# ACR Reactor and Fuel Handling

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Office of Nuclear Reactor Regulation

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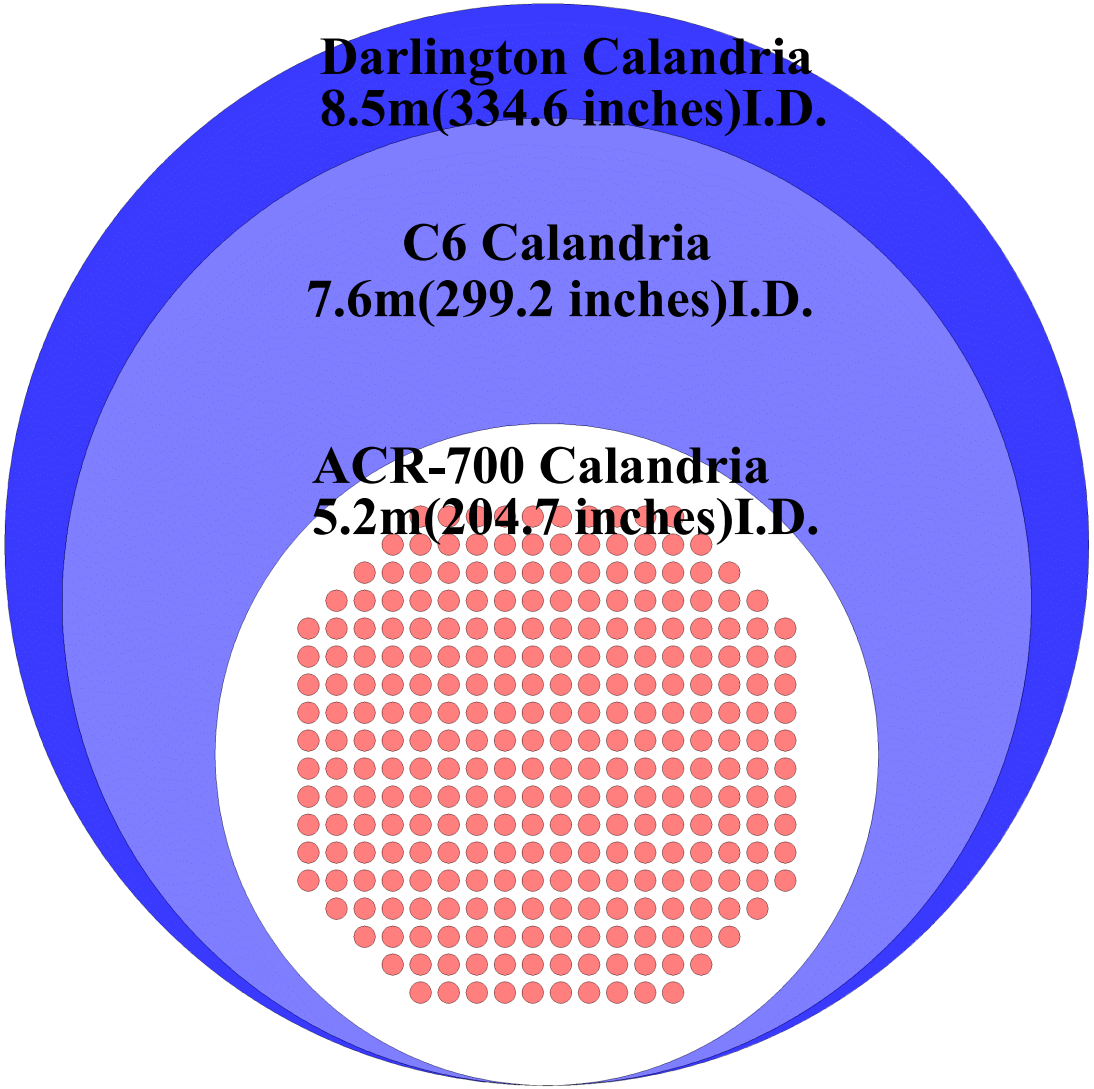
# Reactor Design Basis

- The ACR reactor is based on a typical CANDU design
- Features an array of fuel channels passing horizontally through calandria containing the moderator heavy water
- Calandria is a horizontal cylindrical vessel closed at each end by circular flat plates (calandria tube sheets)
- The calandria tubes pass horizontally through the calandria and restrain the calandria tube sheets
- The calandria is enclosed by end shields
- The shield tank encloses and supports the calandria and end shields

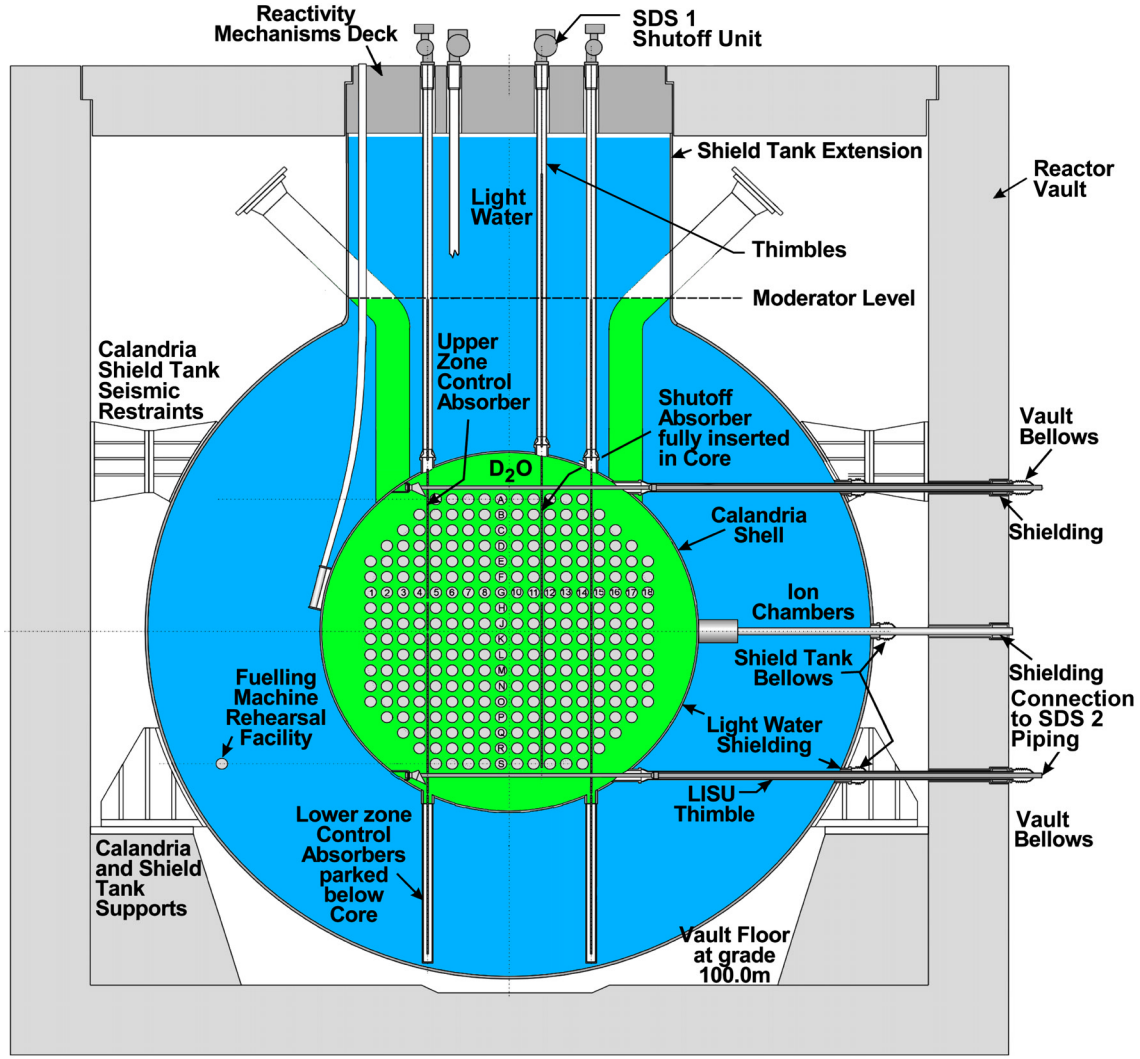
# ACR-700 Reactor Size



# ACR Reactor Design utilizes proven features of CANDU

- The calandria contains heavy water moderator
- The end shields contain light water and shielding balls.
- The shield tank contains light water, which serves as both a thermal and a biological shield
- The cool moderator is independent of the hot, pressurized light water coolant in the fuel channels

