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Heat Loss Evaluation of Large-scale Sodium Test Facility, STELLA-2

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1. Introduction

The experiment activities using large-scale facility always experience the heat loss during its operation. The transient tests are especially challenging to quantify the heat loss amount due to its changing states with time. Furthermore, experiments at high temperature with high thermal-conductive fluids, such as 600℃ liquid sodium, are more prone to losing heat. However, it must be considered with best effort to understand the behavior of transients and thus the prediction of code analysis can have credibility.

In this paper, one of the transient test results from large-scale sodium test facility, STELLA-2, was selected to compare the heat loss modeling effect for code calculation. The hypothetical heat removal was modeled and the condition was arbitrarily set to see the effect.

The scope of this paper is only limited to the evaluation of heat loss effect of concern and it does not suggest any design changes or specific modification to the facility to reduce the heat loss.

2. Test Facility and Condition

2.1 Test Facility

The Sodium Integral Effect Test Loop for Safety Simulation and Assessment(STELLA) program was first launched to support the development of Sodium-cooled Fast Reactor in Korea[1]. The STELLA-2 is the second phase facility and it is capable of testing various transients including the Design Basis Events (DBEs)[2]. It resembles the reactor but in smaller scale. The scale ratio of STELLA-2 is 1/5 in length and 1/125 in volume[3]. It is designed to conserve most of the estimated behaviors during accident conditions and the focus is especially on the natural circulation inside the system[4]. In Figure 1 and 2, schematic and image of STELLA-2 is shown, respectively.

2.2 Test Case Condition

Among many cases of previous experiments, asymmetrical operation with Intermediate Heat Transfer System(IHTS) working condition was selected. The followings are the summarized version.

- Core power: simulated decay heat
- PHTS pump: 1 nominal flow & 1 coastdown flow
- IHTS pump: 1&2 remain unchanged
- UHX heat transfer: nominal heat rejection
- DHRS: no engagement

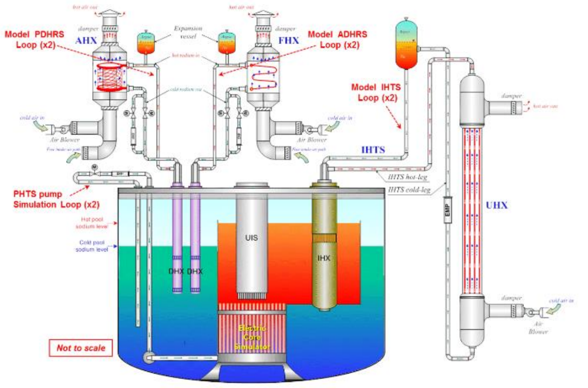

Figure 1 Schematic of STELLA-2 system

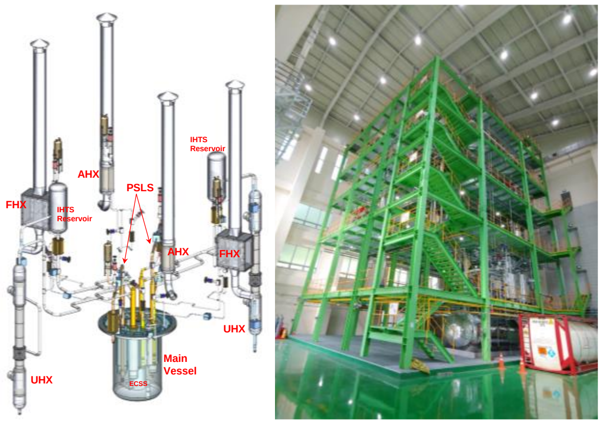

Figure 2 3D image and photo of STELLA-2 facility

3. Heat Loss Effect

3.1 Code Analysis

For the code calculation, MARS-LMR, the reactor safety analysis code was used. The basic assumption and approach were kept same as the reactor safety analysis to be consistent with reactor design philosophy including node layout, heat structures in heat exchanger and so on. The comparison result between reactor and STELLA-2 is not the scope of this paper and a dedicated paper[5] is previously published in journal. In Figure 3, the node layout of STELLA-2 is illustrated.

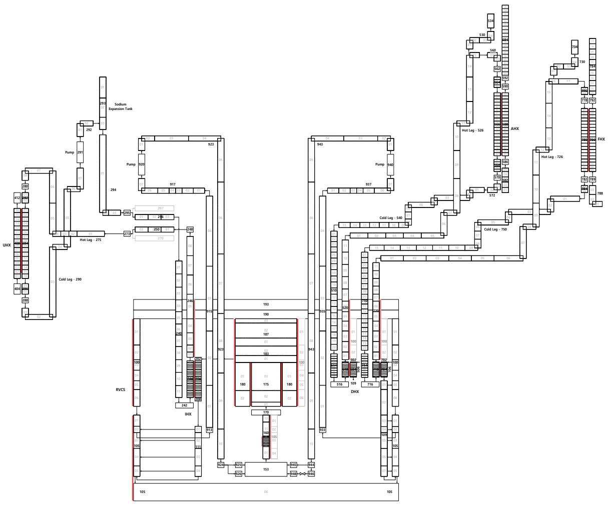

Figure 3 Node layout of STELLA-2

3.2 Result of Core Temperature

In Figure 4, the core inlet and outlet temperature trend is shown. The general behavior does not show any similarity and the long-term difference is obviously large. In experiment, the temperature decreases after ~1,000 sec but in code calculation it increases gradually after ~300 sec. The main reason of this difference is due to the unwanted heat loss at hot pool. It was observed that the core outlet temperature and the IHX inlet temperature were quite different meaning the heat loss.

