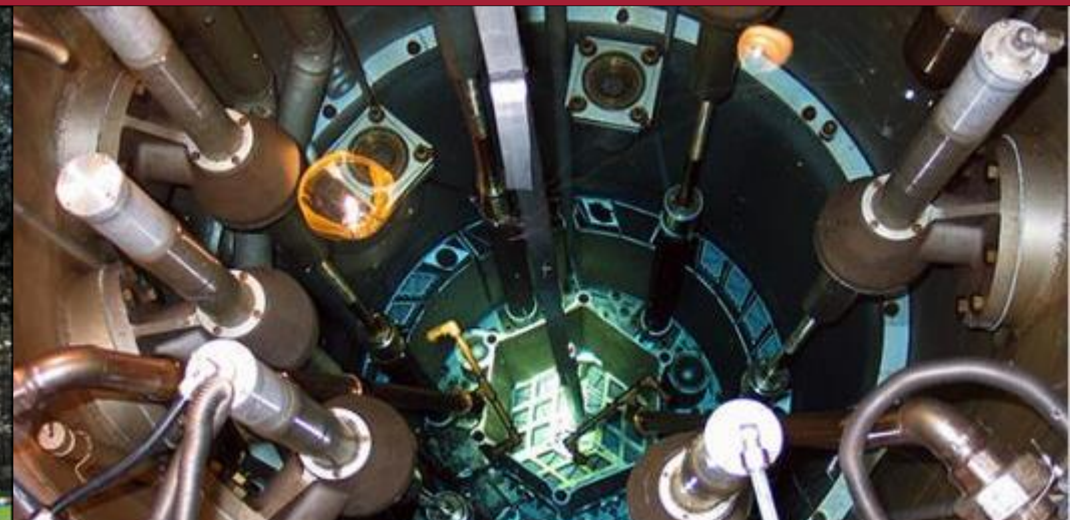
MIT NUCLEAR REACTOR LABORATORY

an MIT Interdepartmental Center



Defueling the MITR-II for Leak Repair

Sara Hauptman

Reactor Engineer

Senior Reactor Operator / Shift Supervisor

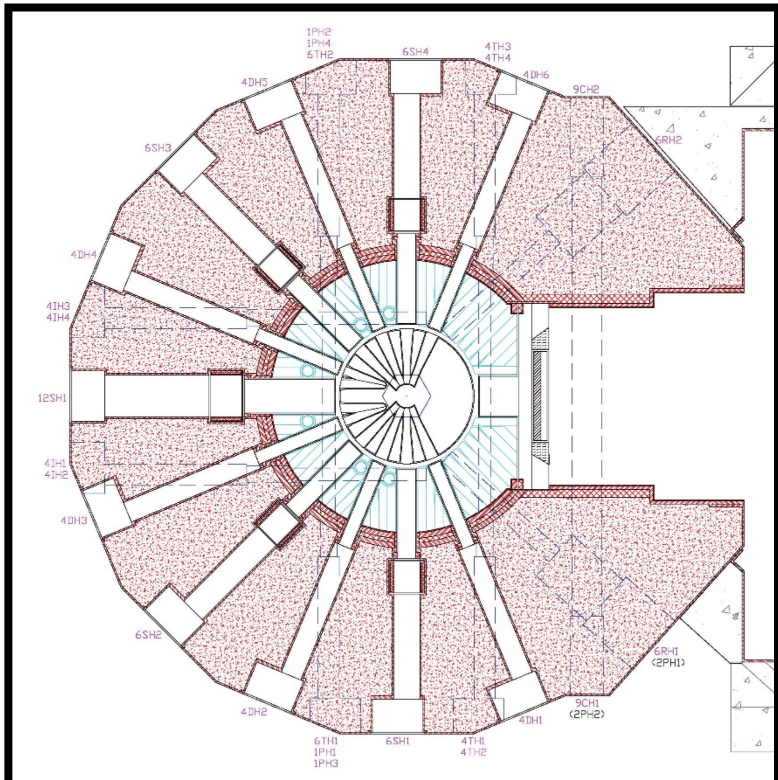
June 18th-22nd, 2023
University of Maryland

