Component Arrangement Design of Two and Three Loop Systems for a Large Capacity SFR

Lee, Jae-Han [a*] and Park, Chang-Gyu [a]
[a] *Korea Atomic Energy Research Institute*
[*] *jhlee@kaeri.re.kr*

1. Introduction

The economic improvement is a hot issue as one of Gen IV nuclear plant goals. It requires many researches and development works to meet the goal by securing the same level of plant safety. One of the key research items is the increase of the plant capacity with the minimum number of components and loops. It is a large-size scale effect obtained by reducing the plant maintenance, repair, and construction costs.

Through the successful conceptual design experience for the KALIMER-600[1], the structural design study for a 1200MWe large capacity of sodium-cooled fast reactor has been performed to achieve the above plant size effects. The component number and reactor structural sizing was determined based on the core and fluid system design information [2].

The structural design issues of a cost competitive large capacity SFR are listed in Table 1. Several research items can be also contributed to the construction cost reduction of NSSS in structural point of view, for example, a simplified component arrangement, a high temperature LBB application technology, an innovative in-service inspection (ISI) tool, and integrated component concepts.

Table 1. SFR Structural Design Issues

Design goals	Issues	Design Approach
- Large capacity 1,200MWe	- Number of loop (2 or 3)	- Extension design concept of KAIMER-600 - New component arrangement - Large component (SG, pump, piping)
- Core exit temperature 545^{o}C	- 60 years design life	- Improvement of the design and evaluation technologies - High temperature material DB - Seismic isolation
- Simple IHTS piping layout	- Large diameter piping, 110cm	- Evaluation of piping size limit - Large coaxial piping on reactor head [3] - Minimization loop length - New materials
- Economic improvement	- Safety - Simple - LBB - Inspection & repair	- Proper safety target level - Integrated components - LBB application for RV & IHTS piping - Innovative ISI, minimizing welds, allocating access root
- 72hours 650^{o}C	- Creep deformation	- Stress relaxation design technology (180MPa)

2. Component Arrangements

Two and three loop systems of a large pool type SFR are suggested. The component arrangements are based on the layout design of KALIMER-600 system. An alternate NSSS arrangement was also studied using an integrated SG-pump design concept. This concept can drastically reduce the IHTS piping length, and adopts a maintenance free canned motor pump attached at bottom of SG [4].

But, in this paper, component arrangements based on the typical design concept of KALIMER-600 are presented. Fig.1 shows the reactor internal and component arrangement inside the reactor vessel for a two loop system, but the values in Fig.1 represent the two and three loop design data of each component, respectively.

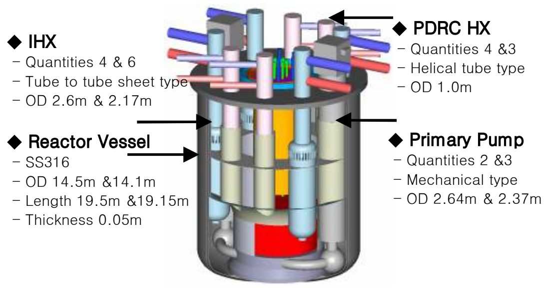

Fig. 1. Preliminary component arrangement in reactor vessel for two loop system of a pool type SFR of 1200MWe.

2.1 Two loop system

The NSSS arrangement design of this system has two heat transport loops as shown in Fig.2. It needs several large size components. The reactor vessel is 14.5 m in outer diameter, 0.05m in thickness. It accommodates the core size of 7.4 m to 7.9 m. The major material of reactor vessel and internal structure is SS316. There are 4 IHXs, 2 primary mechanical pumps, and 4 decay heat removal heat exchangers inside the reactor vessel. The two IHTS loops outside of the reactor vessel have 2 mechanical pumps and 2 SGs.

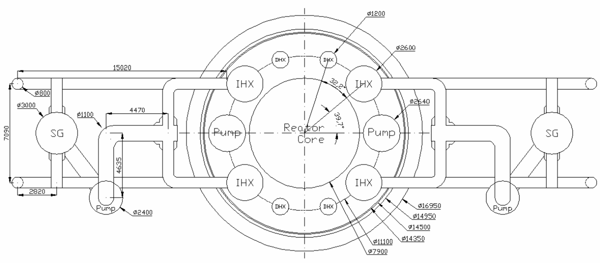

Fig. 2. Preliminary NSSS arrangement of two loop system of a pool type SFR of 1200MWe.

