- stop severe core damage at calandria boundary using the shield tank (no melt-through)

Severe Accident Prevention and Mitigation

- **Shutdown**
  - three methods: control system & two shutdown systems
- **Decay heat removal**
  - normal & auxiliary feedwater (Group 1)
  - full-pressure & temperature shutdown cooling system
  - emergency high-pressure feedwater (Group 2)
  - makeup from reserve water tank to steam generators
  - moderator as emergency heat sink
  - shield tank / end shield cooling
- **Electrical power**
  - normal Class IV
  - emergency Group 1 Class III
  - seismically-qualified Group 2 Class III

CANDU Fuel Channel Cross-Section



Fuel

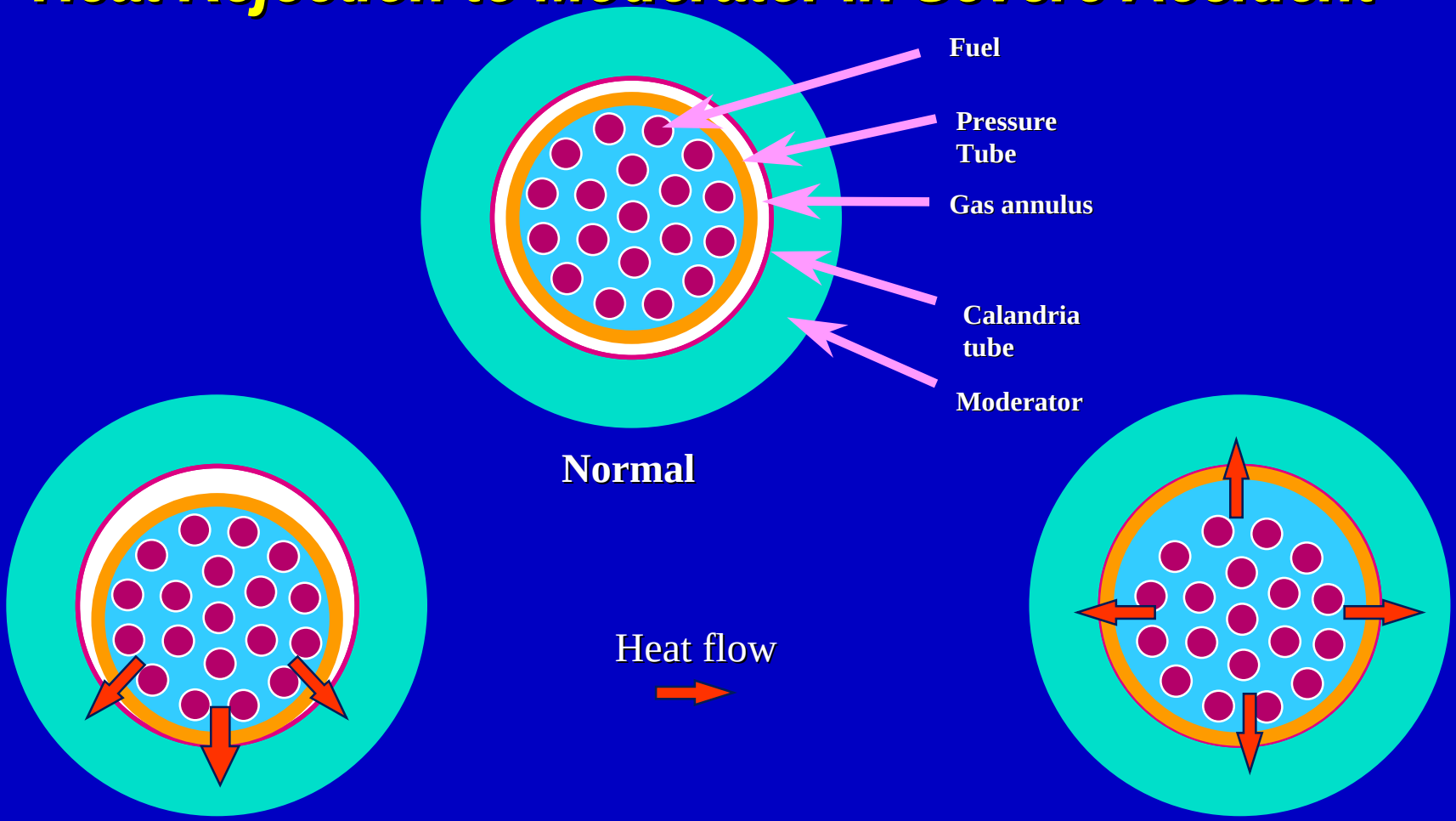
Pressure Tube

Gas annulus

