CANDU Safety
#18 - Safety Research and Development

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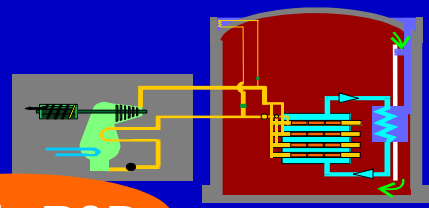
CANDU Evolution

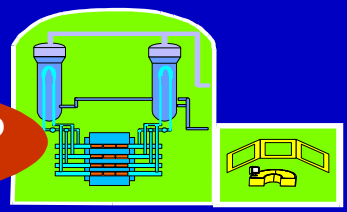
Future Generation CANDU (25 years)



Mostly R&D

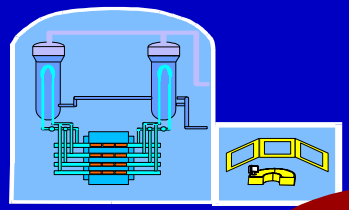
Evolutionary CANDU

Combination of R&D and Engineering



Project Experience

Improved CANDU



Operating Feedback

Mostly Engineering

Product Evolution

R&D

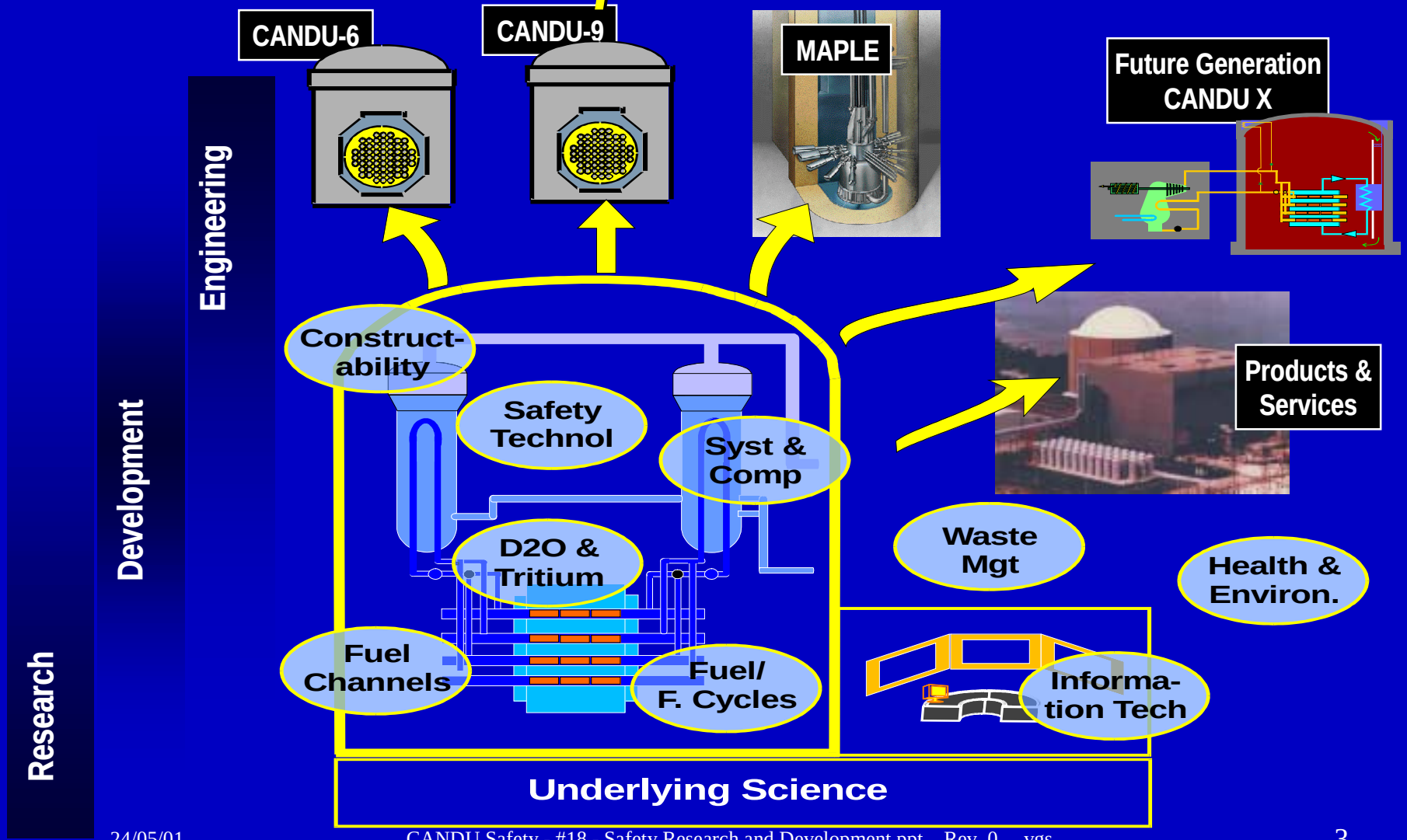
Engineering

Market Pull

Technology Push

- *Improved Economics*
- *Enhanced Safety*
- *Fuel Cycle Flexibility*

Research & Development



Safety R&D Goals

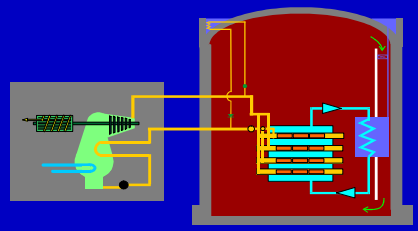
- Resolve AECB Generic Action Items
- Reduce releases during normal operation
- Improve protection against higher frequency events
- Improve system response to design basis events
- Contain severe core damage consequences
- Validate and improve safety analysis codes
- Develop passive and advanced safety concepts

Focus

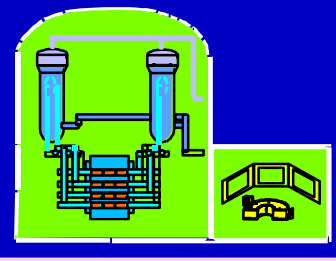
- safety R&D in Canada is done by the industry (AECL and the 3 domestic nuclear utilities)
- AECB does a small amount of confirmatory R&D and reviews & critiques the industry programme
- R&D split into 2 main areas:
  - unique aspects of CANDU
    - physics, fuel, fuel channels, heavy water, moderator
    - emphasis on realistic models
  - generic nuclear world-class R&D in areas of strength
    - hydrogen ignition and detonation, iodine behaviour

