Measurement of Critical Heat Flux in Narrow Gap with Two-Dimensional Slices

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Abstract

A cooling mechanism due to boiling in a gap between the debris crust and the reactor pressure vessel (RPV) wall was proposed for the TMI-2 reactor accident analysis. If there is enough heat transfer through the gap to cool the outer surface of the debris and the inner surface of the wall, the RPV wall may preserve its integrity during a severe core melt accident. If the heat removal through gap cooling relative to the counter-current flow limitation (CCFL) is pronounced, the safety margin of the reactor can be far greater than what had been previously known in the severe accident management arena. Should a severe accident take place, the RPV integrity will be maintained because of the inherent nature of degraded core coolability inside the lower head due to boiling in a narrow gap between the debris crust and the RPV wall. As a defense-in-depth measure, the heat removal capability by gap cooling coupled with external cooling can be examined for the Korean Standard Nuclear Power Plant (KSNPP) and the Advanced Power Reactor 1400MWe (APR1400) in light of the TMI-2 vessel survival. A number of studies were carried out to investigate the complex heat transfer mechanisms for the debris cooling in the lower plenum. However, these heat transfer mechanisms have not been clearly understood yet. The CHFG (Critical Heat Flux in Gap) experiments at KAERI were carried out to develop the critical heat flux (CHF) correlation in a hemispherical gap, which is the upper limit of the heat transfer. According to the CHFG experiments performed with a pool boiling condition, the CHF in a parallel gap was reduced by 1/30 compared with the value measured in the open pool boiling condition. The correlation developed from the CHFG experiment is based on the fact that the CHF in a hemispherical gap is governed by the CCFL and a Kutateladze type CCFL parameter correlates CCFL data well in hemispherical gap geometry. However, the results of the CHFG experiments appear to be limited in their value because the power of the heaters was restricted by the three-dimensional (3D) geometry. The two-dimensional (2D) geometry relative to the 3D geometry enables the heaters to produce higher power. Experiments were conducted to develop the CHF correlation for gap cooling with the 2D slices. The experimental facility consisted of a heater, a pressure vessel, a heat exchanger and the pressure and temperature measurement system. Tests were carried out in the pressure range of 0.1 to 1 MPa for the gap sizes of 1mm and 2mm using demineralized water