The Advanced Test Reactor Capabilities Overview

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ATR Historical Perspective

Materials Test Reactor (MTR)

- 1952 through the early 1970’s
- First of its kind to study material behavior in a radiation field

Engineering Test Reactor (ETR)

- 1958 through the early 1980’s
- Studied fuel performance and reactor components, including sodium reactor experiments

Advanced Test Reactor (ATR)

- Initial operation in 1967 – continuous operation until present
- Fuels and materials development for the Naval Nuclear Propulsion Program, the Department of Energy, and others

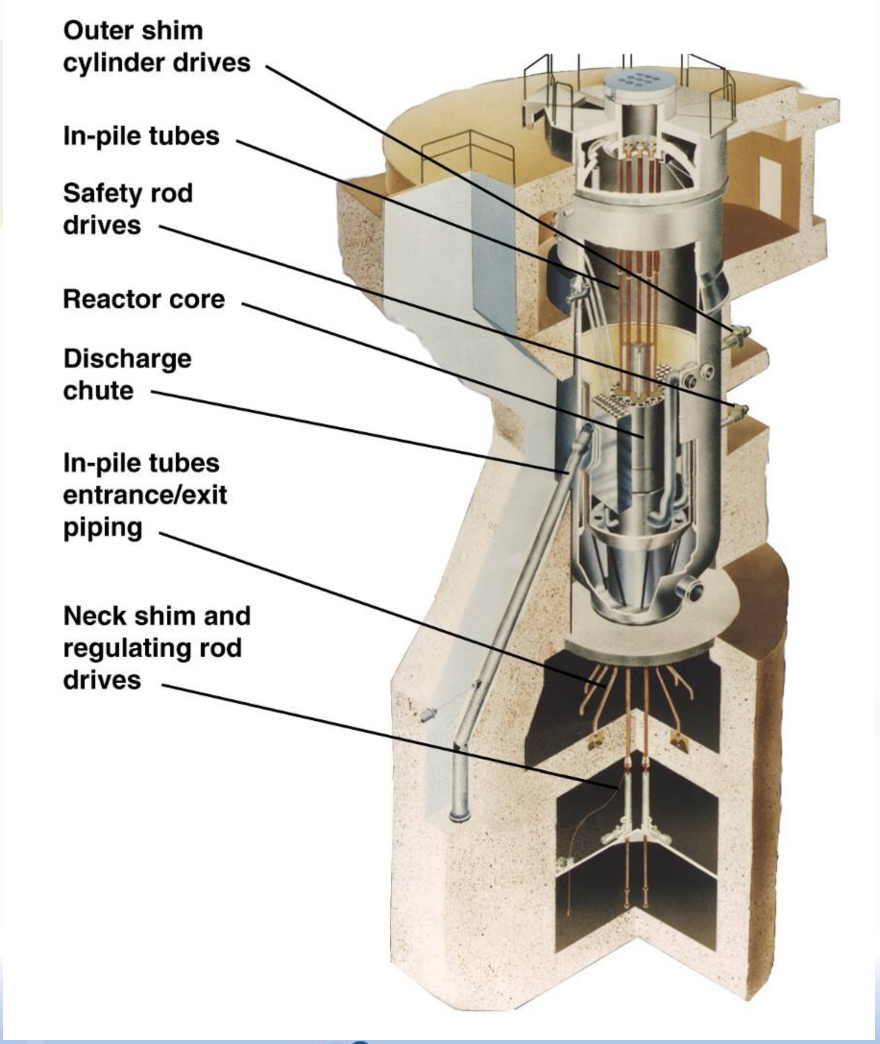
ATR Description

Reactor Type
Pressurized, light-water moderated and cooled; beryllium reflector
250 MWt design

Reactor Vessel
12 ft (3.65 m) diameter cylinder,
36 ft (10.67 m) high stainless steel

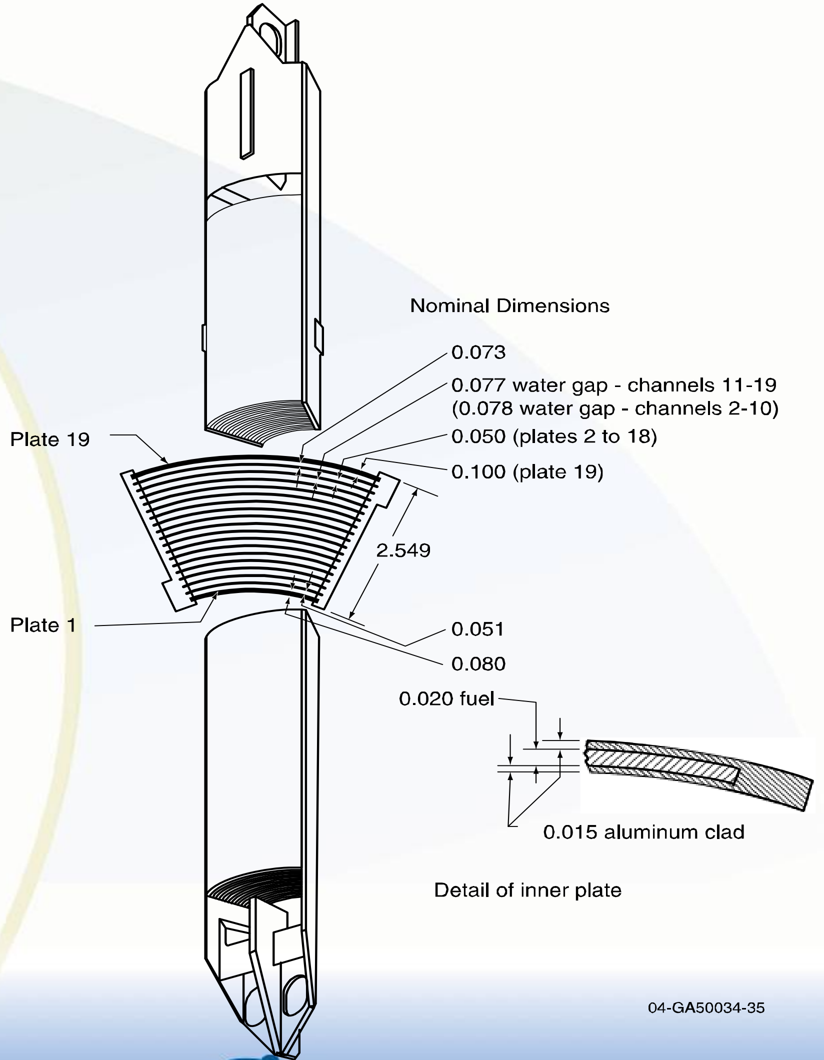
Maximum Flux, at 250 MW
1×10^{15} n/cm^2-sec thermal
5×10^{14} n/cm^2-sec fast

Reactor Core
40 fuel assemblies
U-Al plates – 19/assembly



ATR Fuel Element Design

- Fuel plates contain HEU
- Fuel plates Consist of Ual_x Powder Dispersed in Al
  - High power density, high burnup
  - Accommodate fission products in deliberate voidage
  - Tolerance for fission gas
- Small Amounts of Natural B_4C Powder Included as Burnable Poison
  - Minimize flux peaking, control reactivity
- Narrow Cooling Channels Maximize Heat Transfer



