FERMI-I FUEL MELTDOWN INCIDENT

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11/20/2014

INTRODUCTION

The Fermi-1 reactor was a 200 MWth and 61 MWe fast Na cooled reactor demonstration commercial fast reactor power station that was located on the western shore of Lake Erie at Laguna Beach, south of the city of Detroit, Michigan. It was designed by Atomic Power Development Associates, APDA, constructed by Power Reactor Development Company, PRDC, and operated by the Detroit Edison electrical utility. The reactor achieved first criticality on August 1963, and produced first power in August 1966.

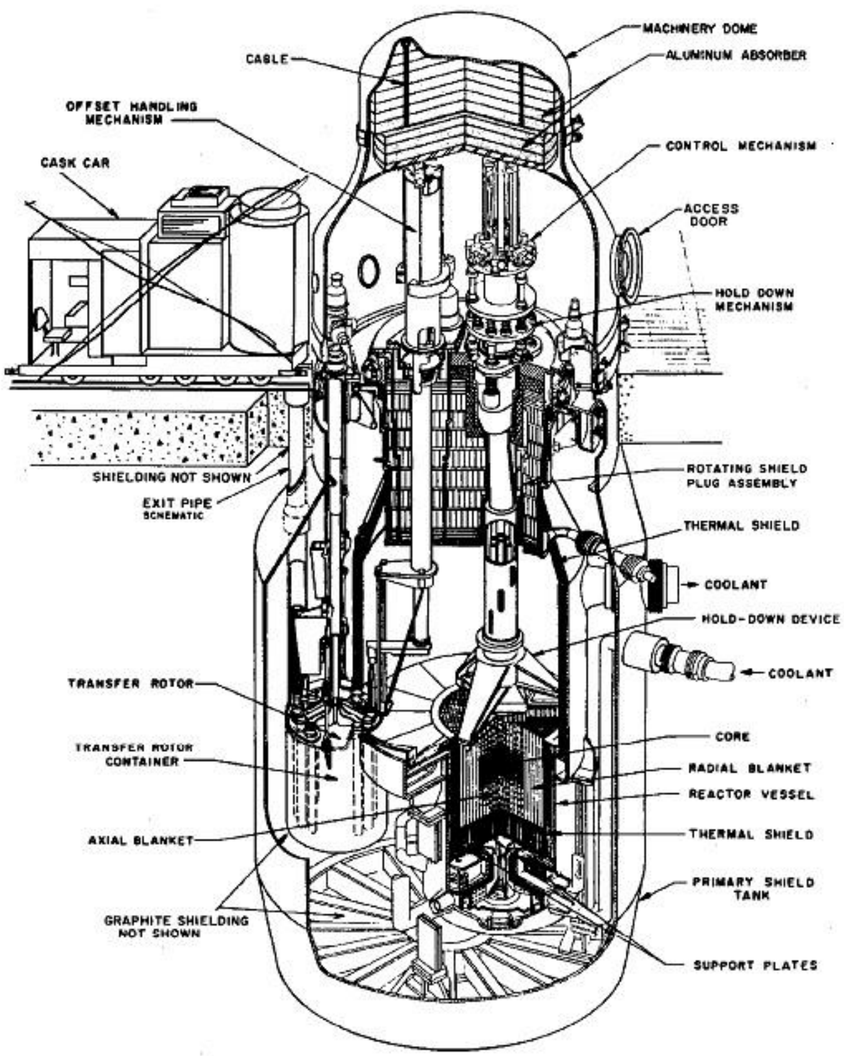

Figure 1. Fermi-1 reactor perspective view.

It was subject to an accident resulting from a restricted cooling experiment called for by the Atomic Energy Commission (AEC) head who was an old Naval Water Reactors expert. The experiment proceeded until an improvised plate used to blank some of the Na flow broke loose and flopped against the bottom part of the core obstructing the coolant flow and causing a core meltdown. The AEC refused to pay for the repairs. The core was redesigned with UO2 as a fuel and the unit was run for several more years and remained unfixed and un-decommissioned.

TECHNICAL SPECIFICATIONS

The fast neutron spectrum Na cooled breeder reactor Fermi-1 was a sodium cooled reactor with an inlet temperature of 288 ^{o}C and an outlet temperature of 427 ^{o}C operating at a pressure of 120 psia.

