ACR-1000® Design Features Minimizing Collective Occupational Radiation Exposures and Public Dose to ALARA

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Outline

- **ALARA Requirements and Guidance for new build Nuclear Power Plant (NPP) in Canada (ACR-1000 and EC6)**
- **Application of the ALARA Principle to the ACR-1000 and EC6 Designs:**
  - **Overall ALARA Design Process**
  - **Application of ALARA Principle**
- **ACR-1000 Design Features to Minimize:**
  - **Occupational Radiation Exposure or Worker Dose**

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ALARA Requirements and Guidance in Canada

- **Canadian Nuclear Safety Commission (CNSC)**
  - **The CNSC under the umbrella of the Nuclear Safety and Control Act establishes the rules and regulations to be followed for radiation protection in Canada.**
- **Nuclear Safety and Control Act**
  - **Radiation Protection Regulations (SOR/2000-203).**
  - **Regulatory Guide G-129, “Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)”.**
  - **Regulatory Document RD-337, “Design of New Nuclear Power Plants”.**

Radiation Protection Regulations

- **CNSC Radiation Protection regulations include an ALARA requirement for all licensees to establish a radiation protection program to keep exposures ALARA through the implementation of a number of control programmes, including:**
  1) ***Management control over work practices***
  2) ***Personnel qualification and training***
  3) ***Control of occupational and public exposure to radiation***
  4) ***Planning for unusual situations***

Regulations are focused on an operational ALARA program with Items 3 and 4 being addressed during the design process.

ALARA Guideline (G-129)

- **CNSC Guide G-129 Keeping Radiation Exposures and Doses As Low As Reasonably Achievable (ALARA)", specifically addresses how the ALARA principle should be applied to NPP design:**
  - ***The Radiation Protection Regulations require licensees to implement measures to keep doses received by workers and members of the public from exposure to sources of radiation ALARA. It is insufficient for the licensee to simply respect the appropriate dose limits; efforts must be made to further reduce doses.***

RD-337

- **CNSC RD-337 "Design of New Nuclear Power Plants" in which the need to keep the doses ALARA is outlined in Section 4.1.1 of the document:**
  - ***The radiation protection objective is to provide that during normal operation, or during anticipated operational occurrences, radiation exposures within the NPP or due to any planned release of radioactive material from the NPP are kept below prescribed limits and as low as reasonably achievable (ALARA).***

Application of ALARA Principle in Design of CANDU Reactors (ACR-1000 and EC6)

- **Advanced CANDU Reactor (ACR-1000) and Enhanced CANDU 6 (EC6) are designed to comply with the CNSC regulatory requirements (including RD-337) for radiation protection for plant personnel, the public and the environment.**

- **ACR-1000 and EC6 designs consider ALARA principle to ensure radiation exposures to plant personnel, the public and the environment are properly controlled, economic and social factors taken into account during all phases of the plant life cycle (i.e. design, commissioning, operation, maintenance and decommissioning).**

- **Application of the ALARA principle is imbedded in the design process of ACR-1000 and EC6 by application of the ALARA assessment methodology described in the next slides.**

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Overall ALARA Design Process

- In the design phase of the CANDU reactors, designers followed a series of established procedures to ensure that the design proceeded through an orderly process of review and quality checks:
  - Plant Performance Specification
  - Safety Design Guides (e.g., Radiation Protection)
  - Design Guides
  - Design Requirements

- To reduce radiation exposure to ALARA, designers reviewed:
  - Operating Experience (OPEX) and Feedback Monitoring System (FMS) from previous CANDU plants.
  - OPEX and FMS include, e.g., details of equipment reliability, frequency of maintenance, inspection or repair, as well as the station exposures associated with the equipment.

