Introduction to SPACE-ME Methodology for Containment Design

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1. Introduction

KIMERA methodology (so called as 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 (Advance Power Reactor 1400) in 2012 [2]. The methodology for the mass and energy release using new computer codes such as SPACE (Safety and Performance Analysis CodE for nuclear power plants) and CAP (Containment Analysis Package) is being developed. SPACE-ME methodology (so called as SPACE-ME) uses the best-estimate SPACE code which calculate the system thermal-hydraulic behavior, linked with the CAP code which demonstrates the phenomena of containment.

This paper introduces the characteristic of SPACE-ME and compares the initial condition, the major assumption and the thermal-hydraulic model with the existing KIMERA.

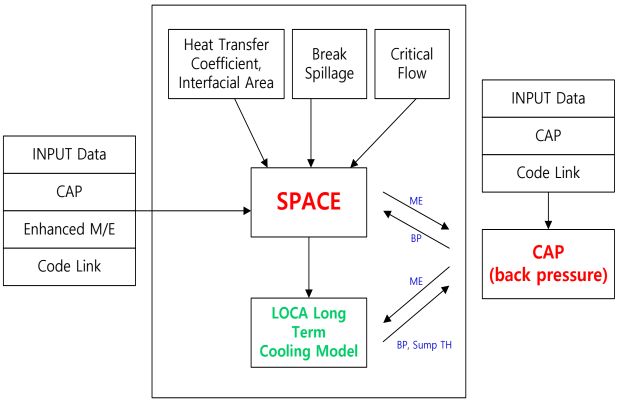

Fig. 1. Linked module diagram of SPACE and CAP code

2. Major Assumptions and Initial Conditions

Major assumptions and initial conditions for the M/E release analysis in the SPACE-ME are basically the same as those of KIMERA. The major assumptions used in the M/E analysis are as follows:

- Minimum containment back pressure conditions
- Loss of offsite power (LOOP) for LOCA
- Non-LOOP for MSLB

Conservative initial conditions are decided to maximize the M/E release to containment and assumed as Table I.

Table I. Conservative Combination of Initial Conditions

Parameters	Remark
Core Power	Max
PZR* Pressure	Max
Core Inlet Temperature	Max
PZR* Water Level	Max
RCS Flow Rate	Min
SG Water Level	Max

* PZR: Pressurizer

3. Thermal-hydraulic Model in SPACE-ME

SPACE-ME introduces thermal-hydraulic model such as break spillage model, IRWST-SI linked model and long-term cooling model as in KIMERA.

3.1 Break spillage model

KIMERA developed the break spillage models such as direct spillage model and break separation model applied to LOCA and MSLB analyses. And, the SPACE-ME demonstrates the same break spillage models to apply the conservatism in M/E release of KIMERA.

Direct spillage model is typically applied to discharge leg break of LOCA in OPR1000 power plants to reflect the cold water injection of SIT (safety injection tank), HPSI (high pressure safety injection) and LPSI (low pressure safety injection) at the break location. Cold safety injection water tends to release directly to containment atmosphere without cooling the core and RCS. SI water at break is considered as direct spillage falling into the pool region, and this model is conservative for the M/E release analysis. Otherwise, the APR14000 features the DVI (Direct Vessel Injection) nozzles for safety injection and integrated SIS (safety injection system) unlike OPR1000 which has HPSI and LPSI. Since the SI water is directly injected to reactor vessel downcomer though DVI nozzles and mixed with RCS coolant easily. Therefore, the direct spillage model will not be applied to APR1400.

Break separation model can be applied to LOCA and MSLB analysis in both OPR1000 and APR1400 power plants. In the LOCA or MSLB accident, the inventory in RCS or SG is released to containment as a mixture of steam and liquid. Steam goes to containment atmosphere, and some portion of liquid will be flashed in the containment atmosphere, while the rest falls into the pool region. To reflect flashing phenomena of break flow, SPAEC-ME models the flashing option based on the containment condition as in KIMERA. Application of flashing option is determined depending on the break mixture and containment condition as shown in Table II.

In the LOCA accident, KIMERA recommended to use the flashing option 2 and option 4 conservatively. And in Fig.2 and Fig.3, SPACE-ME shows lower M/E release behavior than those of KIMERA, but the limiting M/E release is obtained from flashing option 2 and option 4. Further study needs to verify the M/E release behavior during reflood period that could be resulted from the difference in heat transfer to steam generator.

Table II. Flashing Option in KIMERA Methodology

Flashing option	Remark
1	Break spillage from the liquid flashing on containment pressure
2	Break spillage from the liquid flashing on containment temperature.
3	Break spillage from the mixture on containment pressure.
4	Break spillage from the mixture on containment temperature

