Design of a Gas Test Loop Facility for the Advanced Test Reactor

TRTR/IGORR Joint Meeting

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Overview

- GTL Purpose
- ATR Description
- Methods and Models
- Present Design
- Status/Future Work

GTL Purpose

- Provide fast flux testing for materials and fuels testing in support of:
  - The Next Generation Nuclear Plant (NGNP)
  - Gen-IV reactor systems
    - 3 of the Gen-IV systems are fast reactors.
  - Advance Fuel Cycle Initiative (AFCI)
  - Space nuclear propulsion

GTL Purpose (cont.)

Selected performance requirements needed to fulfill the GTL purpose

Parameter	Required	Desired
Test volume length (cm)	15.5	89
Test volume diameter (cm)	2.54	5.9
Fast flux intensity (n/cm^2.s, E>0.1 MeV, unperturbed)	1.0E+15	3.0E+15
Fast/thermal neutron flux ratio	>15	>100
Flux uniformity in test space (%)	±10	±5
Heat Removal Temperature (°C)	500 ±15 to 1,100 ±20	500 ±15 to 1,830 ±50
Maximum Test Article Linear Heat Rate (W/cm)	2,300	3,000
Total Heat Flux (kW)	200	3,600
Design Lifetime (years)	30	Life of Program

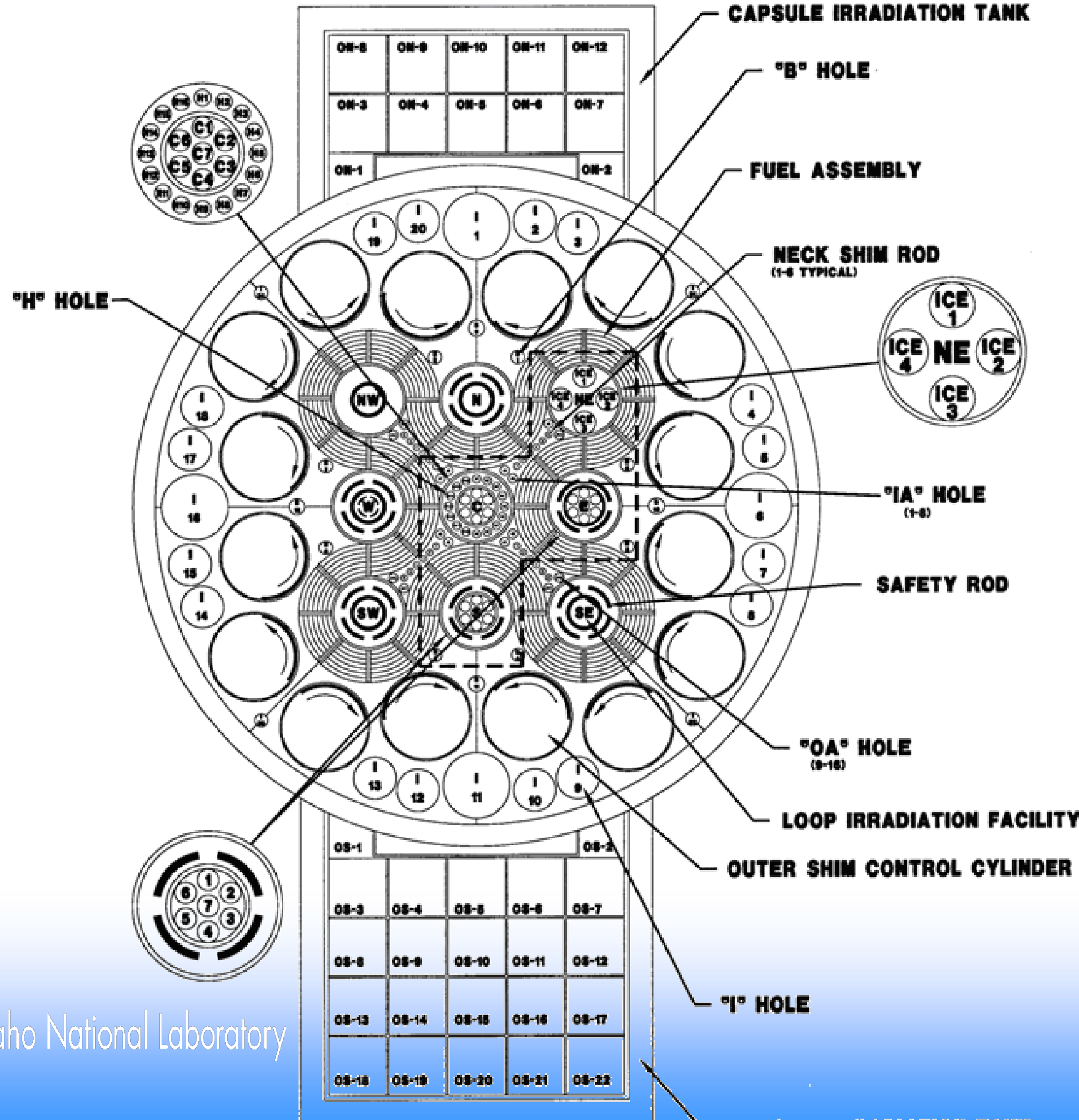
ATR Description

- High enriched uranium (93%)
- Light water primary coolant system
- Beryllium reflector
- Rated maximum power of 250 MW
- Peak unperturbed thermal neutron flux of 1.0×10^{15} n/cm^2-s

ATR Description (cont.)

- Serpentine fuel arrangement provides:
  - 9 high-intensity thermal neutron flux traps
    - 5 flux traps nearly surrounded by fuel
    - 4 flux traps with fuel on 3 sides
  - 68 additional irradiation positions