Application of the ALARA Principle

- **The steps in determining if an ALARA assessment is required are as follows:**
  1) **Identify systems and practices that result in radiation exposure to workers and members of public.**
  2) **Estimate the total doses resulting from identified systems and practices.**
  3) **If the doses are above the dose limits (worker dose: 50 mSv/a over one-year dosimetry period or 100 mSv/a over five-year dosimetry period, and public dose: 1 mSv/a), radiation protection must be improved.**
  4) **If the doses are below the design dose targets:**
     a) **collective worker dose: 0.6 person-Sv/a**
     b) **public dose: 10 μSv/a**

     then no further ALARA assessment is required. Designers are encouraged to reduce doses below the design targets where this can be done without significant expenditure.
  5) **If the doses are above the design dose targets given above, an ALARA assessment is required, as described in the next slide.**

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Application of the ALARA Principle (cont'd)

- **To apply the ALARA principle to CANDU NPP systems, the following procedure is used in determining which design option is the ALARA option. The procedure is as follows:**

  1) **Define the situation which requires consideration of a dose reduction**
  2) **Identify the options for dose reduction and factors to be assessed**
  3) **Evaluate the options using quantitative techniques or judgments**
  4) **Evaluate other non-radiological or non-quantifiable factors**
  5) **Decide which, if any, of the options to implement taking into consideration cost associated to dose reduction**
  6) **Document the basis of the judgement**

Occupational and Public Doses

- **Occupational and public doses has been assessed based on radiation source terms, CANDU 6 station data, ACR and EC6 design features/improvements and maintenance activities:**
  - **The estimated average annual occupational dose is well below the design target (0.6 person-Sv/a):**
    - **20% from reactor operations**
    - **80% from maintenance during outage**
  - **The upper-bound annual radiation dose received by individual members of the public from radioactive gaseous and liquid effluent emissions is well below the design target (10 μSv/a).**

ACR-1000 Twin Plant Layout

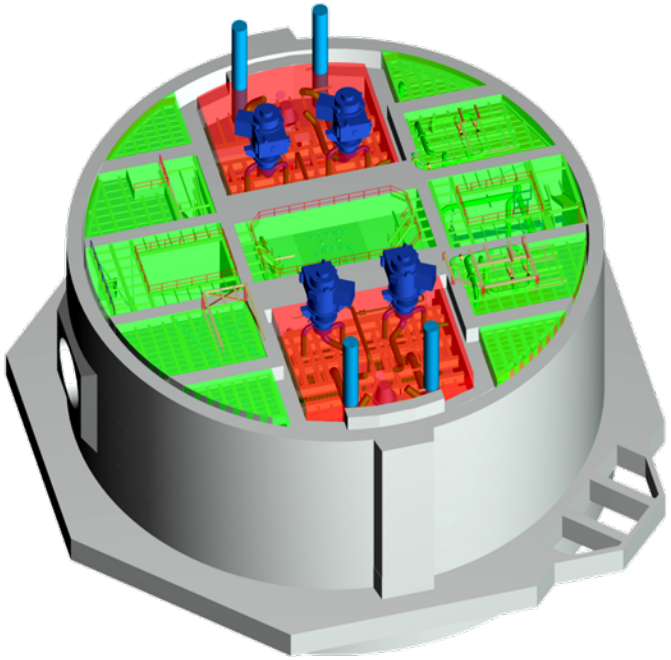
State-of-the-Art Generation III+ Technology

ACR-1000 Design Features to Minimize Occupational Radiation Exposure (External Radiation)

Common Equipment and Component and Layout

- **Plant has two major radiological zones, i.e., Radiological Control Area (RCA) and non-RCA. This reduces the time taken to enter and exit the facility, particularly during reactor shutdown, and makes it easier to control contamination.**

