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Allowable Flow Band Design of the Primary Cooling System in consideration of the Pump Performance Test Results

Hyun-Gi Yoon *, Kyoung-Woo Seo and Dae-Young Chi
Research Reactor System Design Division, KAERI, Daejeon
**Corresponding author: hyungi@kaeri.re.kr*

1. Introduction

Primary coolant pump circulates the coolant from the reactor structure to the heat exchanger in the primary cooling system in order to continuously remove the heat generated from the reactor core in the research reactor as shown in Fig. 1. Transferred heat to the secondary cooling system is released to the atmosphere by the cooling tower.

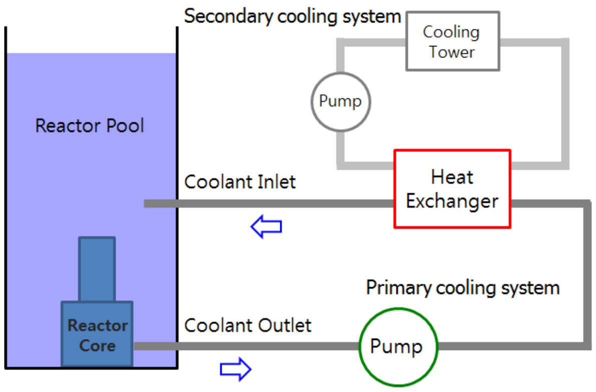

Fig. 1. Schematic diagram of the flow path of the coolant in an open-pool type research reactor

In the system design stage, rated head and flow rate of the primary coolant pump are calculated considering the thermal design flow rate, uncertainty of the measurement and system resistance curve, aging effect of the plant and so on. Figure 2 shows the relationship between the flow band of the primary cooling system and the design flow rate of the primary coolant pump. Actual flow rate of the primary cooling system is confirmed during the commissioning and that system flow rate shall be on the allowable flow band in Fig. 2 in order to guarantee the thermal design flow rate.

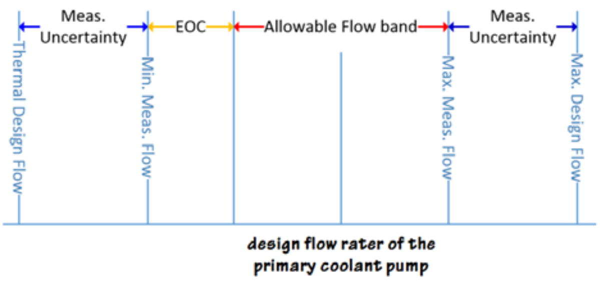

Fig. 2. Flow band of the primary cooling system and the design flow rate of the primary coolant pump

2. Flow Band Design

In the previous research, the type of the primary coolant pump was determined based on a slope of the pump performance curve, NPSH (Net Positive Suction Head) margin, design speed and pump size. Centrifugal pump with a non-dimensional specific speed of 0.59 [-] and specific diameter of 4.94 [-] was determined as the primary coolant pump [1]~[4].

Allowable flow band is finally determined based on the relationship between the system resistance curve and pump performance curve as shown in Fig. 3. If pump performance curve is fixed, allowable flow band can be calculated from the uncertainty of the system curve. The range of the allowable flow band is in proportion to the uncertainty of the system resistance. Generally, a wide range of the allowable flow band is avoided because the maximum flow rate of the system is increased.

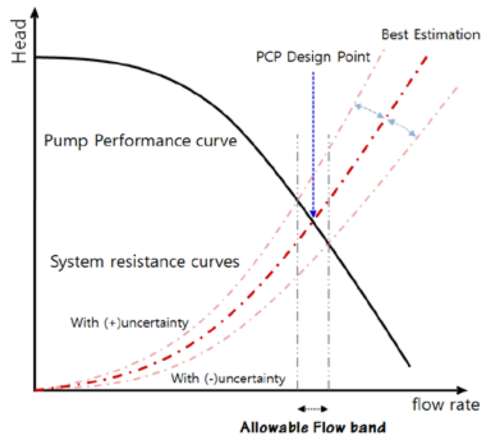

Fig. 3. Allowable flow band with the uncertainty of the system resistance curve and pump performance curve

3. Pump Performance Test

The Primary coolant pump consists of the pump hydraulic part, flywheel and motor as shown in Fig. 4.