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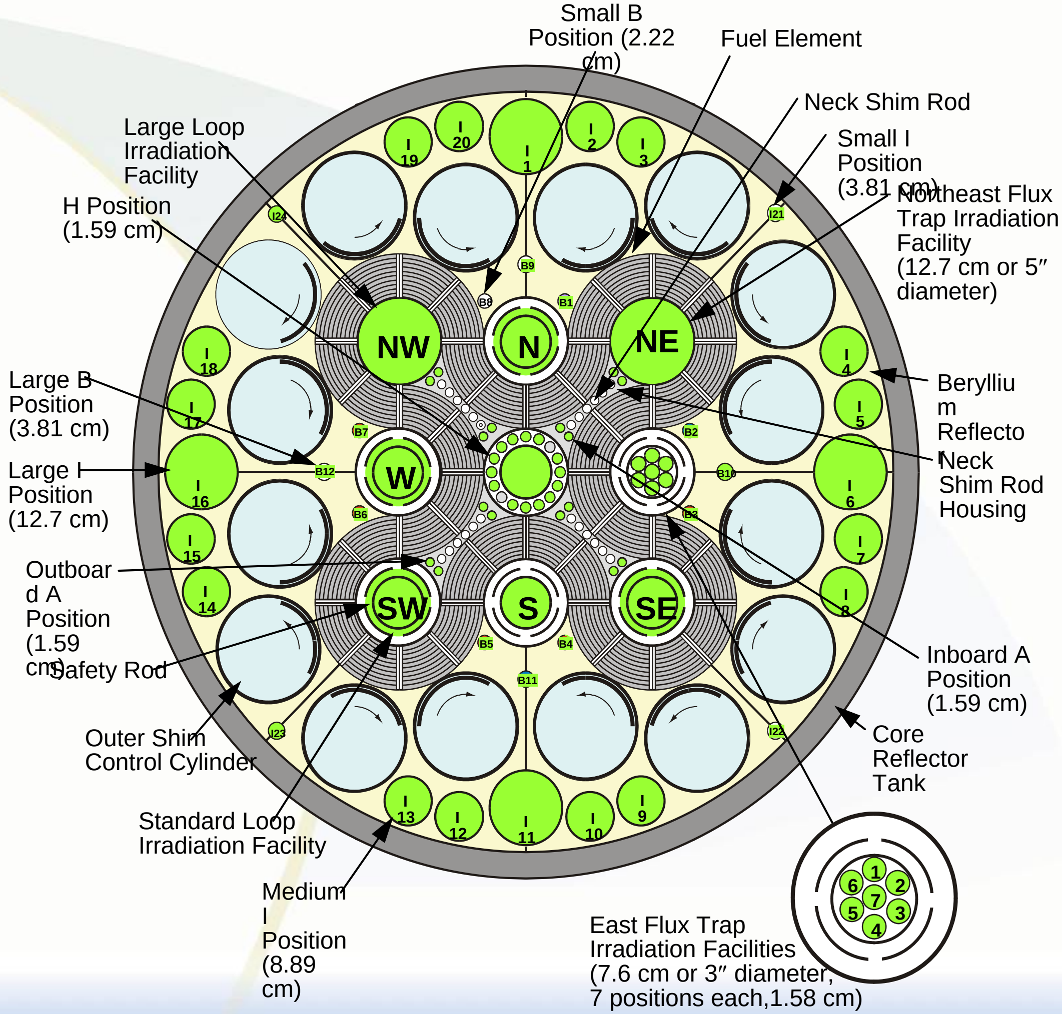
Comparison between ATR and Power PWR

Reactor Features	ATR	PWR (Typical)
Power (MW_{th})	250 (Max Design)	~ 3,800
Operating Pressure (psig)	~ 355	~ 2235
Inlet Temp. (F)	~ 125	~550
Outlet Temp. (F)	~ 160	~620
Power Density (kW/ft^3)	~ 28,300	~ 2,800
Fuel	Enriched U-235	3 – 4 % U-235
Fuel Temp. (F)	~ 462	> 1000

ATR Test Positions

- Test size – 48” length, 0.5” to 5.0” diameter
- 77 Irradiation Positions
- Rotating Hafnium Control Cylinders – symmetrical axial flux
- Power/Flux Adjustments (“Tilt”) across the Core - ≤ 3:1 ratio



Unique ATR Design Features

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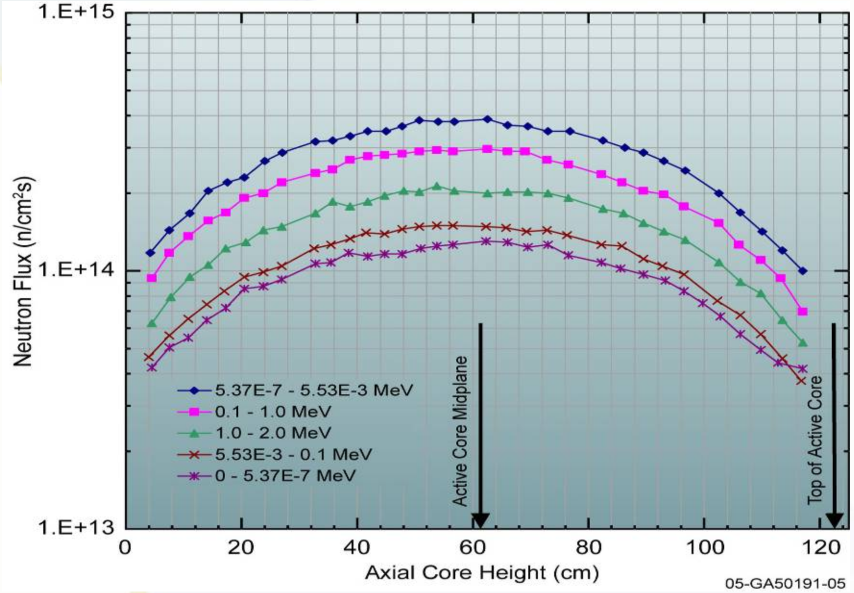
- Combination of high flux and large test volumes
- Symmetrical axial power profile
- Power tilt capability between all four corners of core ($\leq$3:1 ratio)
- Individual experiment parameter control for multiple tests in a single irradiation position
- Individual experiment control in separate loops
- Accelerated testing for fuels – up to 20x actual operation time for some fuel types
- No design limited lifetime: expected to operate for many more years
  - CIC outages – new reactor internals
  - Large stainless steel reactor vessel – minimal embrittlement



Center Flux Trap Flux Profile (125 MW)

