The MIT Research Reactor as a National User Facility for Advanced Materials and Fuel Research

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Overview of the MIT Nuclear Reactor Laboratory

- The MIT Nuclear Reactor Laboratory (NRL) is an interdepartmental laboratory that operates a 5 MW research reactor (MITR-II) in support of MIT's education and research objectives.

- It has a long history of providing faculty and students from MIT and other institutions with a state-of-the-art neutron source, infrastructure and a experienced staff to support research in nuclear fission engineering, radiation effects in biology and medicine, neutron physics, digital control of reactors, and geochemistry and environmental studies.

- The MITR is one of the few university research reactors in the U.S. where students can be directly involved in the development and implementation of nuclear engineering experimental programs with neutron flux levels comparable to power reactors.

MIT Research Reactor

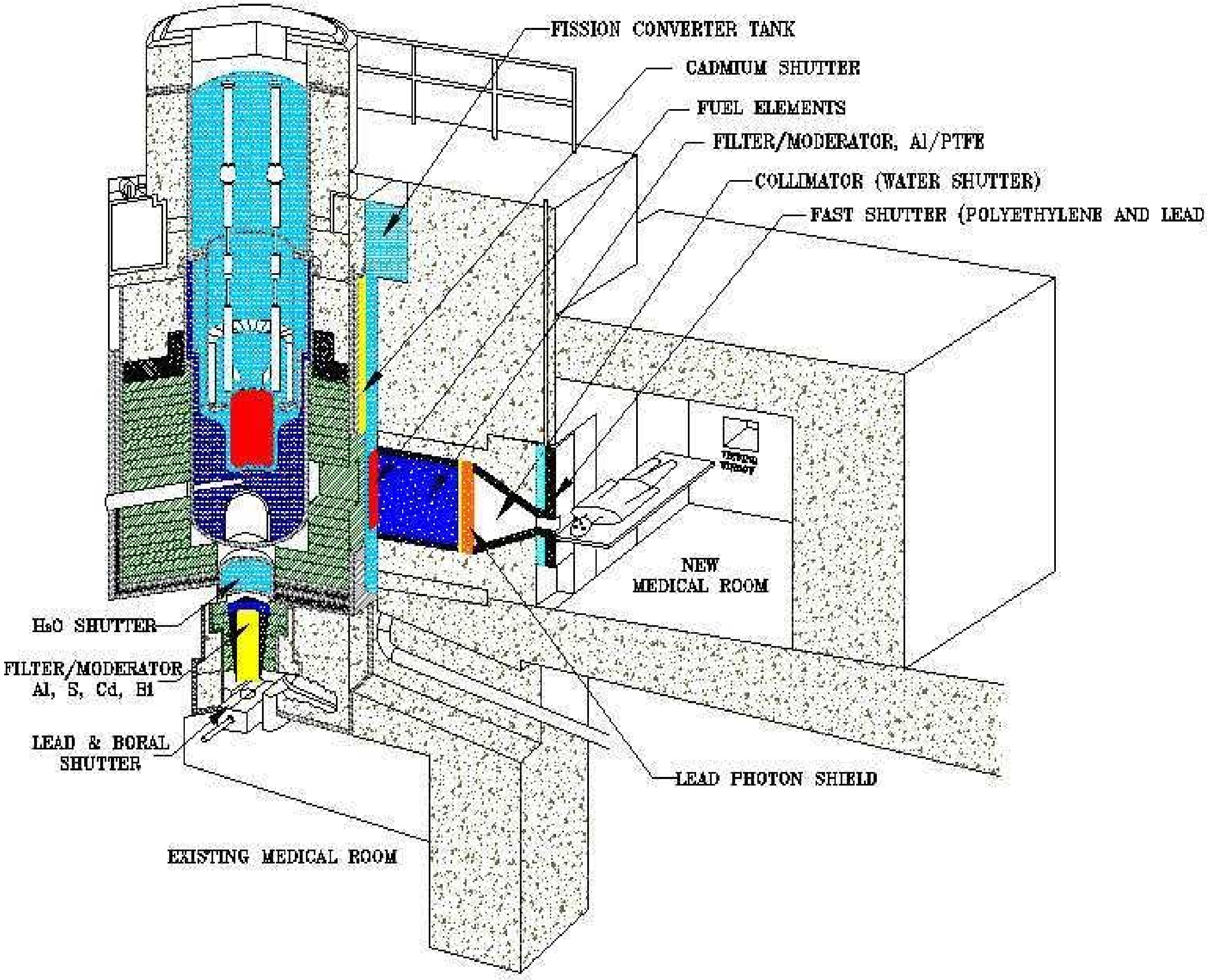
- The MIT reactor is a 5 MW tank-type reactor that is light water cooled and moderated and heavy water/graphite reflected. The in-core thermal and fast fluxes are 3×10^{13} and 1×10^{14} n/cm^2-sec, respectively. These flux levels are comparable to a commercial light water reactor. Up to three positions are available for in-core experiments.