Linkage of Safety Research to Plant Licensing

SAFETY R&D



ADVANCED DESIGNS



CURRENT PROJECTS

KNOWLEDGE

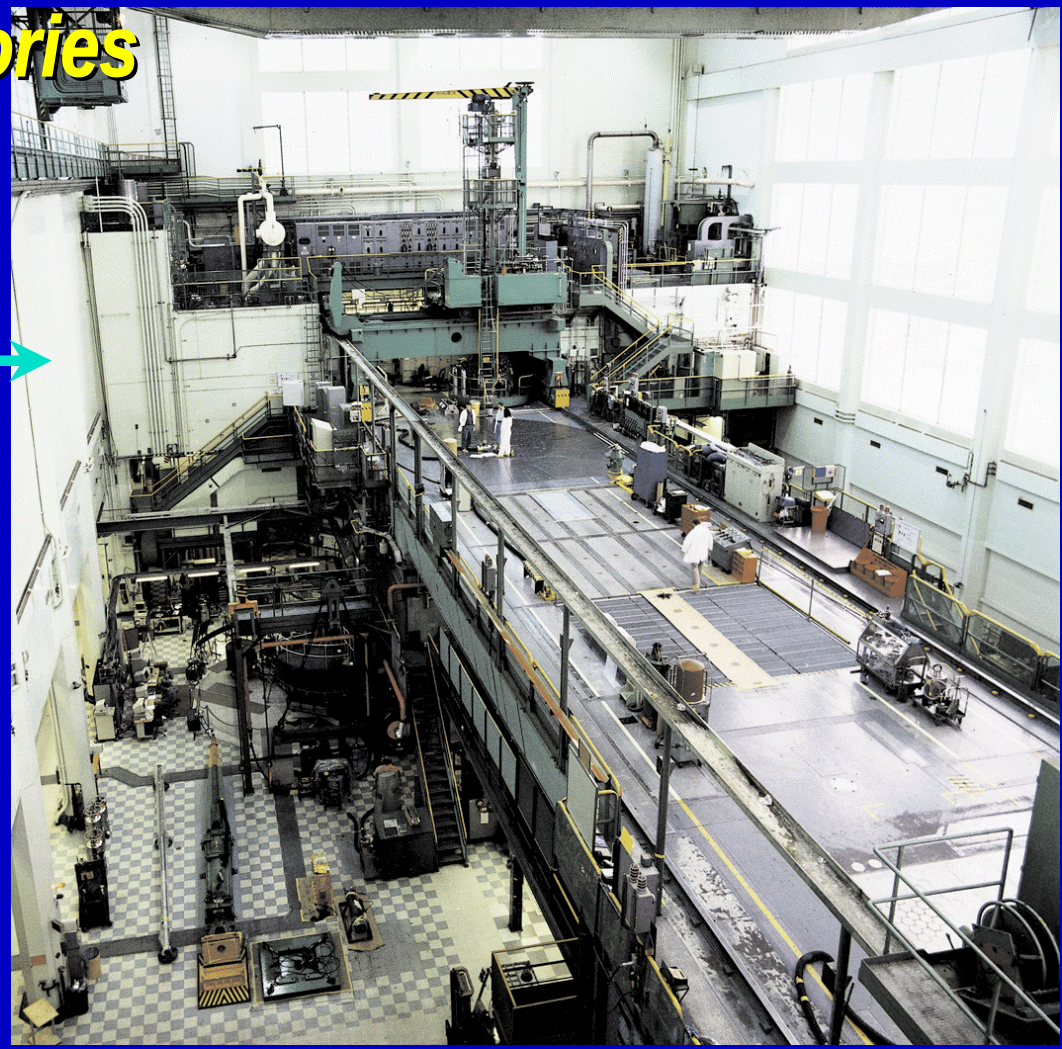
MODELS

CODES

SAFETY REPORT

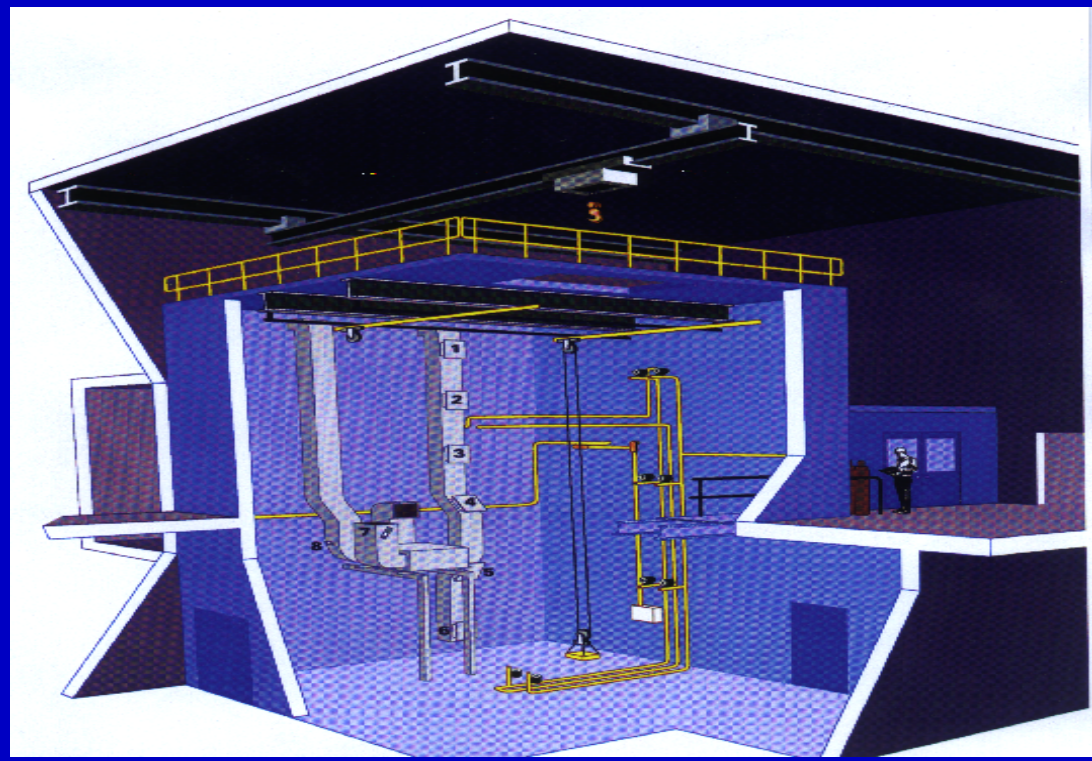
Chalk River Laboratories

- 2000 people
- large (orig. 200 MW(th)) heavy-water moderated research reactor (NRU)
- severe accident in-reactor loop (Blowdown Test Facility) in NRU
- zero-energy reactor (ZED-2)
- hot cells
- fuel fabrication and test
- detritiation
- critical heat flux
- moderator circulation



