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Source term analysis of OPR1000 plant using CINEMA code

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1. Introduction

Reactor thermal-hydraulics and in-vessel core degradation will be nearly identical to the break location at large-break loss of coolant accident (LOCA). When the radioactive fission products are released by core degradation, however, their path from the core to the containment is determined by break location: hot-leg and cold-leg. Generally, cold-leg break can increase the mass deposition of fission product aerosols in the reactor coolant system (RCS), as fission products are released into the containment building through the steam generator tube region [1], compared to a hot-leg break. Therefore, the break location in LOCA scenario can result in different in-containment source term. CINEMA code is the integral code to analyze the severe accident from the in-vessel to ex-vessel phenomena as well as source term [2]. Present study is focused on the source term analysis at large break LOCA scenario depending on the break location (cold-leg or hot-leg) for OPR-1000 plant using CINEMA code.

2. Methods and Results

2.1 Plant modeling

OPR-1000, a pressurized water reactor (PWR) with two loop configurations, has 12 units currently under operation in South Korea. Modeling about the reactor coolant system, the reactor core, and the containment building of OPR-1000 plant is detailed in the referenced literature [3]. For the LOCA (Loss-of-Coolant Accident) scenario, a break size of 9.5" was selected, and calculations were performed for both the cold-leg (CL) and hot-leg (HL). The SIRIUS calculation for the OPR-1000 is conducted based on the initial inventory in table I, which is identical to the MAAP code [4]. Using the CORSOR release model, the release of radionuclides for a total of eight groups is simulated. In the lumped code system, the form of radionuclide release, whether gas or aerosol, is determined by the temperature and pressure conditions within the specific node. In the RCS and containment building, aerosol deposition on the ceiling, walls, and floor is simulated, which is determined by aerosol removal mechanism models (sedimentation, impaction, diffusio-phoresis, thermo-phoresis) within the SIRIUS code [4]. A hygroscopic model was applied in this calculation. Regarding the accident progression, a pipe break occurs at 0 seconds, and all four SITs (Safety Injection Tanks) are passively injected, while the other safety injection systems of RCS and the containment spray system were neglected.

Table I. OPR-1000 inventory for fission product

ID	Name	Species	Inventory [kg]
1	Noble gas	Xe, Kr	1.85E+02
2	Alkali metal iodides	I	6.37E+00
3	Alkali metal hydroxides	Cs	9.40E+01
4	Chalcogens	Te, Sb, Se	1.77E+01
5	Alkaline earths	Ba, Sr	7.85E+01
6	Platinoids	Ru, Mo	1.86E+02
7	Rare earths	La, Zr(fission)	1.61E+02
8	Structure materials	Zr, Fe, Cr, Ni, Mn	-

2.2 Result and discussion

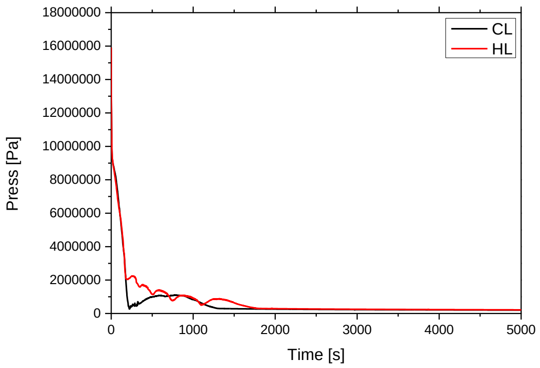

Fig. 1. Primary loop pressure

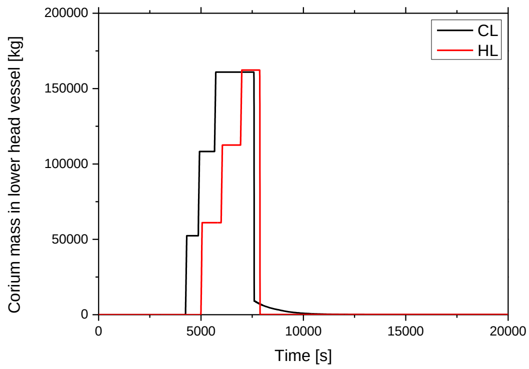

Fig. 2. Corium mass in lower head vessel

Two case shows nearly identical behavior of reactor thermal-hydraulics, failure time of reactor pressure vessel and containment thermal-hydraulics. Transferred corium from the reactor pressure vessel to the reactor cavity leads to evaporation of water and an increase of the containment pressure. Unique feature of OPR-1000 plant is that most of the liquid coolant by wall condensation or spray in the containment is flowed into the cavity. It means that fuel-coolant interaction is under wet-cavity condition in the present study.

