Innovations in Water-Cooled Technologies: Candu Energy Perspective

OECD/NEA Workshop

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Innovations: past, present and future

Agenda:

- Past history of CANDU evolution
- Innovation processes
- Heavy Water Reactor technology today
- Heavy Water Innovations and future potential

Background history — technology milestones

	Canadian Nuclear Milestones	World Technology Milestones
1950s	• CRL development • NRU, build up fuel testing, range of design concepts, materials research	
1960s	• AECL R&D delivery • Fuel, fuel channel fundamentals • Starting fuel cycle research • CANDU and other prototypes	
1970s	• Start of AECL/industry R&D linkage • Focus concept—delivery—operations • Safety and licensing engagement	
1980s	• First wave completion • Safety and licensing agenda identified	
1990s	• Operating issues identification • Fuel cycle international cooperation	
2000s	• Canadian consolidation	

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CANDU Evolution:
Examples of development milestones

Risk-based safety requirements (1960s)

Digital computer control of reactor operation (1970s)

Demonstrate inherent decay heat removal by CANDU Moderator/shield tank (1980s)

Safety System Software qualification (1990s)

Innovation processes

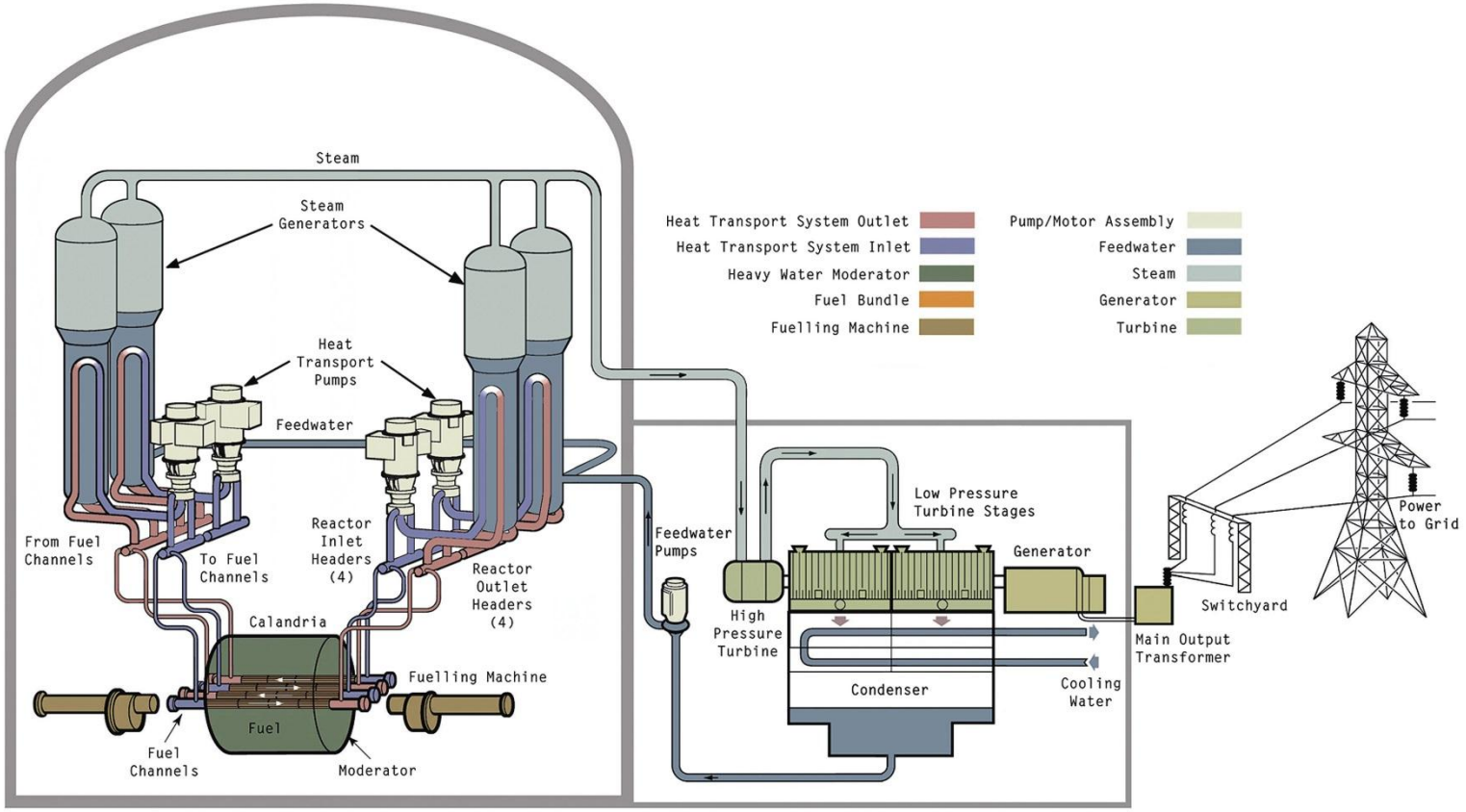
- **Breakthroughs**
  - New fuels
  - Passive safety
  - Digital safety systems
- **Incremental improvements**
  - Increased plant lifetime
  - Improving safety margins
- **Consolidation**
  - Increasing capacity factor
  - Addressing emerging problems
  - Safety software validation