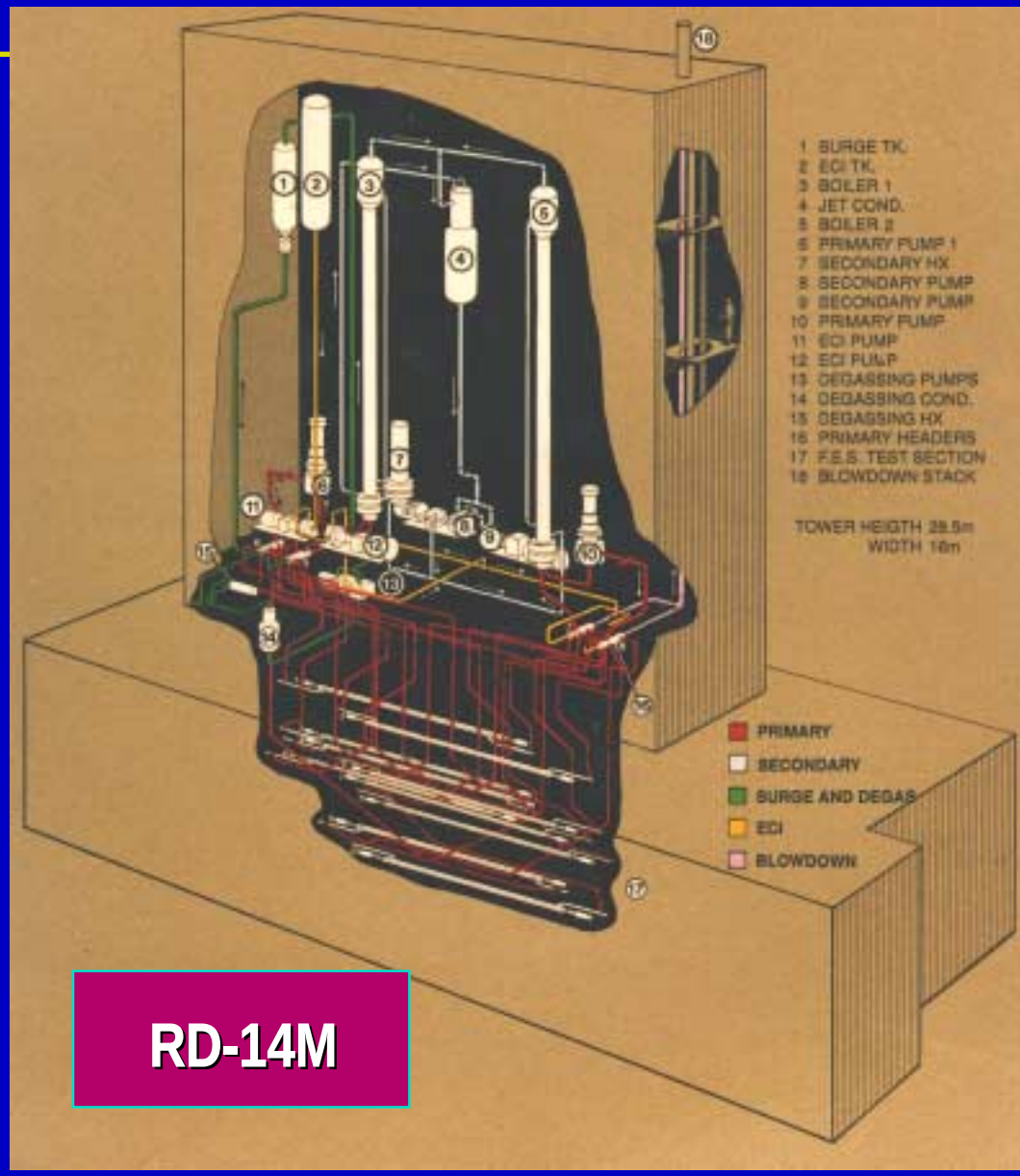
Whiteshell Laboratories

- organic-cooled reactor (now decommissioned)
- large scale vented combustion facility
- radio-iodine test facility
- RD-14M figure-of-eight thermohydraulics test loop
- large-scale gas mixing facility
- pressure-tube ballooning and moderator subcooling



