Development of Large Air Flow Calibration System

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Abstract: The volumes of a storage tank and a temperature control loop of the high pressure gas flow standard system in KRISS were increased about three times to calibrate large flow meters and to test the flow capacity of control valves. Sonic nozzle bank consisted of 15 sonic nozzles (10, 13, and 19 mm diameters) is used as reference flow meter. The performance of this large air flow calibration system was evaluated.

Keywords: Sonic nozzle, Calibration system, Uncertainty analysis

1. Introduction

It is essential to precisely measure very large flow-rates especially in the field of natural gas and control valves. Therefore, technology development in measurement of large air flow-rates has been studied. Due to the limit of calibration capacity of the primary calibration system, build-up technique is used to increase the calibration capacity. Several reference flow-meters calibrated in the primary calibration system are installed in parallel lines. Then the sum of those reference flow meter capacities will be calibration capacity.

As a reference flow meter, sonic nozzle, turbine meter, ultrasonic meter, and etc are used. Only sonic nozzle is able to calibrate directly in the primary gravimetric weighing system. It means the lowest uncertainty can be achieved with sonic nozzle as a reference flow-meter.

A sonic nozzle is nowadays widely used for measuring flow-rates in industrial areas, because of its various merits including its convenience, high precision, and good repeatability. However, in order for a nozzle to be used as a sonic nozzle, it must meet the condition that a higher pressure ratio between the upstream and downstream pressures of the nozzle than a certain criterion should be needed. Thus, in spite of such merits of a sonic nozzle, the condition of high pressure ratio is not easy to be obtained in the primary gas flow calibration facilities, such as bell-prover and piston-prover.

It was the best way to use the storage tank and temperature control loop of the primary gas flow standard system for the large flow system development in KRISS. The flow capacity of the original second pressure control valve used in gravimetric system was smaller than 10,000 m/h. The large flow system was connected to the temperature control loop with the manual glove valve of 150 mm diameter.

This large air flow system was developed to test the safety and control valves. For this valve test, the large flow-rate is important compared with small uncertainty. This valve test facility is modifying to calibrate flow meters until the end of this year.

2. Calibration System

The sonic nozzles used for the calibration system were manufactured according to the specifications of ISO 9300. Sonic nozzles with the nozzle throat diameter of 19 mm, 13 mm, and 10 mm were manufactured as shown in Fig. 1. Up to 3 sonic nozzles were installed in the sonic nozzle package of 150 mm diameters as shown in Fig. 2.