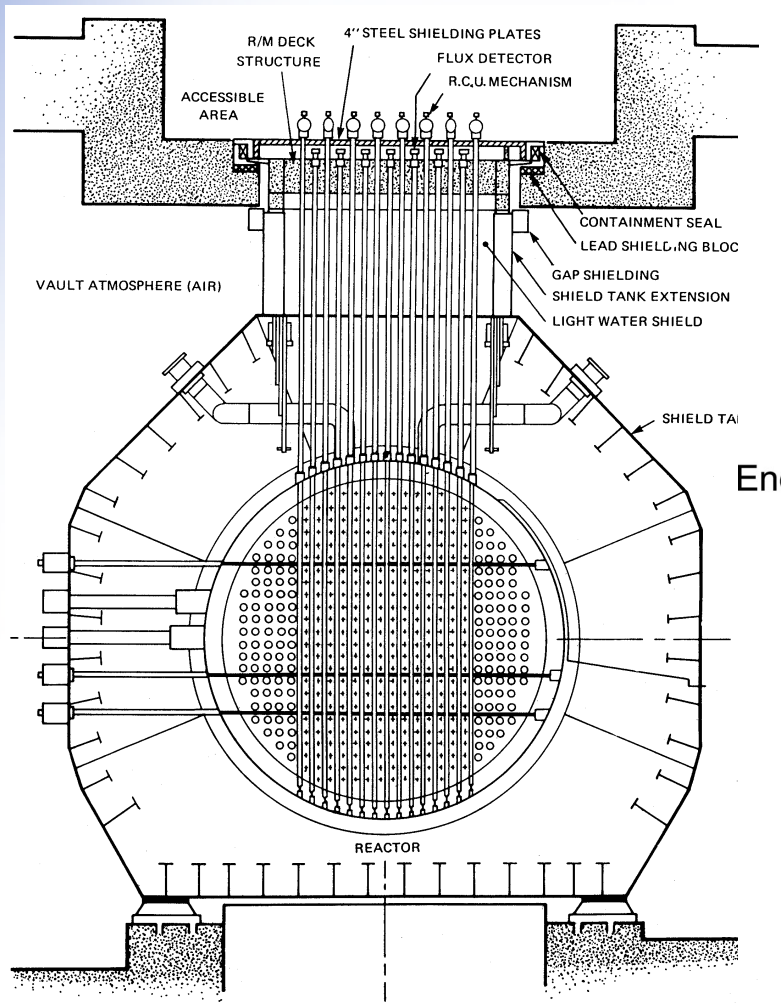
# ACR Calandria & Shield Tank Assembly



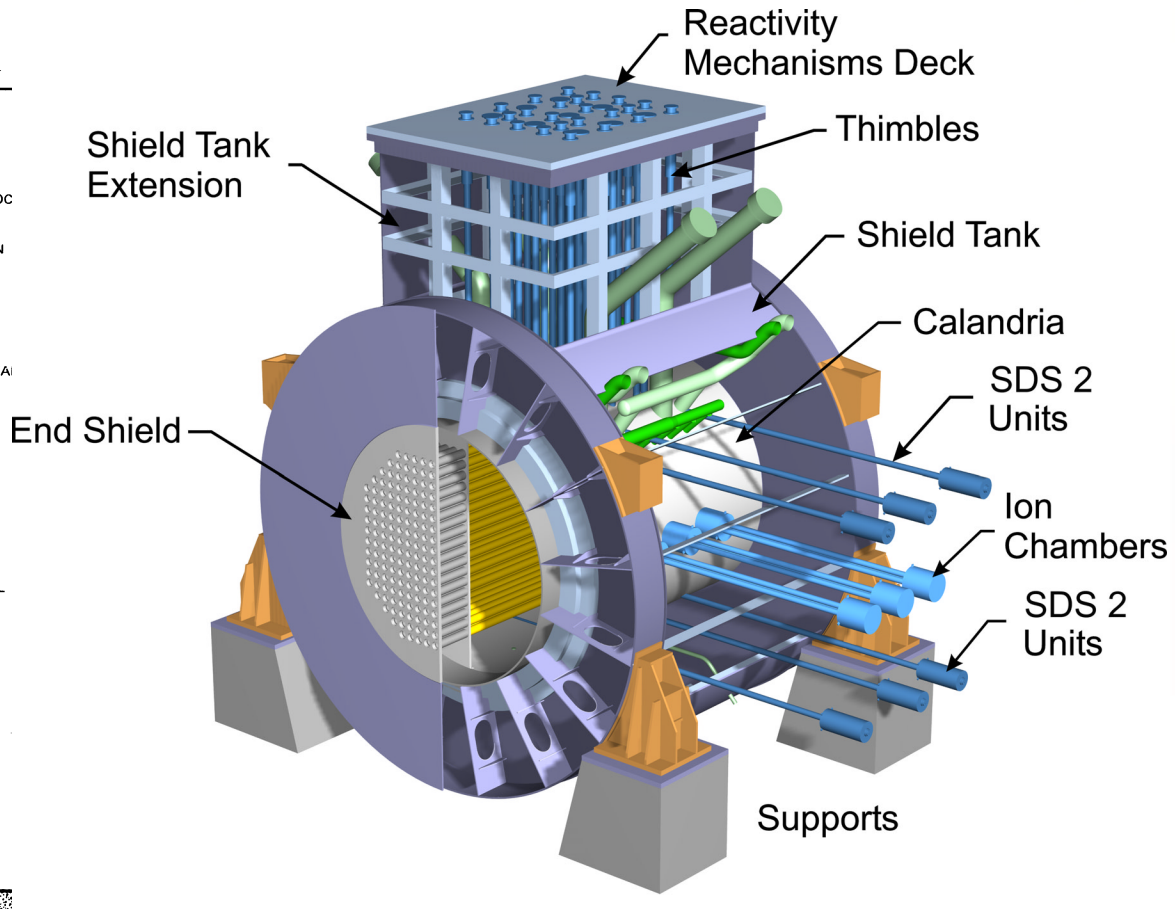
# ACR Reactor Design utilizes proven features of CANDU

- The shield tank has an integral rectangular extension extending up and supporting the reactivity mechanisms deck
- Thimbles guide reactivity mechanisms from the reactivity mechanisms deck to the top of the calandria
- The assembly of the calandria and integrated shield tank and reactivity mechanisms deck is called the Calandria Shield Tank Assembly (CSTA)