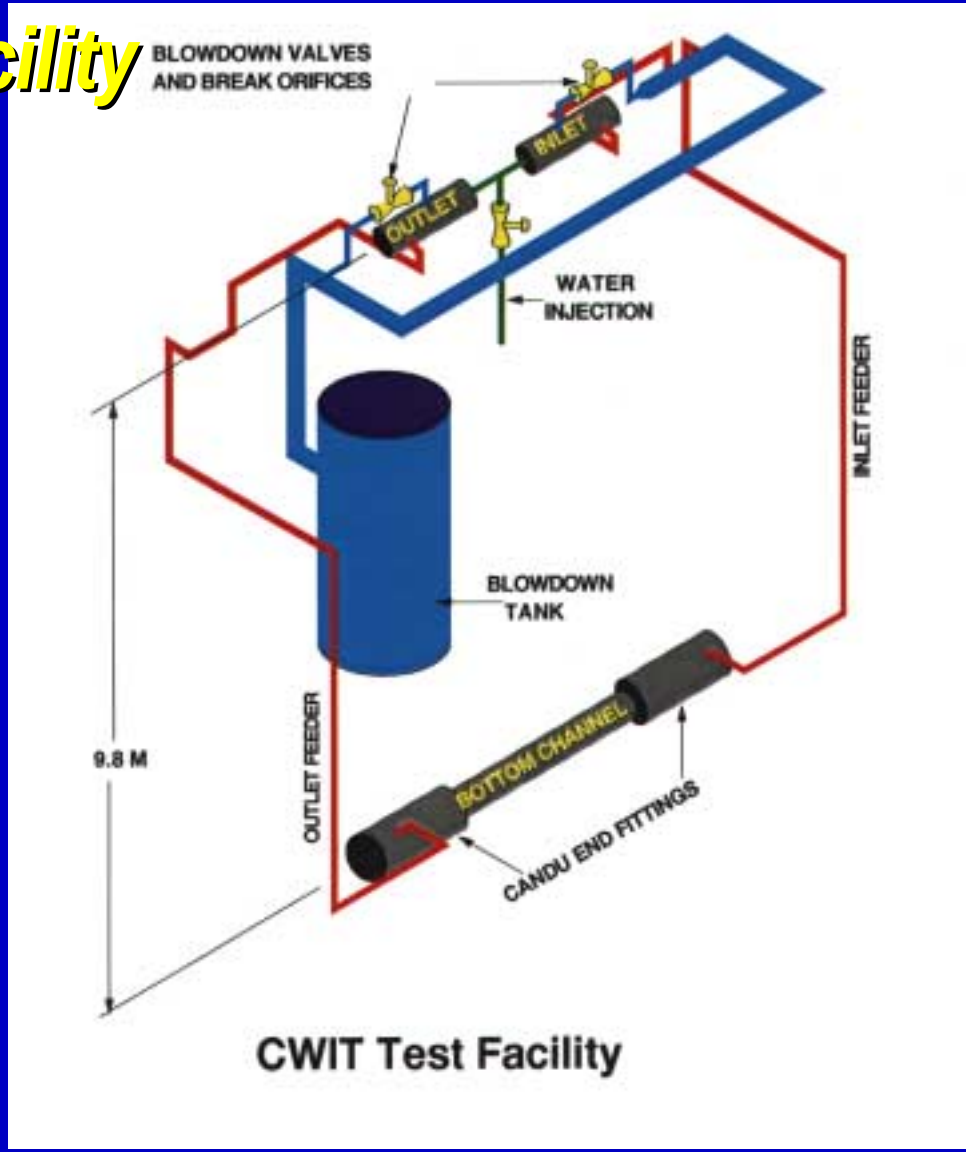
Thermohydraulics of Figure-of-Eight Loop

- full elevation simulation of heat transport system
- 10 full-length channels
- mass flux, transit times, pressure & enthalpy distribution similar to CANDU
- large and small LOCA
- ECC injection & refill
- natural circulation at full and partial inventory
- loss of shutdown cooling
- primary purpose: code validation



Cold Water Injection Facility

- full-scale, full length heated fuel channel
- representative feeders and end-fittings
- 37-element fuel
- blowdown and refill performance
- LOCA in CANDU channel can be tested in full scale
- primary purpose: code validation



Critical Heat Flux

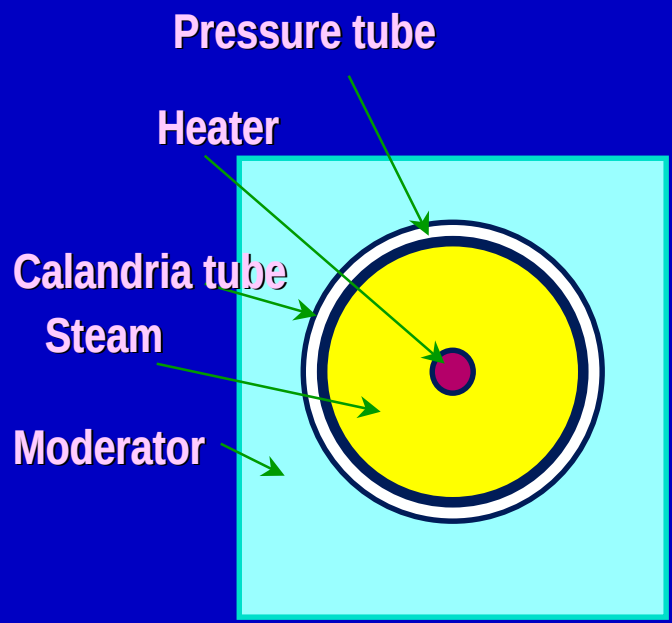
- purpose: to determine with high accuracy the onset of critical heat flux under high-power conditions
- used to determine overpower trip setpoints
- fundamental & parametric studies in freon
- final tests in full-scale, full-length heated 37-element channels with realistic bundle end-plates, appendages, etc.
- onset of dry-patch, dry-patch spread, and post-dryout temperatures
- now testing CANFLEX fuel (43-element)
  - carrier for advanced high-burnup fuel
  - increase margins for natural uranium fuel

