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Estimation on the Pressure Loss of the Conceptual Primary Cooling System and Design of the Primary Cooling Pump for a Research Reactor

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1. Introduction

A new conceptual primary cooling system (PCS) for a research reactor has been designed for an adequate cooling to the reactor core which has various powers ranging from 30MW through 80MW. The developed primary cooling system consisted of decay tanks, pumps, heat exchangers, vacuum breakers, some isolation and check valves, connection piping, and instruments. Because the system flow rate should be determined by the thermal hydraulic design analysis for the core, the heads to design the primary cooling pumps (PCPs) in a PCS will be estimated by the variable system flow rates.

The heads of the part of a research reactor vessel was evaluated by the previous study [1]. The various pressure losses of the PCS can be calculated by the dimensional analysis of the pipe flow and the head loss coefficient of the components [2], [3].

The purpose of this research is to estimate the various pressure losses and to design the PCPs.

2. Pressure loss of the PCS at 80MW

The schematic diagram and the design parameters for the PCS are shown in Figure 1 and Table 1, respectively.

The friction pressure losses in the pipe of the PCS, which are proportional to the pipe length and friction factor, are calculated as follows:

$$\Delta P_{fric} = f\left(\frac{l}{D}\right)\frac{\rho V^2}{2} \quad (1)$$

The friction factor, *f*, for clean commercial steel pipes is dependent on the Reynolds number for the system [2]. The pipe lengths of the PCS, *l*, are described in Table 2, and the pipe diameter and velocity of each section are estimated, as shown in Table 3.

The head losses of the valve, elbow, and tee are determined with the resistance coefficient and the quantity. The resistance coefficients, *k*, are obtained from the design guide by reference [2] and [3] and the valve designer. (Table 4)

$$\Delta P_{valve,elbow,tee} = k_{valve,elbow,tee}\frac{\rho V^2}{2} \quad (2)$$

The pressure loss of the decay tank (Figure 2), whose purpose is to provide a delay time to decay the radioactivity of N-16 contained in the primary coolant coming from the reactor core, is estimated by the resistance coefficients of the decay tanks including the exit and the entrance loss and compared with CFD results. The estimated head loss through the decay tank is about 11.6 kPa.

The primary cooling heat exchangers are designed and will be fabricated to be a double-wall plate-type heat exchanger. The pressure loss of the plate-type heat exchanger is designed to be 100 kPa at 80MW.

Table 1. Design parameters

Core power (MW)	30	47	75	80
T_{in} (°C)	35	35	35	35
T_{out} (°C)	48.7	52.1	52.2	52.2
Design PCS flow (m/s)	590	750	1180	1260
Number of PCPs/HX	2/2	3/3	4/4	4/4

Table 2. Pipe lengths

	Reactor vessel ~ Decay Tank	Decay Tank ~ PCP	PCP ~ Reactor vessel	Total
Length (m)	36.4	20.0	108.2	164.6

Table 3. Diameter and velocity calculation at 80MW core power

	Main pipe	Decay Tank branch	PCP branch	HX branch
Flow rate (kg/s)	1260	630	315	315
I.D (m)	0.575	0.428	0.303	0.333
Velocity (m/s)	4.9	4.4	4.4	3.6

Table 4. The resistance coefficients

		Isolation valve	Check valve	Elbow	Tee
k		0.45	0.24	0.4	0.78
Quantity	Main	1	-	21	5
	Branch	2	1	9	-

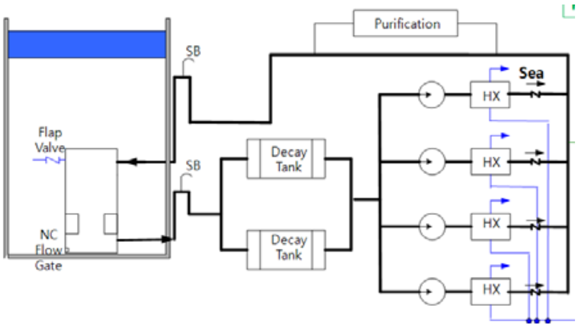

Figure 1. Schematic of the primary cooling system

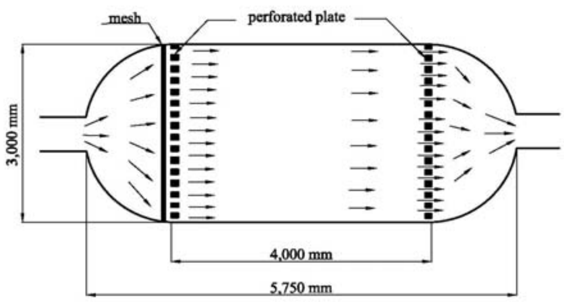

Figure 2. Schematic of the decay tank

3. Primary cooling pump design

The total PCS pressure losses (Table 5) for each power and the flow rate were estimated by the methods described in chapter 2.

The primary cooling pump is designed in such a way that the speed of the pump can be changed with the ranges of 10% to 100% by the variable frequency drive. With this design concept, it is possible to change the primary coolant flow rate and the head corresponding to any reactor power ranges of 30MW to 80MW just by changing the primary cooling pump speed.

The PCPs were mounted horizontally at an elevation of -13.8m. The location to secure enough available net positive suction head (NPSH$_A$, Table 5) of PCPs at 80MW was determined by the water elevation of the reactor pool and the NC flow gate, which is the hydraulic connection PCS to the reactor pool.

$$NPSH_A = \frac{p_{atm}}{\rho g} - \Delta z - \sum h_L - \frac{p_v}{\rho g} \qquad (3)$$

where Δz and h_L represent vertical distance and head losses between the free surface and pump impeller inlet. p_{atm} and p_v represents atmospheric and liquid vapor pressure.

The performance and efficiency curves of the designed PCP are in Figure 3.

Table 5. Total PCS pressure loss

Core power (MW)	30	47	75	80
Design PCS flow (m/s)	590	750	1180	1260
Pressure loss (kPa)	760	790	965	1010
NPSHA (m)	19.2	17.4	7.9	5.5

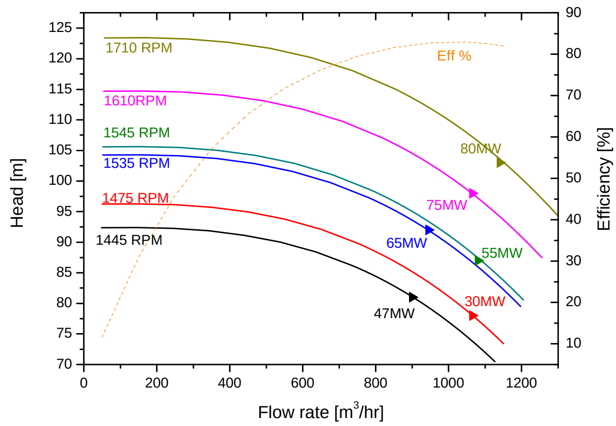

Figure 3. Performance and efficiency curves of the PCP

4. Conclusion

Our research work sought to design the primary cooling pump for the new conceptual primary cooling system of the research reactor.

The pressure losses of the pipes and the components were estimated by obtaining the friction factors and resistance coefficients, by the design guide of the references [2] [3] and the component designer, and by comparing the CFD result.

The total PCS pressure losses and available NPSHs corresponding to any reactor powers and the flow rates were evaluated and used to design the PCP.

REFERENCES

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[3] Idelchik, I.E., "Handbook of Hydraulic Resistance", 3rd Edition, 1994