Non-condensable Gas Elimination using CPRSS Return Line in SMART100 CPRSS

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1. Introduction

SMART100 adopts a passive safety system for containment cooling and radiation exposure reduction, containment pressure and radioactivity suppression system (CPRSS) [1]. It is operated in natural circulation system for long-term cooling after 3 days from break accident, for example, SBLOCA. We discussed about that the pressure and temperature of containment were maintained lower than design criteria during 3 days after SBLOCA in the previous study [2]. However, there was remained non-condensable gas which did not move from lower containment area (LCA) to upper containment area (UCA) in the SMART100 CPRSS and it could interrupt condensation in the heat exchanger.

In this study, we will introduce the effective way to remove the non-condensable gas from the lower part of the system during 3 days after SBLOCA using the CPRSS return line (CRL) in the SMART100 CPRSS.

2. Experimental Facility

The description about SISTA2 for long-term cooling test was presented in the previous paper [2]. Figure 1 shows the temperature measuring points from CPRSS heat exchanger (CHX) to LCA reactor vessel (LCA_RV) and IRWST. The non-condensable gas was accumulated in this lower part of the system. The local measured temperatures were converted to mass fraction of non-condensable gas. The method how to estimate air mass fraction is described in the previous study [1].

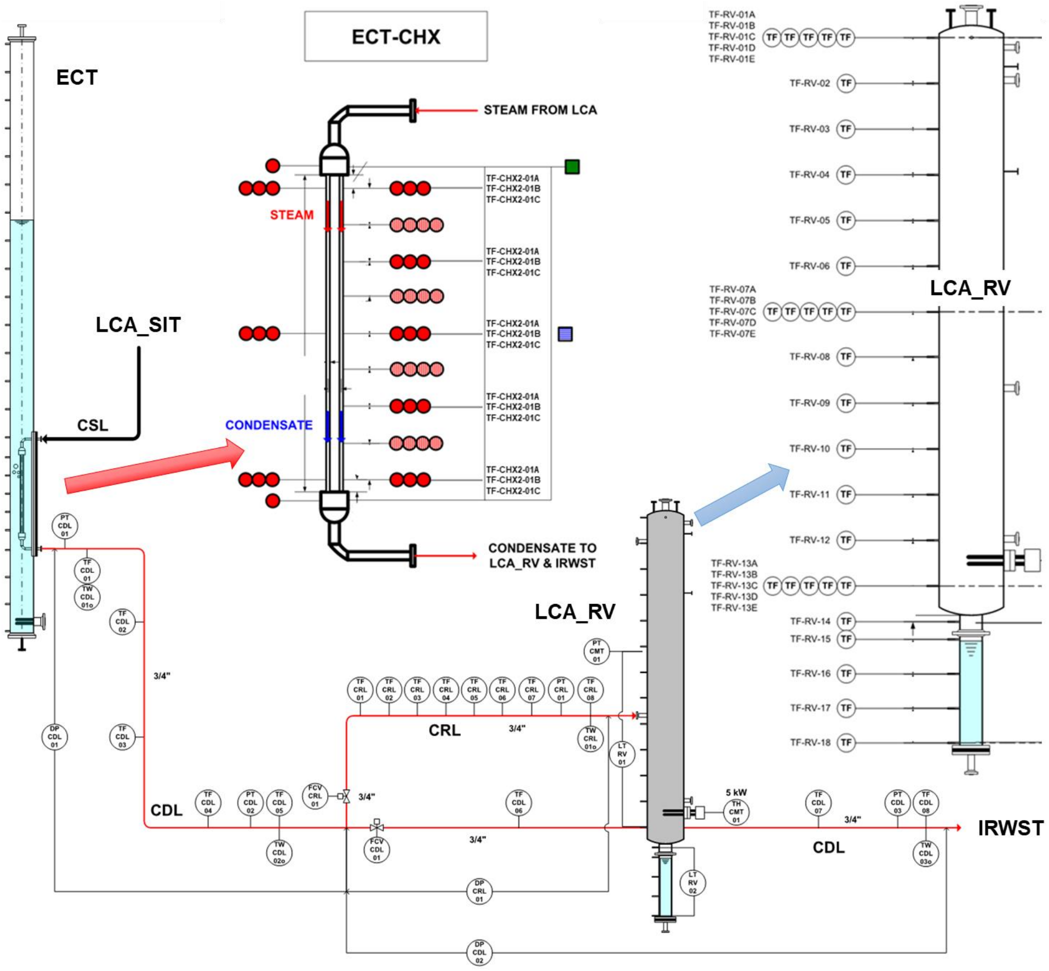


Fig. 1. Schematic diagram of SISTA2 with temperature measurement points (from CHX to LCA_RV and IRWST)

Table 1 Initial Conditions of Components.