# Darlington/Bruce Calandria and Shield Tank



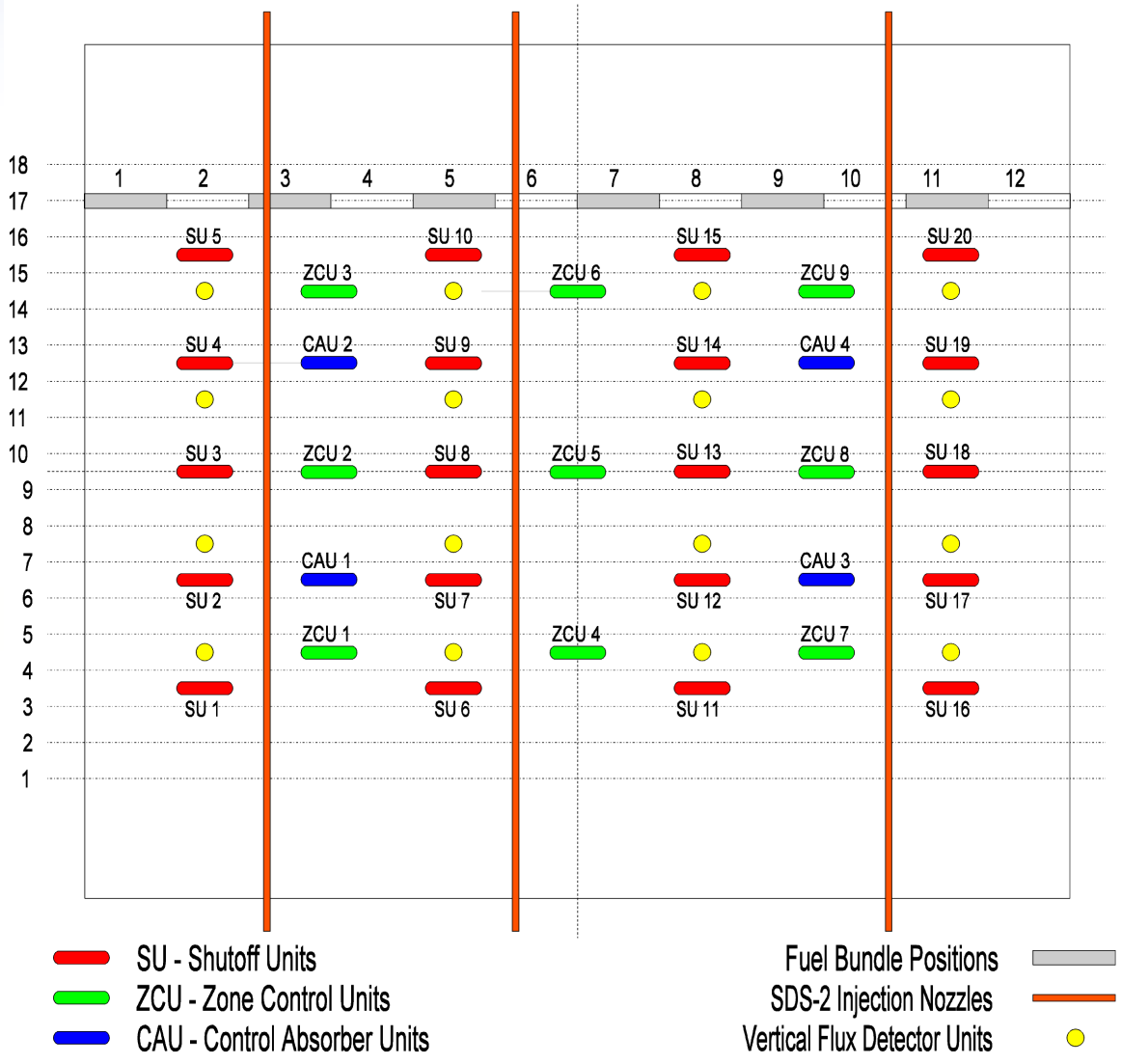

# ACR Calandria Shield Tank Assembly



# Reactivity Control Units

- Reactivity mechanisms include:
  - Reactivity control devices (control absorber units and mechanical zone control units)
  - Safety shutdown systems (shutoff units for shutdown system 1, and liquid injection nozzles for shutdown system 2)
  - Neutron flux measuring devices (self-powered flux detector, fission chamber and ion chamber units)
  - All reactivity mechanisms operate in the low temperature, low pressure moderator environment
  - Designs are simple, rugged, require little maintenance, are highly reliable and are based on CANDU 6 designs
  - Reactivity control units are testable on line.

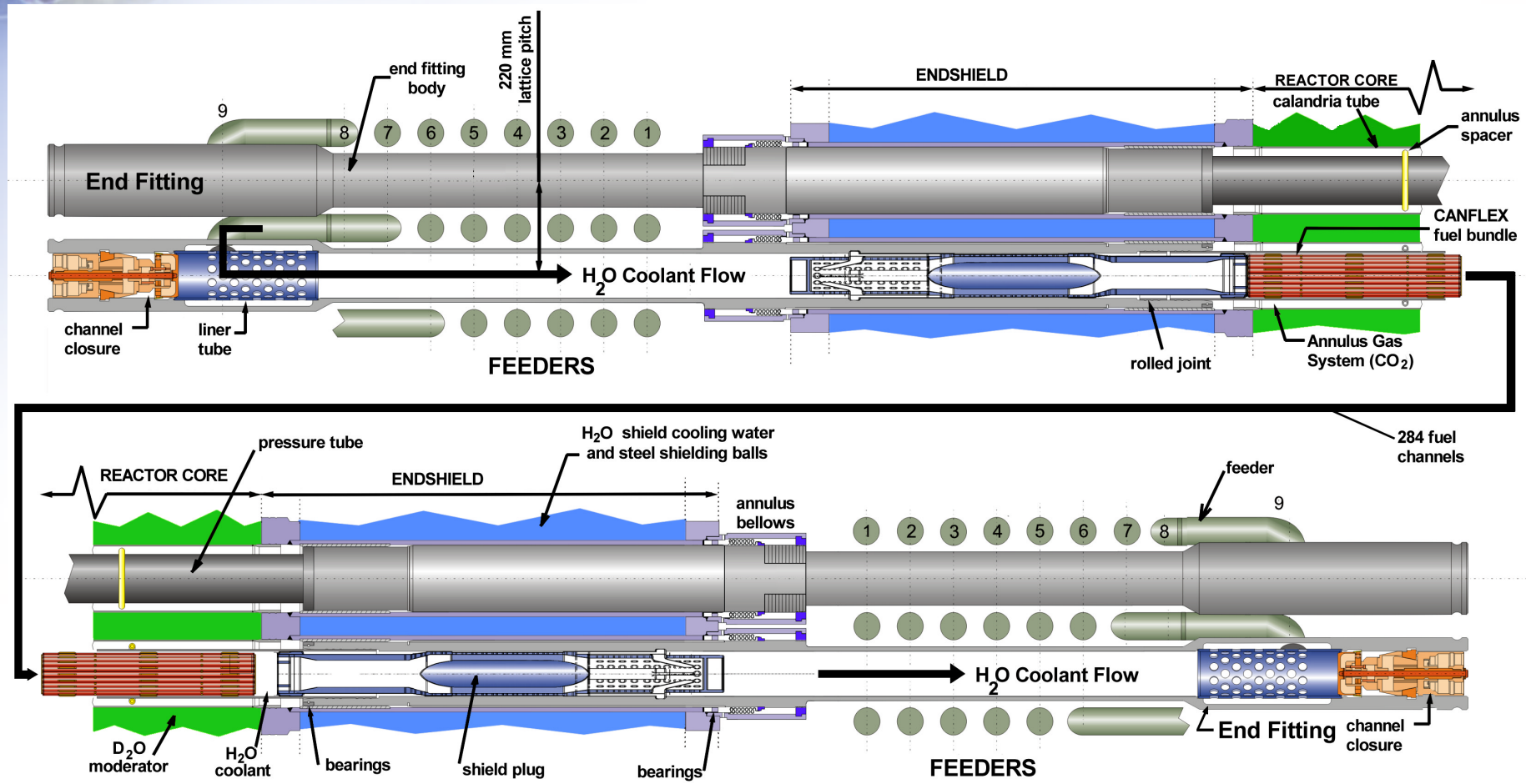
# Reactivity Mechanisms Layout



# Fuel Channel

- Supports twelve fuel bundles
- Facilitates flow of coolant past fuel to steam generators
- Accommodates dimensional and performance changes during operating life
- Permits inspection and replacement, if necessary (Single-Channel and Large-Scale Retubing)
- Prevents damage to other channels and calandria in accident scenarios if pressure tube failure occurs
- Pressure boundary consists of closure plugs (2), end fittings (2), and pressure tube.