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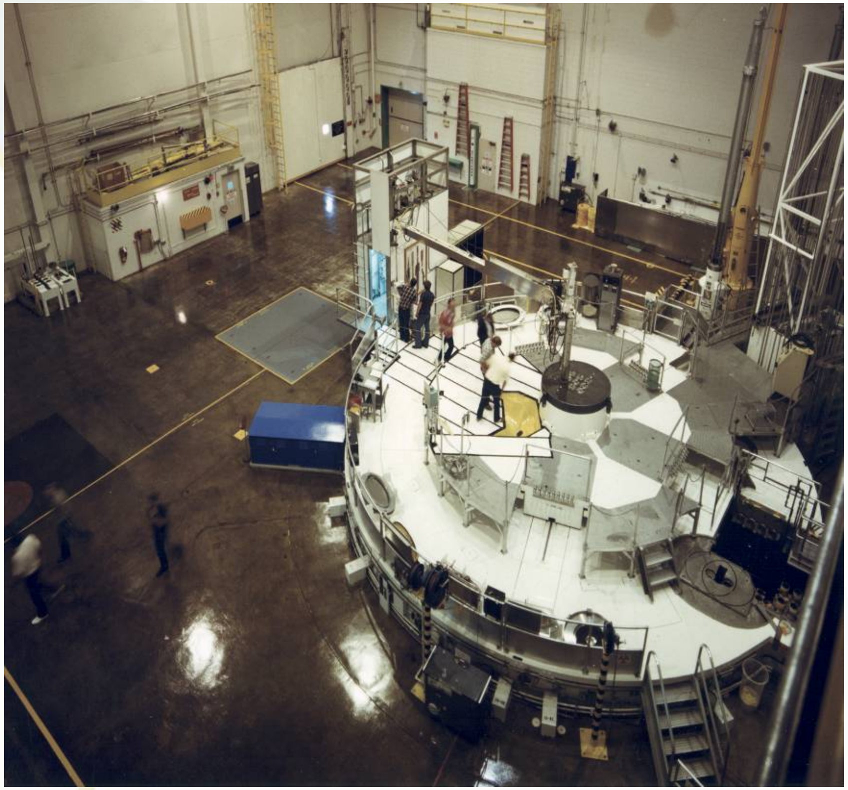
ATR Operations

- Operating Cycles
  - Standard operating cycle is 6 to 8 weeks
  - Occasionally short high power cycles of 2 weeks
  - Standard reactor outages are 1 or 2 weeks
  - Operations for approximately 250 days per year
- Core Internals Changeout (CIC), every 7 to 10 years
- ATR Critical Facility – used for reactivity measurements



Experiment Configurations

Simple Static Capsules

- Reflector positions or flux traps
- Isotopes, structural materials, fuel coupons or pellets

Instrumented Lead Experiments

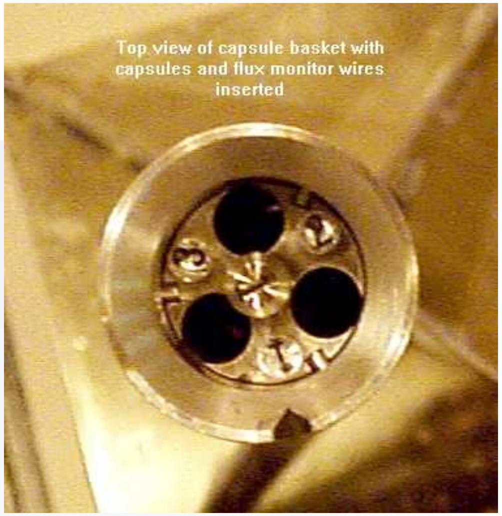
- On-line experiment measurements
- With or without temperature control
- Structural materials, cladding, fuel pins

Pressurized Water Loops

- Five presently installed in flux traps
- Control pressure, temperature, chemistry
- Structural materials, cladding, tubing, fuel assemblies