Pressure Tube Integrity

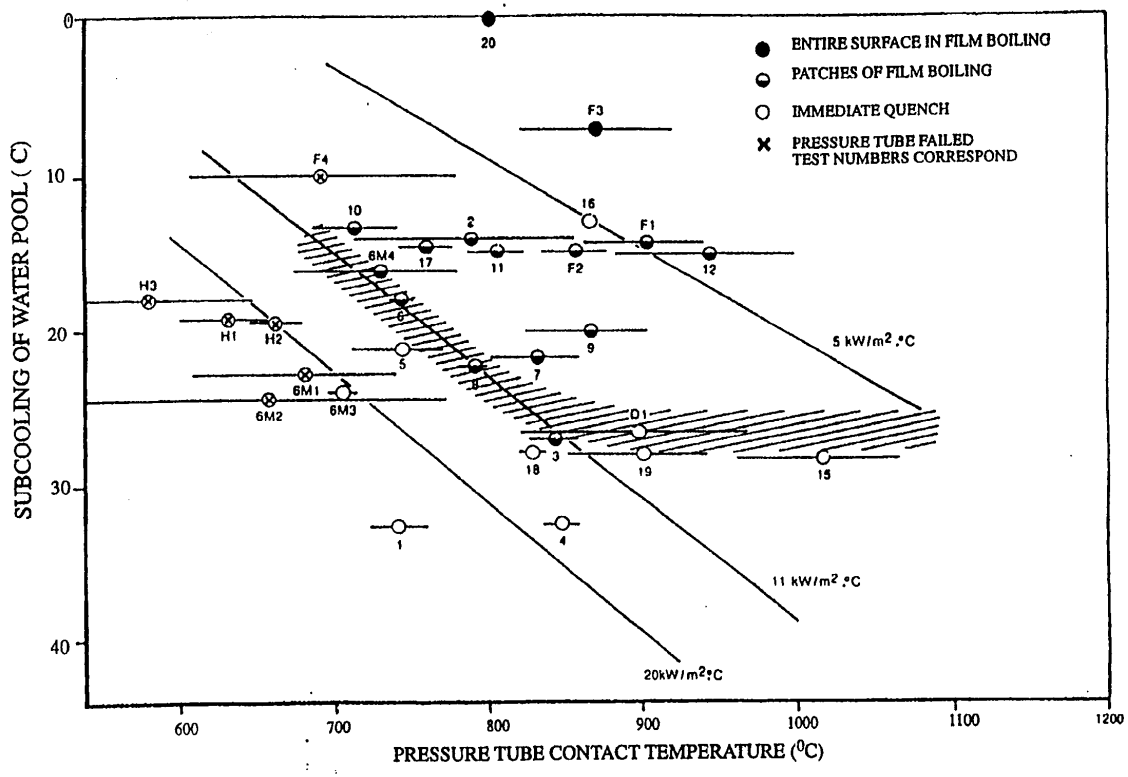
- fracture properties of pressure tube (Zr-2.5%Nb alloy) under normal operating conditions
- effects of irradiation and ageing (creep & growth)
- set fitness-for-service conditions
- support leak-before-break
- properties monitored by samples removed from operating reactors

High Temperature Fuel Channel Integrity

- internally-heated and pressurized pressure-tube inside calandria tube inside water tank
- strains or sags to contact calandria tube
- integrity of pressure tube before contact
- integrity of channel after contact
- defines required moderator subcooling to prevent calandria tube dryout after contact



