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DHRS Performance Test Results of STELLA-2 and Comparison with MARS-LMR Analysis

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1. Introduction

The STELLA program originally started to support the development of PGSFR in KAERI to validate the long-term coolability of DHRS and to verify the safety analysis code, MARS-LMR[1]. However, PGSFR development plan has been postponed and STELLA facilities are now utilized to investigate various phenomena in SFR system. The simulation of main DBEs is expanded to cover wider range of system states such as transient experiments starting from cold steady-state. Moreover, experiments to extend the research scope has been added to the test matrix and the experiment is on-going. One of the example is the natural circulation capability test.

In this paper, one of the test results of DHRS cooling capability is described and the code calculation result is also compared with this experiment data. To check the decrease in core temperature in long-term with the decay heat generation by 1 PDHRS and 1 ADHRS, the experiment was set up and conducted for 20,000 sec, which is equivalent to ~50,000 sec in real time.

The scope of this paper does not include specific solution to modify neither the facility nor the code to respond to the difference between the experiment and the calculation. However, the reasoning and discussion about possible causes of difference is included.

2. Test Condition

2.1 Steady-state point

The transient of DHRS cooling starts from the heat balance of the normal operation condition of the reactor. Therefore, it is very important to set-up the experiment steady-state as close as possible to the target point. The steady-state result of the experiment is shown in Fig. 1. It is reasonably well-balanced but it does not precisely match the target reactor condition, because it is very challenging and excessively time-consuming.

2.2 Code result of quasi steady-state

Using MARS-LMR, the steady-state point was set to be same as the experiment result as seen in Fig. 2 ~ 7. Considering the system code characteristic, the quasi steady-state was set. From this calculation result, the transient will start.

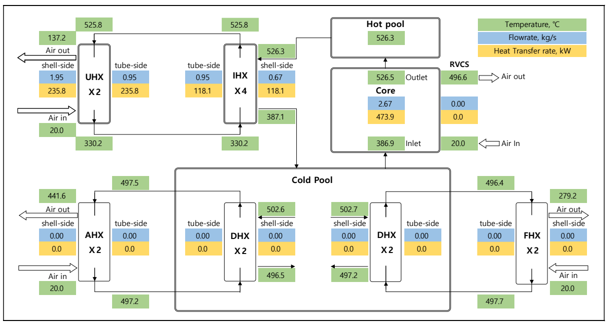

Fig. 1 Target steady-state point of experiment

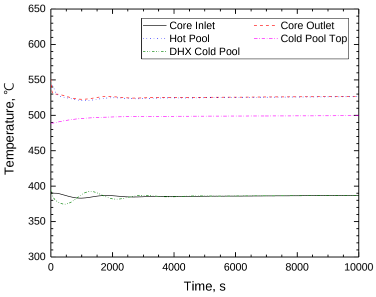

Fig. 2 Code result of steady-state (core temp)

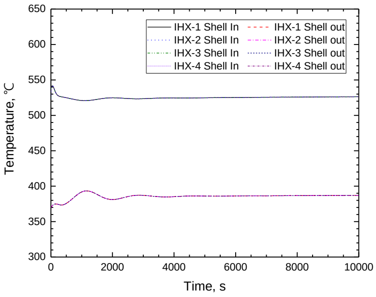

Fig. 3 Code result of steady-state (IHX temp)

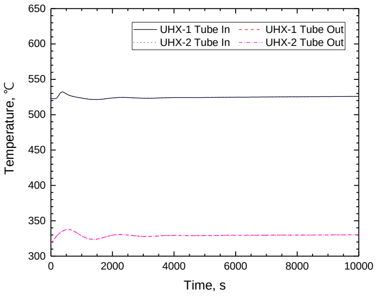

Fig. 4 Code result of steady-state (UHX temp)

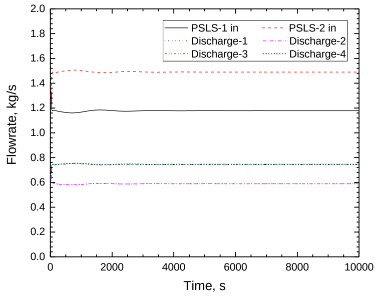

Fig. 5 Code result of steady-state (primary flow)