Since the heat transfer capacity of two loop system is twice of KALIMER-600 reactor, the piping diameter of each loop becomes larger and the fabricability and strength of the pipe and elbows are key measures for realizing this system. The piping diameters for the hot and cold legs are 80 cm and 110 cm, respectively.

The piping length of each loop is between 127 m to 180m. It depends on the elevation of the SG and the location of the circulation pump as shown in Fig.3. The pipe material is a Mod.9Cr-1Mo, which has a higher mechanical strength and a low thermal expansion. These have an advantage for obtaining a simple layout of IHTS piping subjected to a high temperature environment.

The height of the SG is about 37.4 m in this IHTS arrangement. The SG heat transfer tube is a double-wall straight type concept. The double-wall helical tube is also considered as candidate concept.

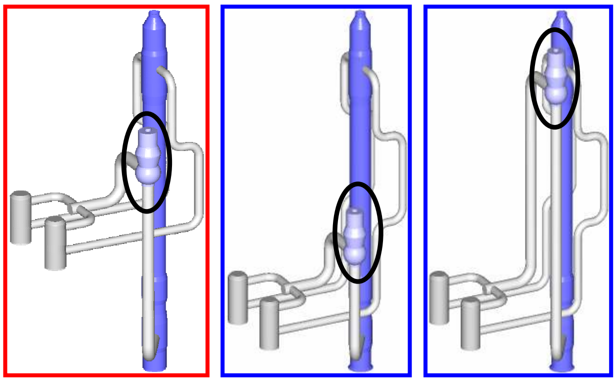

Fig. 3. IHTS layout according to SG and pump locations

2.2 Three loop system

The NSSS of this system has three heat transport loops, and accommodates the core size of 7.4 m to 7.9m. It needs relatively small size components. The reactor vessel is 14.1m in outer diameter, 0.05 m in thickness. There are 6 IHXs, 3 primary mechanical pumps, and 3 decay heat removal heat exchangers inside the reactor vessel as shown in Fig.4. Each IHTS loop has a mechanical pump and a SG.

Since the heat transfer capacity of this loop is 1.5 times of KALIMER-600 reactor, the piping diameter of each loop is smaller than the two loop system and thus the fabricability is more feasible. The piping diameters for the hot and cold legs are 65 cm and 90 cm, respectively. The pipe length of each IHTS loop is between 126 m to 177m when the height of SG is about 38.7 m.

2.3 System arrangement comparison

The two loop system has some advantages like as a compact building size because the number of component is relatively less, and the total piping length is short. But the main obstacle is the fabricability of large size components, pipes & elbows, and the large coaxial piping structures.

The three loop system has a technical feasibility because the component and piping sizes are only lightly increased than KALIMER-600 design, so the design experiences can be fully utilized.

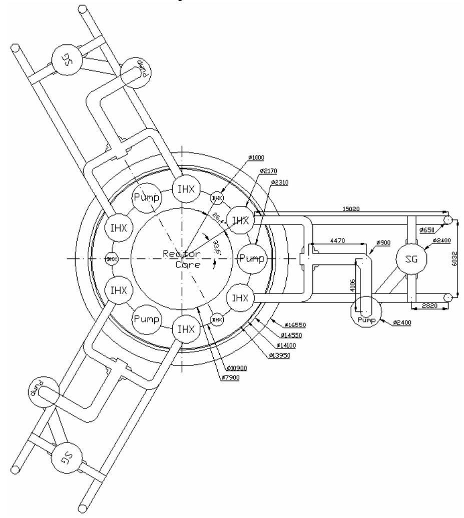

Fig. 3. Preliminary NSSS arrangement of three loop system of a pool type SFR of 1200MWe.

3. Conclusions

The component arrangement and reactor structural sizing for two and three loop systems for a 1200MWe capacity of a SFR are suggested.

The IHTS piping length can be minimized through the properly locating the SG and pump by 126m, which is much shortened piping length compared with other design.

Further studies of these concepts are required to confirm on the fabricability and the structural integrity for the operating and design loads. The proposed concepts will be optimized to a unified conceptual design through several trade-off studies.

ACKNOWLEDGEMENT

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