STATUS OF DISASSEMBLY OF THE DAMAGED TMI-2 REACTOR CORE

GREG R. EIDAM
BECHTEL NATIONAL, INC.

The March 1979 accident of the Three Mile Island Unit 2 (TMI-2) pressurized water reactor was the most severe accident to occur in a commercial operating power reactor in the United States. The progression of the TMI-2 accident was finally mitigated by the presence or injection of coolant water. The integrity of the reactor vessel was challenged, but remained intact. During the past 9 years, the TMI-2 accident has been a unique and invaluable source of information for improving and expanding the present knowledge of severe accidents of core melt progression, and of mitigating severe accidents before the reactor vessel and containment are threatened.

The post-accident condition of the plant presented an extremely difficult and complex plant cleanup challenge. The first major step in defueling the TMI-2 core was the removal of the reactor vessel (RV) head in July of 1984. With the head removed from the reactor vessel, it was then possible to lower cameras into the lower plenum region to allow engineers and scientists to see for the first time that 10,000 to 20,000 kg of core material, which appeared to have been molten at one time, was resting on the reactor vessel lower head. This examination, along with metallographic examinations of particles taken from the upper debris bed, indicated that the damage to the core was more extensive and severe than first thought. The upper plenum assembly was removed in May of 1985, and the final preparations to commence defueling operations were completed. On October 30, 1985, defueling began with the first core alterations.

The task of defueling the RV and accounting for all fissile materials has been difficult due to the extensive damage to the core and some of the core support structures, and because of the radiation fields in the Reactor Building. Fuel removal and handling have been challenging. Continuing development and application of unique tools and methods are relied upon to defuel the reactor.

An accurate determination of the post-accident state of the plant has been required to understand not only the accident progression and fission product transport and deposition, but to understand as well the properties of post-accident core material in order to defuel the reactor. This information has been developed from several sources: visual inspections of the reactor vessel internals, metallurigcal-radiochemical examinations of samples during the course of defueling, and readings from on-line instrumentation and experimental data developed from smaller scale tests conducted at various facilities.

Extensive damage to the TMI-2 core has presented unique problems. After the plenum was removed, a shielded rotatable work platform was mounted on top of the RV to provide access to the core through a 45 cm slot. Special long-handled tools, for use with underwater and shielded remote canister handling equipment, were developed to remove the core materials and place them in specially designed shipping canisters for transport to the Idaho National Engineering Laboratory (INEL). Removal of core material progressed in stages, with each of the different regions of core material being removed individually.

The end state configuration of the original core included a core void or cavity which was approximately 1.5 m deep with an overall volume of approximately 9.3 m^3. Forty-two of the original 177 fuel assemblies standing at the periphery of this void surrounded this cavity. Only two of these fuel assemblies contain more than 90% of their full-length cross section with the majority of the fuel rods intact. The first step in defueling of the core region was to reduce these fuel assemblies and fuel rods into manageable lengths to provide clearance for the rotatable work platform and canister handling equipment beneath the platform. This reduction was accomplished by hydraulic cutters. Beneath this void, a loose debris bed varying in depth from 0.6 to 1 m existed consisting of whole and fractured fuel pellets, control rod spiders, end fittings, and resolidified debris totaling approximately 26,400 kg. This material was picked up with long-handled, pick-and-place tools and loaded into defueling canisters.

Beneath the loose debris bed was a large resolidified mass which was approximately 3 m in diameter, 1.5 m thick at its center, and 0.25 m thick at its periphery and containing approximately 32,700 kg of core debris. A special drilling machine was mounted on the work platform to break up this consolidated mass. The resulting fragmented debris was then placed in defueling canisters by using the pick-and-place tools. Some large pieces, composed of previously molten metallics and ceramics which were too large to be placed directly into the defueling canisters, were broken apart with the use of a hydraulic underwater jackhammer. Beneath this large resolidified mass stood undamaged fuel assembly stubs extending upward from the lower grid plate to the bottom surface of this resolidified region. These stubs varied in lengths of approximately 0.2 m to 1.5 m. Longer, partial fuel assemblies stood at the periphery and the resolidified mass. These fuel assembly stubs were removed with a specially designed fuel assembly puller tool that lifted each assembly and loaded them into defueling canisters. On the east side of the core, four adjacent fuel assemblies were almost completely replaced with previously molten core material; this has indicated a possible relocation path of molten material into the lower core support assembly (LCSA) and core bypass region. During December of 1987, all fuel assembly stubs, with the exception of one, were removed. The remaining assembly (R-6) consisted of a partial end fitting frame with resolidified material filling the space where the assembly would have been. This mass continues into the bypass region. During March of 1988, a hole was drilled into this one remaining stub assembly with a junk mill bit attached to the special drilling machine which was remounted on the work platform. After the drilling, portions of the end fitting and resolidified mass still remained. The standing fuel assembly stubs and peripheral assemblies constituted approximately 44,500 kg of core debris.

