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LOHS Analysis for a Proto-type Generation IV SFR (PGSFR)

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1. Introduction

A LOHS (Loss Of Heat Sink) accident was analyzed for safety evaluation of the conceptual design of a PGSFR (**P**roto-type **G**eneration IV **S**odium cooled **F**ast **R**eactor) with 150 MWe. The accident initiator in the present analysis was an inadvertent isolation of the feed-water valves among various causes. In addition, the loss of off-site power was also postulated in the analysis for a conservative point of view, and thus the two pumps in both the primary and intermediate systems would be tripped in the transient. The DHRS (Decay Heat Removal System) is a unique safety grade system for removing decay heat. Therefore, the study was aimed at evaluating whether the core damage resulted from the accident can be prevented within the designed DHRS capacity.

2. Analysis

2.1 Input model and accident simulation

Figure 1 demonstrates a nodalization for the MARS-LMR input with the PGSFR [1]. The safety grade decay heat removal system, DHRS consists of two loops of a passive system and two loops of an active system. Since one of the two emergency diesel generators was assumed to malfunction in the analysis, only an active loop with two passive loops would be available to provide service in the accident scenario.

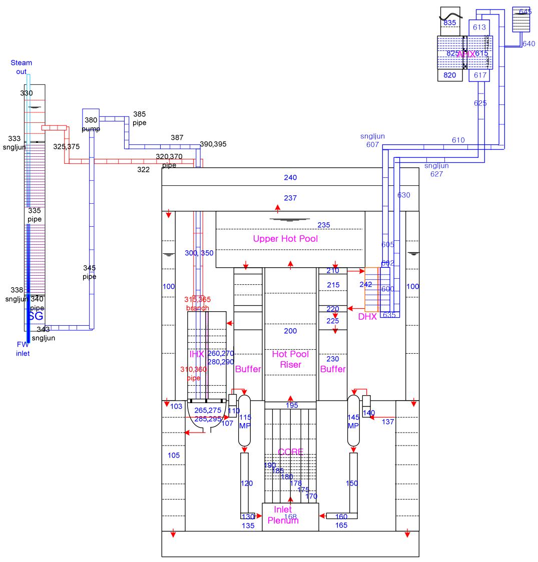

Figure 1. Nodalization for MARS-LMR to the PGSFR

In consequence of the loss of off-site power, the pumps in the primary and secondary systems were tripped, and the air control valves for the AHX (Air Heat Exchanger) and FAHX (Forced Air Heat Exchanger) were opened at the loss of off-site power.

2.2 LOHS analysis

2.2.1 Accident scenario

The accident was initiated by the feed-water isolation signal at 10.0 s. Reactor trip signal was then occurred with a delay of 8.5 s after the accident initiation, and the reactor was tripped 0.01 s later. The loss of off-site power also took place with a time delay of 5.0 s after the reactor trip.

2.2.2 Results

The IHX (Intermediate Heat Exchanger) inlet and outlet temperatures soared owing to a sudden absence of heat removal through the SGs (Steam Generators) at the accident. The reactor trip signal was caused by a high IHX inlet temperature. The analysis results showed that the IHX set-point was reached at 66.34 s, and the reactor trip signal occurred at 74.84 s. Subsequently, the reactor was tripped at 74.85s. The pump coast-down arising from the loss of off-site power began at 79.85 s. Figure 2 represents transient behaviors of the core inlet and outlet, and the IHX inlet temperatures. The core outlet temperature which plummeted after the reactor trip, escalated owing to the core power to flow ratio (P/Q) to show a peak around 880 s. The peak outlet temperature then turned into a descending trend with the natural circulation flow induced by the enough temperature difference between the hot and cold pools.

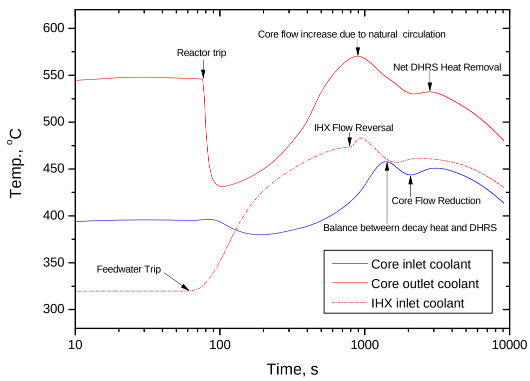

Figure 2. Behaviors of core inlet and outlet temperatures

In contrast to the outlet temperature in the early transient, the core inlet temperature decreased primarily owing to a reduced heat transfer from the primary system to IHTS (Intermediate Heat Transport System) after the reactor trip (see Fig. 3) until 180 s, and then the decreasing inlet temperature kept on going up for about 1,200 s. A peak was met because the core heat generation became less than the DHRS heat removal since approximately 1,400 s.

