

IN-HOUSE COMPARISON BETWEEN SMALL HYDROCARBON FLOW FACILITY AND SMALL WATER FLOW FACILITY AT NMIJ

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Abstract

Continuing efforts to expand the calibration flow range of small liquid hydrocarbon flow facility at NMIJ is being carried out. To justify the calibration capability of the facility in the flow range of 1 L/h ~ 10 L/h, an in-house comparison with small water flow facility at NMIJ was conducted. Two Coriolis flowmeters were used as transfer meters. Effect of zero instability of the transfer meters on calibration results in flow range near zero was found significant and compensation of zero point flowrate was applied to reduce the effect. Sufficient number of measurements were done to reduce the uncertainty due to the reproducibility of transfer meters. The comparison by Coriolis flowmeters showed a reasonable agreement between the two facilities.

Introduction

Measurement accuracy in small flow range of liquid hydrocarbon is becoming critical in industrial practices such as evaluation of automobile fuel efficiency, blending of bio-fuel and petrol, and metering of household fuel consumption. With the aim of establishing the measurement traceability in such flow range (below 0.1 m³/h), the calibration flow range at National Metrology Institute of Japan (NMIJ) is being expanded by stages. The current calibration flow range at NMIJ is 0.01 m³/h ~ 300 m³/h. Out of this flow range, small hydrocarbon flow facility covers 0.01 m³/h ~ 0.1 m³/h (equivalent to 10 L/h ~ 100 L/h) [1].

Recently the calibration flow range of small hydrocarbon flow facility has been expanded one more decade lower to 1 L/h. To justify the calibration capability for this new flow range of 1 L/h ~ 10 L/h, a comparison needed to be carried out and the only facility at NMIJ which is available for comparison over this flow range is the small water flow facility whose calibration flow range is from 2 L/h ~ 1200 L/h.

However the working liquid at the two facilities is different, one is hydrocarbon and another is water. It is essential to pick a transfer meter that can work well on both liquids. Coriolis flowmeter was chosen as the transfer meter as it works on both water and hydrocarbon without much problem and only requires minimal decontamination work.

This paper presents the comparison results between the two facilities as well as characteristics of the Coriolis transfer meters that need to be taken care of for a reasonably meaningful comparison to be done. Hopefully this information would be helpful for future comparisons.

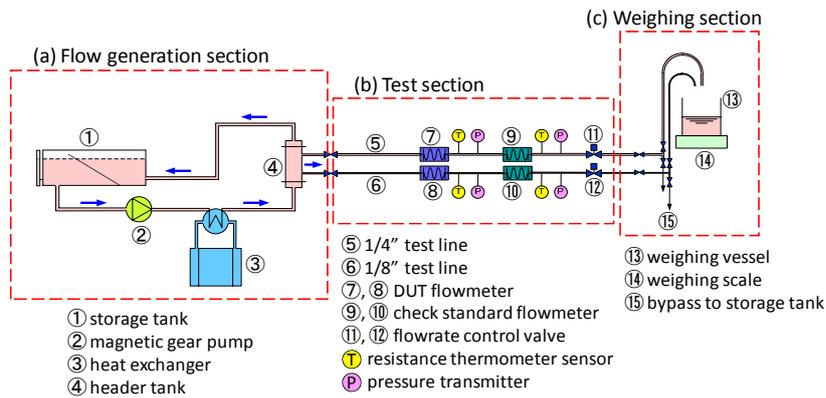
Facilities and Transfer Meters

Small Hydrocarbon Flow Facility

A schematic diagram of the facility is shown in Fig. 1(a). The facility comprises three main sections, namely (a) flow generation section, (b) test section and (c) weighing section. The flow generation section consists of a storage tank, a magnetic gear pump, a heat exchanger and a header tank. The working fluid, either light oil or kerosene, is delivered into the flow loop by the magnetic gear pump whose revolution speed is variable. Temperature of the working fluid can be maintained at any value in the range of 15 °C ~35 °C. In the flow generation section, the flow circulates from the pump to the header tank and back to the storage tank. From the header tank, a portion of the working fluid is released into the test line. The header tank takes the role of stabilizing any pulsating flow as well as adjusting the fluid pressure.

In the test section, there are two test lines of which the outer diameters are 6.35 mm and 3.2 mm respectively. Coriolis mass flowmeter or PD flowmeter, being used as check standards, are mounted downstream of the DUTs (device under test). Meanwhile, thermometer sensor

(a)



(b)