Heavy Water Reactor technology today (1)

- **CANDU 6 family of designs**
  - EC6 (Enhanced CANDU 6) design:
  - Canadian regulatory review complete 2013
  - Generation III basis
  - Incorporates Fukushima Lessons Learned
  - Evolutionary design – benefits of provenness
  - Completely updated design basis and safety case
  - Flexible fuel capability

- **Design basis**
  - Safety based on Engineered systems augmented by inherent features

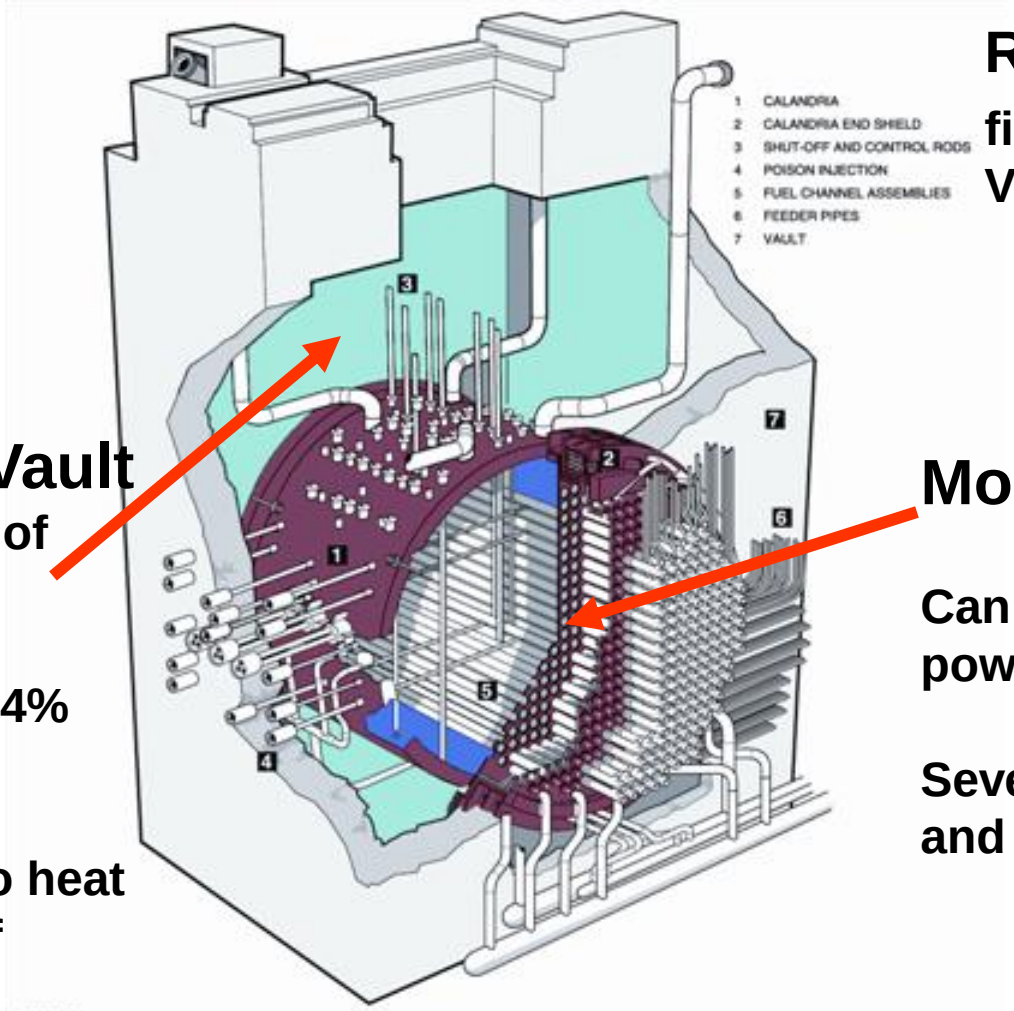
General View of an EC6 Plant



Heavy Water Reactor technology today (2)

