

The Development of Small Water Flow Facility at National Institute of Metrology, Thailand

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Abstract. The flow and volume of liquid laboratory of the National Institute of Metrology, Thailand (NIMT) has developed the latest facility which covers the liquid flow measurement ranges from (10 – 1,000) g/h. This facility has been developed according to the need of high accuracy equipment in several industries such as pharmaceutical products, fuel cells, semiconductor and medical devices. For accuracy purposes, the gravimetric method is decisively implemented as the main principle of the calibration rig. It comprises of three main parts; water supply system, weighing system and data acquisition system. Practically, the capability of the facility is confirmed via a transfer standard. With high accuracy and repeatability, the Coriolis mass flow controllers were selected as the transfer standard. The facility can provide the best capability of calibration, CMC, at 0.30% of reading. Moreover, the evidence of unofficial comparison between NIMT and Federal Institute of Metrology, METAS, Switzerland, has confirmed this capability via the degree of equivalence, E_n ratio. The E_n ratios represent that the comparison of the flow rates from (10 – 1,000) g/h between NIMT and METAS is agreed.

1. Introduction

The small water flow at National Institute of Metrology (Thailand), NIMT, has been developed since 2014. The project was initiated due to the need of small flow calibration in several industries. The flow rate ranges from (10 to 1,000) g/h is requested from the users not only in the medical devices but also pharmaceutical products, fuel cells and semiconductors. Moreover, the gravimetric method is brought to use as the main principle of the design for the facility as it has been widely used in many calibration laboratories and also recommended in ISO/IEC60601-2-24 [1].

In order to proof the traceability and capability of the system, the calibration comparison is needed. Normally, the calibration capability is compared via a transfer standard which has good accuracy and repeatability. Thus, the Coriolis mass flow controller (Bronkhorst Model M12 and Model M13) is selected and used as NIMT transfer standard (TS). The TSs have been sent to Federal Institute of Metrology, METAS, in Switzerland for calibration. METAS is one of the ten NMIs which has CMC in small water flow calibration. The calibration result was then compared by using the

degree of equivalence. With this unofficial result, the flow laboratory at NIMT can claim the facility can perform the best calibration with uncertainty $\pm 0.30\%$.

2. NIMT Facilities

The equipment used in the small water flow calibration system can be separated into three groups which are water supply system, weighing system and data acquisition system. Each equipment is selected based on the availability, user friendly and service from manufacturer.

2.1 Water supply system

The water supply system is aimed for generating flowrates in the range of (10 – 1000) g/h. The multi-stage pump with 1hp is chosen to be the source of water supply. The 10L buffer tank and storage tank are combined with the pump. Moreover, the pressure gauge and control valve are selected to control the flow rate before going through the inlet of the unit under calibration, UUC. At the outlet of the UUC, the 1/4" stainless steel tube is connected. The flow rates are controlled by the bank of valves and then the measured water is flowing through the tube to the weighing balance. The reverse osmosis, RO, water is used for this system.

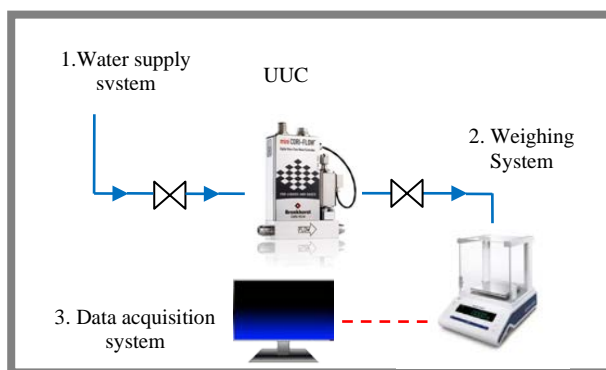


Figure 1: The system setup

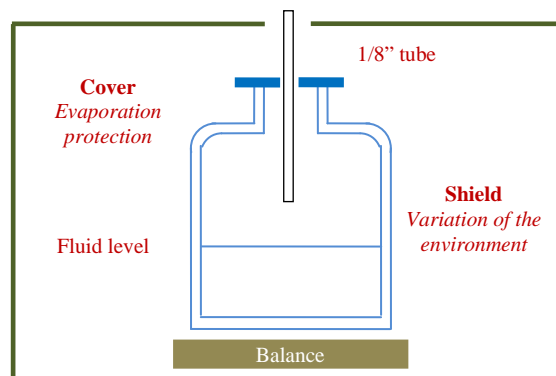


Figure 2 Shield of weighing balance

2.2 Weighing system

The study of effects on weighing balances due to the infusion devices [2] shows the factors that affect the uncertainty evaluations. Some of those factors are recognized by the users who often use the balances. However, for the small flow rate calibration, more factors have to be considered such as evaporation rate and environmental vibration. The Figure 2 shows the shield that prevents the variation due to the laboratory vibration and air flow.

Evaporation is another factor that has to be considered. The evaporation rate is directly related to the mass loss during the calibration period. Then, the evaporations are tested with four different conditions; largemouth of polyethylene containers with and without cover, and small mouth of polyethylene containers with and without cover. The result of evaluation testing reveals that the small mouth with covers gives the best result among four conditions. Moreover, the evaporation rate has to be counted into the uncertainty due to mass measurement.

