MIT NUCLEAR REACTOR LABORATORY

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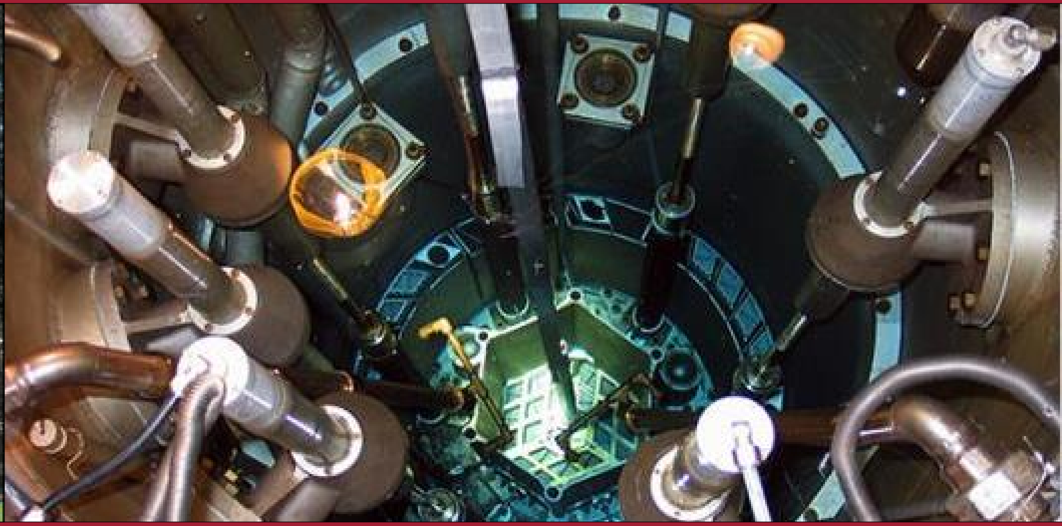

Startup Plan for Initial LEU Fueled Core of MIT Reactor

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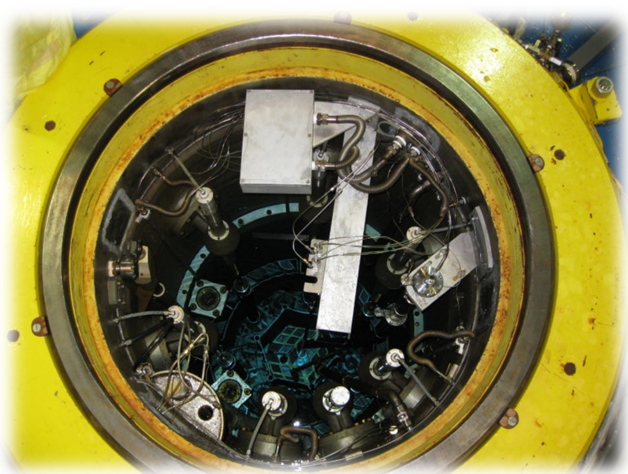
MIT Nuclear Reactor Laboratory

- MIT-NRL is an interdepartmental laboratory with missions in nuclear technology applications, neutron science research, and training/education.
- Primary facility is MIT Reactor (MITR), a multi-purpose research reactor owned and operated by MIT. A partner facility of DOE's *Nuclear Science User Facilities (NSUF)*.
- Constructed in 1958 (MITR-I), upgraded in 1975 (MITR-II) with a new core tank.
- Uprated from 5 MW to 6 MW_{th} (2^{nd} largest university reactor in US) in 2010.
- Compact core with power density similar to an LWR. Operates 24/7, up to 10-week cycles.
- Tank-type, light water cooled and moderated, D_2O and graphite reflector.
- Excellent track record in in-pile irradiation experiments including LWR loop, fuel, high-temperature materials, and molten salt irradiations.



Startup Plan for Initial LEU Core

Reactor Conversion Program is working to convert MITR-II from highly enriched uranium (HEU) fuel to low enriched uranium (LEU) fuel. The primary changes due to the conversion:

- Fuel element design is changed from 15-plate finned HEU fuel to 19-plate unfinned LEU fuel
- Reactor operating power increases from 6.0 MW to 7.0 MW,
- Primary coolant flow rate increases from 2000 gpm to 2400 gpm.