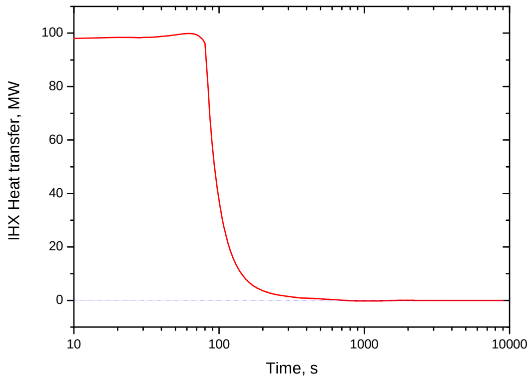

Fig. 3. IHX heat transfer from the primary system to the IHTS

The core flow reduced around 2,040 s (see Fig. 4). Accordingly, the descending core inlet and outlet temperatures after the first peaks shifted to an ascending trend to reach the second peaks ~ 800 s later, as shown in Fig. 2. The coolant eventually cooled down since after the second peaks, because the DHRS effectively removed the decay heat.

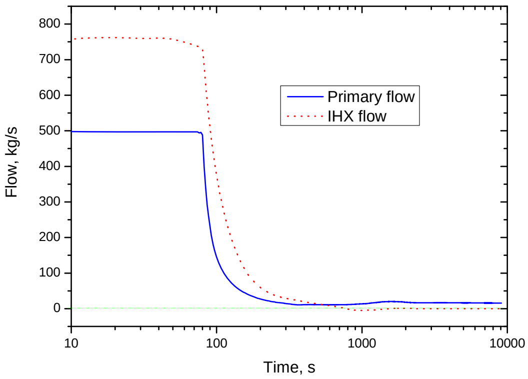

Figure 4. Result of the primary and IHTS coolant flows

Figure 5 depicts the DHRS heat removal, and shows that the AHX sustained almost a steady heat removal after 2,000 s. Since the sodium in the DHRS loops should be heated up in the early transient, the DHX heat transfer was much larger than the AHX heat removal. The gap between the DHX and AHX heat transfers, however, would be agreed eventually when the transient calculation lasts for a longer time.

Figure 6 represents the cladding temperatures for 4 axial nodes, and their behaviors look alike. The maximum temperature was predicted in the 8^{th} axial node around 440 s. The core flow was the lowest around that time.

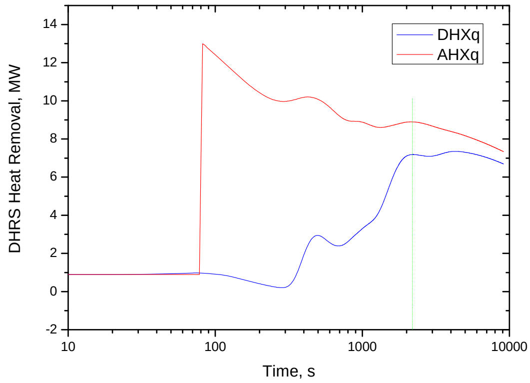

Figure 5. DHRS heat removal; DHX and AHX

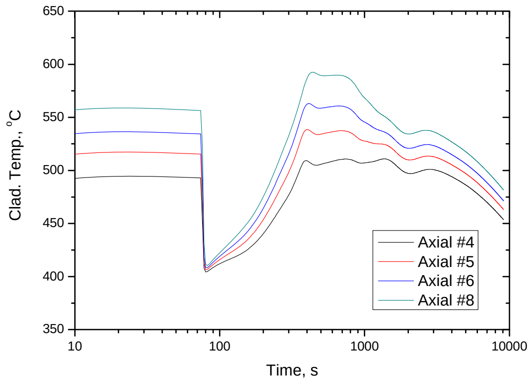

Figure 6. Axial cladding temperatures

3. Conclusion

Analyses were performed for a loss of heat sink accident in the TGSFR using the MARS-LMR. The accident was initiated by an inadvertent isolation of the feed-water valves.

In the results, the maximum cladding temperature was predicted below a design criterion of 650 ^{o}C with a sufficient margin. The DHRS functioned acceptably for removing the decay heat in a long term cooling of the accident analyzed in this study.

REFERENCES

[1] Jinwook Chang, et al., “Conceptual Design Status of a Prototype SFR in Korea,” SFR-DD112-DC-001-2012 (2012).