U. S. DOE Experience with D&D of EBR-2 and FFTF

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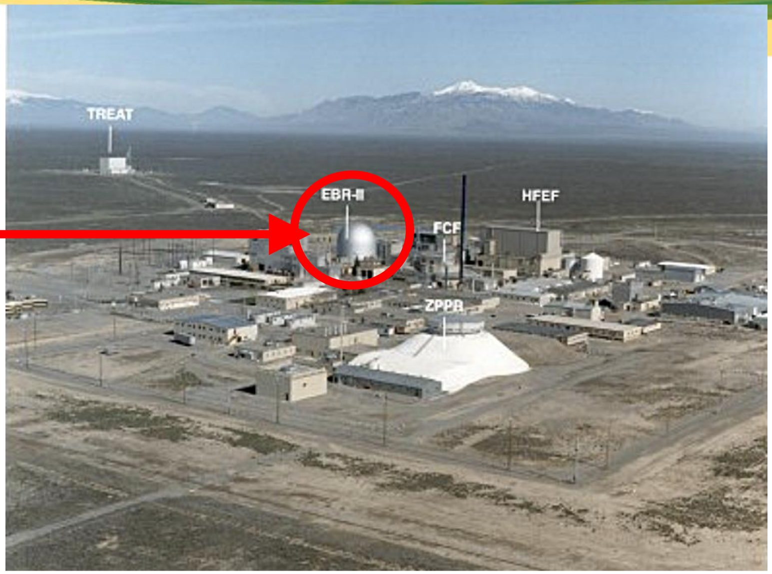
for the
Second Expert Panel on Monju Decommissioning
Tsuruga, Japan, 19 July, 2017