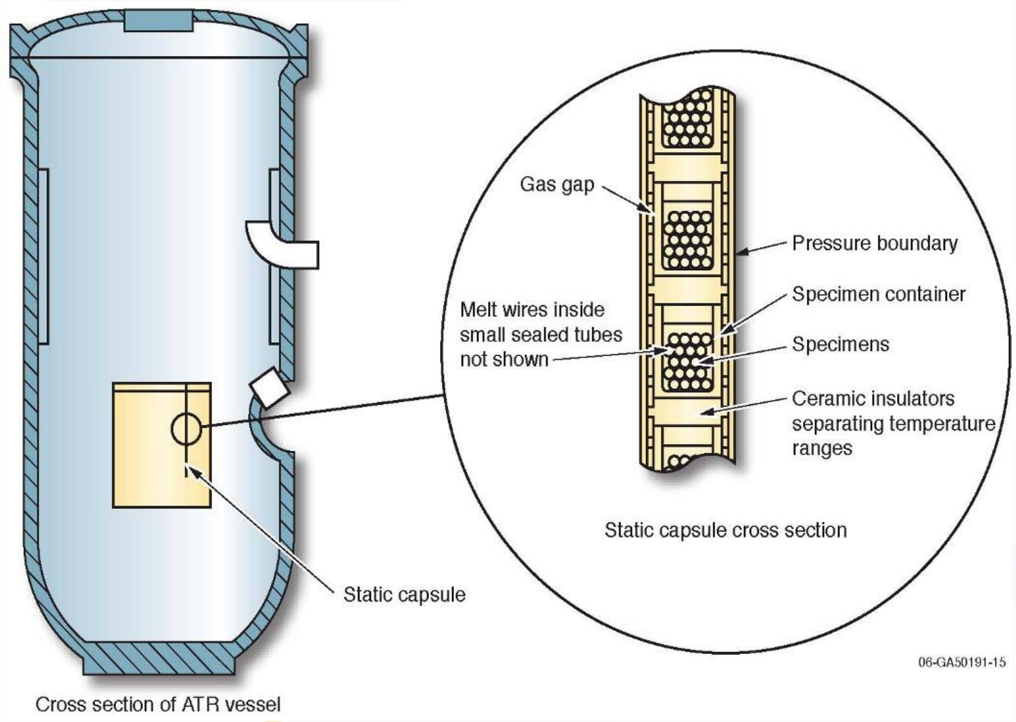
Hydraulic Shuttle Irradiation System

- 14 capsules in a set
- Inserted and removed during reactor operations

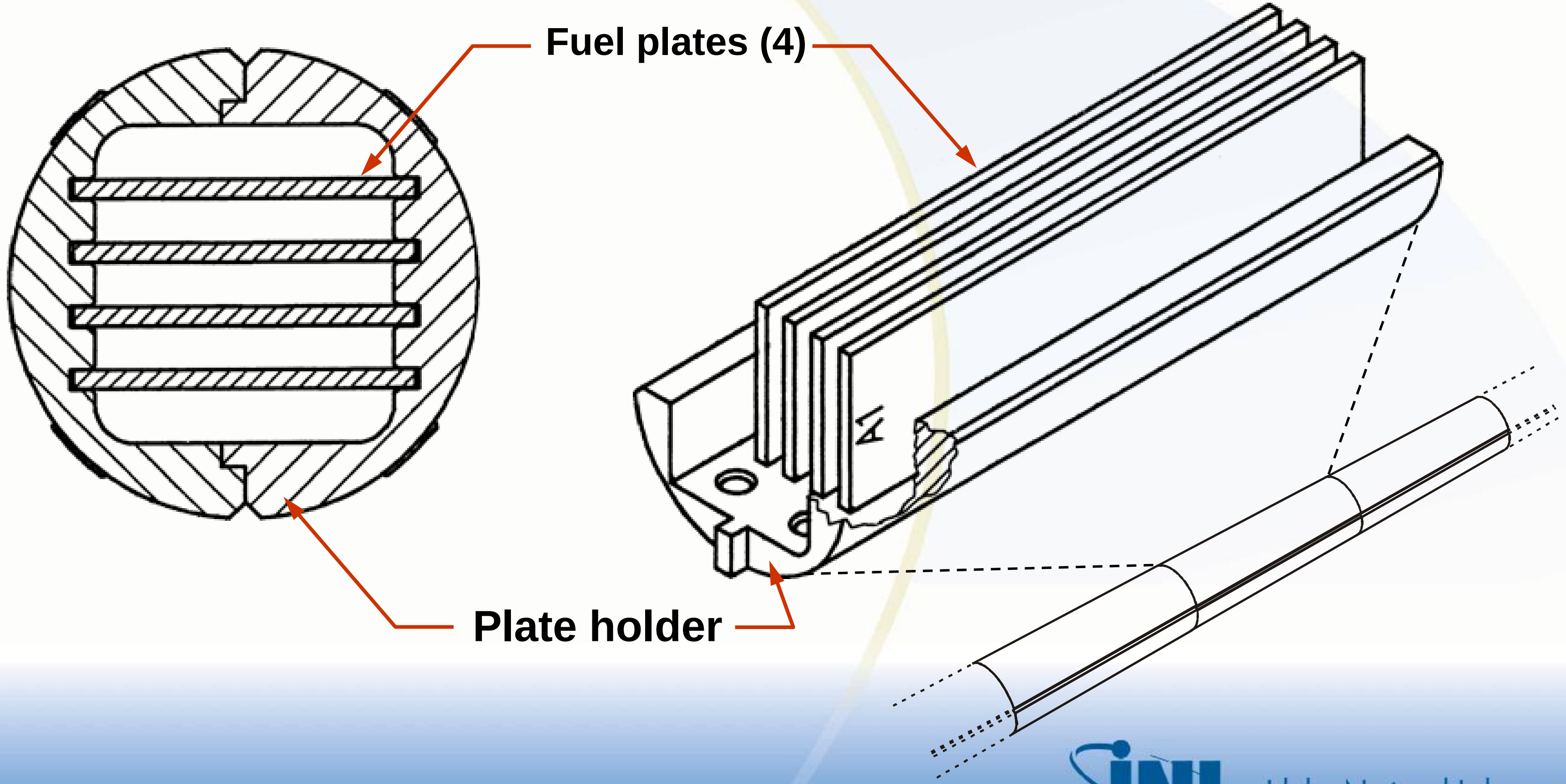


Simple Static Capsule Experiments

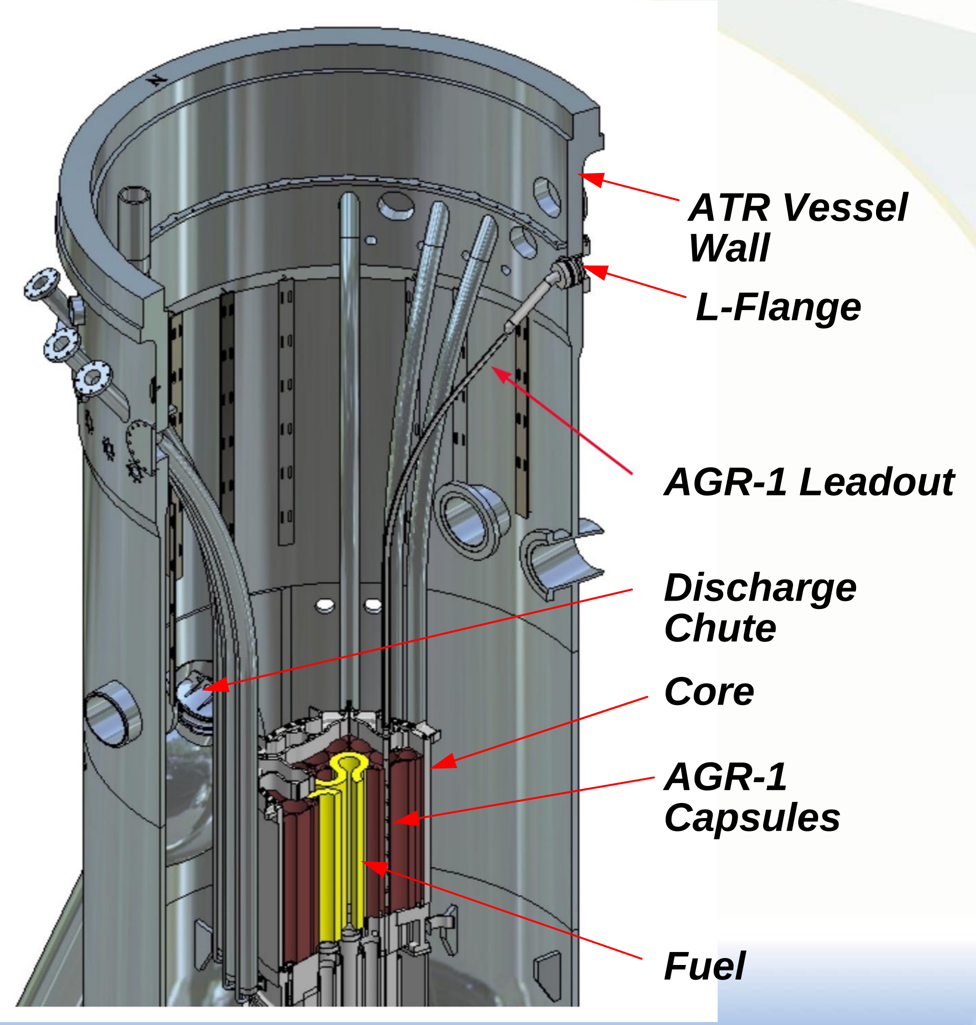
- Passive instrumentation (flux wires, melt wires)
- Enclosed in sealed tube, or fuel plates
- Temperature target controlled by varying gas mixture in conduction gap and with material selection
- Lengths up to 48”; diameter 0.5” – 5.0”
- Used for isotope production, fuel and material testing



Miniplate Fuel Capsule



Instrumented Lead Experiments



- On-line experiment measurements
- Temperature control range 250-1200°C, within +/- 5°C
- Monitoring of temperature control exhaust gases for experiment performance (e.g., fission products, leaking materials, etc.)
- Specialized gas environments (oxidized, inert, etc.)

Pressurized Water Loop Tests

- Five flux trap positions currently have pressurized water in-pile loop tests (1 large diameter, 4 small diameter)
- Separate from ATR primary coolant system
- Each loop has its own temperature, pressure, flow, and chemistry control systems – can exceed current PWR operating conditions
- Transient testing capabilities (cycle/seconds)
- Potentially feasible to simulate boiling water reactor void conditions