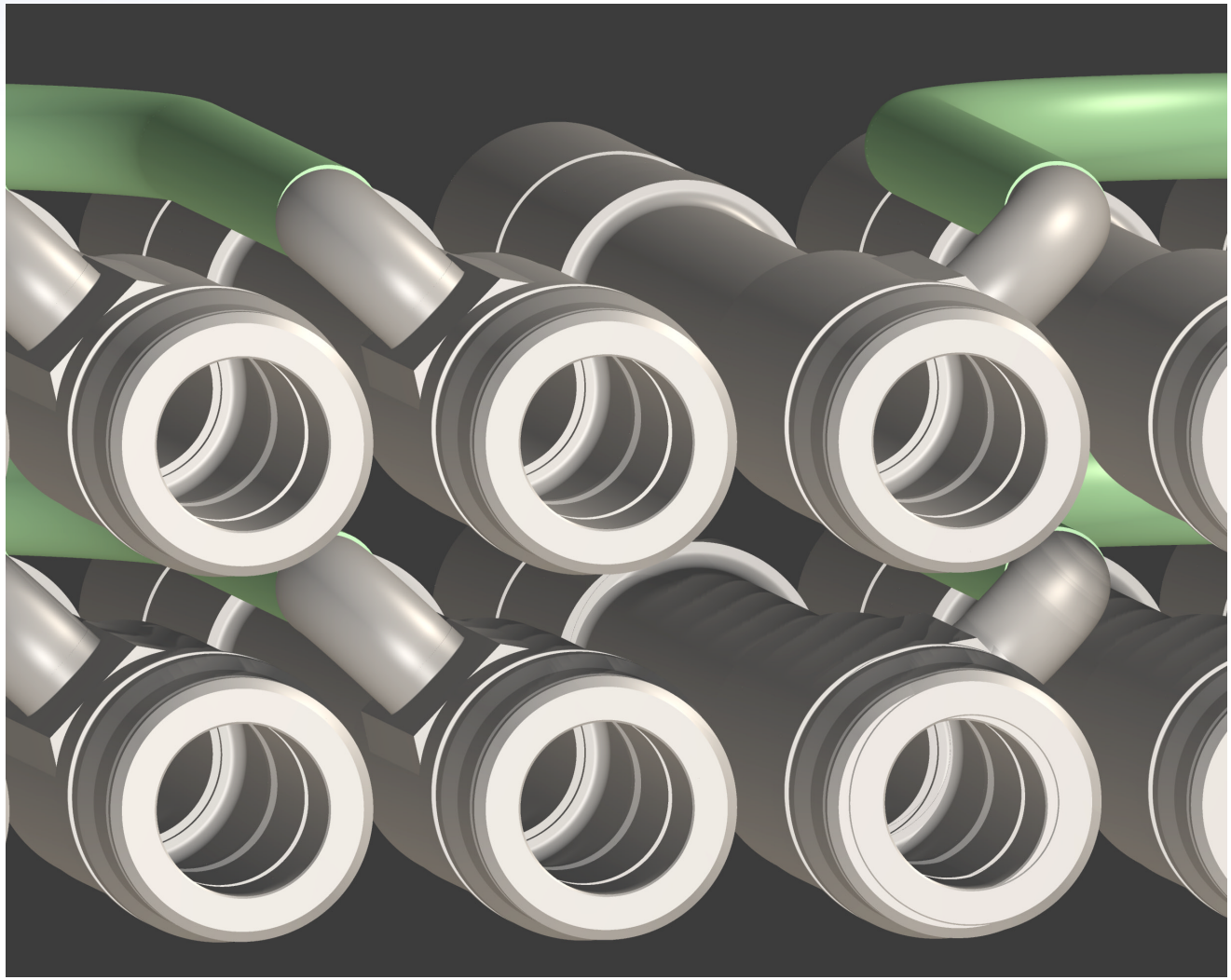
# ACR Fuel Channel



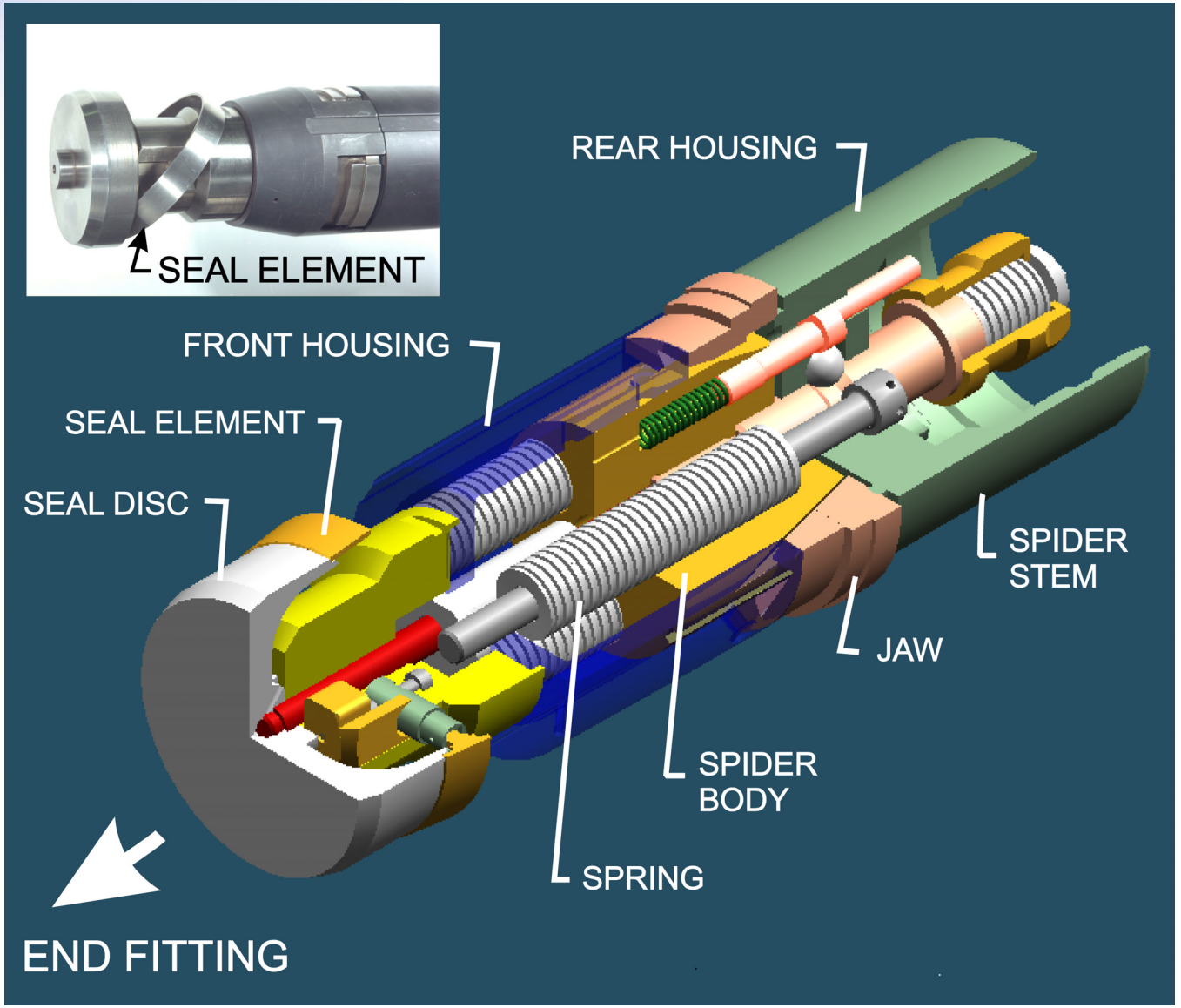
# Fuel Channel Design

| | CANDU 6 | ACR |
|---|---|---|
| Lattice pitch | 286 mm (11.26”) | 220 mm (8.66”) |
| PT material | Zirconium 2.5wt% Niobium alloy | Zirconium 2.5wt% Niobium alloy |
| PT wall thickness | 4.2 mm (0.165”) | 6.5 mm (0.256”) |
| PT max. operating temperature | 313.2 $^{o}$C (596 F) | 327.7 $^{o}$C (622 F) |
| PT max. operating pressure | 11.1 MPa (1610 psi) | 13 MPa (1886 psi) |
| PT max. operating flux (n/m$^2$/s) | 3.7x10$^{17}$ | 4.1x10$^{17}$ |
| Calandria tube material | Zircaloy-2 | Zircaloy-4 |
| Calandria tube wall thickness | 1.4 mm (0.055”) | 2.5 mm (0.098”) |
| Fuel channel operating life | 25 years at 80% capacity | 30 years at 90% capacity |