- The MITR is licensed to irradiate fissile materials up to 100 gm of U-235 or equivalent.

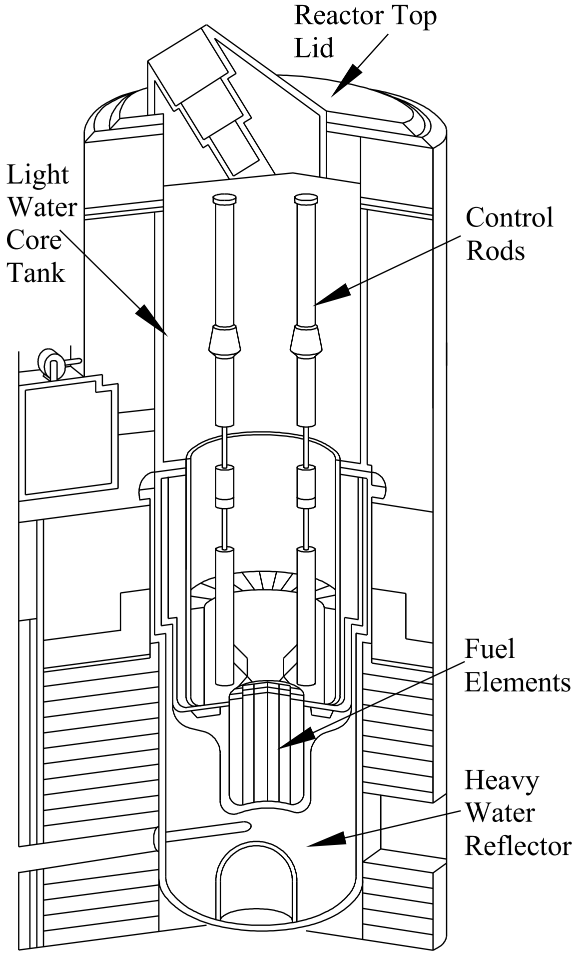
- The MITR has submitted a license renewal to NRC for a power uprate from 5 MW to 6 MW. Operation at 6 MW is expected to increase neutron fluxes by 20% in the various experimental facilities.

- The MITR is operated 24 hours a day, 7 days a week, with regularly scheduled outages for refueling and maintenance.