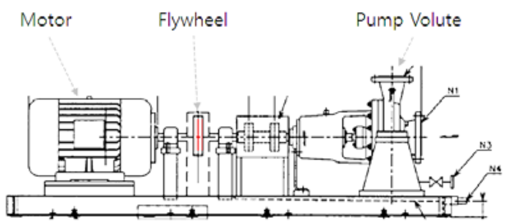

Fig. 4. Outline drawing of the primary coolant pump

The accuracy of instrument shall be certified by the authorized accreditation scheme and used within its credited calibration duration. Instruments shall provide the acceptable fluctuation and accuracy as listed in Table 1 [5].

Table 1. Fluctuation and accuracy

Measurement	Acceptable fluctuation of readings ±% of the values	Accuracy of the instrument as a ±% of the values
Flow rate	2.0	1.5
Suction head	2.0	0.5
Discharge head	2.0	0.5
Input power	2.0	1.5
Pump Speed	0.3	0.3

4. Allowable Flow Band

Pump performance curve for the allowable flow band is obtained during the factory acceptance test. Figure 5 shows the allowable flow band of the primary cooling system. Pump performance curve with the ±2.0% uncertainty in consideration of the fluctuation and accuracy of the instrument is applied to the allowable flow band design based on the test results.

The ±2.0% uncertainty of the pump performance curve decreases the design margin of the system resistance curve as shown in Fig. 5. Best estimated design point is placed at the point of the intersection between the normalized flow rate and head with the value '1'. The design margin of the system resistance curve is summarized on Table 2.

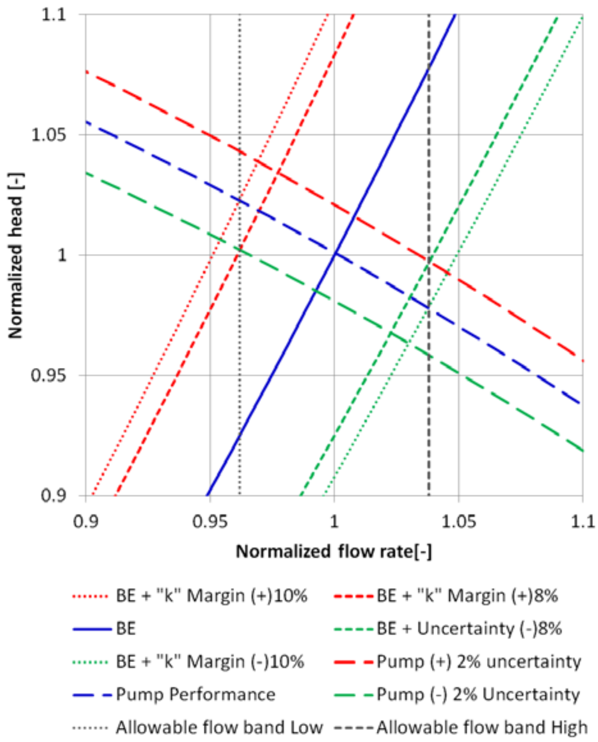

Fig. 5. Allowable flow band for the commissioning

Table 2. Design margin of the system resistance curve

Uncertainty of the pump performance curve	Allowable flow band low limit	Allowable flow band high limit
±0.0%	+10%	-10%
±2.0%	+ 8%	- 8%

4. Conclusions

Allowable flow band of the primary cooling system is designed in consideration of the pump performance test results and the design margin of the system resistance curve. The ±2.0% uncertainty of the pump performance curve decreases the design margin of the system resistance curve from the ±10% to the ±8%. The accuracy of the instrument used during commissioning shall be equal or less than that used during the factory acceptance test.

REFERENCES

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[3] Gulich, J. F., Centrifugal Pump, Springer, 2007

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[5] ANSI/HI 1.6-2000, American National Standard for Centrifugal Pump Tests, 2000

Nomenclature

d_s	Specific diameter, $D\cdot(g\cdot H_d)^{0.25}/Q_d^{0.5}$, [-]
g	Acceleration of gravity, 9.81[m/s^2]
n_s	Specific speed, $\omega\cdot Q_d^{0.5}/(g\cdot H_d)^{0.75}$, [-]
D	Diameter of the impeller outlet, [m]
H	Pump head, [m]
H_d	Pump head at the design point, [m]
H_{ratio}	Normalized pump head, H / H_d [m]
N	Revolutions per minutes, [rpm]
N_{margin}	NPSH margin, $NPSH_A / NPSH_R$, [-]
NPSH	Net Positive Suction Head, [m]
$NPSH_A$	Available NPSH, [m]
$NPSH_R$	Required NPSH, [m]
Q	Flow rate, [m^3/s]
Q_d	Flow rate at the design point, [m^3/s]
Q_{ratio}	Normalized flow rate, Q / Q_d, [-]