MITR-II LEU core startup plan:

- Follows the pre-operational testing, criticality studies, start-up experiments and stepwise power increase tests outlined in the MITR-II Start-up Report after it major modifications.
- As the existing systems and extensive operational experiences acquired during several decades of operations, only confirmatory tests will be performed for auxiliary systems that will be not be affected by LEU fuel conversion (heavy water reflector, shield cooling system).
- Main sections of the MITR-II LEU core startup plan:
    - Pre-operation testing: cold operational test of process systems
    - Criticality studies: evaluation of the initial fresh LEU fuel loading
    - Startup experiments: planned measurements during stepwise power increase

Pre-Operation Testing

Process System

- **Primary H_2O System:** Existing main pumps, piping, and main heat exchanger will be evaluated and upgraded, as necessary, to achieve 2400 gpm (tested at 2500 gpm)
  - Flow-induced Vibration
  - Heat Exchanger Upgrade
  - Core-Tank Overflow
  - Primary Flow Instrument Noise
  - Core Tank Pressure Increase
- **D_2O Reflector System:** reflector coolant flow rate meets requirement of > 75 gpm.
- **Secondary H_2O System:** secondary pumps are updated from 1600 to >2000 gpm
- **Shield Coolant System:** to confirm system coolant flow rate > 50 gpm.
- **Core Purge System:** to ensure the hydrogen concentration in the upper core tank air space is below the Technical Specification limit of 3.5 vol% during steady-state and transient, such as core purge blower trip.

Pre-Operation Testing (cont.)

Performance Testing and Inspection of Reactor Control

- Any new instrumentation in the LEU core will require testing and calibration.
- **Shim Blade Drop Time:** will be tested for each blade at primary flow rate of 2500 gpm

Performance Testing and Inspection of Reactor Building and Facility

- LEU conversion has no impact on the specifications, performance or testing requirements of the reactor building and facilities.
- **Fuel Element Storage & Handing Equipment:** must be sufficient for handling LEU elements
- **Other facilities:** ensure electrical power (pumps) / city water (cooling tower) sufficient

Fuel Element Inspection

- Element inspection procedures will need to be modified based on final LEU fuel manufacturing and labeling specifications when established. The revised procedures will include specific LEU fuel plates (i.e., F-Plate, Y-Plate, and T-Plate) verification to ensure proper identification

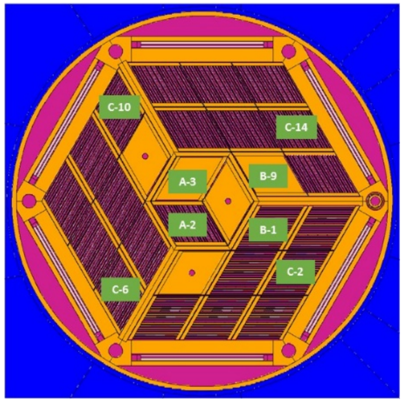
Pre-Operation Testing (cont.)

- **Experimental Facility Tests and Inspections**
  - Neutron flux characterization will be performed for irradiation facilities such as pneumatic tubes as part of the startup testing. Shielding for external beam lines need to be verified as approach to 7 MW is attained.
  - Silicon processing procedures may need adjustment on resistivity calculation procedures to account for changes in thermal flux at the corresponding thru-ports.
- **Engineered Safeguards Tests**
  - **Emergency Cooling**: estimated minimum flowrate required for LEU core is 9.5 gpm (comparing to 7.6 gpm for HEU), but there are two nozzles supporting 10 gpm each and hence, no modifications are required.
  - **Anti-Siphon Valves:** Design is unchanged, existing operating procedure will be used.
  - **Natural Circulation Valves**: Design is unchanged, existing procedure will be used.
  - **Hold-Down Grid Plate**: Design is unchanged.
  - **Operator Retraining:** covers process systems, core operating characteristics, fuel design characteristics, burnup & off-gassing characteristics, mechanical differences and fuel handling, limiting safety system setting changes and basis, and initial startup procedures.

