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TMI-2 VESSEL INVESTIGATION PROJECT (VIP) METALLURGICAL PROGRAM*

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The TMI-2 Vessel Investigation Project (VIP) Metallurgical Program is a part of the international TMI-2 Vessel Investigation Project being conducted jointly by the U. S. Nuclear Regulatory Commission and the Organisation for Economic Co-operation and Development (OECD). The overall project consists of three phases, namely (1) recovery of material samples from the lower head of the TMI-2 reactor, (2) examination and analysis of the lower head samples and the preparation and testing of archive material subjected to a similar thermal history, and (3) procurement, examination, and analysis of companion core material located adjacent to or near the lower head material.

The specific objectives of the ANL Metallurgical Program, which comprises a major portion of Phase 2, are to prepare metallographic and mechanical test specimen blanks from the TMI-2 lower head material, prepare similar test specimen blanks from suitable archive material subjected to the appropriate thermal processing, determine the mechanical properties of the lower vessel head and archive materials under the conditions of the core-melt accident, and assess the lower head integrity and margin-to-failure during the accident. The ANL work consists of three tasks: (1) Archive Materials Program, (2) Fabrication of Metallurgical and Mechanical Test Specimens from the TMI-2 Pressure Vessel Samples, and (3) Mechanical Property Characterization of TMI-2 Lower Pressure Vessel Head and Archive Material.

It was anticipated that the amount of material actually obtained from the lower head of the TMI-2 reactor would not be sufficient to carry out all of the mechanical tests and microstructural studies necessary to thoroughly assess its integrity during the accident. The archive materials activity was therefore created to provide supplemental material for these studies. Unfortunately, no actual archive material from the TMI-2 lower head was available, and it was necessary to obtain material as similar as possible from another source. The source selected for this alternative "archive" material was the lower head of the Midland nuclear reactor (which was never operated due to cancellation of the plant before completion) in Midland, MI. The Midland reactor was a sister plant to TMI, and the lower heads of both vessels came from the same supplier with virtually identical fabrication histories.

The Midland material was obtained in the form of four plates, each approximately 0.3 x 1.2 x 0.14 m thick (12 x 48 x 5-5/8 in. thick). Chemical analyses and checks on hardness and microstructure were carried out to verify that the Midland material was suitable for use in the program.

A heat treatment program was conducted on the archive material to produce a set of standard microstructures for comparison with those observed in the actual TMI-2 lower head material. Three types of thermal cycles were studied, each designed to simulate the thermal history at some point in the TMI-2 lower head during the accident. The results of the heat treatment program, along with supplementary hardness studies, demonstrated that those regions in the TMI-2 lower head where the maximum temperature exceeded the 727°C ferrite to austenite transformation temperature during the accident should be identifiable on the basis of microstructural observations.

A series of round-robin mechanical tests and microstructural studies on the as-received archive material was conducted to better characterize this material and to determine the level of variability in mechanical test data obtained by the OECD laboratories participating in the program. This test series consisted of tensile tests at room temperature and 600°C, as well as short-term stress-rupture tests at 600°C. The results of these tests and examinations indicate good agreement among the various laboratories.

Most recently, 15 actual samples removed from the TMI-2 lower head, including 4 samples with the remains of instrument penetration nozzles, have been received. One of these samples, from a region of relatively severe damage in the lower head, contained a crack in the cladding ~5 mm (0.2 in.) wide and extending for ~75 mm (3 in.) on the sample surface. This crack was associated with and encircled an instrument penetration nozzle adjacent to the location from which the sample was removed. Microstructural and SEM examinations of metallographic sections through the crack determined that it penetrated through the stainless steel cladding on the vessel surface but extended for only a short distance into the underlying A533B base metal. The total depth of the crack was ~8 mm (0.3 in.). Extensive oxidation of the base metal was observed at the bottom of the crack, and control assembly material from the core was present on the crack surfaces. However, only minor incidental fuel fragments were detected, indicating that there was no intrusion of the molten fuel in this crack. A comparison of the microstructures and hardnesses of samples from the archive heat treatment program with those present in the base metal of this sample indicate that the temperature of the TMI-2 lower head at this location substantially exceeded 727°C.