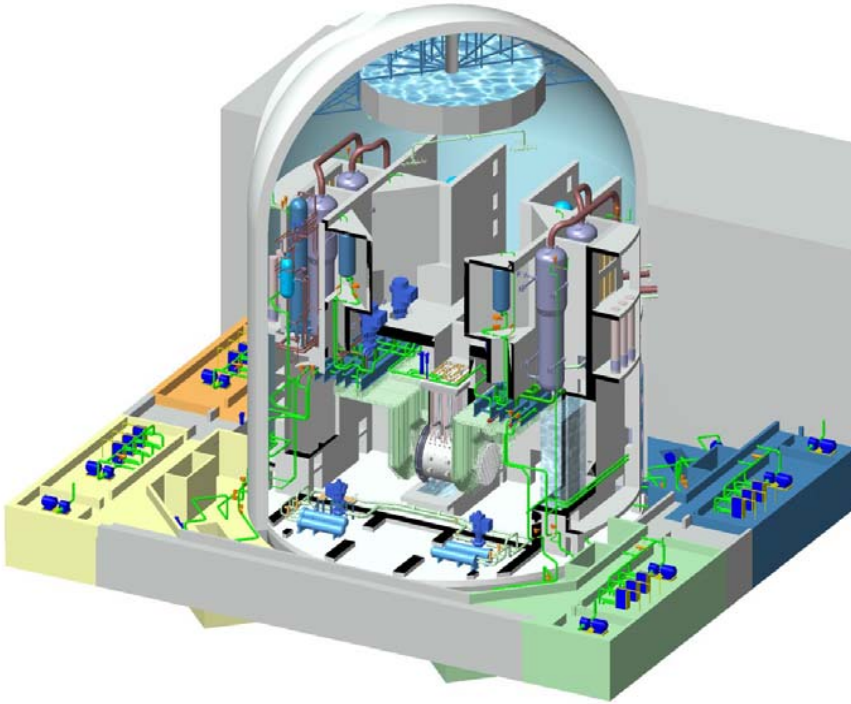
- **Fewer monitoring stations at zone boundaries are needed, leading to reduced manpower needs at the fewer monitoring stations and reduced collective doses.**



ACR-1000 Design Features to Minimize Occupational Radiation Exposure (External Radiation)

Common Equipment and Component and Layout

- Improved plant layout and improved access controls result in avoidance of high-radiation areas and provide increased radiation protection for operations and maintenance staff.
- Where possible, equipment requiring more frequent access and maintenance is located in low-dose and non-RCA areas.
- A maintenance-based design provides space allocation and reduction in temporary scaffolds and hoists, and includes provisions for built-in electrical, water, and air supplies for on-power and normal shutdown maintenance.



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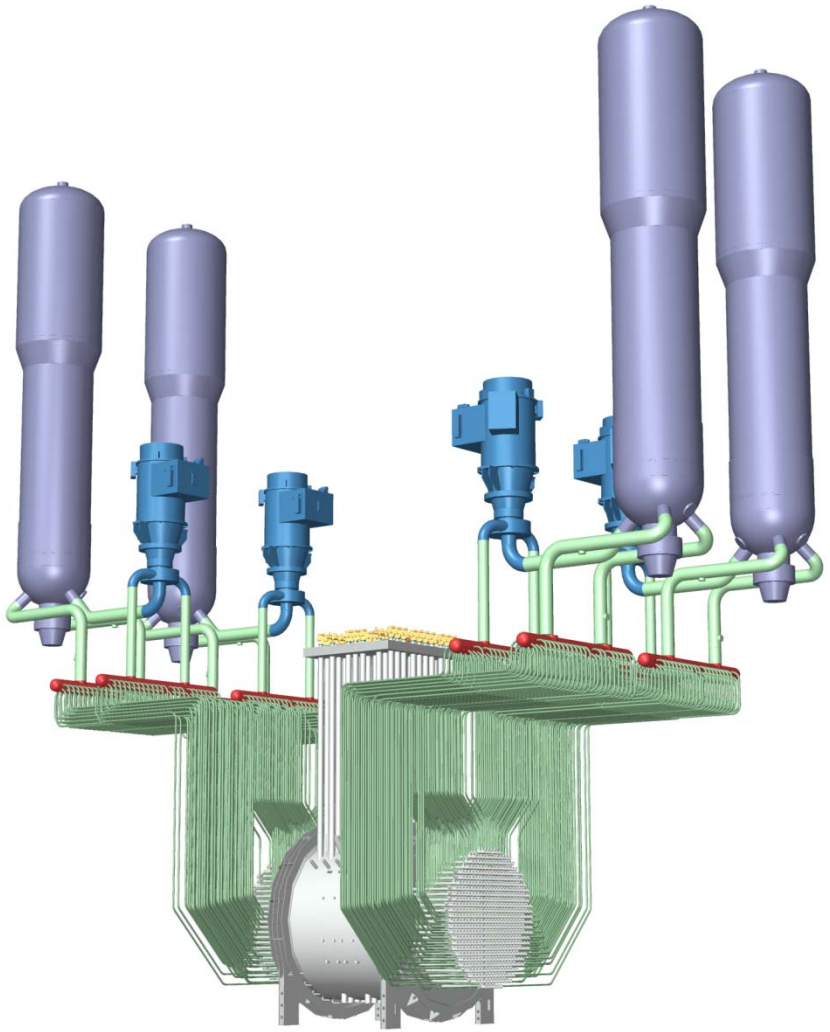
ACR-1000 Design Features to Minimize Occupational Radiation Exposure (External Radiation)

