ACR Moderator Circulation

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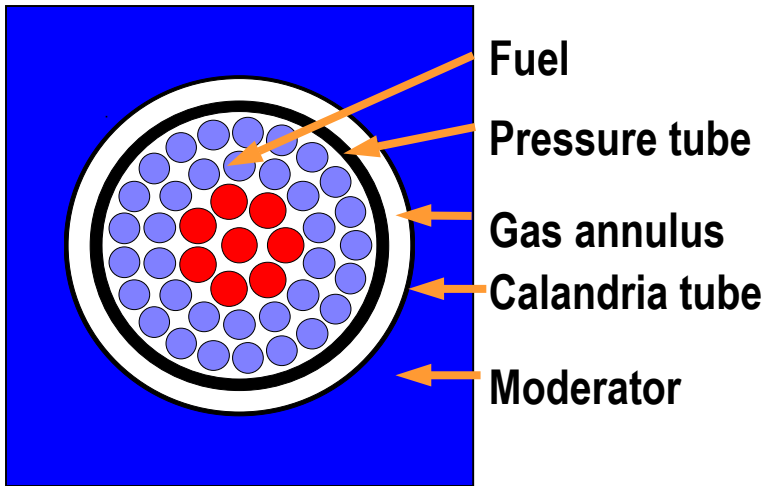
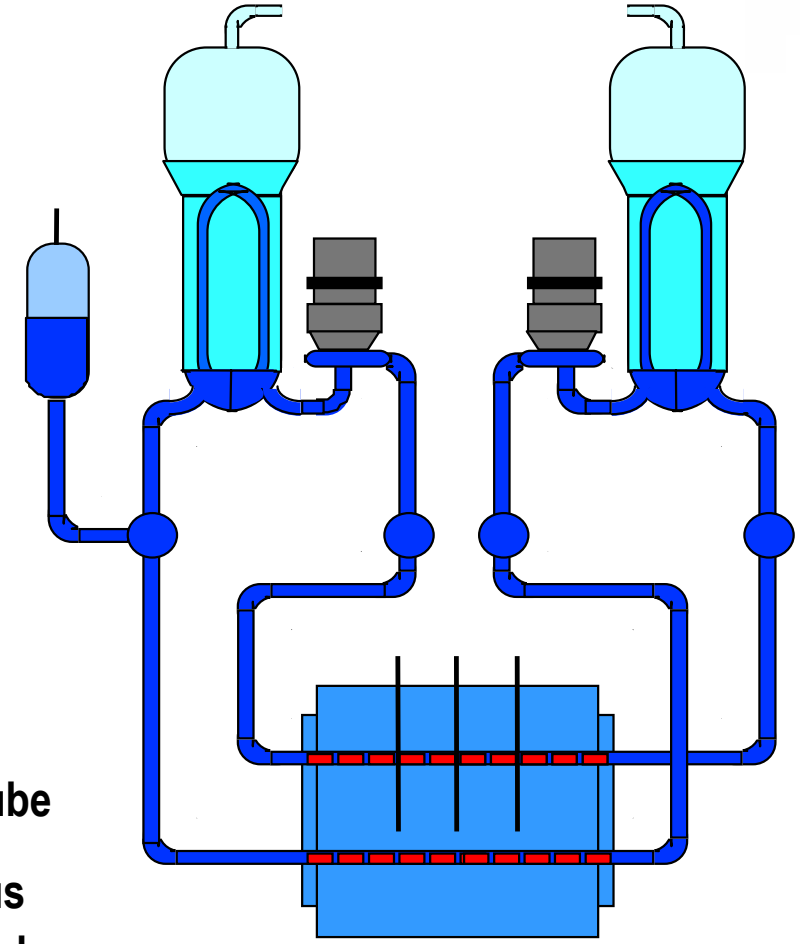
CANDU Moderator

- The moderator is a low-pressure, low temperature system (separate from the reactor coolant).
- Heat is continuously removed from the moderator during normal operation.
- The moderator acts as a heat sink in the event of certain accident sequences





