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LBLOCA M/E Release and Containment P/T Analysis using KIMERA Methodology for APR1000

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1. Introduction

About a year ago, the European Utility Requirements (EUR) Design Certification was acquired for Advanced Power Reactor 1000 (APR1000) and it is being developed for exportation to Europe. In development process, the safety analysis must be performed for APR1000, and among them is containment integrity analysis. It must be assured the integrity of containment when the Large Break Loss of Coolant Accident (LBLOCA) or Main Steam Line Break (MSLB) accidents are occurred. Prior to containment analysis, the Mass and Energy (M/E) release analyses should be performed and the M/E data be provided for Containment Functional Design Analysis.

To attain M/E data, the KIMERA methodology [1,2] is applied for M/E release analysis. This methodology uses RELAP5-ME code that apply the best estimate code for system analysis (RELAP5) coupled with containment analysis code (CONTEMPT4).

This paper shows the results of M/E data for LBLOCA using RELAP5-ME and containment pressure and temperature (P/T) using CONTEMPT4-PC for APR1000 plant. This data will be used as basic material for comparison with SPACE-ME methodology.

2. Design Feature for APR1000

APR1000 produces 1000MWe power same as Optimized Power Reactor 1000 (OPR1000). But, a few different design features are adopted from OPR1000. The In-Containment Refueling Water Storage Tank (IRWST) and Safety Injection Tank (SIT) with Fluidic Device (FD) are selected for APR1000. The High Pressure Safety Injection (HPSI) pump is only selected without the Low Pressure Safety Injection (LPSI) pump and the Direct Vessel Injection (DVI) nozzle is installed, so the SI directly flows into core through downcomer.

Importantly, the Passive Auxiliary Feedwater System (PAFS) is selected to replace the active AFS for APR1000. PAFS uses natural phenomenon for driving force, so can exclude the active component and have more unique safety. The PAFS plays an important role for safety analysis, but it is not used for LOCA M/E release analysis because it cools down the Steam Generator (SG) resulting in a decrease of the M/E release.

The above design features excluding the PAFS are applied for LOCA M/E release analysis on APR1000 using KIMERA methodology.

3. Analysis Methodology and Initial Conditions

3.1 Conservative Analysis Methodology

Using the KIMERA methodology, the conservative analysis methodology is applied to the LBLOCA analysis to maximize the M/E release data. The main points used in analysis are as follows;

- LOOP (Loss of offsite power) concurrently with accident initiation
- No PAFS
- 3% thermal expansion for NSSS system volume
- Minimum K-factor for NSSS System
- No or one Emergency Diesel Generator (EDG) failure assumed
- Minimum containment back pressure conditions

3.2 Conservative Initial Conditions

Using the KIMERA methodology, the conservative initial conditions for LBLOCA M/E release analysis are applied as Table 1. These conditions maximize the initial system energy inventory.

Table 1: Conservative combination of initial condition

Parameters	Values	Remark
Core Power	2871.3 MWt (102% of 2815 MWt)	Max
PZR Pressure	16.03 MPa (2325 psia)	Max
Core Inlet Temperature	573.15 K (572 ºF)	Max
PZR Water Level	60 % span	Max
RCS Flow Rate	95% of design flow	Min
SG Water Level	98.2 % WR*	Max

* WR : Wide range

As the containment back pressure is lower, the pressure difference between break location and containment increases and more M/E can be released.

So, the minimum back pressure conditions are assumed as Table 2.

Table 2: Minimum containment back pressure conditions

Parameters	Remark
Spray flow	Max
Fan cooler capacity	Max
Passive heat sink Area	Max
Heat transfer through wall	Max

