Radiation Protection:

Service Protection vs. Self Protection

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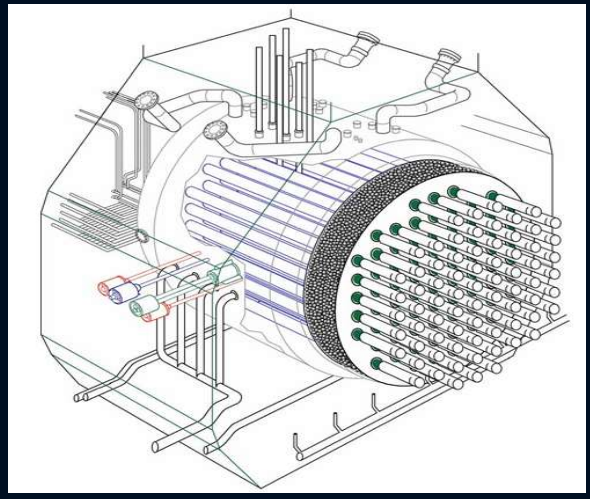
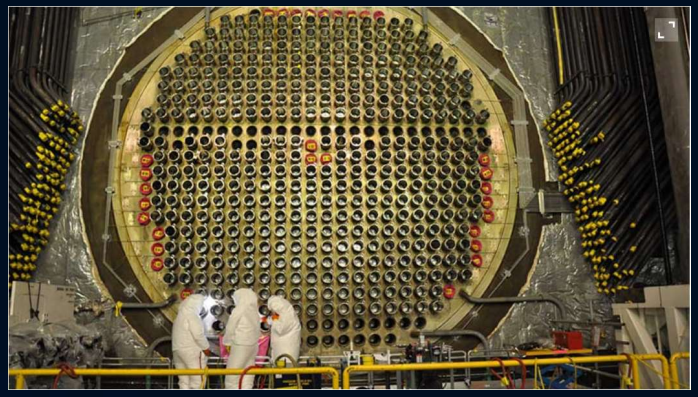
INTRODUCTION

CANDU is the main type nuclear reactor that is used to generate electricity in Canada.

- CANDU (CANadian Deuterium Uranium): A heavy water moderated and cooled.
  - CANDU-6: Bruce, Darlington, Pickering, Point Lepreau
- Open Pool Light Water Reactor (SLOWPOKE) – Research purposes only
- CANDU-9 and Advanced CANDU (ACR-1000) - next-gen designs but only on paper – no reactors built.
- 4 Small Modular Reactor (SMR) 300 MW developed by GE Hitachi Nuclear Energy (GEH):
  - Started in 2025, in commercial operation in 2029 for first unit.
  - The rest expects to be completed between 2034 and 2036.



Source: https://canteach.candu.org/content%20library/20040700.pdf

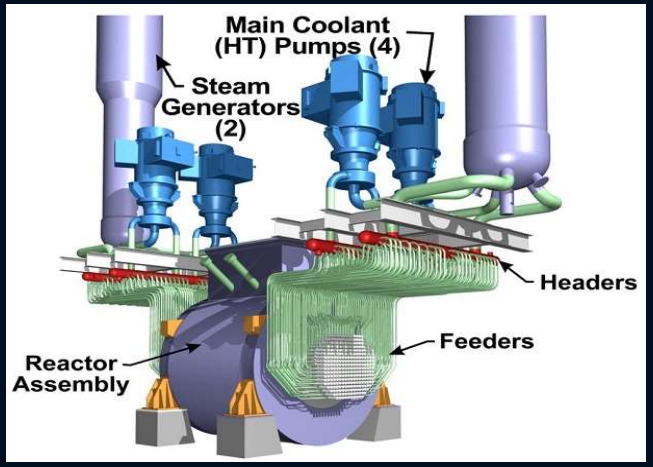


Source: https://canadiangeographic.ca/articles/candu-a-canadian-success-story/

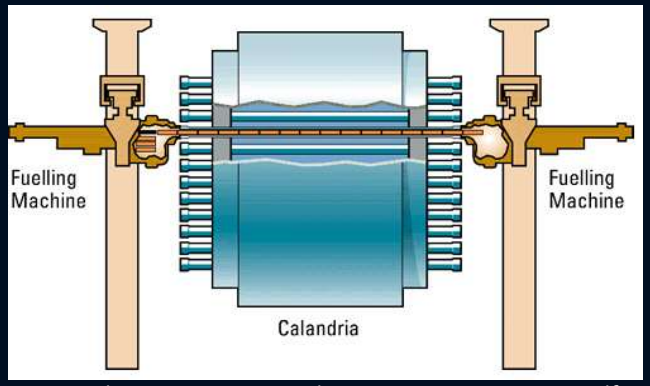
SLOWPOKE: Safe Low Power Kritical Experiment

