Analysis on the ex-vessel core debris cooling and containment pressurization in 1000MWe PWR plant

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The impact of the ex-vessel core debris cooling by pre-flooding AM on the long-term containment pressurization was analyzed for a Korean PWR model plant. COOLAP-II, a parametric model for melt jet breakup and debris bed formation/cooling, was used in tandem with MELCOR for MCCI and containment thermohydraulics.

Keywords: Severe accident, Ex-vessel debris coolability, Containment pressurization

1. Introduction

Ex-vessel core debris cooling by pre-flooding the reactor cavity is an important part of severe accident mitigation measures. The process includes a sequence of phenomena such as melt jet breakup, debris bed/continuous melt lump formation and MCCI. Also, the steam production during the debris cooling can be a significant containment pressurization source. We developed a simplified model for melt breakup and debris bed formation/cooling, COOLAP-II [1], and used it in tandem with MELCOR 2.2 [2] to examine the long-term containment pressurization influenced by the ex-vessel debris cooing and MCCI.

2. Analytical Method and Conditions

The containment geometry and accident scenarios for OPR1000-like PWR were assumed [3]. COOLAP-II was used for simulation of the initial 1h following the RV failure (start of melt drop) and the calculated debris bed/melt lump configuration was passed to MELCOR handling the MCCI and containment pressurization, with several options on the additional water supply starting at 24h by cavity flooding or containment spray with/without the heat sink. The initial containment condition, 0.12MPa/320K, and the core melt mass dropping to the cavity, 99t (70% of whole core material), were common for all cases. The effect of scenario related variables, namely the time after shutdown (5h), initial water level in the cavity (3m), melt jet diameter (0.2m) and velocity (6m/s), debris accumulation area (40m), were examined parametrically. (numbers in parenthesis are the base case condition)

3. Results

COOLAP-II: The initial fast pressurization during melt jet breakup within several minutes was less than 0.1MPa of increment, and following pressurization in 1h reached 0.2—0.3MPa. The fraction of the continuous melt lump fraction was ~17% (~17t) for the base case. Water pool depth and melt jet diameter dominated the lump fraction. The shallow pool case (1.5m deep) showed ~50% of core mass in the lump.

MELCOR: Fig.1 shows the pressurization and concrete ablation without additional water supply. Most of the cases except the shallow water or large jet cases initially showed cooling of the melt. Most of the cases also showed water dry up before 24h and re-melting of the debris bed triggered faster concrete ablation that did not terminate. The pressurization was suppressed only when recovery of the ultimate heat sink was assumed.

The present analysis depicted the impact of melt breakup and separation of the particulate and continuous debris on the following cooling process, importance of the continued availability of cooling water in the cavity and early recovery of the ultimate heat sink or other measures for pressure suppression, e.g. CFVS.

Acknowledgements

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety(KOFONS), granted financial resource from the Nuclear Safety and Security Commission(NSSC), Republic of Korea (No. 1305008)

References

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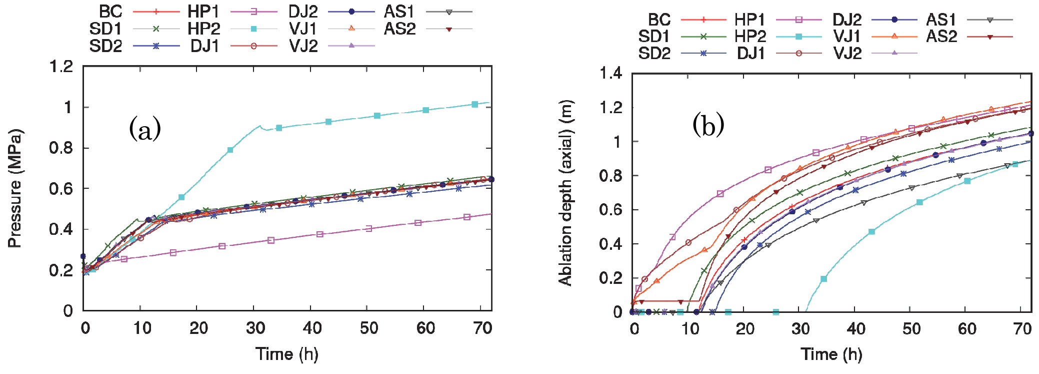

Fig.1 MELCOR calculation results (a) containment pressure, (b) axial concrete ablation depth. (BC:base case, SD1/2:2/12h after shutdown, HP1/2:pool depth 1.5/6m, DJ1/2:jet dia. 0.4/0.1m, VJ1/2:jet velocity 12/3m/s, AS1/2:accumulation area 67.6/25m^2).