An Overview of the ACR Design

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AECL TECHNOLOGIES INC.

ACR Design

- The evolutionary approach has great advantages
  - Can deliver safety enhancement and economic savings with practical innovation, building on strong CANDU knowledge base
  - Priority on ensuring robust safety case
- Key elements:
  - Application of enabling technologies
  - Balance of experience and innovation in design
- Feedback from CANDU plants
  - Operating CANDU plants
  - Construction/commissioning feedback from Qinshan III CANDU 6 project

Status of ACR Design

- **Design definition and optimization**
  - Conceptual design studies for ACR-700 completed in March 2001
  - Defined optimized reference ACR-700 design in March 2002
  - Basic design engineering program started in January 2002
  - Other size option: ACR-1000

Engineering Program

- January 2002 to September 2005
- 45-month program to perform generic engineering to have market-ready product and to support pre-project licensing
- Submissions for Canadian licensing will be completed by end of 2004
- Program infrastructure is in place
- Program is mobilizing with a total of 160 staff currently working on basic engineering and specific anticipatory R&D support
- Major contributions from partners and staff in support of business development are in addition to the above

Systematic Approach to Optimization

- Ffuel performance
- Fuel channel output
- Reactor core configuration
- System simplification
- Plant components standardization
- Construction
- Plant operability and maintainability

Enhanced Safety

ACR Features Overview

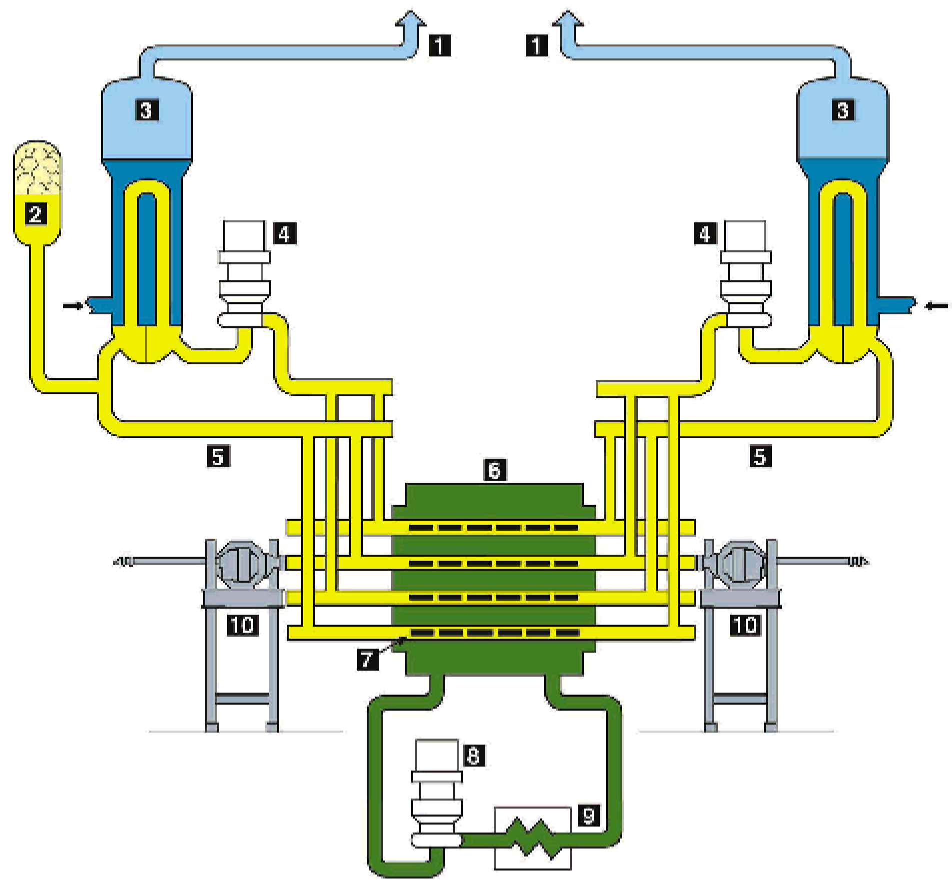
- Traditional Features
- Safety Systems
- Safety Innovations and Cost Optimizations
  - Use of CANFLEX and SEU Fuel
  - Improved Core Characteristics
  - Use of Light Water as Reactor Coolant
  - Plant Arrangement
  - Reserve Water System
- Control Centre and Control Systems
- Reactor Coolant System (Heat Transport System)
- Fuel Handling
- Non-Proliferation & Safeguards

Nuclear Steam Systems

Major nuclear systems

- STEAM
- FEEDWATER
- LIGHT WATER COOLANT
- HEAVY WATER MODERATOR

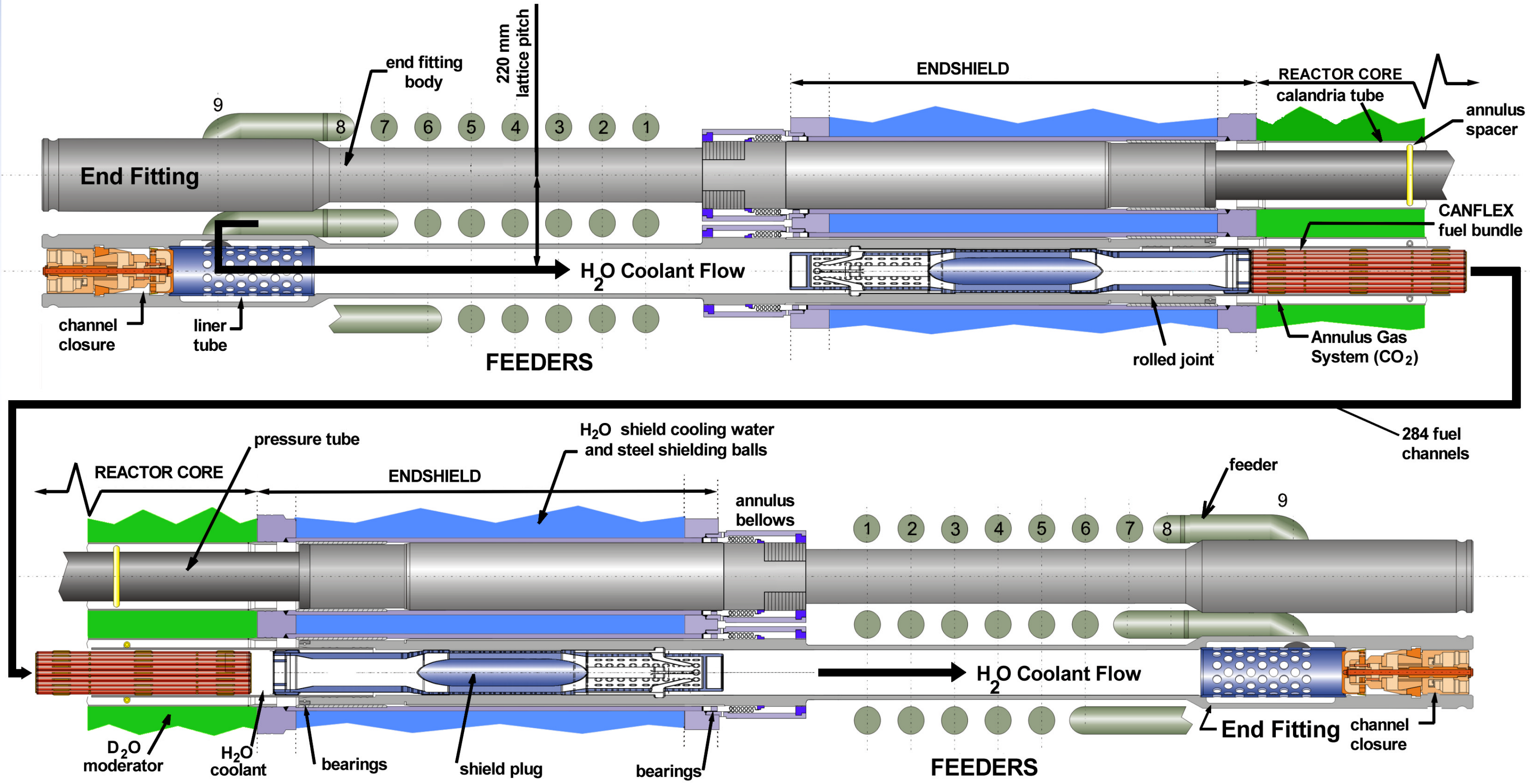
1. MAIN STEAM PIPES
2. PRESSURIZER
3. STEAM GENERATORS
4. HEAT TRANSPORT PUMPS
5. HEADERS
6. CALANDRIA
7. FUEL
8. MODERATOR PUMP
9. MODERATOR HEAT EXCHANGER
10. FUELING MACHINES