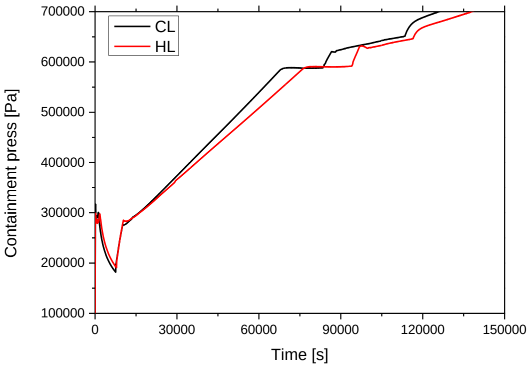

Fig. 3. Containment pressure

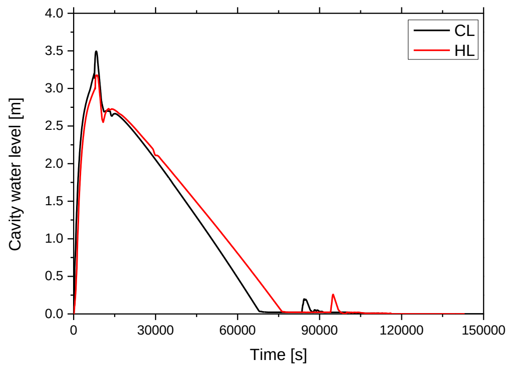

Fig. 4. Cavity water level

Noble gas (Group1, Xe, Kr) is released when the cladding temperature is beyond 1173 K under gap-release stage and its phase is always gas which does not consider aerosol deposition at the surface of the heat structure. On the other hands, iodine (Group2) is released by the form of aerosol and gas and its release behavior is strongly influenced by the break location during LOCA. Distribution of released iodine in cold-leg break shows that fraction of aerosol deposition in RCS is larger than that of hot-leg break case. This can be explained by the flow path from the core to containment. Cold-leg is connected to the down-comer in the reactor pressure vessel and released fission product is transported from the reactor core to upper head of reactor vessel, hot-leg, U-tube of steam generator and break location of the cold-leg, sequentially. Long path of fission product transportation at case of cold-leg break results in large surface area for aerosol deposition. However, the hot-leg is connected to the upper head of reactor pressure vessel and fission product is easy to be directly transported to the containment building. Significant deposition of aerosols in the U-tube of steam generator was reported by PHEBUS-FPT experiment and CINEMA code shows similar results [1].

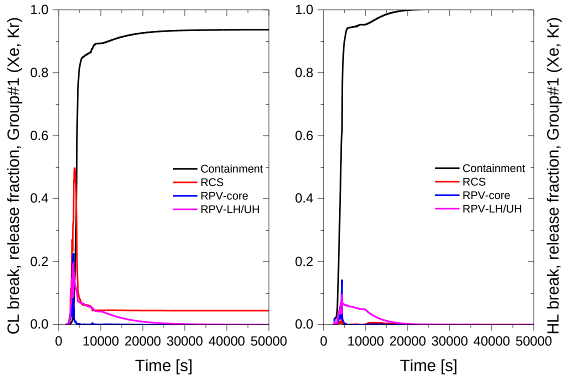

Fig. 5. Release fraction in group#1

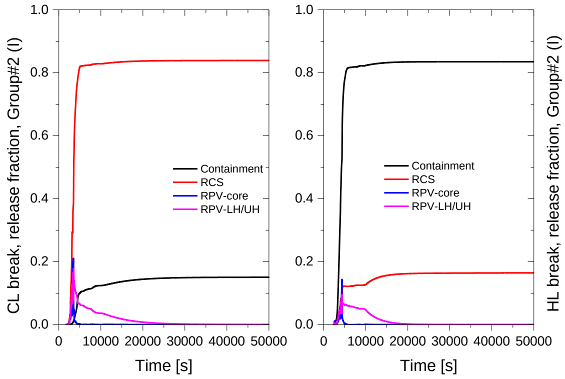

Fig. 6. Release fraction in group#2

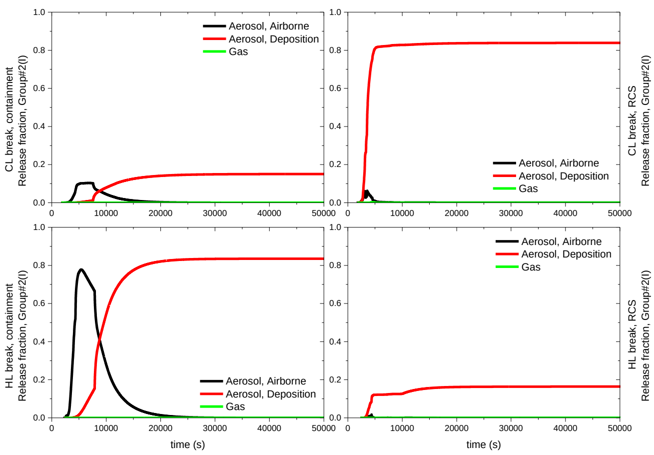

Fig. 7. Distribution of released fission product in RCS and containment

3. Conclusions

Present study shows the results of LOCA-induced severe accident scenario of OPR-1000 plant by using CINEMA code. Different break location results in different in-containment source term. Cold-leg break shows large deposited mass of aerosol in RCS and results in decreased in-containment source term, compared to hot-leg break case. Present study is assumed that aerosol deposition in core region is negligible and is required to evaluate parameters relevant to deposition area in the future.

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