ATR Cross Sectional Diagram

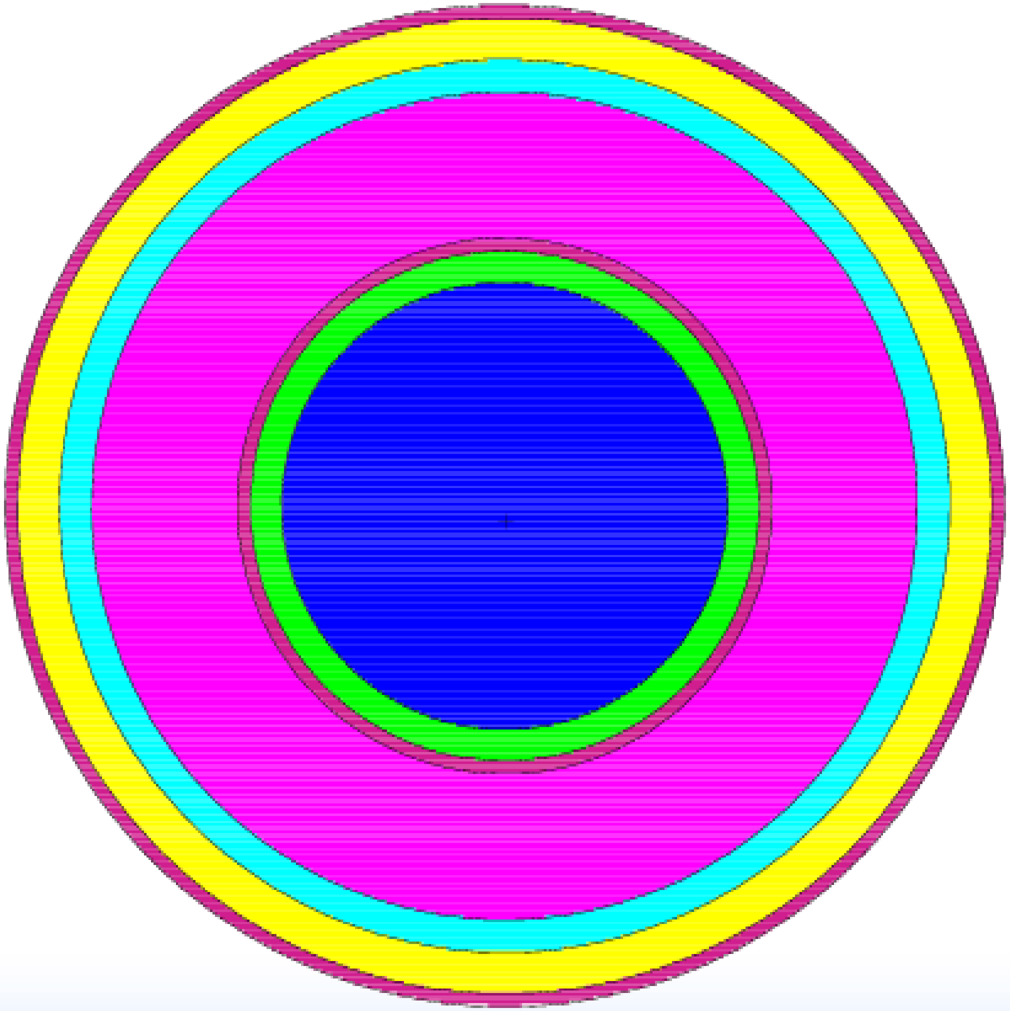


Idaho National Laboratory

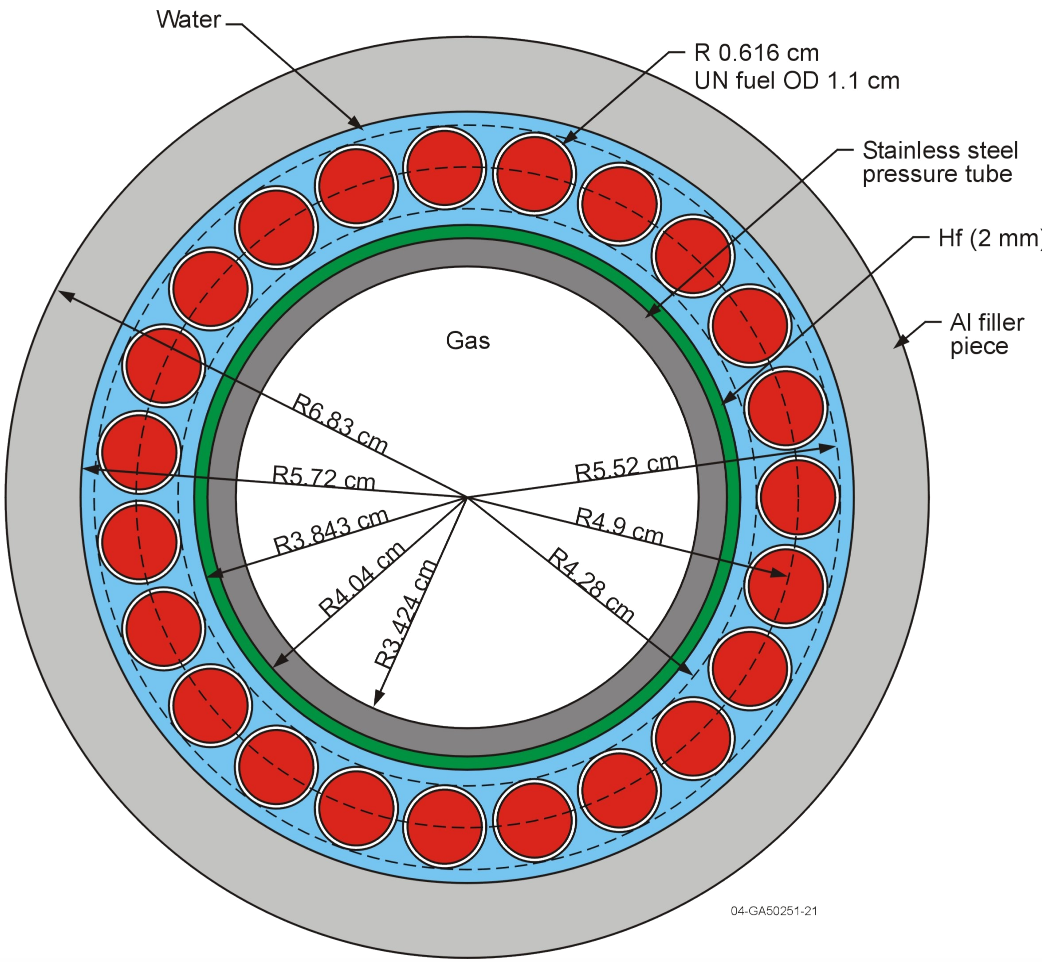
Methods and Models-Parametric Studies

- MCNP version 4C used for the neutronics modeling
- Surface source generated for the inner surface of the flux trap baffle to speed calculations
- Several fuel configuration classes examined