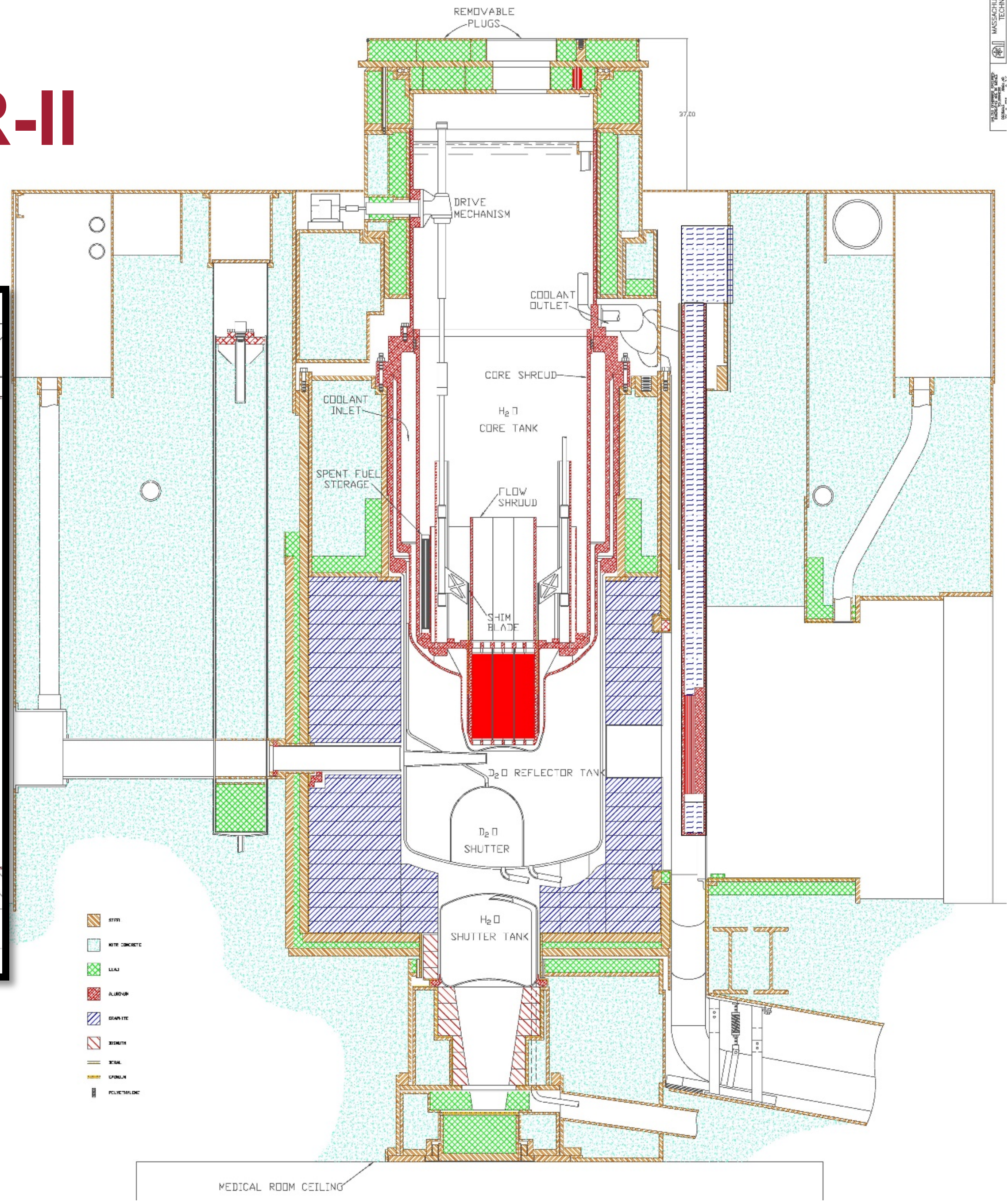
TRTR/IGORR

MIT Research Reactor (MITR-II)

- MITR-I constructed 1956-1958
- Core and process systems redesigned for MITR-II
    - Light water cooled and moderated, heavy water reflected
    - First criticality on August 14th, 1975
- Primary/Secondary systems rebuilt in 2010 for relicensing and power uprate up to 6.0 MW
- Operates 24/7 except during scheduled outages

Overview of MITR-II





Drawings courtesy of D. Carpenter

Description of Events

- ~0900 Dec 12, 2022
  - Console Operator observes Ch #2 signal has decreased since previous hourly log
  - Reactor S/D on suspicion of leak
- Dec 14, 2022
  - Vertical port plug removed, flooding of thimble confirmed
- Initial findings:
  - Activity sampling verified primary water
    - Na-24 content from (n, α) fast reaction with Al6061
  - Estimated 7.5 gal/day losses
  - Water collected in pipe chase tunnel in basement equipment room

[1,6]

Defueling

- Preliminary investigation of all accessible systems
  - Pneumatic tubes, basement medical room, reactor top, equipment room
  - Attempts to lower core tank level to determine height at which leak stopped
    - Narrowed leak down to one of several core tank penetrations at height of Anti Siphon Valves
  - Endoscope camera used to inspect all accessible locations
- Shielding blocks must be removed to check final possible leak locations