Moderator Thermalhydraulics

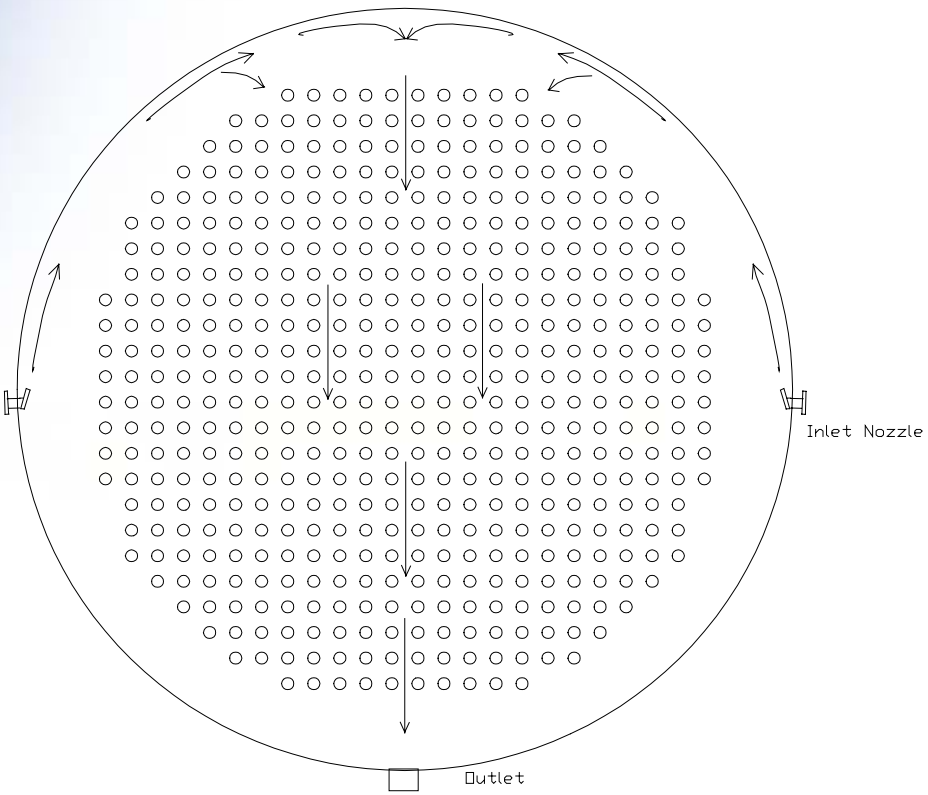
- Need to predict moderator circulation patterns and temperature distribution to ensure adequate cooling margin for all channels.
- Need to predict moderator circulation for postulated accident scenarios to ensure availability of moderator heat sink.
- A 3-D single phase computational fluid dynamics computer code (MODTURC_CLAS) is used to predict moderator flow and temperature distribution.