CANDU Reactors

- Features:
  - Online fueling (2-3 years cycle)
  - Use natural uranium as fuel
  - Heavy water (D2O) as coolant and moderator
  - Instead of one big reactor vessel, hundreds of horizontal tubes
  - Defense in depth safety features: two independent shutdown systems (e.g., gravity-driven shutoff rods and liquid poison injection – Gadolinium Nitrate and Boron) for redundancy.



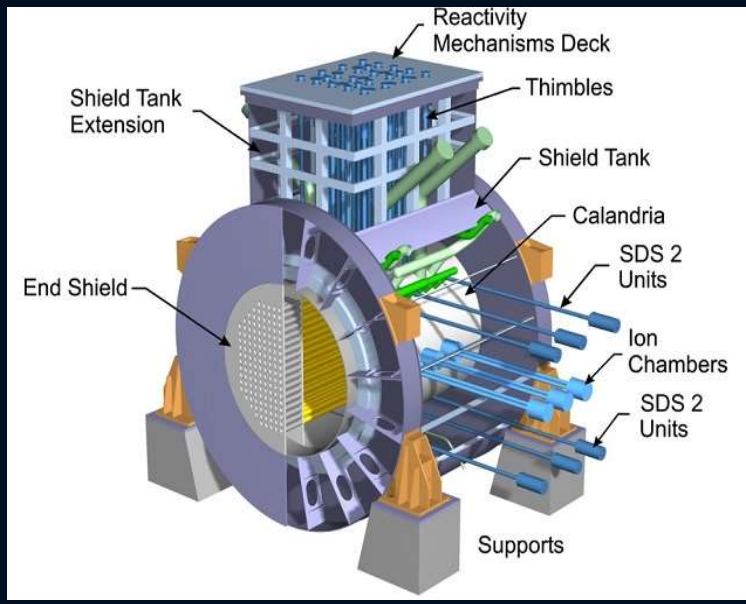
Source: http://ascenttrust.com/CANDU-6/index.html



Source: https://www.nrc.gov/docs/ML0325/ML032530144.pdf

CANDU Reactors:

- Like any other reactors, they need to be maintained in order to achieve its best performance and improve reliability.
- When reactor is shutdown for maintenance - systems need to be opened - Radiological hazards introduced.
- Personnel radiation exposure is under stringent scrutiny from Regulators, WANO/INPO and the public.
- Licensees must demonstrate personnel radiation exposure As Low As Reasonably Achievable (ALARA) – do more good than harm.
- Service Protection and Self Protection models are implemented at CANDU plants



Source: http://ascenttrust.com/CANDU-6/index.html

WANO: World Association of Nuclear Operators
INPO: Institute of Nuclear Power Operations

