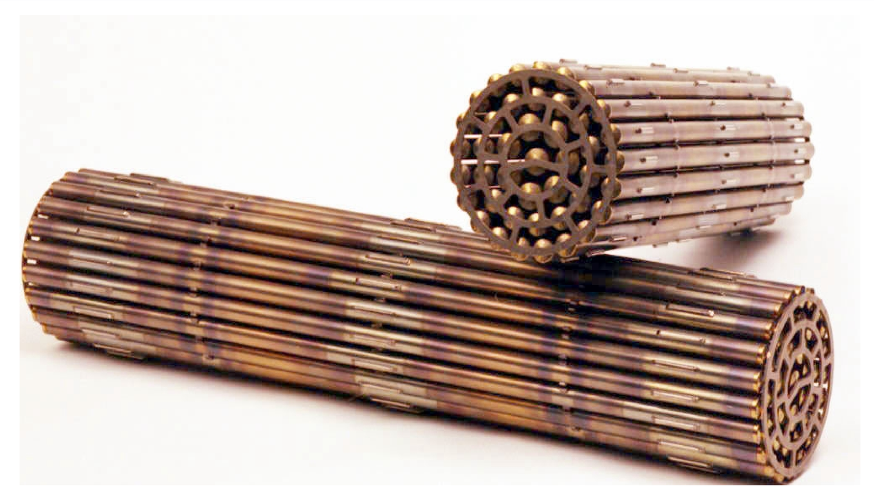
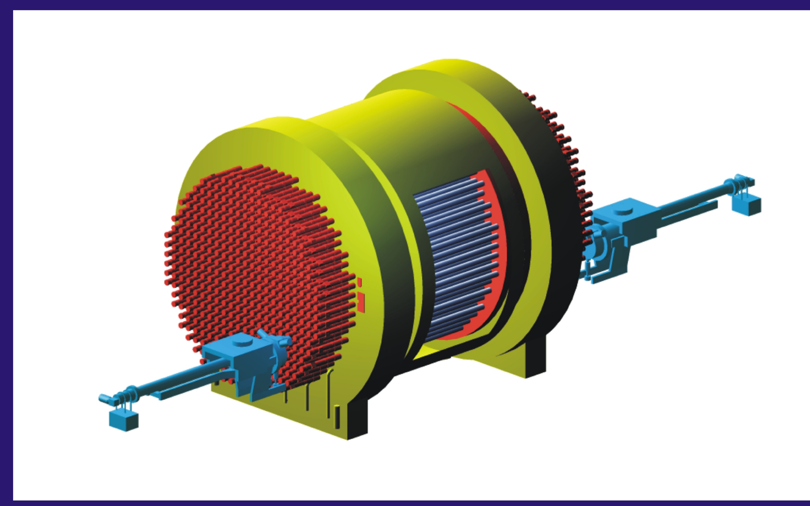
CANDU®: Setting the Standard for Proliferation Resistance of Generation III and III+ Reactors



CANDU fuel bundles (0.5 m length, 23 kg)

J.J. Whitlock, A.G. Lee

Atomic Energy of Canada Limited
Chalk River Laboratories
Chalk River, Ontario, Canada K0J 1J0



CANDU calandria and fuelling machines

PROLIFERATION RESISTANCE:

Proliferation resistance: "that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material, or misuse of technology, by States intent on acquiring nuclear weapons or other nuclear explosive devices". In general, proliferation resistance results from a combination of, inter alia, technical design features, operational modalities, institutional arrangements and safeguards measures. (IAEA)

"INTRINSIC":

- Nuclear material's chemical form, radiation field, heat generation, and spontaneous neutron generation rate;
- Complexity and time required for modifications necessary to misuse a civilian facility for weapons production purposes;
- Mass and item quantity of nuclear material relevant to weapon production (e.g. one Significant Quantity as defined by the IAEA);
- Expertise and time required to divert or produce nuclear material and convert it to weapons useable form;
- Design features that limit access to nuclear material.