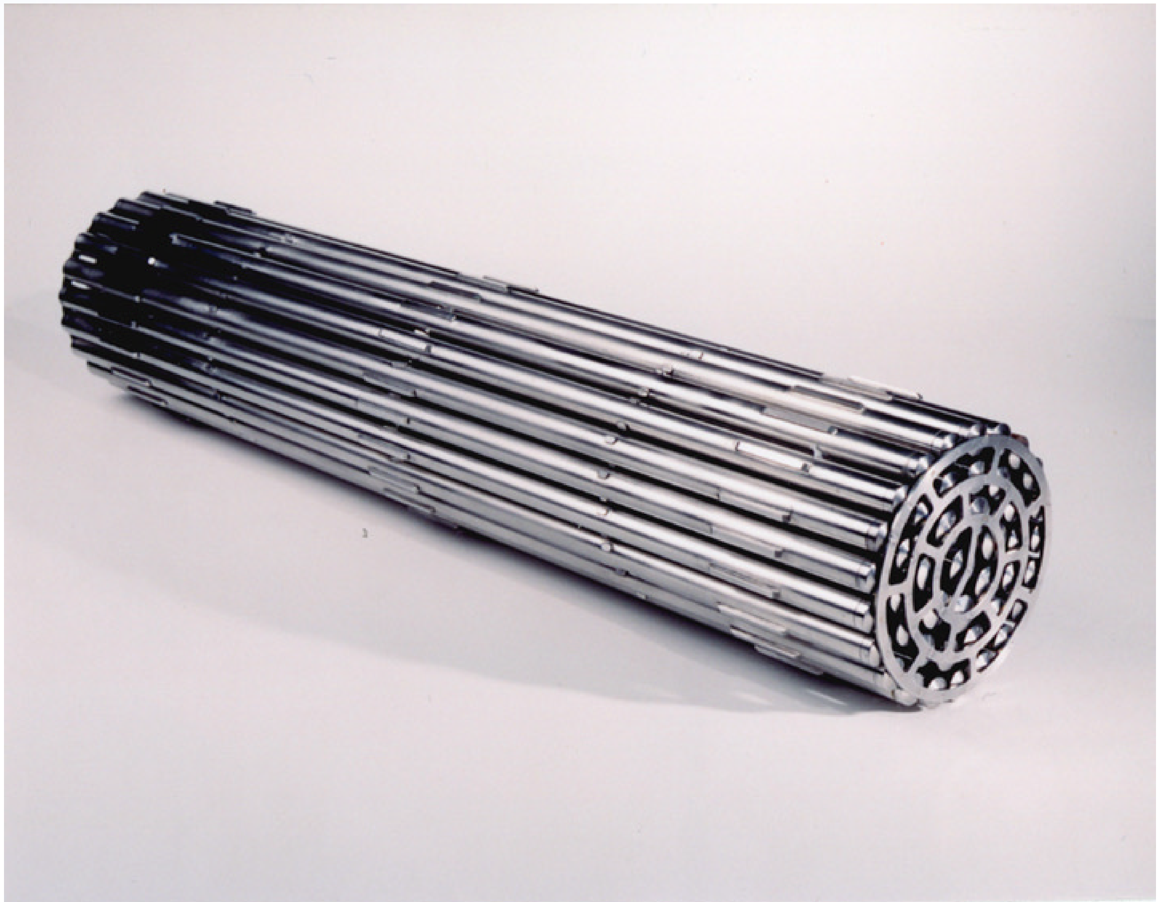
Basis of ACR Design

- Evolutionary approach adopted by building on CANDU 6 design, project and operational experience
- Retained traditional CANDU features:
  - Modular horizontal fuel channels
  - Simple, economical fuel bundle design
  - Cool low pressure heavy water moderator
  - High neutron efficiency
  - On-power fueling
  - Passive shutdown systems in low pressure moderator
  - Light water shield tank as back-up heat sink for severe core damage

