ATTACHMENT A

MIT Nuclear Reactor Laboratory: Safety and Security

Presented to

Cambridge City Council
Public Safety Committee

by

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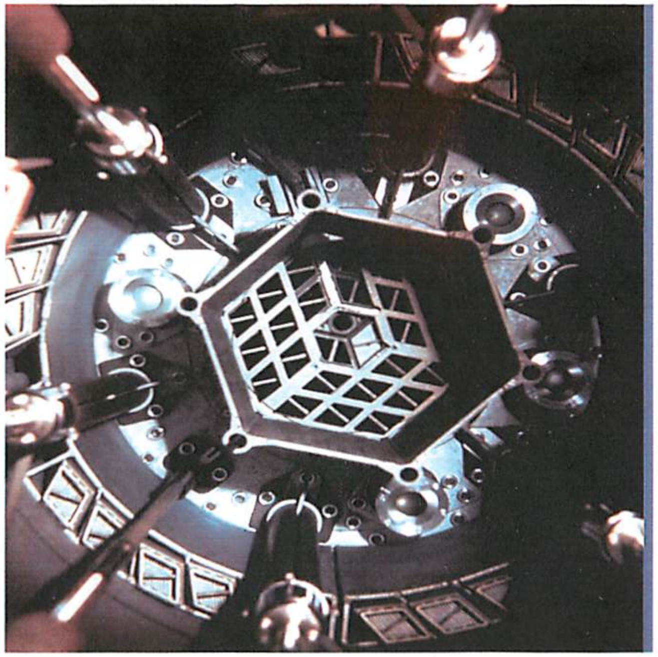
Overview of the MIT Nuclear Reactor Laboratory

- The MIT Nuclear Reactor Laboratory (NRL) is an interdepartmental center that operates a 6 MW research reactor in support of MIT's education and research objectives.

- It has a distinguished history (54 years) of providing faculty and students from MIT and other institutions with a state-of-the-art neutron source, appropriate infrastructure, and a well qualified staff to support research in the areas of:
  - nuclear fission engineering,
  - radiation effects in biology and medicine,
  - neutron scattering,
  - computer control of reactors, and
  - geochemistry and environmental studies.
- It is the only university research reactor facility 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. The MITR is an indispensable resource for developing the workforce for the future of nuclear power.

MIT Nuclear Reactor (MITR)

- The MIT reactor (MITR) is a 6 MW tank-type reactor.
  - Light water cooled and moderated.
  - Heavy water/graphite reflected.
  - The in-core thermal and fast fluxes are 6×10^{13} and 1.2×10^{14} n/cm^2-sec, respectively.
  - These flux levels are comparable to a commercial power reactor.
- The MITR usually operates 24 /7.
  - About 5000 hours per year.
  - Regularly scheduled outages.
    - to accommodate experiment needs.
    - maintenance and repairs.

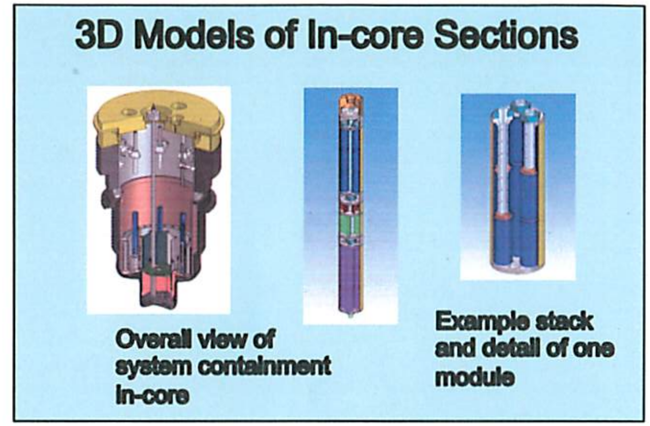


Top view of the MITR core tank

- The MITR is currently fueled by HEU. The fuel is delivered a few times per year on a just-in-time basis; therefore avoiding on-site HEU inventory.
  - Waste is shipped out regularly.
  - Plan to convert to LEU as soon as fuel is approved for use.