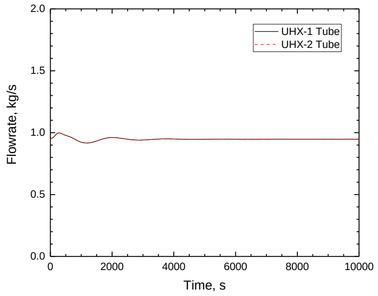

Fig. 6 Code result of steady-state (intermediate flow)

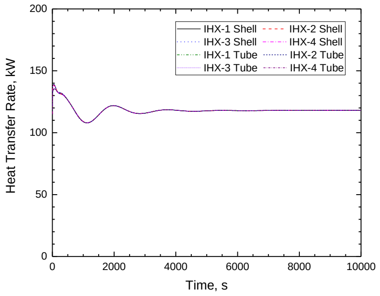

Fig. 7 Code result of steady-state (IHX heat transfer)

2.3 Event sequence

The transient of concern has several important events and their sequence is as follows. The time in bracket is the time in STELLA-2 and the equivalent reactor time corresponds to the safety analysis result of PGSFR.

- PHTS pump 1&2 stop (4.47s):
  1.25 → 0.0kg/s
- IHTS pump 1&2 stop (4.47s):
  0.92 → 0.0kg/s
- UHX 1&2 stop (4.47s)
- Reactor Trip (5.81s):
  Follows the decay curve
- DHRS starts to operate (8.26s)
  100% 1PDHRS + 100% 1ADHRS

This transient is the case of LOF with LOOP condition and so the pumps in both loop stop at the same time and the UHX blowers also stop. After some time, the reactor signal trip occurs and the core starts to follow the decay heat curve. Due to the damper opening time, the DHRS does not start instantly. One active and one passive line are assumed to fail and so two out of four lines are working.

3. Comparison Btw Experiment & Code

3.1 Natural circulation flowrate

The primary flowrate comparison result is shown in Fig. 8. In this experiment, the most important factor is the flowrate on primary side because it decides whether the decay heat is safely removed or not. The experiment result shows that there is stronger driving force to induce the natural circulation flow through the core than the calculation. In the calculation, the flowrate is smaller by 35~53% of the experiment. It is notable that the PSLS-1 flowrate is smaller in calculation whereas PSLS-2 flowrate is smaller in experiment. This can happen because the flows from 1 and 2 are mixed in the inlet plenum causing asymmetrical flow distribution. The calculation cannot exactly predict this phenomena. Moreover, in the experiment, the pump power was set to be constant, and not controlled by the flowrate measurement.

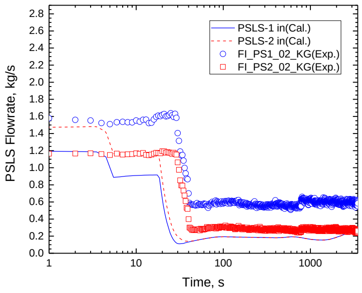

Fig. 8 Comparison result (primary flow)

3.2 Core in/out temperature trend

The temperature behavior is shown in Fig. 9 and it can be seen that the long-term cooling is working where the core outlet temperature is decreasing. Due to the high flowrate, the temperature rise near 100s is suppressed strongly and the continuous drop trend can be observed. The calculation result of the core ΔT is 1.6~2.8 times larger than experiment. The overall trend is in similar form.

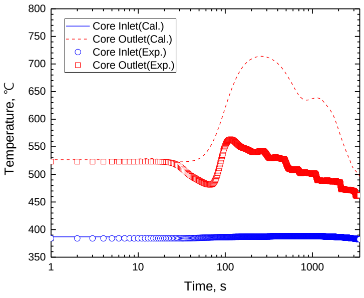

Fig. 9 Comparison result (core temp)

3.3 IHX shell-side temperature difference

The temperature of IHX shell inlet shows relatively large difference from the calculation result as seen in Fig. 10. In ideal case, it should be same as the core outlet temperature. However, the IHX shell inlet temperature is lower and resulting in smaller ΔT.

