Three Mile Island Unit 2 Case Study Overview

IAEA International Project on Managing the Decommissioning and Remediation of Damaged Nuclear Facilities (DAROD)

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United States Nuclear Regulatory Commission

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Accident Overview

- A combination of equipment malfunctions, design-related problems and worker errors led to TMI-2's partial meltdown and very small off-site releases of radioactivity

Accident Progression

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- At about 4 a.m. on Wednesday, March 28, 1979, TMI-2 experienced a failure in the secondary, non-nuclear section of the plant
- A mechanical or electrical failure prevented the main feedwater pumps from sending water to steam generators that remove heat from the reactor core
- The plant's turbine-generator and then the reactor itself automatically shut down
- Immediately, pressure in the primary system (the nuclear portion of the plant) began to increase

Accident Progression

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- To control pressure, a pilot-operated relief valve (a valve located at the top of the pressurizer) opened -*The valve should have closed when the pressure fell to proper levels, but it became stuck open.*
- Control room instruments incorrectly indicated that the valve was closed leaving staff unaware that cooling water was pouring out of the stuck-open valve
- As coolant flowed from the primary system through the valve, other instruments available to reactor operators provided inadequate information, and no instrument showed how much water covered the core

Accident Progression

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- Plant staff assumed if the pressurizer water level was high, the core was properly covered with water and did not realize the plant was experiencing a loss-of-coolant accident
- Water escaping through the stuck valve reduced the primary system pressure so much that reactor coolant pumps had to be turned off to prevent dangerous vibrations
- To prevent the pressurizer from filling completely, staff reduced emergency cooling water amounts into the primary system – starving reactor core of coolant, causing it to overheat
- Fuel overheated to the point at which the zirconium cladding ruptured and the fuel pellets began to melt
- Later found that about half of the core melted during the early stages of the accident

Accident Animation

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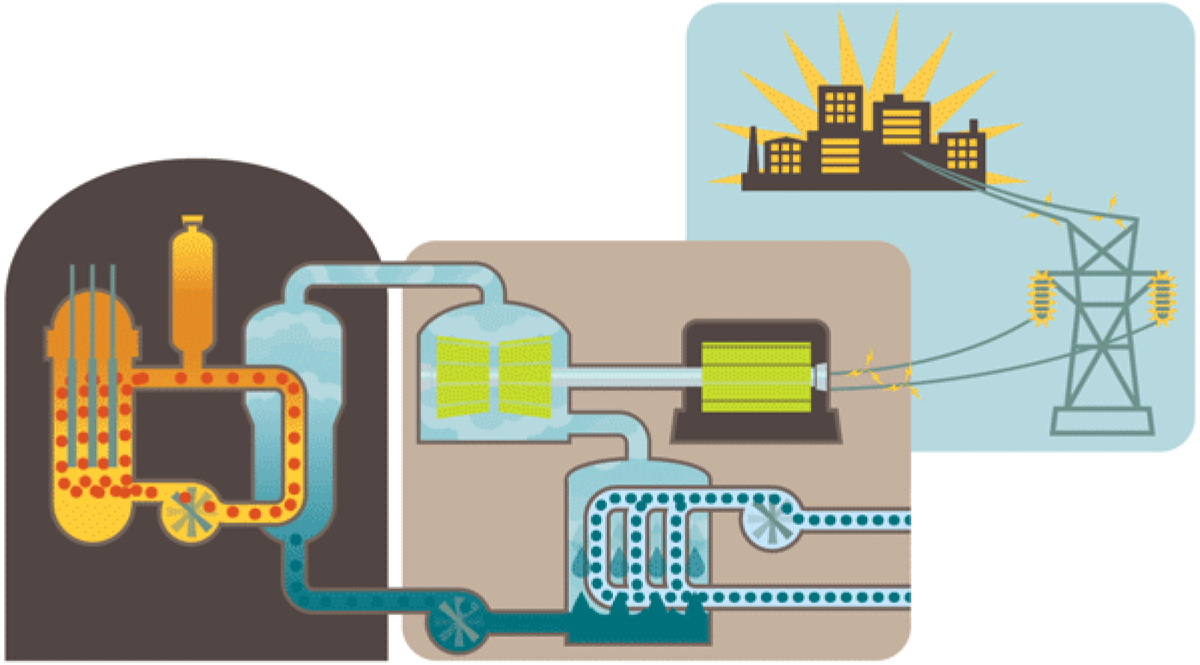