The LCSA region consists of 5 stainless steel structures: four plates and a lower grid assembly. The structures vary in thickness from 0.025 m to 0.33 m, with 0.080 m or 0.15 m diameter flow holes. During the accident, molten material flowed through the periphery of these structures and came to rest on the lower head of the RV. There is resolidified material at various locations on the circumference of the structures. In several places, resolidified material completely fills the flow holes, and columns of once molten material are observed between the plates. The largest accumulation of resolidified material appears to have flowed into the LCSA from the east side of the core. Although most of this material was seen on the southeast side, many columns of resolidified material have been seen all the way around the core beneath the core bypass region.

The special drilling machine was again mounted on the defueling platform to begin disassembly of the LCSA during January 1988. This machine was used to section the LCSA grid plate which was removed from the reactor vessel and transferred to a core flood tank for storage during April. During May, an automated cutting equipment system (ACES), which includes a manipulator arm and an X-Y bridge and trolley system, was installed in the reactor vessel to cut the remaining stainless steel structures. The ACES has completed cutting two of these structures and is currently in the process of cutting the remaining two. During the early part of 1989, the last of these remaining structures will have been removed to provide access to the lower head region. Inspections have revealed that a large quantity of previously molten core material rests on the lower head. The post-accident debris in the lower head region accumulated to a depth of 0.75 m to 1 m above the lower head elevation, and to a diameter of 4 m. Particle sizes varied from granular particles (less than 0.010 m) to large rocks (up to 0.20 m). Visual inspections have indicated that larger rocks, especially in the northeast and southwest areas, were located towards the periphery and the debris pile was lower at the vessel center than at the periphery. A large cliff-like structure formed of previously molten core material exists in the northern region. The cliff base was approximately 0.38 m high and 1.25 m wide. It has been estimated that 19,200 kg of core material was in the lower head region as a result of the accident. The only significant structural damage observed to date in the lower head region was the melting of an incore instrument guide tube.

As a result of defueling the core region, additional material from the core region has been relocated to the LCSA and lower head regions. Therefore, over 28,000 kg of material must be removed from the lower head region. When this region is defueled, additional damage may be identified.

The final stage of defueling will be to disassemble the core baffle plates and remove the previously molten material from the core bypass regions. This core bypass region consists of vertical core baffle plates that form the peripheral boundary of the core, horizontal core former plates to which the baffle plates are bolted, the core barrel, and thermal shield. There are a number of flow holes in the baffle core former plates to which coolant flowed during normal reactor operations.

A large hole approximately 0.6 m wide and 1.5 m high exists, extending across the lower portion of 3 baffle plates. The 0.019 m thick baffle plates and sections of 3 horizontal core former plates (approximately 0.032 m thick), were melted in this region. Molten core material from the core region appears to have flowed through this hole into the upper CSA. The area behind the baffle plates contains loose debris all the way around the core region. The depth of this debris within the upper CSA is approximately 1.5 m on the northside and a few millimeters thick on the southwest side. There appears to be a resolidified crust on the upper horizontal surfaces of the 3 bottom core former plates. The molten material moved down into the lower CSA through the flow holes in the core former plates. It is estimated that 4,200 kg of core debris is retained in this region. The annulus between the core barrel and the thermal shield was visually inspected and only fine particulate was observed. No major damage to any of the components in the upper CSA have been seen beyond what has been described here.

Defueling will be completed when these operations are concluded. Visual examinations and sampling, which will be conducted during later defueling operations, will give additional insight into the margin-of-failure of the reactor vessel, the core damage progression scenario, and the fission product inventory.