MODTURC_CLAS Validation Base

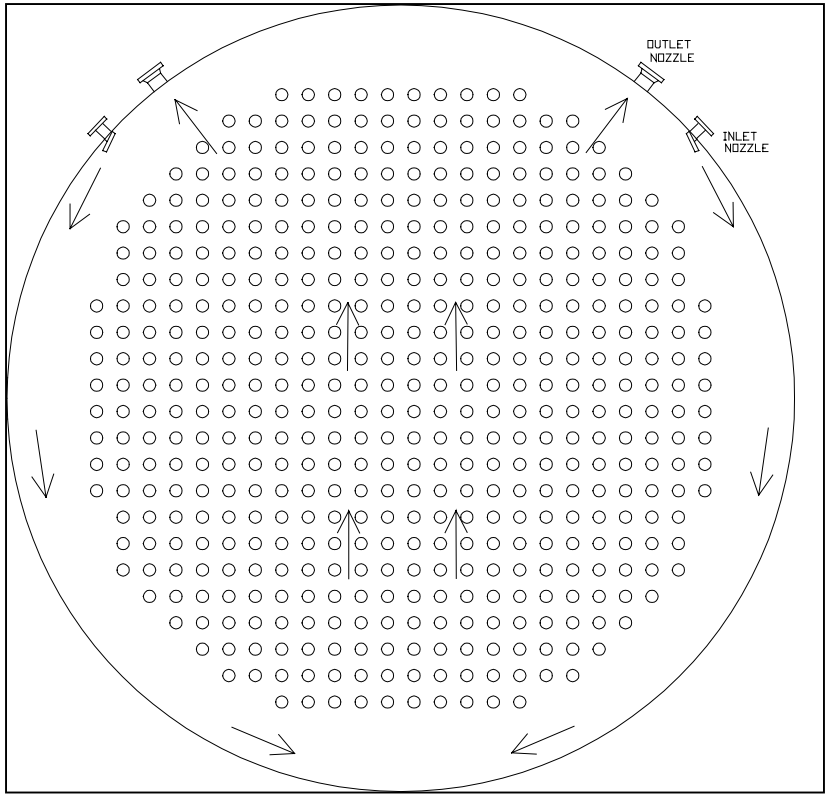
- Database for operating CANDU reactors
  - Data from a 2D facility (1/4-scale)
  - In-reactor temperature measurements
  - Difficulties in validating flow conditions
- A more efficient circulation system was developed and validated for CANDU 9.
- A similar design will be used for ACR.

Moderator Circulation Design

CANDU 6



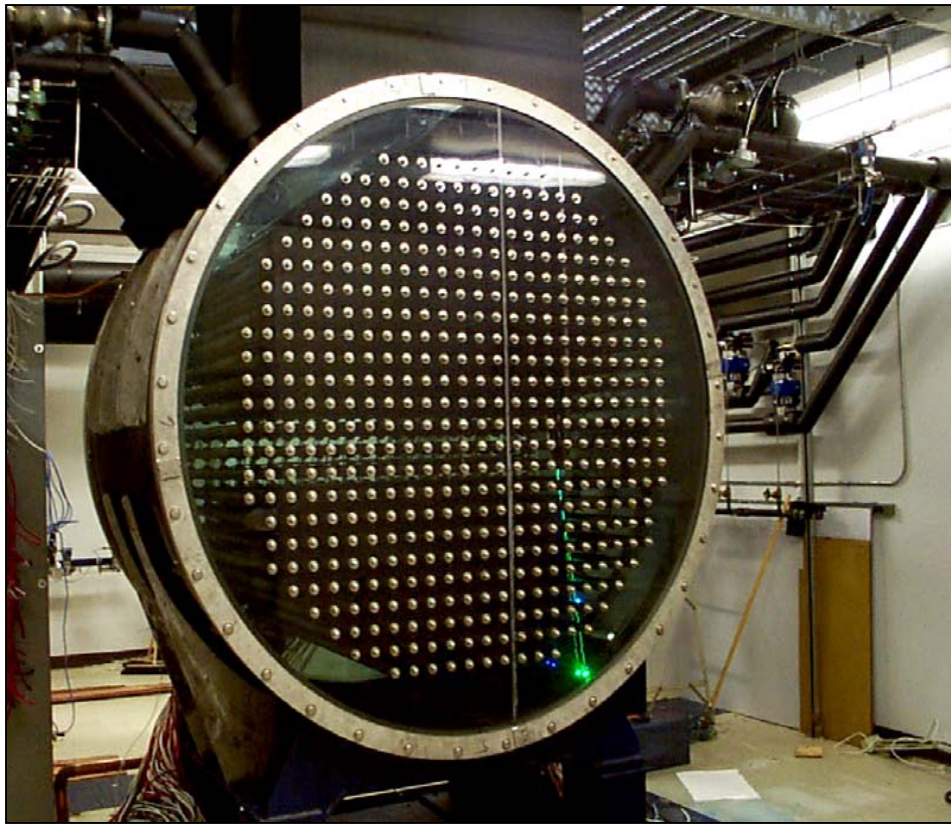
CANDU 9 and ACR



Moderator Test Facility

- Large-scale facility to measure three-dimensional velocity and temperature distributions in moderator geometry

