Preliminary safety analysis on 100MWe long fuel cycle sodium-cooled fast reactor under the unprotected loss of power to all IHTS pump

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***Keywords :** SALUS, MARS-LMR, safety analysis, loss of power to all IHTS pump

1. Introduction

A 100MWe long fuel cycle sodium-cooled fast reactor system called SALUS (Small, Advanced, Long-cycled and Ultimate Safe sodium-cooled fast reactor)[1] is currently under development in KAERI. With the exception of the core, SALUS's overall system design features are comparable to those of the 150MWe PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor).

Due to SALUS's lengthy fuel cycles, safety assessment must be conducted for each cycle. It is assumed that the safety acceptance criteria for SALUS is the same as those for PGSFR[2,3].

The MARS-LMR code has been used to do a series of safety analyses on the current design of the SALUS[4,5]. MARS-LMR code[6] is the modified version of MARS code, which has been supplemented with SFR features including liquid metal heat transfer and additional reactivity feedback models.

In this study, a model is constructed and calculations are performed using MARS-LMR code[4,5] to determine conservative initial conditions and perform sensitivity analysis for the loss of power to all IHTS pumps without a reactor scram, one of the unprotected LOHS(Loss Of Heat Sink) accidents. Based on the obtained conservative initial condition, the transient calculation has been carried out and the related results are presented.

2. MARS-LMR model for SALUS

In Fig. 1, nodalization of MARS-LMR model for the analysis of SALUS was presented[4] briefly, since the methods used in this study's modeling and analysis were the same as those used in previous studies[4,5]. The core is modeled with 8 channels including driver fuel, control rod, reflector and shield assemblies.

In SALUS, the IHTS(Intermediate Heat Transport System) consists of two loops and the DHRS(Decay Heat Removal System) is composed of two passive trains and two active trains. The two passive trains and two active trains of DHRS are modeled as single passive train and single active train by preserving the total heat removal capacity, respectively.

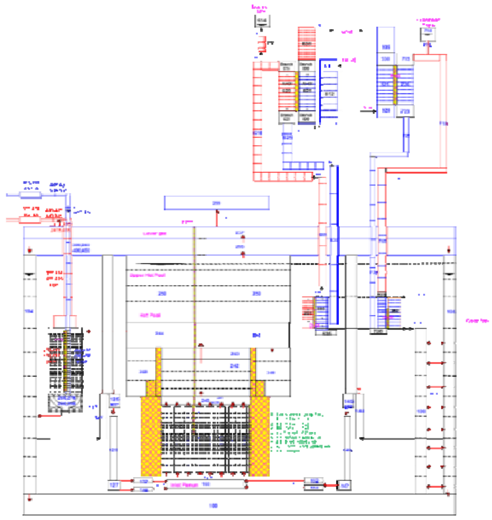

Fig. 1 Nodalization of SALUS for MARS-LMR

3. Results

3.1 Sensitivity Analysis

In order to determine the most conservative initial condition for the analysis, a series of transient calculation has been done for the various LCO(Limiting Conditions for Operation)s. The parameter considered are core inlet temperature, core outlet temperature and core power at BOC(Begin of Cycle) and EOC(End of Cycle). In the sensitivity analysis for BOC and EOC, the ±4℃ of temperature and ±2% of power with respect to the nominal value are taken into accounted.

The following assumption were used as a basis for the analysis of the unprotected loss of all IHTS pump accidents. The DPS(Diverse Protection System) is assumed to be available while the reactor protection systems are assumed to be unavailable until operator action is taken after all IHTS pumps have shut down due to a power outage or other malfunction.

From the sensitivity analysis, it was found that the peak coolant temperature increases with the increase of reactor power and core outlet temperature, and with the decrease of core inlet temperature as presented in Fig. 2. The most sensitive parameter out of the three was found to be the core outlet temperature. With a core power of

102%, a core inlet temperature of 356°C, and a core outflow temperature of 514°C for EOC, the coolant temperature shows the highest peak value. That was selected as the most conservative case for the following unprotected loss of all IHTS pump accident.

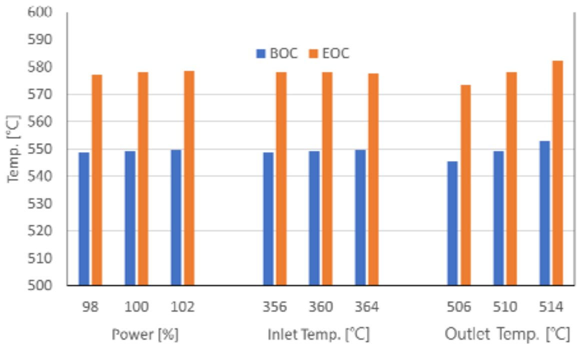

Fig. 2 Effects of variation in power, inlet and outlet temp. at BOC and EOC on coolant peak temp.

3.2 Unprotected Loss of all IHTS Pump Accident

At unprotected loss of all IHTS pump accident, two IHTS pumps stop operating at 10 seconds, however, PHTS pumps is still operating. The DHRS starts to remove heat around 110 seconds, and the DPS does not cause the reactor to trip.

Fig. 3 shows the flowrates of PHTS(Primary Heat Transport System) and IHTS. The flowrate through the core is depicted by red line. That of the IHTS loop-1 and loop-2 is depicted by the solid mark and empty mark respectively. After an accident, the flowrate within a reactor pool is maintained. Natural circulation still keeps the flow through IHTS loops at approximately 9% of the typical flow rate, even without IHTS pumps operation.