Current Conditions at TMI-2

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- TMI-2 reactor is permanently shut down and all its fuel has been removed
- Reactor coolant system is fully drained and the radioactive water was decontaminated and evaporated
- Radioactive waste from the accident was shipped off-site to an appropriate disposal area, and the reactor fuel and core debris was shipped to the Department of Energy's Idaho National Laboratory
- Current plan is to keep the TMI-2 facility in long-term, monitored storage until the operating license for the TMI-1 plant expires, at which time both plants will be decommissioned

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Regulatory Issues

Regulatory Approaches/Issues

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- A specialized U.S. NRC team was established shortly after the accident - including representatives of the NRC's Office of Inspection and Enforcement (IE), the 5 NRC Regions, and the Office of Nuclear Reactor Regulation (NRR)
- A Public Affairs Office was established in Middletown, PA, and staffed on a 24-hour basis

Regulatory Approaches/Issues

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- The NRC site team initially supported emergency response functions
- Within days of the accident, the site team performed on-site recovery activities, which can be broken down into four major areas:
  1) Reviewed system modifications and system additions
  2) Reviewed all procedures (emergency and normal operation and maintenance) which were necessary to post-accident activities
  3) Provided close and continuous monitoring for the operations
  4) Provided consultation, review, and analysis of the ongoing rad-waste, cleanup, and health physics activities

Regulatory Approaches/Issues

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- The NRC's licensing process was generally utilized to allow for remediation/decommissioning of TMI-2
- For example, NRC Orders were issued to:
  - Suspend operating license and require maintenance in a shutdown condition per NRC approved procedures
  - Permit the usage of the Epicor-II filtration and ion exchange system to decontaminate intermediate level waste water
  - Incorporate revised technical specifications to reflect the damaged condition
  - Permit the licensee to purge the reactor building of krypton-85
- Public comments were sought and several Environmental Assessments were prepared

Regulatory Approaches/Issues

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- The overall NRC regulatory approach was impacted as a result of the TMI accident, both in the short term and the long term
- Short Term (days to months) – The NRC issued several orders to individual licensees and issued generic communications, such as bulletins and generic letters, to all nuclear power plant licensees
- Long Term (months to years) - Investigations and the implementation of lessons learned brought about sweeping changes in the U.S. nuclear industry – including improvements in emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations

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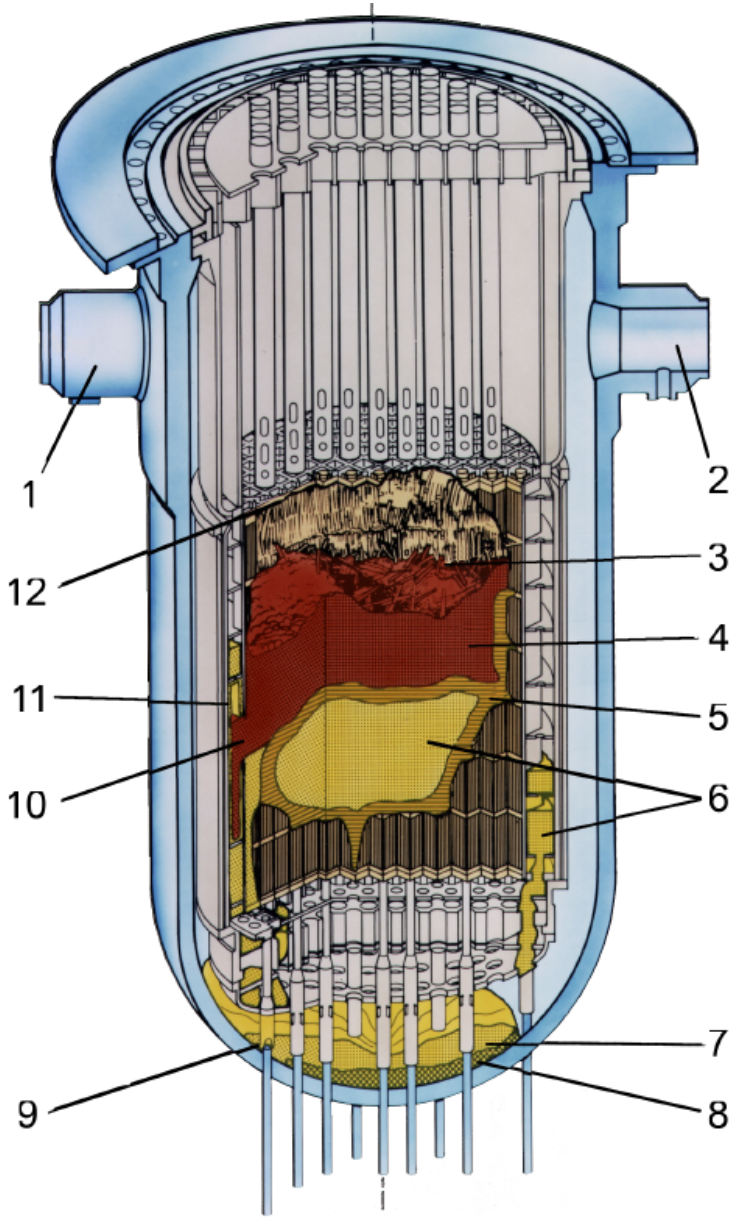
Technical Issues