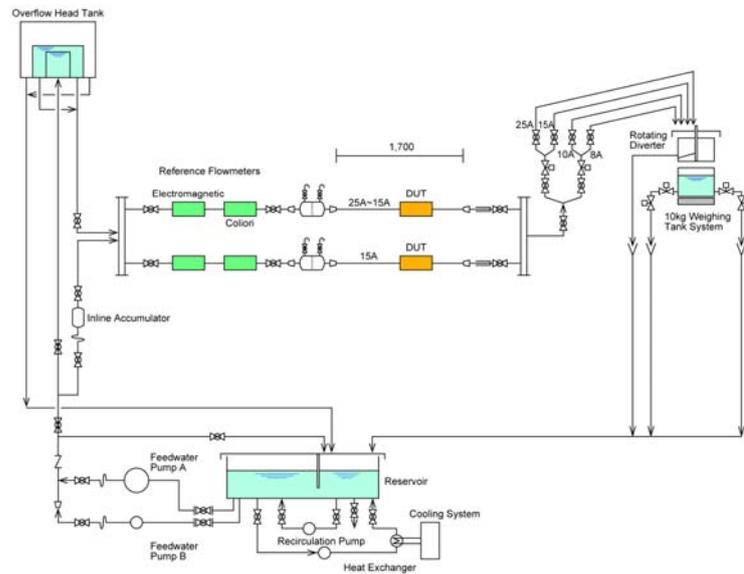


Fig. 1 Schematics of (a) small hydrocarbon flow facility and (b) small water flow facility.

and pressure transmitter are being set up downstream of each DUT and check standard.

The facility adopts gravimetric calibration method of standing-start and finish. In the weighing section, working fluid can be accumulated up to 2 L in a weighing vessel being placed on a weighing scale. Switching of flow direction either to weighing vessel or bypass back to storage tank is controlled by air-actuated valves.

Small Water Flow Facility

A schematic diagram of the facility is shown in Fig. 1(b). Water is supplied into the test lines either by a pump or an overflow head tank depending on the flowrate. There are two test lines, namely 15A and 25A, either one being used according to the size of DUT and flowrate. Check standards (referred to as reference flowmeters in Fig. 1(b)) comprising one

electromagnetic flowmeter and one Coriolis mass flowmeter are mounted upstream of each test line. In each test line, DUT is mounted downstream of check standards with a header separating them. Temperature sensor and pressure transmitter are set up downstream of DUT.

The facility employs gravimetric calibration method of flying-start and finish. In the weighing section, a rotating diverter system [2] is used to divert the water either into a weighing vessel or to the bypass. Nozzles delivering the water into the diverter system are available in four sizes, namely 25A, 15A, 10A and 8A. The nozzle to be used is selected according to the flowrate in order to produce the best velocity profile at the nozzle exit and to reduce water scattering. The maximum amount of water accumulated in the weighing vessel is set at 10 L. A mass comparator with a weighing resolution of 5 mg is used as the weighing scale.

Characteristics of Transfer Meters

The Coriolis transfer meters used in the present comparison are designated as A and B as shown in the following Table 1.

Table 1 Transfer Meters (Coriolis)

Transfer Meter A	Endress Hauser Promass 83A02
Transfer Meter B	Micro Motion Elite CMF 010

It is commonly known that Coriolis flowmeters enjoy the advantage of being not affected by the variation of viscosity or density of the working fluid.

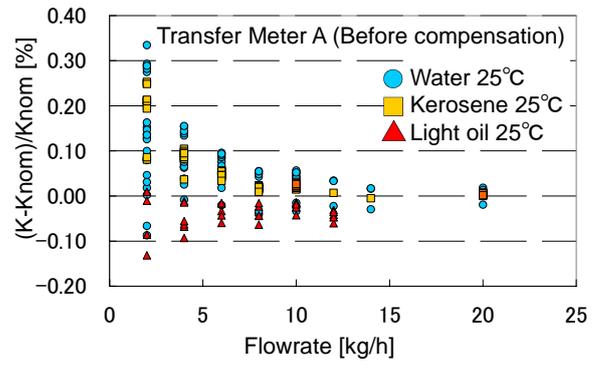
However it was found that instability of zero point flowrate significantly affect the calibration result near the bottom limit of the measuring range of the flowmeter. As shown in Fig. 2, the calibration results are getting more dispersed as the flowrate becomes nearer to zero. Applying the zero adjustment of the flowmeter would not make things better. To solve this problem, before and after each calibration was executed, the flow in the test line was completely stopped and the flowrate (zero point flowrate) indicated by the flowmeter at this point was recorded for compensation to be applied to the calibration value [3]. By doing this, a more stable and reliable calibration result was obtained. As shown in Fig. 3, the scattering of calibration results near zero flowrate is much reduced by applying the compensation of zero point flowrate.

Evaluation of the present comparison between the two facilities was conducted in terms of K factor for mass flowrate. The uncertainty of K factor, u_K , can be expressed as follows.

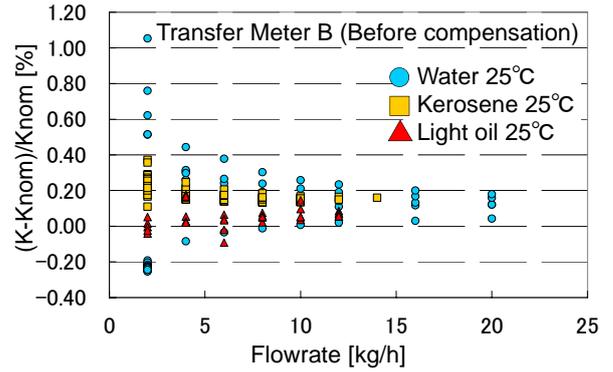
$$u_K^2 = u_F^2 + u_{TM}^2 \quad (1)$$

where u_F is uncertainty due to facility and u_{TM} is uncertainty due to transfer meter. Here the standard uncertainty for small hydrocarbon flow facility, u_{FH} , is estimated at 0.01 % whereas the standard uncertainty for small water flow facility, u_{FW} , is estimated at about 0.02 %.