For	Against
Dose from less shielding	Dose from defueling
Leak could worsen	Add 4-8 weeks to outage
Other jobs (2PH, M3)	Novel evolution

[1,6]

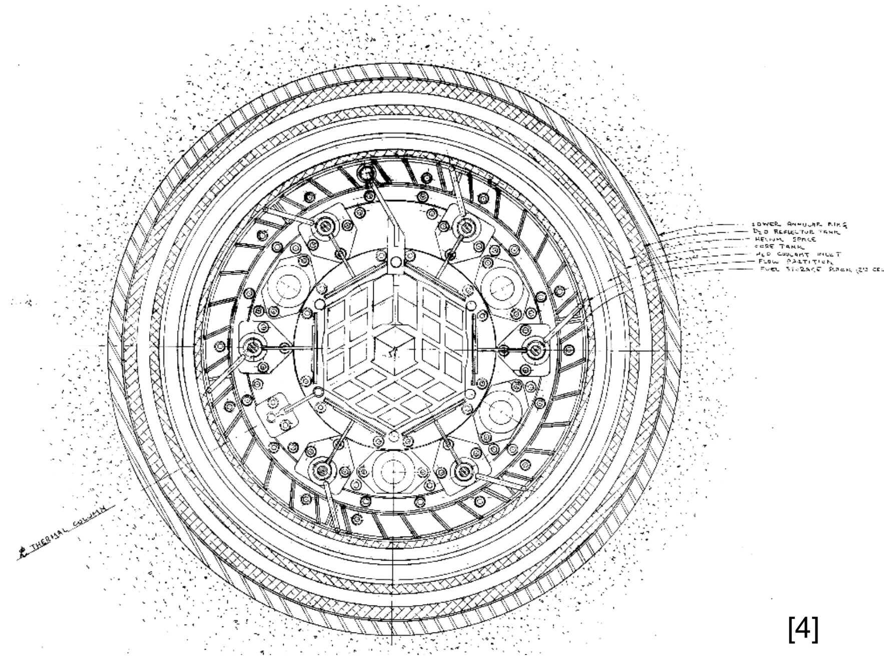
Procedural Guidelines

- All fuel movements into, out of, and within the core tank are controlled by written procedure
    - Typical evolutions include fuel shuffling, movements between core positions and the storage ring, and removal of spent fuel from the core tank

- New questions to address:
    - Moving fuel back into core tank from storage pool
    - Source neutron counts
    - Proper documentation and oversight

Storage Space and Logistics

- Discharged elements are pulled into a cask through a plug in the reactor lid and transferred to storage pool
  - Only 4 positions in the storage ring can be reached and one element may sit in basket
- Defueling done on day shift only
  - One maintenance crew sufficiently trained and experienced to perform fuel removal
  - Radiation protection coverage only available during the day



[4]

Storage Space and Logistics

- Spent fuel pool has three racks with 5x5 grids
  - Total storage requirement of 63 positions for elements
  - Some positions marked as undersized
  - 5 positions in each rack administratively restricted

- Relocate all non-fuel objects to locations without neutron absorbing material
  - Experiment facilities, retired equipment

- Additional analysis required to verify acceptable storage for element inventory

[8]

Criticality Safety – Element Storage

OMB Control No.: 3150-0231

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
WASHINGTON, DC 20555-0001

April 7, 2016

NRC GENERIC LETTER 2016-01: MONITORING OF NEUTRON-ABSORBING MATERIALS IN SPENT FUEL POOLS

ADDRESSEES

All nuclear power reactors with a license issued under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those that have permanently ceased operations with all reactor fuel removed from onsite spent fuel pool (SFP) storage.

AND

All holders of an operating license for a non-power reactor (research reactor, test reactor, or critical assembly) under 10 CFR Part 50 who have a reactor pool, fuel storage pool, or other wet locations designed for the purpose of fuel storage, except those who have permanently ceased operations with all reactor fuel removed from onsite wet storage.

Specifically, the NRC is issuing this GL for two purposes:

(1) To request that addressees submit information, or provide references to previously docketed information, which demonstrates that credited neutron-absorbing materials in the SFP of power reactors and the fuel storage pool, reactor pool, or other wet locations designed for the purpose of fuel storage, as applicable, for non-power reactors, are in compliance with the licensing and design basis, and with applicable regulatory requirements; and that there are measures in place to maintain this compliance.

(2) To collect the requested information and determine if additional regulatory action is required.