Technical Issues – Post Emergency State of the Facility

- Fuel melting and reactor core damage had occurred
- Contaminated coolant water remained in the basement of the containment building
- The containment building was contaminated but remained in-tact and functional
- First entry into the reactor building containment was conducted by two utility staff on July 23, 1980 (image to the right)

Technical Issues – Post Emergency State of the Core

1. Cold leg Loop 2B inlet
2. Cold leg Loop 1A inlet
3. Cavity
4. Loose core debris
5. Crust
6. Previously molten material
7. Lower plenum debris
8. Hard layer debris
9. Damaged in-core instrument guide
10. Hole in baffle plate
11. Coating of previously molten material on bypass region interior surfaces
12. Upper grid damage



Technical Issues/Challenges

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- Decontamination of intermediate-level contaminated water (defined as less than 3.7 MBq/mL [100 µCi/mL]) in the auxiliary building
  - Environmental Assessment issued and approval granted to use the Epicor-II filtration system

- Purging of the reactor building atmosphere
  - Environmental Assessment and evaluation completed
  - Controlled and filtered purge accomplished over a 14 day period, per NRC approved procedures
  - The maximum cumulative radiation dose and the maximum dose rate measured at off-site locations were a fraction of the limits allowed under NRC regulations

Technical Issues/Challenges

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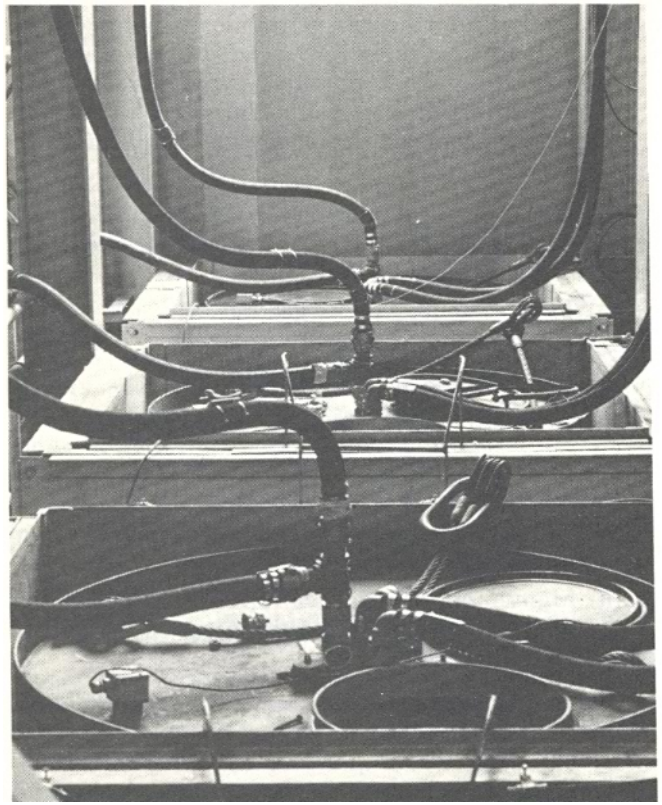