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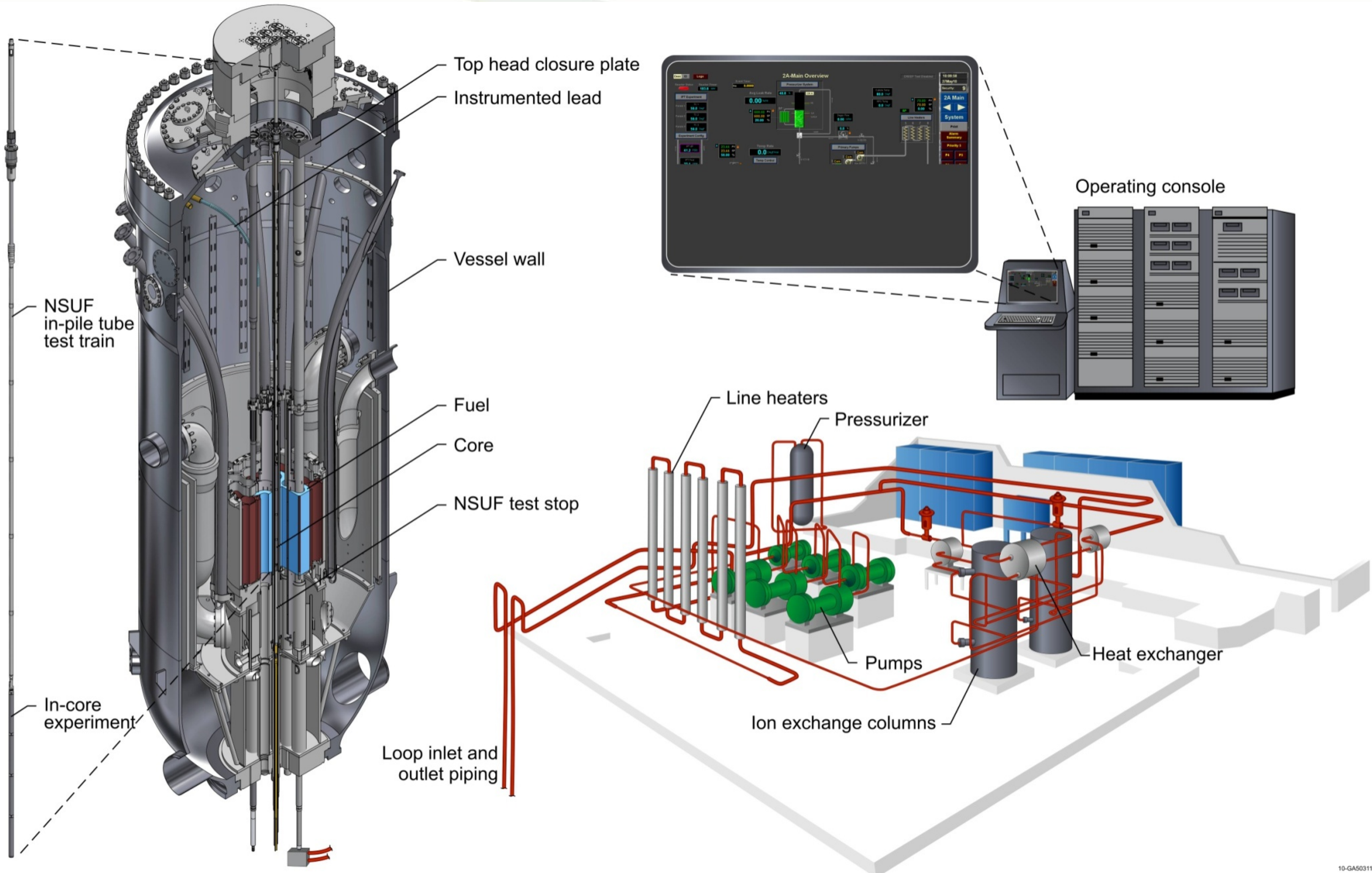
PWR Loop Layout



Hydraulic Shuttle Irradiation System

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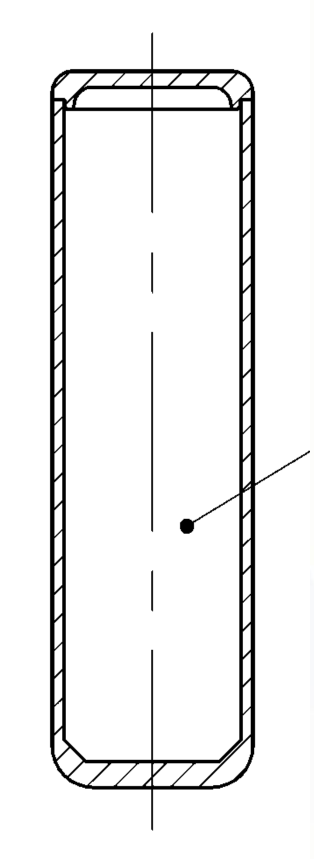
- 14 shuttle capsules
- Simultaneously irradiated
- Flux, at 110 MW:
  - Thermal: 2.5E14 n/cm^2-s
  - Fast (>1MeV): 8.1E13 n/cm^2-s
- Dimensions:
  - ~ 0.55" ID, ~2.1" IL
  - ~ 7 cc useable volume
- ~35 gm Contents
- Shuttle Wall Temp:
  - ~ 180 F to 240 F
- Max. Internal Pressure
  - < 215 psig



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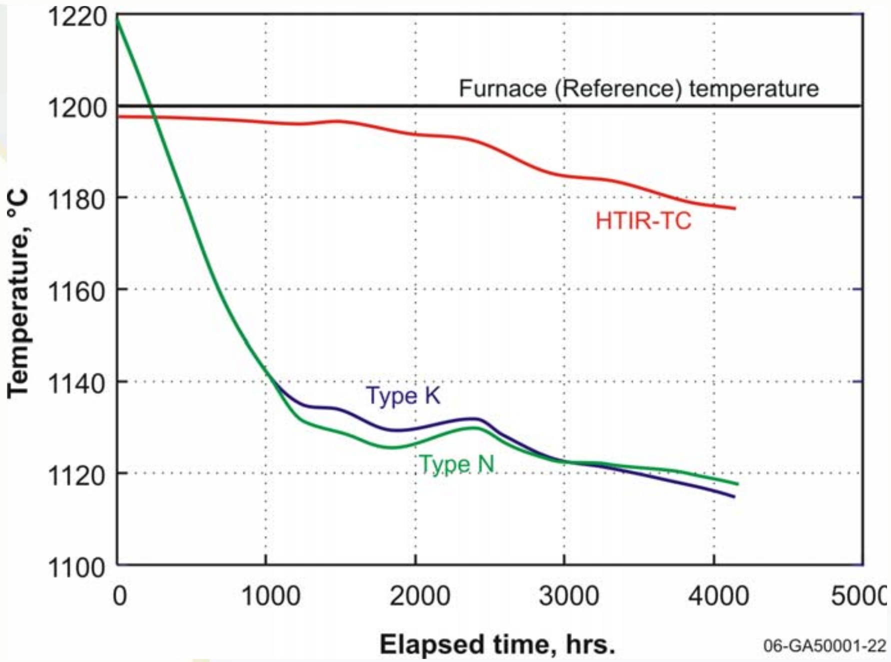
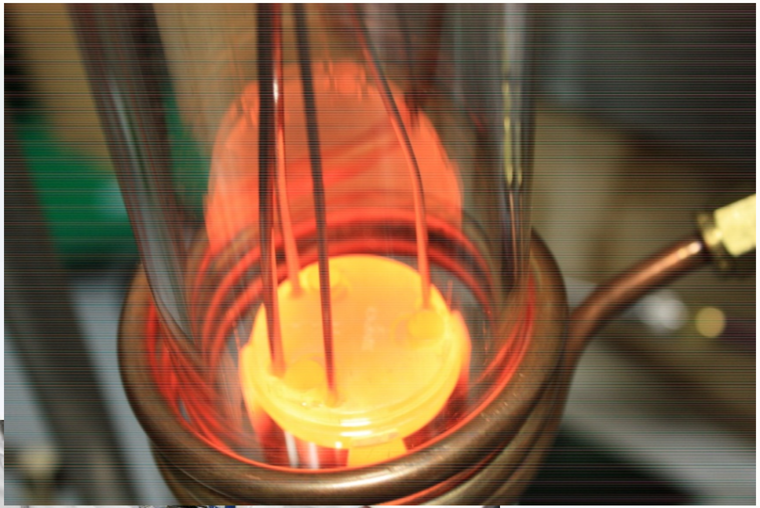
Experiment Measurement Capabilities