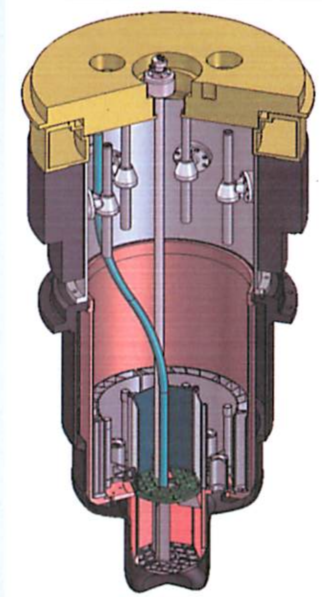
Experimental Facilities and Capabilities

- **The MITR facilities and capabilities include:**
  - Up to 3 in-core loop locations are available.
  - 15 beam ports available for research and educational use.
  - Automatic transfer facilities (pneumatic tubes) for irradiation.
  - Graphite-reflector (vertical thimble) irradiation facilities.
  - Medical irradiation rooms.
  - Time-of-flight experimental facility.
  - Neutron scattering experimental facility.
  - Nanofluids laboratory.
  - Neutron activation analysis (NAA) facility (prompt and delayed gamma).



Research and Services

- Support of cutting-edge research being conducted at the MITR include:
  - Providing researchers with a service-based infrastructure that supports the US initiative for designing and building the next generation of nuclear reactors as a means of reducing the country's reliance on fossil fuels.
  - Supporting research in the area of advanced materials and fuel research through utilization of the MITR's in-core loop capabilities and program. Because the NRL offers such a unique in-core loop program, it was chosen to be a working partner facility of the Department of Energy's Idaho National Laboratory's Advanced Test Reactor National Scientific User Facility which is charged with performing fuel and advanced materials irradiation experiments crucial to future generation reactors.
  - Providing researchers with a service-based infrastructure that utilizes the MITR for trace element analysis, isotope production, and irradiation services.
  - Working with the Department of Energy to provide a safe and productive means to convert research reactors worldwide from HEU fuel to LEU fuel.
  - Research in neutron optics for advanced imaging and scattering.
- Current services provided by the MITR include the production of neutron transmutation doped of silicon.



Cutaway 3-D model of the MITR showing an ICSA (blue) and an in-core water loop installed in the reactor core (fuel elements removed for clarity.)

Education Opportunities and Reactor Operator Training

- As an educational tool, the MITR is unique:
  - It is the only university-based reactor in the US, where students can be directly involved in in-core research;
  - It offers neutron flux levels comparable to power reactors; and
  - It is an indispensable resource for the future of nuclear power.

- As part of the NRL's educational initiatives, the MITR
  - Provides and supports outreach to the educational community as well as the general public that encourages understanding of nuclear energy by providing tours and lectures.
  - Provides staff support for research projects, theses, sample irradiations, neutron activation analysis, experiments, hands-on training, and other educational activities for students from MIT as well as other schools and universities.
  - Offers a web-enabled time-of flight experimental facility.
  - The NRL Reactor Operator's Training Program where:
    - Selected MIT students undergo several months of training and studying.
    - Take a two-day exam administered by the U.S. Nuclear Regulatory Commission.
    - Obtain their Reactor Operator's License.
    - Offered part-time positions as Reactor Operators.
    - This program is exceedingly popular among students.

Reactor Safety

- Reactor safety is an overarching priority at the NRL.
  - Close coordination with Cambridge Police, Fire, and State Police.
  - Frequent communications with NRC on all nuclear safety matters.
  - Strong oversight by the proactive MIT Reactor Safeguards Committee.
  - Modern safety management systems including ALARA, CIP, LOTO, etc.
  - Excellent support from MIT Campus Police.
- Safety of the MITR versus nuclear accidents is well-established.
  - Reactor operates at 130 deg F and atmospheric pressure. (Little stored energy.)
  - Natural convection cooling is adequate following scram. (Electricity not required.)
  - 54-year history with no accidents. (No public exposure, no environmental releases above de minimus levels.)

MIT Reactor Major Safety Features

Passive safety features that ensure safe operation and shutdown:

- Reactor Shutdown:
  - Reactor operation requires electricity. Electromagnets are used to withdraw the control elements to create the nuclear chain reaction. On loss of electricity, magnets de-energize and the control elements drop, under gravity, into the core thereby shutting down the reactor.
  - Any loss of electricity results in a shutdown. Thus, if there were an external event (hurricane, flood, earthquake, car crash into a utility pole) that disrupts the electricity supply, the reactor shuts down.
  - Backup power systems are available, but natural convective circulation is adequate for shutdown.
- Building Isolation:
  - The MITR is located inside a containment building (two feet reinforced concrete with a steel shell) that serves to isolate the reactor from the environment. If there were a radiation release from the core, it could be entirely contained within that building thereby protecting the general public. The building automatically isolates if any one of four redundant sets of effluent radiation monitors senses an abnormal radiation level. Isolation can be achieved by the forced closure of hydraulically-operated dampers or by the closure of gravity-operated backup dampers. Either way, the building is sealed. The gravity-operated dampers also seal the building (passive feature) on loss of off-site electricity. This containment structure is beyond NRC requirements.