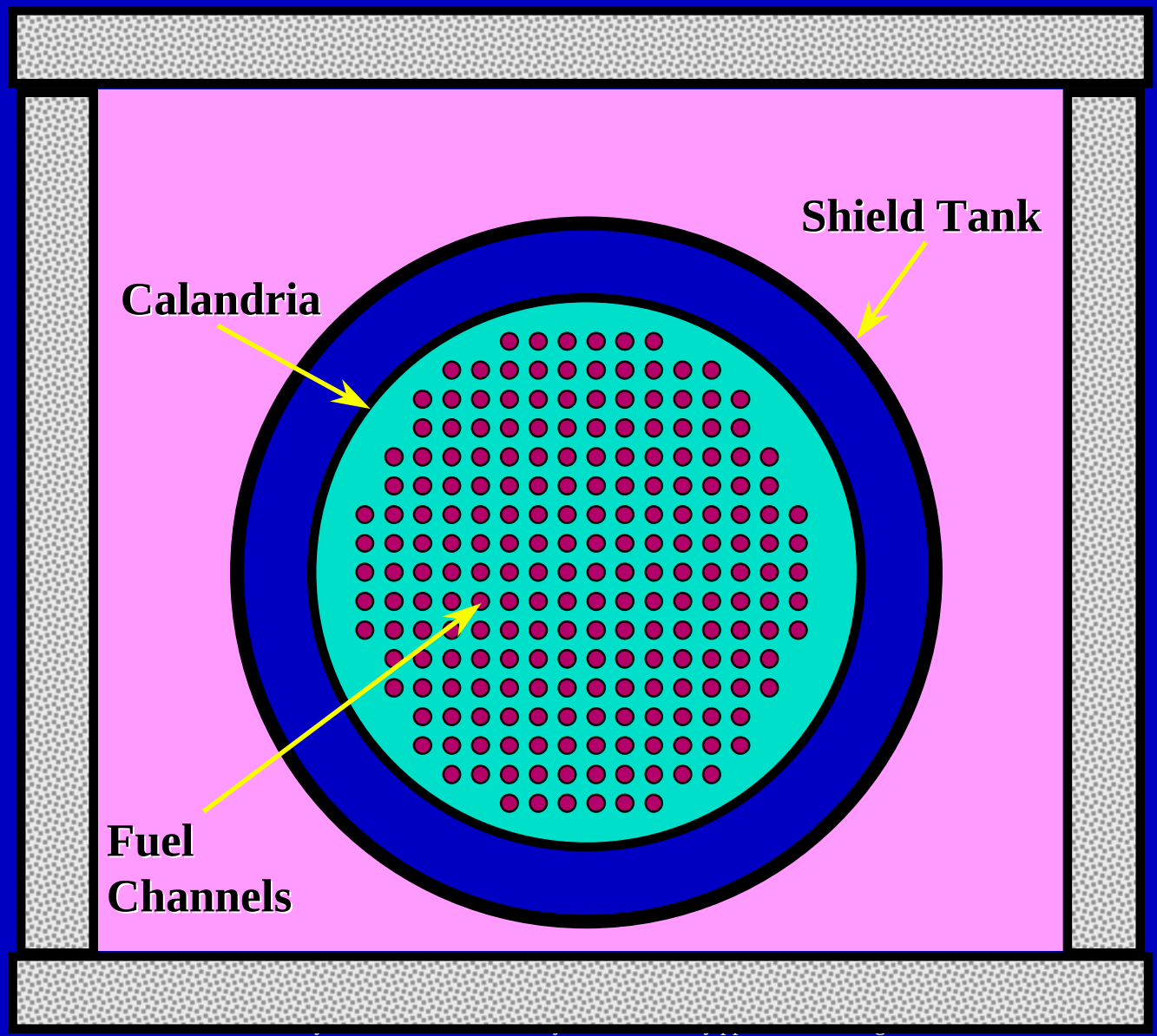
Calandria tube

Moderator

Heat Rejection to Moderator in Severe Accident

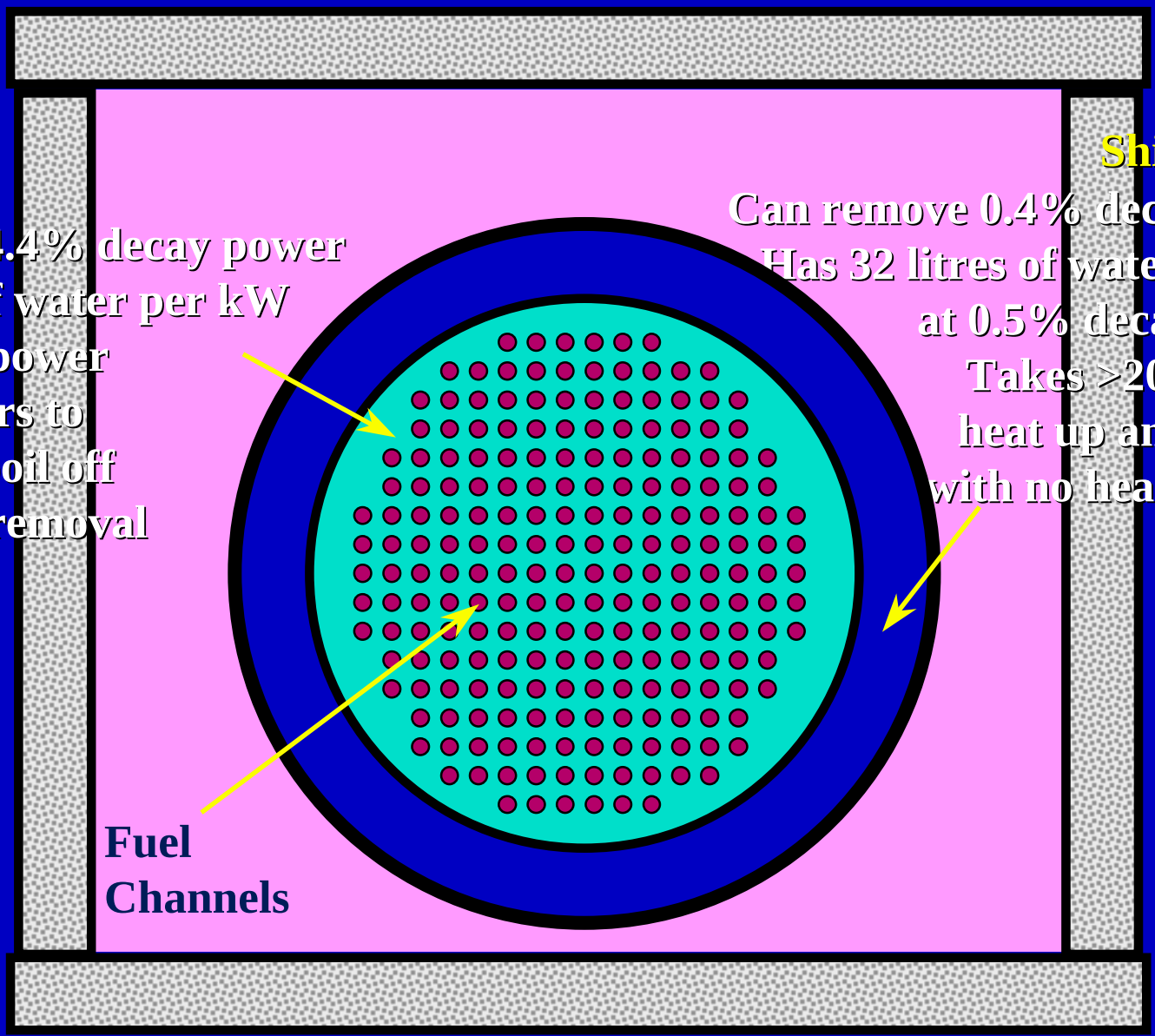


Calandria as Core Catcher



Specific Water Volumes Near the Fuel

Moderator
Can remove 4.4% decay power
Has 8 litres of water per kW
at 1% decay power
Takes >5 hours to
heat up and boil off
with no heat removal