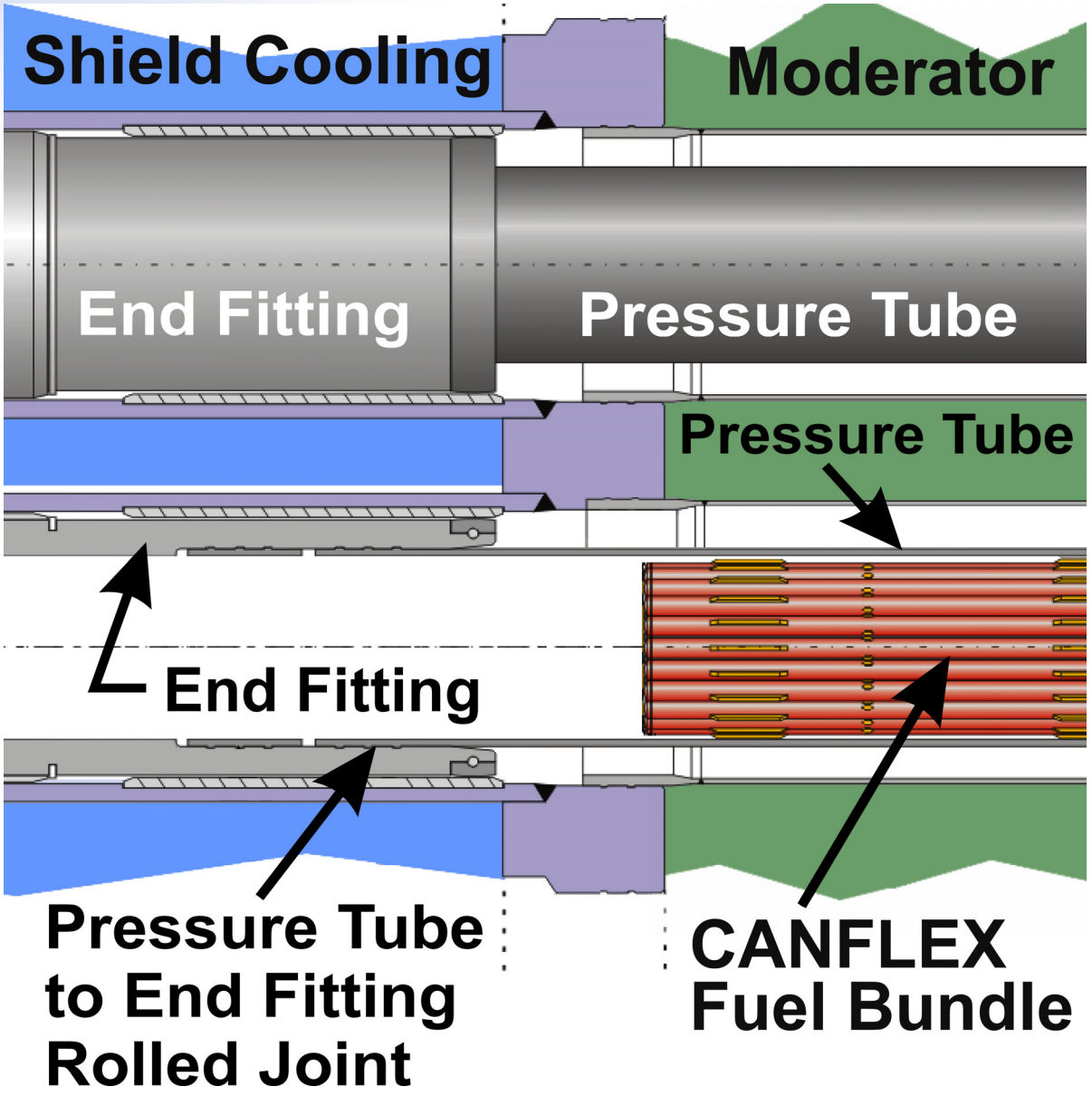
# ACR Fuel Channels with Feeders



# ACR Channel Closure



# ACR Pressure Tube Rolled Joint



# Assessments of ACR Pressure Tube Aging

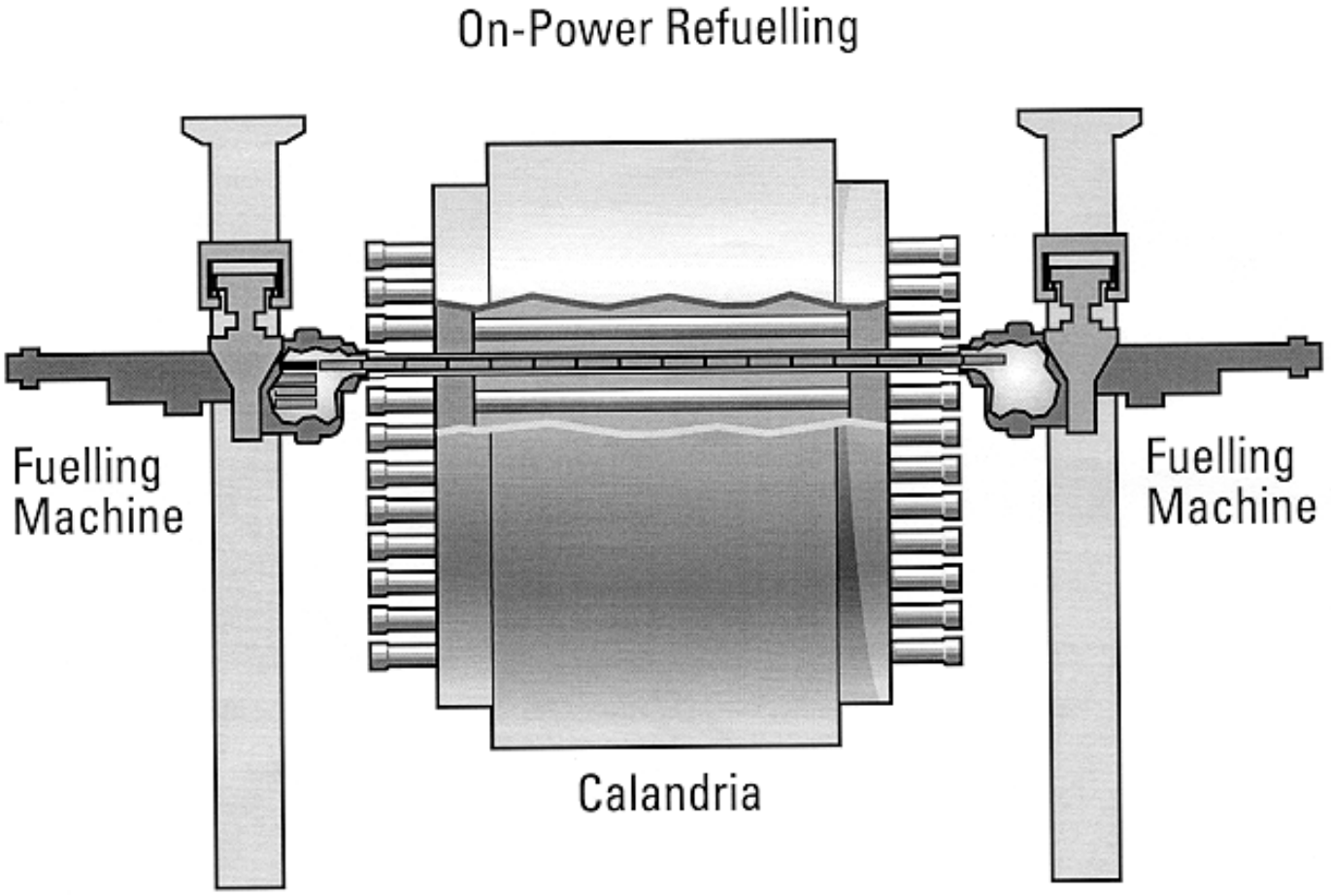
- Assessments of PT deformation, H ingress, fracture and DHC are based on existing models and data
  - Extrapolated to 30 years and considers ACR conditions
  - Assume highest power channel, worst case material variability
  - Conservative estimates of benefits of improvements to PT (as compared with historical data on which models are based)
- Effects of deformation and H ingress will be acceptable over 30 years at 90% capacity
- Fracture behavior will also be acceptable
- Testing will be performed to confirm assessments results

# Fuel Handling System

- The ACR Fuel Handling System is an evolution of the CANDU 6 system

- It consists of :
  - New fuel transfer and storage
  - On-power fuel changing
  - Spent fuel transfer and storage