MIT Reactor Major Safety Features (Cont.)

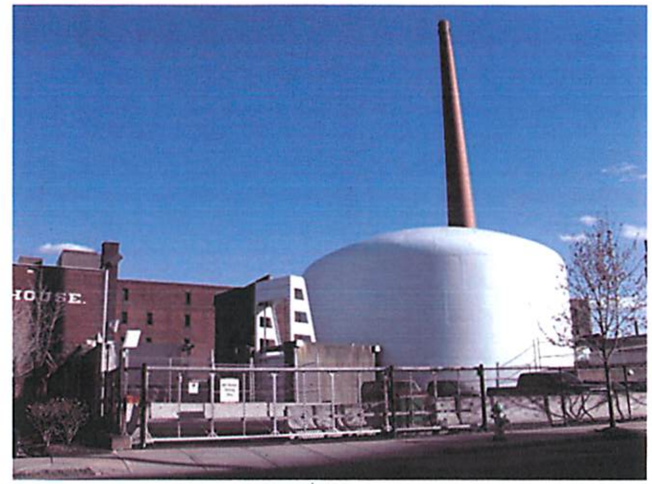
- **Building Pressure Relief:**
  - In the event that pressure builds within the isolated building to levels that are excessive, venting via filters (charcoal to remove iodine, coarse and fine to remove particulates) is possible. The driving force for the venting is the difference between the building pressure and that of the atmosphere (i.e., the outside air). Hence, it is passive. To place this system on line, two valves, both located outside the reactor building and hence both accessible even if the building is isolated, need to be opened.
- **Loss of Coolant Flow:**
  - Coolant flow is maintained during operation by motor-driven pumps. On loss of electricity, these pumps stop. Special valves, which are held open by the force of the flow, close under gravity and establish a path for natural circulation. Under this condition, hot water in the core rises to the top of the core tank where heat is removed. The cooler water sinks down and into the core. This flow is sufficient to remove the decay heat associated with the shutdown reactor.

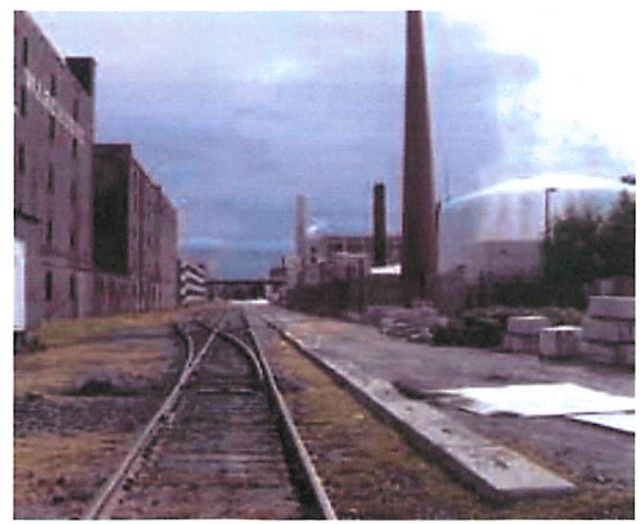
MIT Reactor Major Safety Features (Cont.)

- Loss of Coolant Level:
  - The MITR core is located inside a core tank surrounded by eight feet of high density concrete. There are no penetrations to this tank below the core. Thus, the tank cannot drain. Piping for the forced flow of the primary coolant enters and leaves the tank at a point well above the core. In the event of a pipe break, the core tank will remain full of water, natural circulation will be established as described above, and there will be no overheating of the fuel.
  - A further safety feature is that this first tank is wholly contained within a second one for the heavy water reflector. Therefore, the reactor is protected from the failure of either tank.

