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Preliminary SBLOCA M/E Release Analysis using SPACE-ME Methodology

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1. Introduction

To attain a qualification requirement for the accident-mitigation equipments using in containment, it is required that the Large Break Loss of Coolant Accident (LBLOCA), Main Steam Line Break (MSLB) and Small Break Loss of Coolant (SBLOCA) mass and energy (M/E) release analyses be performed and the M/E data be provided for Environmental Equipment Qualification Analysis.

Referring to the existing KIMERA methodology [1][2], in which RELAP5 and CONTEMPT4 codes has been applied, a new M/E methodology (so called SPACE-ME) is being developed using SPACE (Safety and Performance Analysis CodE for nuclear power plants) code [3] linked with CAP (Containment Analysis Package) code [4].

The SBLOCA M/E release data are dominant for the late period of the accident (after about 10^4 seconds). This paper shows the preliminary analysis results on SBLOCA M/E release using SPACE-ME and the resultant pressure and temperature (P/T) of containment by using CAP code for APR1400 plant.

2. Modeling for SBLOCA Analysis

The nodalization of NSSS (Nuclear Steam Supply System) with SPACE code should be required to simulate the thermal-hydraulic behaviors during the SBLOCA transient period. The reactor core, RCS (reactor coolant system) and secondary system are organized by using SPACE code models such as branch, pipe, face, etc. The DVI (Direct Vessel Injection) nozzle and SIT (Safety Injection Tank) are modeled to simulate SIS (Safety Injection System) and IRWST (In-Containment Refueling Water Storage Tank) to simulate the source of SIS.

The CAP code is used with SPACE-ME. It consists of the spray, RCFC (Reactor Containment Fan Cooler), heat exchanger, heat-conductor, atmosphere, and pool models to predict containment state. It calculates the P/T of containment during the transient by using M/E release data provided through SPACE Code. Also, it plays a role in the back pressure as a boundary condition to calculate M/E release data and provides the IRWST thermal condition to SPACE.

3. Analysis Methodology and Initial Conditions

3.1 conservative Analysis Methodology

Referring to KIMERA methodology [2], the conservative analysis methodology is applied to the SBLOCA analysis to maximize the M/E release data. The main points used in analysis are as follows;

- Maximum Safety Injection (no single failure)
- LOOP (Loss of offsite power) with reactor trip
- No auxiliary feedwater system
- 3% thermal Expansion for NSSS system volume
- Minimum K-factor for NSSS System

3.2 Conservative Initial Conditions

Referring to KIMERA methodology [2], the conservative initial conditions for SBLOCA M/E release analysis about plant operating condition range are applied as Table 1.

Table 1: Conservative Combination of Initial Condition

Parameters	Values	Remark
Core Power	4063 MWt (102% of 3983 MWt)	Max
PZR Pressure	2325 psia (16.03 MPa)	Max
Core Inlet Temperature	572 ºF (573.15 K)	Max
PZR Water Level	60 % span	Max
RCS Flow Rate	95% of design flow	Min

4. SBLOCA Analysis Results

Preliminary SBLOCA M/E release analysis is performed by SPACE-ME and the containment P/T is calculated by CAP code. The RCP (Reactor Coolant Pump) discharge line is considered as the SBLOCA break location. Also, for break area spectrum, 3, 4, 6, 8 in diameters are selected and the break type is assumed to be a slot break. Figures 1 and 2 show the M/E results. At the onset of the SBLOCA, a large M/E release are formed because of the high RCS pressure. Due to continuous break flow release, the RCS is depressurized and the two-phase flow is released and oscillation phenomenon of break flow appears. Also, SIS are activated to make up the RCS and the reverse heat transfer through the steam generator is made and act as an energy source of the break flow. After the above short-term period, the SPACE-ME enters the long-term cooling phase. During this phase, the boil-off model, in which all the remaining and decay heat in NSSS is used as the energy source for the steam generation, is applied. Therefore, the M/E release according to break size are almost same until the end point (10^6 sec).