It used a metallic uranium fuel with a Zr cladding. The fuel elements had 0.158 in of outer diameter, had a height of 31 in, and were positioned in a square lattice.

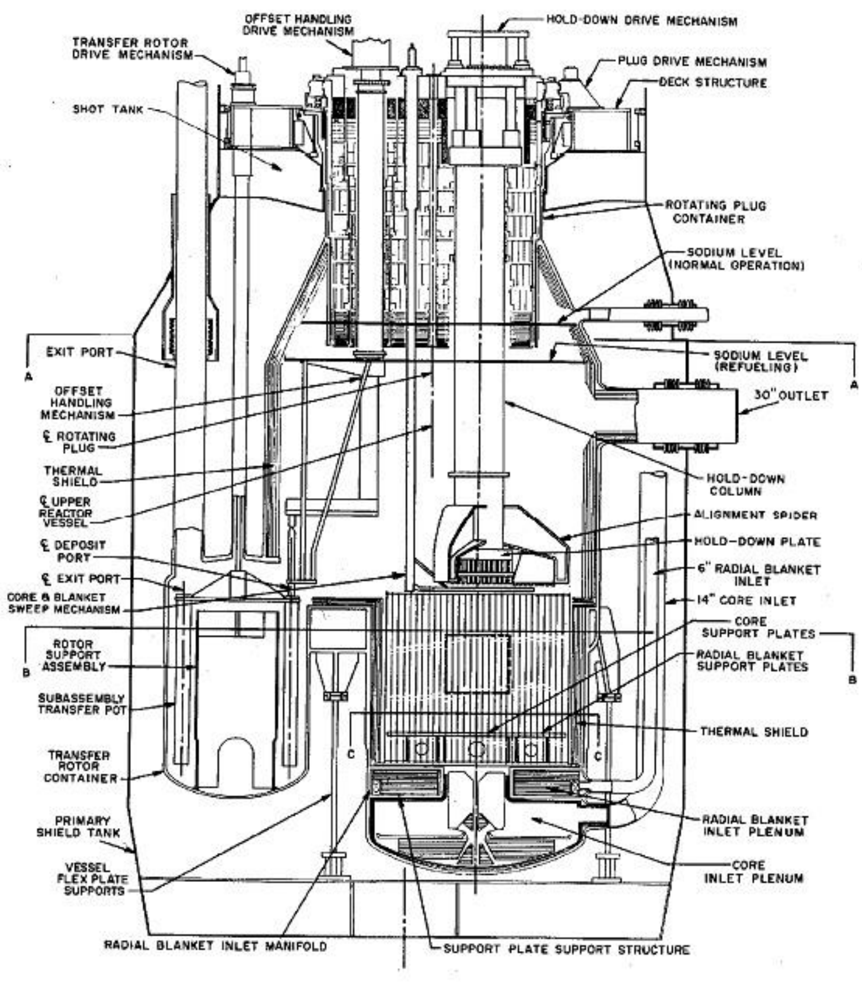

Figure 2. Fermi 1 vessel elevation.

INCIDENT DESCRIPTION

Fermi-1 was subject to a subassembly flow blockage resulting in fuel melting incident during power ascension on October 5, 1966. The metallic fuel core was removed and replaced with a uranium dioxide core, and achieved full power in 1969. Its operation ceased in 1972.

Prior to October 5, 1966, higher than normal fuel temperature was observed in a fuel assembly, which is a cluster of fuel rods. The coolant outlet thermocouple temperatures readings were observed at 2 out of 155 fuel assemblies during low power level operation. The temperature of the coolant above one fuel assembly was lower than normal.

The readings of the thermocouples were initially suspected. To check the validity of the readings, the reactor was shut down and the fuel assemblies exhibiting the abnormally high temperature reading were relocated to positions under different thermocouples. What was observed was that the locations of the high temperature readings varied at each startup, but did not correlate with the fuel subassemblies movement. The reactor operated without incidents at a power level of 100 MWth.

On October 5, 1966, on the ascension to a selected 67 MWth power, at a power level of 20 MWth at 3:00 pm, the reactor operator observed a control signal indicating an erratic neutron population. The problem was experienced earlier and was thought as resulting from electrical fluctuation in the control system.

The reactor was placed on manual control, and when the fluctuations disappeared, the control system was reinstated to automatic control.

At 3:05 pm, with the reactor power level at 27 MWth, the erratic signals were again observed. It was noted later that the control rods were withdrawn farther than normal.