ACR Fuel Channel Schematic



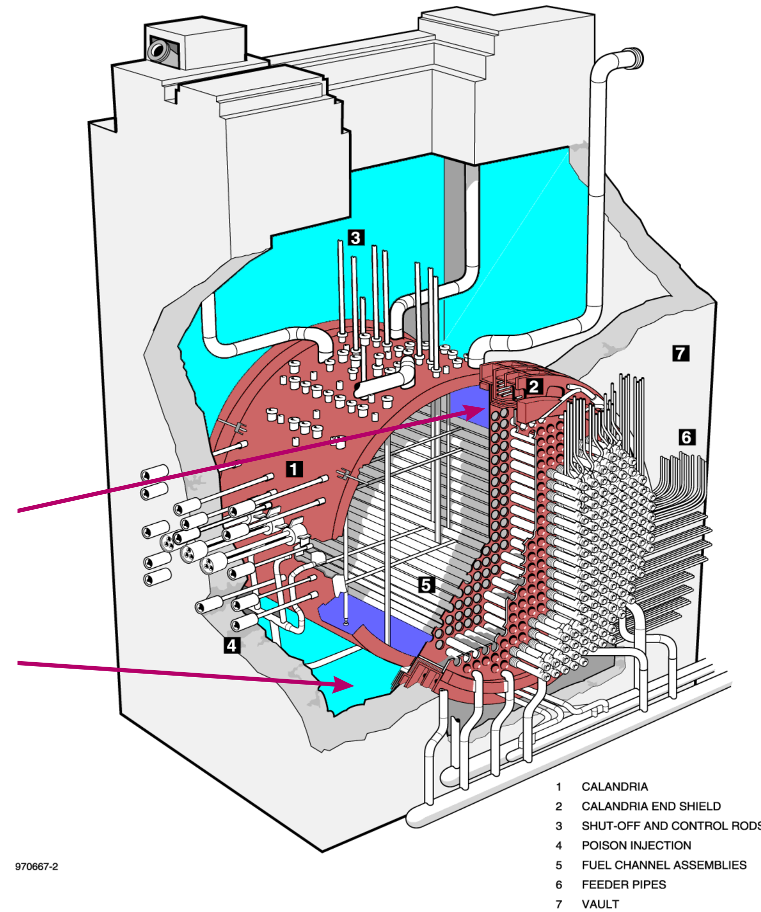
CANFLEX Fuel Bundle



CANDU 6 - Calandria and Shield Tank

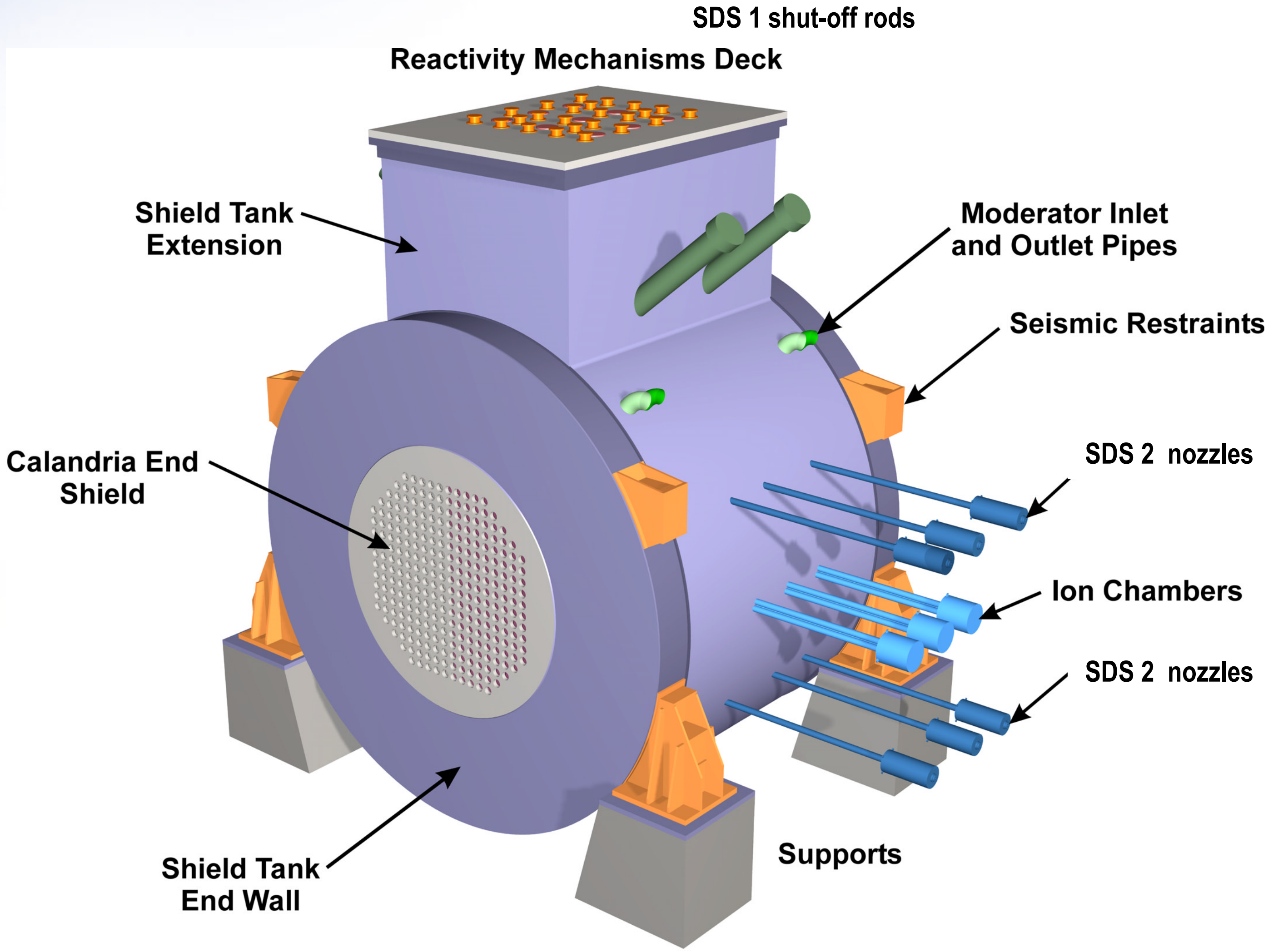
Heavy water moderator in calandria

Shield tank water

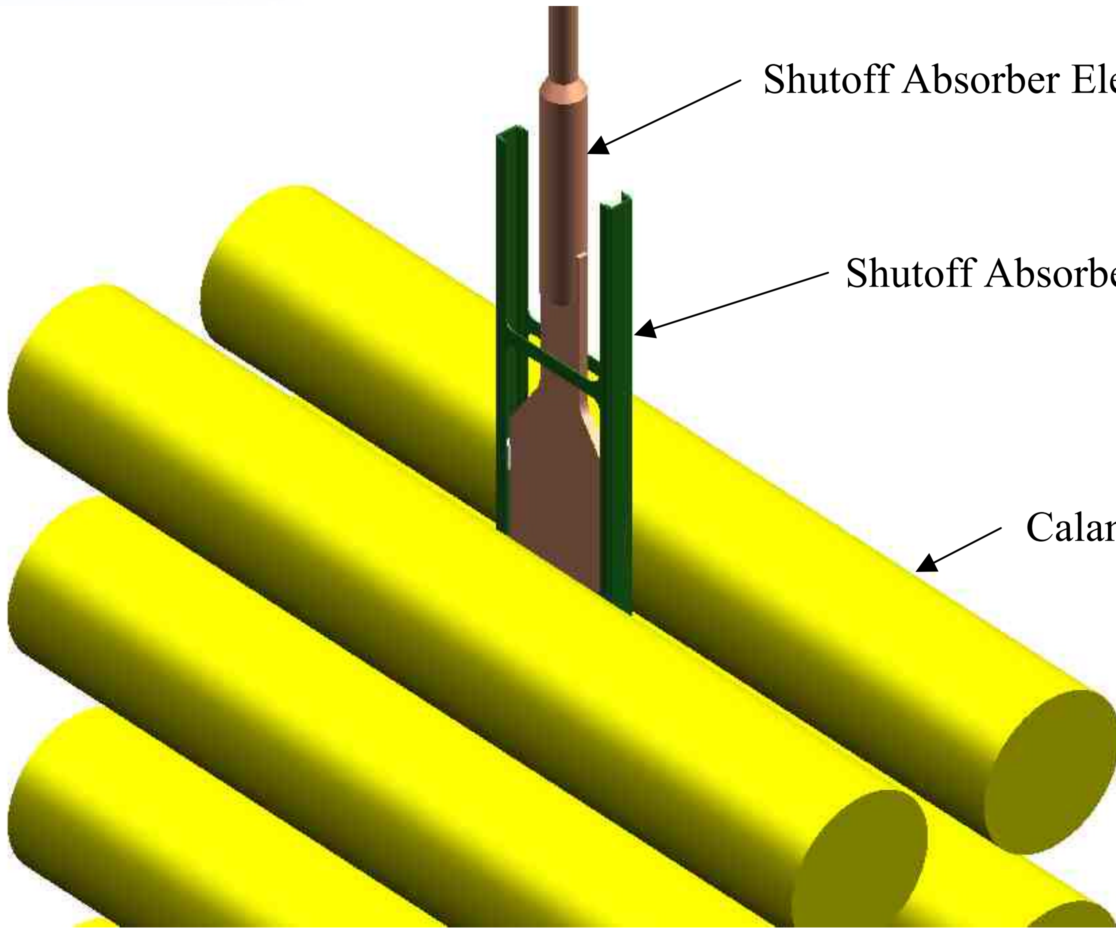


CANDU 6 Reactor Assembly

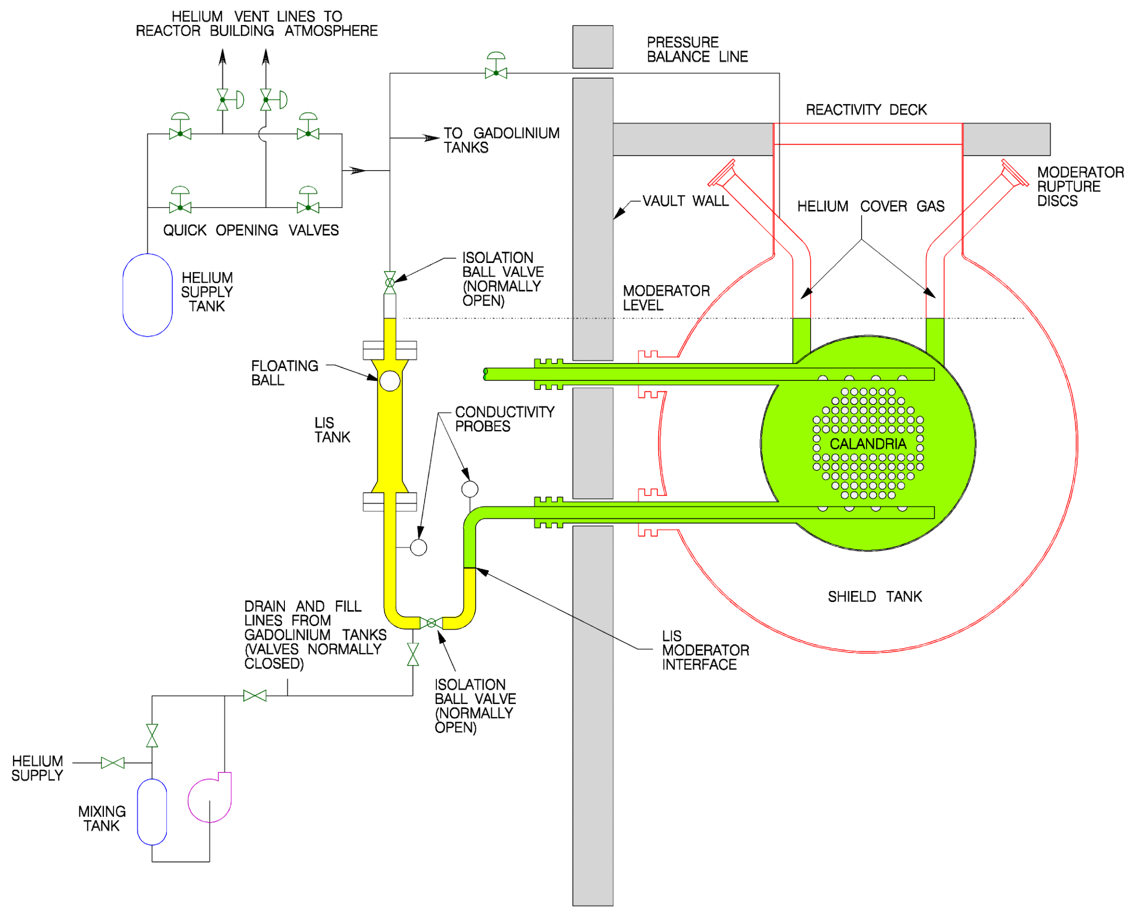
ACR-700 Reactor Assembly



ACR-700 Reactivity Control Units



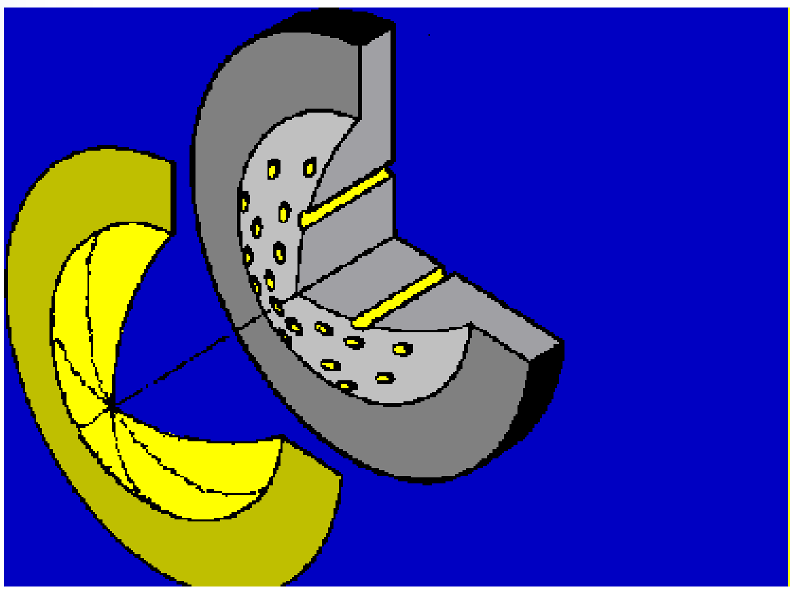
Shutdown System 2 – Liquid Injection Shutdown System



Safety Systems

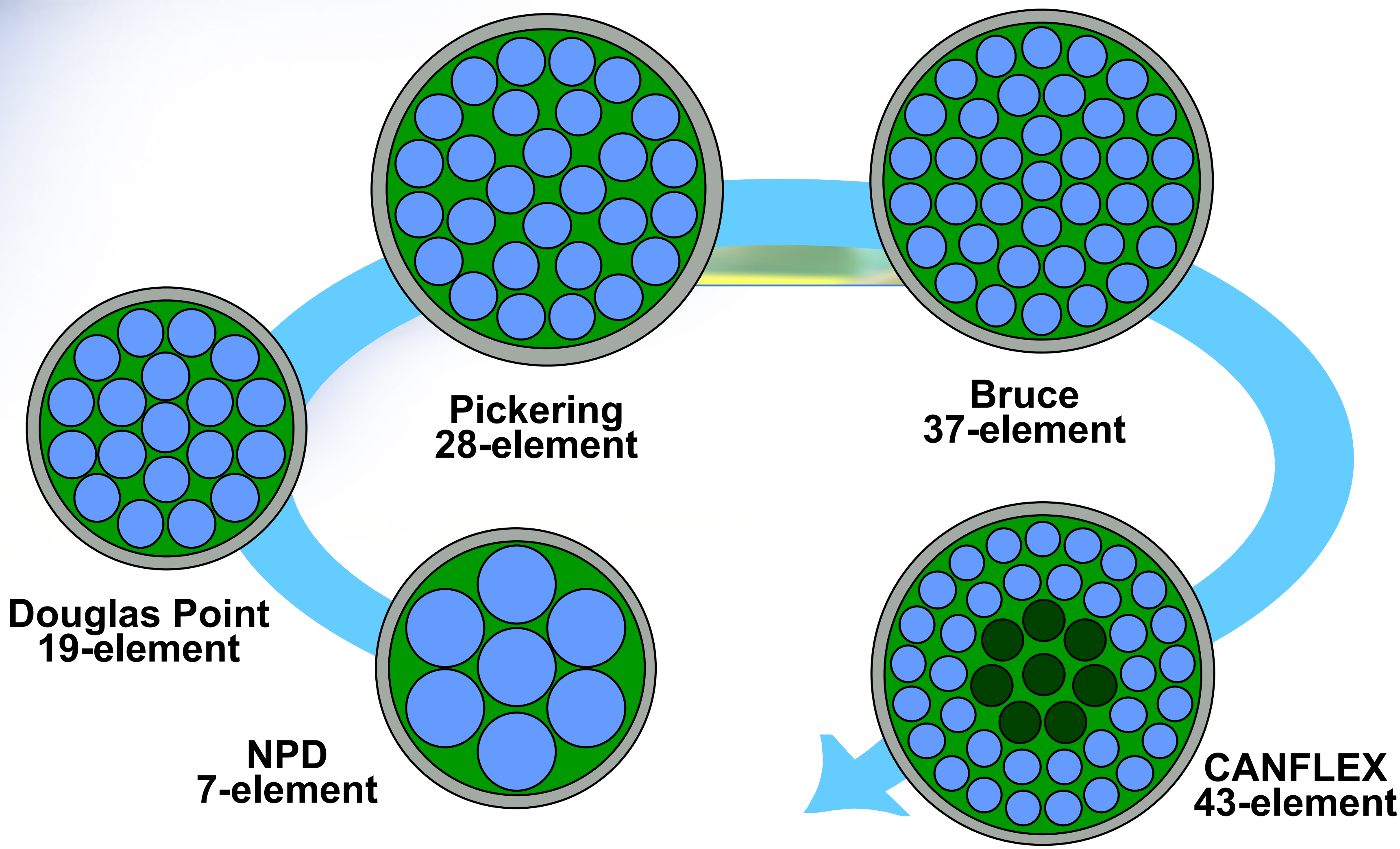
- Safety Systems based on existing, proven CANDU designs
- Safety Shutdown System 1 (SDS1)
- Safety Shutdown System 2 (SDS2)
- Emergency Core Cooling System (ECCS)
  - High-pressure emergency coolant injection using accumulators
  - Long Term Cooling system for coolant recirculation and long-term heat removal. Also used for reactor cooling for non-LOCA transients and accidents
  - Simplified ECCS design when compared with CANDU 6 due to light water coolant and passive one way rupture discs
- Containment
  - Pre-stressed concrete containment structures with steel liner (based on CANDU 9 and PWR designs)

