Design concept of fluid system for 600MWe grade SFR

S.O. Kim[a*], T.H.Lee[a], J.H. Eoh[a], S.K. Choi[a], E.K. Kim[a], J.W. Han[a], Y.I.Kim[a], Dohee.Hahn[a]
[a]*KAERI, 150, DukJin-Dong, Yuseong-Gu, Daejeon, 305-353, The Republic of Korea*
[*]*Corresponding author:sokim@kaeri.re.kr*

1. Introduction

KAERI has developed a design concept of 600MWe Sodium-cooled Fast Reactor(SFR) for demonstration of commercial plant. The fluid system of the SFR has been designed to ensure safety goal of Gen IV reactor system and to enhance economics through trade-off study between proposed various design candidates.

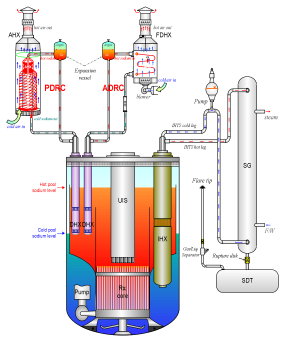

Figure 1 Design Concept of 600 MWe grade SFR Fluid system

The fluid system consists of sodium system and power conversion system and the sodium system consist of heat transport system and safety system.

2. Heat Transport System

The heat transport system consists of Primary Heat Transport System(PHTS), Intermediate Heat Transport System(IHTS) and Steam Generator(SG). PHTS is a pool type in which all the primary components and primary sodium is within reactor vessel to prevent primary sodium from leaking to outside of containment as shown in Figure 1. The IHTS is two loop system and two IHX are connected to one SG through IHTS piping branches. The IHTS piping has inverse 'U' shape in the top of the piping in order to passively protect water/steam and SWR products from entering reactor vessel and containment with axial pipe of inside SG in case of SG tube rupture.

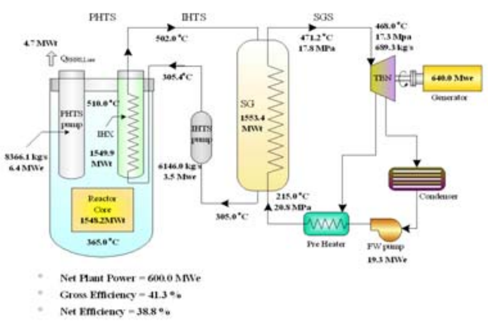

Figure 2 Heat Balance at full power condition

The operating condition of heat transport system was established in considering design limit and capability of component manufacture. The 510°C of core exit temperature was selected to protect eutectic melting of fuel rod in accidents and 365°C of core inlet temperature was decided in considering PHTS pump capacity, thermal stress and linear power density of fuel rod. The primary pump flow rate was decided based on the pump capacity of existing plants to ensure manufacturability [1].

The 215°C of feed water temperature was decided to protect sodium freezing of IHTS cold loop. Generally, plant cycle efficiency almost linearly changes to the temperature of turbine stop valve. Therefore, the steam condition was chosen the same as S-PRISM design of 468°C, 17.8MPa to ensure turbine manufacturing. IHTS temperature and flow rate was decided to minimize the total heat transfer area of Intermediate Heat Exchanger(IHX) and steam generator(SG).

Based on the operating condition of nominal power and considering manufacturability of components, 2 mechanical type PHTS pump, 4 IHX, 2 IHTS pump and 2 helical type SG are used as shown in Figure 3 and the components are arranged as shown in Figure 4.

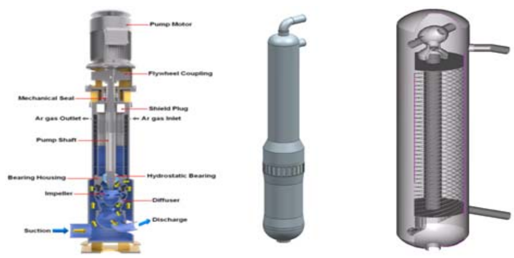

Figure 3 Design concept of PHTS pump(L), IHX(C) and SG(R)

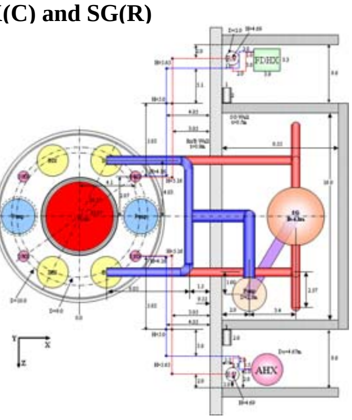

Figure 4 Arrangement of PHTS, IHTS

3. Residual Heat Removal System

The RHRS of demonstration SFR has 2x50% Passive Decay heat Removal Circuit(PDRC) and 2x50% Active Decay Heat removal Circuit(ADRC) to ensure triple paths of decay heat removal including normal decay heat removal route of steam and feed water system.