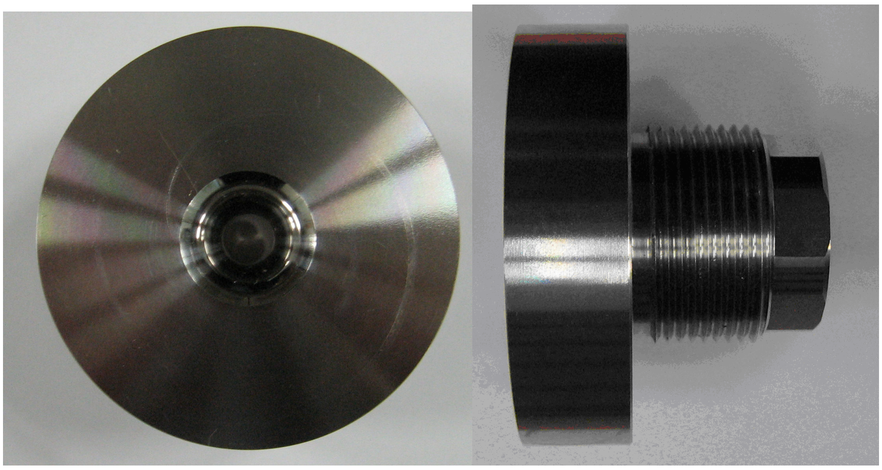

Fig. 1 Configuration of sonic nozzle

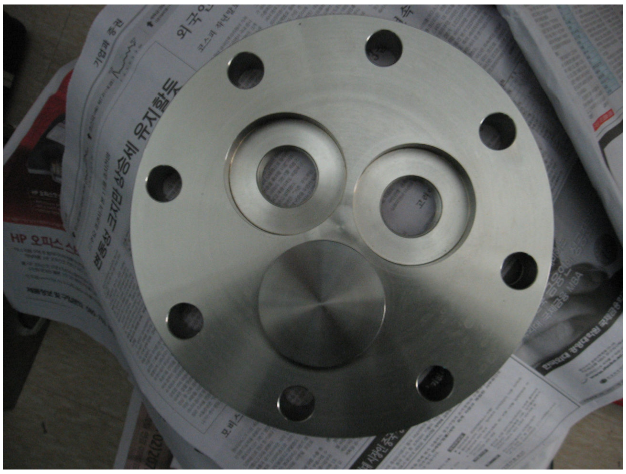

Fig. 2 Installation plate of sonic nozzles

Sonic nozzle bank is constituted of 6 packages as shown in Fig. 3 as follows:

1) 4 packages - 3 sonic nozzles of 19 mm throat diameter in each package

2) 1 package - 2 sonic nozzles of 13 mm throat diameter in each package

3) 1 packages - 1 sonic nozzles of 10 mm throat diameter in a package

Fig. 3 Sonic nozzle packages

3. System Evaluation

3.1 Uncertainty Analysis

The volumetric flow rate q_v is given as follow:

$$q_v = \sum \frac{A_{*i} C_{di} C_{*i} P_{0i}}{\sqrt{RT_{0i}}} \frac{RT_t}{P_t} \tag{1}$$

where

A_{*i} : Throat area of a sonic nozzle

C_{*i} : Critical flow function of a sonic nozzle

C_{di} : Discharge coefficient of a sonic nozzle

P_{oi} : Stagnation pressure at a sonic nozzle

T_{oi} : Stagnation temperature at a sonic nozzle

R: gas constant

P_t : Pressure at test meter/valve

P_t : Temperature at test meter/valve

1) The function of C_{*i} are same in calibration as test meter and as reference meter. Also the values R and A_{*i} are constant. It means there is no additional uncertainty in these three variables.
2) The uncertainty of C_{di} is given by the calibration of each sonic nozzle in the gravimetric primary calibration system as better than 0.18%. Then we can used uncertainty $A_{*}C_{d}$ instead of C_{di}.
3) The stagnation pressure is sum of absolute pressure at the head tank and differential pressure between the head and sonic nozzle. The differential pressure is smaller than the absolute pressure. If B-type uncertainties of absolute pressure gauge and the largest B-type uncertainty of differential pressure gauge are used, and if the largest A-type uncertainty among sonic nozzle packages is used, then we can used uncertainty P_o instead of P_{oi}.
4) If the largest uncertainty of stagnation temperature is used, then we can used uncertainty T_o instead of T_{oi}.

The uncertainty of q_v is

$$\frac{u(q_v)}{q_v} = [(\frac{u(C_d)}{C_d})^2 + (\frac{u(P_o)}{P_o})^2 + \frac{1}{4}(\frac{u(T_o)}{T_o})^2 + (\frac{u(P_t)}{P_t})^2 + (\frac{u(T_t)}{T_t})^2]^{0.5} \quad (2)$$

The uncertainty of $A_{*i}C_{di}$ is given by the calibration of each sonic nozzle in the gravimetric primary calibration system as better than 0.18%.

3.2. Preliminary A-type uncertainty of presure and temperature

The pressure and temperature was very unstable at the large flow-rate due to hot ambient condition, sunlight, manual control. As the system construction will be finished soon, more stable flow condition is expected.