ECCS Improvements



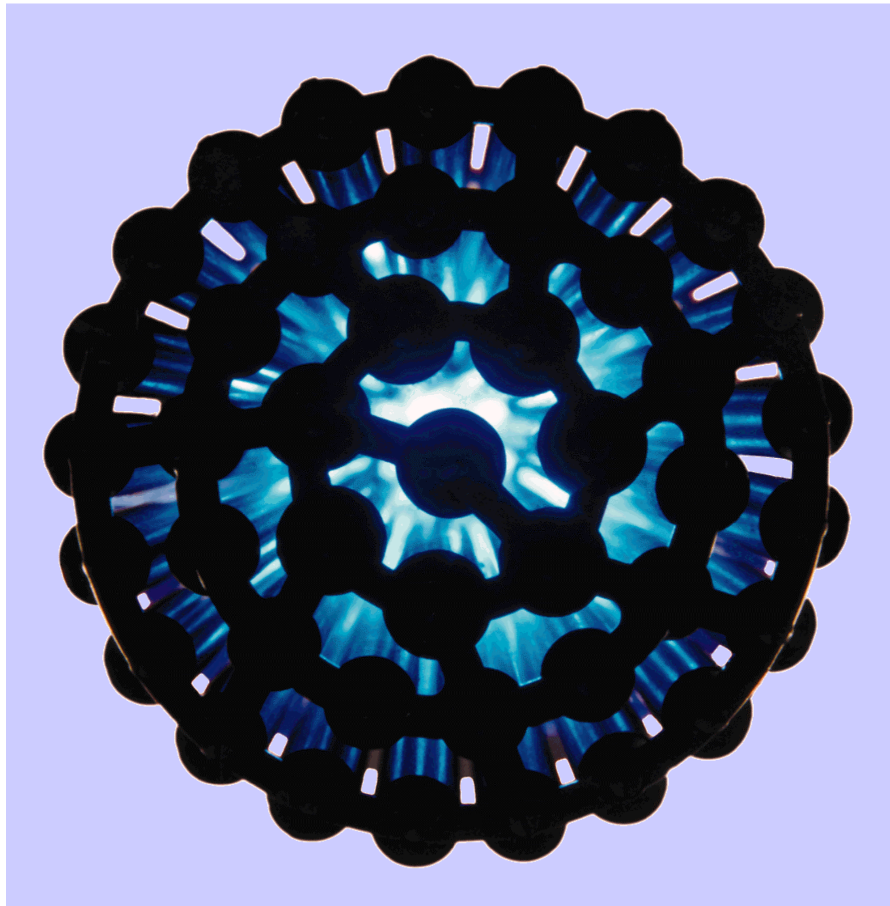
- Use of one-way rupture discs
- Backing plate supports rupture disc against reactor coolant pressure during normal reactor operation
- Rupture disc burst by accumulator pressure for emergency coolant injection

EVOLUTION OF CANDU FUEL



ACR CANFLEX Fuel

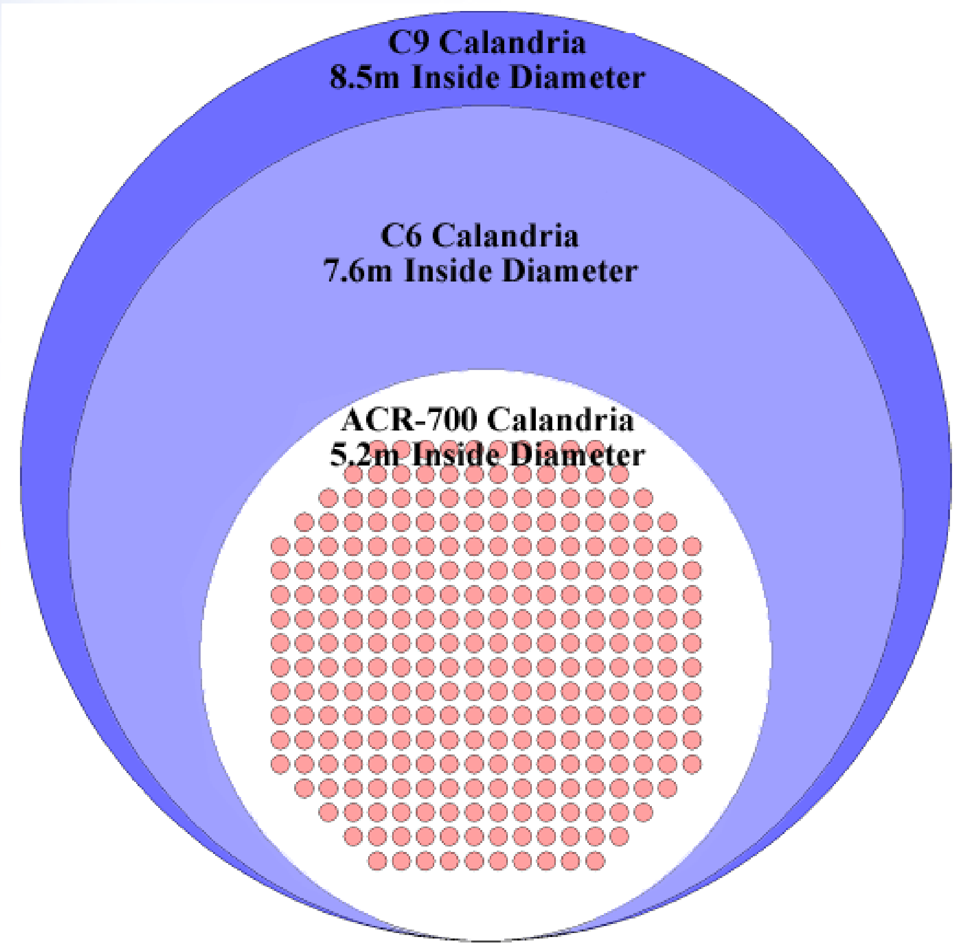
- **2 pin sizes, 43 elements**
- **Peak ratings reduced**
- **Extended burnup**
- **CHF-enhancing appendages**

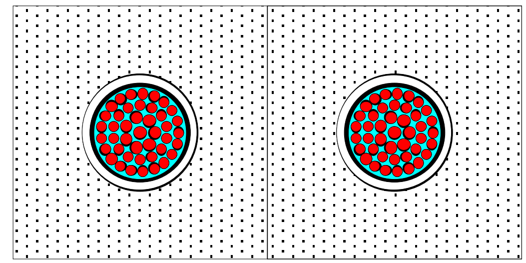


ACR-700 CANFLEX Fuel

- CANFLEX NU fuel bundles have been tested in operating CANDU 6 reactor
- Substantial experience in slightly enriched uranium fuel in test reactors
- Main features of the ACR CANFLEX fuel bundle:
  - Central element contains NU pellets with ~4% dysprosium
  - All other fuel elements contain 2.0 wt% ^{235}U SEU pellets
  - Fuel burn-up 20,500 MWd/MT (U), and further increase with operating experience
  - Thicker cladding

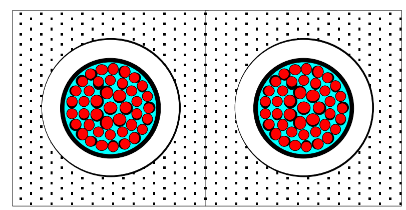
ACR-700 Reactor Size vs. Other CANDU Reactors





NU CANDU

Lattice Pitch = 28.58 cm (11.25”)
PT O.R. = 5.6 cm (2.2”)
CT O.R. = 6.6 cm (2.6”)
VM / VF = 16.4



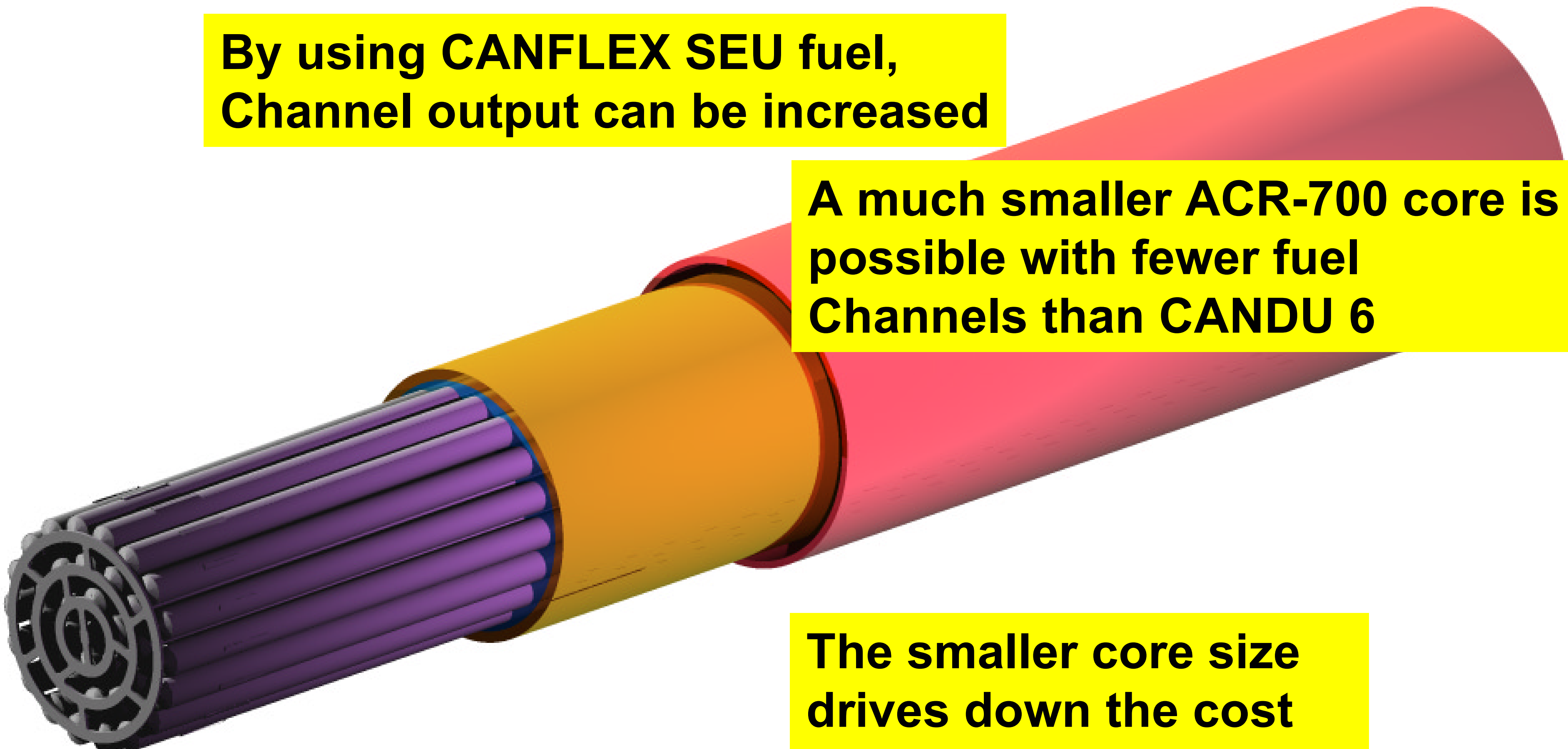
ACR-700

Lattice Pitch = 22.0 cm (8.7”)
PT O.R. = 5.6 cm (2.2”)
CT O.R. = 7.8 cm (3.1”)
VM / VF = 7.1

