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Temperature behavior of transmitter room of HWR for the accident conditions of the loss of coolant in the primary circuit

Seyun Kim*, Dong Hyuk Lee, Jae Yong Lee
Korea Electric Power Research Institute, Munji-ro 65, Yuseong, Daejeon, Korea, 305-380
**Corresponding author: seyunkim@kepri.re.kr*

1. Introduction

As a part of an assessment of instrument uncertainty of safety system of HWR (Heavy Water Reactor), a temperature behavior of the transmitter room and the transmitter in the containment for the accident conditions are investigated. As a limiting case, the loss of coolant accident (LOCA) is considered and both of a large break LOCA and a small break LOCA conditions are postulated for the analysis. To investigate the modeling uncertainties, sensitivity studies also are carried out.

2. Methods and Results

2.1 Analysis conditions and methods

In the analysis, the design parameter and the safety analysis results of Wolsong 2, 3 and 4 plants are adopted. For the large break LOCA, 100% break of reactor outlet header (ROH) condition and for the small break LOCA, 2.5% break of reactor outlet header with total loss of dousing are selected as limiting cases [1]. The transient pressure and temperature of containment which is shown in the FSAR are applied as a boundary condition for the analysis.

For the calculation, the thermo-hydraulic safety analysis code, MARS-KS 3.1 is used [2]. The nodalization diagram of transmitter and transmitter room is depicted in Figure 1.

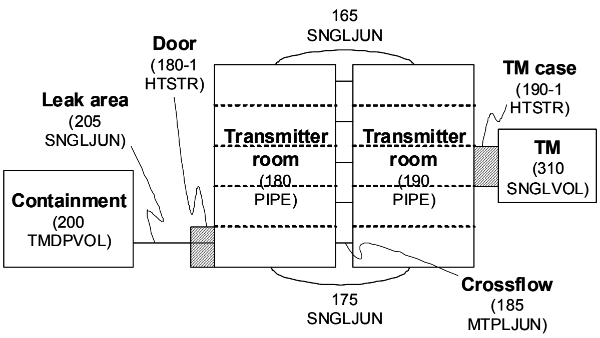

Fig. 1. Nodalization diagram of transmitter and transmitter room for the analysis with MARS.

The containment volume is relatively large when compared to the volume of transmitter room and the mass of leak is negligible, so the containment could be modeled as boundary condition. The transmitter room could be modeled with a single volume and multiple pipe components. The major design parameters are tabulated in Table 1.

Table 1. Major design parameters

Parameter	value	Parameter	value
TMR height	1.96m	TM diameter	0.1m
TMR width	7.315m	TM height	0.1m
TMR depth	2.007m	TM case thickness	7.6mm
TMR door height	1.9m	TM case material	Al
TMR door width	0.7m	TMR door material	SS
TMR door thickness	0.0082m		

The temperatures of the transmitter (TM), the transmitter room (TMR) and the door are in equilibrium state of 313.15 [K]. Transient calculation is carried out for 300 seconds.

2.2 Sensitivity studies

One of the significant parameters for the analysis is the leak area of the door in the transmitter room in containment. The transmitter case is hermetically sealed and the leak through the transmitter case is not considered. The transient pressure of TMR is function of the leak area of the door. For a large leak area, the pressure of TMR strongly depends on the containment pressure and follows pressure transient of the containment. However, the leak through the closed door gap is quit small. Therefore, the leak area of 1×10^{-4}[m^2] is used with a reasonable margin in this study. As a thermal conduction media, the door transfer heat from the containment to the TMR. However, according to the calculation, the total transferred heat from the containment to the TMR is negligible when compared to the transferred energy due to the leak. The variation of TMR temperature from TMR modeling (single volume vs. multiple volumes) is below 1%.

In the modeling of the leakage, the choking model and the abrupt area change model have significant roles. In this study, Henry-Fauske model for choking and full abrupt area change model are used. The modified PV terms in the energy equations have insignificant effect on the temperature behavior of transmitter room in the current analysis conditions, that is, the temperature variation due to the modified PV term is below 0.7 [K].

2.3 Temperature behaviors

In the analysis result for the small break LOCA, the total inflow mass is 2.60 [kg] by the leakage. The transient temperature and pressure behavior of TM and TMR is shown in Figure 2 and 3.

