SUMMARY

THREE MILE ISLAND UNIT 2: MATERIALS BEHAVIOR

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INTRODUCTION

The 1979 accident at Three Mile Island Unit 2 (TMI-2) and the decade of TMI-2 research that followed have dramatically changed the nuclear industry's understanding of high-temperature core materials behavior during a severe accident. The TMI-2 accident caused reactor safety research programs in the United States and around the world to focus more on accident consequences, not just on accident prevention. These experimental programs and the TMI-2 research results have given scientists and engineers a very clear picture of core damage mechanisms and have improved computer models for predicting severe accident progression. As Chair of the Materials Behavior Subcommittee for the American Nuclear Society topical meeting, the TMI-2 Accident: Materials Behavior and Plant Recovery Technology, I am pleased to introduce over 30 technical papers on TMI-2 materials science, fission product behavior, and computer code development research. I have prepared a brief summary of some of the important observations and conclusions presented by the authors. Since this summary only touches on the wealth of important reactor safety information presented, readers of *Nuclear Technology* (*NT*) will want to explore the full papers in detail. They will find a very complete picture of the materials behavior aspects of the accident that continues to impact the nuclear industry 10 years later.

HIGH-TEMPERATURE INTERACTIONS

Three sessions at the topical meeting were devoted to high-temperature core materials behavior and vessel component interactions. Several papers from U.S. and international laboratories address the materials interactions and peak core temperatures, based on metallurgical examinations of TMI-2 core debris specimens. Analysts have documented a broad spectrum of reactions ranging from

- low-temperature oxidation (<1000 K); to
- a variety of intermediate temperature solid and liquid state reactions between Zircaloy, stainless steel, Inconel, Ag-In-Cd control rod alloy, and Al_2O_3-B_4C control rod material (1000 to 2000 K); to
- high-temperature previously molten ceramic phases (including UO_2 melting at 3100 K).

These reactions are documented in some outstanding microstructural photographs. These studies have pointed out the need for new phase diagram research for these complex interactions, and for simplifying theories that will allow these interaction and transport phenomena to be accurately modeled.

Anyone who would question the adequacy of reactor design should examine the papers on TMI-2 core melting and relocation. The reactor pressure vessel (RPV) withstood the formation of 50 tonnes of molten core material, ~20 tonnes of which relocated onto the RPV bottom over a 1-min period. The melt progression is described in detail, and heat transfer calculations explain why some stainless steel internal structures (e.g., baffle plates) melted while others (e.g., in-core instrument penetrations) did not. We are also reminded just how forgiving light water reactor designs are, by a discussion of how little water is really needed to cool a molten core, and the variety of safety systems that can be called on to provide it.

FISSION PRODUCT BEHAVIOR

Radionuclide release to the primary system, to the plant building, and to the environment are summarized in a series of papers on TMI-2 fission product behavior. While the details of radionuclide behavior are important, one TMI-2 fission product lesson remains foremost: Despite a 50% fuel melt, environmental releases were very small. Inventory tables are presented for the major isotopes that indicate that the sites of major migration and deposition have been largely identified (though data are still incomplete for fuel material on the bottom of the vessel). Metallic melts within the core were found to retain significant quantities of ruthenium, antimony, and technetium. Curiously, major retention of some volatile fission products was observed within very high temperature, once-molten core samples. Various hypotheses—gas bubble dynamics, diffusion rates, chemical form, postaccident aqueous transport, oxygen potential variations—are offered to account for these details of fission product retention. Clearly, many aspects of fission product behavior remain obscure. This subject will offer ample research opportunities for many years to come.

COMPUTER MODELING

One session was devoted to the TMI-2 international code exercise, an effort to use the TMI-2 accident data as a benchmark for severe accident computer codes. Twelve countries have collaborated to create a series of data bases containing reviewed and qualified TMI-2 accident data that are available to the reactor safety community. Computer code calculation results are presented for the early phases of the accident (loss of coolant, boil down, heatup, and initial melting). In general, the current codes predict the early phase thermal-hydraulic behavior quite well (coolant flow rates, primary system pressure, fuel rod temperature rise, pressurizer level, hydrogen generation, etc.), though each author points out areas where their codes fall short.

Readers interested in modeling the accident's later stages—rubble bed formation, debris bed cooling, fuel relocation, and fission product release—will have to be patient. The international code analysis exercise results for the complete TMI-2 accident will not be available until late 1989.

IN APPRECIATION

Finally, reactor safety research in general and the TMI-2 program in particular owes a great debt to Dr. Sidney Langer, Technical Program Chair for the TMI-2 topical meeting. His efforts are largely responsible for all that you see in these special issues of *NT*. On behalf of all who participated in the topical meeting, attended the sessions, and who now read these technical papers, thank you Sid.