ACR Safety Innovation and Costs Optimization

- **Use of CANFLEX and SEU fuel**
  - Larger thermal margins due to CANFLEX fuel
  - Remove constraints associated with using natural uranium fuel
  - Reduce fuel element rating
  - Thicker pressure tube and stronger calandria tube to increase margin
  - Pressure-tube failure contained within calandria tube
  - Higher reactor coolant and secondary steam temperature and pressure
  - Increase operating margin and turbine cycle efficiency
- **Improve Core Characteristics**
  - H2O coolant in D2O moderated lattice
  - Small negative void coefficient
  - More negative power coefficient over operating range
  - Very flat and stable flux shape across the core reduces the number of reactivity control devices and minimizes the demand on the reactor control system

Fuel Channel/Core Optimization

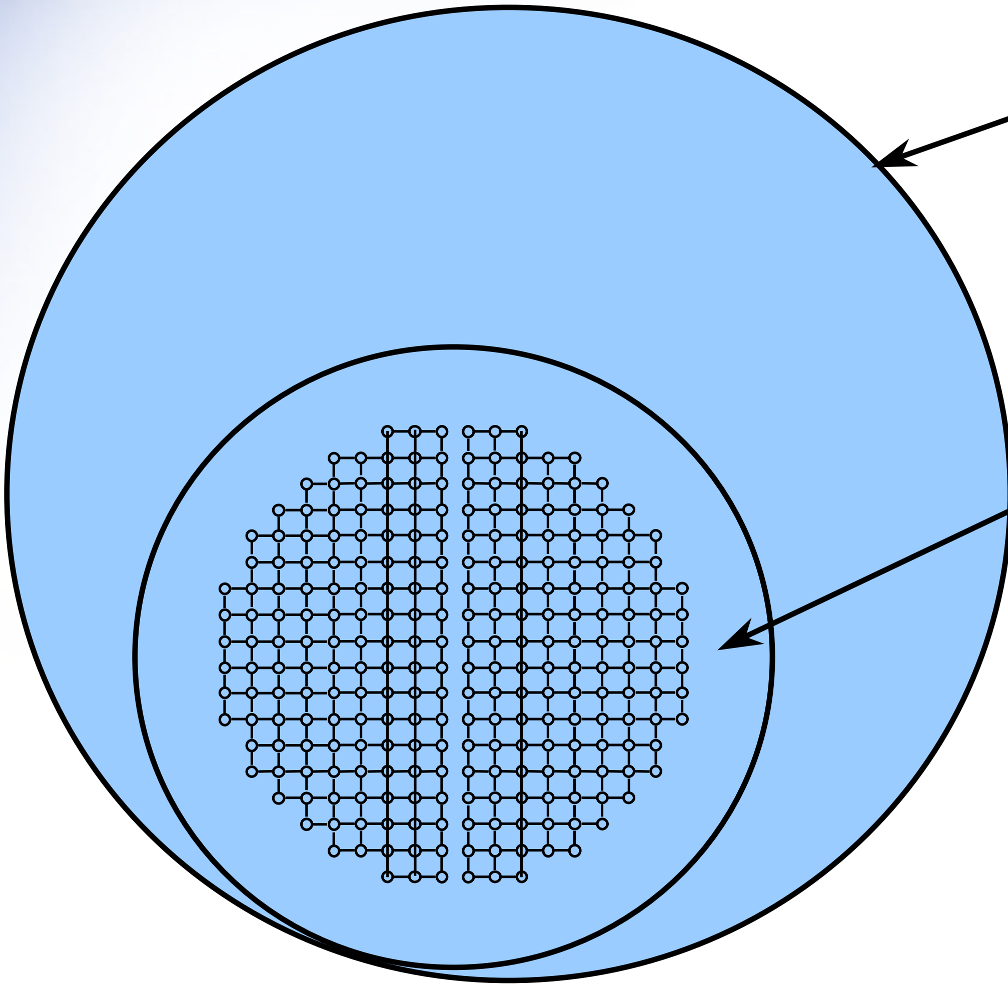


By using CANFLEX SEU fuel, Channel output can be increased

A much smaller ACR-700 core is possible with fewer fuel Channels than CANDU 6

The smaller core size drives down the cost of many other systems.

Core Size Reduction



CANDU 6
728 MWe
380 channels
Diameter = 7.6m (24.9')

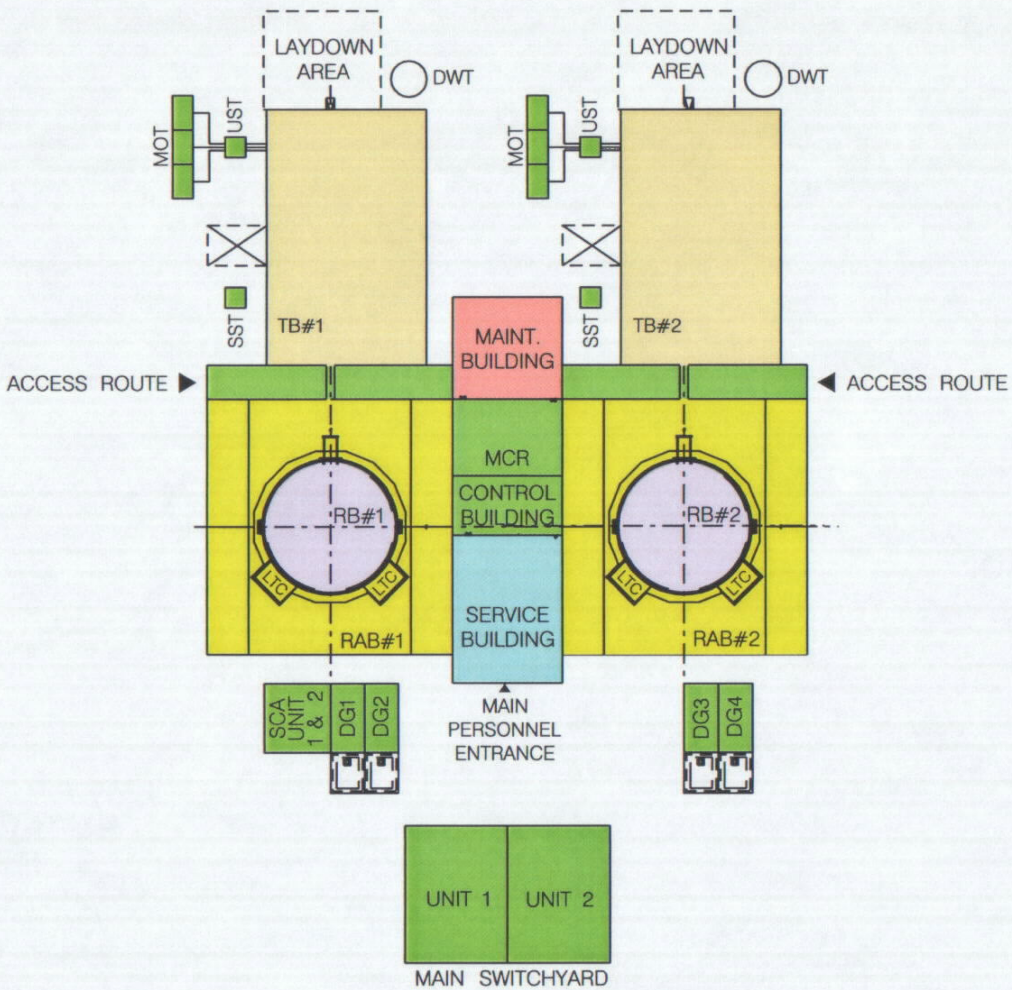
ACR-700
731 MWe
284 channels
Diameter = 5.2m (17.1')

- **Calandria volume reduced by 60% from C6**
- **By using H_2O coolant, less than 25% of D_2O used in C6 is required**

ACR Safety Innovations & Costs Optimization

- Use of Light Water as Reactor Coolant
  - Smaller lattice pitch - 11.25” to 8.7” (22 cm)
  - reduce D_2O inventory
  - Reduce size of reactor core, number of fuel channels and reactor building
- Integrated 2 unit plant layout for ACR-700
  - Seismically qualified safety support cooling water and Class III power
  - Inter-unit ties of safety support systems for increased reliability
- Reserve Water System
  - Severe accident prevention & mitigation
- Improved control center
  - Separate secondary control area as backup