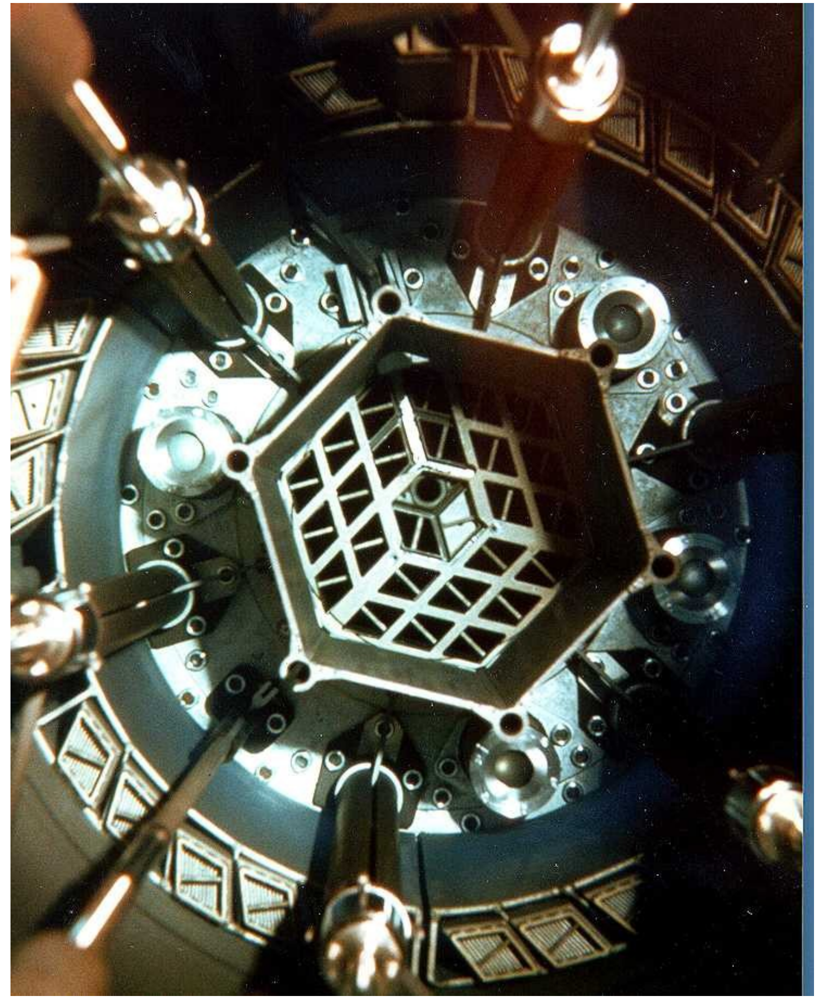
- Major equipment upgrades are ongoing such as the replacement of cooling towers, area radiation monitors, main pumps and heat exchangers.



