Simulation of Core Melt Progression Using a Simulant Metal Alloy

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Abstract

Numerous experiments were conducted to address when and how the core can lose its original geometry, what geometries are formed, and in what processes the core materials are transported to the lower plenum of the reactor pressure vessel during a severe accident. Core degradation progresses along the line of clad ballooning, clad oxidation, material interaction, metallic blockage, molten pool formation, melt progression, and relocation to the lower head. Relocation into the lower plenum may occur from the lateral periphery or from the bottom of the core depending upon the thermal and physical states of the pool. Determining the quantities and rate of molten material transfer to the lower head is important since significant amounts of molten material relocated to the lower head can threaten the vessel integrity by steam explosion and thermal and mechanical attack of the melt. In this paper the focus is placed on the melt flow regime on a cylindrical fuel rod utilizing the LAMDA (Lumped Analysis of Melting in Degrading Assemblies) facility at the Seoul National University. The downward relocation of the molten material is a combination of the external film flow and the internal pipe flow. The heater rods are 0.8 m long and are coated by a low-temperature melting metal alloy. The electrical internal heating method is employed during the test. External heating is adopted to simulate the exothermic Zircaloy-steam reaction. Tests are conducted in several quasi-steady-state conditions. Given the variable boundary conditions including the heat flux and the water level, observation is made for the melting location, progression, and the mass of molten material. Finally, the core melt progression model is developed from the visual inspection and quantitative analysis of the experimental data. As the core material relocates downwards a blockage may be formed and grow both radially and axially. The velocity of the melt can be calculated from a force balance between the gravity and frictional losses at the melt-rod interface. When the heater rod is uncovered completely, the melt progression is initiated at the mid-point, which is the hot spot in the rod. However, the melting location is elevated as the water level rises because of the downward heat transfer. Considering the melt flow as a film, the steady-state film thickness on the cylindrical heater rod and the average velocity are computed. The steady-state film flow rate is determined in terms of the density, film thickness, and film velocity.