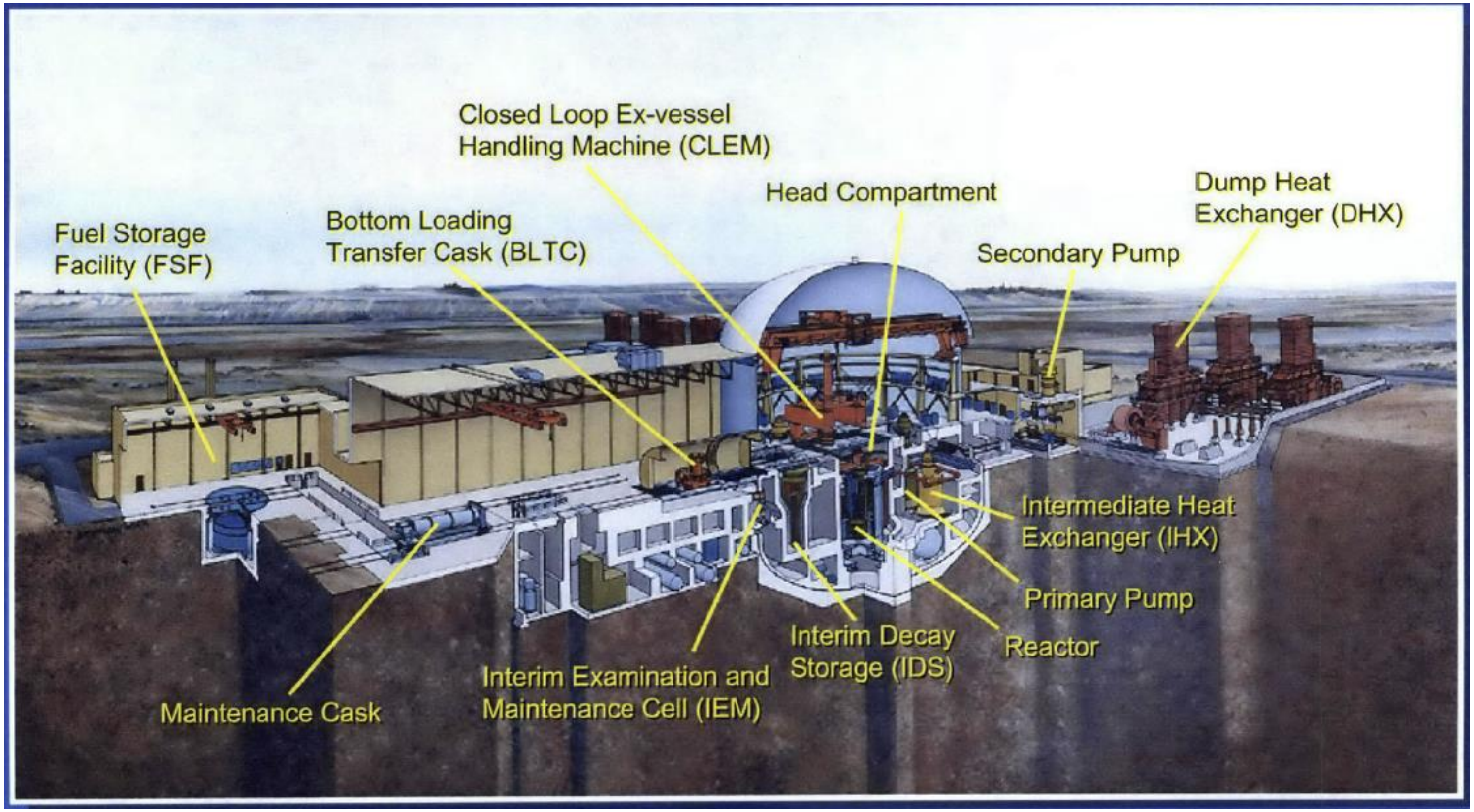
Experimental Breeder Reactor-2

- 1964: Full Power
- 1994: Shutdown
- 1996: Defueled
- 2001: Bulk Sodium Removed
- 2015: Reactor Entombed
- 2019: Start Dome Demolition



Fast Flux Test Facility

- 1982: Full Power
- 1992: Shutdown
- 1995: Defueled
- 2005: Bulk Sodium Removed
- 2007: Deactivated
- 2030's: Final Decommissioning: Entombment Anticipated



Project Phases

- Planning
  - Project Strategic Objectives
  - Project Execution Planning
  - Supporting Plans
- Deactivation
  - Fuel Removal, Washing, and Storage
  - Sodium Draining and Residual Sodium Removal, Passivation, and Storage
  - Deactivation of Structures, Systems, Components, Materials
- Surveillance and Maintenance Waiting for Final Decommissioning
- Final Decommissioning
  - Entombment
  - Demolition

Strategic Objectives

- Deactivation End State Definition (depends on if continuing directly to final decommissioning or if the facilities will sit idle for many years)
- Final Decommissioning End State Definition (Green Field, Brown Field, Entombed)
- Environmental Evaluations; in the U.S., this is the basis and justification for the chosen final End State
- Sequence for Deactivation and Decommissioning of Major Site Facilities (example: electrical supply routing on the site may be important if power is needed to be retained in some buildings when others are isolated or demolished)
- Individual demolition projects can include several facilities associated with a major building

Individual Project Plans

- Characterization
  - Radiological contamination, airborne, and direct radiation
  - Chemical and Hazardous Materials
  - Physical (use of LIDAR for inaccessible areas)
- Project Baseline
  - Scope
    - deactivation, demolition, entombment
    - number of buildings in a single project
  - Schedule
    - Will depend on many site limitations and available resources, need for technology development, testing of methods, and others
  - Cost
    - Detailed activity-based estimate
    - Basis of estimate assumption must be documented
- Technology and Demonstration Needs
  - Adaptation of existing technologies (preferred)
  - Development of new technology for unusual situations
- Project Risk Assessment
  - Risk Identification that could have an effect on the ability to conduct the project activities
  - Chances of Occurrence
  - Methods for Avoidance and/or Mitigation

Supporting Plans

- Regulatory Compliance
- Worker Safety
- Training of Workers for D&D activities
- Environmental Protection
- Stakeholders, Public, and Local Government Communication
- Emergency Response

Fuel Removal & Washing

- From an FFTF Review
  - Fuel removal rate will be controlled by the rate of washing
  - At Super Phoenix, the fuel washing process was based on injection within the washing pit of water mist and C02
  - At FFTF water vapor and argon were planned
  - The water mist and CO2 would be much faster
  - The washing schedule will be controlled by the availability of sufficient storage casks for the fuel

FFTF Draining

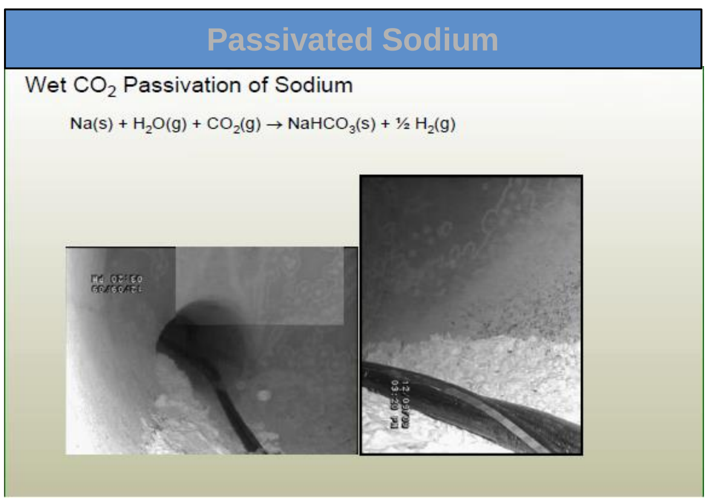
- All bulk sodium was drained (except for cold traps) and stored in 4 large tanks at the FFTF site pending future use
- Draining of reactor vessel required the drilling of a 3/4” hole between the high pressure and the low pressure volumes near the bottom of the reactor vessel.
- Piping changes made to NaK systems to allow mixing of NaK with primary sodium to assure complete removal of NaK.
- Used a one-third size mockup of the reactor vessel to demonstrate use of super-heated steam to react residual sodium

