Preconceptual Component Arrangement for a Pool-type Sodium-cooled Fast Reactor of 1200MWe Capacity

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1. Introduction

The Gen-IV nuclear reactors are required to assure the economic improvement and enhanced safety but it is not so easy to satisfy both goals at the same time. SFR(Sodium-cooled Fast Reactor) is a leading one of the candidate Gen-IV reactor types and it should acquire the economic competitiveness compared with other reactor types. This study is to develop the component arrangement of a pool-type SFR with 1200MWe at the preliminary conceptual design level and the object subsystems for it composed of PHTS, IHTS and RHRS. This design will be expected to provide the basic concept in developing the future sodium-cooled fast reactor of commercial electric capacity.

2. Component Arrangement

2.1 Overall Description

The object reactor has 1200MWe capacity with sodium coolant. The core inlet and outlet temperatures are 390℃ and 545℃ respectively and its net efficiency is 39.4%. Figure 1 shows the full power condition of 1200MWe reactor system. The component arrangement for PHTS, IHTS and RHRS of 1200MWe reactor was performed by considering the structural and functional requirements as well as the core size and reactor cooling system concept.

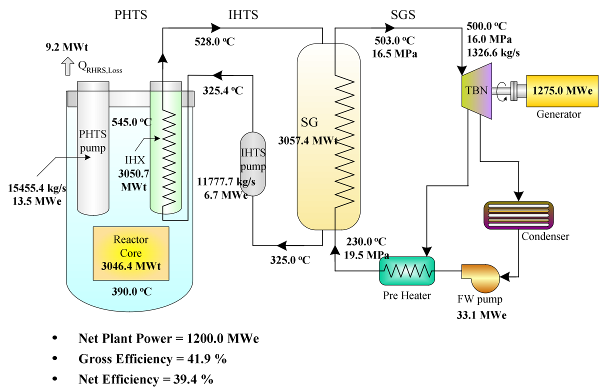
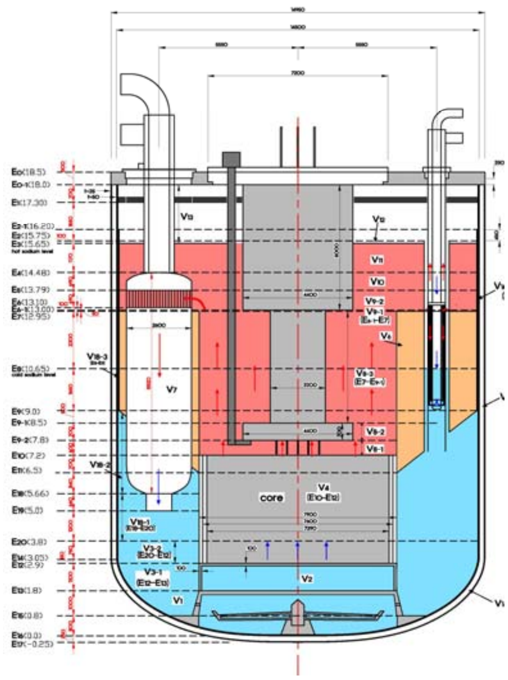


Fig. 1. Steady-state heat balance diagram of 1200MWe reactor

2.2 PHTS Arrangement Design

The object reactor adopts a pool-type system. The main components located in the reactor vessel are 4-IHXs, 4-DHXs and 4-Primary pumps and it is caused by adopting large components to minimize the number of main components as a way to achieve the enhanced economics. The primary pump is a mechanical type with long shaft driving impeller and submerged into a cold pool volume. The structural concept is similar to the KALIMER-600[1]. The resultant outer diameter of a reactor vessel is 14.5m and its height is 18.0m. The internal structures including the reactor vessel are fabricated from a Type 316 stainless steel but the containment vessel surrounding the reactor vessel completely is made of 2.25Cr-1Mo steel. The vertical requirement is to maintain the 5.0m height difference between hot pool and cold pool free surfaces during the normal operating condition. The total reactor structural mass without main components is about 1800 tons excluding sodium coolant and it accommodates the maximum core size of 7.29m. Figure 2 shows the structural arrangement concept and elevations of primary components.