Reactor Safety and Security Enhancements (Post 9/11)

- **Post 9/11 - Safety and Security Measures (coordinated with NRC and DOE (NNSA)):**
  - **Perimeter hardened with fence and Jersey barriers**
  - **Updated emergency plans**
  - **Doors and entrances locked and monitored**
  - **State-of-the-art surveillance system**
  - **Certain other security enhancements which cannot be disclosed.**
  - **Full background checks on all visitors well in advance of visit**
  - **Detailed finite-element bomb blast studies confirmed containment integrity for large truck bomb at the perimeter**
  - **Security and emergency exercises with MIT Police, Cambridge Police and Fire, State Police and FBI.**





Radiation Monitoring

- MIT's radiation monitoring systems exceed the NRC requirements.
- Area Radiation Monitors – NRC requires only one area monitor, the NRL has nine fixed position area monitors, several experiment specific monitors, and more new monitors are planned.
- Effluent Radiation Monitors – These systems have redundancy built in that is not required by the NRC. Data from this system is monitored continuously by NRL staff.
- Environmental Roof Top Monitors – Most research reactors do not choose to have real-time monitoring off site. MIT has five locations for off site monitoring which far exceeds the NRC requirements.

Monitoring for Hydrogen and Tritium

Going beyond NRC Requirements

- **The production of hydrogen gas and tritium in nuclear reactor power reactors is often reported in the news and both have become a matter of public concern.**
- **Hydrogen is produced in nuclear reactors by the radiolytic decomposition of water and by a reaction with zirconium-based clads that occurs at very high temperatures. The later was the source of the hydrogen at both Three Mile Island and at Fukushima. Research reactors do not use such clads so that source is not an issue for MIT. Radiolysis does however generate hydrogen at a very low rate. The amount produced is readily removed by ventilation systems. The NRC requires periodic sampling if the ventilation systems should not be functional. The periodic samples are not completely accurate because they do not, by definition, allow real-time tracking of hydrogen levels. Our use of such samples had created a concern (now known to be incorrect) that hydrogen levels could exceed the threshold limit if the dedicated ventilation blower were off. In 2011, MIT purchased an on-line hydrogen sampling system that allows continuous sampling of hydrogen in the air above the reactor core. The resulting data has shown that even with loss of ventilation system's blower that is used to sweep any hydrogen out of this area, hydrogen levels remain below that threshold of concern. Hydrogen buildup is not an issue for the MIT Research Reactor.**
- **Tritium is produced from the absorption of neutrons by heavy water, which is present in light water and which is also used as a reflector for the MIT Research Reactor. The NRC requirement is for daily (24 hour) grab samples whenever the reactor is operating. Nevertheless, MIT has procured and installed a continuous monitor for the detection of tritium in our secondary coolant effluent.**

Reactor Security

- Reactor security exceeds federal requirements (10 CFR 73).
  - High redundancy built into new security system –
    - no single adversary action can destroy its capability;
    - overlapping cameras (64), card readers, layered barriers, monitoring points, and detection points;
    - multiple duress initiators; diverse technologies;
    - additional & independent systems in vital areas.
  - Access controls & procedures in place to identify authorized personnel / materials / vehicles; all visitors escorted; unescorted access includes NRC-FBI fingerprinting + criminal history background checks.
  - System-wide test quarterly with MIT Police & Security Office (SEMO); internal tests weekly with MIT Police; internal surveillances daily.
  - Emergency communications and off-site response force notification enhanced by mobile wireless & radio repeaters enabled for NW12 & Containment.
  - Security data stored locally & remotely; entire system is backed up with emergency power supply.

Reactor Security (Cont.)

- Special Material storage & inventory requirements.
- MIT Police on-site patrols & annual reactor training.
- Pre-determined emergency responses; annual emergency exercises with MIT emergency operation groups including Police, EHS, and Medical.
- Biennial training with Cambridge Fire (now includes Cambridge Police).

Reactor Safety: Containment Integrity

- MITR commissioned a study by Lincoln Laboratory experts in 2002, which showed that:
  - The reactor containment maintains its integrity versus the NRC design basis blast (greater than Oklahoma) outside the perimeter.
  - That the biological shield maintains its integrity even when the blast is sited immediately adjacent to the containment building.