Sodium Treatment Methods (Not one method works for all of it)

- Moist CO2 for passivation (but see next viewgraph)
- Superheated Steam for non-passivated sodium
- Acidic aqueous solution for passivated and non-passivated sodium and NaK
- Saturated steam/condensate treatment for heat exchangers
- Important Lesson Learned: An attempt to use citric acid treatment to treat sodium in a network of pipes led to excursions of increasing intensity with movement of treatment solution back and forth between branches. Ultimately, this resulted in a larger reaction of sodium and water moving a slug of water rapidly down a pipe and against a dead end, causing a breach of the piping by water hammer.
- Lessons from this event are in the reference titled: EBR-II D&D Update—September 2012 CWI Completes Treatment of Primary System Sodium

Pros and Cons of Passivation (moist CO2)

- PROS
  - Stabilizes sodium by creating a bicarbonate crust 3.9 in (10 cm) deep over the remaining reactive sodium
  - Good for long term in-situ storage of sodium
- CONS
  - Creates an approximate 3.9 in (10 cm) thick hard crust over the sodium hindering further treatment of the sodium using moist CO2 or superheated steam treatment methods
  - In order to treat the sodium, the bicarbonate crust must be treated through erosion, high heat, or acid.
  - Much easier to treat non-passivated sodium



Deactivation

Example of Deactivation Planning

FFTF-25070 Revision 0, Fast Flux Deactivation End Points Criteria

Definition

- Deactivation: Placing a facility in a stable and known condition including the removal of hazardous and radioactive materials to ensure adequate protection of workers, public health and safety, and the environment, thereby limiting the long-term cost of surveillance and maintenance.
- Same as IAEA's "Transition from Operation to Decommissioning"

FFTF – 25070 Table of Contents

Surveillance & Maintenance

FFTF Example: Table of Contents

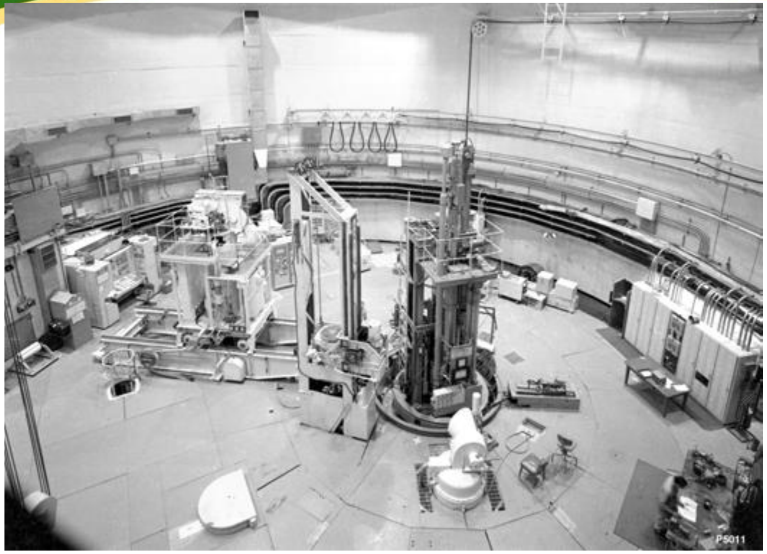
DOE/RL-2009-26 Revision 0, Surveillance and Maintenance Plan for the Fast Flux Test Facility

Final Decommissioning

FFTF Example

- Environmental Impact Statement issued in November 2012; Alternatives Evaluated were:
  - No Action
  - Entombment
  - Removal
- The Preferred Alternative selected was "Entombment" and consists of the following actions:
  - Removal of all above grade structures
  - All below grade facilities/components filled with grout to immobilize radioactive and hazardous constituents
  - Engineered barrier to be placed over area
  - Remote-handled "special components" processed at Idaho National Laboratory and waste returned to Hanford
  - Bulk sodium (currently in storage at FFTF) would be used as product at the Waste Treatment Plant at Hanford

