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Safety Evaluation of the Double-Ended Letdown Line Break Outside Containment in SMART

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1. Introduction

For the purpose of electricity generation and sea water desalination, SMART (System-Integrated Modular Advanced ReacTor) has been developed by KAERI (Korea Atomic Energy Research and Institute) [1].

In this paper, LetDown Line Break (LDLB) outside containment event in SMART standard design is evaluated using the system analysis code of TASS/SMR-S [2] and the evaluation results are described.

The LDLB event is caused by the break at the letdown line and it induces a direct release of radioactive reactor coolant to the atmosphere. In SMART, this event is categorized into the anticipated operational occurrence (AOO) by considering the event frequency. The letdown line is included in chemical & volume control system (CVCS) that controls water quality and volume of RCS. The CVCS of SMART is similar to that of APR1400, except for the connection point of the CVCS to RCS. In SMART, the letdown line is connected to the discharge part of reactor coolant pump (RCP). On the other hand, the charging line is connected to the suction part of RCP.

Figure 1 presents the partial schematic of SMART CVCS. In the CVCS, two different kinds of isolation valves are installed: letdown isolation valves (CH-515, CH-516) and containment isolation valves (CH-522, CH-523). The regenerative heat exchanger (RHX) and the letdown heat exchanger (LHX) are installed between these two different isolation valves. The LHX transfers the coolant heat in letdown line into the component cooling water system. The orifices are installed in parallel at the downstream of the LHX. Therefore, the coolant pressure is considerably decreased by passing through orifices. The differential pressure through the each orifice is 11.0 MPa.

2. Analysis Methods

In the LDLB evaluation, the break is assumed to occur at the upstream of the containment isolation valve outside the containment.

As mentioned above, this event is categorized into the AOO. Therefore, the safety evaluation was performed by focusing on the minimum DNBR and the radiological consequences.

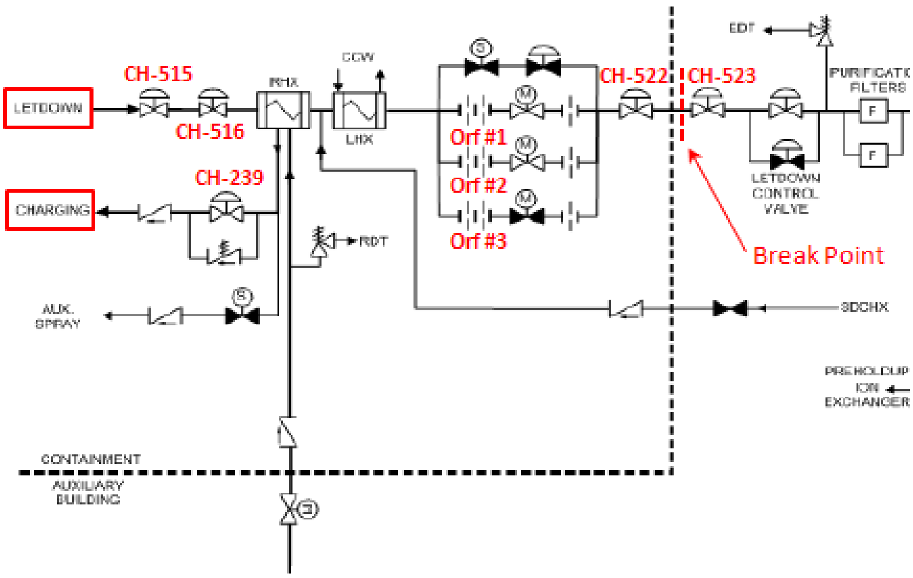

Fig. 1. The partial Schematic of SMART Chemical Volume Control System

After the initiation of the event, various kinds of alarms such as a low pressure of letdown line, a high radioactivity of auxiliary building are going to immediately alert to operator. In the evaluation, an operator action is conservatively assumed to be delayed by thirty minutes after the first alarm. Additional assumptions used for conservative analysis are: 1) the pressurizer pressure control system and pressurizer level control system are in automatic modes which work to maximize the integrated mass release. 2) offsite power is lost at reactor trip time. 3) the constant injection of the charging flow throughout the transient.