"EXTRINSIC":

- IAEA comprehensive safeguards and additional protocol;
- Commitments to effect international nuclear non-proliferation norms and guidelines such as the Nuclear Suppliers' Group Supply Guidelines;
- Bilateral treaties concerning nuclear co-operation for peaceful purposes;
- National policies and laws regarding exports

INTRINSIC PROLIFERATION RESISTANCE FEATURES

(a) FUEL CYCLE FEATURES:

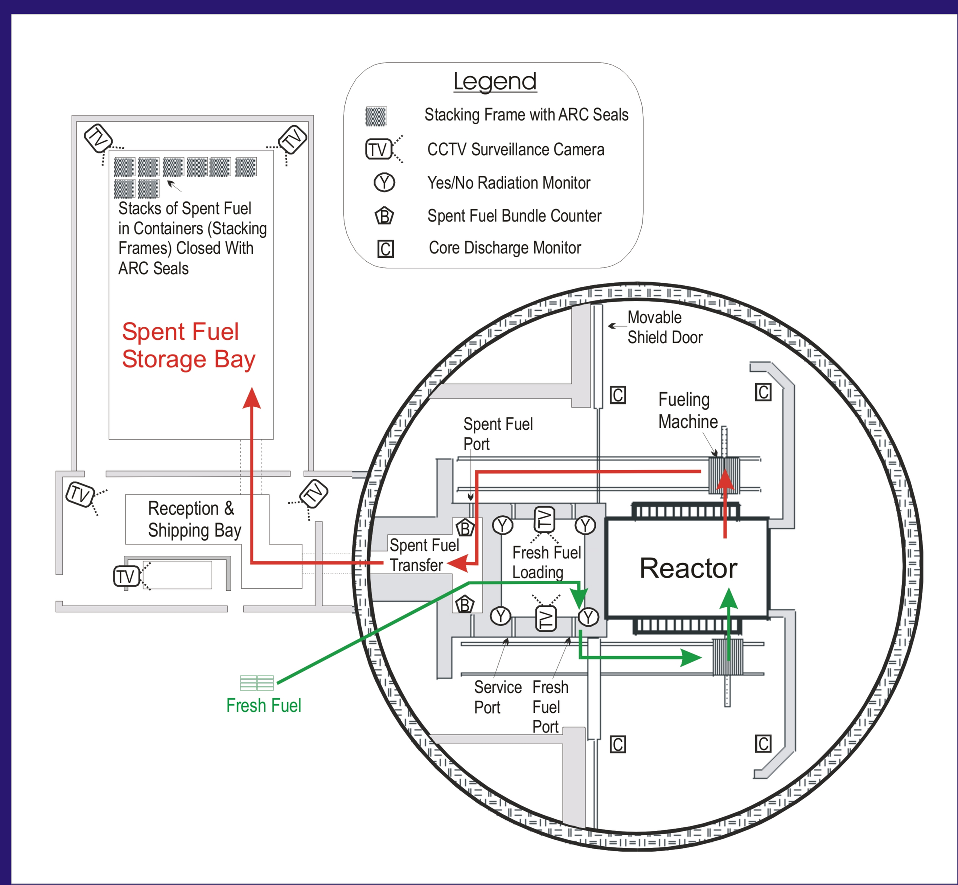
- Natural uranium fuel cycle does not require enrichment – reduces safeguards complexity of Nuclear Energy System infrastructure.
- Plutonium isotopic is reactor grade (similar to LWR) despite significantly lower burnup (fissile Pu fraction ~ 70%)
- Plutonium concentration in spent fuel is low (about half that of LWR)
- High number of items, high mass required for diversion of 1 "Significant Quantity" of plutonium In spent fuel
- High uniformity of burnup in spent fuel due to fuel shuffling – simpler characterization of spent fuel, avoidance of low-burnup end-regions as in LWR

(b) OPERATIONAL FEATURES:

- Low excess reactivity in core – does not support significant undeclared irradiation, nor significant deviation from declared fuelling scheme
- On-load fuelling process highly automated and easily monitored
- On-load fuelling rate cannot be significantly increased due to physical constraints of fuelling machines
- Core flux distribution constantly calculated and verified against >100 in-core flux detectors, as a necessary part of on-load daily fuel management – this information is available to IAEA
- CANDU fuel historically has low defect rate (<0.1%), which counters diversion strategies seeking to exploit defective fuel management activities
- Automated nature of entire fuelling process creates a continuous, comprehensive digital record that could provide IAEA with ability to perform independent, automated, remote, real-time trend analysis – a unique opportunity for "operational transparency"

