THERMAL BEHAVIOR OF MOLTEN CORIUM DURING TMI-2 CORE RELOCATION EVENT *

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During the TMI-2 accident, a pool of molten corium formed in the central region of the core and was contained by solidified crusts. Failure of the crust surrounding the molten material, at approximately 224 min, resulted in a relocation of an estimated 20-25 tonnes of molten corium through peripheral fuel assemblies in the east side of the vessel, as well as through the core barrel assembly (CBA) at the periphery of the core. These major pathways are shown in Figure 1.

This paper presents the results of an analyses carried out to investigate the thermal interactions of molten corium with the CBA structures during the relocation event. The principal objectives of the analyses are: (a) to assess the potential for relocation to take place through the CBA versus the flow of molten core material directly downward through the core via the fuel assemblies; and (b) to understand the distribution of prior molten corium observed during vessel defueling examinations.

Corium which streams laterally out of a side breach in the crust

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surrounding the pool will impinge upon the vertical baffle plate structure immediately surrounding the core. Calculations were carried out investigating the ablation of the 1.9 cm thick baffle plate by a lateral jet of impinging corium. For an assumed circular jet diameter, the velocity of the impinging corium stream was determined from the estimated relocation time, which was varied from 30 to 120 seconds, and the total relocated mass which is known to be about 25 tonnes. Forced convection heat transfer from the impinging corium to the baffle plates was assumed to be limited by the presence of an oxide crust of solidified corium between the flowing molten corium stream and the underlying steel [1]. Boundary conditions on the back side of the plate appropriate to liquid at saturation temperature (584 K) were used. Following the inception of ablation, the crust within the jet impingement region is envisioned to exist as thin segments which move along the top of a film of melted stainless steel. The crust acts as a significant resistance to heat flow from the corium to the baffle plate. Corium thermophysical properties were obtained from MATPRO [2] for the composition of 65 mole % UO_2 - 35 mole % ZrO_2 corresponding to the mean proportions determined from analysis of the lower plenum samples [3]. A nominal stream diameter of 10-cm was assumed based upon observed damage to the core barrel [4]. The nominal molten superheat was taken equal to 200 K, reflecting an analysis of convective heat transfer from the molten pool immediately prior to the relocation event [5].

The calculational results are given in the full paper for a range of jet diameters, total relocation times, and initial corium superheats (i.e., excess temperature above the corium oxide phase liquidus). For the nominal conditions of a 10 cm stream diameter and 200 K of superheat, melt through of the 1.9 cm thick baffle plate is predicted to occur within 14 to 29 seconds after initial impingement. During the 14-29 sec prior to melting of the baffle plate, an estimated 6-11 tonnes of corium would flow downward through the core peripheral assemblies. The remainder of the estimated 25 tonnes of relocated corium would subsequently have access to the CBA and could then relocate through the CBA. Similar melt through calculations were performed to estimate the time for melting the 5.1 cm thick core barrel structure (Figure 1). The results indicate that an impingement time between 36-77 sec would be required for melting the core barrel. This would require an additional 30 tonnes of corium flow. Since only 25 tonnes of corium is estimated to have relocated, the calculation suggests that core barrel melting would not be expected.

In summary, an analysis of the melt through of the vertical baffle plate by an impinging corium stream predicts that breaching of the baffle plate occurred early enough during the TMI-2 relocation event to permit the greater portion of the relocated corium mass to enter the core barrel assembly. Following baffle plate penetration, breaching of the core barrel representing the CBA outer boundary is not predicted before the inventory of impinging corium has been exhausted. These predictions are in agreement with visual examinations of the corium debris which have established baffle plate melt through, core barrel survival, and which indicate that a major portion of the molten corium relocated by way of the core barrel assembly. The full paper will also present the results of additional analyses of the flow and freezing of corium within the CBA, including the effects of heat transfer from the corium to surrounding water and steel structure.

