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

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1. Introduction

KIMERA methodology (so called KIMERA), KEPCO E&C improved mass and energy (M/E) release analysis methodology was developed for the M/E analysis [1] and applied to APR1400(Advanced Power Reactor 1400) in 2012 [2]. SPACE-ME methodology (so called SPACE-ME) is being developed using SPACE (Safety and Performance Analysis CodE for nuclear power plants) code linked with CAP (Containment Analysis Package) code using the approach referred from the KIMERA. And, the preliminary LOCA M/E release analysis for APR1400 is performed using SPACE-ME and compared with KIMERA. Based on the M/E release data, the containment pressure and temperature (P/T) are analyzed to confirm the difference by using CONTEMPT4-PC code.

This paper also compares the resultant containment pressure and temperature (P/T) of APR1400 from KIMERA during a large break LOCA.

2. APR1400 Plant Modeling for SPACE-ME

The nodalization of NSSS (Nuclear Steam Supply System) for APR1400 Plant is decided to predict the thermal-hydraulic behavior as in Fig. 1. Safety injection through DVI (Direct Vessel Injection) nozzles, SIT with fluidic device (FD-SIT) and IRWST (In-Containment Refueling Water Storage Tank) in the APR1400 plant are properly modeled to simulate the LOCA accident. And, these safety components and design concepts are referred from the KIMERA as well.

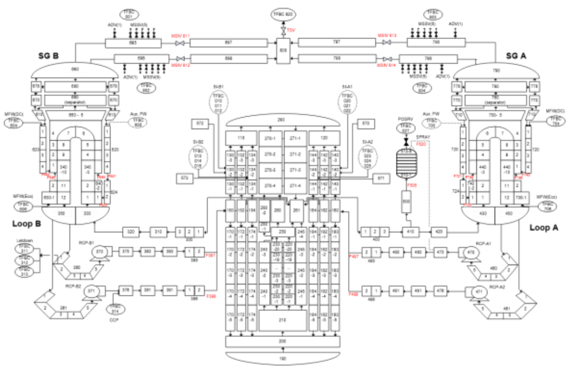

Fig. 1. Nodalization of NSSS in SPACE

The CAP code is used to demonstrate the thermal-hydraulic phenomena of containment as a boundary condition for the LOCA accident, and the configuration of the safety features such as spray system, spray-heat exchanger, spray pumps, fan cooler and containment passive heat sink are modeled as in Fig. 2.

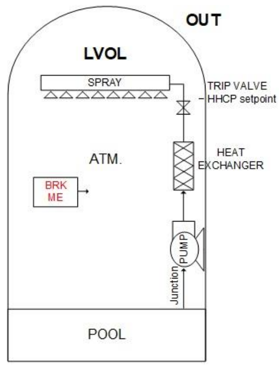

Fig. 2. Configuration of containment in CAP

3. Major Assumptions and Initial Conditions

Major assumptions and initial conditions for the M/E release analysis are basically the same as those of KIMERA [2]. The major assumptions used in the LOCA M/E analysis are as follows:

- EOPR (end of post-reflood) time: 2000 seconds
- Minimum containment back pressure conditions
- LOOP (Loss of offsite power) condition
- Maximum SI flow
- Maximum SIAS (Safety Injection Actuation Signal) set point with minimum delay
- No single failure for the M/E analysis
- One EDG (Emergency Diesel Generator) failure for the containment P/T analysis

Conservative initial conditions for the M/E release analysis are assumed as Table I and Table II.

Table I. Initial Conditions Applied in NSSS

Parameters	Values	Remark
Core Power	4063 MWt (102% of 3983)	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
SG Water Level	95% NR	Max

*PZR: Pressurizer

Table II. Initial Conditions Applied in Containment Back Pressure Analysis

Parameters	Remark
Spray flow rate	Max
Passive heat sink	Max
Fan cooler capacity	Max

4. Analysis Results

Using the SPACE-ME, the preliminary large break LOCA mass and energy release analysis for APR1400 is performed and the resultant containment P/T are calculated using CONTEMPT4-PC (PC version of CONTEMPT4) code. The containment peak pressure and temperature are compared with those of KIMRA. The CONTEMPT4-PC code which shows similar containment P/T results with CONTEMPT-LT/028 used in design is applied to calculate the containment peak P/T.

The LOCA mass and energy release analysis is performed for the typical double ended RCP discharge leg (DEDL) break at 102% power with maximum emergency core cooling system (ECCS) flow.

Fig. 3 shows behavior of the blowdown M/E for DEDL LOCA by comparing with that of KIMERA results. In the blowdown period, the M/E results using the SPACE-ME are much similar to KIMERA results. However, for the post-blowdown period, the M/E release rates are lower than those of KIMERA as shown in Fig. 4 due to the SG heat transfer.