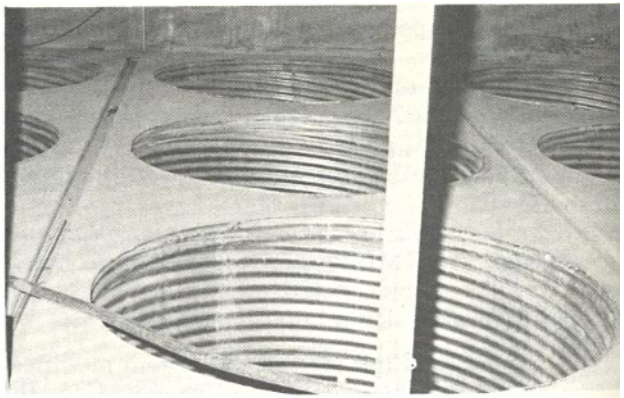

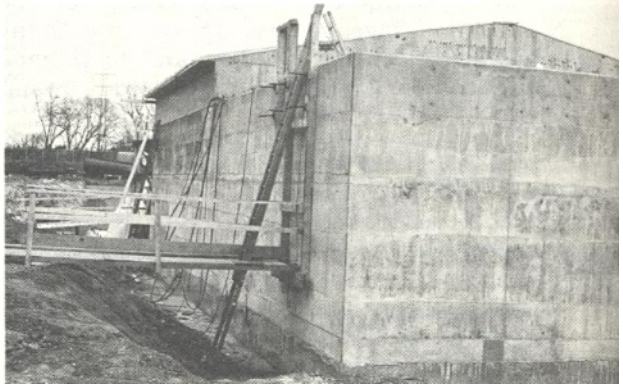

EPICOR-II System

Technical Issues/Challenges

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- Decontamination of highly contaminated wastewater
  - The NRC Approved the use of the Submerged Demineralizer System (SDS)
  - The SDS operated underwater, in one of the spent fuel pools of TMI Unit 2
  - It consisted of a liquid waste treatment subsystem, a gaseous waste treatment subsystem, and a solid waste handling subsystem
  - The approval to operate the SDS did not include water disposal

Technical Issues/Challenges

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- Removal of fuel debris from the reactor
  - Operators removed damaged fuel and structural debris from the reactor vessel by “pick and place” defueling of loose core debris
  - Workers performed defueling operations from a shielded defueling work platform (DWP) located nine feet above the reactor vessel flange
  - The DWP had a rotating 17-foot diameter surface with six-inch steel shield plates, and was designed to provide access for defueling tools and equipment into the reactor vessel

