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# Preliminary Test to Measure the Liquid-Sodium Velocity with a Correlation Technique

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## 1. Introduction

Correlation flow measurement is a powerful technique for measuring flow based on the some fluctuations that often exist at the output of process sensors in the operating plant. In case of a liquid-sodium flow, the electromagnetic flow meter has traditionally been used to measure the mean velocity. However, it is necessary to develop a new technique for the application of the low velocity such as natural circulation and the complex geometry such as reactor core. The correlation technique was previously investigated in the water circulation loop to develop the systematic signal processing logic and to know the feasibility in the sodium flow.

## 2. Methods and Results

### *2.1 Experimental apparatus*

Figure 1 shows the schematics of the flow measuring apparatus installed at KAERI. Most parts of the piping system were made of stainless steel pipe with 1 inch in inner diameter (SUS304, 1 inch schedule 80) for the prevention of a thermal deformation after welding.

A total of ten Swagelok fittings were welded to install the thermocouples as a measuring device. Before the first thermocouple, a fitting in 3/8 inch was mounted in the 1-$D_i$ position to insert the flow disturber such as vortex generator or electric heater to make temperature fluctuation.

A centrifugal stainless pump circulated the tap water and a vortex flow meter and rotor meters were used for the measurement of the water flow rate. A surge tank was installed in front of the test-section to reduce the flow fluctuation due to the pump characteristics. The temperature of the water was controlled with the cable heaters attached on the surface of the piping system up to 90$^o$C. Flow rate was controlled with the flow of the by-pass line.

### *2.2 Measuring thermocouples*

The non-linear lines in the Figure 3 show the time responses of the thermocouple in case of the air flow, the water flow, and the liquid sodium flow. The linear lines were the time delays between two sensors along the flow. The response time was calculated with a lumped parameter method and the convective heat transfer coefficient. It was assumed that the hot junction of the thermocouple had a spherical (or cylindrical) shape and the bead was perfectly exposed in the main flow.

The K-type thermocouples were specially manufactured, which have the dimension of 0.1mm hot-junction bead and 0.5mm stainless steel sheath.

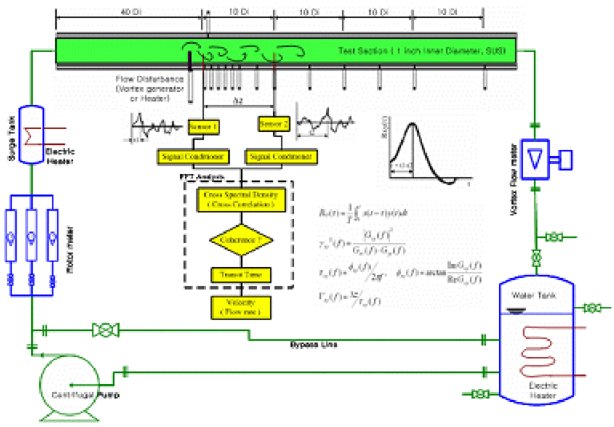


Figure 1. Schematics of the experimental apparatus

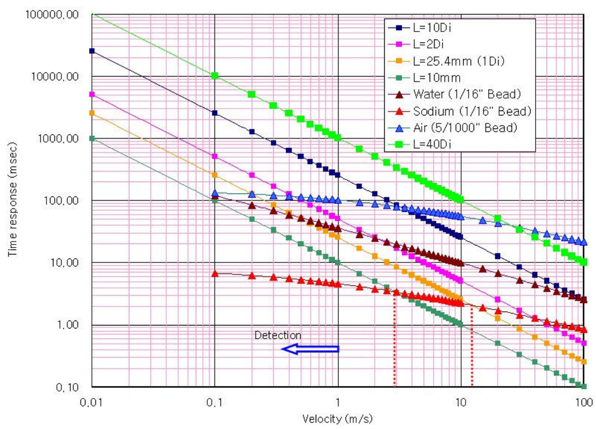


Figure 2. Time response of the thermocouple with velocity

### *2.3 Test results*

The experiment was conducted by changing the water velocity over the range from 0 to 80 *lpm* at the liquid water temperature below the 90$^o$C. The data was sampled at 500Hz with the data acquisition system of NI DAQPad-6015(16bit-200kS/s-8Ch differential). The cold-junction was compensated with IC sensor(LM 35, National Semiconductor) and every junction was thermally insulated to reduce the flow effect nearby the cold-junction. Measuring software was constructed with LabView 7.0 version to process the complex flow and temperature data.