MIT-NRL-16-03
Revision 2

Massachusetts Institute of Technology

Criticality Study for MITR Wet Storage Systems: 1) Spent Fuel Pool and 2) Wet Storage Ring

prepared by

Kaichao Sun and Paul J. Nawazelski
Nuclear Reactor Laboratory, Massachusetts Institute of Technology

August 2016

MIT NUCLEAR REACTOR LABORATORY
AN MIT INTERDEPARTMENTAL CENTER

[8]

Criticality Safety – Element Storage

# Elements	Storage Limits
0-9	None, no credit for Cd.
10-20	Use only one rack, do not use centermost position or its four neighboring positions (8, 12, 13, 14, 18). No credit for Cd.
20-60	Maximum of 20 fuel elements per rack, same restrictions as above. Racks should be mechanically fixed or a spacer installed to maintain distance. No credit for Cd.
61+	Taking credit for cadmium content required, no specific configuration guidelines listed.

Summary of conclusions in 2016 Criticality Study

- Previous modelling performed with no neutron absorbing material
  - Most conservative case, 100% Cd liner degradation

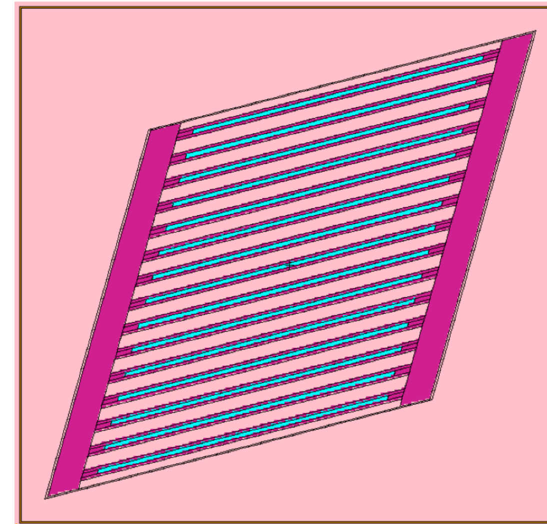
- Existing reports to NRC *addressing theoretical Cadmium liner degradation* do not include calculations for storage >60 fuel elements
  - No reason to suspect degraded cadmium (previous liner mass measurements, detector verification, water quality sampling, etc.)

- k_{eff} limit of 0.9 for storage locations (TS 5.4.4)

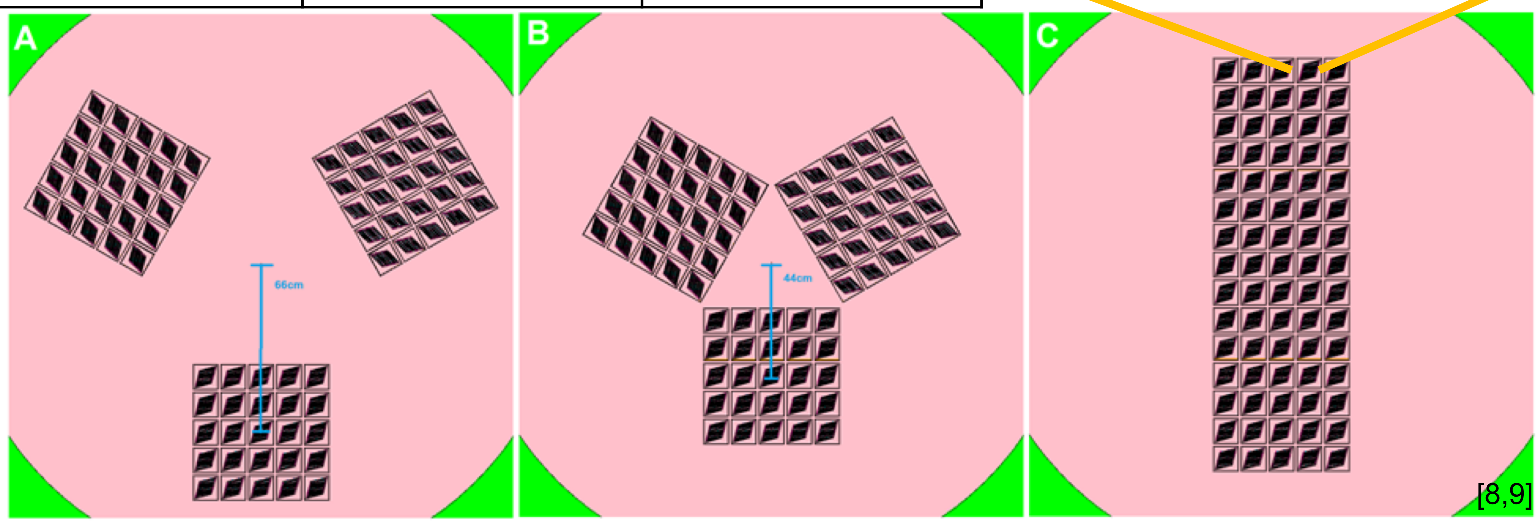
[8,11]