- Flux Wires
  - Co-Al
  - Fe-Ni
  - Others
- Thermocouples
- Tritium Monitors
- Moisture Monitors
- Fission Product Monitors
- Specimen Creep
  - Tension (in development)
  - Compression
- Oxidation Measurements on Graphite Experiment



Test Train Assembly

- Induction brazing of instrument leads (e.g. thermocouples) to penetrate capsule boundaries
- Electro-plating, typically in support of induction brazes
- Thermocouple splicing
- Heat treatment and (specimen) vacuum drying ovens
- Welding - Standard GTAW and MIG, tube welder
- Pressure and helium leak testing
- Laser micrometer



Previous Research Programs in the ATR

- Naval Reactors Fuels and Materials
- Material and Fuels for High Temperature Gas Reactor in 1990's
- Graphite Oxidation and Aging Studies for Magnox
- Pu-238 Production Studies
- Weapons Grade Mixed Oxide Fuel
- Reduced Enrichment for Research and Test Reactors (RERTR) – High Density, Low Enrichment Fuel
- Plant Maintenance Technology & Welding of Irradiated Materials

AFCI Flux Spectra with Cadmium Sleeved Basket

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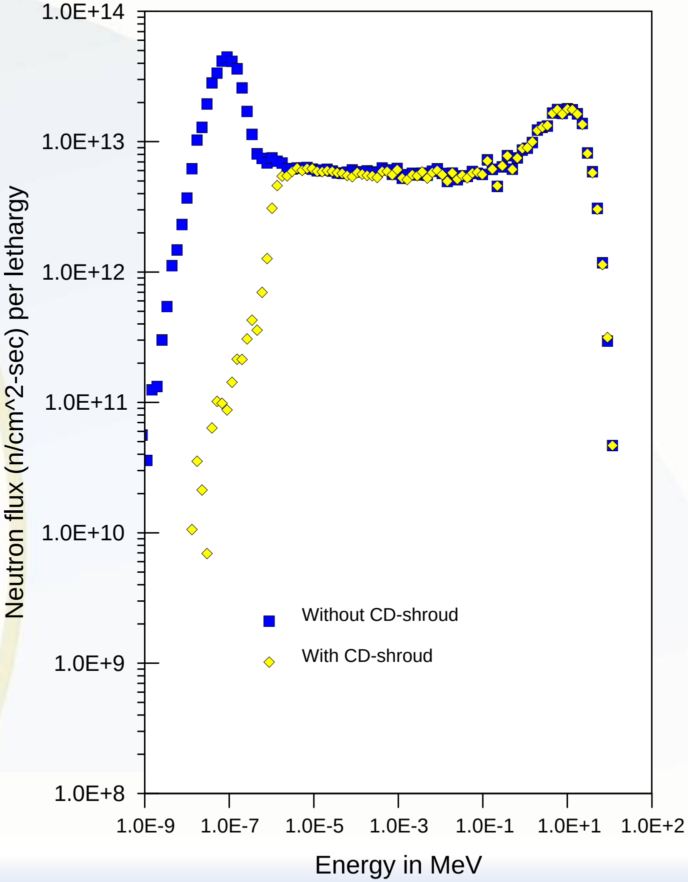
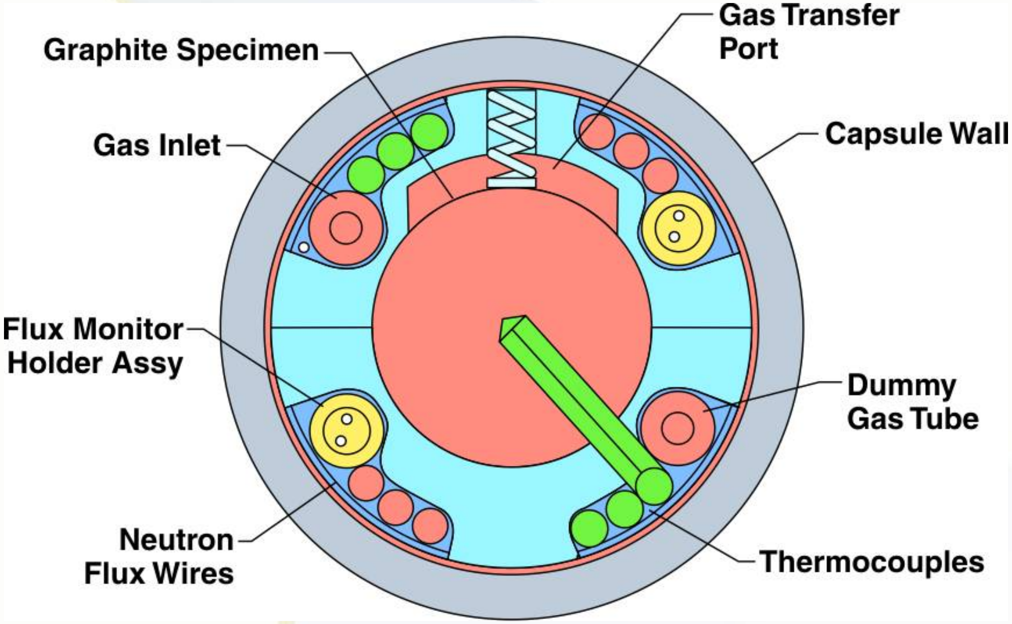
- Hard Spectrum Achieved in ATR by Use Of .045 inch Thick Cadmium
- > 97% of Thermal Flux is Removed

	Thermal neutron flux (E < 0.625 eV) n/cm^2-sec	Fast neutron flux (E > 1.0 MeV) n/cm^2-sec
With CD-shroud	8.46E+12	9.31E+13
Without CD-shroud	3.71E+14	9.39E+13
Ratio	2.28%	99.14%
Note: the flux tallies are normalized to a E-lobe power of 22 MW.		



