# Experimental Study on Discharge coefficient of Pitot-Static Tube with Varying Pitch Angles

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## 1. Introduction

In the Nuclear power plant (NPP), the degree of thermal stratification in the hot leg grows as the non-uniformity of power distribution grows in the reactor core, usually having a peak in the center area. Since the average value of the Resistance Temperature Detectors (RTDs) installed at hot legs may not correctly represent the coolant bulk temperature, the correction offset and associated uncertainty based on the coolant velocity profile should be quantified. [1,2]

Kim et al. [2] investigated the velocity profile at the hot leg with the aid of Pitot-static tube. The problem, however, is that the location where the flow velocity needs to be measured is the hot leg, which is where the fluid direction rapidly changes due to the structural design of reactor. As a result, if the Pitot-static tube is not positioned vertically, the reliability of the measured flow velocity cannot be guaranteed. Therefore, this study aims to investigate the discharge coefficient of the Pitot-static tube according to the pitch.

## 2. Description of the experiment

### *2.1 Experiment methodology*

The measurement of the flow rate through the pitot-static tube is made through the Bernoulli equation (Eq. 1) below.

$$\frac{v_1^2}{2}+\frac{p_1}{\rho}+gz_1=\frac{v_s^2}{2}+\frac{p_s}{\rho}+gz_z$$

$$p_s - p_1 = \rho\frac{v_1^2}{2} \tag{1}$$

$$v_1=\sqrt{\frac{2(p_s-p_1)}{\rho}}$$

And the flow rate measured by the mass flow meter is shown in Eq. 2 below.

$$Q=\rho v_0 A$$

$$v_0=\frac{Q}{\rho A} \tag{2}$$

The velocity $v_0$ measured by the mass flow meter is used as the reference value, while the velocity $v_1$ measured by the pitot-static pressure tube at various pitch angles is defined as the reference value. The ratio of the two velocities, $C_{p,\theta}$ is calculated using Eq. 3.

$$C_{p,\theta}=\frac{v_{1,\theta}}{v_{0,\theta}} \tag{3}$$

The pitch angle of the pitot-static tube is adjusted to simulate the angle between the rapidly changing flow in the hot-leg and the pitch of the pitot-static tube, allowing for the evaluation of the pitot-static pressure tube at each pitch angle by comparing $C_{p,0°}$ (when the pitch angle is 0°) and $C_{p,\theta}$ (when the pitch angle is various).

### *2.2 Description of Test Loop*

The specific test section is shown in Fig.1, and the experiment is conducted by using a boss for each angle that can simulate the pitch angle of the pitot-static tube between the pipe with flanges.

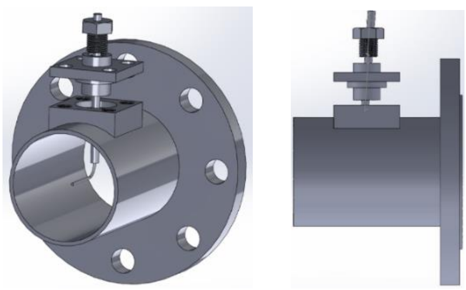

Fig.1 Schematic of test section

The entire loop is briefly shown in a P&ID in Fig.2.

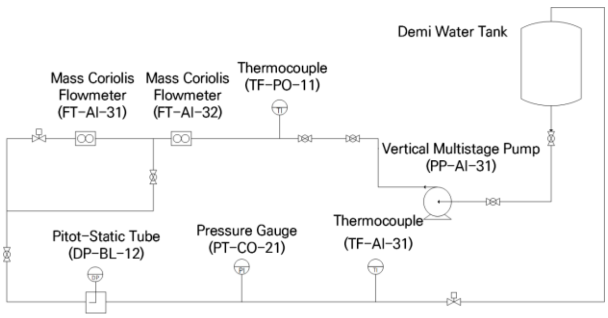


Fig.2 P&ID of test loop

### *2.3 Verification of Fully Developed Region*

In the current loop, as shown in Fig.2, there is an elbow in front of the Pitot-static tube, which can disturb the streamlines of the fluid. Therefore, it is necessary to create a fully developed flow at the Pitot-static tube. In this experiment, a straight section was created by 20D (1,650mm, D = inner diameter of the pipe = 82.4mm) from the pressure tap of the Pitot-static tube to the elbow, and 9D (740mm) from the rear of the Pitot-static tube to the straight section. To verify this, the Aichelen method [3] was used. This method considers flow to be fully developed if the velocity at 0.119D and 0.881D depths from the pipe radius differs by less than 6%, as shown in Eq.4.

$$Q = Av_{0.119} = Av_{0.881} \qquad (4)$$

Upon fixing the pitot-static tube at the specified depths (0.119D, 0.881D) and collecting data according to the corresponding Reynolds numbers, it was confirmed that the difference in Cp at the two depths was within 2.5%. This indicates that the fluid can be considered fully developed when it reaches the pitot-static tube.

### *2.4 Experiment Procedure*

In this experiment, the test section (flanged duct) was equipped with a Boss and a Pitot-static tube for each angle (-10°, -6°, -4°, -2°, 0°, 2°, 4°, 6°, 10°) and installed in the experimental loop. The Reynolds numbers ($2.0 \times 10^5, 4.0 \times 10^5, 6.0 \times 10^5$) and the temperature of the test section was maintained constantly at 60℃ using a heater in the tank. The sampling rate of DAS was 1,000 Hz and the Data were collected for 120 seconds. After data collection was complete, the pump was turned off and the test section was drained before being separated. This procedure was repeated for each test case.

### *2.5 Experimental Results*

Fig.3 shows $C_{p,\theta} / C_{p,0°}$ for each Reynolds number and angle, providing insight into the performance of the Pitot-static tube for measuring the flow rate at a specific pitch angle. Specifically, for angles between -6° and +6°, the experimental results showed an error of less than ±2% compared to the results obtained at 0° for all Reynolds numbers tested. However, at ±10°, the error increased rapidly, likely due to a misalignment of the Pitot-static tube's pitch angle, causing a lower velocity measurement as the flow entered the pressure tap with decreased dynamic pressure and increased static pressure.

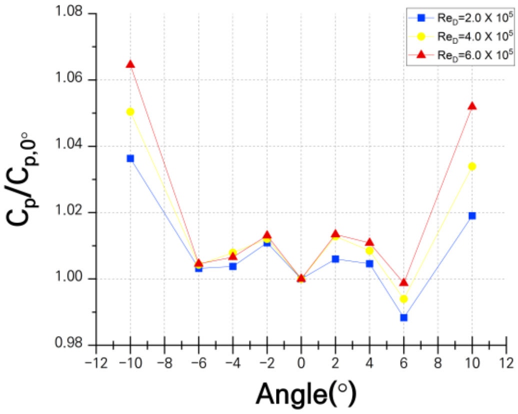

Fig. 3 Nondimensionalized discharge coefficient

## 3. Conclusions

A calibration test facility was construed to evaluate the effect of the pitch angle misalignment on the accuracy of single pitot static tube. All tests were performed at 0.2MPa, 60℃ under water condition. The discharge coefficients were examined by varying Re number and the pitch angle. The discrepancies along the pitch angle were less than ±2% comparing the reference test case. The obtained results from this study are expected to contribute to calibration of the pitot tube and evaluation of the uncertainty for the misalignment of pitot tube.

## ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge the financial support of Korea Government (MOTIE, Ministry Of Trade, Industry and Energy) (No. 20217810100010)

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