Preconceptual Structure Design for Sodium-Cooled TRU Burner Reactors

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1. Introduction

Sodium-cooled fast reactors to transmute the recycled transuranics elements are the dominant contributors to spent fuel radiotoxicity, long-term heat and dose. The I-NERI project to develop conceptual core designs for sodium-cooled TRU burner reactor is now performed by collaboration between ANL and KAERI. The core power levels under investigation of this project are 600, 1200, 1800MWe. The main object of this study is to develop the structural design concepts corresponding to the core designs and provide the data of safety evaluation for the object three reactor systems.

2. Component Arrangement

2.1 General Descriptions

Though the SFR reactor system generally consists of the PHTS, IHTS and several safety systems, this study of the preconceptual structure design focuses on the only PHTS and IHTS. Followings which are based on the KALIMER-600 reactor system are commonly assumed to be applied in the three object reactors[1].

- Pool-type reactor system
- Mechanical pump for PHTS
- Two rotatable plugs
- Top closure type to support the RV
- Torispherical bottom heads of RV and CV
- Double-walled straight tube type SG
- Gaps between each structure are maintained constantly irrespective of the capacity

The minimum distance between each component for the arrangement is tentatively assumed to be about 0.8m. The sizes of primary pump and IHX are determined based on the proven technology concept and the arrangement is performed by considering the reactor core layout[2] and fluid requirements.

2.2 600MWe Reactor

600MWe reactor core consists of 673 assemblies and its diameter is 446cm. The support barrel outside the core has 5.1m diameter. The main components located in the RV(Reactor Vessel) are IHX, Pump and DHX which is a decay heat exchanger for the PDRC. To simplify the system arrangement and improve the economical efficiency, 2-loop system is adopted for the PHTS. Each loop consists of 2-IHXs, 1-Pump and 1-DHX. The diameters for IHX, Pump and DHX are 2.3m, 2.15m and 0.65m respectively. For the pump and DHX, they need support barrels outside the components to isolate the components from the primary sodium coolant. Figure 1 shows the component arrangement for 600MWe burner reactor. The coolant levels are determined from the fluid system requirements and thus the RV height is 18.0m. From above arrangement, the required material mass of the reactor structure except the components is about 1,140tons and the primary coolant volume is about 1,110m^3.

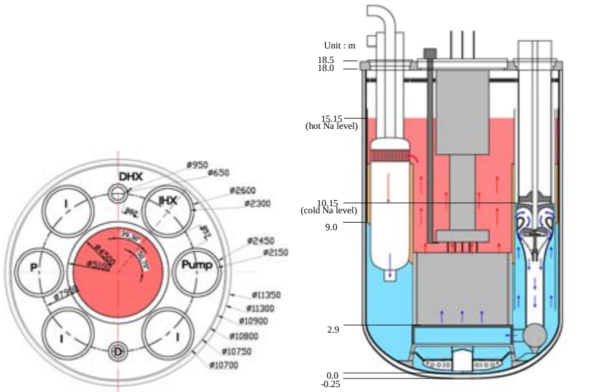

Fig. 1. Component arrangement for 600MWe pool-type burner reactor.

2.3 1,200MWe Reactor

For the 1,200MWe reactor, the IHX size has to increase comparing with that of 600MWe reactor. Its height and diameter are 8.7m and 2.6m respectively and thus it requires a larger RV. The reactor core of 1,200MWe consists of 1381 assemblies and its diameter is 619cm. To accommodate the large IHXs and reactor core, RV diameter increases up to 14.0m. The required numbers of primary pump and DHX are 4 equally. For the vertical arrangement, it needs an increase of a reactor height to reflect the height increase of IHX about 1.0m. To accommodate the increased IHX height without RV height change, the height of cover gas region and the thermal center distance between IHX and core are reduced by 0.5m each.

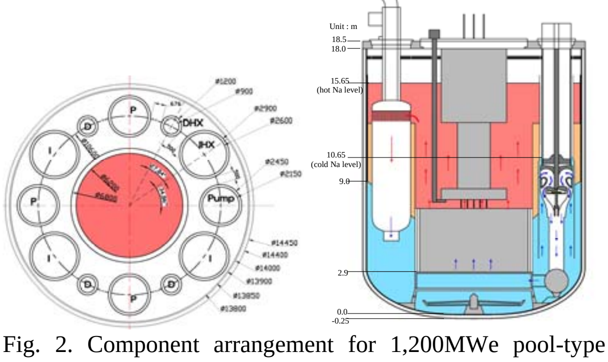

Fig. 2. Component arrangement for 1,200MWe pool-type burner reactor.