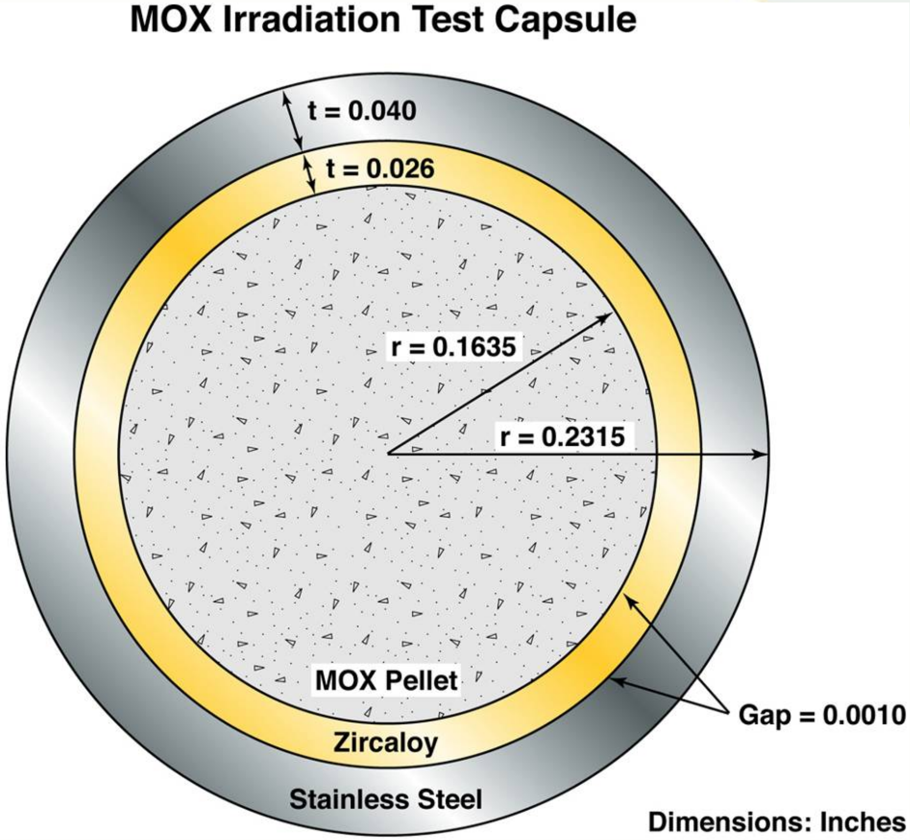
Magnox Generation Graphite

- Experiment Purpose – Better understanding of Magnox gas reactor graphite density losses and fast fluence damage to support life extension of Magnox power stations in UK
- Standard Magnox graphite PIE specimens (Ø12 mm x 6 mm thick)
- Fast neutron dose of 18 x 10^{20} n/cm^2 (E>0.1 MeV)
- Two equal size capsules - one oxidizing & one inert, minimize all other differences (e.g. mirror images about ATR core centerline)



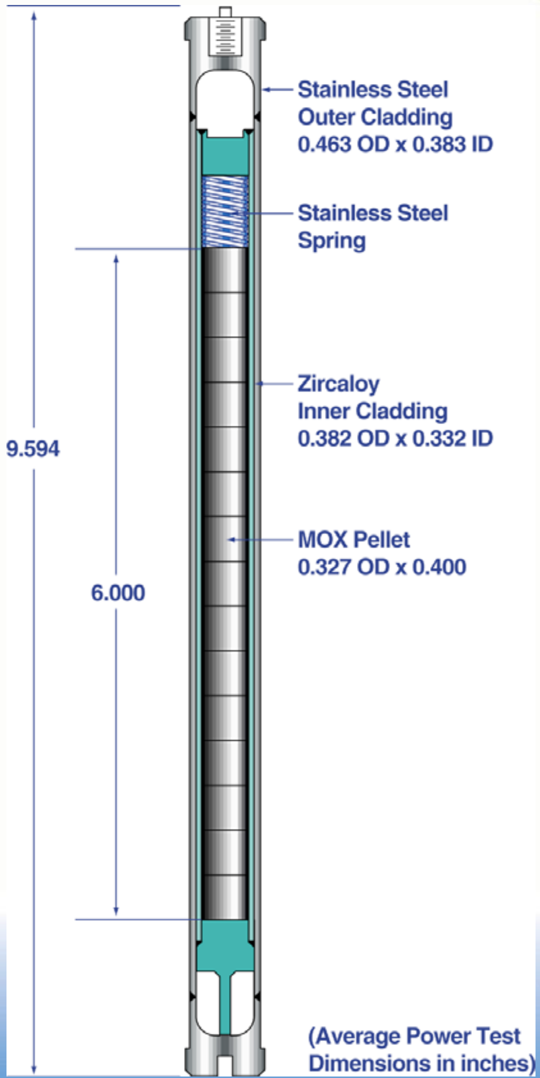
Capsule Cross Section

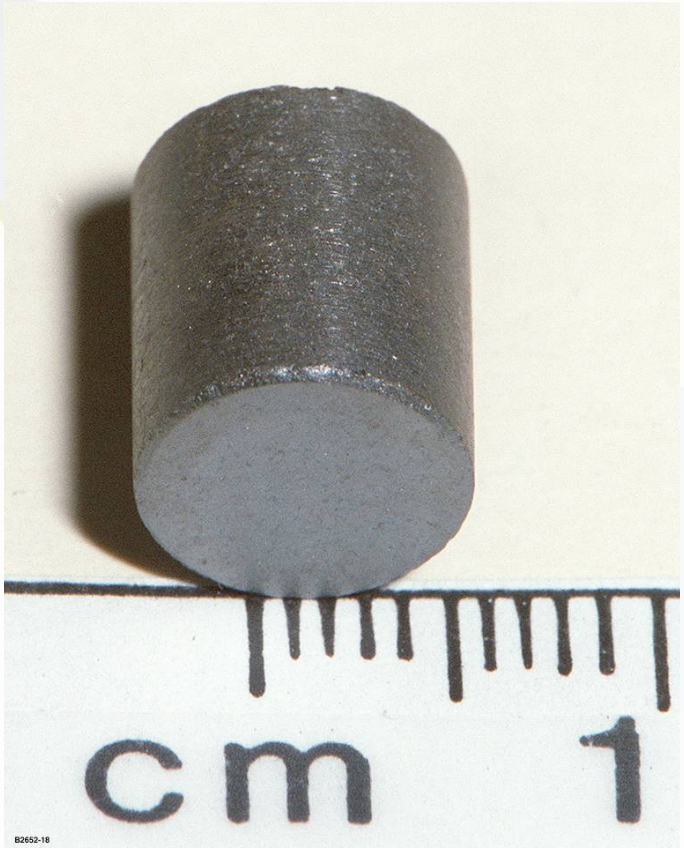
Mixed Oxide (MOX) Fuel Irradiation



- Purpose: Obtain Mixed Oxide Fuel (MOX) fuel and cladding irradiation performance data
- PWR temperature at surface of fuel pin cladding
- Zircaloy fuel pin
  - 15 MOX fuel pellets
  - Fission gas chamber
  - Spring to limit pellet movement
- Stainless steel capsule
- Capsule designed to ASME Section III Class 1 requirements
- Small (0.001”) insulating gas gap between fuel pin and capsule provided desired temperatures

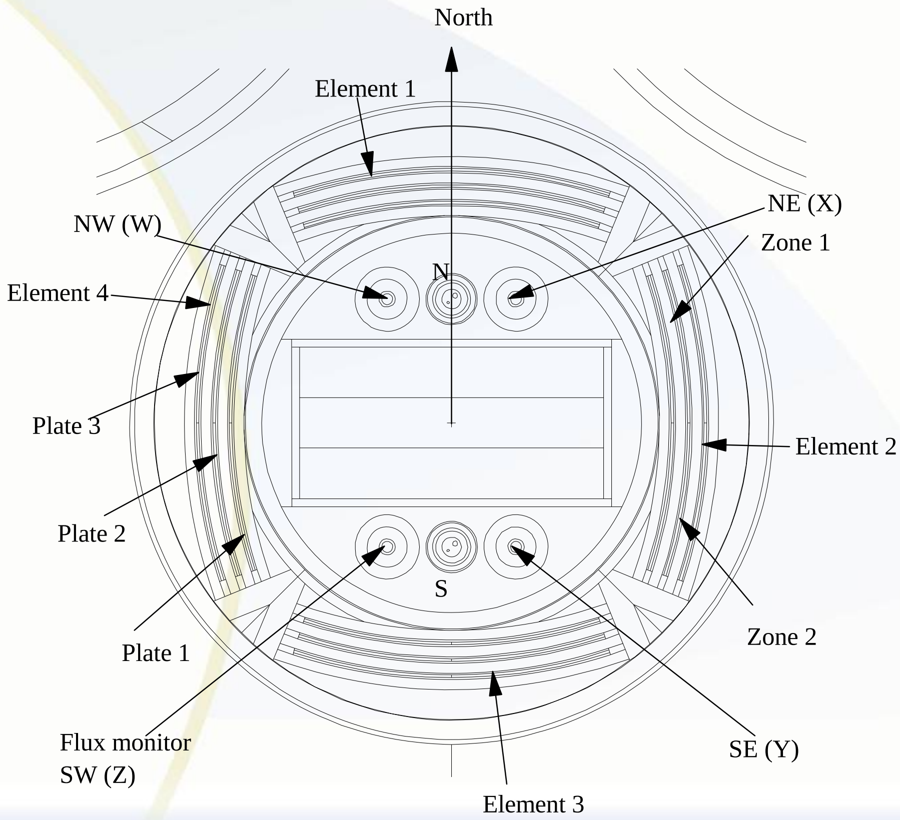
MOX Test Fuel Pellets





Flux Enhanced Large I Test (FELI)

