Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Evaluation of Passive Containment Pressure Suppression and Radioactivity for SMR

Kyung Jun Kang [a*], Ji-Han Chun[a], Han-Ok Kang [a], Seong Su Jeon[b], Soon Joon Hong[b]
[a]*SMART Development Institute, Korea Atomic Energy Research Institute, 989-111 Daedoek-daero, Yuseong-gu, Daejeon, 305-353*
[b]*Future&Challenge Company,*
[*]*Corresponding author: kkj@kaeri.re.krk*

1. Introduction

Korea- Saudi SMART Pre-Project Engineering (PPE) for FOAK plant construction in the Kingdom of Saudi Arabia is on-going project to be performed by Korea Atomic Energy Research Institute. In the PPE phase, SMART aims at achieving enhanced safety and improved economics. To achieve the goals, the passive containment cooling system was proposed and introduced in the PPE project, reflecting the design characteristics of SMR(Small Modular Reactor). The system is the passive system utilizing heat sinks and natural circulation inside the plant to cool the containment. The objective of the paper is to evaluate a design concept for passive containment pressure suppression and radioactivity system.[1]

2. Description of the System

Figure 1 illustrates the conceptual design of CPRSS introduced in PPE. The CPRSS is the safety system of the SMART. The system suppresses the increase of P/T in the containment following accidents such as LOCA. The CPRSS consists of a LCA(Lower Containment Area), PRLs(Pressure Relief Lines) and PRL-spargers, an IRWST(In-containment Refueling Water Storage Tank), RTLs(Radioactive material Transport Lines), two RRTs(Radioactive material Removal Tanks), ECTHS(Emergency Cooldown Tank Heat removal System) and etc. The ECTHS consists of four mechanically independent trains. Each train of ECTHS comprises an ESL(ECTHS Steam Line), one ECTHX(Emeregency Cooldown Tank Heat eXchanger), valves, an EDL(ECTHS Discharging Line), an ERL(ECTHS Return Line) and one ECT(Emergency Cooldown Tank). The IRWST is connected to the LCA via the RTL and the RTL-sparger, and the UCA(Upper Containment Area) is connected to the RRT via the RRT vent located at the top of the RRT. When accident occurs, the steam and gas mixture of LCA flow into the IRWST through PRL. The system have three heat sinks, IRWST, RRT and ECT. IRWST is located beside LCA and RRT is a water tank located at the top of the IRWST. RRT top is fully opened and connected to UCA atmosphere. ECT is installed outside the containment building. Heat exchanger is installed inside ECT tank. This three tanks play a role of inner heat sink and ultimate heat sink. The connecting pipe lines consist of PRL, RTL, EDL, ESL and ERL.

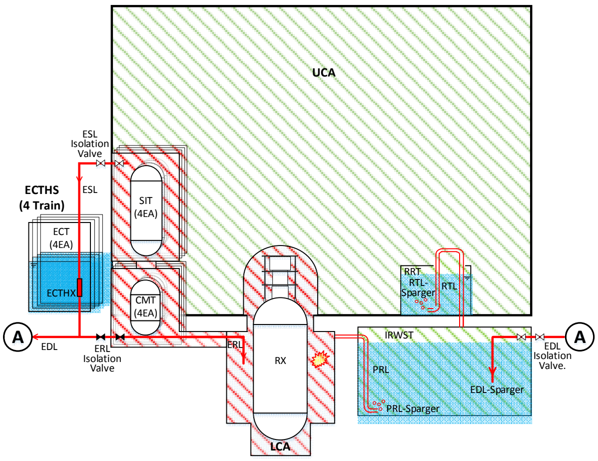

Fig. 1 Conceptual view of containment pressure and radioactivity suppression system(CPRSS) for SMART

3. Analysis Method and Results

3.1 Analysis Model and Method

Figure 2 shows the MARS nodalization scheme for the T/H performance analysis of the CPRSS for SMART. The time-dependent volumes, TDV-100 and TDV-102, and the time-dependent junctions, TDJ-101 and TDJ-103, were used to provide the inlet boundary condition for the Mass/Energy(M/E) which represents the high pressure steam-water two phase flow released from the reactor vessel following LOCA. The pipe components V110,V172 and V174 were used to model the RV-side LCA, CMT-side LCA, and SIT-side LCA. Pipe components,V130 and V132, are used to model the effective volume region in the IRWST. The IRWST(V130) is connected to the LCA(V110) via the PRL and the PRL-sparger(J125). Pipe components,V150 and V152, were used to model the RRT. The RRT(V150) is connected to the IRWST(V132) via the RTL(J135,V138,J139 and V140) and the RTL-sparger(J145), and the UCA(V160 and V162) is connected to the RRT(V150 and V152) via the RRT vent(J153 and J157). For the modeling of the ECTHS, the pipe components, V176,V178,V180, and V184 are used to model the ESL, the ECTHX, the EDL, and the ERL, respectively. The ESL,EDL, and ERL isolation valves are modeled using the valve component, J175,J179, and J183, respectively. The condensate water from the ECTHX(V178) is drained into the IRWST and LCA through the EDL and ERL(V180,184).