So, some parts of the coolant elevation are different from the 600MWe reactor. Figure 2 shows the component arrangement of 1,200MWe reactor. The required material mass of the reactor structure is about 1,750tons and the primary coolant volume is about 1,870m^3.

2.4 1,800MWe Reactor

The reactor core of 1,800MWe consists of 2077 assemblies and its diameter is 754cm. To conduct the components arrangement for 1,800MWe reactor, the number of primary loop has to be determined first. The 2-loop layout requires too large diametric components and thus it is less favorable in view of system performance and component manufacturing. Therefore, 1,800MWe reactor adopts 3-loop primary system and each loop consists of 2-IHXs, 2-DHXs and 2-Pumps. The calculated RV diameter for 3-loop system is 17.3m. The height of RV is 18.0m and the vertical elevations are same as those of 1,200MWe reactor. Figure 3 shows the component arrangement of 1,800MWe reactor. The required material mass of the reactor structure and the primary coolant volume are is about 2,370tons and 2,830m^3 respectively.

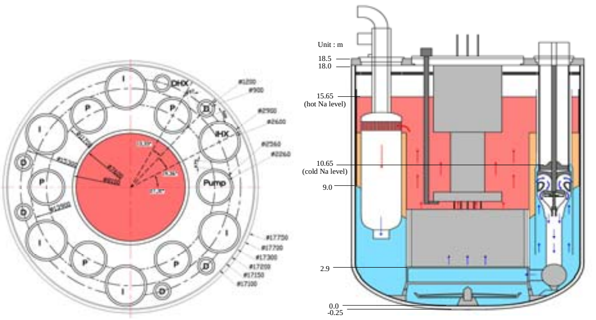

Fig. 3. Component arrangement for 1,800MWe pool-type burner reactor.

2.5 IHTS Arrangement

The major components in each loop of IHTS include the 2-IHXs, circulation pump, SG(Steam generator) and the piping connecting these components to each as well as the IHX and SG. The IHTS piping material is Mod.9Cr-1Mo steel and it is beneficial to reduce the piping length. SG adopts the straight tube and its height is assumed to be 37.4m.

For 600MWe reactor, the IHTS is composed of two independent loops and the diameters for SG and 2nd pump from the scale-down calculation are assumed to be 1.7m and 2.4m, respectively. The total piping length per each loop is about 136.9m. The 1,200MWe reactor adopts the two independent IHTS loop. The diameter of SG is 2.4m and 2nd pump diameter is assumed to be 2.8m. The total piping length per each loop is about 135.6m. The IHTS of 1,800MWe reactor is composed of three independent loops and major components are same as those of 1,200MWe reactor. The IHTS piping length per each loop is about 136.3m.

Table 1 shows the summary of the main components for the three object reactor system.

Table 1 : Summary of the system arrangements

Components		600MWe	1,200MWe	1,800MWe
RV	Dia.	10.9m	14.0m	17.3m
IHTS	No	2	2	3
IHX	Dia.	2.3m	2.6m	2.6m
	No.	4	4	4
1st Pump	Dia.	2.15m	2.15m	2.26m
	No.	2	4	6
DHX	Dia.	0.65m	0.9m	0.9m
	No.	2	4	6
SG	Dia.	1.7m	2.4m	2.4m
	No.	2	2	3
2nd pump	Dia.	2.4m	2.8m	2.8m
	No.	2	2	3
Hot leg	Dia.	0.6m	0.8m	0.8m
	Length	87.78	87.02m	87.52m
Cold leg	Dia.	0.6/0.82m	0.8/1.1m	0.8/1.1m
	Length	34.68m	34.43m	35.22m
Suction leg	Dia.	0.82m	1.1m	1.1m
	Length	14.35m	14.0m	14.0m

3. Conclusions

The component arrangement and preconceptual structure design of pool type sodium-cooled burner reactors for the three core power levels of 600, 1200, 1800MWe are carried out. The 600MWe and 1200MWe reactors adopt 2-loop system, whereas 1800MWe reactor needs 3-loop system. The diameter of reactor vessel for a burner reactor is smaller than that for a breakeven reactor by 0.5m and it is mainly caused by the core size. The IHTS is arranged by considering system design requirement. The IHTS piping material is Mod.9Cr-1Mo steel to minimize the piping length and piping length per each loop is about 135m. The structural design data are provided for the assessment of the enhanced safety design feature.

Further studies of these structural designs are required to investigate the feasibility of the manufacturing and fabrication for the large diametric structures such as reactor head and reactor vessel.

ACKNOWLEDGEMENTS

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