Depleted Uranium Model



Pin Model



Water
R 0.616 cm
UN fuel OD 1.1 cm
Stainless steel
pressure tube
Hf (2 mm)
Al filler
piece
Gas
R6.83 cm
R5.72 cm
R5.52 cm
R4.9 cm
R3.843 cm
R4.04 cm
R3.424 cm
R4.28 cm
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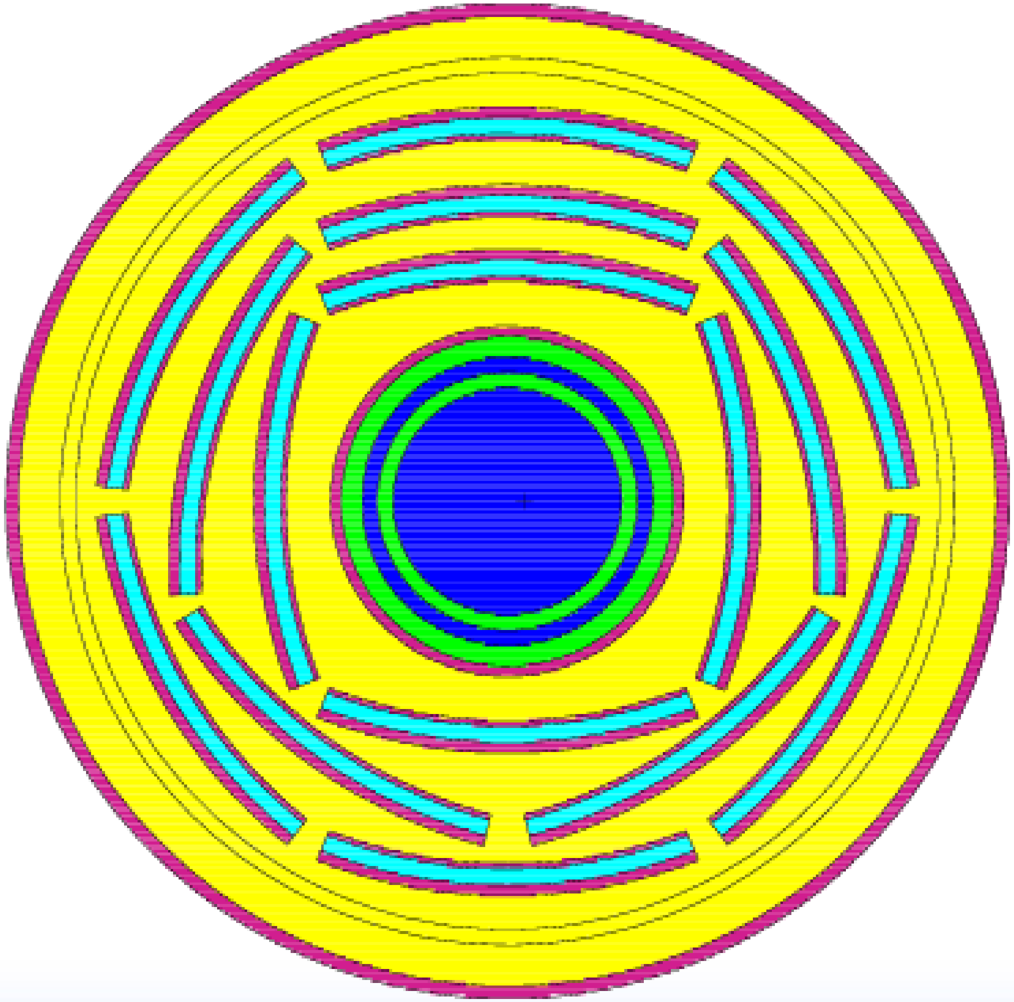
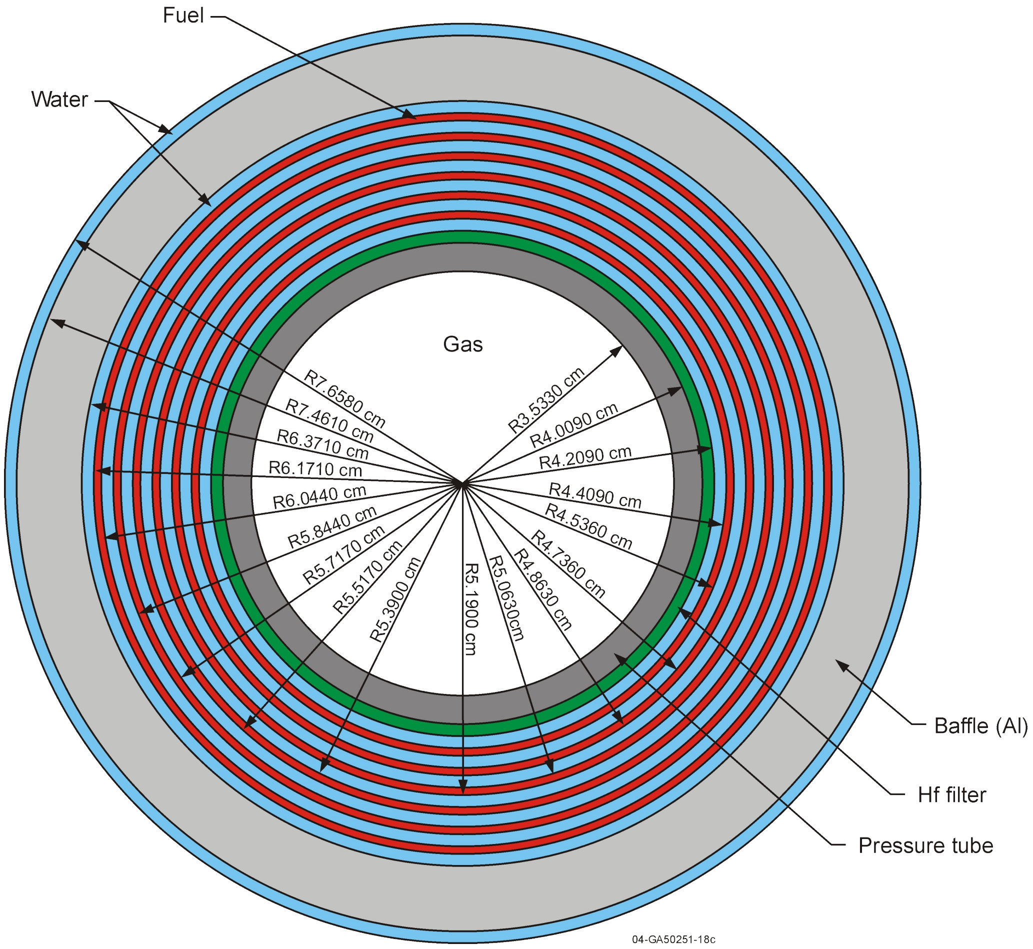
ATR Plate Model