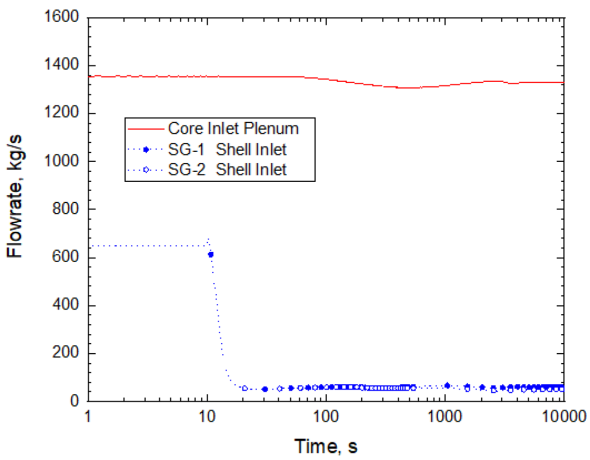

Fig. 3 PHTS and IHTS flowrate

The variance in inlet and outlet temperatures at the core and two IHXs are shown in Fig. 4. The core inlet temperature shows the peak value of 500°C at 480 seconds and converges to 430°C. The core outlet temperature approaches the peak value of 547°C and subsequently converges to 449°C. The IHX-1 and IHX-3's outlet temperatures start to drop after 400 seconds and eventually reach 240°C and 290°C, respectively.

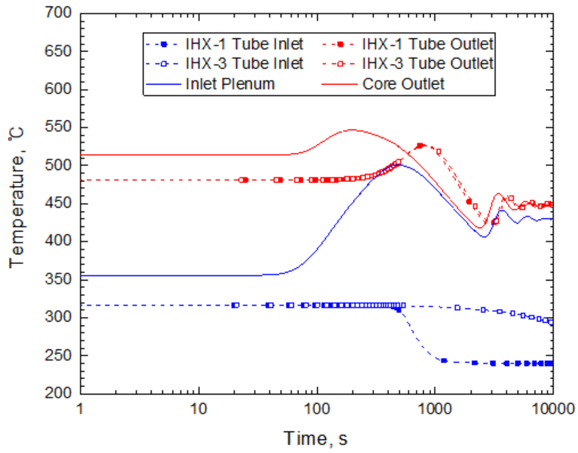

Fig. 4 Temperature variation

The heat balance of SALUS is shown in Fig. 5. Due to the loss of all IHTS pumps, the heat removal rate through IHTS reduces to 26 MWt at 10,000 seconds. the heat removal rate through DHRS increases to 9 MWt. Around 100 seconds, core power begins to decrease due to the increased negative reactivity feedback. As a result, the stability of the reactor can be maintained even if all IHTS pumps are lost, which is identical to the results proven through EBR-II test program[7].

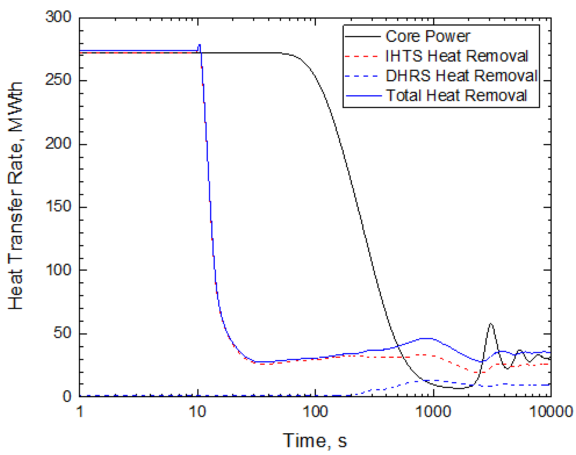

Fig. 5 Heat balance of SALUS

The coolant temperature at every core channel is shown in Fig. 6. The coolant's peak temperature of the hottest channel(CH01) becomes 583°C at 167 seconds, which is substantially lower than its boiling temperature

(882°C), and converges to 453°C. It is evident that SALUS has adequate safety margin under the unprotected loss of all IHTS pump accident.

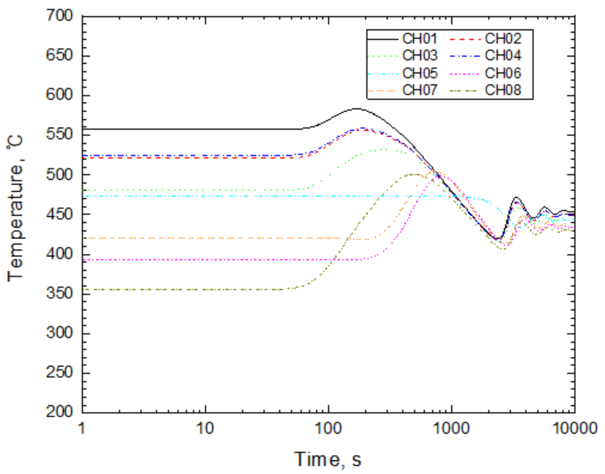

Fig. 6 Coolant temperature at core channel

3. Conclusions

Various calculations using MARS-LMR code has been done for the safety analysis of SALUS under the unprotected loss of all IHTS pump accidents.

The most conservative case, with a core power of 102%, a core inlet temperature of 356°C, and a core outflow temperature of 514°C for EOC, was found through the sensitivity analysis among LCO.

For the selected case, overall thermal hydraulic transient behavior such as flow rates, temperature, and heat transfer rate were investigated.

The safety analysis for the conservative conditions shows that the SALUS satisfies the safety acceptance criteria under the loss of all IHTS pump accidents.

4. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). (No. 2021M2E2A1037871).

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