- **CANDU Innovation: recent progress**
  - Fuel cycle
    - Use of Recovered Uranium-blended fuel
    - Thorium-based fuels
    - MOX fuels
  - Operational Performance
    - Build in 3 year interval between plant outages
  - Extending plant life
  - Towards 40 years plus 40 years
  - EC6 Design features
    - Improved reactor instrumentation array
    - Improved shutdown units
    - Severe accident protective measures
    - Operator information systems
    - Distributed control system
  - Inspection and Maintenance Tooling
    - Improved inspection speed and accuracy

Passive Heat Removal for Severe Accident Mitigation



Reserve Water Tank

fills the Calandria and its Vault by gravity (EC6)

Calandria Vault

(Large source of water)

Can remove 0.4% decay power

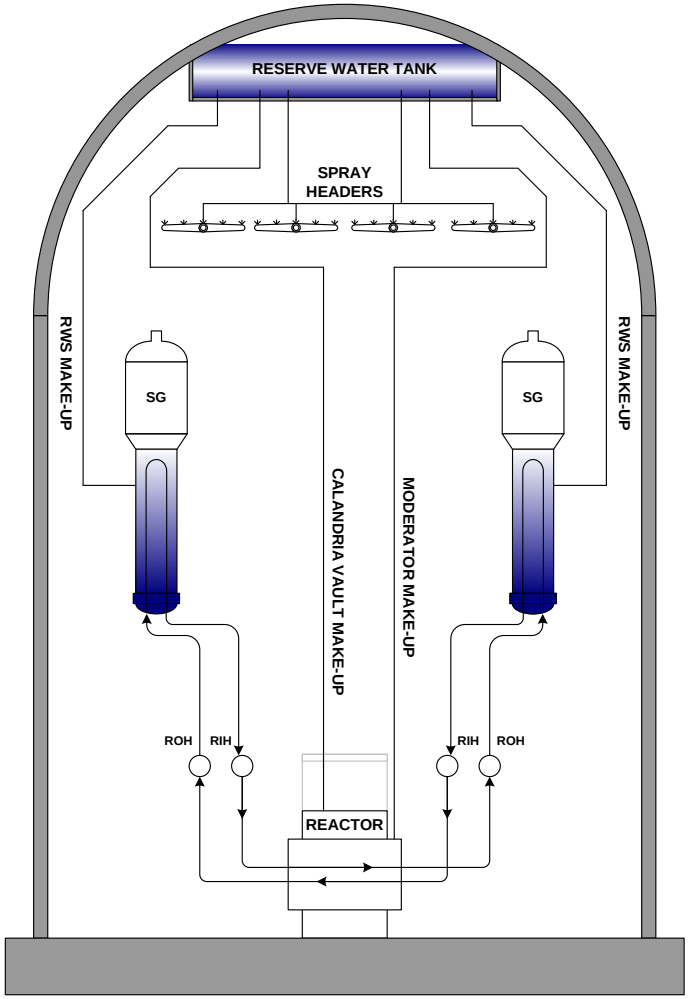
Many hours to heat up and boil off

Moderator

Can remove 4% decay power

Several hours to heat up and boil off

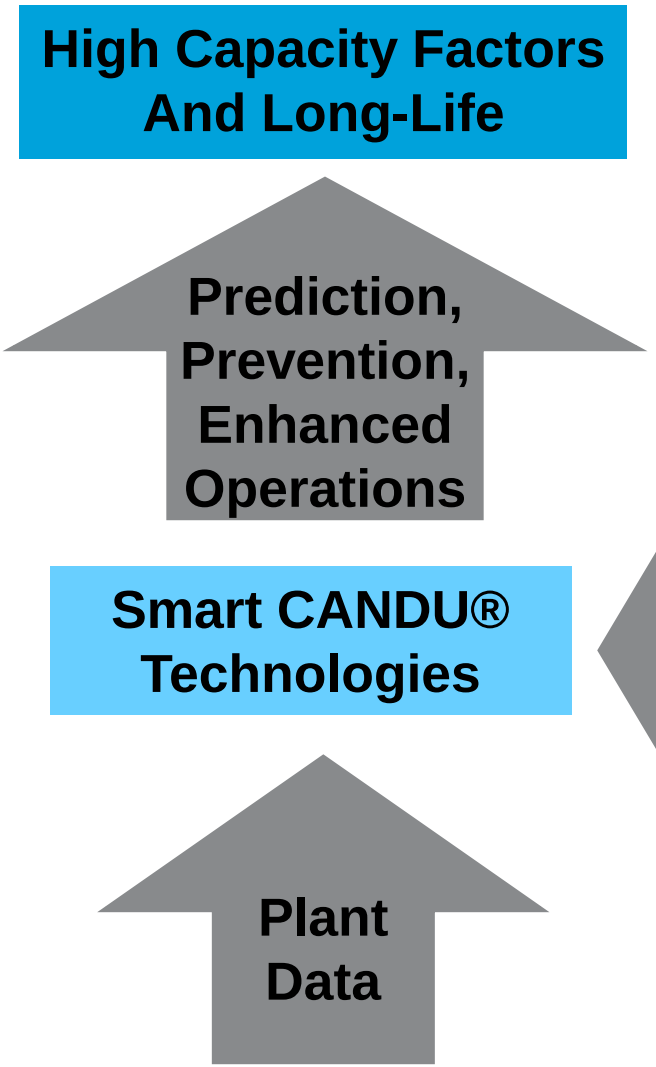
Extra EC6 passive safety features



- Elevated Reserve Water Tank to make-up:
  - Steam generators
  - Moderator
  - Calandria vault
  - Spray system
- Robust seismically qualified and aircraft crash-proof containment

ONLY ONE LOOP OF HTS IS SHOWN

Smart CANDU® technology – Gen III



CAMLS *CANDU Alarm Message List System*

Intelligent System assists operators to cope with events such as blackouts.

ChemAND *Chemistry Analysis and Diagnostic System*

Health monitor for plant chemistry. Predicts performance of components, determines maintenance requirements and optimal operating conditions.

ThermAND *Thermal Analysis and Diagnostic System*

Health monitor for heat transfer systems & components. Ensures optimal margins and maximum power output.