Technical Issues/Challenges

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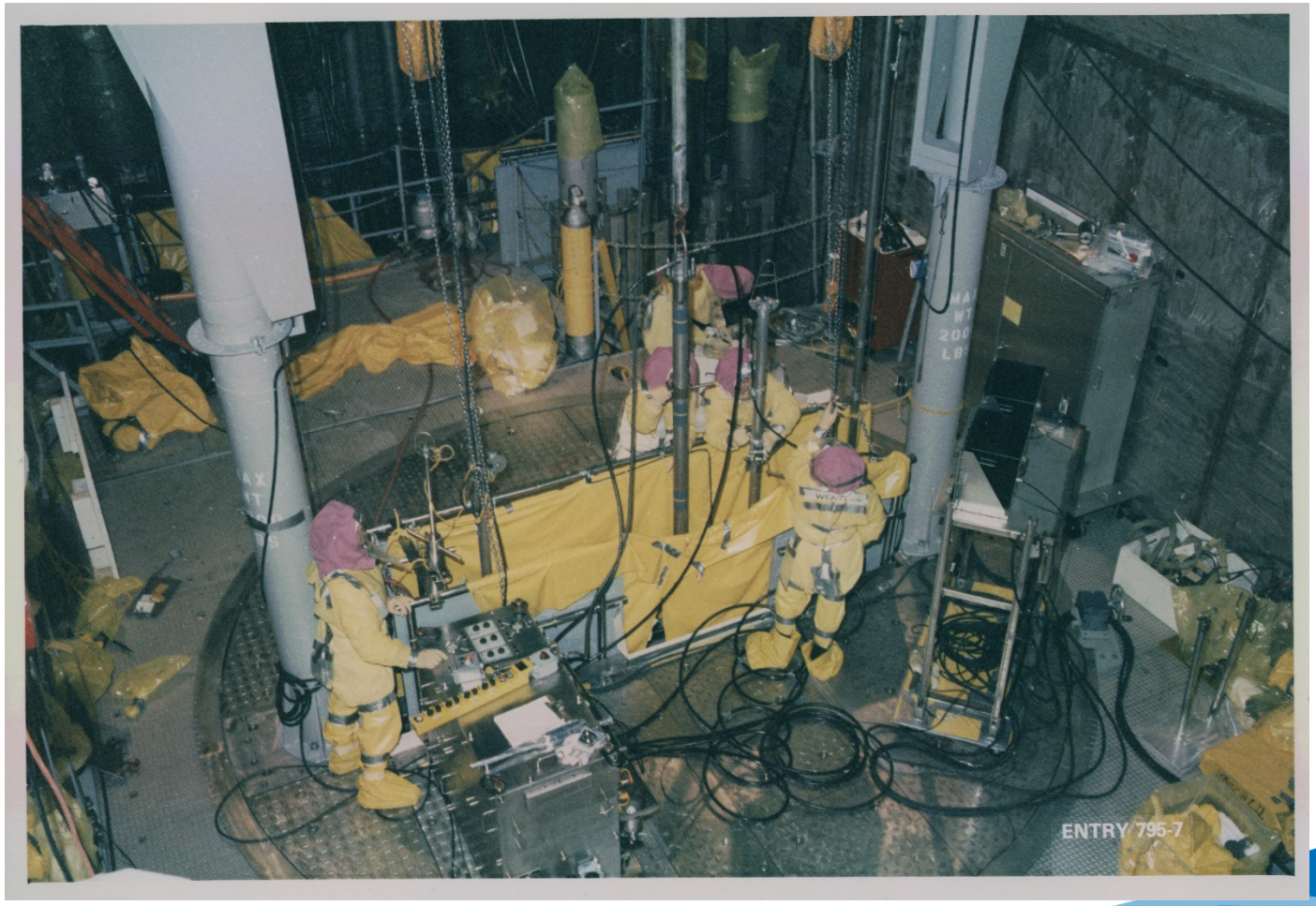
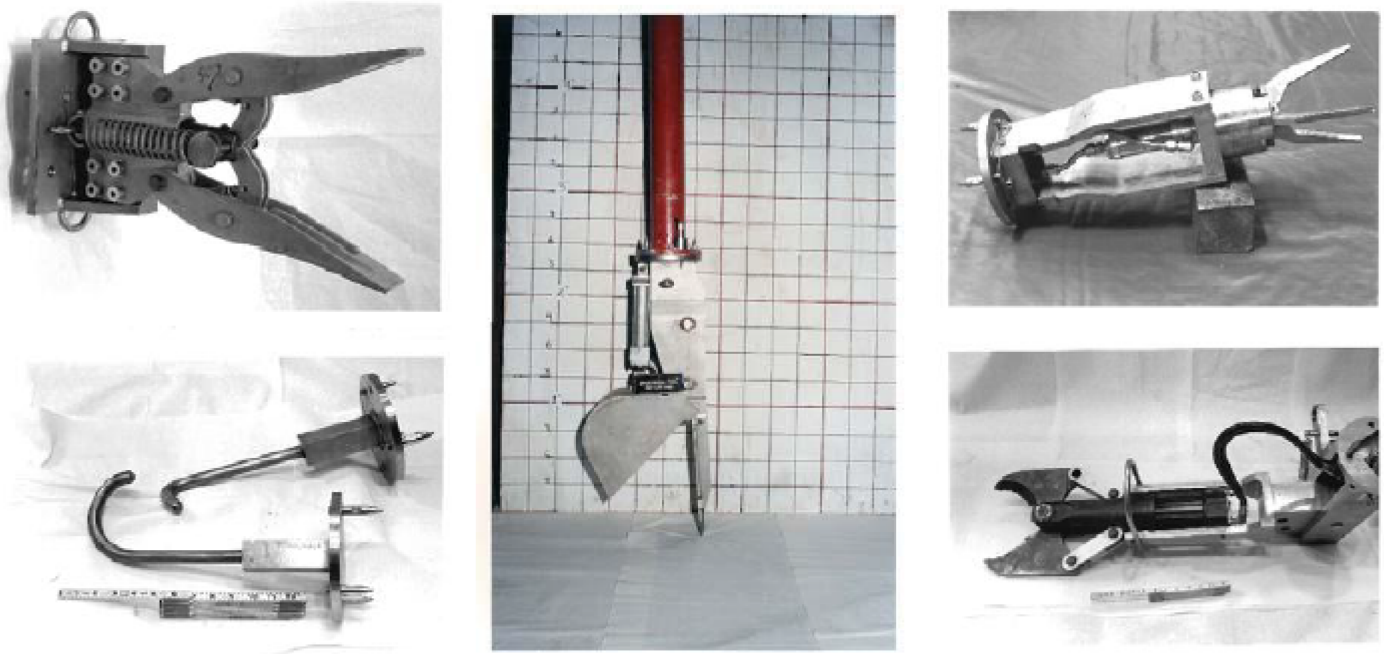