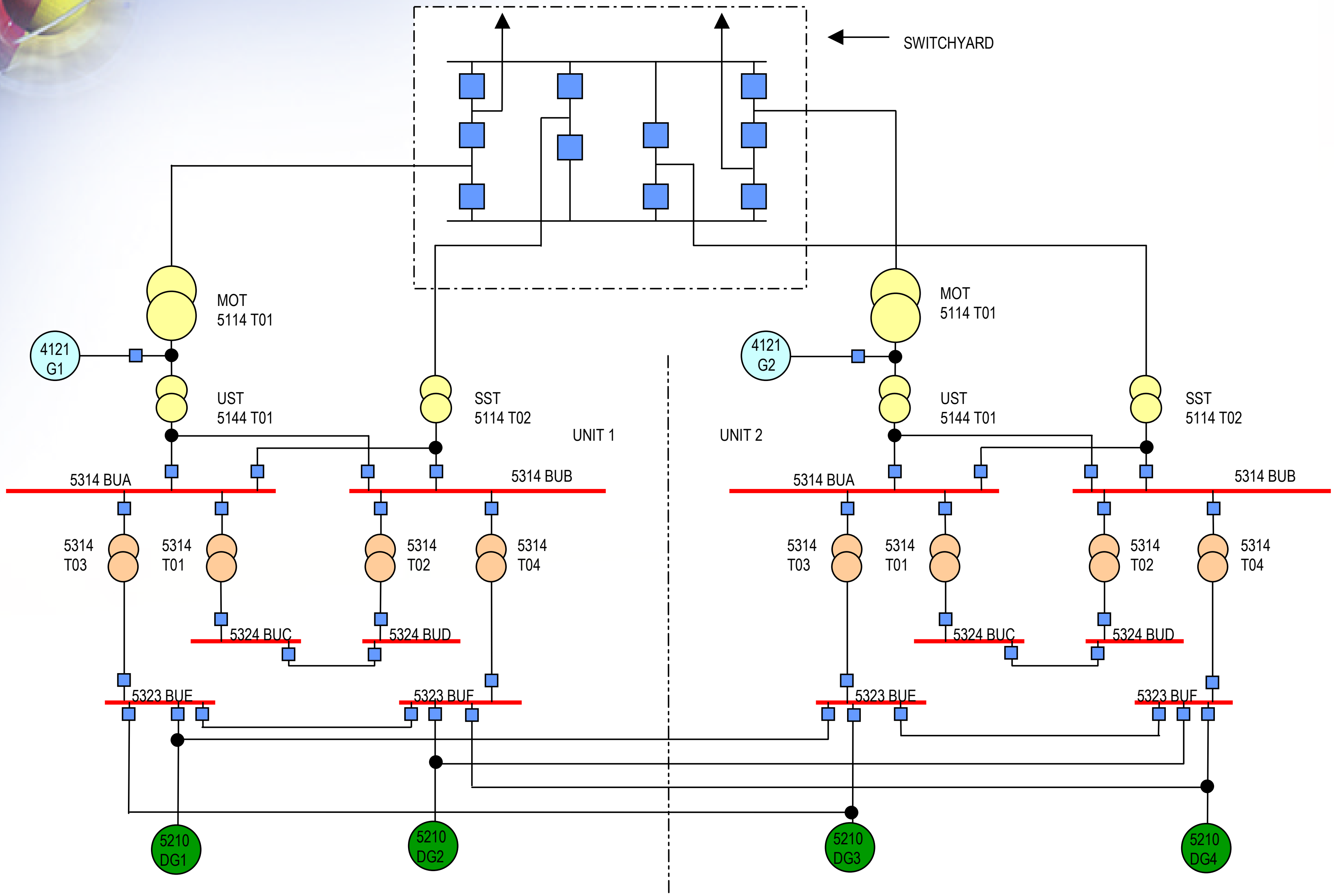
2 Unit ACR-700 Plant Layout



LEGEND

RB	REACTOR BUILDING
RAB	REACTOR AUXILIARY BUILDING
TB	TURBINE BUILDING
MCR	MAIN CONTROL ROOM
SCA	SECONDARY CONTROL AREA
DWT	DEMINERALIZED WATER TANK
DG	DIESEL GENERATORS
TG	TURBINE GENERATOR
MSH	MAIN STEAM HEADER
LTC	LONG TERM COOLING
MOT	MAIN OUTPUT TRANSFORMER
UST	UNIT SERVICE TRANSFORMER
SST	STATION SERVICE TRANSFORMER
RSW	RAW SERVICE WATER

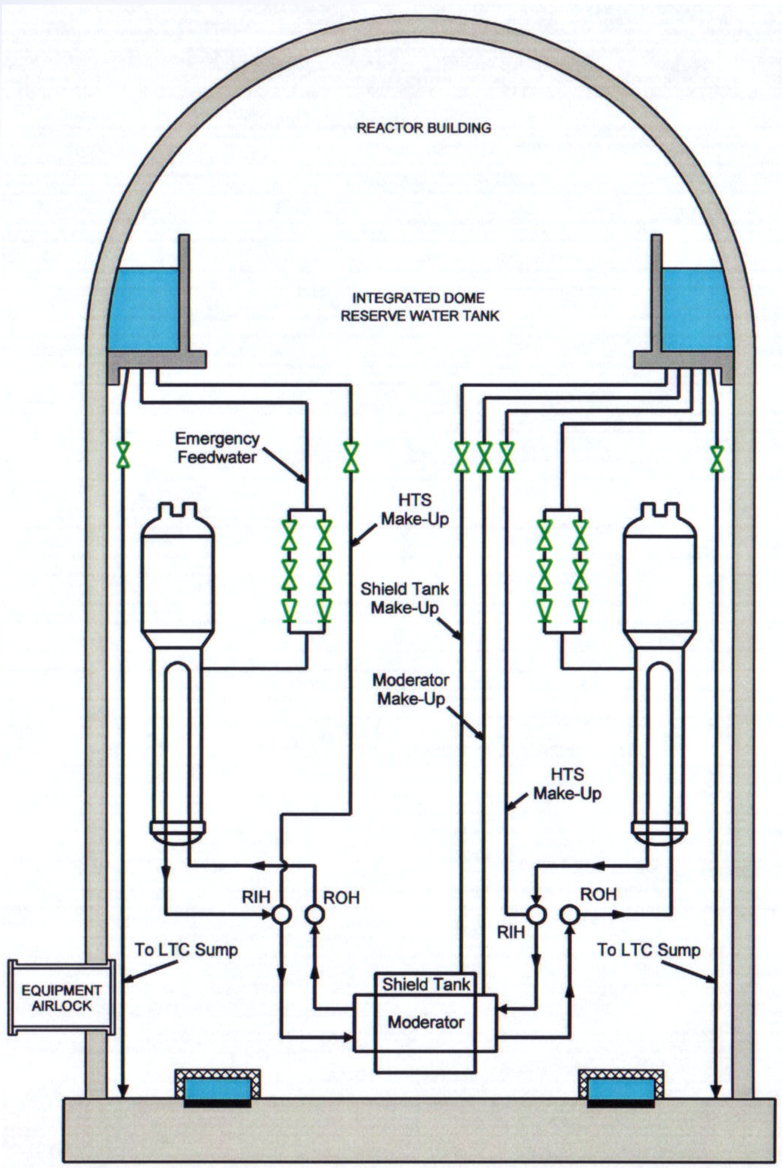
ACR-700 Class IV & III Systems (2 units)



ACR Electrical System

- Four Class III standby generators common for the two units
- Class III medium voltage distribution system includes inter-unit interconnections allowing sharing of the standby diesel generators

ACR Reserve Water System



- Emergency Feedwater
- Backup supply to moderator and shield tank heat sink for severe accidents

ACR Control Centers

- Majority of the controls and set points from the main control room (MCR)
- Testing of safety systems from main control room
- Very few actions required in the field.
- On-line fueling a daily routine unaffecting the other controls of the reactor
- Primary control of process and safety systems from the MCR for all design basis events including common mode events such as seismic
- The SCA is completely separate from MCR and only required for events when MCR is uninhabitable
- The SCA provide controls for safety shutdown, heat sink and monitoring of key safety functions