- Calandria vessel with fuel channel simulator heaters and coolant flow system
- 1/4 scale calandria used to validate CANDU 9 design
- 1/3 scale calandria is being built to validate ACR design



Moderator Test Facility Scaling

- Scale was decided based on analysis of the relevant equations (mass, momentum, and energy).
- The following dimensionless numbers were identified:
  - Archimedis Number (Ar)
  - Dimensionless volumetric heat source
  - Prandtl Number (Pr)
  - Reynolds Number (Re)
- It was shown that only the first three dimensionless numbers needed to be matched, provided the flow was turbulent (verified in tests).

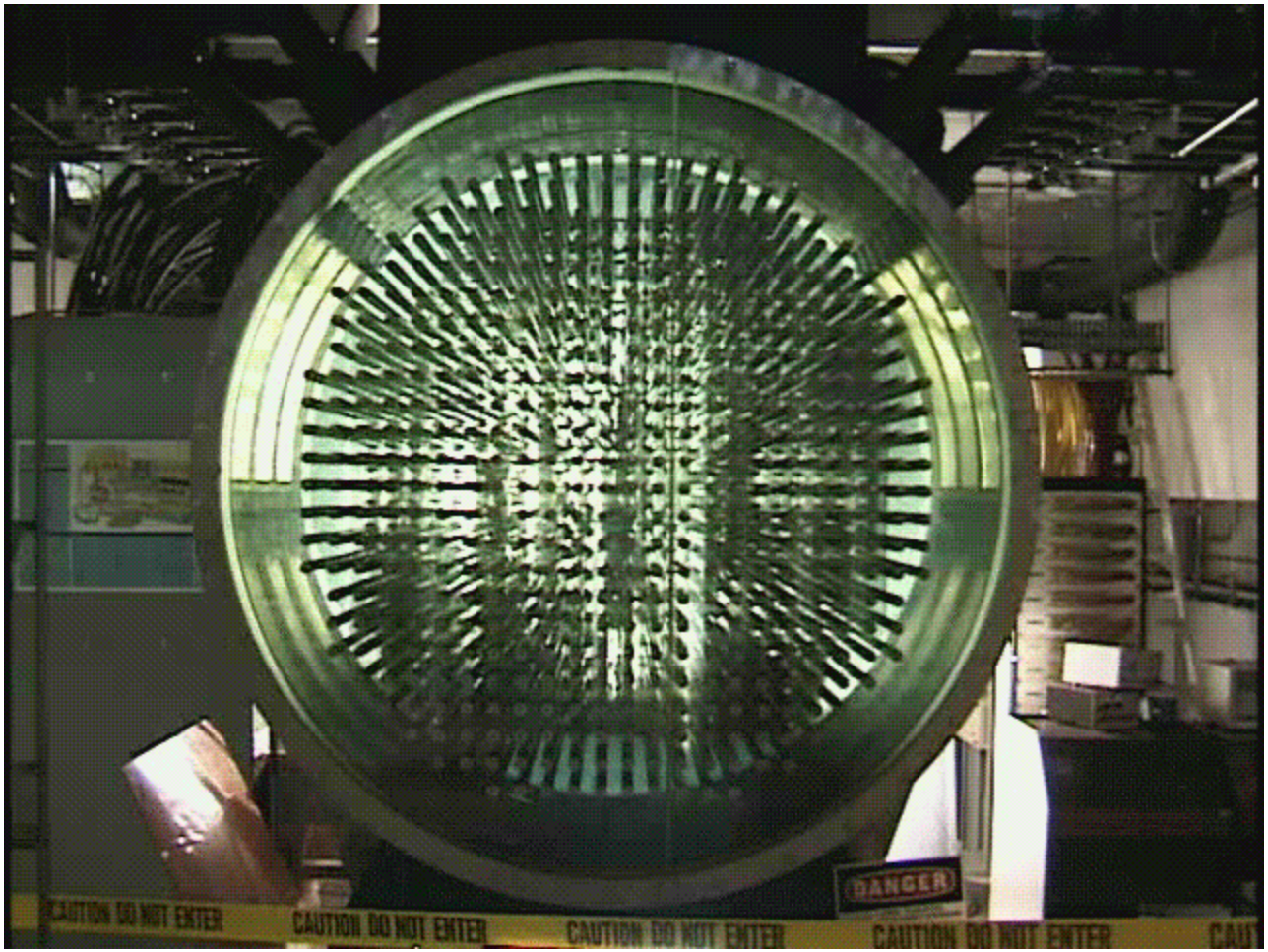
Moderator Test Facility

Parameter	CANDU 9	ACR
Number of heaters	480	284
Calandria diameter	2 m (6.6 ft)	1.3 m (4.3 ft)
Calandria length	1.5 m (4.9 ft)	1.9 m (6.2 ft)
Heater diameter	3.3 cm (1.30 in)	5.2 cm (2.05 in)
Fuel channel pitch	7.2 cm (2.83 in)	7.3 cm (2.87 in)
Maximum Power	1.7 MW	1.7 MW