Schematic view of the MITR and its two medical rooms



Cross-sectional view of MITR core tank



Top view of the MITR core tank

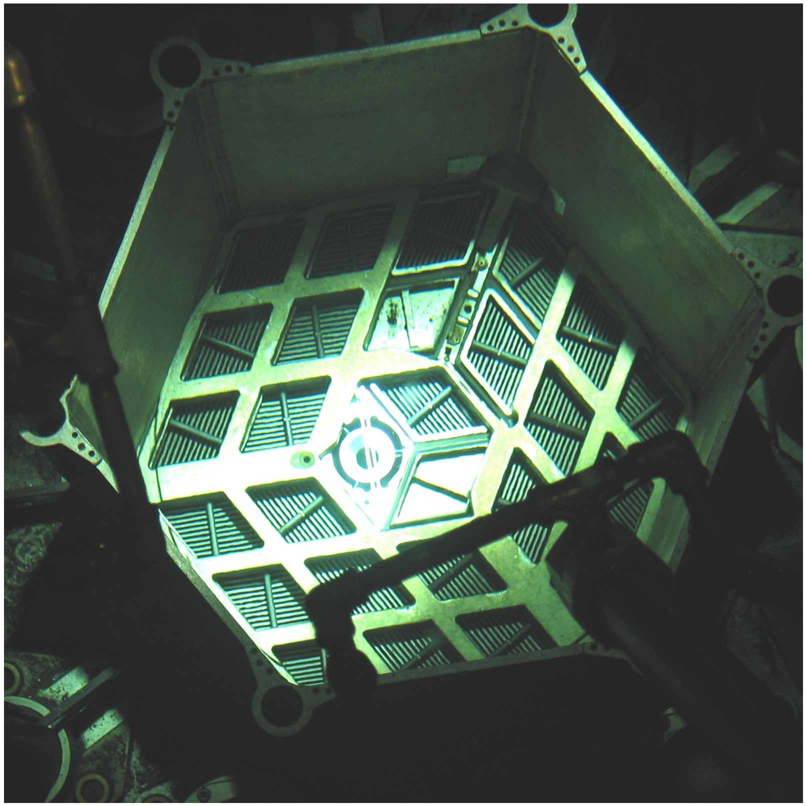
MITR Experimental Facilities

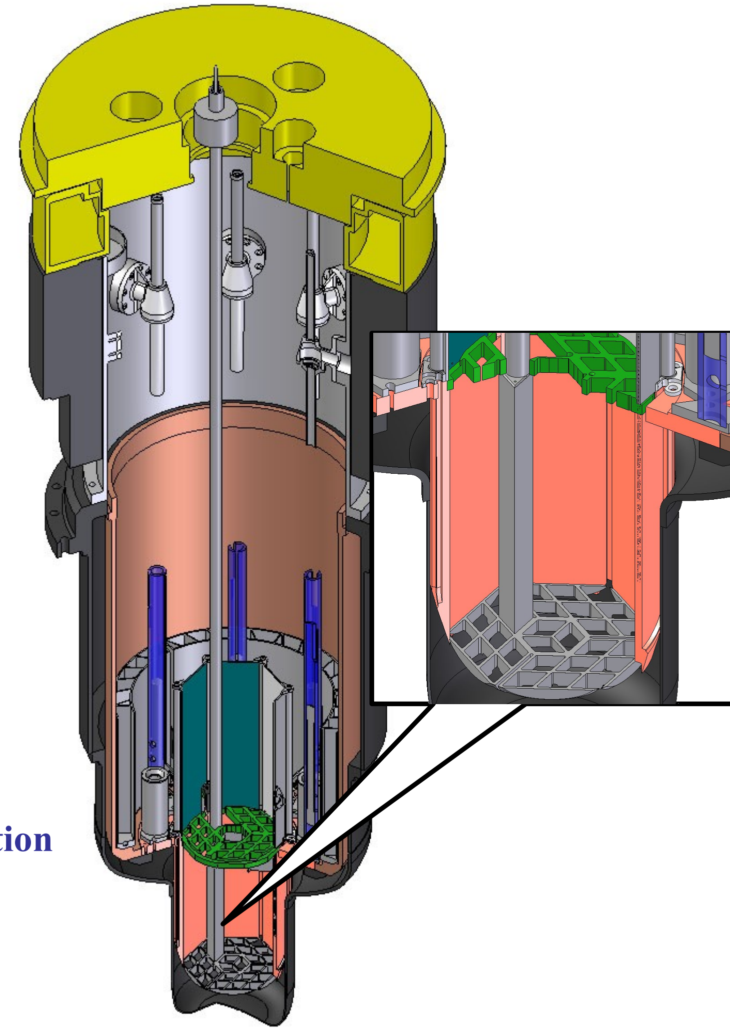
- 15 beam ports available for research and educational use.
- Automatic transfer facilities (pneumatic tubes) that allow samples to be exposed to various neutron fluxes.
- Graphite-reflector irradiation facilities comprise of vertical thimbles that penetrate the graphite reflector that surrounds the MITR. These facilities are normally used for the activation of geological samples that require a uniform neutron flux.
- Neutron Capture Therapy (NCT) User Facility is comprised of:
  - Epithermal neutron irradiation facility which is licensed by the NRC and has an intensity of ~5 x 10^9n/cm^2-sec with low inherent beam contamination which approaches theoretical optimum.
  - Thermal neutron irradiation facility which has high intensity, ~1 x 10^{10}n/cm^2-sec, and low contamination thermal neutron beam.
  - Prompt Gamma neutron activation analysis facility.
  - Irradiation facility for use in high-resolution track etch autoradiography.

MITR Materials and In-Core Loop Capabilities

- The MITR has a strong in-core experiment program that supports research in the areas of advanced materials and fuels which are necessary for both existing and Gen-IV reactors.
- The MITR offers a unique technical capability that involves the design and operation of in-core loops that replicate LWR conditions to study materials behavior and water chemistry.
- The MITR is one of the best suited university reactors for carrying out such basic studies because of its relatively high power density (similar to an LWR).
- The irradiation tests suitable for the MITR are screening/scoping studies and those require thermal/fast neutron flux similar to a power reactor. While similar studies could in principle be carried out at certain national laboratory reactors, the costs are far greater.