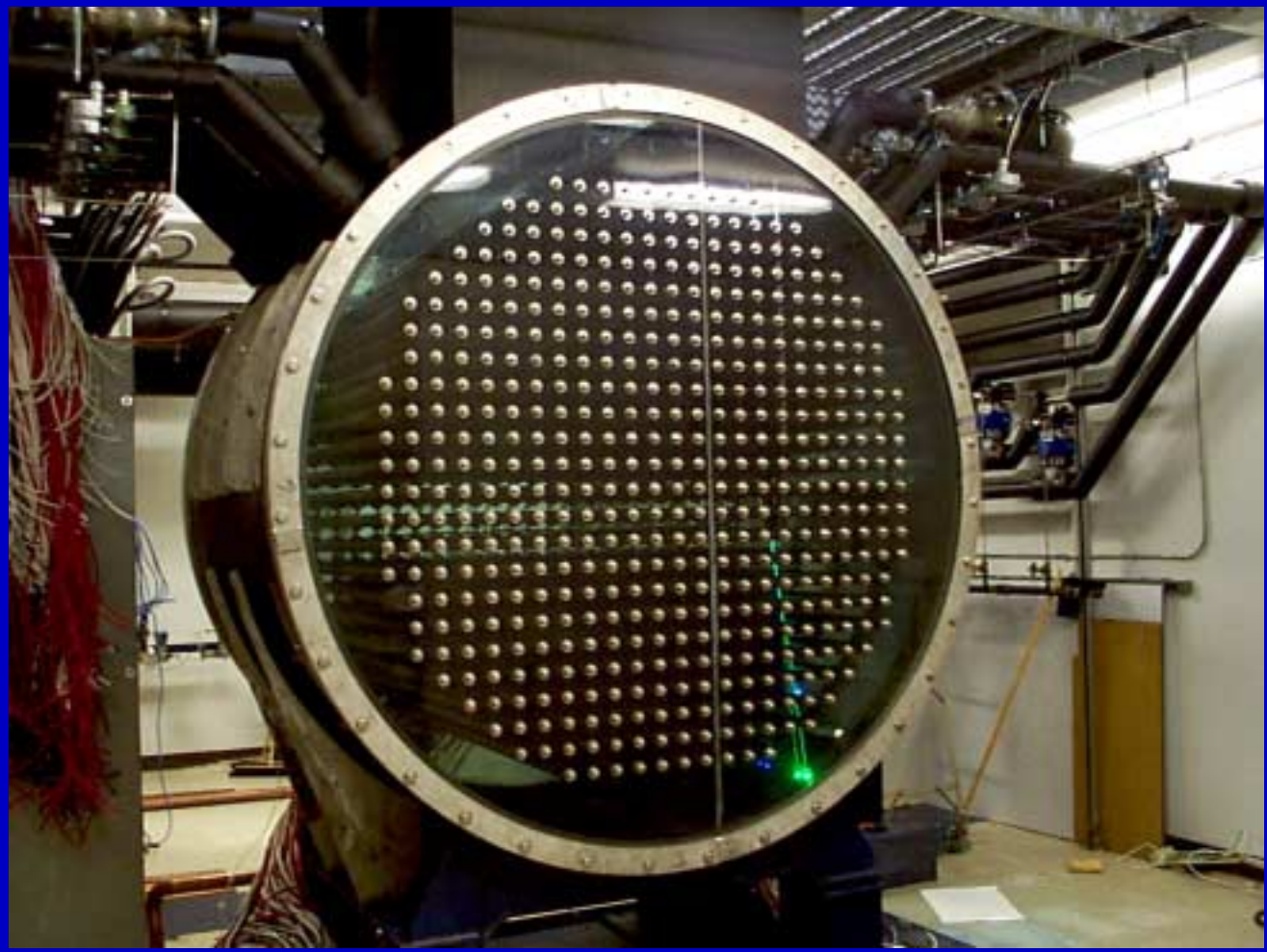
Moderator Subcooling Requirements



Results of Contact Boiling Experiments

Moderator Circulation

- measure three-dimensional velocity and temperature distributions in CANDU moderator geometry
- used for code validation