For the safety evaluation, a series of sensitivity analyses are performed to determine the most conservative initial condition for the minimum DNBR and the integrated mass release. The initial condition parameters considered are core power level, RCS mass flow rate, core inlet coolant temperature, pressurizer pressure and a pressurizer level. In addition, the sensitivities of other parameters such as a charging flow rate, gap conductance, pellet power distribution, moderator temperature coefficient and a fuel temperature coefficient on the integrated mass release are also performed.

3 Analysis Results

According to the sensitivity evaluation from the viewpoint of the minimum DNBR, a considerable DNBR margin to the specified acceptable fuel design limit (SAFDL) exists in the LDLB event in SMART.

According to the sensitivity evaluation from the viewpoint of the integrated mass release, the limiting combination of initial condition is a high power level, low RCS mass flow rate, high core inlet coolant temperature, high pressurizer pressure and a high pressurizer level. The integrated mass release is much larger in case of using the maximum charging flow. The usage of the maximum charging flow maintains the pressurizer pressure much higher and increases the integrated mass release through the break. On the other hand, the other parameters such as a charging flow rate, gap conductance, pellet power distribution, moderator temperature coefficient and a fuel temperature coefficient have little impact on the integrated mass release through the letdown line break.

Figure 2 shows the behavior of a pressurizer pressure in case of using the initial condition identified through the sensitivity evaluation from the viewpoint of the integrated mass release. At the initiation of the event, pressurizer pressure decreases due to the mass release through the letdown line break. The pressurizer pressure increases when the backup heater of the PLCS actuates at 48.6 seconds. The backup heater turns on when the pressurizer level is higher than 72% of pressurizer internal volume. The pressurizer pressure decreases when the backup heater turns off at 847.9 seconds. The maximum pressurizer pressure does not exceed the 110% of the design pressure (18.7 MPa). Compared with the initial pressurizer pressure, it does not change considerably due to the continuous charging flow injection and PLCS actuation. The minimum DNBR is shown in Fig. 3. By using the integrated mass release, the offsite doses are also calculated and its results are well within the acceptance criteria.

4. Conclusions

The safety analysis of the LDLB at outside containment is performed from the viewpoint of the minimum DNBR and the radiological mass release.

The analysis results show that the minimum DNBR satisfies the acceptance criteria of SAFDL and the maximum RCS pressure and doses are well within the acceptance criteria.

REFERENCES

[1] KAERI, 2010, "System description", KAERI, 000-NA403-001.

[2]Kim et al., 2010, "TASS/SMR-S Code Tropical Report", KAERI, Korea, Vol., 911-TH464-001.

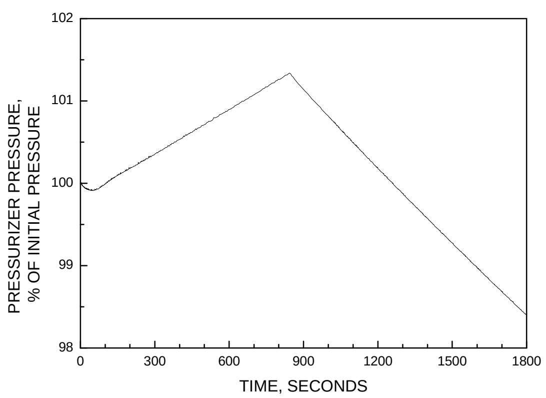

Fig. 2. Pressurizer Pressure

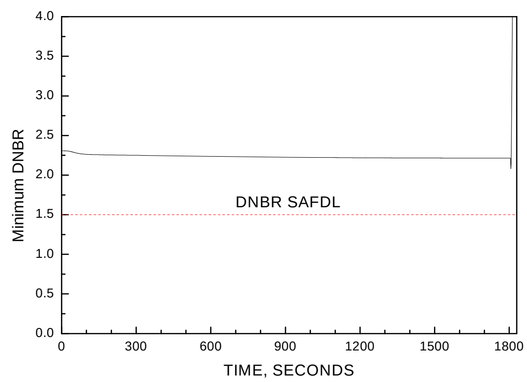

Fig. 3. Minimum DNBR