EXTRINSIC PROLIFERATION RESISTANCE MEASURES

- International trade of CANDU technology is tied to bilateral agreements requiring all related technology be subject to safeguards + consent rights on reprocessing, enrichment, and retransfer of equipment or technology
- CANDU reactors are the most comprehensively safeguarded power reactor technology in operation
- Methods for safeguarding CANDU reactors developed in 1970s and 1980s, and constantly improved as required
- All bundles are tracked as they move through a CANDU plant, from new-fuel receipt to spent-fuel storage



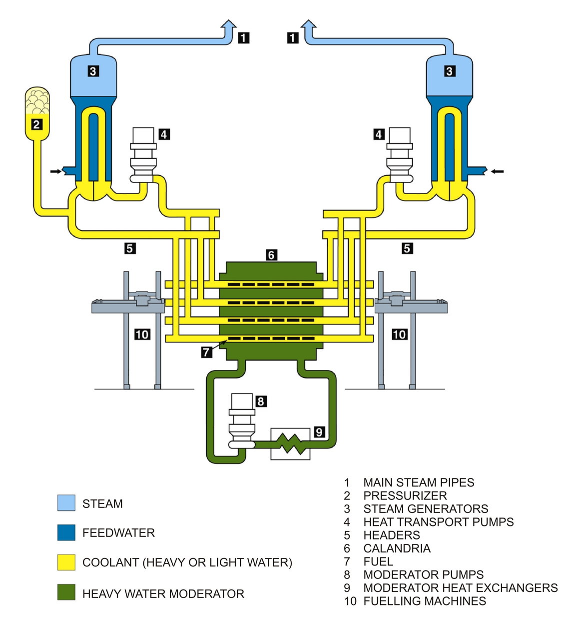
Typical IAEA safeguards equipment for CANDU

SUMMARY

- Nuclear weapons proliferation is ultimately a political decision that can be mitigated through technological barriers and institutional controls. Historically, civilian nuclear power reactors under international safeguards have not proven to be attractive targets for nuclear weapons proliferation, but do present a valid proliferation risk that must be managed. Accordingly, achieving the highest degree of proliferation resistance is both a responsibility of technology suppliers and an expectation of the public and political leadership, with transparency and confidence afforded through international oversight, such as that provided by the IAEA.
- CANDU technology has incorporated intrinsic proliferation resistance features since its outset, derived mainly from the fundamental physics of heavy-water moderated reactors. While these intrinsic features minimize the attractiveness of CANDU technology as a target for proliferation, extrinsic measures are still required to provide verification and deterrence through timely detection. IAEA safeguards have been successfully incorporated in CANDU reactors for decades, and continue to evolve as newer technologies are introduced.
- Through these intrinsic features and extrinsic measures, CANDU technology has a proliferation resistance that is second to none. Combined with its unparalleled safety and fuel-cycle flexibility, CANDU technology provides an attractive platform for meeting the global needs of safe, secure, and non-polluting energy supply.

CANDU:

- Developed originally by Canada in the late 1950s - 60s
- In operation in Canada, Argentina, Romania, South Korea, China, Pakistan, India
- Heavy-water moderated
- On-load refuelled (using fuel channels)
- Enhanced CANDU 6: natural-uranium fuelled, heavy-water cooled & moderated, 700 MWe class (Gen III)
- ACR-1000: LEU fuelled, light-water cooled (heavy water moderated), 1000 MWe class (Gen III+)
- High level of passive safety, fuel cycle flexibility, resource utilization efficiency



ATOMIC ENERGY OF CANADA LIMITED
www.aecl.ca

Main author contact:

Dr. Jeremy J. Whitlock
Manager, Non-Proliferation & Safeguards
Atomic Energy of Canada Ltd.
Chalk River Laboratories
Chalk River, Ontario, CANADA K0J 1J0
+1 613 584-8811 ext. 44265
whitlockj@aecl.ca

International Conference on Opportunities and Challenges for Water Cooled Reactors in the 21st Century, Vienna, Austria, Oct. 27-30, 2009