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# Conceptual Design of an IHTS Piping System for an Integrated SG/Pump System Subjected to Elevated Temperatures

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## 1. Introduction

As one of the goals for the GEN-IV reactor development, its economic enhancement is pursued in this paper through a simplification of the IHTS (Intermediate Heat Transfer System) piping system by introducing an integrated SG/Pump design concept as an alternative for the sodium-cooled fast reactor [1]. To assure the structural integrity of a hot leg design with a large diameter, 1.0m, for a 60 years design lifetime, structural evaluations were carried out for the steady state and the assumed 72 Hour accident conditions. For the elevated temperature structural evaluation, the SIE ASME-NH program [2], which is a computer program with implementing detailed rules from the ASME-NH code for class 1 components [3], was used.

## 2. Concept Design and Evaluations

The new concept of the integrated SG/Pump system should meet the specified top tier target structural design goals such as

- ❑ New Advanced Design Concept
- ❑ Simplifications
- ❑ 60 Years Design Lifetime
- ❑ Seismic Integrity
- ❑ Fabrication Availability
- ❑ ISI Guarantee
- ❑ Resolution of Structural Design Issues

This section includes a description of the tentative conceptual design of an integrated SG/Pump, an IHTS piping system, a simple structural evaluation, and detailed IHTS hot leg structural evaluations and discussions.

### *2.1 Concept of Integrated SG/Pump Design*

The main design features of the newly proposed structural design concept for G4SFR (1200MWe) are an integrated SG/Pump and the introduction of a canned motor pump which has a great advantage for no-leakage of sodium. Fig. 1 shows the basic concept of an integrated SG/Pump system. As shown in the figure, two canned motor pumps are attached to the SG bottom head and a feed line nozzle is vertically connected to the center of the bottom head. Currently, the SG tube is a helical type but it may be a straight type like the IHX concept. The support for the SG is a skirt type to resist a seismic load. The design material for the outer shell is a modified 9Cr-1Mo steel which is chosen to eliminate a dissimilar weld with the IHTS pipe made from the same material.

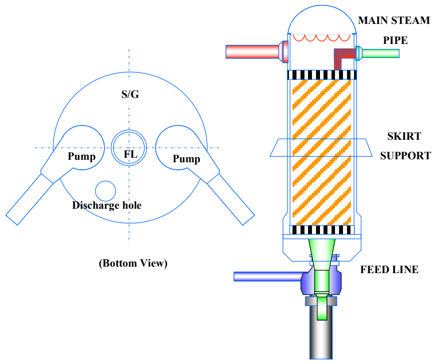


Fig. 1 Schematics of Integrated SG/Pump System

### *2.2 IHTS Piping System*

To realize a large size pipe design over 1.0m in diameter for a hot leg side, a plane layout concept is introduced to the IHTS piping system. Fig. 2 shows the concept of a two loop system. As shown in the figure, a loop consists of two cold legs with curved sections and one hot leg. The diameters are 0.8m for a cold leg and 1.0m for a hot leg. The wall thicknesses are both 1.0 Cm. The hot leg pipe runs in a vertical direction in front of a SG to be connected at a top cylinder part of the SG. The operating sodium temperature for a hot leg is over 500$^{o}$C which is an elevated temperature invoking creep damage. Therefore, it is important to establish a curved pipe design to assure its structural integrity when subjected to elevated temperatures for a long design lifetime.

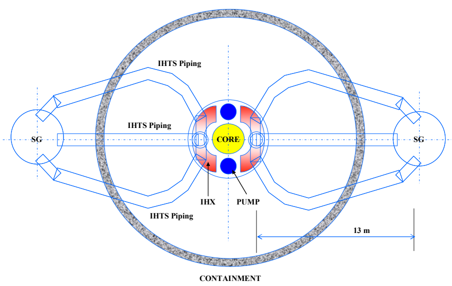


Fig. 2 Layout for 2-Loop System

### *2.3 Finite Element Modeling*

To perform structural integrity evaluations including the creep ratcheting strain and creep-fatigue damage of the hot leg pipe by using the ASME-NH rules, a 3-

dimensional finite element modeling system is used to define the sections.

For the loading conditions, two cases are considered. One is a steady state operation (545°C) and the other is a 72 Hours accident condition without an operator action, which has a transient condition increase from 545°C to 650°C. For a tentative evaluation, the stress is assumed to be free during a hot standby condition when calculating the secondary stress range.