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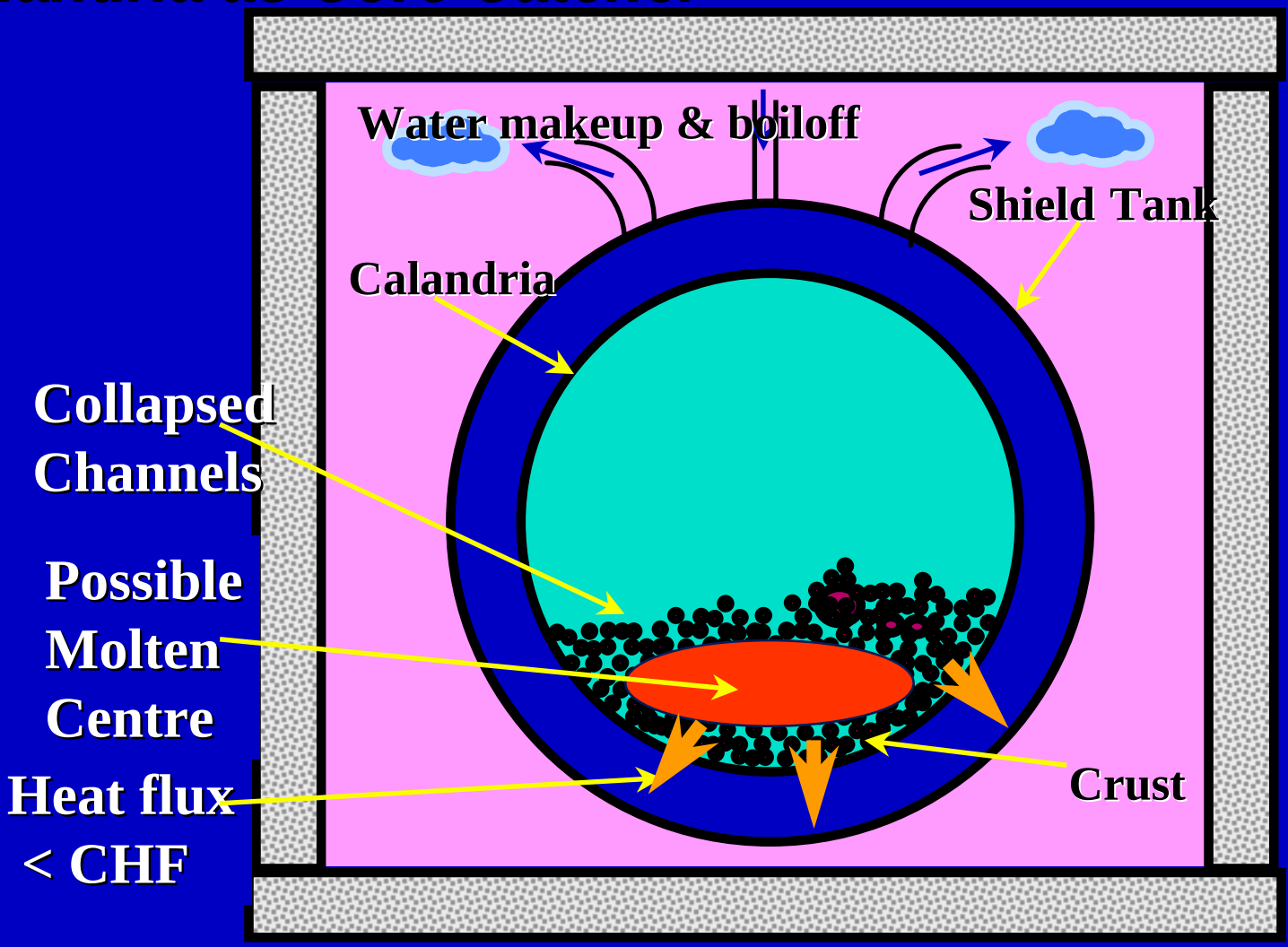
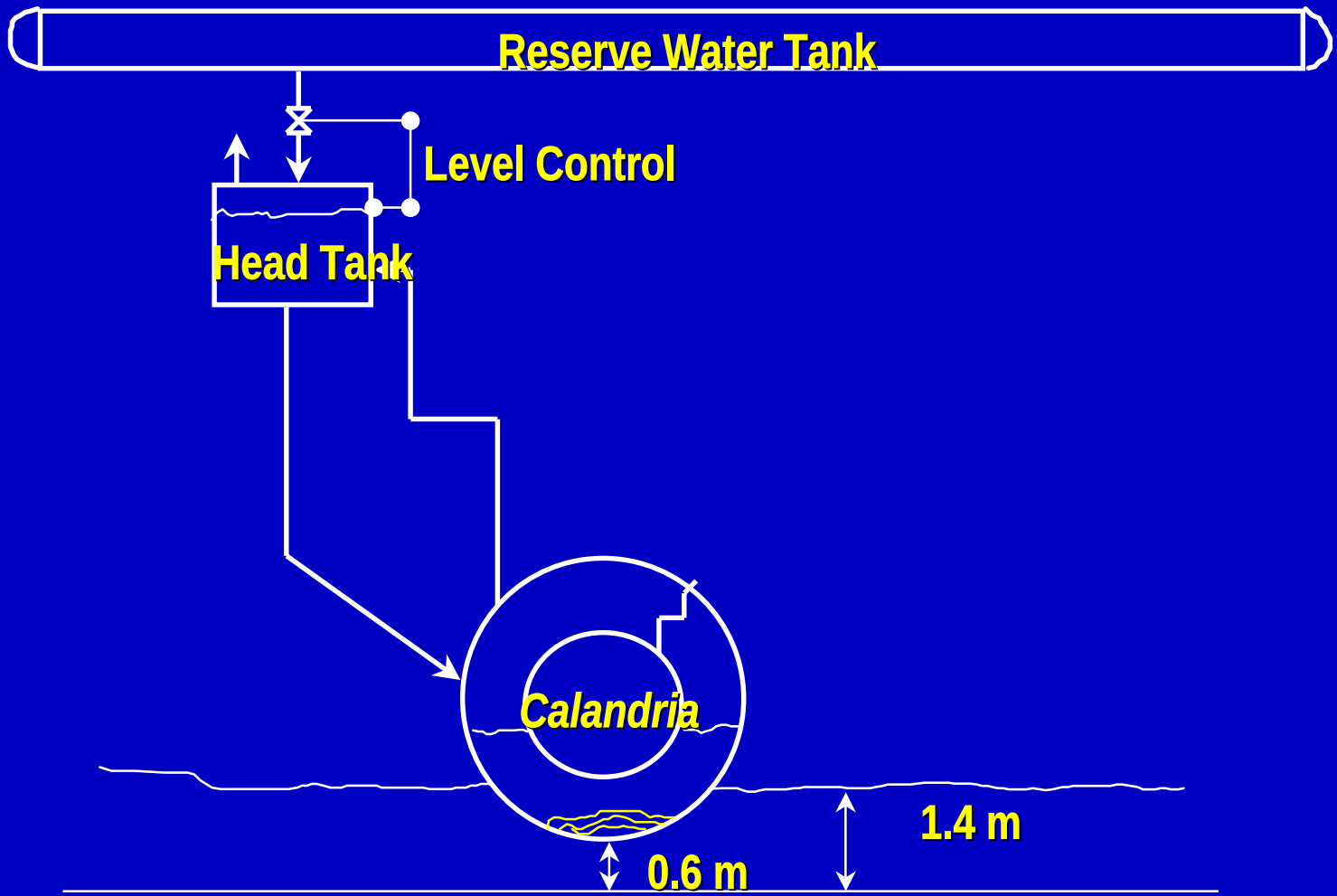