Criticality Safety – Element Storage

- Previous analysis conditions as baseline
  - Cold 20 C pure light water
  - All fresh HEU elements
  - No structural materials
- Added Cadmium liner box
  - Cd based on surveillance T&C, 10% of original mass acceptance criteria



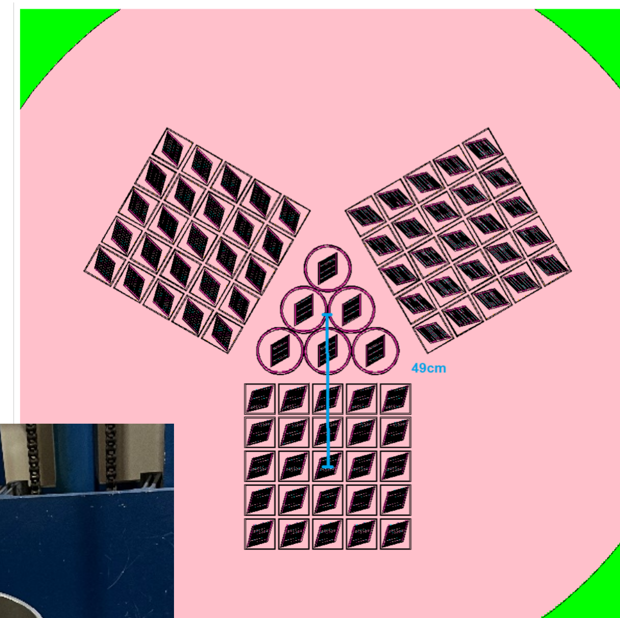
Case	k_{eff}	1 σ uncertainty
A - Nominal (66 cm)	0.52860	0.00019
B - Minimum (44 cm)	0.52983	0.00013
C - Stacked	0.55994	0.00013



[8,9]

Criticality Safety – Temporary Rack

- Fit testing of racks found several warped/swollen positions
- 6 extra spots needed for total 63 elements
- Model updated with rack and total of 81 fresh fuel elements
    - k_{eff} = 0.61020 ± 0.00014
- Design and fabrication for new racks in progress with analysis for HEU/LEU mixed storage



Refueling Considerations

- Source neutrons
  - MITR usually relies on significant photo-neutron source from heavy water reflector
  - Strongest external source kept on site produces ~10^7 nps

- Instrumentation monitoring
  - Safety channels calibration period elapsed
  - Fission chambers housed in ex-core ports, not sensitive to low neutron signal
  - He-3 detectors extremely sensitive, suitable for low initial neutron count measurements, can saturate quickly

Acknowledgements

NRL Operations and Maintenance Staff

John DiCiaccio

Paul Nawazelski

Tim Leurini

Adam Grein

Dane Kouttron

Photo/video documentation

David Carpenter

Taylor Tracy

Thank you, Questions?

References

[1] Console Operator, NRL Digital Logbook Entry, (Internal) December 12, 2022.

[2] MITR Staff, “MITR-II Startup-up Report”, January 1977, MITNE 198.

[3] MIT Research Reactor, http://nrl.mit.edu/reactor [accessed: May 2023]

[4] M. K. Simpson, “MITR-II Isomeric View” Drawing R3G-16. June 25, 1974.

[5] Barnett, “MIT Reactor Mk-2” Drawing R3G-04. July 7, 1969.

[6] “3GV2 Planning Meeting”, NRL Operations Office, Meeting Notes, December 14, 2022.

[7] “PM 1.15 Fuel Loading Permission Form” SR# 2019-20. MITR Administrative Procedures, June 25, 2019.

[8] K. Sun, P. Nawazelski, "Criticality Study for MITR Wet Storage Systems: 1) Spent Fuel Pool and 2) Wet Storage Ring," MIT-NRL-16-03 Rev. 2, August, 2016.

[9] “PM 7.4.6.4 SFP Fuel Storage Rack Cadmium Degradation Monitoring” SR# 2017-8. MITR Test & Calibration Records, Performed SAT Feb. 2, 2021.

[10] X-5 Monte Carlo Team, MCNP – A General Monte Carlo N-Particle Transport Code, Version 5, Volume II: User’s Guide. April 24, 2003.

[11] Technical Specifications for the MIT Research Reactor (MITR-II), Rev. 6, August, 2010.