Two of the core subassemblies indicated outlet coolant temperatures of 370 and 380 ^oC or 695 and 715 ^oF. This was higher than a bulk coolant temperature of 315 ^oC or 600 ^oF.

At 3:09 pm the upper building ventilation exhaust ducts radiation monitors sounded an alarm indicating radiation release from fuel damage.

The containment building was automatically isolated. A radiation emergency was declared. The reactor power increase was stopped at 31 MWth, followed by a power reduction.

At 3:20 pm, the power decreased to 26 MWth, and the reactor was manually shutdown.

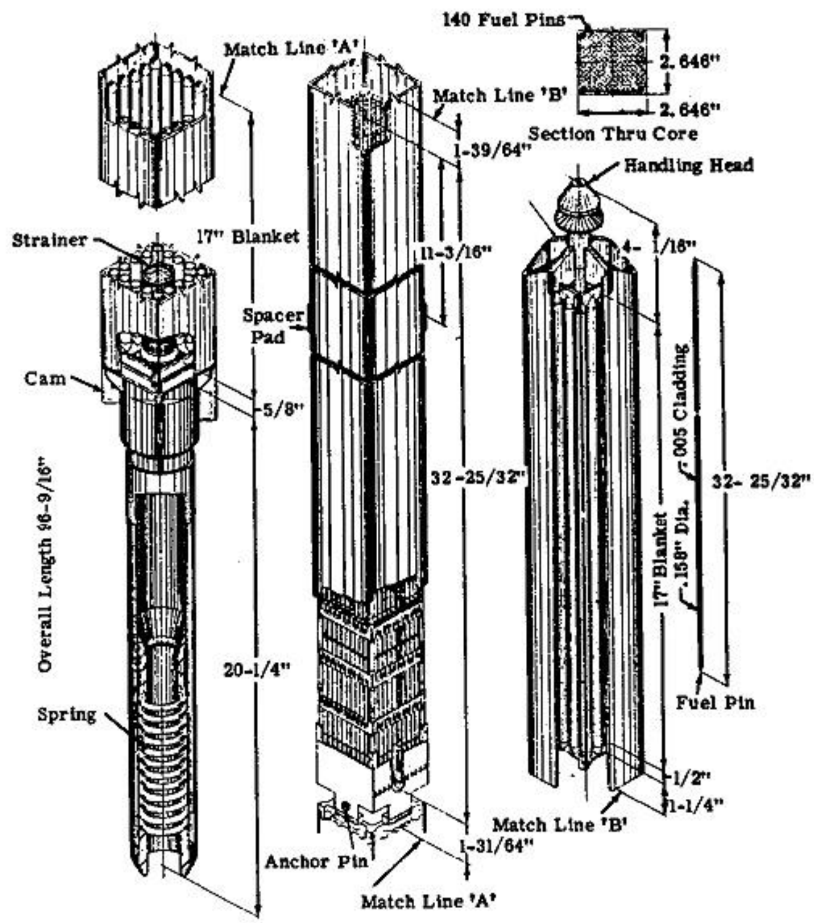

Figure 3. Fuel subassembly in the Fermi-1 reactor.

INCIDENT ANALYSIS

Over a year period many fuel assemblies were removed for examination. The cause of the incident was characterized as "relatively trivial."

Investigations revealed that fuel melting occurred in two adjacent fuel assemblies, with a third fuel assembly bent without internal damage.

A piece of debris referred to as "foreign object" was found stuck in the inlet plenum. This proved later to be a loose crumpled Zircaloy plate from the melt-down section liner.

At the bottom of the core, 6 small Zircaloy plates had been installed to direct the Na coolant flow to the upward direction. One of these 6 plates broke loose and caused flow starvation at the entrances of the fuel assemblies.

The loose Zircaloy plate had been swept away by the flowing coolant and floated to different locations to partially or completely cover the inlet nozzle of various fuel assemblies during the multiple shutdowns and startups.