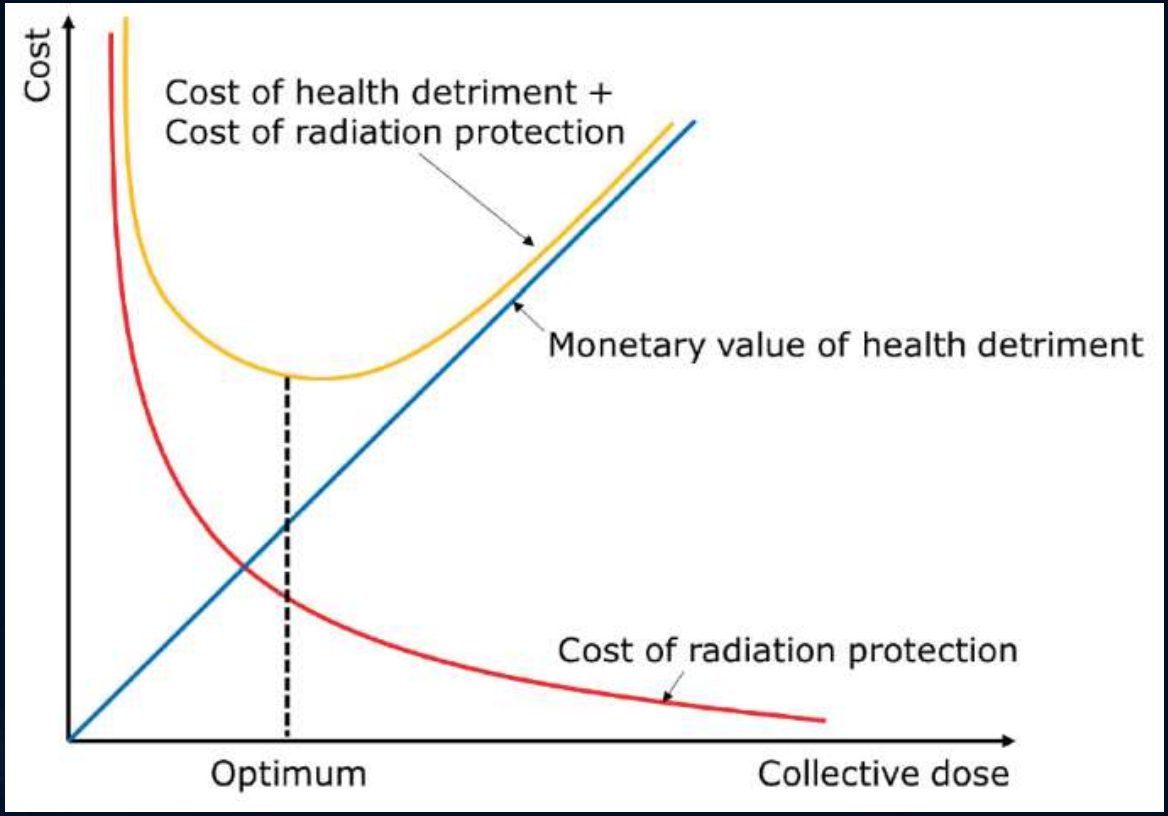
What is Service Protection?

- Well trained and highly qualified RP personnel are deployed to provide direction and protection guidance to maintenance staff.
- Their role and responsibilities:
  - Identify, eliminate, control the hazards and protect workers from unnecessary and unplanned exposures, i.e., keeping workers dose ALARA and ensuring **Justification, Optimization, Dose Limitation** principles are applied.
  - Conduct pre-job briefs/post-job debriefs.
  - Prepare and issue dosimetry to workers.
  - Ensure workers donning and doffing personal protective equipment (PPE) properly.
  - Provide basic consultation to staff w.r.t. health effects associated with ionizing radiation.

What is Self Protection?

- Workers are responsible for their own radiation protection and radiological safety, including use of personal protective equipment (PPE), dosimetry and back-out when specified limits are reached.
  - Involves extensive RP training and continuing training (annually).
  - Expects qualified staff to be able to don/doff PPE themselves (including half-mask respirator and plastic suits), use radiation survey instruments, and issue and return their own dosimetry.
  - Requires personal discipline and self-reporting
  - For high radiological risk jobs, self-protection may not be adequate which requires additional oversight to ensure all potential issues are considered.

Objective of these protection models?



Source: https://link.springer.com/chapter/10.1007/978-981-97-2795-7_15

Pros and Cons Comparison

Service Protection	Self Protection
- Allow maintenance staff to focus on task, eliminating distractions. - Minimize risk of unplanned exposure - Keep doses to workers low - Higher labour cost - Collective dose may be higher.	- Enable Operations staff to perform routine checks without the need for RP staff to be present. - Ability to address urgent matters (non-emergency issues) in a timely fashion - Lower labour cost - Lower collective dose

Putting it in Perspective (1-unit plant)

- Considering 1-unit CANDU plant:
  - → Revenue: $500K/day
  - → The shorter the outage days, the less operating cost ($ = Day = Dose)
  - → More staff, more work get done. Thus, shorten outage days

- Issue:
  - → Once the outage is completed (i.e., the unit is up and running), not much work is available for staff – not economical.
  - → There is a need to balance the staffing level – having adequate staff to support day-day operations, while maintaining adequate level of personnel to support outage work.

Putting it in Perspective

- Cost estimates:
  - Salary of RP Technician per year: $80K - $100K
  - During outage: 100+ RP Technicians
  - During non-outage (on-power mode): 10-15 RP techs → $850K potentially saved (excluding benefits)
  - In order to address potential radiological events during the unit is on power, station staff, particularly operations/maintenance, need to have basic RP knowledge and the RP instruments.
- Combination of these two models is the most economical, while radiological safety is maintained.

Conclusion

- Both protection models are important and interdependent – utilizing one without the other may be costly and provide no additional improvement in safety
- Together, they form a **comprehensive safety framework** for large nuclear power utilities.
- Optimum outcomes or a balance between cost vs. health detriment can be achieved with proper implementation of both models.

Thank you.