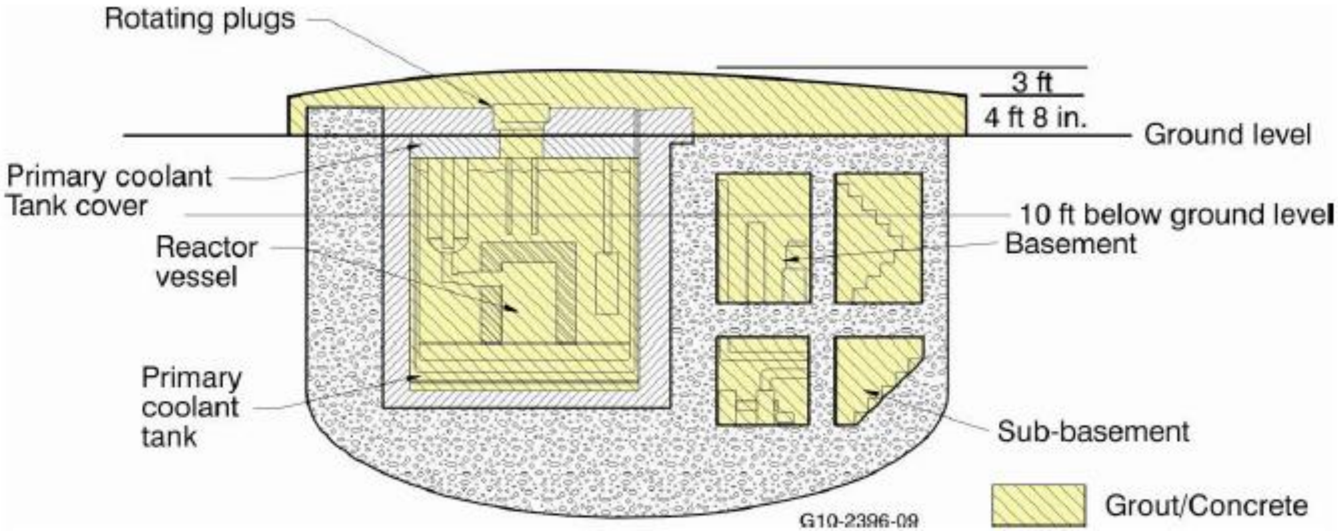
EBR-2 Final Decommissioning Reactor Entombment



Main Floor above the Reactor

Reactor is now Entombed with Grout

Entombment Concept



Lessons Learned-1

- Expect the Unexpected! You will meet situations that were not planned; such as physical configuration different than documented, contamination or high radiation not anticipated, air flow in the wrong direction, or many other kinds.

- It is important to accelerate the transition from an operating culture to the decommissioning culture and mission. Until this is done, progress will be delayed. This will require re-training of workers that wish to stay and hiring others with needed skills. Engineering and work practices and procedures will need to change for the new work and mission environment.

- Understand and plan for the safety of workers and the public for which many potential threats will be different than during operations.

- Regulatory oversight will need to adapt to the changes in mission, conditions, types of activities, and other issues that differ considerably from previous operations. Many of the previous issues will also remain.

- Inform Stakeholders as early as possible of future uses and end states. Continue to communicate as progress is made.

- Understand the need for different and evolving technologies; encourage innovation.

Lessons Learned-2

- Characterization is essential to project planning
- Several methods for sodium removal and processing will be needed. Do not plan on one.
- The use of mock-ups to test and qualify sodium removal methods and processes proved to be valuable
- Record knowledge of technical staff prior to their departure
- Maintain “as-built” drawings for equipment and systems that will continue to be needed (recognizing they may be inaccurate)
- Maintain spare parts that may be needed to “re-configure” systems for D&D
- Maintain records of past operational upsets

OFFICE OF ENVIRONMENTAL MANAGEMENT

Acknowledgements & References

- Acknowledgements
  - EBR-2, Mr. Kirk Dooley
  - FFTF, Mr. Al Farabee

- References

  - U.S DOE Hanford Office, Fast Flux Test Facility Closure: Accomplishments and Plans, January 26, 2017.
  - Idaho Cleanup Project, D&D Sodium Treatment Overview
  - Experimental Breeder Reactor (EBR-II) D&D Overview
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  - DOE/EA – 0993, Environmental Assessment, Shutdown of the Fast Flux Test Facility
  - DO E/RL-2009-26 Revision 0, Surveillance and Maintenance Plan for the Fast Flux Test Facility
  - FFTF-25070 Revision 0, Fast Flux Test Facility Deactivation End Point Criteria
  - IAEA-TECDOC-1633, Decommissioning of Fast Reactors after Sodium Draining
  - IAEA-TECDOC-1769, Treatment of Residual Sodium and Sodium Potassium from Fast Reactors
  - DOE EM Project Experience & Lessons Learned for In Situ Decommissioning, U.S. Department of Energy Office of Environmental Management, Office of D&D and Facility Engineering
  - EBR-II D&D Update—September 2012 CWI Completes Treatment of Primary System Sodium