Annular Plate Model

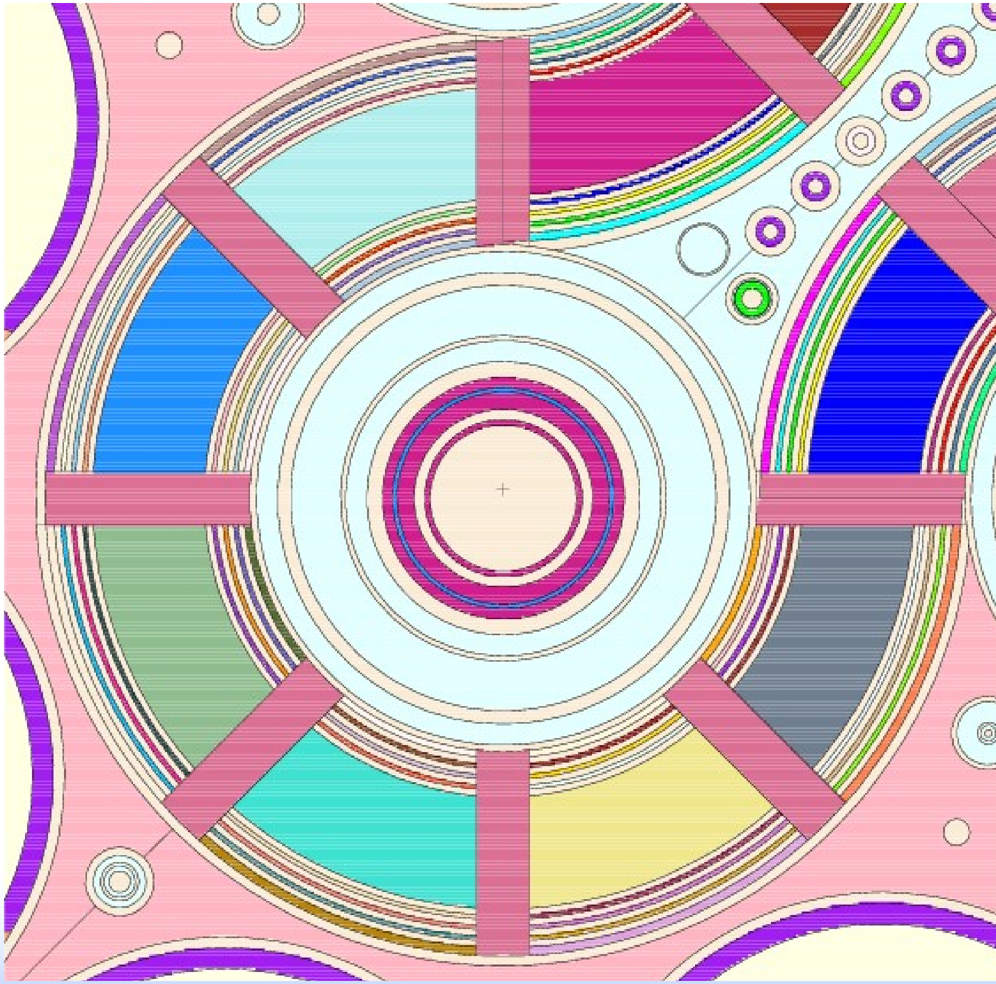


Methods and Models-Detailed Analysis

- Neutronics calculations performed with MCNP version 4C - full-core ATR model
  - Calculated flux
  - Calculated energy deposition
- Driver core loading based on actual ATR core loading procedures
- Two neutronics models used for detailed analysis
  - Static BOC model
  - Depletion model