Facility	In-Service	Objectives of Experiments
PWR Coolant Chemistry Loop	1989	Measure the effect of pH on corrosion product transport and ex-core radionuclide deposition to optimize PWR chemistry specifications.
BWR CCL	1990	Evaluate effect of chemical additives on N-16 carryover.
Irradiation Assisted Stress Corrosion Cracking	1990	Test the effects of coolant chemistry on IASCC of BWR alloys.
SENSOR	1994	Test in-vessel detectors related to O_2 potential in BWR primary coolant.
Shadow Corrosion	1999	Test clad samples and counter materials at varying gaps under BWR conditions.
Ceramic Clad	2000	Test ceramic fiber composites as potential cladding materials under PWR conditions .
Annular Fuel	2004	Evaluate annular fuel including the manufacturing process.
Shadow Corrosion	2004	Test clad samples and varying chemical condition effects on shadow corrosion.
Electro-Chemical Potential	2004	Evaluate the electrochemical environment in the Shadow Corrosion test rig.





Above: Top view of the MITR core. One of the two in-core irradiation positions in the center region (A-ring) is an annular dummy that replicates an internally and externally cooled fuel capsule. Another irradiation location is available in the intermediate region (B-ring).
Right: This schematic depicts an in-core irradiation facility that extends through the top lid. The water level above the reactor core is about 10 ft.

MITR Materials and In-Core Loop Capabilities (Cont.)

- The MITR is equipped with post-irradiation examination (PIE) facilities to support its advanced materials and fuel research program that include:
  - Two top-entry hot cells with manipulators (1000 Ci capacity each),
  - A lead shielded hot box (20 Ci capacity) with manipulators,
  - An overhead crane at 3-ton and 20-ton capacity, and
  - Several transfer casks.

- A fracture toughness testing capability is available to support irradiation testing.

- Hot cell facilities can accommodate a Charpy testing machine that could be used for on-site testing of irradiated materials.

- The PIE facilities are currently being refurbished with DOE’s INIE funds. Additional equipment upgrade/purchase to support PIE, such as manipulators, alpha detectors, ventilation, etc. are also being funded by DOE’s INIE.

MITR Advanced Materials and Fuel Research Survey

- The survey package includes an invitation letter from detailing our goals of establishing a national user facility for advanced materials and fuel research, a brochures describing our in-core irradiation facilities, and a survey form.

- We collected a survey database that consists of about 150 researchers from DOE lab, industry, and universities who might have an interest in using the MITR to support their research projects. (Their on-going research projects and current funding support were not taken into account.)

- The survey package was mailed and emailed around late May through early June. 25 replies were received as of July 31, 2005.

MITR Advanced Materials and Fuel Research Survey (Cont.)

- **Summary of survey results:**
  - **The following organizations will potentially benefit from access to the MITR (asterisk denotes the organizations that responded to the survey):**
    - **MIT (NSED)*, Univ. of Wisconsin-Madison*, University of Nevada- Las Vegas*, Texas A&M*, University of Illinois*, Univ. of Michigan, Idaho State Univ., U of Florida, Auburn Univ.**
    - **INL*, ANL, PNNL*, Los Alamos National Lab*, BNL, ORNL, Sandia National Lab**
    - **Westinghouse*, General Atomics, Gamma Engineering*, NovaTech International, COI ceramics inc.*, Giner inc.*, Payload Systems Inc*.**
    - **KAPL expressed interests in using the MITR for their future research but was not able to respond to our survey due to laboratory policy.**

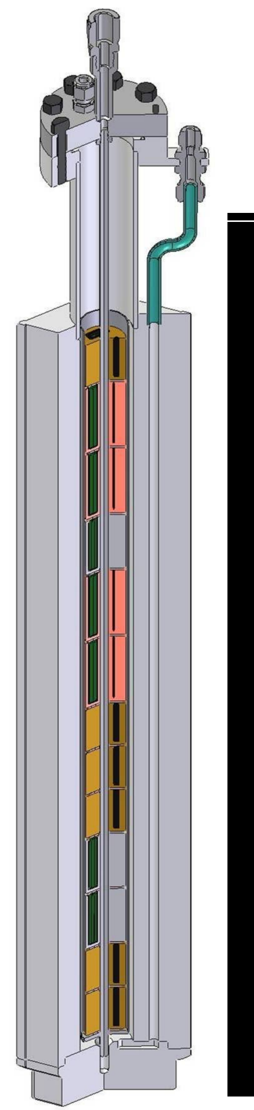
  Projects of interest ranges from existing LWR chemistry and materials development, Gen-IV reactor materials and fuel research (e.g., GFR and VHTR), hydrogen generation, to neutron detector development for NASA spacecraft.