The trend is also different and this is because there is no IHTS flowrate in calculation whereas in experiment there was small natural circulation flow.

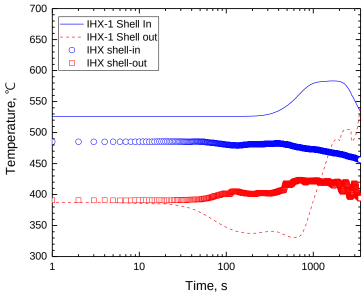

Fig. 10 Comparison result (IHX temp)

3.4 Heat removal thorough AHX & FHX

The heat removal rate is much smaller in experiment than the calculation as seen in Fig. 11. The final heat sink ΔT clearly indicates that the heat transfer is much smaller.

The general trend of temperature and flowrate in the loop is similar(Fig. 12 ~ 15). However it can be observed that the natural circulation flow inside the DHRS loop is much smaller for both PDHRS and ADHRS in experiment. As a result, the temperature response is delayed and the ΔT becomes larger in experiment.

4. Discussion

After this comparison work, we have found that the sodium flowmeter on the primary side of the facility is over-measuring the real value and we are now re-calibrating the flowmeter during maintenance period. Another finding was that the heat loss at the hot pool was much larger than we expected due to numerous instrumentation and heater lead cables. These two factors are critically influential to the experiment result and are the main reason of difference in previous chapter.

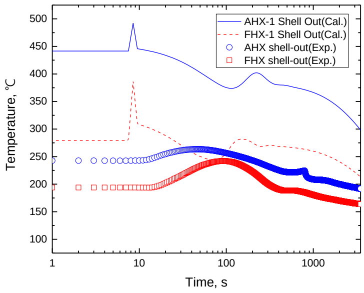

Fig. 11 Comparison result (Air temp)

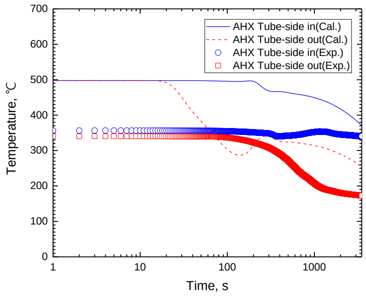

Fig. 12 Comparison result (AHX temp)

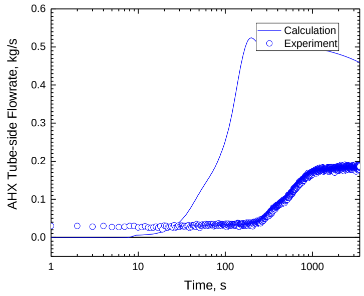

Fig. 13 Comparison result (AHX flow)

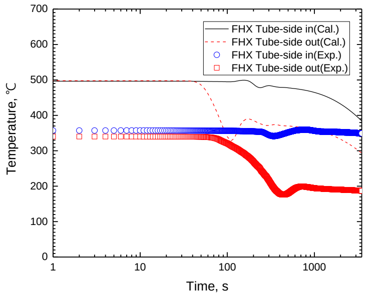

Fig. 14 Comparison result (FHX temp)

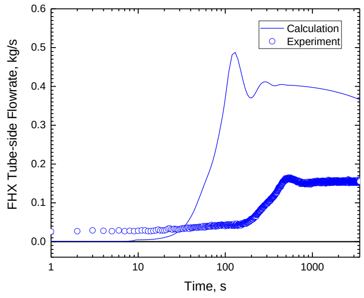

Fig. 15 Comparison result (FHX flow)

5. Conclusion

The LOF transient experiment was conducted using STELLA-2 facility and the data was compared with the code calculation. The difference was observed and there were two major factors. With this preliminary analysis, we will re-adjust the instrumentation and also will find a way to take into consideration of the excessive heat loss.

For further work, various test data will be analyzed with the MARS-LMR code and the comprehensive comparison result will be published.

ACKNOWLEDGMENTS

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