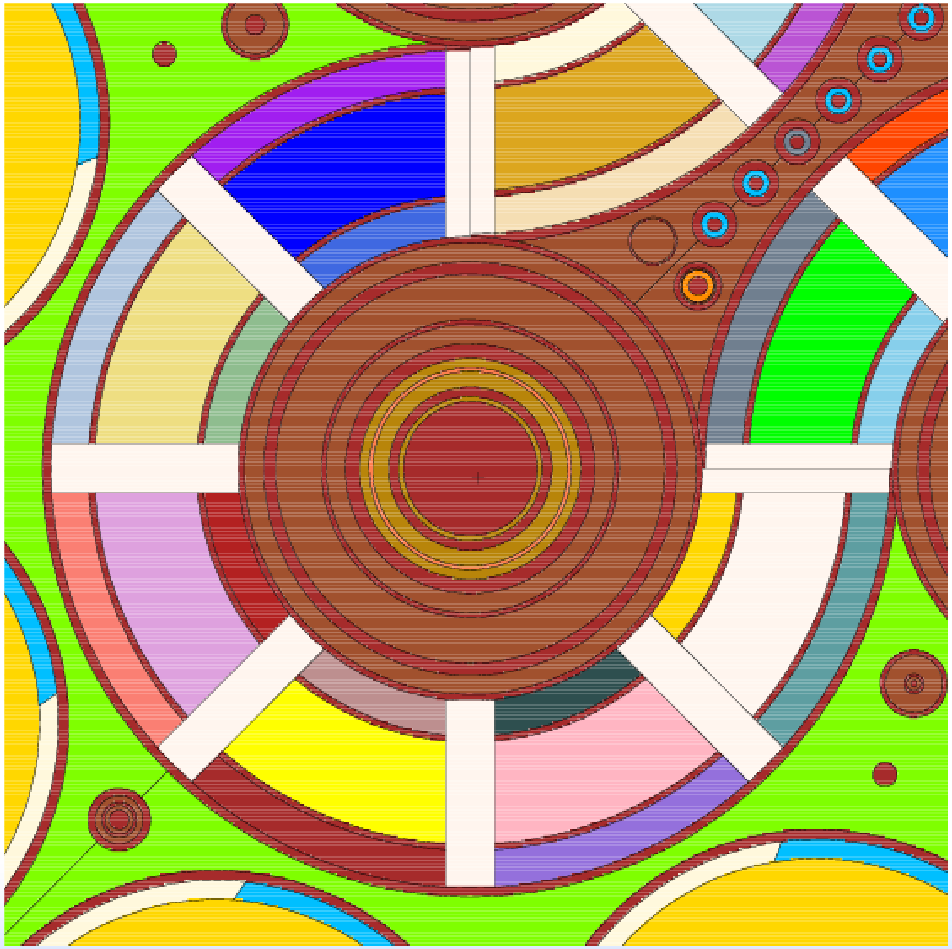
Static BOC Model

- **Explicit representation of fuel plates 1-4 and 16-19**
- **Fuel plates 5-15 smeared into a single region**



Depletion Model

