Proficiency test for measurement equivalence in water flow metering with Coriolis mass flow meters in South Korea

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Abstract

There are more than twenty accredited laboratories for flow measurement in South Korea according to KOLAS, the Korea Laboratory Accreditation Scheme. Among them, twelve accredited laboratories participated in the proficiency test for water flow metering arranged by KASTO, the Korea Association of Standards and Testing Organization, in 2015. KRISS prepared for the proficiency test with the water flow standard system (WFSS), of which measurement range was between 3.6 m^3/h – 200 m^3/h. The participating laboratories were divided into three groups to test low flow range (3.6 m^3/h – 12 m^3/h) and high flow ranges (40 m^3/h – 80 m^3/h and 40 m^3/h – 200 m^3/h). The transfer standards were two Coriolis mass flow meters. All the participating laboratories satisfied the measurement equivalence with the WFSS at KRISS. However, there was one example which demonstrated the importance of density measurement for volume flow metering with the mass flow meters.

Keywords: Coriolis flow meter, flow standards, gravimetric flow metering, proficiency test, water flow

1. Introduction

It is necessary to monitor flow rate as well as pressure and temperature for safe operation of plants used in many industrial sectors such as water resource management, power plant, and custody transfer. In the water industry, daily amount of water processing is an important part[(1)]. In the nuclear power engineering, the efficiency of steam turbine is monitored by flow metering[(2)]. The notion of measurement uncertainty recapture (MUR) came from the idea that the steam turbine efficiency can be increased just below the limit posed by safety code if a flow meter can measure flow rate accurately[(2,3,4)]. The accuracy required for water resource management is within ±2 %. And the accuracy for the steam turbine is within ±0.3 %.

There are 22 laboratories for flow meter calibration in Korea. They are accredited by KOLAS, the Korea Laboratory Accreditation Scheme[(5)]. Proficiency test is needed to recognize the calibration and measurement capability (CMC) of the laboratories by KOLAS. KASTO, the Korea Association of Standards and Testing Laboratories, organizes the proficiency test and KRISS, the Korea Research Institute of Standards and Science, plays a role as a reference testing laboratory.

This study reports the results of proficiency test held in 2015 (PM2015-08). Two Coriolis flow meter were used as reference flow meters to cover the flow range between 3.6 m^3/h and 200 m^3/h. 12 accredited laboratories for water flow metering participated in the proficiency test. Some detailed explanations on this test are given as follows.

2. Proficiency Test

2.1 Reference testing laboratory

KRISS played a role as a reference testing laboratory in the proficiency test. The water flow standard system (WFSS) as shown in Fig. 1 was used to provide reference flow rate. The flow range of the WFSS was from 0.6 m^3/h to 2000 m^3/h. And its measurement uncertainty was 0.06 % ($k = 2$). Two test lines (25A, 100A) were used to generate three flow ranges of (3.6 ~ 12) m^3/h, (40 ~ 80) m^3/h, and (40 ~ 200) m^3/h. Two weighing tanks (0.1 t, 5 t) were used to calibrate the reference flow meters for the proficiency test.

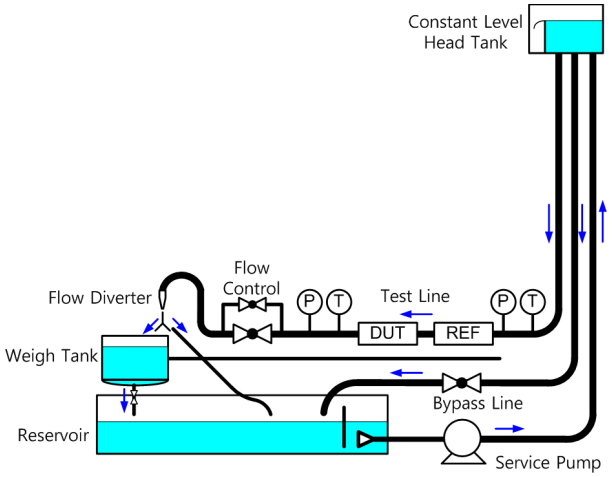

Figure 1: Schematic diagram of water flow standard system (WFSS).

Table 1: Specifications of the reference flow meters.

Name	REF#1	REF#2
Model	E+H 83F25	E+H 83F1H
Serial number	F411A602000	5604DD02000
Pipe diameter (mm)	25	100
Flow range (m^3/h)	1 ~ 18	15 ~ 250
Accuracy (%)	±0.10	±0.10
Repeatability (%)	±0.05	±0.05
Zero stability (m^3/h)	0.00054	0.014
Uncertainty (%)	0.14	0.13

Figure 2: Reference flow meters. (left) REF#1, (right) REF#2.

2.2 Reference flow meters

Two Coriolis flow meters (E+H 83F25, E+H 83F1H) were used as reference flow meters in the proficiency test. The specifications of the reference flow meters are indicated in Table 1. Long-term stability of the reference flow meters was tested before starting the proficiency test. According to F statistics, the characteristics of variances was equivalent irrespective of each test. This means that the reference flow meters have good stability suitable for this proficiency test.