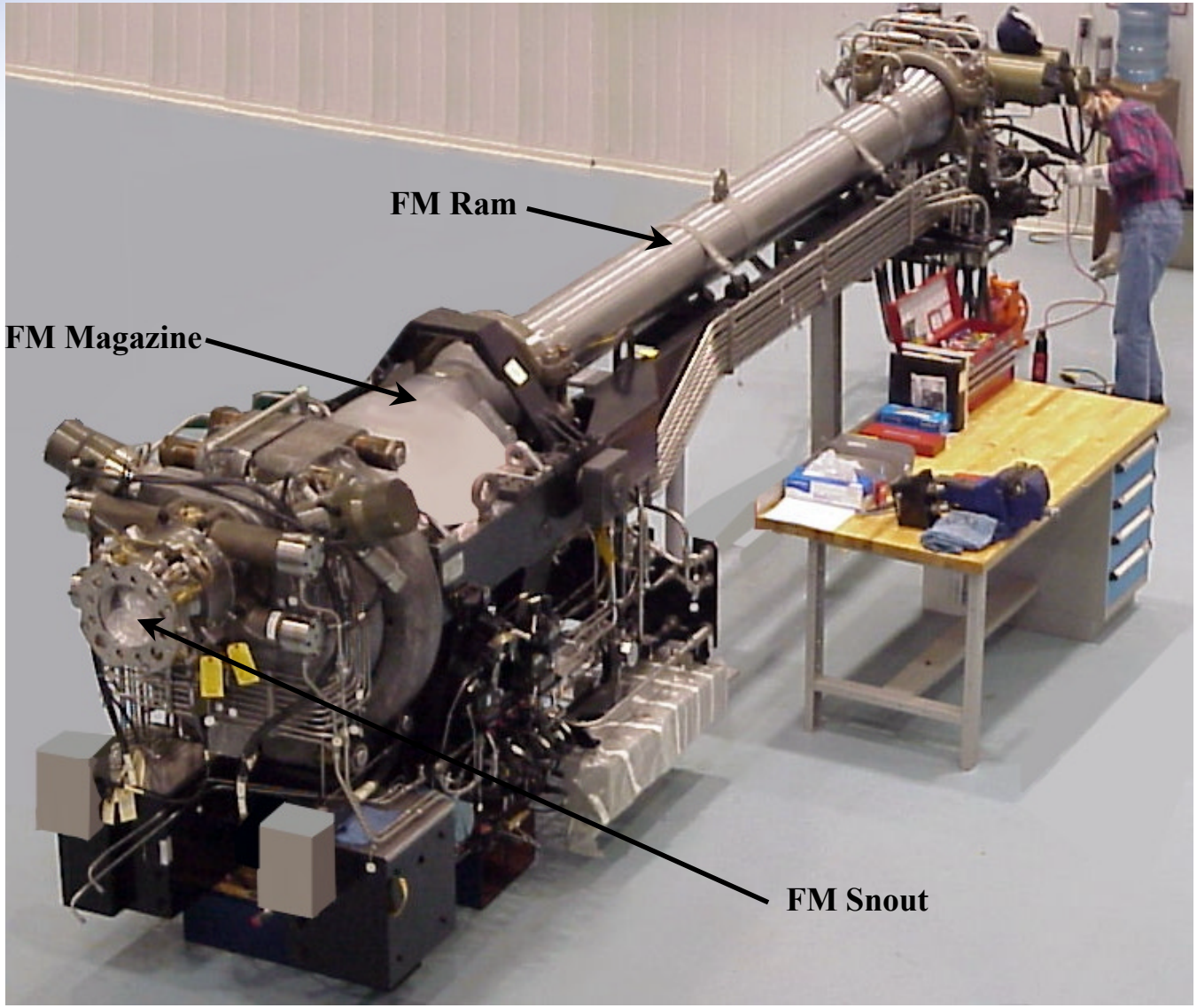
# On-Power Refueling



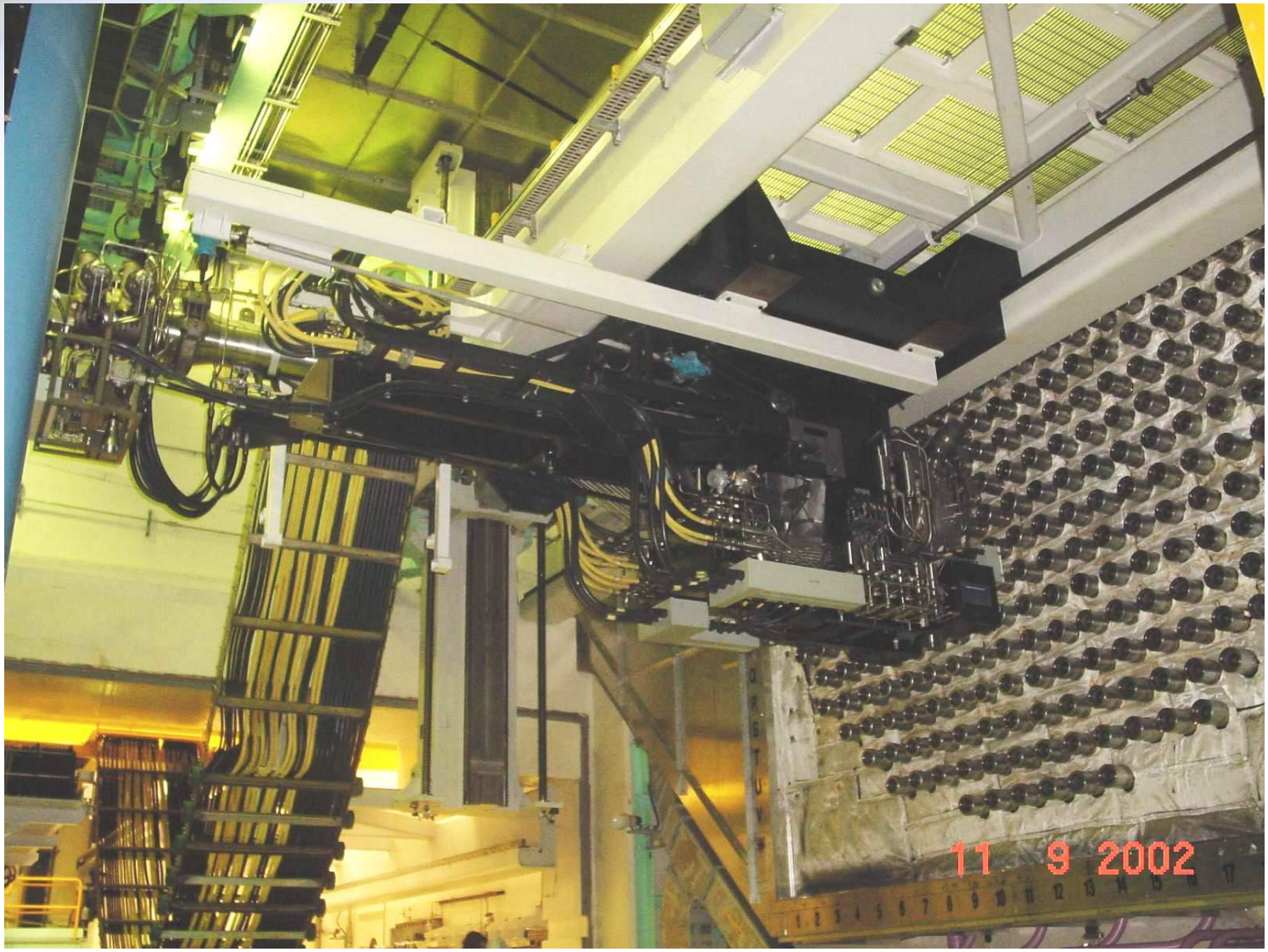
# Fuel Handling System

- Provides a safe and reliable method to refuel reactor on power
- ACR system is designed to:
  - simplify manufacture, installation and commissioning
  - reduce O & M costs
- Major improvements in the design include:
  - Fueling machine head and carriage simplified
  - Elimination of $D_2O$ from fueling machine system
  - Electric drives replace oil hydraulic drives
  - Fueling machine support enhanced
  - Spent fuel transferred in water ($H_2O$)