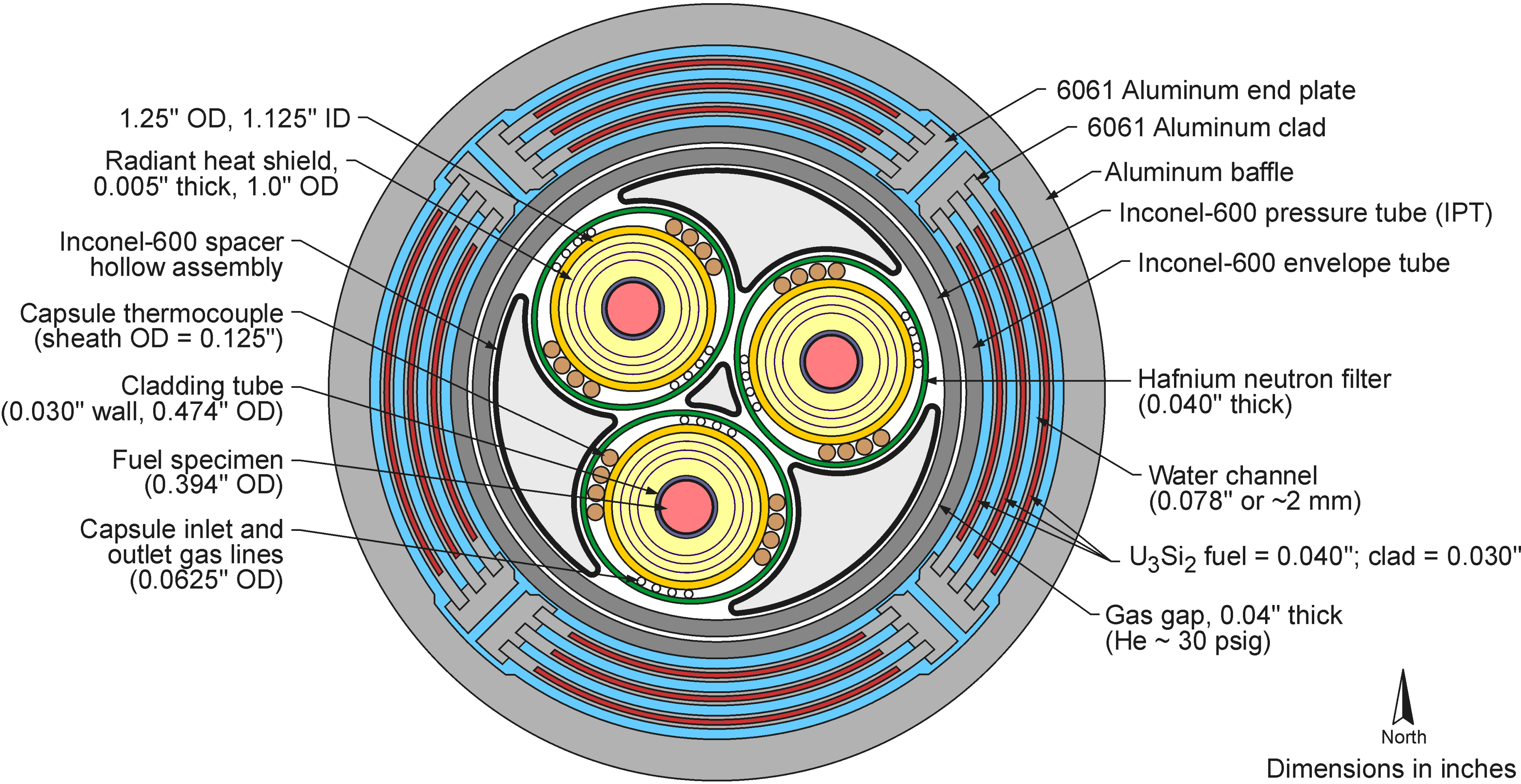
- 3 smeared radial regions consisting of plates 1-4, 5-15, and 16-19
- Fuel divided into 7 axial zones
- MOCUP is used to couple MCNP with ORIGEN2