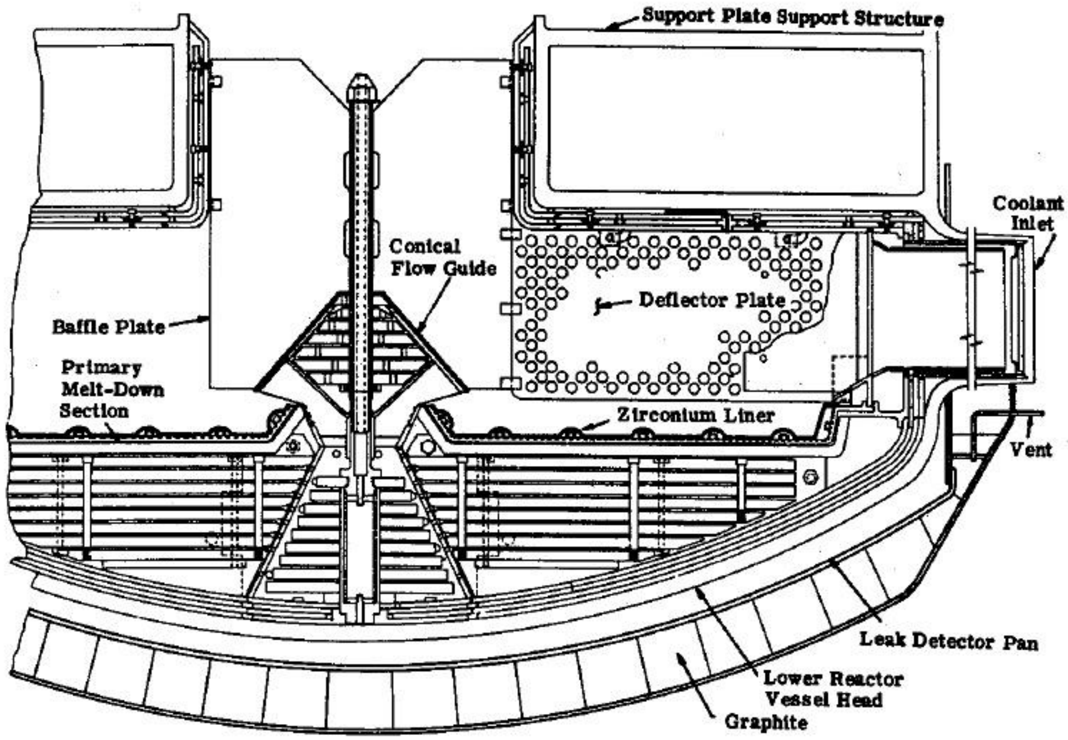

Figure 4. Fermi-1 core coolant inlet, dispersion and meltdown section. The loosened plates Zircaloy at the inlet coolant flow were broken loose to partially or totally obstruct one or the other fuel subassemblies inlet plenums during startups and shutdowns.

INCIDENT RECOVERY AND CONSEQUENCES

There was a need to use a specially designed remotely controlled tool capable of operating in the high radiation environment to repair the damage and the reactor restarted operation in October 1970, 4 years after the incident.

No injury occurred and no radioactivity was released to the environment. The safety system operated as designed in containing 10,000 Curies of fission products activity released into the Na coolant.

The damage did not propagate to the adjacent fuel assemblies and the accident did not escalate according to the worst case scenarios.

The incident focused the attention on the problem of flow blockages that could be caused by unintended debris in the circulating sodium coolant.

The Zircaloy plates were found not to be included in the original reactor design and were added at a later stage in the design.

Any late fix-ups should be strictly avoided in the design and construction of reactor systems especially since these late additions would escape the quality control and design scrutiny of the other components.

SAFETY DESIGN CONSIDERATIONS

Since the Fermi-1 incident, the inlet nozzles for the fuel assemblies include multiple coolant inlet passages so that complete external blockages would not be possible.

Research and testing on internal and external blockages has been undertaken to quantify and understand the corresponding damage mechanisms.

The internal and external assembly blockage scenario is addressed in the assembly design by:

1. Providing inlet flow diversity for the fuel subassemblies.
2. Assuring coolant flow distribution and assurance of assembly coolant supply in the inlet plenum design.
3. Using multiple coolant temperature measurement thermocouples, delayed neutrons detectors, and gas tags in the instrumentation design.
4. Improvement in fuel handling equipment design such as spent fuel casks.

DISCUSSION

Parts of any reactor that are susceptible to vibration damage should be carefully designed and monitored against the release of debris.

In all reactor designs careful consideration is given to flow testing in the different components.

Late fix-ups to the original design escaping quality control and careful scrutiny must be strictly avoided in reactor designs.

In some countries, the fuel assembly blockage scenario is adopted as the “design basis accident” for fast reactors.