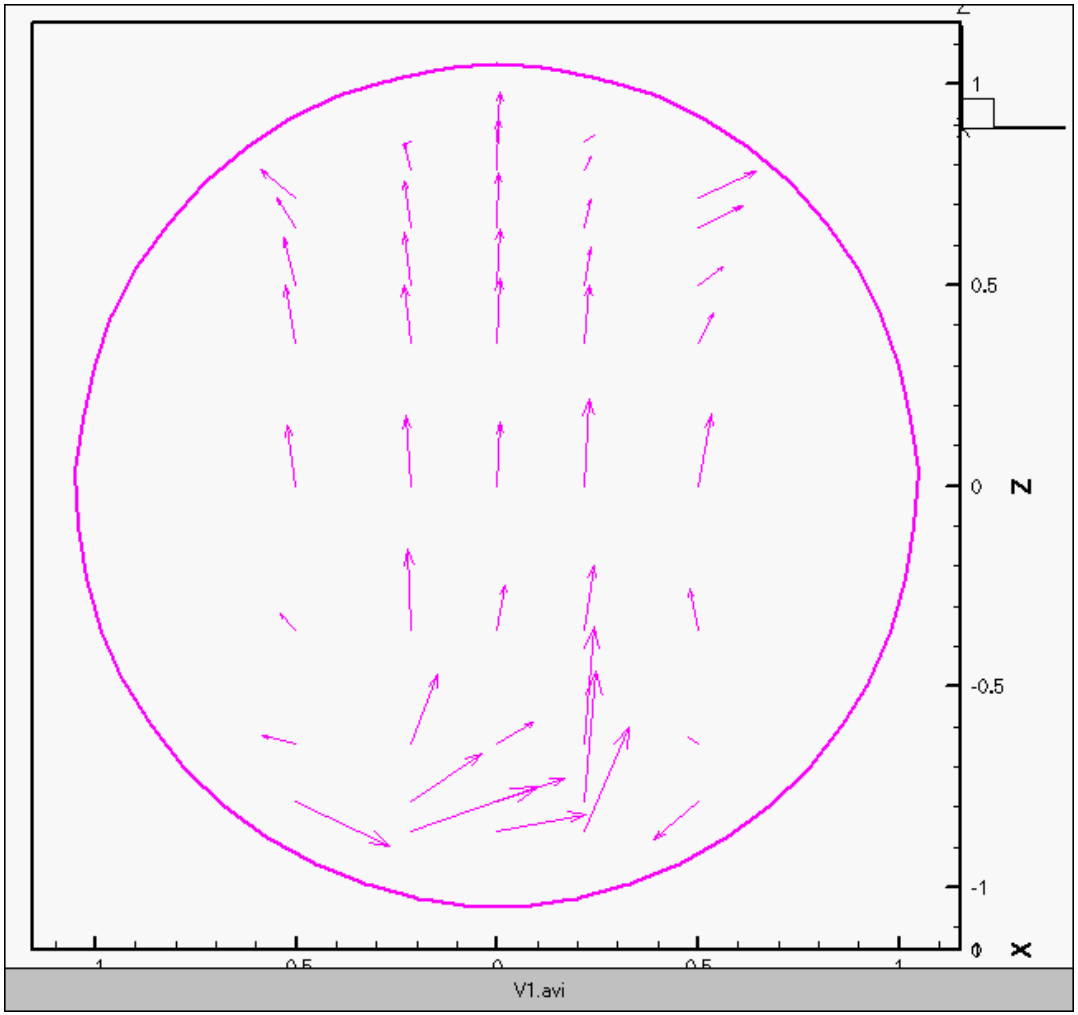
Moderator Test Facility Capabilities

- Typical measurements in MTF (steady-state tests)
  - Flow visualization (using dye injection at the inlet nozzles).
  - 3-component velocity measurements using 3-D Laser Doppler Velocimetry (LDV).
  - Temperature distribution measurements using arrays of fixed and movable thermocouples.
  - A typical steady-state test lasts for 4 weeks.
- Transient tests can also be performed (temperature measurements only) and last for about a day.
- Separate effects tests can also be performed to provide additional measurements to validate models used in MODTURC_CLAS (pressure drop, jet development, buoyancy, etc).