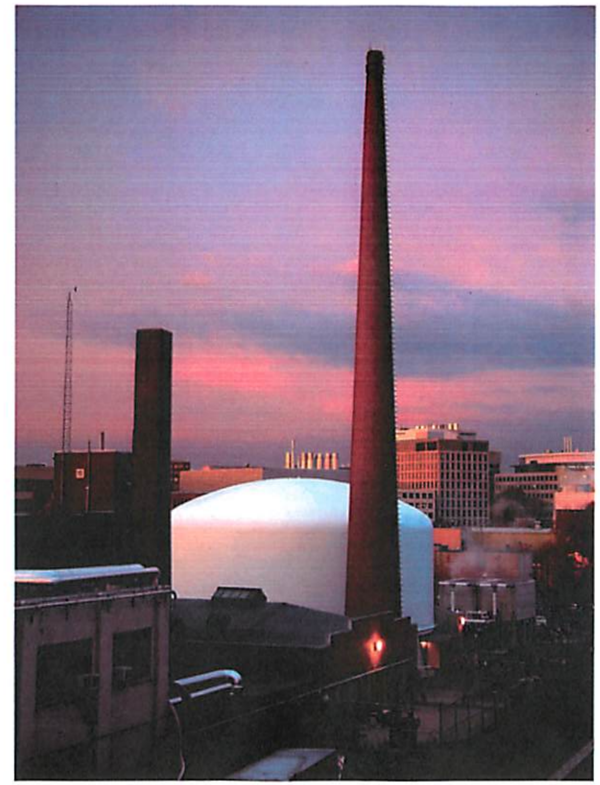
"Photograph by Judith M. Daniels"

Severe Natural Phenomenon

- The MITR is a university research reactor and does not operate during adverse conditions such as a severe natural phenomenon such as a hurricane, tornado, flood, a seismic event, or fire.
- Administrative directions are for the reactor to be shut down when such events occur, or before when warnings are available.
- While it is anticipated that the MITR's instrument and control systems would remain operable during such events, once the reactor is shut down, there is no further safety risk.

Severe Natural Phenomenon - Hurricane

- Containment building was conservatively designed to conform to the wind load criteria of Massachusetts building codes.
- The reactor ventilation stack was designed to withstand wind loads in excess of 100 mph.
- Containment building is protected against excessive pressure variations by the vacuum relief breakers and the pressure relief system.
- Building and ventilation stack have not sustained any damage from any meteorological condition that has occurred since construction in 1958.
  - Both are maintained in excellent condition.
  - The ventilation stack inspected regularly.
- The public is protected against potential radiation releases by the containment building.



"Photograph by Judith M. Daniels"

Severe Natural Phenomenon - Flooding

- In the unlikely event of a flood, the reactor would be shut down.
- Natural drainage from the reactor site is into the Charles River.
- Flooding from rainfall or melting snow is not an issue in the Cambridge-Boston area because of the drainage provided by the river and also the Charles River Basin.
- Although minor flooding does occur on Memorial Drive and Storrow Drive (underpasses are at or very near water table), that situation has no effect on the reactor site. Emergency vehicles that would respond to a emergency would not use these roads.
- Seismically induced flooding is also unlikely. Failure of man-made structures such as Gridley Locks, would only serve to enhance the drainage away from the area.
- Because of the absence of surface faulting in the area, there are no recorded instances of tsunami.
- Any instances of seismically induced "sea waves" would be too small to have any effect on the MITR.
- Diversion of the Charles River toward the MITR site is unlikely because the site is elevated in relation to the river.

Severe Natural Phenomenon– Seismic Event

- **Seismic Events:** The MITR is protected against the consequences of a seismic event provided that the core tank remains functional. Other types of damage such as disruption of process systems and lack of electrical power may or may not occur. However, these will not result in core damage. Specifically, the location of core tank penetrations, the presence of redundant anti-siphon valves, the provisions for natural convection cooling, and the shutdown of the reactor on loss of electricity protect the core against damage to piping and power supplies. Disruption of process systems would, at most, result in the spillage of primary coolant or heavy water. Any such spills would be contained within the reactor building. A seismic event would also not interfere with the capability to shut the MITR down.

- **Boston Area Earthquake Summary:** The Boston area has one of the longest records of earthquake activity going back to the 16th century--about 450 years of data. About 250 events had epicenters within a 200 km radius and an intensity of 3.0 or greater. The largest event affecting this area was an earthquake off Cape Ann in 1755 (probably around Richter 5-6). That event produced accelerations of about 0.1 g-force in Cambridge. Structures in this area are generally designed, therefore, to withstand a force of 0.225 g, with the expectation that such an event could occur once every 10,000 years based on the existing history. Analysis of the strength of our core tank shows that it can withstand much higher forces (5 g horizontal and 3 g vertical simultaneously).