Design of System Heat Balance in 600 MWe Sodium-cooled Fast Reactor

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1. Introduction

Under the national mid- and long-term nuclear R&D program, the SFR basic key technologies development project is being conducted by the fast reactor development group at KAERI. The objective of this project is to develop a conceptual design of an SFR consistent with the Generation IV SFR system. R&D efforts in fluid system design will be made on a conceptual design of heat transport system, engineered safety features, I&C system, power conversion system, and auxiliary system design for demonstration reactor.

Based on the KALIMER-600[1], Korea Advanced Liquid MEtal Reactor, and the detailed design concepts for demonstration reactor are under review.

For the further development of respective design concepts, the design requirements for system and components should be provided and they are decided based on the system heat balance.

The system heat balance diagram[2-4] displays thermo-hydraulic values of heat transport system such as temperature, pressure, thermal power and etc. For the reasonable decision design value for various reactors should be investigated.

In this research procedure and basis and for the establishment of heat balance in 600MWe demonstration reactor is introduced and final heat balance diagram is presented.

2. Methods and Results

DENOP-K(DEtermination of Normal OPerating condition of Kalimer[3]) code was utilized decide the system heat balance for 600MWe demonstration reactor. The design value for various reactors[5] were investigated and employed as the input value for DENOP-K code. The detailed procedures are as follows ;

2.1 Input data for SGS Design

In order to decide the design values of SGS(Steam Generator System) the design on the BOP(Balance of Plant) should be preceded. However it has not been performed yet, the BOP design values of demonstration reactor are postulated to be the same as those of S-Prism[6] was employed in this calculation. The cited temperature and pressure for TBN(TurBiNe) stop valve is 468℃ and 17.3MPa respectively.

For the decision of feedwater temperature various design values for other countries' reactors were compared in Fig. 1.

The reactor could be classified into metal fuel reactor and oxide fuel reactor by fuel materials. The metal fuels have the advantage of a much higher heat conductivity then oxide fuels but cannot survive equally high temperatures. The demonstration reactor design would be based on the metal fuel.

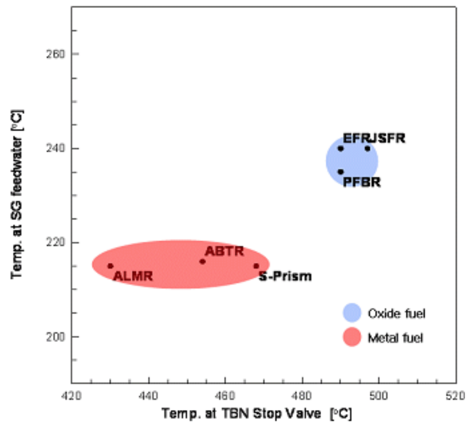

Fig. 1 Temperature at SG feedwater and TBN stop valve for various reactor design

Temperature at SG(Steam Generator) feedwater should be decided large enough to prevent the sodium solidification within the steam generator. As shown in the figure it is maintained at 215℃ regardless of temperature at TBN stop valve for metal fuel reactors. Based on the previous design values 215℃ is selected to be the input value for SG feedwater temperature of demonstration reactor.

2.2 Input data for PHTS Design

In order to decide the core inlet and outlet temperature in PHTS(Primary Heat Transport System) various design values for other countries' reactor was compared in Fig. 2. As shown in figure the core outlet temperature was ranged from 498℃ to 510℃ for metal fuel reactors. In the design of 600MWe demonstration reactor the core outlet temperature was set to 510℃, which was decided from the analysis on cladding materials. For the decision of core inlet temperature, whose candidate is ranged from 355℃ to 371℃ the PHTS pump design should be taken into account since temperature differences between core outlet and inlet decide the mass flow rate of PHTS.

In this calculation the evaluation of the system heat balance has been repeated in terms of core inlet temperatures to find the specific condition to meet the design values of SPX(Super-PheniX) PHTS mechanical pump.

From the evaluation the head and mass flow rate was found to be increased by 23% and 11% with the increase of core inlet temperature from 355℃ to 370℃ and 365℃ was found to be the best estimation for the employment of SPX mechanical pump.

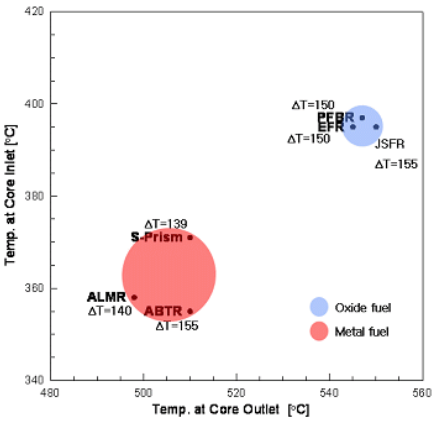

Fig. 2 The core inlet and outlet temperature in various reactor design

2.3 Evaluation of IHTS Design

Based on the prescribe design value the temperature distribution for IHTS(Intermediate Heat Transport System) is evaluated. For the decision of IHTS temperature non-dimensional temperature range is postulated from 0.2 to 0.8 and respective temperature distribution is evaluated taking into account of the followings.

- Specific heat exchanger sizing parameter (UA/Q_{core})
- Flow rate requirement for IHTS
- Thermal efficiency

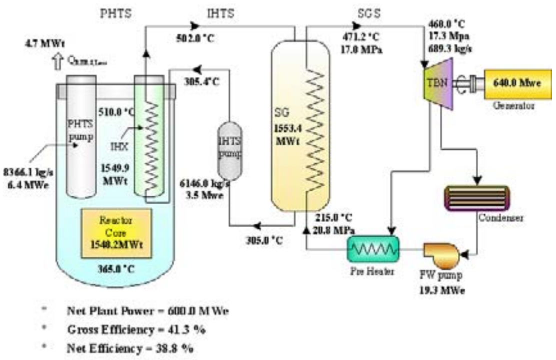

Fig. 3 System heat balance for 600MWe demonstration reactor

Fig. 3 presents the final system heat balance diagram for 600MWe demonstration reactor. The overall gross and net efficiency of plant amounts to 41.3% and 38.8% respectively. The design value in the figure could be changed as the modification of design on the 600MWe demonstration reactor in the future.

3. Conclusion

In this study design values for various reactors has been investigated and the system heat balance for 600MWe demonstration reactor is decided. The PHTS pump and BOP is postulated to have the same performance of SPX and S-Prism respectively. The finally decided overall gross and net efficiency of plant amounts to 41.3% and 38.8% respectively.

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