Shielded defueling work platform (DWP)

Technical Issues/Challenges



Numerous manual and hydraulically powered long-handled tools were used to perform a variety of functions, such as pulling, grappling, cutting, scooping, and breaking up the core debris. These tools were used to load debris into defueling canisters positioned underwater in the reactor vessel.

Technical Issues/Challenges

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- Microorganisms inside the reactor vessel
  - A large population of microorganisms developed in the reactor coolant system (RCS), clogging cleanup system filters and hindering the view of defueling activities
  - Licensee conducted a multi-phase program to restore water clarity consisting of high-pressure hydrolancing, the addition of hydrogen peroxide, and the use of a high-pressure positive displacement pump
  - A diatomaceous earth (swimming pool-type) filter was operated in conjunction with the letdown and makeup of batches of reactor coolant, to remove the organic material and improve the clarity of the RCS water

Technical Issues/Challenges

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- NRC and DOE signed Memorandum of Understanding (MOU) on waste disposal
  - The MOU formalized the working relationship between the two agencies with respect to the removal and disposal of solid nuclear waste generated during the cleanup of TMI-2
  - Significant step toward ensuring the TMI site would not become a long-term waste disposal facility
  - The MOU covered only solid nuclear waste, and did not cover liquid waste resulting from cleanup activities
  - DOE also agreed to accept fuel and highly radioactive resins from the water purification system

Technical Issues/Challenges

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- NRC and DOE signed Memorandum of Understanding
- MOU addressed three basic categories of TMI-2 waste:
  1) waste determined by DOE to be of generic value in terms of beneficial information to be obtained from further research and development activities
  2) waste determined to be unsuitable for commercial land disposal because of high levels of contamination, but which DOE may also undertake to remove, store, and dispose of on a reimbursable basis from the licensee
  3) waste considered suitable for shallow land burial, to be disposed of by the licensee in licensed, commercial low-level waste burial facilities

Technical Issues/Challenges

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- Epicor resin waste disposal
  - The NRC approved the licensee's request to dispose of Epicor resin liners via shallow land disposal, as they were similar to typical reactor resin wastes
  - Several shipments were also made to various laboratories for testing purposes

- Submerged Demineralizer System resin waste disposal
  - Submerged Demineralizer System liners were sent to DOE
  - DOE conducted research on glass vitrification (solidification) of this type of solid waste at Hanford

Technical Issues/Challenges

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- Disposal of slightly contaminated water
  - The licensee was approved for a treatment/disposal method involving the forced evaporation of the water contaminated during the accident and used in subsequent cleanup operations at the TMI site - to be completed over a 2.5 year period
  - Residue from this operation, containing small amounts of the radioactive isotopes cesium-137 and strontium-90, and large volumes of boric acid and sodium hydroxide, would require solidification and disposal as low-level waste