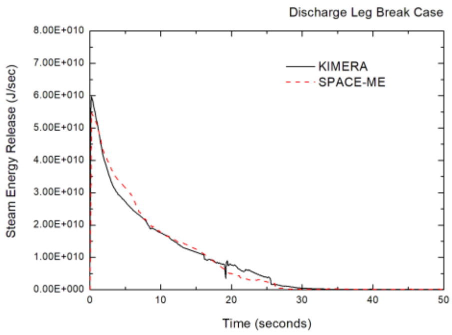

Fig. 3. Comparison of Blowdown M/E Release with KIMERA

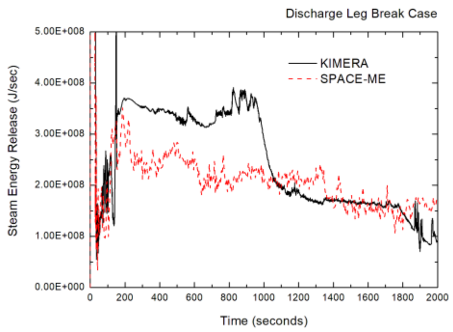

Fig. 4. Comparison of Post-Blowdown M/E Release with KIMERA

Fig. 5 and Fig. 6 provide the comparison of the resultant containment P/T calculated by CONTEMPT4-PC code.

In Table III, based on M/E release data calculated by the SPACE-ME, the first peak pressure (60.46 psia) and the first temperature (267.06°F) are slightly higher than KIMERA results (59.12 psia and 264.75°F).

However, the second peak pressure (54.24 psia) and second peak temperature (258.00°F) are much lower than those of KIMERA (60.76 psia and 267.78°F) due to the difference in M/E release data during the post-reflood period (up to 1050 seconds).

The transient behavior of the containment P/T seems to be appropriate but the further study needs to verify the second peak P/T of containment that could be resulted from the steam generator heat transfer.

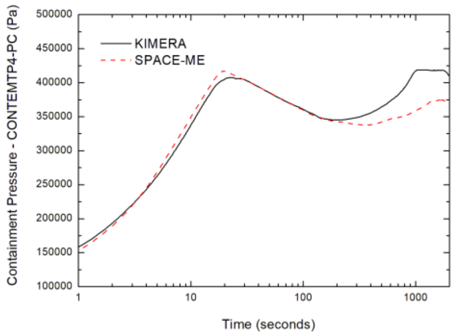

Fig. 5. Containment Pressure Behavior

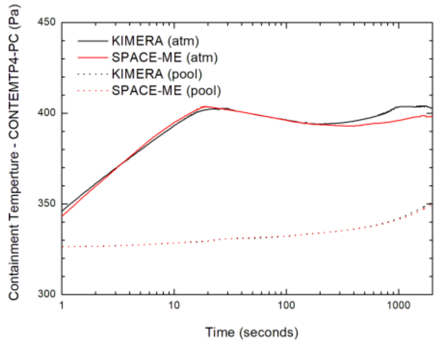

Fig. 6. Containment Temperature Behavior

Table III. Comparison of Containment P/T Results with SPACE-ME and KIMERA

	First Peak*		Second Peak*	
	Press. (psig)	Temp. (°F)	Press. (psig)	Temp. (°F)
SPACE-ME	**60.46 @19.8**	267.06 @19.2	54.24 @1770	258.00 @1735
KIMERA	59.12 @22.7	264.75 @22.7	**60.76 @1070**	267.78 @1705

* Results of CONTEMPT4-PC

In Fig. 7, heat transfer rate of KIMERA is relatively higher than that of SPACE-ME, and it could result in the increase of energy release rate during the post-blowdown.

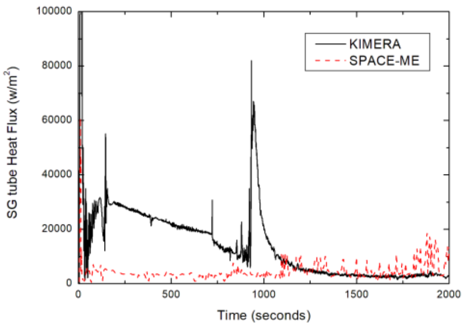

Fig. 7. Comparison of Heat Transfer Rate between KIMERA and SPACE-ME

5. Conclusion

SPACE-ME is being developed using the SPACE-CAP code (SPACE code linked with CAP code), and the preliminary LOCA M/E release and containment P/T analyses are performed for APR1400.

During the blowdown period, the containment P/T behaviors are similar to the results of KIMERA. But, the second peak P/T results are much lower than those of KIMERA.

Developing SPACE-ME can properly predict the M/E release in case of large break LOCA accident. Further study on post-blowdown period is ongoing to find the reasonable conservatism at second peak pressure and temperature of containment.

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.

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