CANDU 9 - Severe Core Damage Mitigation



Demonstration of Licensability in Canada

- two year formal review by AECB
- > 200 documents
- acceptance of Licensing Basis Document (Canadian and foreign requirements)
- review of design requirements, design methods, safety analysis, probabilistic safety analysis, QA, decommissioning, safeguards etc.
- address Generic Action Items
- 13 key issues identified and eventually resolved

Review Focussed on Thirteen Issues

- Large LOCA analysis
- PT rupture/Moderator
- In-core LOCA/SDS1
- Digital control system
- Plant Display System/Control Centre
- Containment design
- Backup heat sinks
- Moderator temperature predictions
- Post-accident monitoring
- Experience feedback
- Safety critical software
- Grouping and Separation
- Severe accident programme

Licensability in Country of Origin

- "The CANDU 9 design complies or can be made to comply with licensing requirements in effect, in Canada, on January 1, 1995;
- "AECL's proposals to address Generic Action Items for the CANDU 9 design are acceptable. In all cases the proposed method for addressing Generic Action Items is equivalent to or an improvement with respect to what is currently accepted on operating CANDU reactors in Canada, and
- "AECL has adequately addressed the major issues identified in the June 1996, *"AECB Staff Interim Statement on CANDU 9 Licensability"*."
- "AECB staff therefore concludes that there are no fundamental barriers to CANDU 9 licensability in Canada"

Conclusions

- CANDU 9 incorporates:
  - emerging international safety standards
  - utility requirements for modern evolutionary plant
  - severe accident prevention and mitigation using inherent CANDU characteristics and passive systems
  - licensability in Canada through formal AECB review
  - lessons learned from licensing CANDU 6 in Asia
- CANDU 9 designed to be an internationally licensable product