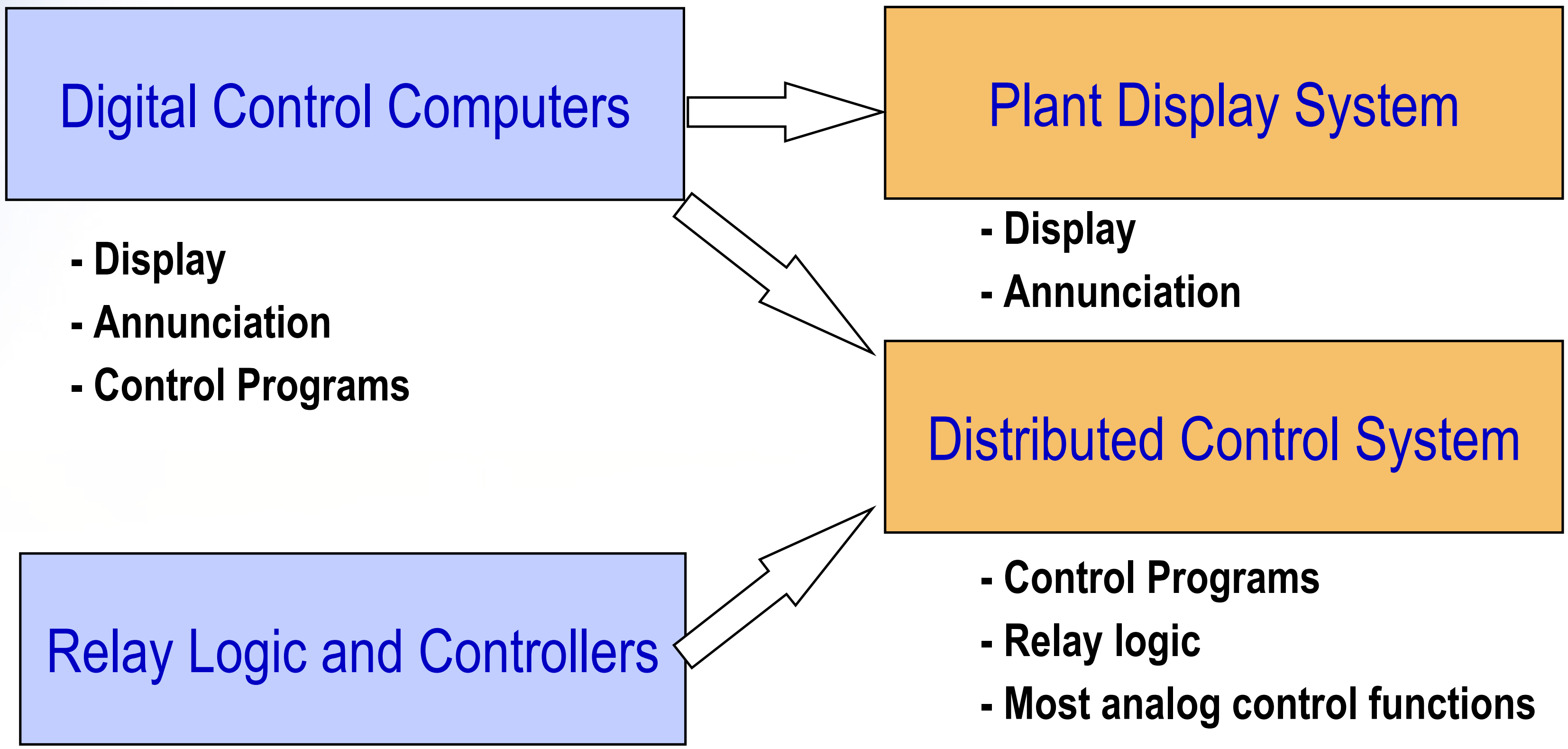
Improved Operability and Performance

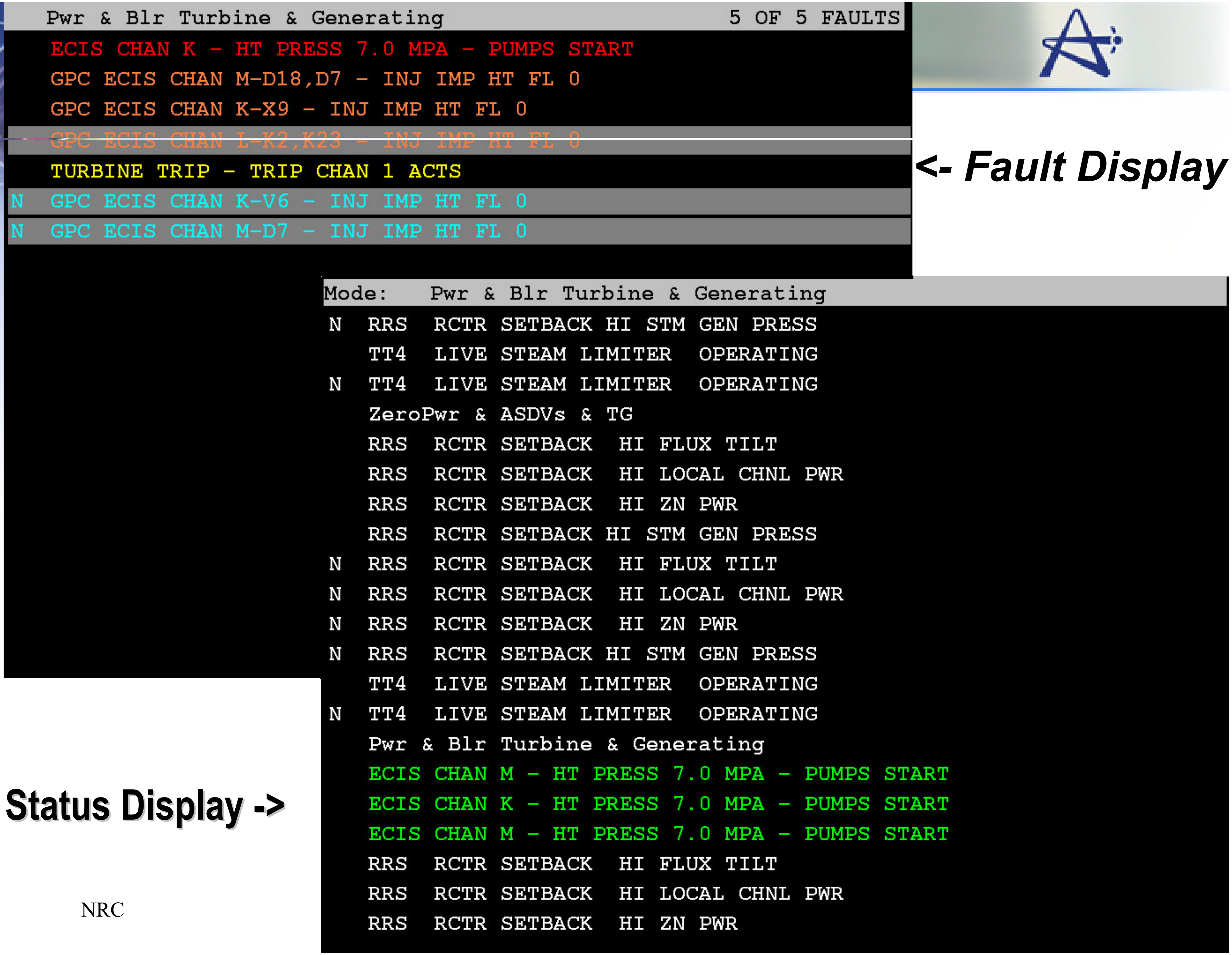
The ACR plant controls and control center have:

- **enhanced functionality of existing CANDU control centers,**
- **separated display and annunciation functions from control function**
- **advanced features made possible by new technology such as plant display system, advanced annunciation, etc.**
- **multiple system failure due to digital control computer failure avoided by partitioning of control actions in distributed control system modules**

QINSHAN MAIN CONTROL ROOM

Evolution of Plant Control and Monitoring





<- Fault Display

Status Display ->

Advanced Computerized Annunciation System

- Alarm processing
  - Prioritization and conditioning based on plant state
  - Alarm coalescing
  - Cause-consequence
  - New types of alarms (expected-but-not-occurred, OP&P violations, rate and margin - advanced warning)
- Alarm presentation
  - Central displays
    - Fault messages ordered and colour coded by priority
    - Status messages ordered by time
  - Interrogation workstation
    - By time, priority, system; access to related data

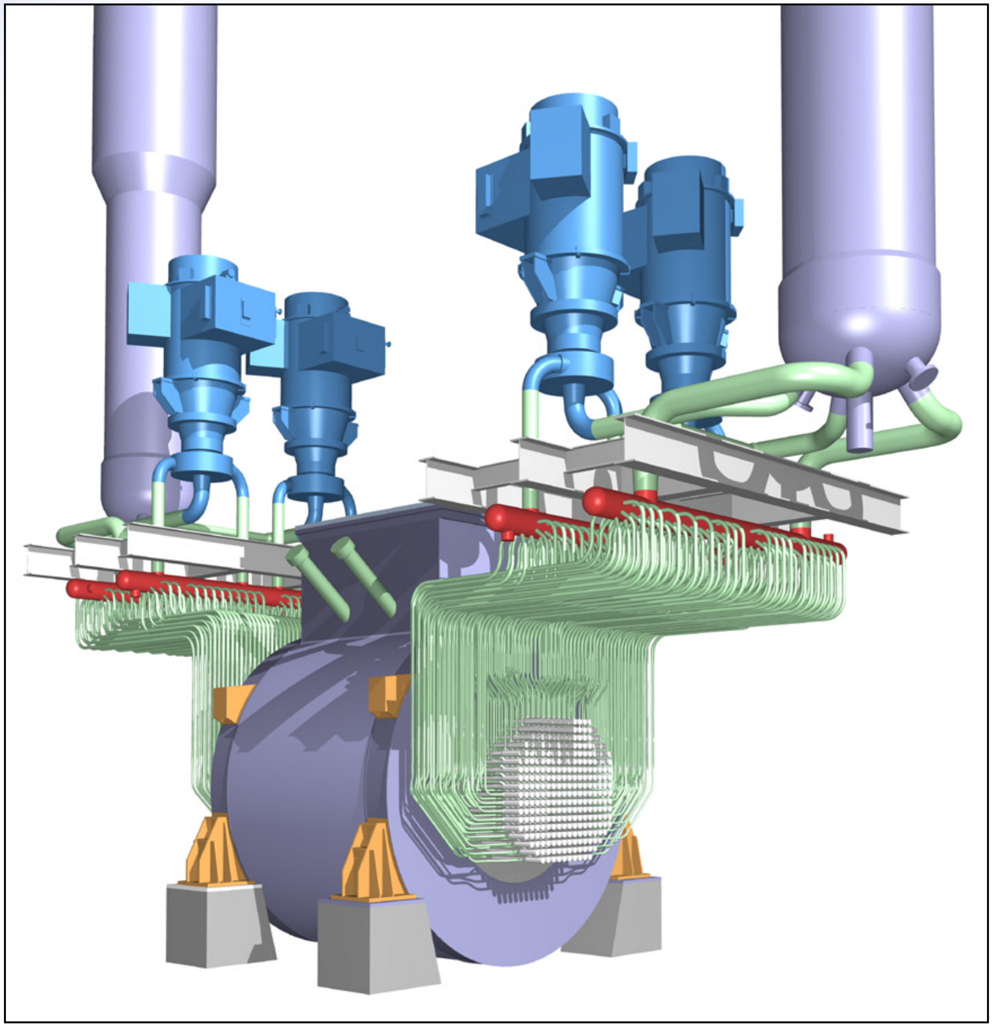
Control Centre Mock-up

ACR Control Center

Human factor improvements:

- Improved operability of the ACR is built on past experience
- CANDU 6 control center functional design basis and operational design basis have been reviewed
- Control center mock up used for the CANDU 9 will support systematic integration of human factors into the ACR design process