*2.4 Results for the Steady State Condition*

The stress distribution of a hot leg pipe for a steady state condition is presented in Fig. 3. As shown in the figure, the maximum stress is 148 MPa which occurred at a lower curved section rather than at a nozzle part. For the calculated maximum stress, the adequacy of the creep design lifetime for a steady state operation with 545°C is investigated through the design material data provided in the ASME-NH code.

Fig. 4 shows an allowable creep time for Mod.9Cr-1Mo steel. As shown in the figure, the allowable creep time at 148MPa and 545°C is over 60 years, therefore the 60 years design lifetime of a hot leg pipe will be assured in spite of a conservative assumption.

Fig. 3 Stress Contour for Steady State

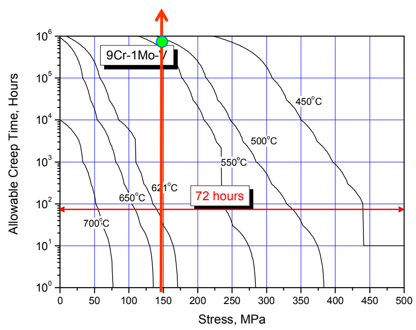


Fig. 4 Allowable Creep Time for Mod.9Cr-1Mo Steel

*2.5 Results for the Transient Condition*

Fig. 5 shows a stress contour for a transient thermal condition and the location of the section used for the structural integrity evaluation. As described in the figure, the maximum thermal membrane stress is 106 MPa and the maximum secondary stress range is 11 MPa.

By using the SIE ASME-NH code, the stress relaxation curves are obtained as shown in Fig. 6. The initial stresses are very high at over 210 MPa and they are relaxed rapidly with time. This high stress state during the initial period results in a very large creep damage. Table 1 presents an evaluation summary. As shown in the results, the tentatively designed hot leg pipe did not meet the inelastic strain limit and the creep-fatigue limit provided in the ASME-NH rules.

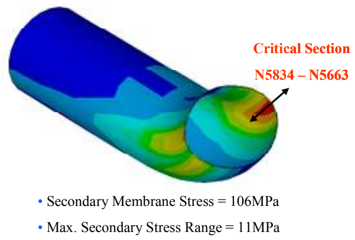


Fig. 5 Stress Contour and Evaluation Section

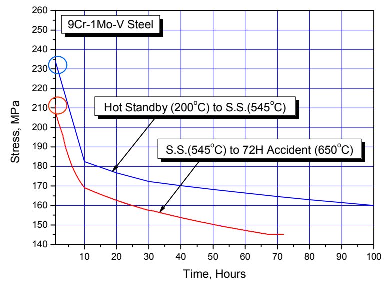


Fig. 6 Calculated Stress Relaxation

## 3. Conclusions

Tentative structural integrity evaluations for a hot leg pipe for an integrated SG/Pump system can not satisfy the ASME-NH rules. Therefore, it is necessary to investigate the design condition in more detail and to perform an inelastic analysis with a verified constitutive model.

## ACKNOWLEDGMENTS

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## REFERENCES

[1] D.H. Hahn, Y.I. Kim, et.al, KALIMER-600 Conceptual Design Report, KAERI/TR-3381/2007, KAERI, 2007.
[2] G.H. Koo and J.H. Lee, Computer Program of SIE ASME-NH Code, KAERI/TR-3526/2008, KAERI, 2008
[3] ASME Code Section III, Subsection NH, 2007.

Table 1. Evaluation Summary

| Evaluation Items | Calculated | Limit value | Check |
|---|---|---|---|
| ❑ Inelastic Strain Limits | | | |
| Ratcheting Limit | (SS) 0.397 | 0.446 | OK |
| | (72H) 0.098 | 0.206 | OK |
| Creep Ratchet Strain | (SS) 1.38 % | 1.0 % | Not OK |
| | (72H) 3.15 % | 1.0 % | Not OK |
| ❑ Creep-Fatigue Limits | | | |
| Fatigue Damage | (SS) 0.000 | 0.011 | OK |
| | (72H) 0.077 | 0.000 | Not OK |
| Creep Damage | (SS) 0.896 | 1.000 | OK |
| | (72H) *** | 0.250 | Not OK |