Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 13-14, 2021

Design of Main Components of Refueling Decay Heat Removal System for the PGSFR

Yohan Jung*, Huee-Youl Ye, Jonggan Hong, Jae-Hyuk Eoh

Korea Atomic Energy Research Institute, 111, Daedeok-daero, Yuseong-gu, Daejeon, Korea

*Corresponding author: yhjung81@kaeri.re.kr

Introduction

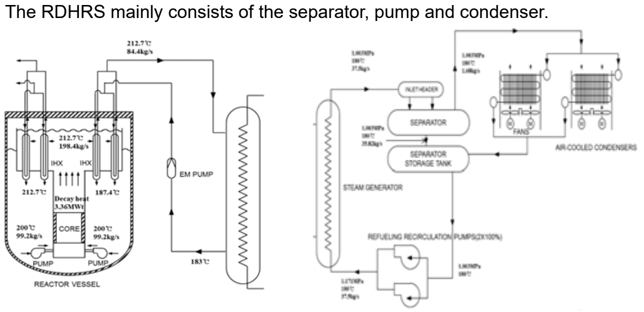
· KAERI (Korea Atomic Energy Research Institute) has performed a conceptual design of the PGSFR (Prototype Gen-IV Sodium-cooled Fast Reactor) which consists of PHTS (Primary Heat Transport System), IHTS (Intermediate Heat Transport System) and DHRS (Decay Heat Removal System).

· In the PGSFR, during the refueling operation after stopping the reactor, an alternate decay heat removal system is additionally required to perform the non-safety function of maintaining the temperature of the PHTS at the refueling operation temperature.

· The RDHRS (Refueling Decay Heat Removal System) was designed to provide decay heat removal capability during the refueling operation.

RDHRS Descriptions

- The heat removal capacity of the RDHRS has 3.36 MWt, which is the decay heat after 24 hours of the reactor shutdown.
- It is necessary to determine the heat balance for the PHTS, IHTS, and RDHRS to design components of the RDHRS.
- The RDHRS mainly consists of the separator, pump and condenser.



(a) PHTS and IHTS **(b) RDHRS**

Fig. 1 Schematic of heat balance of systems at the refueling operation condition

Components Design

· RDHRS pump

- A conceptual design of main components of the RDHRS was conducted based on the heat balance.
- The RDHRS pump provides sufficient circulation flow to the RDHRS so that the residual heat from the core can be properly removed during the refueling operation.
- The design requirements of the RDHRS pump are as follows.
  - · Mass flow rate: 37.5 kg/s
  - · Head: 30.6 m
- The mass flow rate is determined by the heat balance for the RDHRS, and the head is determined by the pressure loss generated in the RDHRS.
- In order to determine the rotational speed of the pump, the efficiency change according to the specific speed as shown in Fig. 2 can be used.
- The specific speed is generally determined as below.

$$N_s = N\frac{Q^{0.5}}{H^{0.75}}$$

- Since the volumetric flow rate and head of the pump are fixed, the rotational speed can be determined for high efficiency using Fig. 2.
- The rotational speed of the pump was determined to be 1800 rpm, and the specific speed was determined to be 219 [rpm, m3/min, m], and the optimal efficiency can reach about 83%.
- The NPSHR (Required Net Positive Suction Head), one of the design requirements of the pump, means the suction head required to operate without cavitation, and can be obtained through the following equations.

$$\sigma = \frac{NPSH_R}{H} \qquad N_{ss} = N\frac{Q^{0.5}}{(NPSH_R)^{0.75}}$$

$$\sigma = 7.88\times10^{-5}N_s^{\frac{4}{3}}\ \text{(single suction)} \qquad N_{ss} = 1200\ \text{(single suction)}$$

$$\sigma = 5.00\times10^{-5}N_s^{\frac{4}{3}}\ \text{(double suction)} \qquad N_{ss} = 1700\ \text{(double suction)}$$

- The NPSHR can be obtained by applying the equation for a single suction pump, and the values obtained through the above two methods were almost the same.
- The NPSHR was determined to be 3.2 m

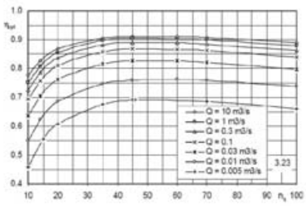


Fig. 2 Efficiency change of the pump according to the specific speed

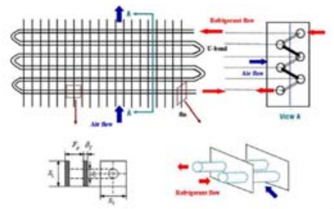


Fig. 3 Schematic of fin-type heat transfer tube air-cooled condenser

· RDHRS condenser

- The RDHRS condenser performs a function of condensing the steam separated from the separator through heat exchange using air.
- The RDHRS condenser type was selected as a fin-type heat transfer tube air-cooled condenser, which generally increases the heat transfer area by installing fins on the outside of the tube in order to reduce the heat resistance on the air side.
- In the RDHRS condenser, the heat of the fluid inside the heat transfer tube is transferred to the outside of the heat transfer tube by convection and conduction.
- The part without fins directly exchanges heat with air, and the part with fins exchanges heat with air through fins.

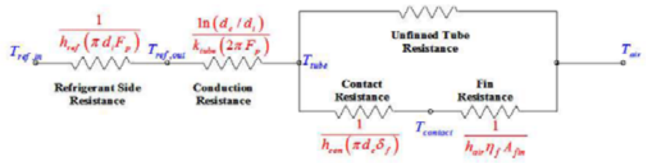


Fig. 4 Schematic of heat resistance of the RDHRS condenser

- The design requirements of the RDHRS condenser are as follows.
  - · Heat removal capacity (per single): 1.68 MWt
  - · Air inlet temperature: 40 °C
  - · Air inlet velocity: 3 m/s
  - · Steam inlet temperature: 180 °C
  - · Steam inlet pressure: 1.0 MPa
- The main design parameters for the RDHRS condenser are summarized in Table 1.

Table. 1 Main design parameters for the RDHRS condenser

Design parameter	Value
Number of depth rows	8
Number of tubes per row	19
Longitudinal tube pitch (mm)	64
Transverse tube pitch (mm)	64
Tube OD/ID (mm)	34/30.7
Tube thickness (mm)	1.5
Fin height (mm)	64
Fin thickness (mm)	1.5
Fin pitch (mm)	5.08

Conclusions

· The RDHRS was designed to provide decay heat removal capability during the refueling operation

· A preliminary design of main components of the RDHRS for the PGSFR was performed.

· The design process and main design parameters for the RDHRS pump and the RDHRS condenser were presented.