(b) Vertical view

Fig. 2. PHTS component arrangement concept

2.3 IHTS Arrangement Design

The IHTS consists of two loops by reason of enhanced economics. The reference concept for a steam generator(SG) is a double-walled straight tube, shelland-tube type heat exchanger and that for a circulation pump is a mechanical type. The design requirement for component arrangement is that the vertical elevation difference between the thermal centers for the SG and IHX should acquire over 20.0m[2]. The IHTS piping material is Mod.9Cr-1Mo and it can shorten the piping length compared to stainless steel because of a low thermal expansion and a high ultimate strength. The IHTS piping diameters for hot leg and cold leg are 0.8m, 1.10m respectively and the overall piping length is simplified to 135m for each IHTS loop[3]. The SG has overall 37.4m in height with 28.3m tube length. Figure 3 shows the IHTS arrangement concept of a 1200MWe SFR.

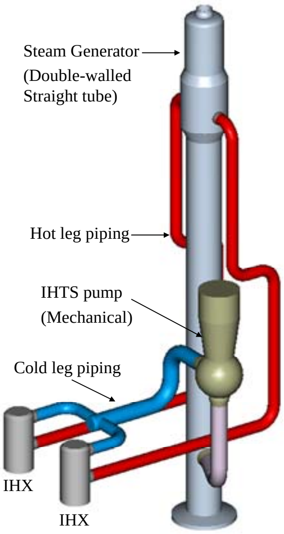


Fig. 3. IHTS component arrangement concept

2.4 RHRS Arrangement Design

When the normal path is not available due to a SG feed water system failure or a total blockage of the IHX, etc., an adequate emergency core decay heat removal method should be provided to accomplish the safe cooling of the core and the sodium coolant boundary without exceeding the temperature limit. KALIMER-600 adopts the two RHRS such as the safety-grade PDRC system and non-safety-grade IRACS and 1200MWe also maintains the same RHRS concept. The PDRC system comprises an independent 4-loop and each loop is equipped with single DHX, single AHX and PDRC piping connecting DHX with AHX. The PDRC piping inner diameters are 0.395m, 0.345m for hot leg and cold leg. The IRACS mainly consists of the tube-side IHX, FDHX, a single electro-magnetic pump, an expansion vessel and IRACS piping connecting IHTS loop with FDHX. The IRACS piping inner diameter for hot leg and cold leg is 0.203m[4]. Figure 4 shows the component arrangement concept of the 1200MWe 2-loop SFR compromised of PHTS, IHTS and RHRS.

3. Conclusions

The conceptual design for a sodium-cooled fast reactor with 1200MWe electric capacity has been carried out. The basic concept from a structural point of view is enhanced economics compared to other reactor types, without loosing the reactor safety level. Thus large diametric IHX in PHTS and 2-loop IHTS with large SG were applied. The 4-loop PDRC for core decay heat removal is adopted to cover the large electric capacity. The arrangement concept of the main components consisting of the PHTS, IHTS and RHRS are conceptually proposed with satisfying the functional requirement. The detailed evaluation of the structural integrity and manufacturing feasibility study for each component of this reactor system will soon follow.

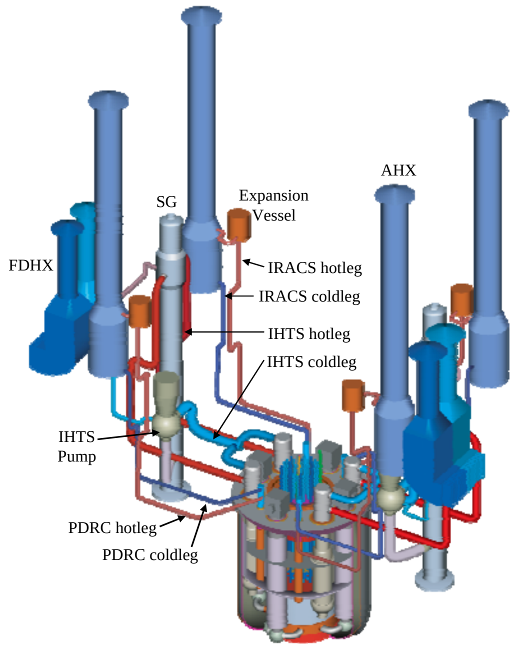


Fig. 4. Component arrangement concept of a 1200MWe pool-type sodium-cooled fast reactor

ACKNOWLEDGEMENTS

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