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Institutional Framework and Strategic Planning

Institutional Framework

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- Organizational arrangements/structures shifted from operational NRC oversight prior to the accident, to an augmented on and off-site emergency response structure during the emergency phase, and to a new structure enhanced by lessons learned after the emergency
- Changes to the NRC's organizational framework occurred in the establishment of a TMI Program Office and a TMI-2 Project Directorate, and an Office for Analysis and Evaluation of Operational Data (AEOD)
- The NRC formed a 12 member Public Advisory Panel including local citizens, local and state governmental officials, and scientists, meeting regularly with both the public and NRC Commissioners

Institutional Framework

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- The pre-existing regulatory and political decision making processes were generally adequate in that the NRC's licensing process was utilized for many decisions
- The current post defueling monitored storage state of TMI-2 represents a unique approach as it placed the facility into monitored storage for an unspecified period of time
- Funding provisions are provided by the licensee, who provides annual funding status and cost analysis reports

Strategic Planning

- Several investigation committees were formed shortly after the accident, which influenced organizational/structure changes
  - The President of the United States, Jimmy Carter, appointed a 12-member Presidential Commission to investigate the accident at Three Mile Island. This group, known as the “Kemeny Commission,” conducted a comprehensive investigation of the accident and made recommendations based upon their findings
  - The NRC sponsored both internal and external investigations, and asked the independent Special Inquiry Group, known as the “Rogovin Committee” to perform an investigation

Strategic Planning

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- Many groups, both internal and external to the NRC, also performed separate investigations.
- These included:
  - The U.S. Congress and its General Accounting Office (GAO)
  - The Ad Hoc Dose Assessment Group, which comprised various Federal agencies
  - The NRC's Advisory Committee on Reactor Safeguards

Institutional Framework Changes

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- The TMI accident permanently changed both the nuclear industry and the NRC
- Public fear and distrust increased
- NRC's regulations and oversight became broader and more robust
- Management of the plants was scrutinized more carefully
- Careful analysis of the accident's events identified problems and led to permanent and sweeping changes in how NRC regulates its licensees – which, in turn, has reduced the risk to public health and safety

Institutional Framework Changes

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- Upgrading and strengthening of plant design and equipment requirements
  - Includes fire protection, piping systems, auxiliary feedwater systems, containment building isolation, reliability of individual components (pressure relief valves and electrical circuit breakers), and the ability of plants to shut down automatically
- Identifying the critical role of human performance in plant safety led to revamping operator training and staffing requirements, followed by improved instrumentation and controls for operating the plant, and establishment of fitness-for-duty programs for plant workers to guard against alcohol or drug abuse

Institutional Framework Changes

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- Enhancing emergency preparedness, including requirements for plants to immediately notify NRC of significant events and an NRC Operations Center staffed 24 hours a day
- Drills and response plans are now tested by licensees several times a year, and state and local agencies participate in drills with the Federal Emergency Management Agency and NRC
- Requirement for plant specific simulators established
- Integrating NRC observations, findings, and conclusions about licensee performance and management effectiveness into a periodic, public report

Institutional Framework Changes

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- Having senior NRC managers regularly analyze plant performance for those plants needing significant additional regulatory attention
- Expanding NRC's resident inspector program
- Expanding performance-oriented as well as safety-oriented inspections, and the use of risk assessment to identify vulnerabilities of any plant to severe accidents
- Strengthening and reorganizing enforcement staff in a separate office within the NRC
- Establishing the Institute of Nuclear Power Operations, and formation of what is now the Nuclear Energy Institute to provide a unified industry approach to generic nuclear regulatory issues, and interaction with NRC and other government agencies

Institutional Framework Changes

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- Installing additional equipment by licensees to mitigate accident conditions, and monitor radiation levels and plant status
- Enacting programs by licensees for early identification of important safety-related problems, and for collecting and assessing relevant data so operating experience can be shared and quickly acted upon; and
- Expanding NRC's international activities to share enhanced knowledge of nuclear safety with other countries in a number of important technical areas

References

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