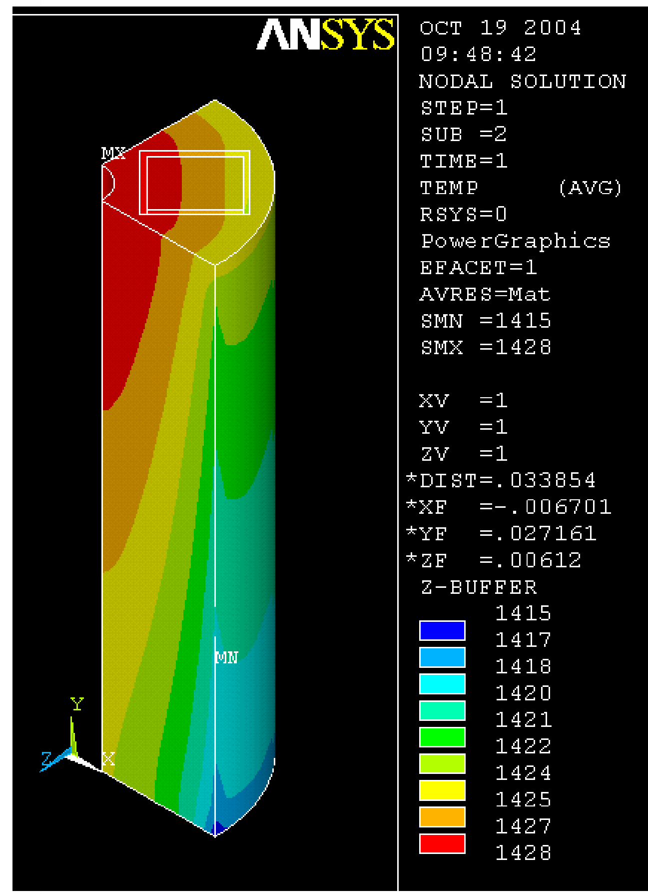
MITR Advanced Materials and Fuel Research Survey (Cont.)

- Participants of this survey include DOE labs, universities, nuclear industry, and small businesses.
- Projects of interest range from existing LWR chemistry and materials development, Gen-IV reactor materials and fuel research (e.g., GFR and VHTR), hydrogen generation, to neutron detector development for NASA spacecraft.
- Majority of the participants were not previously familiar with the MITR in-core irradiation facilities.
- Of particular interest is the new High Temperature Irradiation Facility (HTIF) that is currently being built at the MITR for high temperature materials testing up to 1000 to 1400 ^{o}C.

High Temperature Irradiation Facility (HTIF)

- Design peak temperature up to 1400 C for SiC and SiC composites irradiation testing.
- Tungsten capsules contain various specimen types.
- Ne-He gas mixture for temperature control.
- Desired temperature subject to actual gamma heating and emissivity.
- Temperature gradient is small within the rig.





Broadening the Scope of the Existing NRL Mission

- The NRL is embarking on a process intended to transform it from a research resource predominantly for MIT faculty, to a national user facility that will emerge as the preeminent university center for both education and research in the areas of materials and fuel research for advanced nuclear systems. This will be achieved by:

  - Establishing partnerships with other national laboratory reactor facilities in the areas of fuel and materials development for the next generation of nuclear power and other advanced reactor concepts.

  - Establishing the MITR as an integral part of the national nuclear engineering education infrastructure in the area of undergraduate and graduate education in order to educate new scientists and engineers in the field of nuclear science and engineering, and to provide the technical research basis for the future of nuclear power.

Mission in Support of the NRL as a National User Facility

- The primary mission of the NRL will be the support of research and development toward the next generation of nuclear power technology initiative. The following are areas where the MITR can play a significant role:
  - Corrosion Testing
  - Environmental Degradation Testing
  - High-Temperature Materials Irradiations
  - Fuel Irradiations (small aggregates)
  - Pressure Vessel and Structural Steel Irradiations
  - Advanced Materials and Instrumentation Development