ACR Reactor Coolant System Layout



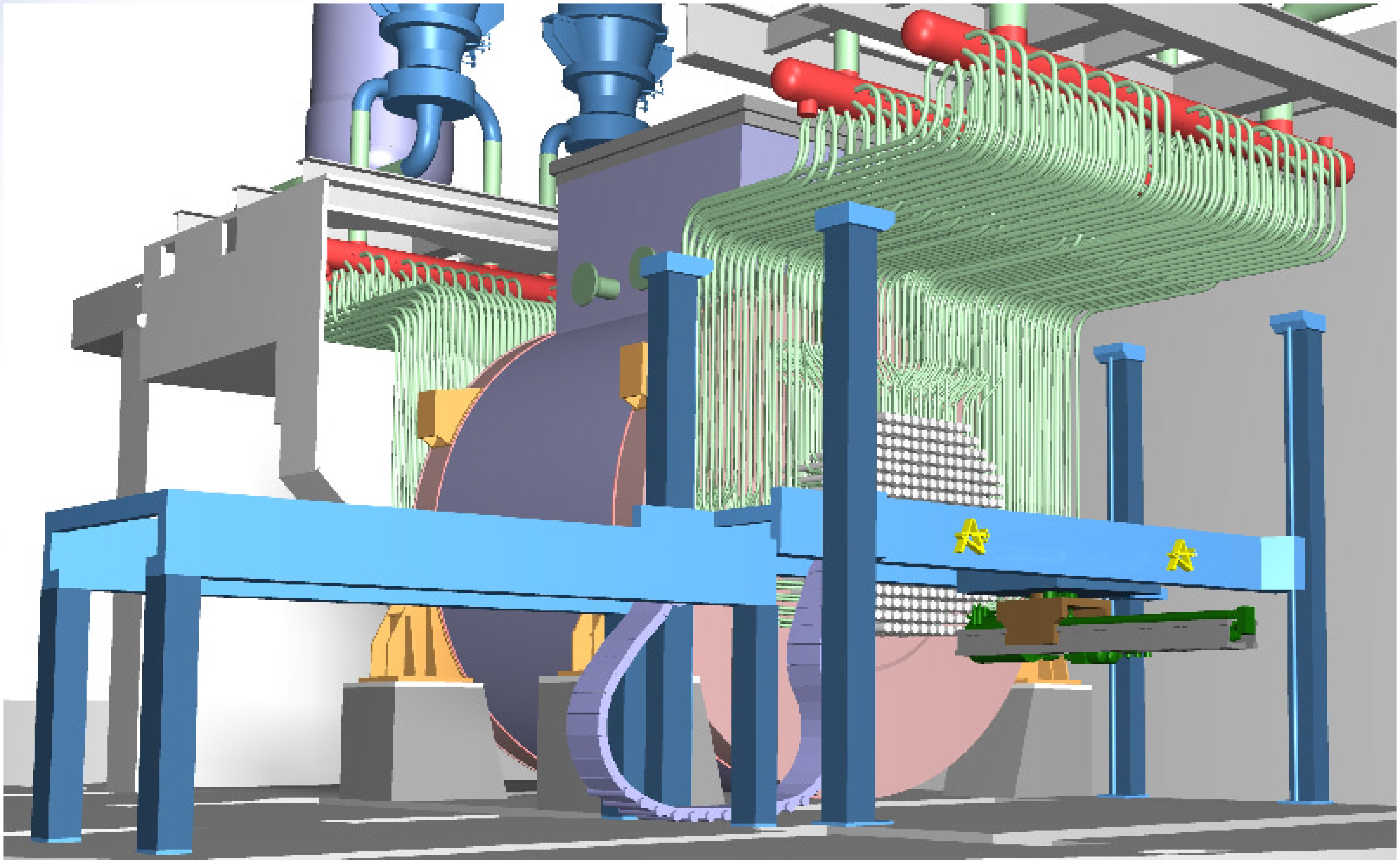
Conventional system piping layout

All large reactor coolant piping above headers

Reactor Coolant System

- The Reactor Coolant System (Heat Transport System) circulates light water (H_2O) coolant through the reactor fuel channels
- The ACR-700 arrangement is similar to a single loop of the two loops of the CANDU 6 design
- Increased coolant pressure enables core outlet temperatures typical of PWRs, and similar steam generator and turbine conditions
- Steam generators (2) are similar to those use in PWR (a taller version of Darlington SG)
- Main coolant pumps (4) are similar to those in operating in CANDU 6 reactors

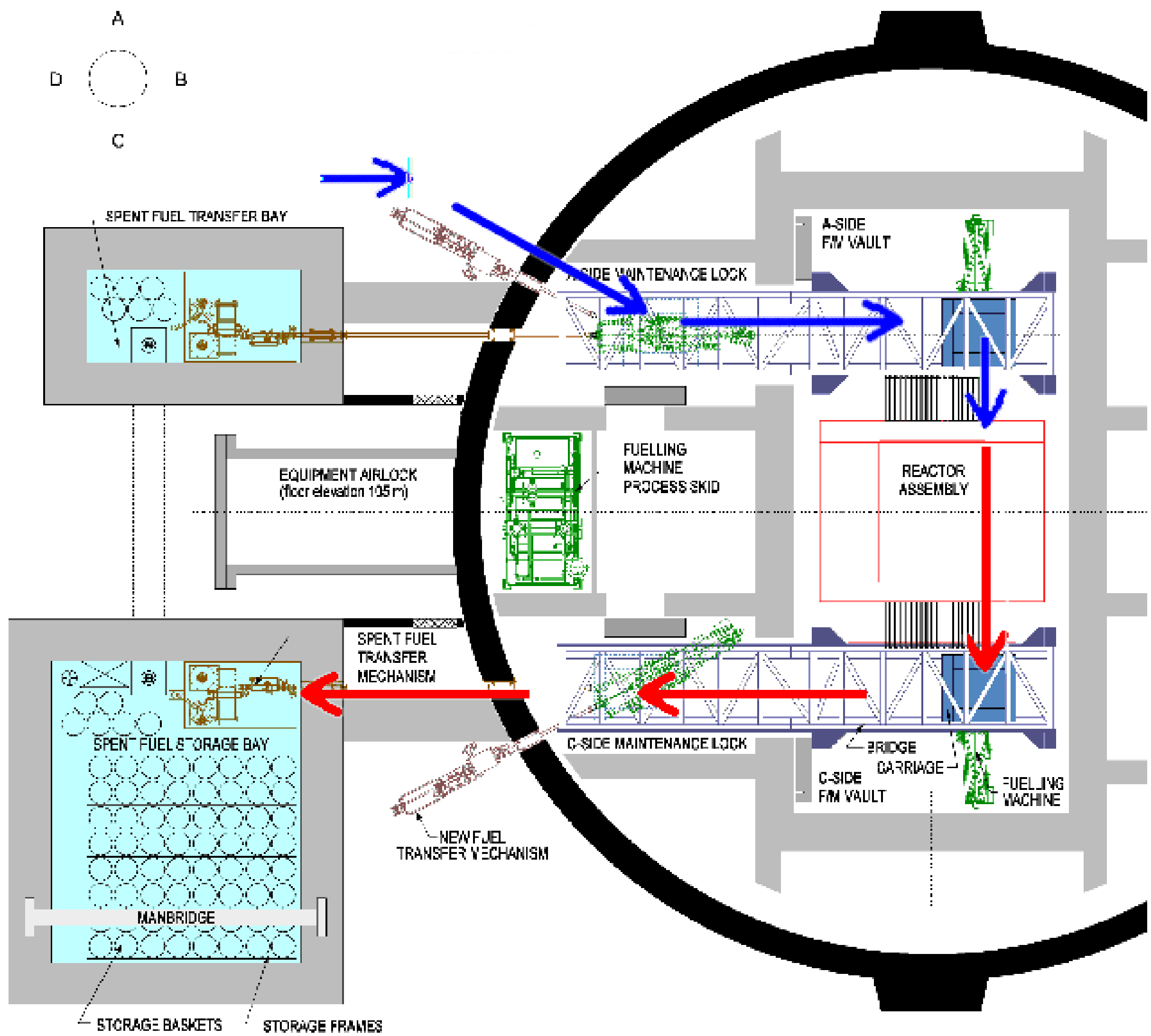
ACR Fuel Handling Equipment



Fuel Handling

- On-power fueling retained
- Simpler fueling with electric drive replacing oil and hydraulic drives
- Enhanced safety due to light water reactor coolant that eliminates the need for heavy water drying from spent fuel

ACR Fuel Path



Non-Proliferation & Safeguards

- Non-Proliferation and Safeguards considered early in design process
- ACR will address both Traditional and Integrated Safeguards
- Addresses guidelines in IAEA STR-392, *Design Measures to Facilitate Safeguards in Future Water Cooled Nuclear Power Plants*
- Target Markets include US and UK
  - Euratom Safeguards in UK

Non-Proliferation & Safeguards

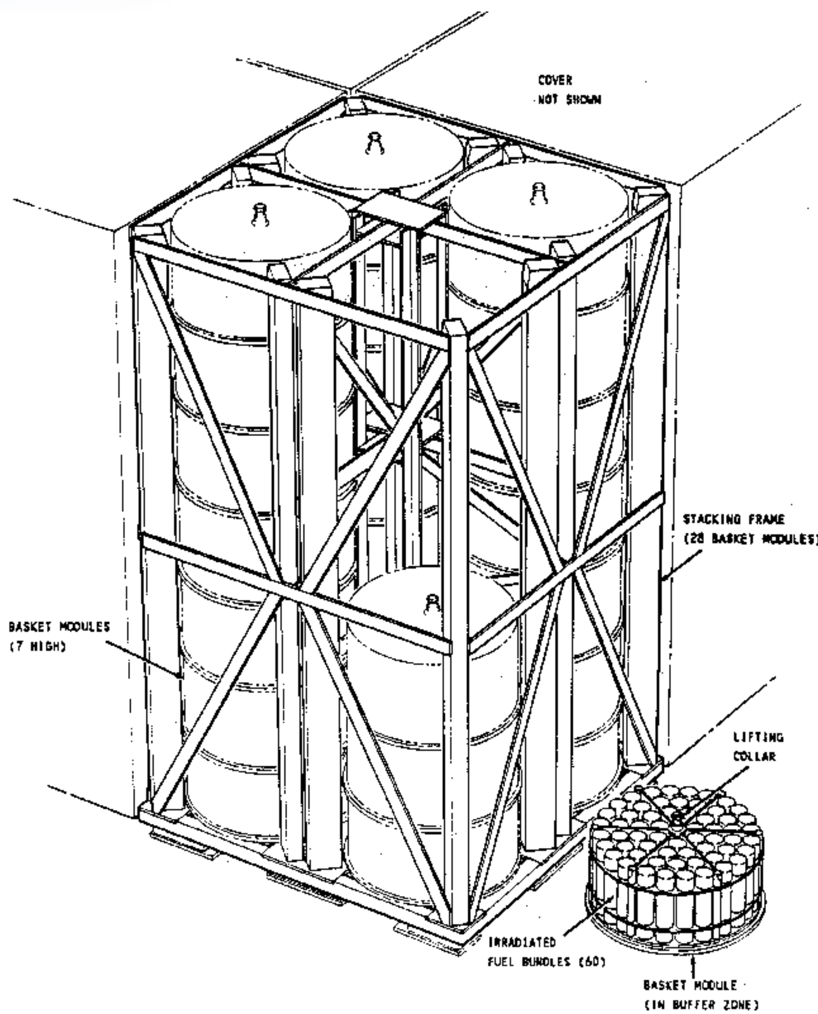
ACR Features Affecting NP&S:

- Slightly Enriched Uranium
  - Reduced fuel movement: ~1800 bundles / year (~40% reduction)
  - Spent Fuel accumulates more slowly in the bay
- Higher Burnup: ~20,500 MWd/te U
  - Reduced ^{239}Pu / ^{240}Pu ratio
  - Higher radiation fields
- Reduced number of openings along the fuel path to monitor
  - e.g. SF discharge through transfer pipe, eliminating C6 elevator

Non-Proliferation & Safeguards (cont.)

- **Provision for Safeguards Equipment, including:**
  - Traditional forms of safeguards equipment (e.g. cameras, fuel monitors)
  - Remote monitoring
  - Shared instrumentation
- **Provision for near real time accounting**
- **Transfers to Dry Storage**
  - Spent Fuel stored in baskets eliminating transfer from trays to baskets
  - Support for sealing baskets
  - Support for instrumentation to track baskets through transfer process

ACR Spent Fuel Storage Baskets



MACSTOR Dry Storage

- Passive storage for decades
- Easy to transfer fuel

Summary

- Robust experience feedback from current CANDU projects
- ACR is an evolutionary adaptation of CANDU 6 by using light water coolant and slightly enriched fuel in traditional CANDU systems, combined with advanced technology base
- ACR uses advanced features from current CANDU and maintains continuity in established CANDU safety features
- The ACR design incorporates enhanced safety characteristics and improved margins
- ACR meets current customers' requirements and designed to be licensed in multiple jurisdictions.

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