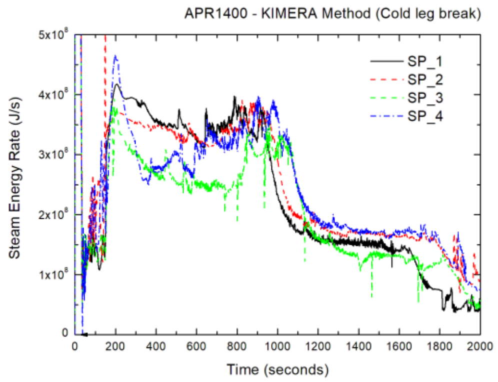

Fig. 2. Steam energy release with flashing option in KIMERA

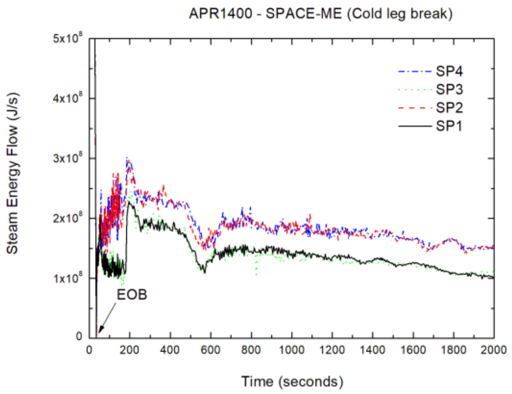

Fig. 3. Steam energy release with flashing option in SPACE-ME

3.2 IRWST-SI linked model

IRWST (In-Containment Refueling Water Storage Tank) tank is one of the distinguishable design features in APR1400 power plant for the water source of emergency core cooling system during a LOCA or any other design base accidents, and it is important to reflect the water temperature and inventory change of IRWST delivered to safety injection system.

SPACE-ME developed the IRWST-SI linked model between SPACE and CAP codes for interfacing the properties of containment pool water and SI water as in the KIMERA. Fig. 4 shows the containment pool inventory during the LOCA accident, and pool water mass is properly reduced following the SI injection from IRWST.

Fig. 5 also shows that the SI water enthalpy properly predicts the increase of IRWST water temperature during the accident.

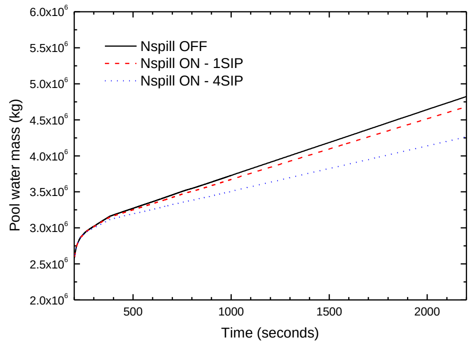

Fig. 4. Containment pool inventory during LOCA accident in SPACE-ME

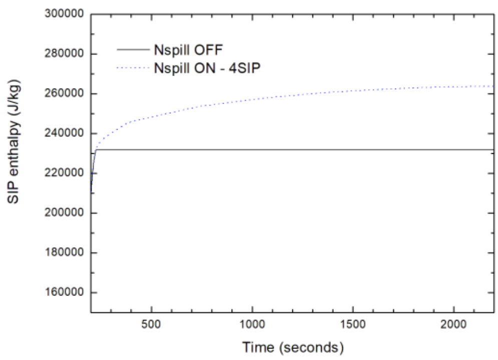

Fig. 5. DVI enthalpy behavior during LOCA accident in SPACE-ME

3.3 Long-term cooling model

In the LOCA accident, the M/E release shall be evaluated in the conservative way following the post-reflood period, and the conservative steam generation of boil-off model is demonstrated in SPACE-ME as in KIMERA. Boil-off model considers the decay heat and sensible heat of RCS and SG as energy sources and the flashing of break water in containment. Fig. 6 and 7 shows the comparison of long-term M/E release rates between SPACE-ME and KIMERA. M/E release behavior using the SPACE-ME are similar to those of KIMERA with a little difference. The study for the difference needs to perform to compare with KIMERA afterward.

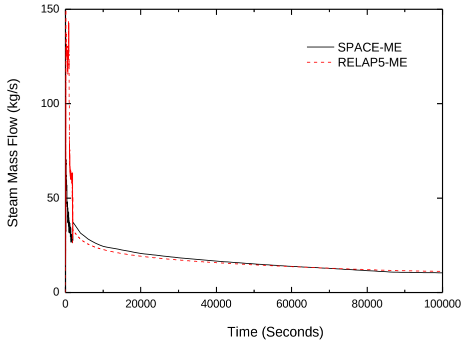

Fig. 6. Comparison of mass release with SPACE-ME and KIMERA in long-term cooling model

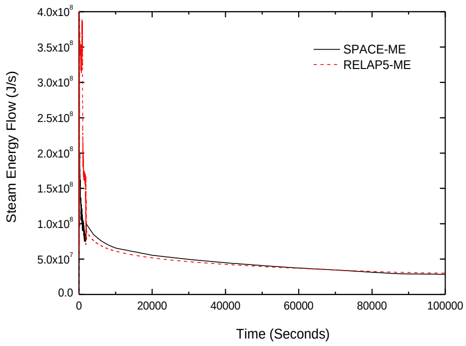

Fig. 7. Comparison of energy release with SPACE-ME and KIMERA in long-term cooling model

4. Conclusion

SPACE-ME methodology is being developed using SPACE and CAP coupled codes with conservative approach, and the most of assumption, initial condition and thermal-hydraulic model are referred from the KIMERA methodology. These break spillage model, IRWST-SI linked model and long-term cooling model are properly demonstrated as in KIMERA methodology, and the further study on short-term and long-term M/E release needs to apply the M/E release analysis.

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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