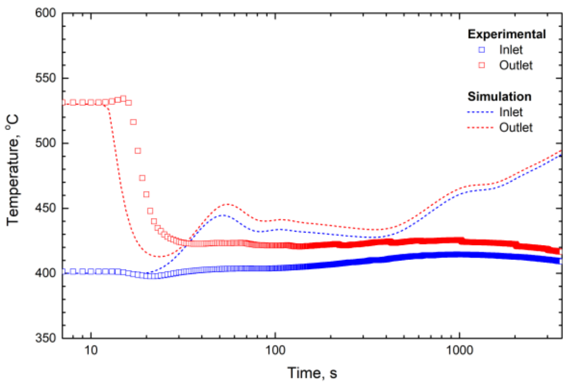

Figure 4 Core in/out temperature trend

4. Heat Loss Modeling

3.1 Hypothetical Heat Transfer

For quantification of the heat loss, firstly, the heat rejection point needs to be identified. In STELLA-2, there is a large bunch of cables at the upper part of core to provide power to the core heaters. These cables turned out to be the major source of unwanted heat transfer to outside.

To model an appropriate heat removal, hypothetical heat transfer path was assumed with heat structures at the hot pool area (Figure 5). The boundary condition for this heat removal was arbitrarily set to match the experiment condition. Especially, it was set to have natural convection because a fixed amount of heat transfer was not desirable for transient experiment. In Figure 5, 160 component corresponds to the core and 175, 180, 183, 187 are the hot pool with sodium.

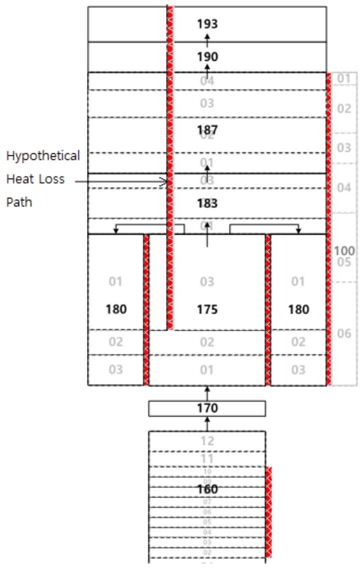

Figure 5 Detailed change in hot pool modeling

3.2 Comparison

In Figure 6, the comparison result of experiment, code calculation with/without heat loss model. It is clearly distinguishable that the calculation with heat loss model follows the experiment trend. Although there is still slight difference in long-term behavior, the general trend is in good agreement. Therefore, the importance of heat loss model is significant and it should be more precisely evaluated with more experiment results.

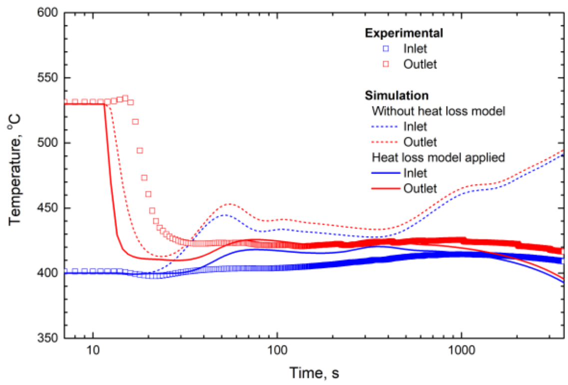

Figure 6 Improvement result with heat loss model

5. Conclusion

For comprehensive evaluation of the reactor behaviors, STELLA-2 facility is actively working on accumulating the experiment data on thermal-hydraulic phenomena. For qualitative analysis of inevitable heat loss for high temperature system, this study tried to identify the heat transfer path as well as model a heat rejection. The test case used in this study is asymmetrical operation with normal cooling through IHTS. The hypothetical path was modelled with natural convection and the comparison result showed some improvements. However, for better prediction, more quantitative analysis will be needed with more experiment data.

ACKNOWLEDGMENTS

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REFERENCES

[1] J. Yoo, et al., "Overall System Description and Safety Characteristics of Prototype Gen IV Sodium Cooled Fast Reactor in Korea", Nuclear Engineering and Technology, Vol. 48, pp. 1059-1070, 2016.
[2] J. Eoh et al., "Computer Codes V&V Tests with a Large-Scale Sodium Thermal-Hydraulic Test Facility (STELLA)," American Nuclear Society 2016 Annual Meeting, New Orleans, US, June 12-16, 2016.
[3] J. Lee et al., "Design of large-scale sodium thermal-hydraulic integral effect test facility, STELLA-2", Nuclear Engineering and Technology, Vol. 54, pp. 3551-3566, 2022.
[4] J. Lee et al., "Heat transfer system design of sodium test facility STELLA-2", Annals of Nuclear Energy, Vol. 191, 109930, 2023.
[5] J. Lee et al., "Design evaluation of large-scale sodium integral effect test facility (STELLA-2) using MARS-LMR", Annals of Nuclear Energy, Vol. 120, pp. 845-856, 2018.