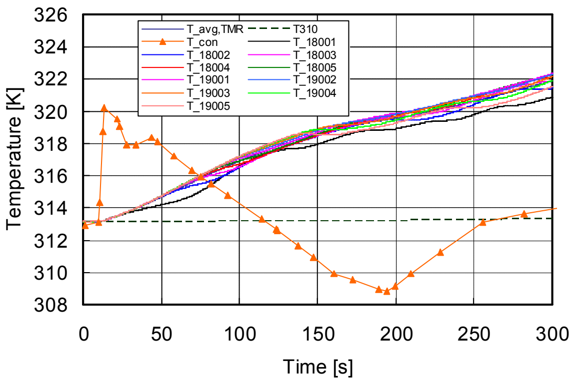

Fig. 2. Temperature transients of transmitter and transmitter room for 2.5% ROH break

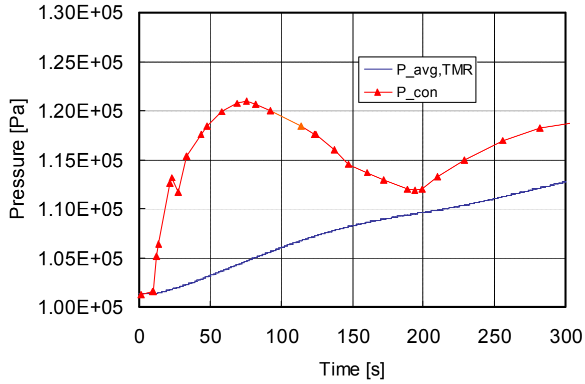

Fig. 3. Pressure transients of transmitter and transmitter room for 2.5% ROH break

The continuous increase of TMR temperature mainly due to the continuous rise increase of TMR pressure according to an isentropic compression process of ideal gas written as [3],

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\kappa-1}{\kappa}}, \qquad T_2 = T_1(P_2/P_1)^{0.4/1.4}$$

The final temperature from MARS shows only 0.3 [%] differences from the final temperature from the above relationship. As a result, the temperature transient of TMR is totally depends on the pressure transient of TMR. However, the temperature increase of TM is 0.17 [K] because the heat transfers only by conduction with a relatively small temperature difference.

For the large break LOCA, the total inflow mass is 2.84 [kg] by the leakage. The transient temperature and pressure behavior of TM and TMR is shown in Figure 4 and 5. The TMR pressure becomes an equilibrium state with the containment pressure about 150 seconds. In the same manner, the TMR temperature transient follows the tendency of TMR pressure transient as shown in Figure 4 and 5.

The analysis results show a slight difference between the large break LOCA and the small break LOCA in the temperature variation and the inflow mass for 300 seconds because of the choking of leakage flow in early phase of accident and the fast transition to the equilibrium state of the pressure between the containment and the TMR.

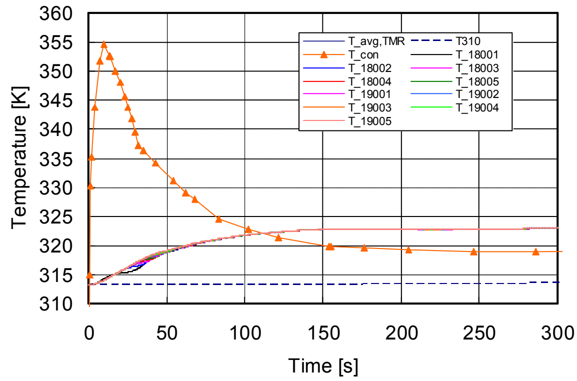

Fig. 4. Temperature transients of transmitter and transmitter room for 100% ROH break

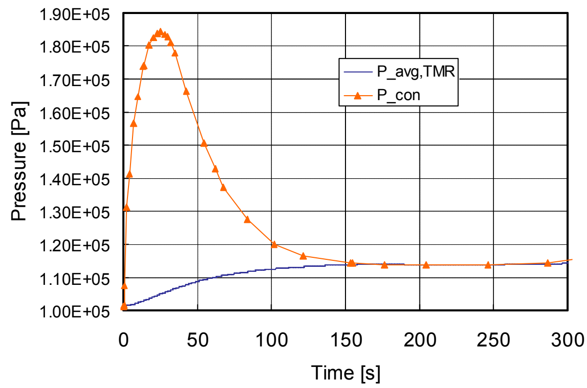

Fig. 5. Pressure transients of transmitter and transmitter room for 100% ROH break

3. Conclusions

The temperature behavior of the TMR and the TM in the containment are analyzed for a large break LOCA and a small break LOCA conditions using MARS-KS 3.1. The sensitivity studies are carried out and the modeling uncertainties are investigated. In the analysis result, the temperature transient of transmitter room is mainly depends on the pressure transient of transmitter room according to an isentropic compression process of ideal gas. However, the temperature increase of transmitter is below 1.0 [K] because the heat transfers only by conduction with a relatively small temperature difference in a short period.

REFERENCES

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[3] G. J. Van Wylen, R. E. Sonntag, Fundamentals of classical thermodynamics, Wiley, 1985