- inlet & outlet pipes can be configured for CANDU 6, 9 etc.

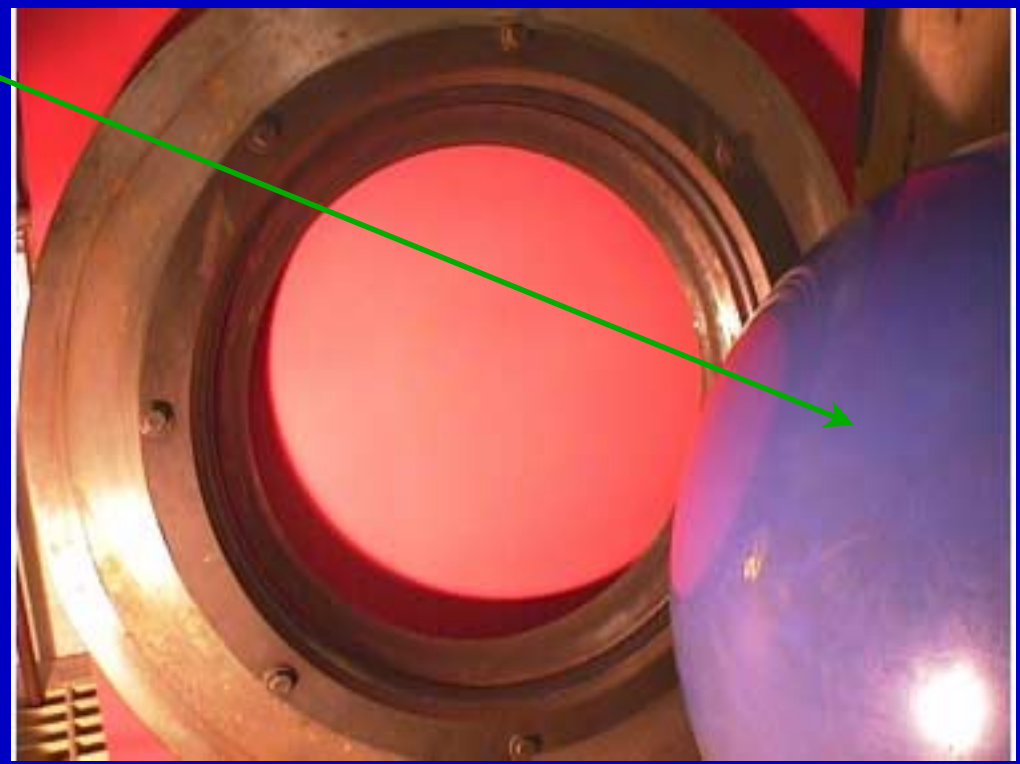


Hydrogen Mixing and Combustion

- Large Scale Vented Combustion Facility
- hydrogen combustion and detonation boundaries in various steam / air/ hydrogen mixtures
- interior geometry can be configured