- Purpose: To Test Reactor Pressure Vessel Steels for Material Embrittlement Studies
- Need Large Test Specimens for Material Tests
- Low Fast Flux in I Positions
- Added Fuel in Test Configuration
- Fast Flux Enhancement ~4.3x Fast Flux without Fuel



Current ATR Irradiation Projects

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- Naval Reactors Materials
- Advanced Fuel Cycle Initiative
- NGNP, Particle Fuel and Graphite
- University NSUF Materials & Fuels
- Tritium Barrier Material
- RERTR Fuel
- Cobalt-60

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ATR Critical Facility (ATRC)

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- ATRC is Geometrically Similar to ATR, Designed for 5kW, Operated Usually <600W
- Mission is to Obtain Nuclear Characteristics Data of Experiments
- Measurements Include
  - Rod Worths
  - Rod calibrations
  - Excess reactivities
  - Neutron flux distribution
  - Gamma-heat generation rates
  - Fuel loading requirements
  - Effects of the insertion and removal of experiments

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ISU/CEA/INL Project Investigating Use of Real-time In-core Flux Detectors in ATRC

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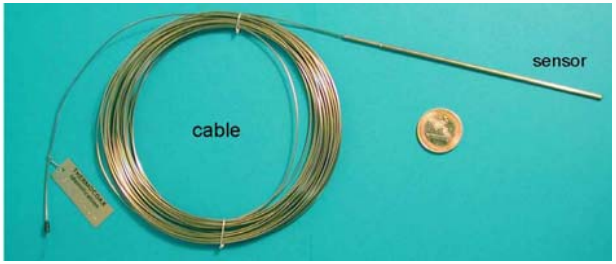
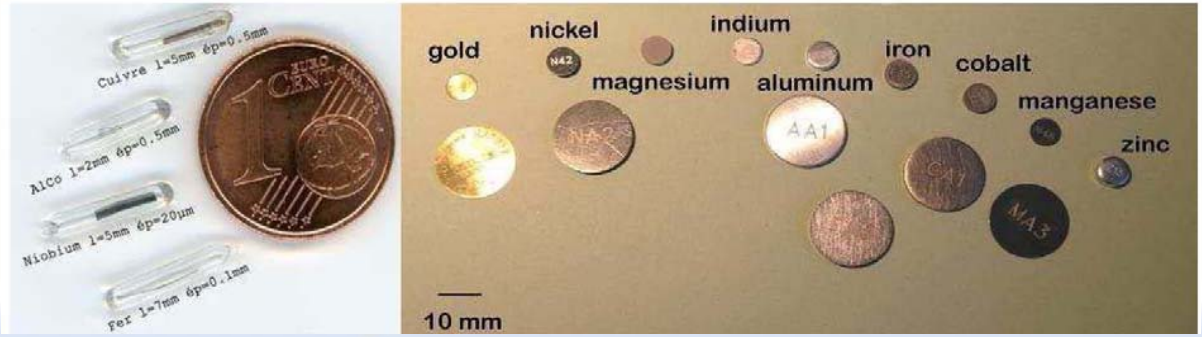
CEA fission chambers



SPNDs

BTB fission chambers

- Fast and thermal flux measurements obtained from foils, wires, SPNDs, and fission chambers
- Sensors cross-compared for response time, accuracy, and longevity.
- Data ultimately will allow development of real-time 3D ATRC core map



Flux wires and foils

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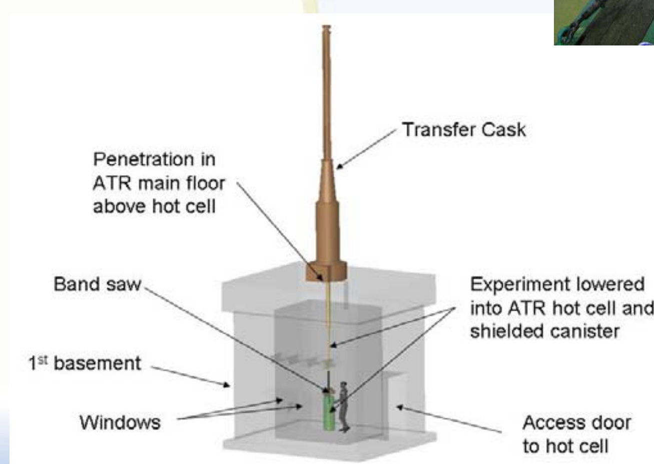
Capsule Handling and Packaging

- Primary Shipping Container is GE-2000
- Most Experiments are Wet Loaded in ATR Canal
- New Capability to Dry Load
- INL Investigating Alternate Shipping Containers



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ATR Analysis and Modeling Upgrades

- Seeking Increased Accuracy and Flexibility in ATR Core and Experiment Modeling
- Initiated in FY 2009 to Develop New ATR Analytical Tools
  - Develop 3D models with existing codes - Helios, Attilla, SCALE/NEWT, MCNP
  - Validation against ATRC, ATR experiments, and ATR fuel
  - Identification of ATR in-core instrument needs
- Key Activities Completed
  - Helios fuel depletions for 4 ATR cycles
  - ATRC tests- establish measurement instruments, test configuration
  - In-canal instruments for fuel burnup measurements, good correlation
- Future Plans – Planned completion in 2014
  - Continued Helios fuel depletions in 2011, in parallel with PDQ
  - Additional testing in ATRC – develop ATRC test criteria vs. analysis
  - Focus on integration and standardization with established industry codes

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Future Activities for the ATR

- Next CIC tentatively scheduled for 2015
- Reactivation of Pressurized Water Loop
  - PWR testing for LWR industry
  - Possibly BWR testing
- Experiment Instrumentation Development
- Expanded Experiment Offerings
- ATR Life Extension and Modernization Projects
- Core Physics Modeling Upgrades, ATRC Testing

ISU Lab in ATR Critical Facility

Summary

- ATR has Unique and Versatile Capabilities
  – High flux/large test volumes
  – Simultaneous tests in different testing environments – power and flux tilt
  – Constant Axial Flux Profile
- ATR Expected to Operate for Many Years
- INL and DOE Investing in ATR Facility and Experiment Capability Enhancements
  – PWR Loop Reactivation
  – Modeling Tool Upgrades
  – Hydraulic Shuttle Irradiation System Installation
  – Instrumentation Development
  – New Test Train Assembly Facility
  – Life Extension and Facility Upgrades