2.3 Data acquisition system

The data from the weighing balance are collected by using the LABVIEW programme. The LABVIEW is connected to the weighing balance (max. load 1020g) via RS232 which is the real-time data processing. Both measured mass and time are recorded every 30 seconds in the form of text

which can be analyzed by using excel or other suitable programmes. The raw data can be calculated to find the discrete and the accumulated flow rate. The successive sequence of data is collected for approximately one hour which is counted as a one loop of calibration.

Moreover, other devices used in this calibration are temperature PT100 for measuring the water temperature and the electronic thermo-hygrometer for measuring the room conditions; room temperature and humidity. The room conditions are controlled at $(23 \pm 2) ^\circ\text{C}$ and $(55 \pm 15) \% \text{RH}$.

3. Transfer standard and measurement procedures

3.1 Transfer standard

The Coriolis mass flow meter was widely used in many industries as well as in the laboratories because of no effect of flow profile, very high accuracy, good repeatability and no requirement of the inlet and outlet distances. The advantages of Coriolis mass flow meter are self-evident, because its measuring principle is not affected by physical factors such as conductivity, pressure, temperature, density and viscosity. There are two Coriolis mass flow controllers from Bronkhorst which are used as the transfer standard. The meter Model M12 and Model M13 can perform at the flow range $(2 - 200)$ g/h and $(100 - 2000)$ g/h, respectively.

3.2 Measurement procedures

At NIMT, the calibrated flow rates of model M12 are 10, 20, 50, 100 and 200 g/h. Also, the flow rates for model M13 are selected at 100, 200, 500, 750 and 1,000 g/h. At each flowrates, mass and time are successively collected every 30 seconds from the weighing system. The calibration period is one hour and repeated for three loops. The data from the meters are recorded by its software which can be selected such as flow rates, collected volume and density. Other relevant parameters such as the water temperature, ambient temperature and ambient humidity are also recorded.

The mass flow rate can be calculated by using equation 1 as shown below. The mass flow rate comprises of mass of measured water flowing into the container on the balance and collecting time. The uncertainty of the system can be shown in the equation 2 [3].

$$Q_m = m_w / t \quad (1)$$

$$u_c = \sqrt{u_{mw}^2 + u_t^2 + u_{instability_WB}^2 + u_{repeat_UUC}^2 + u_{res_UUC}^2 + u_{instability_UUC}^2} \quad (2)$$

The uncertainties due to mass, time, instability of standard calibration system, repeatability of the meter under calibration, resolution of the meter under calibration and instability of the meter under calibration are represented by u_{mw} , u_t , $u_{instability_WB}$, u_{repeat_UUC} , u_{res_UUC} , and $u_{instability_UUC}$.

4. Results of comparisons

The calibration result of transfer standards from METAS and NIMT is shown in Table 2 and 3 for meter model M12 and M13. The comparison between the result of NIMT and METAS is considered by using the degree of equivalent which is expressed as the normalize errorratios (E_n). The equation of E_n can be calculated by equation (3). The measurement is satisfactory if $|E_n| \leq 1$. The uncertainty of NIMT is evaluated according to JCGM guideline [4], E_n ratio of NIMT and METAS are also shown in Tables 2 and 3for model M12 and model M13, respectively.

$$E_n = \frac{|E_{METAS} - E_{NIMT}|}{\sqrt{U_{METAS}^2 + U_{NIMT}^2}} \quad (3)$$

Table 2. Calibration results and E_n ratios of NIMT and METAS of meter model M12

Flow Rate, Q	NIMT				METAS				En ratio
	Flow rate DUT	Measurement Deviation, ΔQ		Relative uncertainty	Flow rate DUT	Measurement Deviation, ΔQ		Relative uncertainty	
	(g/h)	(g/h)	(%)	(%)	(g/h)	(g/h)	(%)	(%)	
10	10.03	0.03	0.31	1.77	10.06	0.06	0.60	0.10	0.16
20	20.00	0.00	-0.02	1.13	20.05	0.05	0.25	0.10	0.24
50	49.94	-0.06	-0.12	0.56	50.08	0.08	0.16	0.10	0.49
100	99.82	-0.18	-0.18	0.38	100.11	0.11	0.11	0.10	0.74
200	199.74	-0.26	-0.13	0.30	200.17	0.17	0.08	0.10	0.68

Table 3. Calibration results and E_n ratios of NIMT and METAS of meter model M13

Flow Rate, Q	NIMT				METAS				En Ratio
	Flow rate DUT	Measurement Deviation, ΔQ		Relative Uncertainty	Flow rate DUT	Measurement Deviation, ΔQ		Relative Uncertainty	
	(g/h)	(g/h)	(%)	(%)	(g/h)	(g/h)	(%)	(%)	
100	99.56	-0.44	-0.44	0.21	99.41	-0.59	-0.59	0.10	0.63
200	199.40	-0.60	-0.30	0.20	199.09	-0.91	-0.46	0.10	0.71
500	497.92	-2.08	-0.42	0.19	498.26	-1.74	-0.35	0.10	0.32
750	747.64	-2.36	-0.32	0.20	747.54	-2.46	-0.33	0.10	0.06
1000	996.22	-3.78	-0.38	0.16	996.70	-3.30	-0.33	0.10	0.26

5. Conclusions

The small water flow facility at NIMT has unofficially confirmed the calibration capability with METAS in the range of (10 – 1,000) g/h with CMC $\pm 0.30\%$. The two Coriolis mass flow controllers were used as transfer standard. The result shows that the degree of equivalence, $|E_n|$, of all flow rates are less than 1.

References

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