MIMC (in testing)
Maintenance Information Management Control

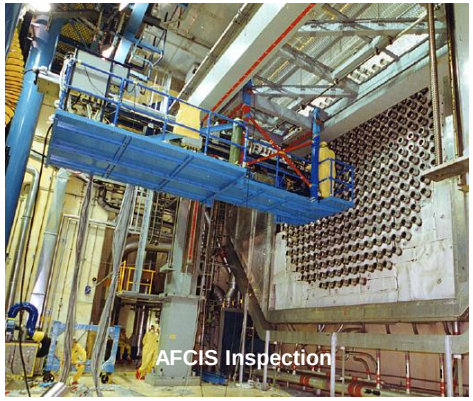
System linking health monitor data to plant work management.

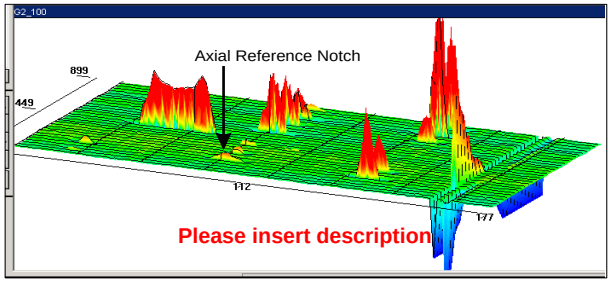
Heavy Water Reactor technology today (3)

- **Needs for CANDU Innovation:**
  - Harmonized safety assessment
    - Develop standard, globally accepted safety case
  - On-line maintenance and inspection
    - Reduce inspection burden during outages
    - On-line fuel channel and piping inspection
  - Effective Innovation Processes
    - Improve time to market
    - Upfront agreements on demonstration requirements
    - Ensure design features fully defined before project start

Improving capabilities in Fuel Channel Inspection

- Candu uses a variety of remotely controlled inspection systems to examine and maintain fuel channel components
- Tooling information systems are geared to rapid application of computer models and condition analysis tools
- Tooling is designed for speedy deployment during standard outages
- Next step – on-line inspection and maintenance





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Heavy Water Reactor innovations and future potential

- **Outcomes and needed innovations**
  - Public acceptance – “no evacuation needed”
    - Expand use of passive features
    - Respond to public acceptance priorities
  - Faster project completion
    - Supply chain innovations
    - Pre-licensing and speedier commissioning
  - Closed fuel cycle
    - Simplify fuel fabrication requirements
    - Make full use of low enrichment requirement
  - Minimize fuel waste
    - DUPIC ? Thorium or inert matrix fuels ?
  - More flexible operation
    - Load and power cycling demonstration