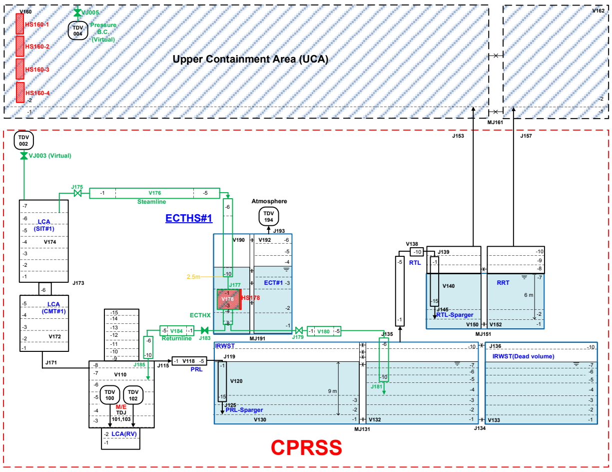

Fig. 2 Analysis model of the system

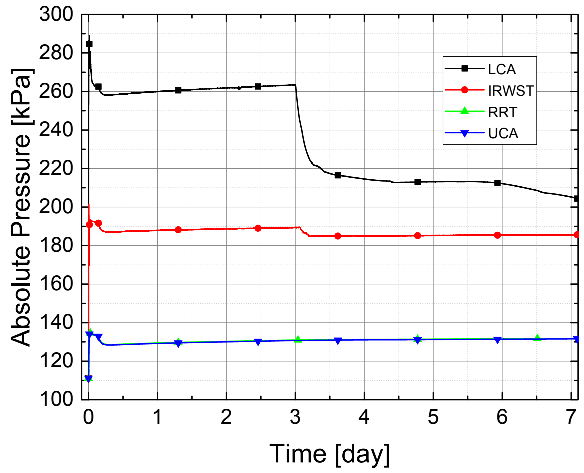

Fig. 3 Pressure behavior inside LCA and UCA

3.2 Analysis Results

Figure 3 and 4 show the pressure behavior inside LCA and UCA during 7 days following LOCA. When LOCA occurs, the steam-water mixture is released from the M/X boundary, CPRSS automatically operates due to the pressure difference between LCA and IRWST. Within tens of seconds after the accident, the steam and non-condensable gas mixtures are released only through the PRL. After that, when the ESL and EDL isolation valves are opened by the LCA high pressure signal the gas mixtures are released via PRL with EDL. In this phase, the LCA pressure increases sharply and reaches to a maximum pressure of 289 kPa at 1130 seconds after the accident. After tens of minutes, the gas mixtures are released predominantly through the EDL. When the CPRSS discharges the steam through the EDL, the ECTHX removes the heat from the LCA to the environment.

As the LOCA proceeds, the LCA and UCA pressure increase consistently for three days and reach to 263 kPa, 131 kPa for each due to non-condensable gas movement inside the LCA and IRWST. The pressure difference between LCA and UCA differs by the pressure head of IRWST and RRT. The temperature of the LCA also increases and reaches to 132 ℃. After 3 days following the accident, the natural circulation loop through the LCA-to-LCA path of the ECTHS is formed by opening the ERL isolation valve manually. The released from the LCA condenses in the ECTHX. Some condensate flows into the IRWST by gravity; however, most of steam and non-condensable gas mixtures, and condensate flow into the LCA along the ERL. Consequently, the LCA P/T becomes to decrease continuously by the formation of the natural circulation loop through the LCA-to-LCA path of the ECTHS. Due to the ECTHS operation, LCA P/T decreases slowly and the increase of UCA P/T is also suppressed. The steam generated in the ECT vented to the atmosphere.

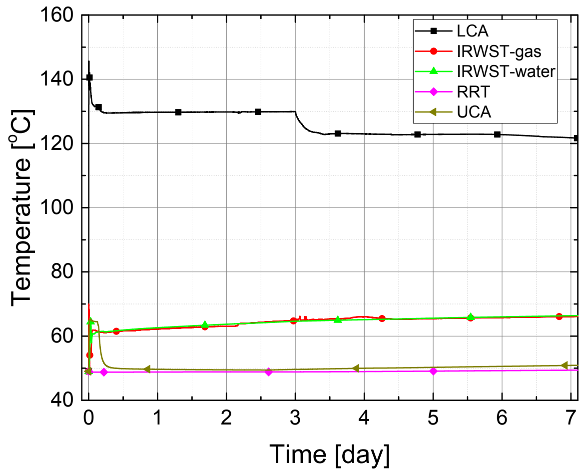

Fig. 4 Temperature behavior inside LCA and UCA

4. Conclusions

The thermal hydraulic evaluation of CPRSS was conducted through MARS code. As a results of the system performance evaluation, LCA peak pressure is less than 3 bar and UCA peak pressure is less than 1.4 bar. After the accident, the pressure peak was reached several minutes before the accident, and the pressure of LCA and UCA was increased very slowly until three days before the pressure was reduced rapidly after the ERL circulation loop was formed.

REFERENCES

[1] K.J.Kang, Y.I.Kim et al, Radioactive Material Reduction Facility and Nuclear Power Plant having the same, 10-2014-003632, Korea Patent(2014)