Table 1. Pressure and temperature at sonic nozzle and safety valve at 11,000 m^3/h

	P test	T test	P nozzle	T nozzle	Qv(m^3/h)
1	0.3612	32.58	9.2884	33.82	11474
2	0.3644	32.75	9.4252	33.21	11618
3	0.3648	32.83	9.5079	32.49	11724
4	0.3644	32.83	9.5552	31.71	11797
5	0.3635	32.74	9.58	30.91	11845
6	0.3636	32.58	9.5884	30.14	11863
7	0.3618	32.36	9.5842	29.39	11881
8	0.3603	32.08	9.5709	28.66	11882
9	0.3593	31.77	9.5503	27.98	11870
10	0.3588	31.43	9.5247	27.34	11845
11	0.3563	31.06	9.496	26.75	11832
12	0.3552	30.2	9.4638	25.64	11794
13	0.3528	29.8	9.3854	25.19	11720
14	0.3513	29.42	9.3502	24.81	11686
15	0.3486	29.04	9.3152	24.45	11662
Ave	0.3591	31.56	9.4791	28.8327	11766
Ua (%)	0.099	0.114	0.280	0.269	0.258

Table 2. Pressure and temperature at sonic nozzle and safety valve at 30,000 m^3/h

	P test	T test	P nozzle	T nozzle	Qv(m^3/h)
1	0.2251	32.39	12.48	27.7	30772
2	0.2426	32.34	13.392	27.49	32408
3	0.2468	32.19	13.915	27.1	33487
4	0.2479	31.92	14.403	26.55	34561
5	0.2665	31.56	14.881	25.88	35117
6	0.2592	31.1	14.781	25.07	35093
7	0.2510	30.53	14.464	24.11	34603
8	0.2398	29.87	14.021	23.05	33900
9	0.2221	29.13	13.6	21.92	33407
10	0.2074	27.98	13.021	20.38	32432
11	0.2066	27.14	12.647	19.4	31547
12	0.1873	26.28	12.342	18.48	31304
13	0.1801	25.45	11.99	17.65	30620
14	0.1722	24.63	11.69	16.88	30068
15	0.1765	23.84	11.41	16.16	29254
Ave	0.2221	29.09	13.269	22.5213	32572
Ua	0.676	0.256	2.220	0.359	1.517

4. Preliminary Calibration/Test Results

The control valve of 10 inch inlet and 12 inch flanges was tested. The flow capacity is shown in Fig. 4. Also the flow capacity for the control valve of 12 inch inlet and 16 inch flanges is shown in Fig. 5.

The flow rate is decreasing due to manual control of a glove valve. The automatic control valve is required for more stable flow rate. The maximum flow-rate should be decided with consideration of uncertainty evaluation results.