$$R_{xy}(\tau) = \frac{1}{T}\int_0^T x(t-\tau)y(t)dt \qquad (1)$$

$$\gamma_{xy}{}^2(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)\cdot G_{yy}(f)} \qquad (2)$$

$$\tau_{xy}(f) = \phi_{xy}(f) / 2\pi f \qquad (3)$$

$$\phi_{xy}(f) = \arctan\frac{\mathrm{Im}\,G_{xy}(f)}{\mathrm{Re}\,G_{xy}(f)} \qquad (4)$$

$$V_{xy}(f) = \Delta z / \tau_{xy}(f) \qquad (5)$$

The experimental data was analyzed with the cross-correlation in the equation (1). $R_{xy}(\tau)$ is the cross-correlation between two temperature signals x(t) and y(t). The mean velocity could be calculated with the equation (5) if we know the distance $\Delta z$ between two sensors and could calculate the time delay $\tau_{xy}$.

Figure 3 shows the raw data measured in the water loop. Figure 4 shows the delay time calculated with cross correlation. The data was analyzed in the time domain with the equation (1). It shows that there is a difficulty in finding the maximum peak in the cross-correlation. For the best analyzing method, the measuring data should be compared with the equation (2) ~ (4) in the frequency domain. The $G_{xx}(f)$, $G_{xy}(f)$, $G_{yy}(f)$, and $\phi_{xy}(f)$ is the power spectral density functions and phase angle in the frequency domain, respectively.

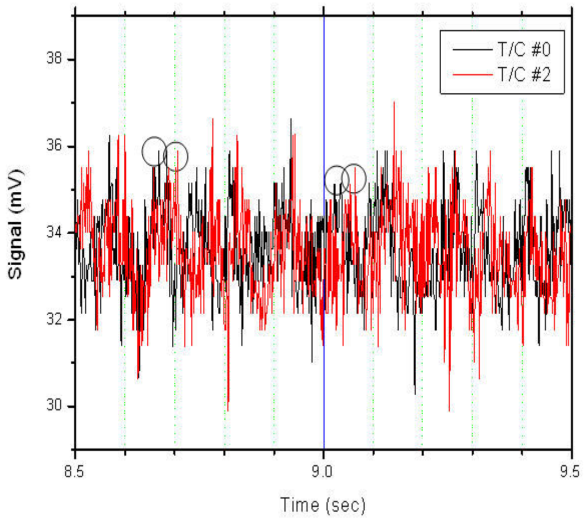


Figure 3. Measured raw data in the water loop

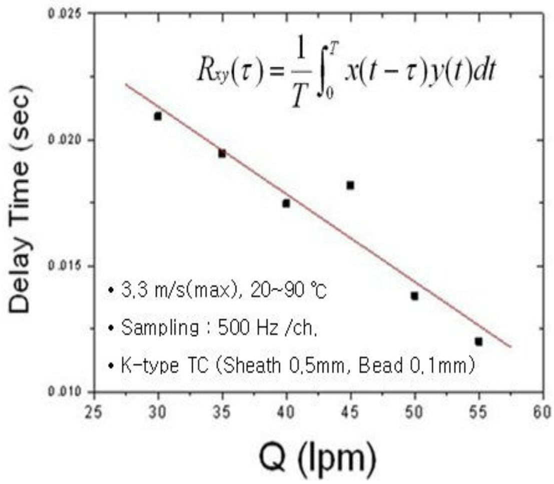


Figure 4. Calculated delay time with water velocity

## 3. Conclusion

The correlation technique was preliminary investigated in the water circulation loop to develop the systematic signal processing logic and to know the feasibility in the sodium flow. To enhance the measuring accuracy, it is necessary to analyze the data in the frequency domain and compare with cross correlation data in the time domain.


## Acknowledgement

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