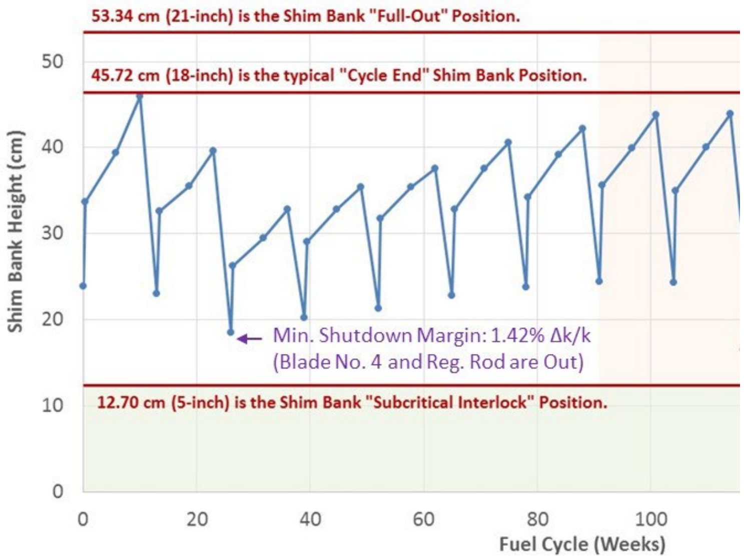
Criticality Studies

❑ Transitional Core Planning and Safety Analyses Results

➢ **Minimum Shutdown Margin:** the margin with the most reactive blade and regulating rod out is 1.42% Δk/k, which is notably higher than the 1.0% Δk/k limit per MITR Technical Specification.



➢ **Shim Bank Movement**: sufficient excess reactivity exists to conduct planned operation; and critical shim bank height is between 6 and 12 inches.



❑ Initial LEU Core Loading

➢ Be similar to special procedures established for MITR-II initial startup and non-routine refueling using Pu-Be neutron source.

➢ Criticality check will be performed for each fuel element added after 15 fuel elements have been inserted to C-ring positions

Startup Experiments

Startup Experiments will be conducted after initial LEU core loading to

(1)Verify that operation of the reactor is in compliance with Technical Specifications

(2)Obtain operational data to confirm the operating characteristics of the reactor

(3)Confirm operability of nuclear instruments at higher power

- **Fresh Core Reactivity (Criticality) Test:** measured to confirm critical shim bank position
- **Shim Blade and Regulating Rod Calibrations:** reactivity calibration methods unchanged
- **Reactor Control Stability with Normal Primary Coolant Flow:** check power fluctuations
- **Heavy Water Reflector Dump Reactivity Worth Measurements:** confirm reactivity worth
- **Void Coefficient Reactivity Measurements:** effect of displacing the moderator
  - In the active core
  - At core edge
  - In the heavy water reflector blister tank
  - Void Coefficient in Graphite Reflector
- **Temperature Coefficient Measurements**: to confirm the "combined" coefficient with uniform temperature in both primary light water and reflector heavy water is negative.
- **General Reactivity Studies:** to confirm various experimental facilities
- **Neutron Flux and Core Power Mapping:** performed using activation wires for thermal and fast neutron flux measurements and/or utilizing self-powered neutron detectors

Stepwise Power Increase Tests

Stepwise Rise to 7 MW will be conducted using special procedures developed for MITR-II power ascension tests from 5 to 6 MW under the supervision of senior licensed operators assisted by the experienced staff, maintenance personnel and radiation protection personnel.

- **Radiation:** All monitoring systems are in scale and no Tech Spec or regulatory limits are exceed. Non-occupational and occupational radiation exposure comply with ALARA.
- **Temperature:** At full power, T(coolant outlet) < 55 ^{o}C; T(medical water shutter) < 70 ^{o}C; T(blister tank) < 60 ^{o}C. Reflector tank temperature < 55 oC with flow at Tech Spec limit of 75 gpm. Shield coolant temperature < 47 ^{o}C with flow at Tech Spec limit of 50 gpm.
- **Instrumentation:** Neutron channels and automatic control systems will be checked. Radiation monitor trip settings will be established appropriately.
- **Fission Product Poisoning:** Xenon poisoning buildup and decay curves will be determined at full power. Reactivity effect of U-235 burnup will be determined.
- **Nuclear Safety System:** must meet operational requirements over the full operating range
- **Natural Convection Heat Removal:** surface temperature < ONB at 100 kW steady state and the maximum fuel temperature < 350 ^{o}C (fuel blistering) for loss-off flow scenario.

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