CANDU 9 Simplification

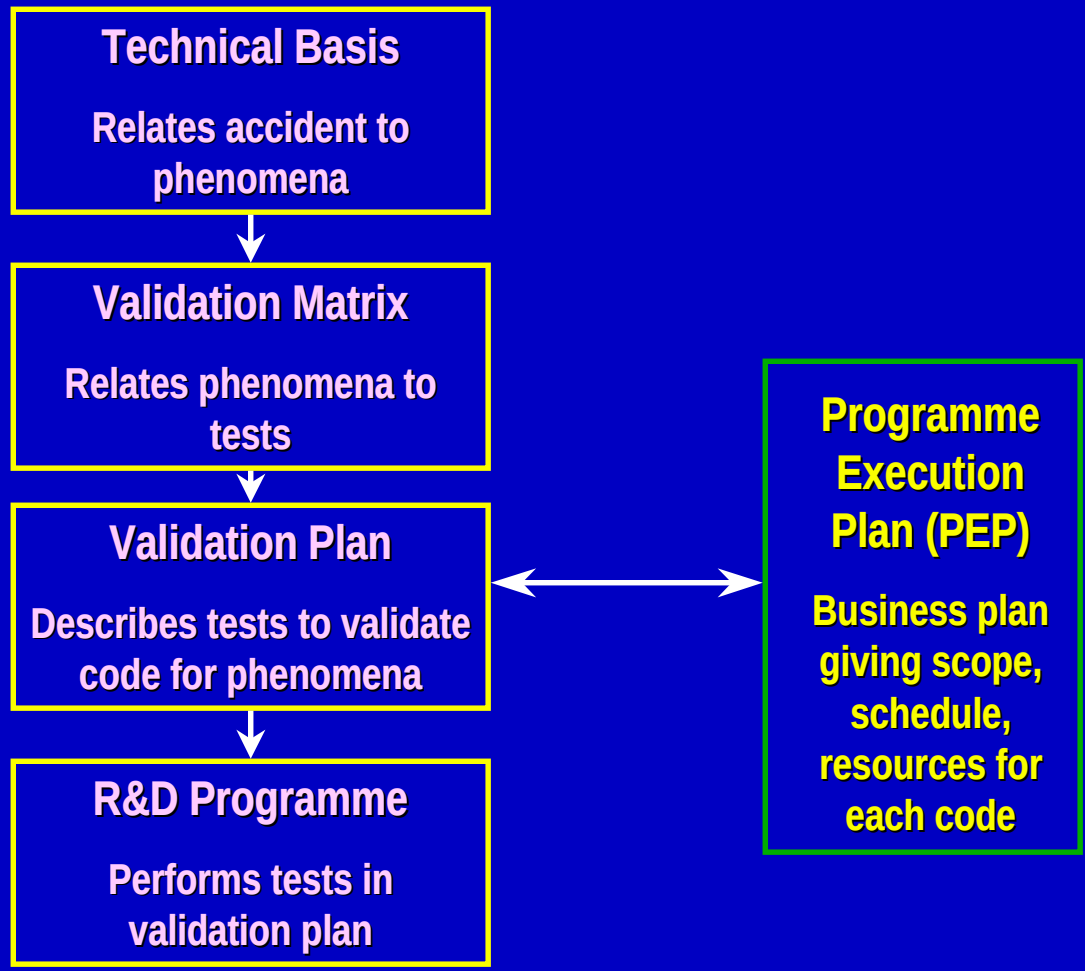
- ECC water tank ball seal
  - leaktightness
  - surface flaws
  - vortexes
  - ageing
  - deformation
- ECC one-way rupture disk
  - large sustained flows from NRU high head tank
  - absence of fragments
  - flow area
  - reverse pressure



Other Areas

- fission product release and transport
  - goal is to develop physically realistic models
  - large feeder & end fitting surface area provides natural trap
  - hot-cell & in-reactor tests in NRU (Blowdown Test Facility)
- severe core damage
  - demonstrate basic phenomena of core collapse for CANDU in scaled facility
- containment thermohydraulics
  - not unique, use world data for code validation
- passive safety designs

Code Validation and R&D



Summary

- CANDU safety R&D focussed on aspects unique to CANDU
- some world-class generic R&D also performed
- industry carries special responsibility for safety R&D
- object is to develop physically realistic models based on experiments, to get an accurate picture of safety margins
- formal code validation process underway, which will require quantification of uncertainties