2.2 Criterion for the proficiency test

E_n number was used as the criterion to assess the measurement equivalence between the reference testing laboratory and the participating laboratories.

$$E_n = \frac{E_{LAB} - E_{REF}}{\sqrt{U_{LAB}^2 + U_{REF}^2}} \qquad (1)$$

Here, E_{LAB} is the relative deviation of flow rate tested at a participating laboratory, E_{REF} is the relative deviation tested at the reference testing laboratory, U_{LAB} is the measurement uncertainty of E_{LAB}, and U_{REF} is the measurement uncertainty of E_{REF}. The assessment criterion is give as follows.

$$|E_n| \le 1 \quad \text{satisfactory} \qquad (2)$$
$$|E_n| > 1 \quad \text{unsatisfactory}$$

Some participating laboratories could only measure flow quantity instead of flow rate. In this case, the K-factor was converted into the relative deviation by the following formulas.

$$E_{LAB} = K - 100 \quad \text{REF\#1} \qquad (3)$$
$$E_{LAB} = 10K - 100 \quad \text{REF\#2}$$

Table 2: Participating laboratories of the proficiency test.

Labor-atory	Flow range			Flow quantity		Meas. equiv.	Success/ Failure
	25 A	100A #1	100A #2	*E*	*K*	$\|E_n\|$	S / F
L-01			○	○		0.21	S
L-02	○		○		○	0.17	S
L-03		○			○	0.60	S
L-04			○		○	0.20	S
L-05			○		○	0.24	S
L-06	○		○	○		0.21	S
L-07	○				○	0.71	S
L-08	○	○			○	0.73	S
L-09			○	○		0.39	S
L-10	○			○		0.43	S
L-11	○	○		○		0.27	S
L-12	○	○			○	0.75	S
KRISS	○	○	○	○	○	-	-

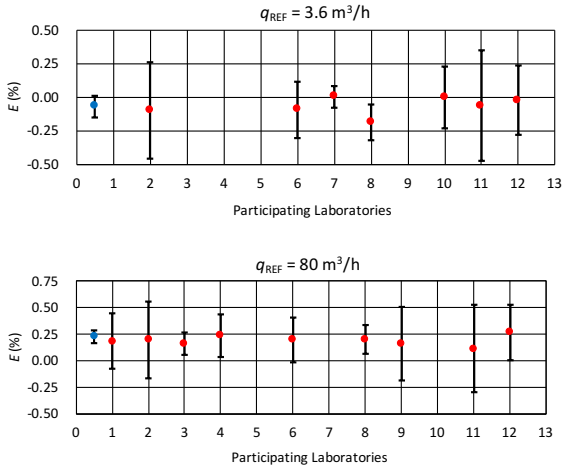

Figure 3: Examples of the test results.

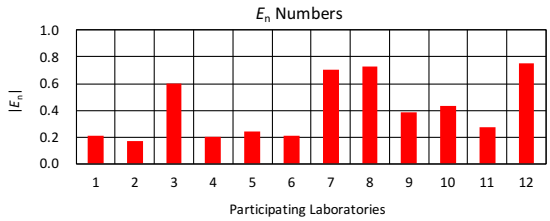

Figure 4: E_n numbers.

3. Test Results

3.1 Relative deviation

E_{LAB} and E_{REF} are displayed for 3.6 m^3/h and 80 m^3/h in Fig. 3. The flow rate at 3.6 m^3/h belonged to 25A and the flow rate at 80 m^3/h belonged to both 100A #1 and 100A #2. The purpose of this classification was to group the participating laboratories with similar CMC's. E_{REF} is displayed as blue circle in the left hand side of the figure. The measurement uncertainty of the reference testing laboratory was small compared with participating laboratories. Thus, the size of error bar was small. On the other hand, the sizes of error bars of the participating laboratories were large because of large CMC's.

3.2 E_n values

E_{n} for the participating laboratories is shown in Fig. 4 and Table 2. All the participating laboratories had $|E_{\mathrm{n}}|$ less than 0.8. Thus, the measurement equivalence with the reference testing laboratory was held. It was noteworthy that L-03, L-07, and L-08 declared the CMC's less than or equal to 0.1 % (k = 2). This could be the reason why they showed E_{n} higher than the other laboratories. L-12 also showed E_{n} as large as the three laboratories. The reason is that L-12 measured E_{LAB} very different from E_{REF} at one flow rate.

Traceability was also important. In the case with L-08, they found that the thermometer to measure water temperature was not good during the proficiency test. It was because traceability of the thermometer to the SI units was broken. Thus, they changed the thermometer with proven traceability. After that, they could report the results with $|E_{\mathrm{n}}| < 1$.

4. Conclusions

A proficiency test to check the measurement equivalence between the KOLAS accredited laboratories and KRISS was performed in 2015. Two Coriolis flow meters were used as reference flow meters to cover flow range between 3.6 m^3/h and 200 m^3/h. The flow meters showed good stability according to F statistics. 12 accredited laboratories participated in the proficiency test with three groups according to flow rate, i.e., (3.6 ~ 12) m^3/h, (40 ~ 80) m^3/h, and (40 ~ 200) m^3/h. The relative deviation was used as measurand because the relative deviation was denoted in many calibrated certificates.

In the proficiency test, all the participating laboratories showed measurement equivalence with the reference testing laboratory (KRISS) since $|E_{\mathrm{n}}|$ was less than 1. Some laboratories showed relatively large value than other laboratories because these laboratories declared their CMC's less than 0.1 % (k = 2). One of these laboratories reported the importance of traceability to temperature standards.

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