Test ID	Heat loss compensation	Initial Air	CRL Open (s)	Test Time (s)
LTC #1	1) Decay curve	Not eliminated	259,200 (about 72 hr)	265,000
LTC #2	1) Decay curve 2) LCA wall temperature 3) ECT water temperature	Not eliminated	21,900 (about 6 hr)	246,000

*LTC: Long-Term Cooling

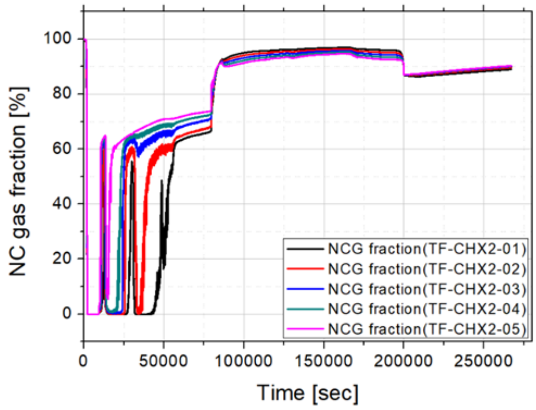
3. Experimental Results

The long-term cooling tests for about 72 hours were carried out to simulate an integral system effect of SMART100 CPRSS after SBLOCA. Initial conditions were described in the previous study [2] and test conditions according to heat loss compensation, initial air, CRL open time, and test time are shown in Table 1. The heat loss compensation of decay curve considered additional steam inlet flow for maintaining of constant pressure of LCA during long-term test. The heat loss compensation of LCA wall and ECT water temperatures was simulated as operation of heaters to maintain the boundary temperatures of LCA wall and ECT water. The CRL open time was different in long-term cooling (LTC) #1 and LTC #2 tests. In the LTC #2 test, '6 hours after accident' was the minimum time to remove the non-condensing gas from the upper part of the flow path from the LCA to the CHX and to make the integrated system stable by changing decay heat.

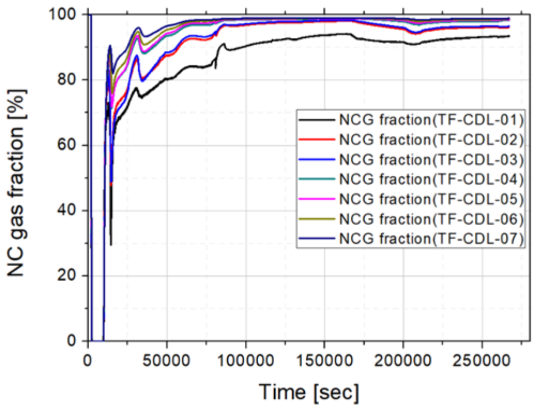
3.1 Non-condensable gas distribution

In the first long-term cooling test (LTC #1), the heat loss compensation for decay heat was simulated and the CRL was opened at 72 hours. Figure 2 shows the non-condensable gas fraction in the CHX and the CDL of the LCT #1. As shown in the Fig. 2(b), non-condensable gas that had not been released through CDL accumulated in the lower part of the system. The heat exchanger, CHX, was also filled with non-condensable gas after about 80,000 s (Fig. 2(a)). It was because of the pressure drop in the flow path from LCA to CSL, CHX, CDL and IRWST. Initial non-condensable gas in the LCA cannot move to the UCA because of the pressure drop in the long flow path.

The second long-term cooling test (LTC #2) was performed with maintaining the temperature boundary conditions. Additional heat loss compensation was simulated for maintaining the LCA wall and ECT water temperatures as constant. Figure 3 shows the non-condensable gas fraction in the CHX and the CDL of the LCT #2. The CRL opened relatively earlier at about 6 hours after accident. The flow path through the CRL induced that steam and air mixture passed through the CDL continuously for 72 hours. It means that the non-condensable gas was continuously discharged to the UCA without accumulating in the lower part of the system. The CHX wasn't filled with non-condensable gas during the test.