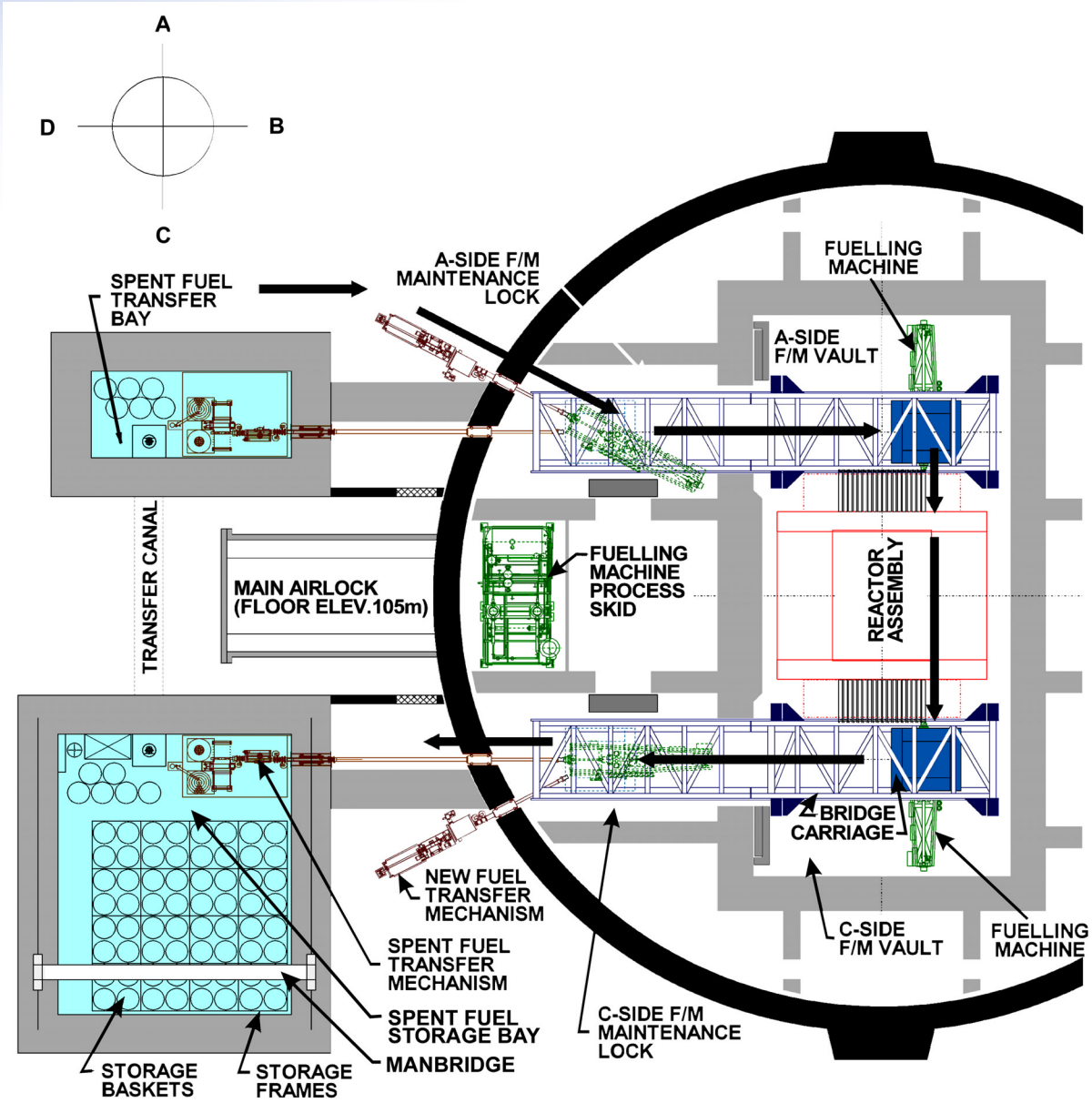
# CANDU 6 Fueling Machine



# Fueling Machine on Reactor



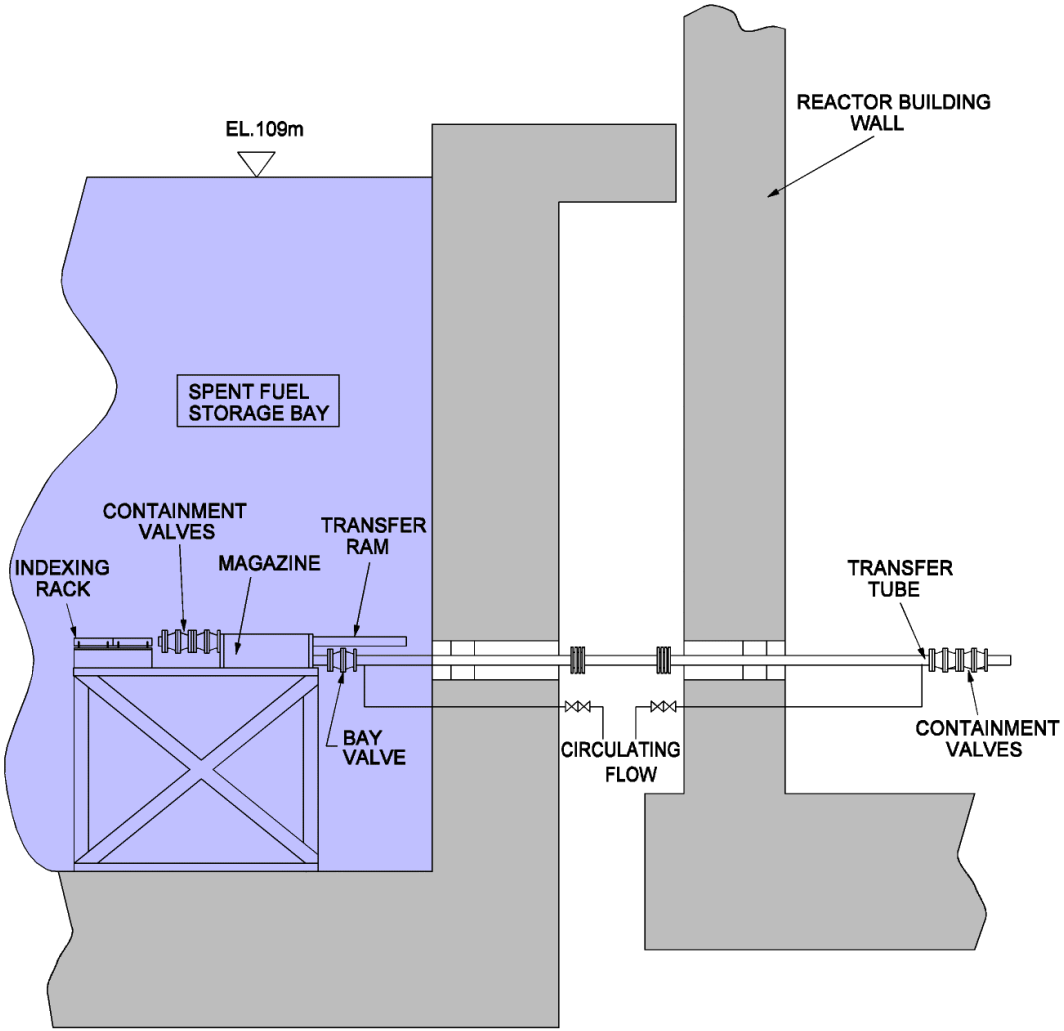
# ACR Fuel Handling Layout



# On-Power Fueling

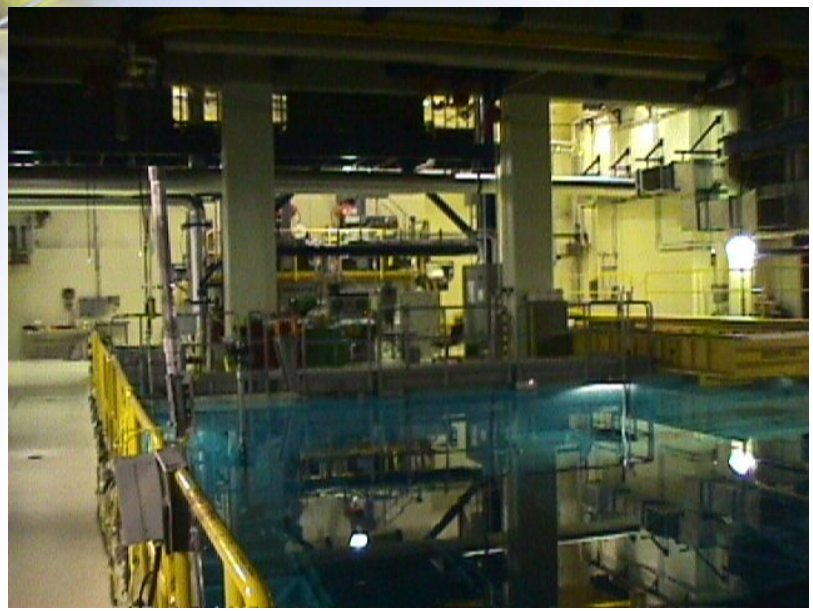
- Controls the global power distribution in the ACR core
- Fueling scheme consists of changing:
  - 2 of 12 bundles per channel visit
  - 21 channels per week
- Requires 4 hours/ day fueling everyday or 6 hours/day fueling 4 days per week
- Channels to be fueled are scheduled to:
  - Control the global flux distribution
  - Maximize fuel discharge burn-up
- Improves fuel economy
- Allows on-power removal of defective fuel