The PDRC consists of sodium-to-sodium decay heat exchanger (DHX), sodium-to-air heat exchanger (AHX), sodium loop piping and expansion tank, where the DHX is a straight tube type and the AHX is a helical tube type as shown in Figure 5. The PDRC is operated by natural circulation by density and elevation difference between DHX and AHX as shown Figure 5. The heat removal capacity of each PDRC loop is 9MWt.

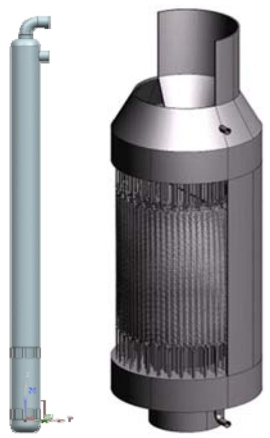

Figure 5 Design concept of DHX(L) and AHX(R)

The ADRC consists of DHX, forced-draft sodium-to-air heat exchanger (FDHX), sodium loop piping, expansion tank and sodium transfer pump and air blower. The design of DHX is the same as the one of PDRC and the FDHX is air heat exchanger where sodium tubes with fin are arranged in serpentine type. The sodium pump is an electro-magnetic type and is installed on each ADRS loop and the blower is installed on each FDHX unit. As the occurrence of ESF actuation signal, the sodium pump and the air blower start their operation. The heat removal capacity of each ADRC is the same as PDRC. The ADRC also can remove decay heat in half of the design capacity by natural circulation even though electric power is not supplied to active components.

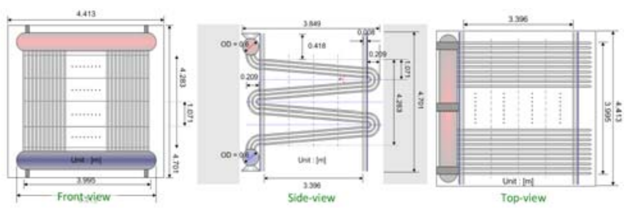

Figure 6 Design concept of FDHX

4. Sodium Water Reaction Pressure Relief System

SWRPRS relieves the SG pressure at a large sodium-water reaction event and it consists of the sodium drain tank(SDT), SWR product separator, rupture disc and piping. Each steam generator has its own SWRPRS and the SWRPRS's are identical. The rupture disc is installed at the piping, which is located at the bottom of the SG. Excessive pressure in the SG will burst the rupture disc, dumping sodium and reaction products to the SDT, gaseous reaction products and some entrained sodium is directed to the SWR product separator where the entrained sodium is removed. The gaseous products are then directed to the stack where an igniter may be installed. The entire SWRPRS is normally filled with an inert gas to avoid the possibility of a hydrogen explosion in the system after activation of the system.

5. Power Conversion System

The power conversion system of the demonstration reactor is a superheated Rankine cycle. The design and operating strategy were developed based on fossil plant[2]. Design features of turbine are modified based on the PFBR system to ensure manufacturability.

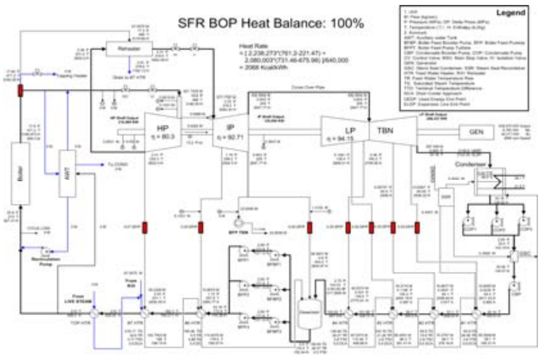

Figure 7 Design concept power conversion system

6. Summary

In order to demonstrate the commercial SFR, KAERI developed a 600MWe demonstration SFR system. The system was designed to ensure Gen IV SFR safety goals and to enhance economics through trade off studies. The fluid system design parameters of the demonstration were established in considering design limit and component manufacturability. The developed system is pool type system and superheated Rankine cycle power conversion system.

ACKNOWLEDGMENTS

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[1] IAEA-TECDOC-1531, Fast Reactor Database, 2006 update, pp.120-178.

[2] E.K.Kim, "Development of SFR secondary system and computer code for system analysis", KAERI internal report, KAERI/TR-4216/201,2010