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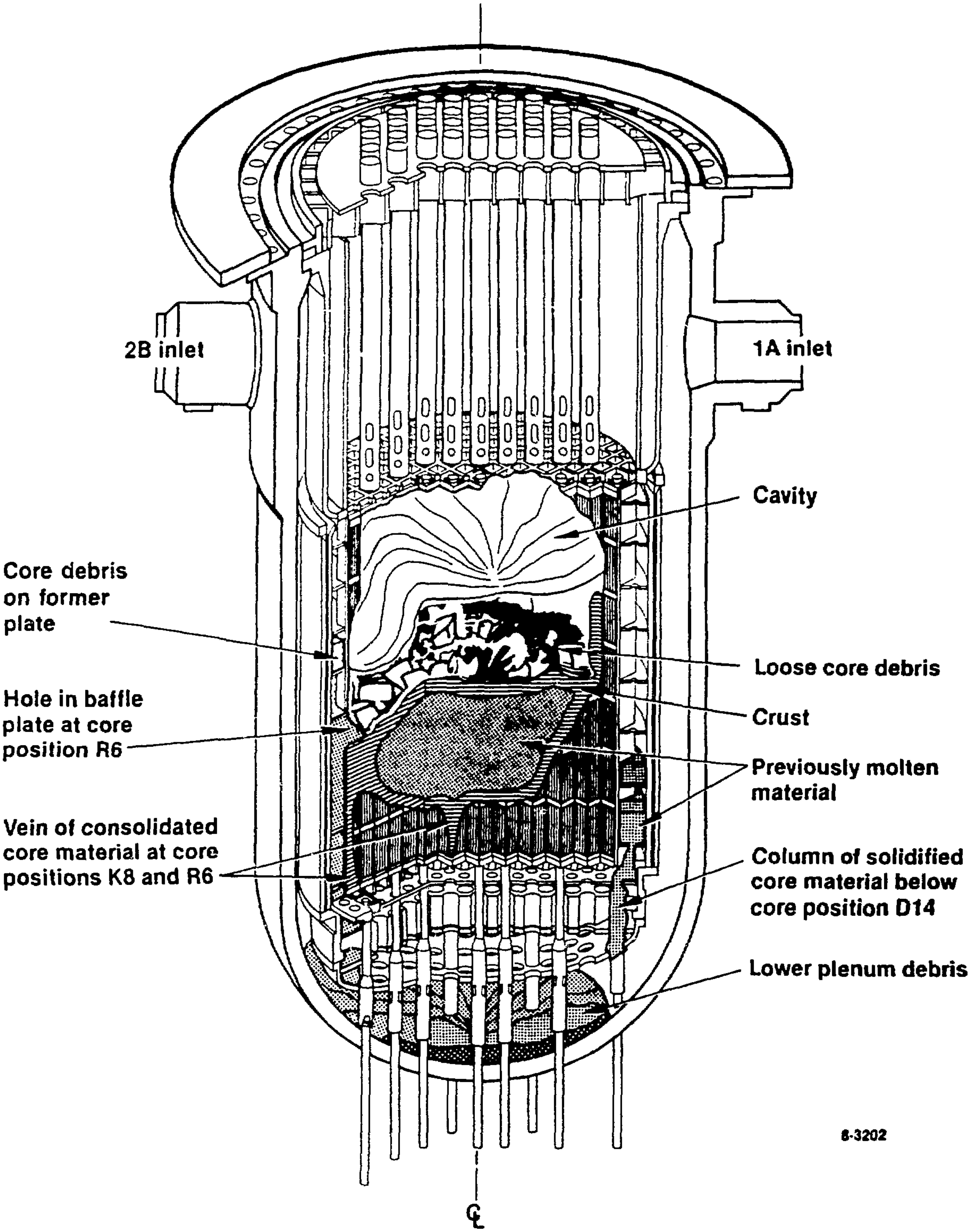

Figure 1. TMI-2 corium relocation paths and core end-state configuration.