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Preliminary Design of Heat Exchanger Considering in Operating Flow Rate Range in a Research Reactor

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1. Introduction

In general, a primary cooling system(PCS) is designed for the core cooling of a research reactor. Recently, efforts are being made to lighten the system by applying a plate heat exchanger. Compared to shell and tube type heat exchangers, the plate heat exchanger has the advantage that the heat transfer area is integrated, so that the thermal size is small and maintenance is simple. For this reason, the plate heat exchanger was applied to the PCS of Jordan Research and Training Reactor(JRTR), which was constructed in 2016, and is currently operating. Lee et al. [1] presented about the design guideline of the heat exchanger applied the JRTR.

Generally, the heat exchanger is designed in consideration of the design point as one operating condition. In the case of the research reactor, the temperature of the cooling water to be supplied to the core must be maintained below a limit temperature for the reactor shutdown. The heat exchanger must be designed to meet this limit temperature over the entire operating flow rate range of the actual primary cooling system.

In this study, a design point that can satisfy the operating flow range was determined by calculation and setting a virtual model as a hypothetical study.

2. Methods and Results

2.1 Cooling system modeling

In this study, the cooling system model of the research reactor is assumed and Fig. 1 shows a schematic of the core cooling system which is composed of the reactor pool, core, a cooling pump, heat exchanger, and piping. In this paper, all the components for core cooling are not considered but minimum components for heat transfer calculation are applied.

For the design of a heat exchanger for core cooling in the research reactor, a virtual model of the following flow conditions was set.

1. Core power: 15 MW
2. Design flowrate for cooling system: 500 kg/s
3. Operating flowrate range for cooling system(±10%): 450 ~ 550 kg/s
4. Inlet temperature of heat exchanger primary side: 42°C (fixed)

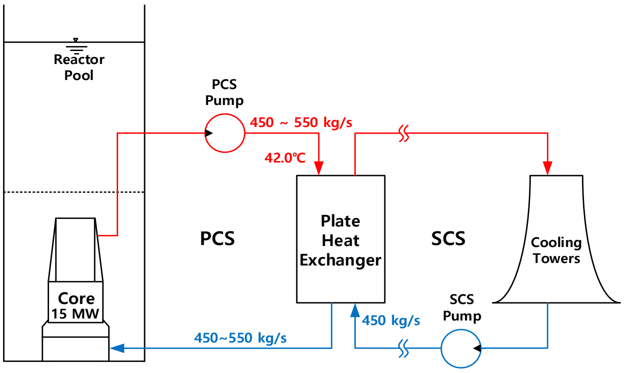

Fig. 1. Schematic of core cooling system in a research reactor.

5. Flow rate of heat exchanger secondary side: 450 kg/s (fixed)

For heat transfer calculation, modeled one-dimensionally with the commercial one-dimensional system code, FLOWMASTER 7.9 [2] was used.

2.2 Result and discussion

When selecting an initial design point of the heat exchanger, one operation condition value, such as the middle value of the operating range, is considered. If 500 kg/s is the design point, Table I shows the calculation result at the upper and lower limit of the operating range. As can be seen from the results, the heat transfer requirement of 1.5MW is unsatisfied at the lowest flow rate (450 kg/s) in the operating range.

Therefore, the operating flow range of the cooling water must be considered and the design reference should be changed to be able to remove 1.5 MW of heat at 450 kg/s. Table II and Fig. 2 show the calculated results. The result is shown that the heat transfer requirements (≥ 1.5 MW) over the entire flow range are satisfied and it is created margin of about 1.0 MW at the upper value(550 kg/s). In this case, the entire outlet temperature of the primary side is reduced.

As Fig 2. Is shown, when designing the cooling system of the research reactor, the maximum temperature of the cooling water entering the core is determined in the highest flow range of the system operating flow range. Therefore, in order to prevent unexpected reactor shutdown due to the reactor inlet temperature of the cooling water, the maximum coolant temperature should be designed to be lower than the limit temperature to secure a stable operating margin.

Table I: Heat transfer result for design point

Primary side				Secondary side		
Flow rate (kg/s)	Inlet temp. (°C)	Outlet temp. (°C)	Heat transfer rate (MW)	Flow rate (kg/s)	Inlet temp. (°C)	Outlet temp. (°C)
450	42	34.27	1.45	450	30.40	38.13
500*	42	34.82	1.50	450	30.40	38.38
550	42	35.27	1.55	450	30.40	38.63
* design point						

Table II: Heat transfer result considering operating flow rate

Primary side				Secondary side		
Flow rate (kg/s)	Inlet temp. (°C)	Outlet temp. (°C)	Heat transfer rate (MW)	Flow rate (kg/s)	Inlet temp. (°C)	Outlet temp. (°C)
450*	42	34.01	1.50	450	30.00	38.00
500	42	34.55	1.55	450	30.00	38.28
550**	42	35.03	1.60	450	30.00	38.51
* design reference ** design point for design specification						

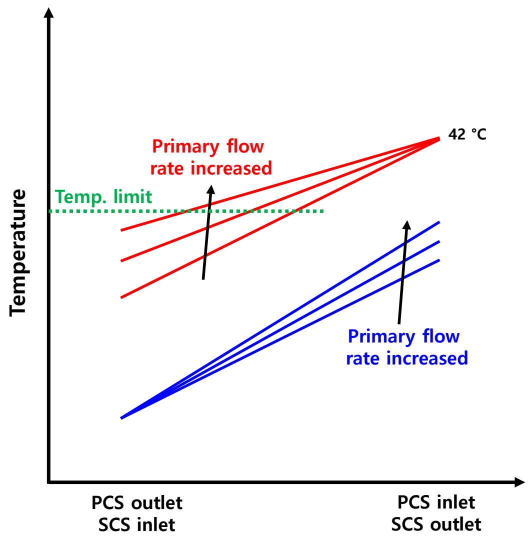

Fig. 2. Calculation results.

A heat exchanger designed with a design reference determined at the lowest flow rate has a large heat transfer amount at a highest flow rate, and can provide outlet temperature of primary side lower than that by the design flow rate. And since the primary outlet temperature at highest flow rate is closely related to the operation of the reactor, it should be designed to have a sufficient margin.

In the design specification supplied to a manufacturer, a margin should be added to the design point for the highest value in the operating range calculated from the design criterion to satisfy the heat transfer requirement over the entire operating range. In addition, in the performance test to be performed by the equipment manufacturer, the outlet temperature of the heat exchanger is related to the operation of the reactor, so the acceptance criteria should be set at the highest flow rate. Also, it is necessary to check whether the temperature requirement can be satisfied at the high flow rate condition.

3. Conclusions

In this study, a design point that can satisfy the operating flow range was determined by calculation and setting a virtual model. When designing a heat exchanger, it is necessary to define the operating flow rate range and to calculate heat capacity at the lowest flow rate. As the results designed with a design reference determined at the lowest flow rate has a large heat transfer amount at a highest flow rate, and can provide outlet temperature of primary side lower than that by the design flow rate.

ACKNOWLEDGEMENT

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