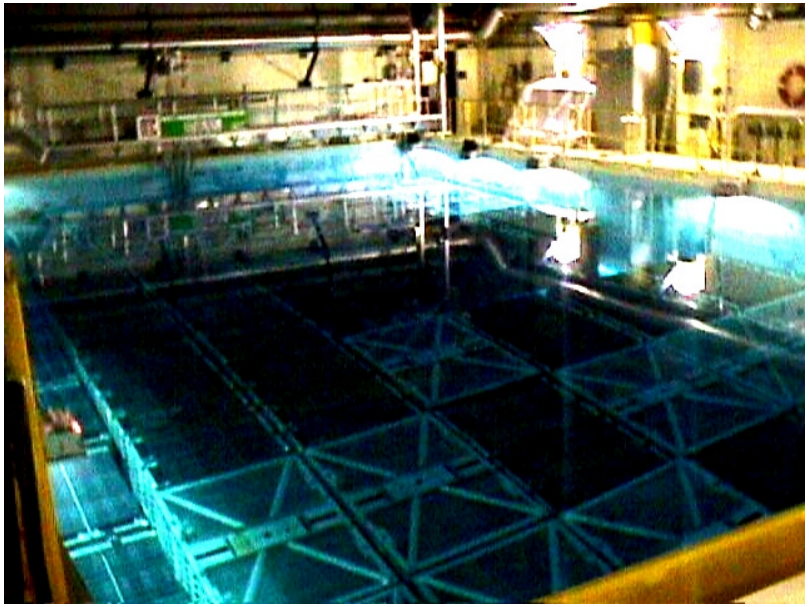
# Spent Fuel Transfer



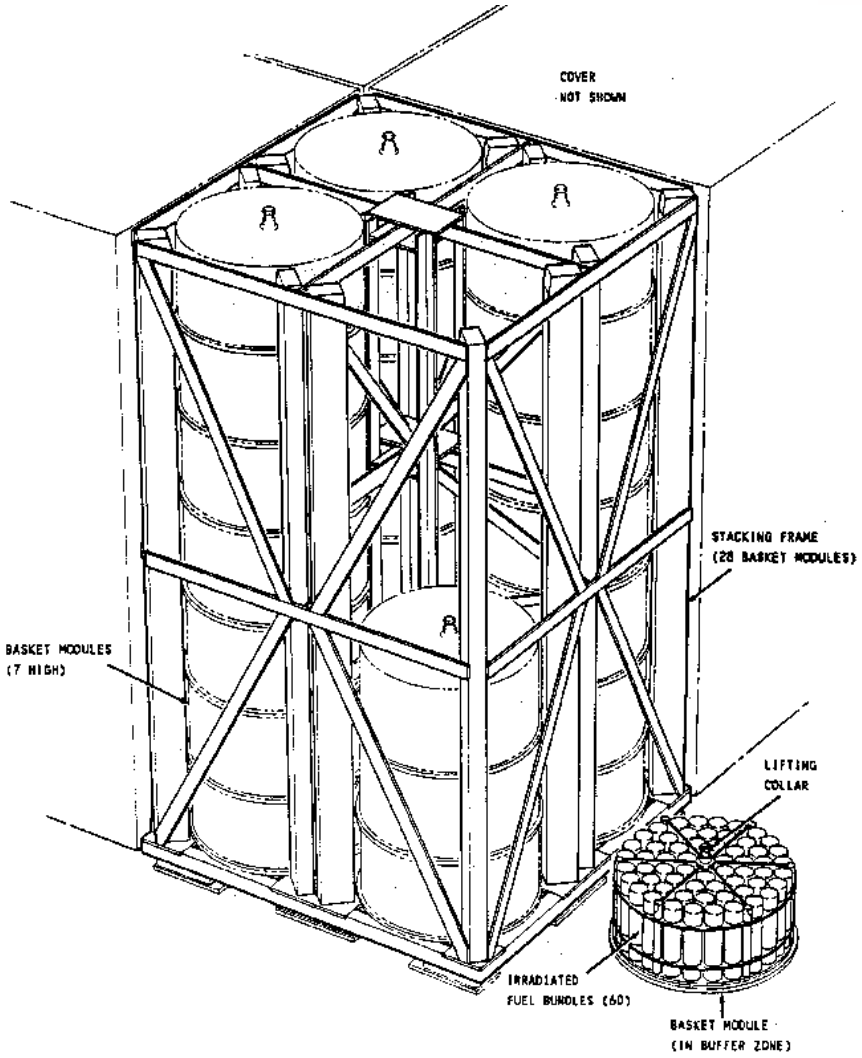

- Spent fuel is transferred in water
- Double containment isolation at both ends of transfer tube

# CANDU Spent Fuel Bay

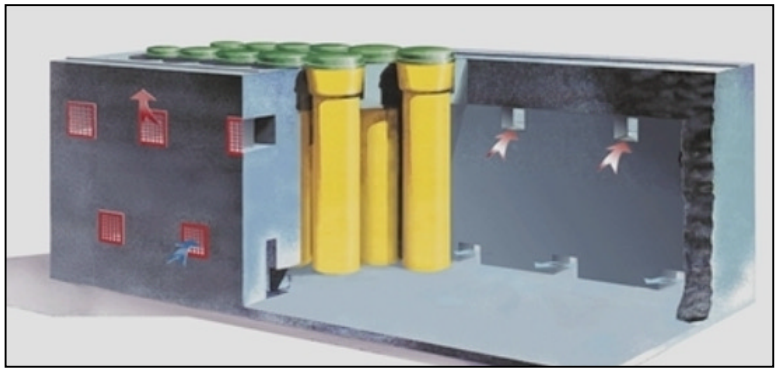


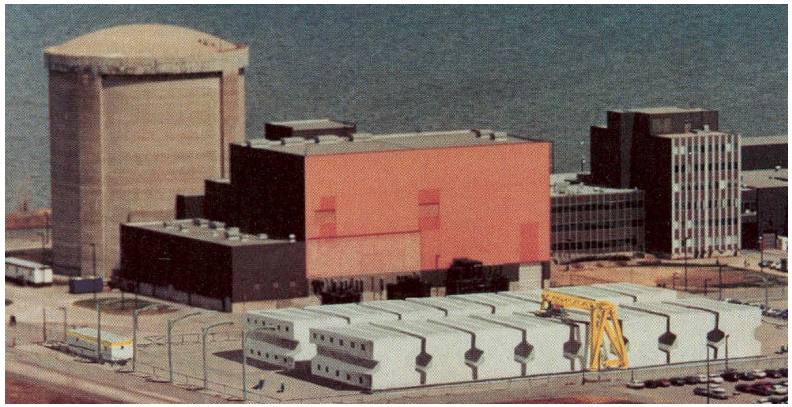


## ACR Spent Fuel Storage



# Dry Fuel Storage





**Module Stores 12,000 Bundles (26 Modules required for 60 years storage)**

# Summary

- Compact ACR core results in smaller lattice pitch and reduced volume of $D_2O$ moderator
- ACR Reactor design is an evolution of existing CANDU reactor designs
- Fuel Channel design has increased margins with extended operating life
- Fuel Handling system design has been optimized and simplified to improve overall performance and availability

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