Heat Transport System

- **Stainless steel for the Heat Transport System (HTS) feeders reduces flow-assisted corrosion and therefore reduces the quantity of mobile material available for activation and reduces the requirement for feeder-thinning inspections.**
- **Provision to supply nitrogen gas to the HTS to provide inert cover gas during drained state to reduce corrosion due to oxidation.**



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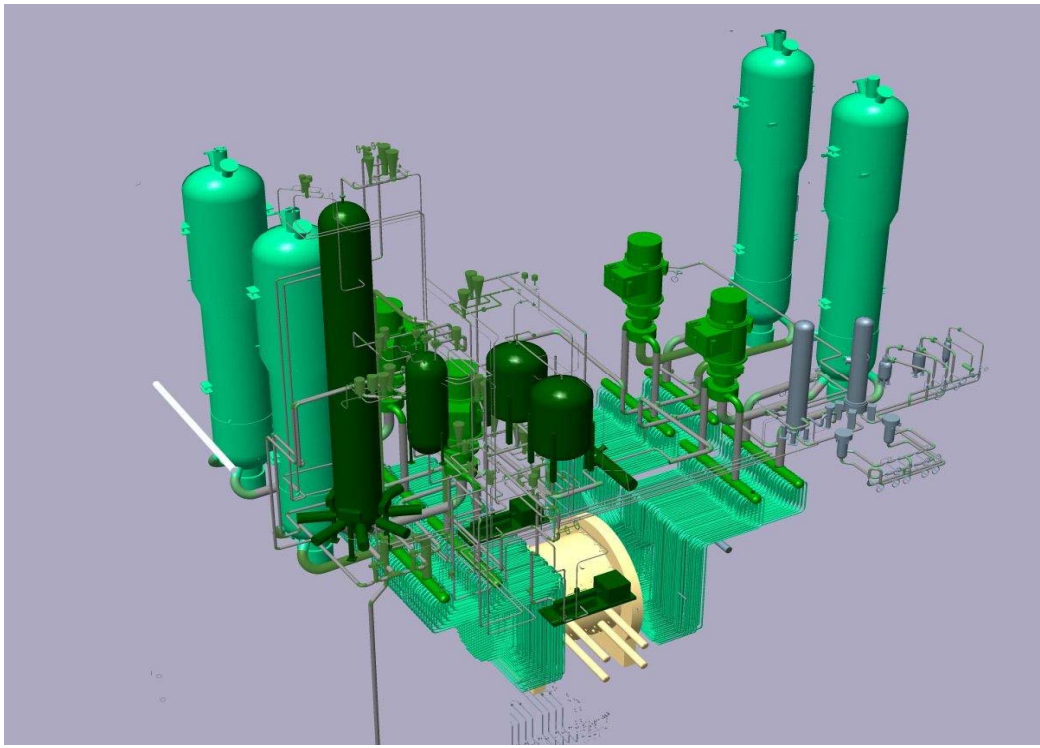
ACR-1000 Design Features to Minimize Occupational Radiation Exposure (External Radiation)

HT Purification System

- **Use of sub-micron filters to remove particulates from the HTS coolant.**
- **Use of a high flow purification system to provide a purification half-life of one hour or less to reduce activity transport and deposition outside the reactor core.**
- **Purification in-service during most shutdown configurations to maintain chemistry control, and to minimize start-up chemistry transients (e.g., crud bursts).**



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Summary

- ACR-1000 and EC6 have evolved from top-performing CANDU 6 reactor line.
- Retains proven CANDU design features while incorporating state-of-the-art innovations.
- Evolutionary ACR-1000 and EC6 designs incorporate significant radiation exposure control improvements based on ALARA assessment using the latest technology and industry best practices with respect to:
  - limitation of potential worker and public doses
  - minimization of radionuclide production at source
- Annual occupational dose and public dose are ALARA and are below design targets 0.6 person-Sv/a and 10 μSv/a, respectively, over the operating life of ACR-1000 and EC6 NPPs.

Questions?

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