Methods and Models (cont.)

- Both models use experiment descriptions for the first cycle after the 2005 CIC
- Fission product concentrations in the recycled elements were scaled from ORIGEN2 calculations for fresh ATR elements
  - Scaling was based on the element fractional burn-up and the PDQ ^{149}Sm concentration

Present GTL Design



Booster Fuel

- Uranium silicide (U_3Si_2) fuel elements in a physical configuration similar to current ATR fuel elements.
- Uranium loadings vary between plates:
  - 4.8 gU/cc inner plate loading, 3.2 gU/cc middle plate loading, 2.0 gU/cc outer plate loading
- Inner test space is configurable:
  - Test assemblies up to 7.5 cm in diameter can be accomodated
- Booster fuel cooling is provided by the ATR PCS

Gas Cooling System

- **Helium gas cooling system to remove up to 500 kW from the experiment area**
  - **2270 kg/hr (5000 lb/hr)**
  - **1.72 MPa (250 psia)**
  - **Bulk gas temperature < 422 K (300 °F)**

Sweep Gas System

- **Independent flowing sweep gas blend available for each experiment capsule**
  - **Provides experiment temperature control adjusted with thermocouple feedback**
  - **Ability to transport experiment emitted gasses to a sampling system**

Thermal-hydraulic Analysis

- The RELAP5 code version 2.36 was used for the thermal-hydraulic analysis
- The MCNP calculated heat rates were used as the inputs for the TH calculations
- All gas test loop components were modeled explicitly in RELAP5 except the spacer assemblies
- Two detailed cases:
  - RC5 – normal 1 mm thick hafnium filter
  - RC5a 0.125 mm thick Inconel 600 cladding on a 0.75 mm thick hafnium filter

Thermal-hydraulic Results

Heat Structure Component	Case RC5	Case RC5a
Experiment Tube Surface	554 K (538 ºF)	551 K (532 ºF)
Filler Block	417 K (291 ºF)	414 K (286 ºF)
Neutron Filter	466 K (379 ºF)	461 K (370 ºF)
Pressure Tube	450 K (350 ºF)	449 K (349 ºF)
Booster Fuel	518 K (473 ºF)	520 K (476 ºF)
Booster Fuel Cladding Surface	423 K (302 ºF)	424 K (304 ºF)
Baffle	345 K (161 ºF)	345K (161 ºF)

Future Work

- Booster fuel qualification to evaluate:
  - Fuel performance
  - Cladding performance
  - Fabrication capability
- GTL and ATR mechanical interface design finalization
- Detailed analysis of the ATR driver fuel and the GTL booster fuel cycles
- Complete safety analysis

Future Work (cont.)

- Analysis of issues relating to:
  - Fuel and experiment transport
  - Waste stream generation and disposal
  - Reactor safety
  - GTL life cycle management
- Submission of CD-1 planned for late FY 2007

Thank you for your attention!