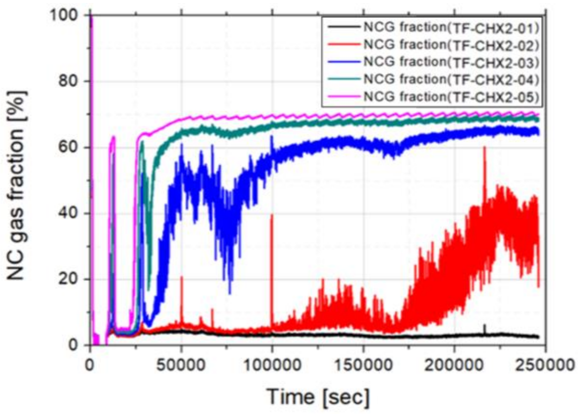


(a) CHX

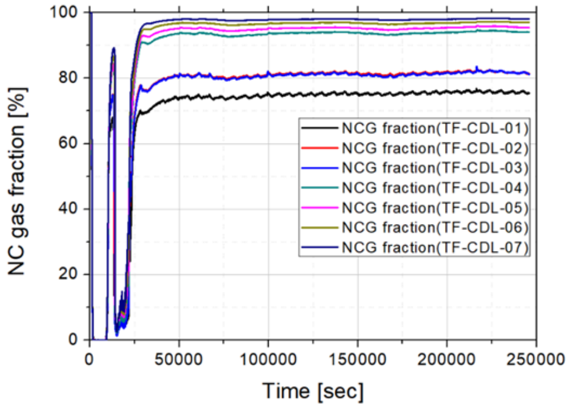


(b) CDL

Fig. 2. Non-condensable gas fraction in CHX and CDL (LTC#1)



(a) CHX

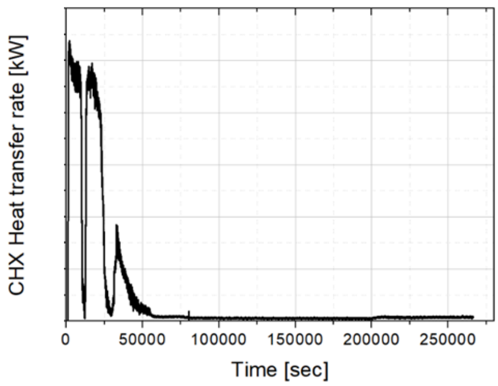


(b) CDL

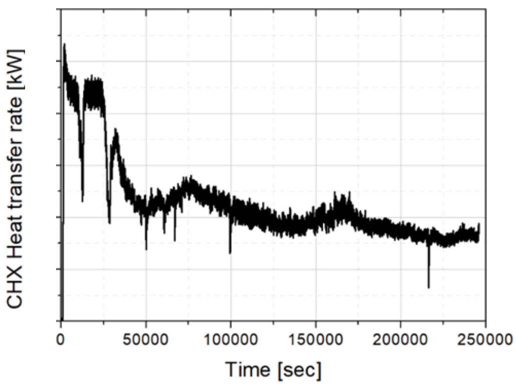
Fig. 3. Non-condensable gas fraction in CHX and CDL (LTC#2)

3.2 Heat transfer rate

Figure 4 shows heat transfer rate of CHX in the LCT #1 and #2. In the LCT #1, heat transfer rate in the heat exchanger was lost because the accumulated non-condensable gas was filled in the CHX. In the LCT #2, although the heat removal performance decreased continuously, heat removal was possible for 72 hours. This means that the CRL was opened early to effectively remove the non-condensable gas from the lower part of the system, thus the CHX could maintain heat removal during long-term cooling.



(a) LTC#1



(b) LTC#2

Fig. 4. Heat transfer rate of CHX

4. Conclusions

A full-height integral system test facility, SISTA2, was used to simulate long-term cooling tests for 72 hours after SBLOCA in SMART100 CPRSS. It was confirmed that initial non-condensable gas in the bottom of LCA could not move to UCA because of the pressure drop in the long flow path. In this study, when we opened the CRL earlier at about 6 hour after accident, non-condensable gas was continuously discharged to the UCA without accumulating in the lower part of the system.

ABBREVIATION

CPRSS: containment pressure and
radioactivity suppression system
LCA: lower containment area
IRWST: In-containment refueling water storage tank
UCA: upper containment area
CSL: CPRSS steam line
CDL: CPRSS discharge line
CRL: CPRSS return line
CHX: CPRSS heat exchanger
RV: reactor vessel

ACKNOWLEDGEMENT

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REFERENCES

[1] J. H. Yang, T. H. Ahn, H. Bae, and H. S. Park, "Investigation of Condensation with Non-condensable Gas in Natural Circulation Loop for Passive Safety System," Nuclear Engineering and Technology, Vol. 55, pp.1125~1139, 2023.

[2] J. H. Yang, et al., Passive Cooling Test using a Full-Height Test Facility for SMART CPRSS, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 19-20, 2022.