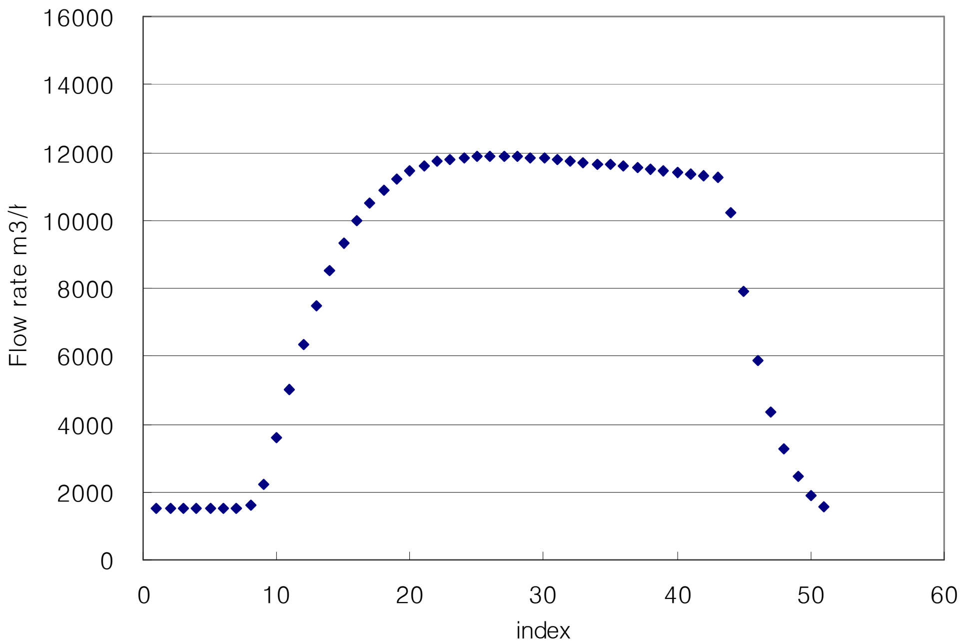

*Fig. 4 Test results of 10 * 12 inch control valve*

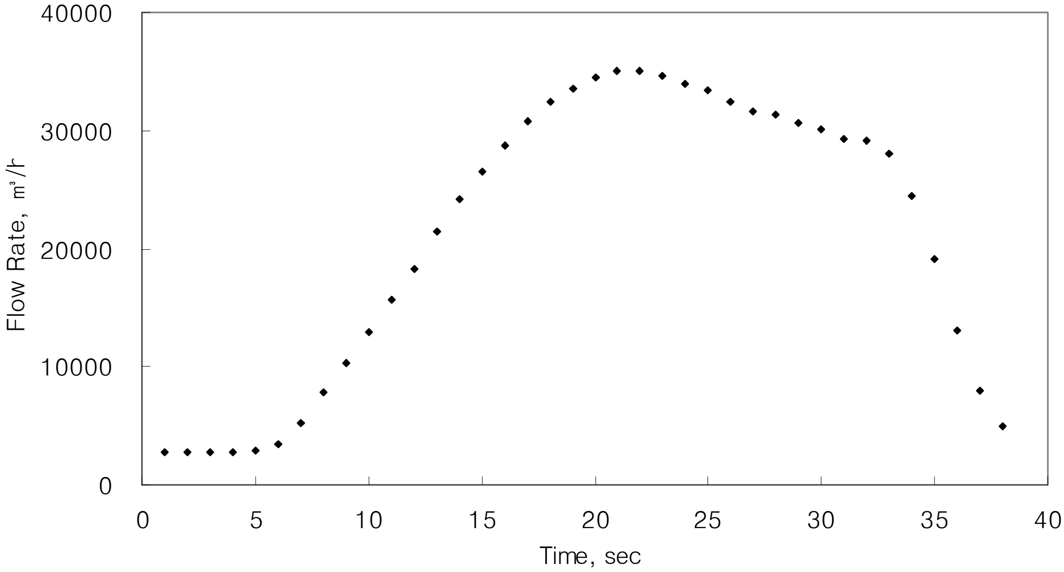

*Fig. 5 Test results of 12 * 16 inch control valve*

6. Conclusion

A calibration facility for large air flow-rate was designed and is implementing because of the needs from natural gas and valve industries. A preliminary uncertainty evaluation was conducted and show large unstable air temperature and pressure due to hot ambient condition at large flow-rate. Sun blocking and insulation device should be installed and evaluated again before FLOMEKO presentation. The system was evaluated to calibrate flow-rate from 10,000 to 30,000 m^3/h.

References

[1] K.A. Park, Y.M. Choi, H.M. Choi, T.S. Cha, B.H. Yoon, 2001, "The evaluation of critical pr essure ratios of sonic nozzles at low Reynolds numbers", Flow Meas. Instrum., Vol. 12, pp. 3 7-41
[2] ISO 9300:Measurement of gas flow by means of critical flow venturi nozzles, 1990
[3] Yong Moon Choi, Kyung Am Park, Seung O. Park, 1997, "Interference effect between sonic nozzle", Flow Meas. Instrum. Vol. 8, No. 2, pp. 113-119
[4] Kyung Am Park, 1995, "Effects of inlet shapes of critical venture nozzles on discharge coeffi cients", Flow Meas. Instrum., Vol. 6, No. 1, pp. 15-19