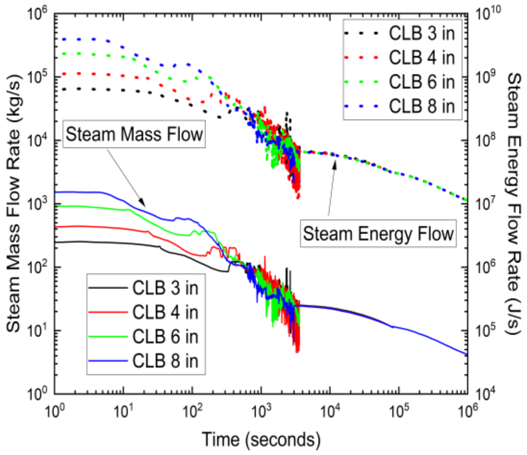

Fig. 1. Steam mass and energy flow rate

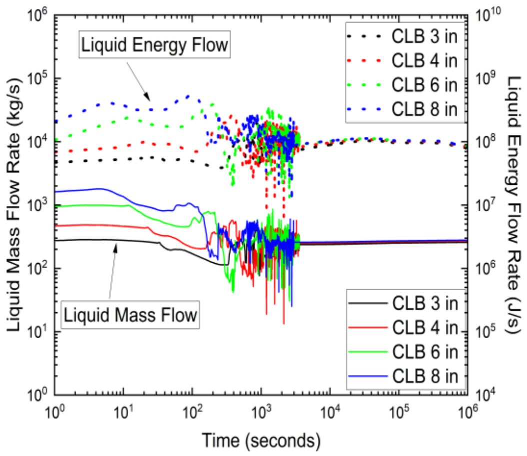

Fig. 2. Liquid mass and energy flow rate

Figures 3 and 4 show the containment P/T results. The P/T are calculated by the stand-alone CAP code using the M/E results. The containment P/T show increasing curve due to released M/E and then rapidly decrease with operation of the containment spray. After that, P/T curves decrease gradually by the reduction of break flow, cooling capacity of spray heat exchanger with CCW (Component Cooling Water) and containment passive heat sink. In all time period, it can be confirmed that the existing EQ Curve is satisfied.

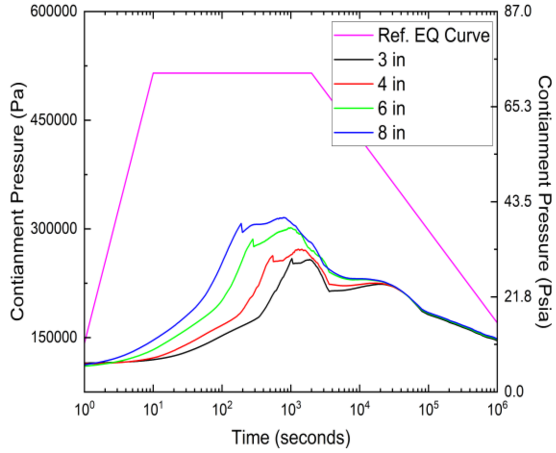

Fig. 3. Containment pressure

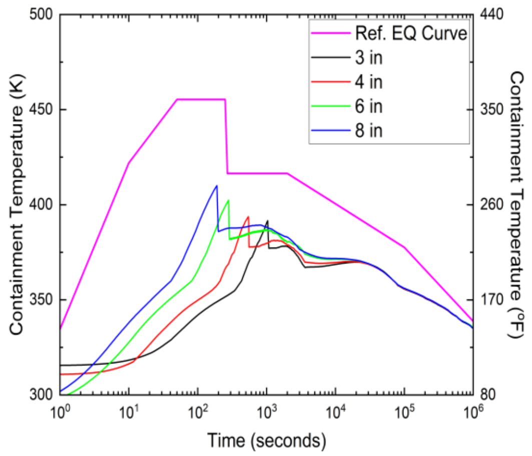

Fig. 4. Containment temperature

5. Conclusion

The preliminary analyses of SBLOCA M/E release and containment P/T are performed using SPACE-ME. The behaviors of M/E and P/T seem to reasonable and existing EQ Curve is satisfied.

To supply preliminary analysis, additional several sensitivity study such as break location (RCP suction leg, hot leg), EOPR (End of Post-Recovery) point are being conducted, and the analyses will help to assist final analysis and verify the equipment qualification by comparing the containment P/T with EQ Curve.

REFERENCES

[1] Topical Report, "KOPEC Improved Mass and Energy Release Analysis Methodology (KIMERA)," KOPEC/NED/TR/06-005, Rev.0, Dec. 2007.
[2] Special Report, "Applicability Assessment of KIMERA to APR1400 Nuclear Power Plants, " KEPCO-E&C/ND/TR/12-008, Rev.0, May.2012.

[3] Program Manual, "SPACE 3.22 manual Vol.1~6," Korea Hydro & Nuclear Power Co., KEPCO Engineering & Construction, Korea Atomic Energy Research Institute Feb. 2017.
[4] Program Manual, "CAP 2.21 manual Vol.1~2," Korea Hydro & Nuclear Power Co., Feb. 2017.

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