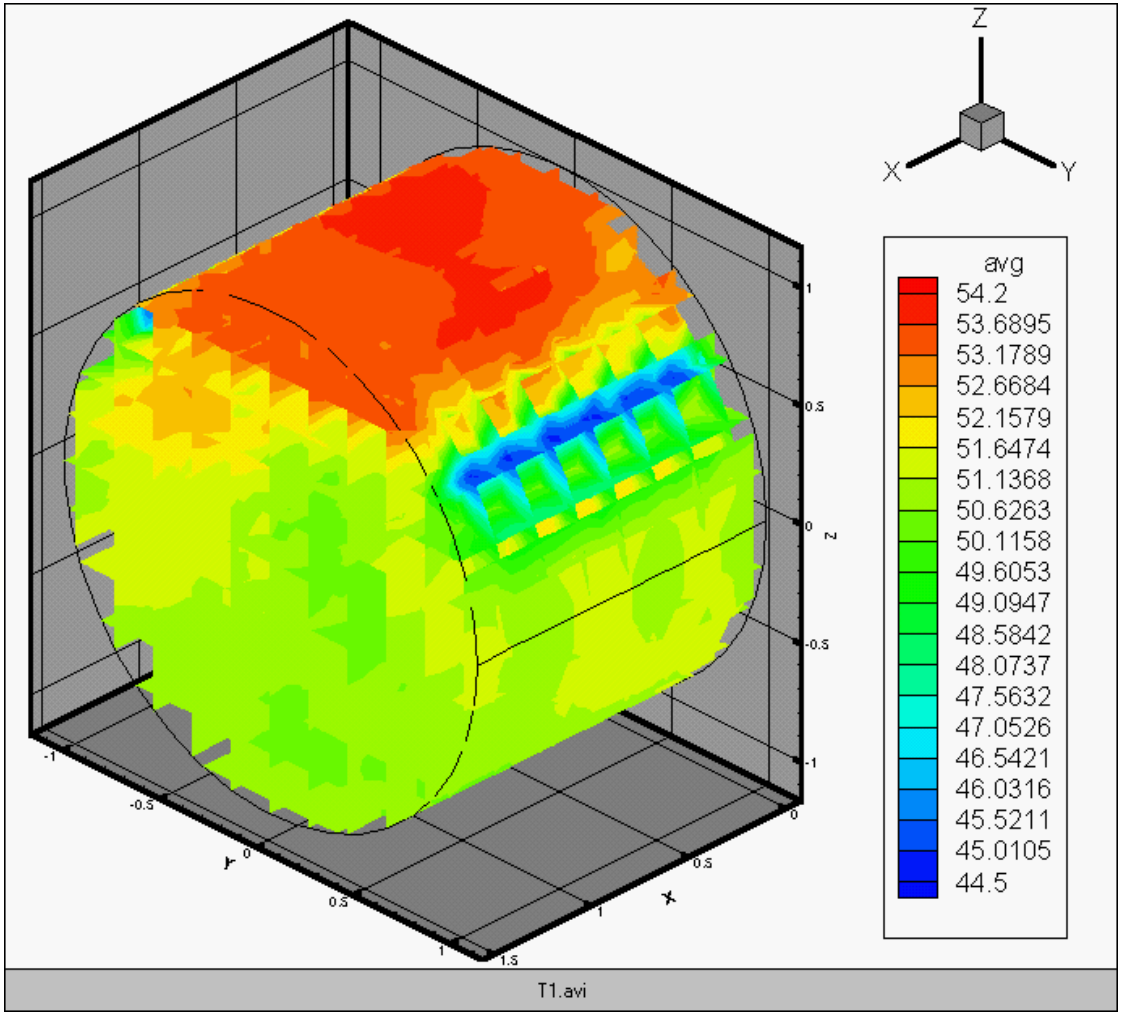
Dye Injection Test



CANDU 9 Flow Velocity Measurements



CANDU 9 Thermal Measurements

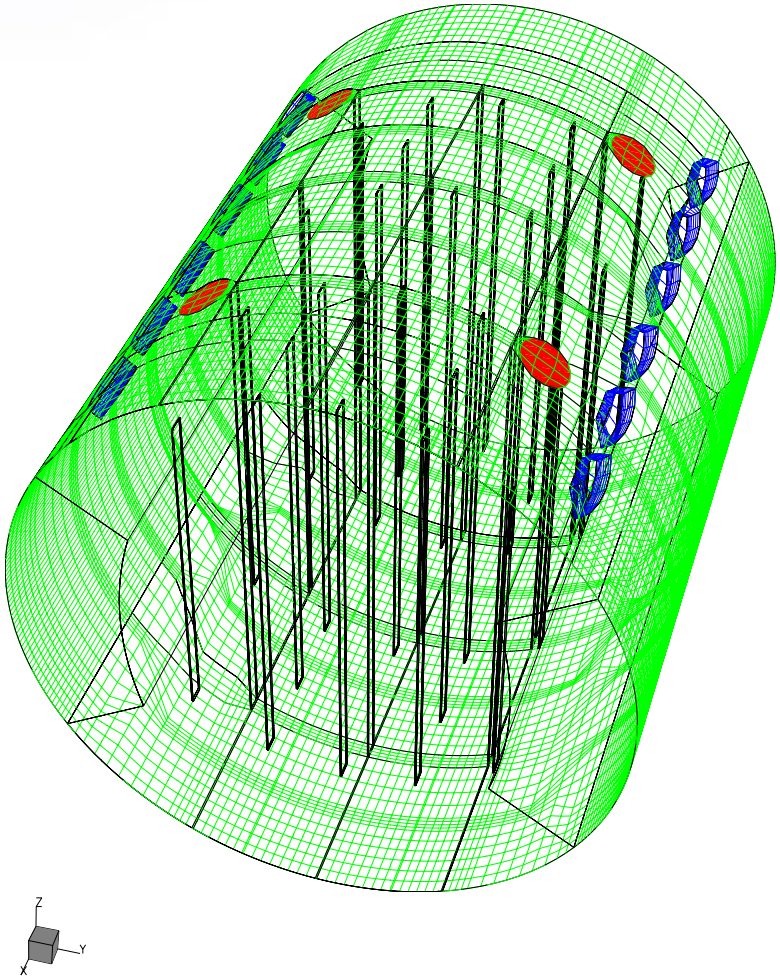


ACR Moderator Circulation Design

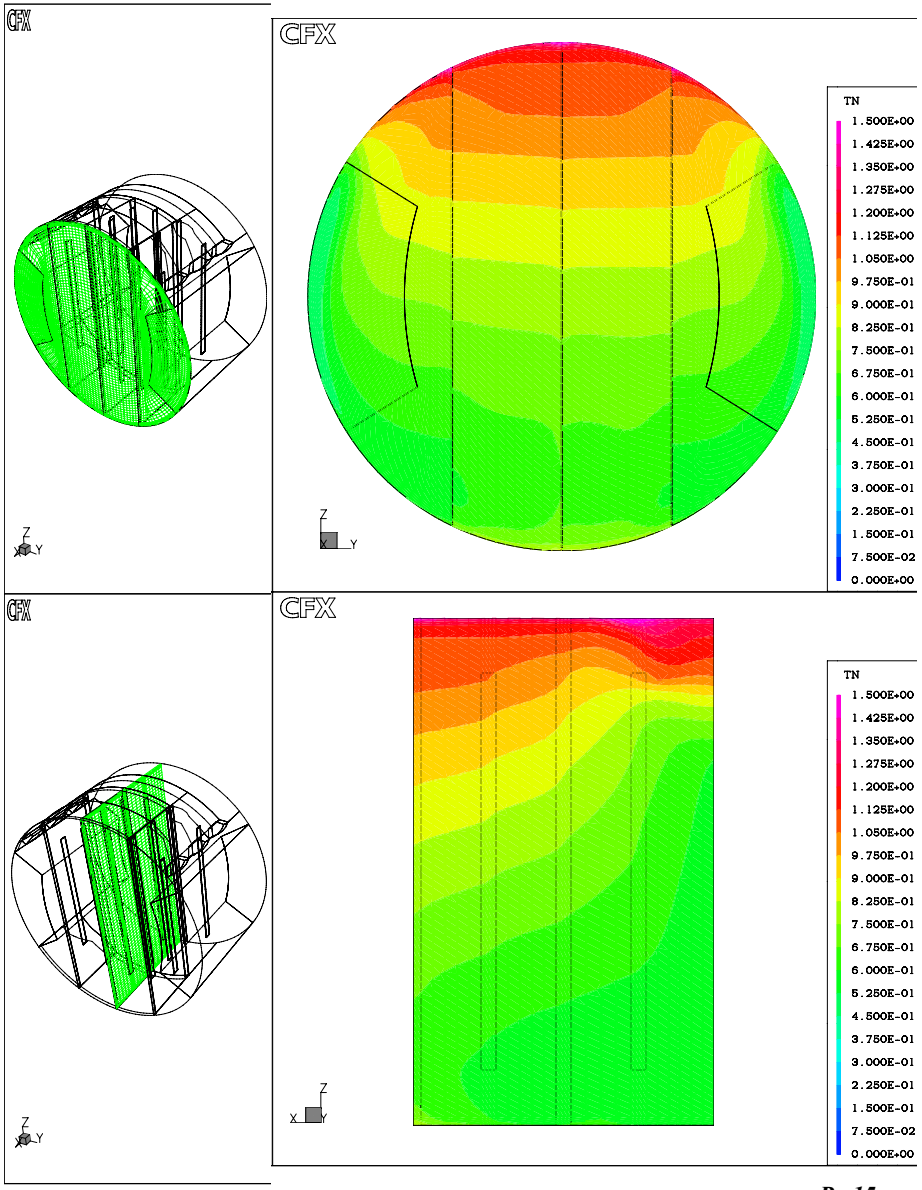
- Key ACR design aspects that affect moderator circulation:
  - Smaller lattice pitch (higher hydraulic resistance).
  - Reactivity devices (could affect local temperatures).
- Assessment of ACR preliminary design using MODTURC_CLAS showed similar thermalhydraulic behavior to the CANDU 9, despite the smaller lattice pitch and the reactivity devices.
- Tests in a modified MTF will be conducted to verify the design.

ACR Moderator Design Assessment

(MODTURC_CLAS Grid)



MODTURC_CLAS predictions of moderator temperature distributions in ACR cross-sectional and longitudinal planes



Summary

- MODTURC_CLAS is a well-validated code for the prediction of moderator thermalhydraulics in current CANDU reactors.
- A test program is a scaled Moderator Test Facility will extend the MODTURC_CLAS validation to include the ACR.

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