4. LBLOCA Analysis Results

The LBLOCA M/E Release data and resultant containment P/T results are presented in Fig.1 through Fig.4. The RCP (Reactor Coolant Pump) discharge line (DL), RCP suction line (SL) and hot leg (HL) are considered as the LBLOCA break location and the break type is assumed double-ended guillotine break. From the perspective M/E release, the Emergency Core Cooling System (ECCS) flow is assumed to be at its maximum (no EDG failure) or minimum (one EDG failure). Fig 1 and 2 show the M/E results. During the blowdown period, a large M/E release are formed because of the high RCS pressure and inventory and the primary system inventory is rapidly exhausted. Therefore, the released M/E are very small at the end of blowdown point. But, for post-blowdown period, the M/E increase due to ECCS that flows to fill the core, which receives heat from the core and produces steam. Also, as the SG pressure is higher than primary system, the reverse heat transfer through SG U-tube is formed and more ECCS flow is vaporized. However, HL break does not have reverse heat transfer because the flow path into U-tube is deleted by break. Over the time, the energy stored in the system and decay heat continue to decrease, then the M/E release are also reduced.

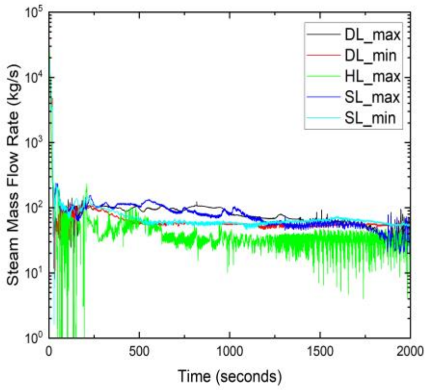

Fig. 1. Steam mass flow rate

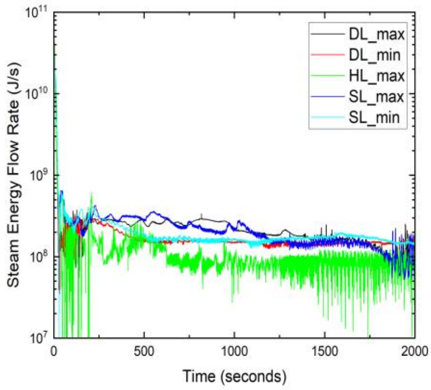

Fig. 2. Steam energy flow rate

Fig 3 and 4 show the containment P/T results. The containment P/T show first peak point because of released M/E during the blowdown period, and then the second peak point by steam vaporization with SG reverse heat transfer. HL break shows only the first peak pressure as the reverse heat transfer cannot be formed, but the first peak pressure is higher than the first and second of the other break cases (DL or SL) because HL break assumes the break at hot leg that have higher energy compared to cold leg, resulting in the higher M/E release.

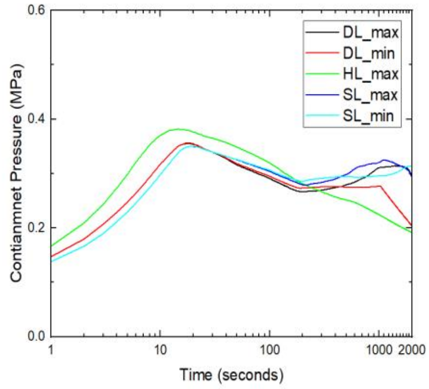

Fig. 3. Containment pressure

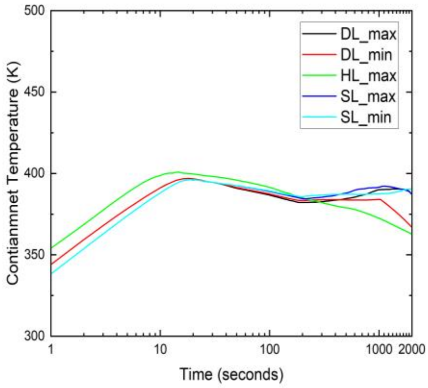

Fig. 4. Containment temperature

5. Conclusion

The LBLOCA M/E release and containment P/T analysis are performed using KIMERA methodology for APR1000. The HL break shows the highest pressure and temperature and the pressure of all cases is well below the 0.494354 MPa (71.7 psia) with OPR1000 containment design pressure. This data will be used as benchmark data with SPACE-ME methodology using SPACE and CAP code for APR1000.

REFERENCES

[1] Topical Report, "KOPEC Improved Mass and Energy Release Analysis Methodology (KIMERA)," KOPEC/NED/TR/06-005, Rev.0, Dec 2007.
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