Normally a few contributing factors exist for uncertainty of transfer meter, u_{TM} , and they are usually evaluated selectively based on how the K factor is obtained and the purpose meant for the

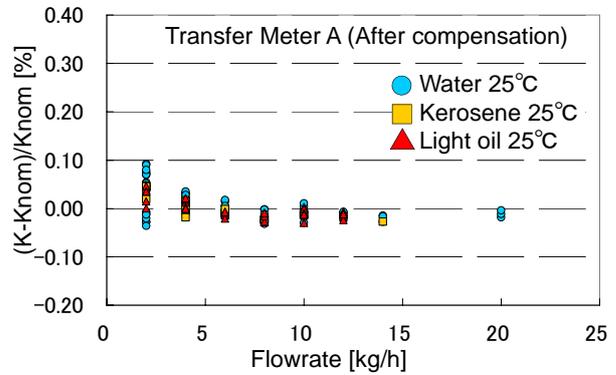


(a) Transfer meter A

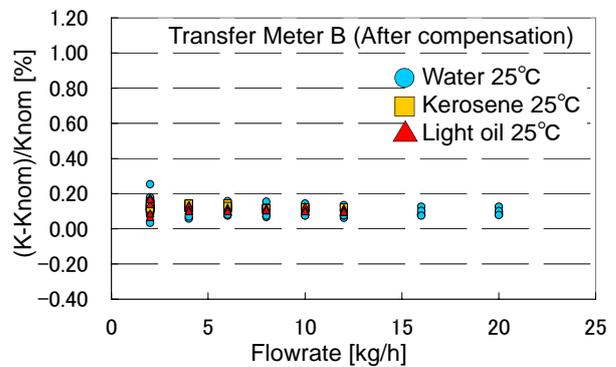


(b) Transfer meter B

Fig. 2 Calibration results before compensation of zero point flowrate.



(a) Transfer meter A



(b) Transfer meter B

Fig. 3 Calibration results after compensation of zero point flowrate.

K factor. In the case of present comparison, the following contributing factors are being considered.

$$u_{TM}^2 = u_R^2 + u_P^2 + u_{SD}^2 \quad (2)$$

Here u_R and u_P are uncertainties due to repeatability and reproducibility respectively. u_{SD} is uncertainty due to the effect of standing-start and finish.

Small hydrocarbon flow facility adopts gravimetric calibration method of standing-start and finish. On the other hand, small water flow facility employs gravimetric calibration method of flying-start and finish. Transfer meter may response differently to different calibration method, especially standing-start and finish which involves a sudden halt of flow during switching of flow. The effect of standing-start and finish on the transfer meters, u_{SD} , was evaluated and it was revealed that the effect was negligible enough.

The present comparison between the two facilities was conducted over a span of few months as the flowmeters were being transferred to and fro between the two facilities repeatedly, involving many times of mounting and dismounting of the flowmeters. Hence it was considered that uncertainty due to reproducibility has to be evaluated. It was found that the daily average of measurement data show little difference compared to the average of all measurement data obtained over the whole span of comparison. This shows the randomness in dispersion of the measurement data. Instead of evaluating the repeatability on a daily basis, it was thought that uncertainty due to the random dispersion of the measurement data could be evaluated based on all measurement data obtained over the whole span of comparison. The uncertainty termed as day-to-day reproducibility, u_{DDR} , is calculated as follows.

$$u_{DDR}^2 = \frac{\sigma_{DDR}^2}{n} = \frac{1}{n(n-1)} \sum_{i=1}^n (K_i - \bar{K})^2 \quad (3)$$

Here σ_{DDR} is the standard deviation of all measurement data. n is the number of all measurements. K_i is measurement data of no. i and \bar{K} is the average of all measurement data.

As mentioned before, since the uncertainty due to standing-start and finish effect can be

neglected, uncertainty of transfer meter can be expressed as follows.

$$u_{TM}^2 = u_{DDR}^2 \quad (4)$$

From Eq. (1), it is understandable that in order to perform a reasonably meaningful comparison between facilities, the smaller the uncertainty due to transfer meter the better as compared to the uncertainty due to facility ($u_{TM} \ll u_F$). As shown by Eq. (4), the uncertainty of transfer meter in the present comparison is solely due to day-to-day reproducibility. As it can be observed from Fig. 3, the reproducibility of transfer meters deteriorates as the flowrate approaches zero. To reduce the uncertainty due to the reproducibility of transfer meters, sufficient number (n) of measurements were carried out especially near the zero flowrate.

Comparison Results

The comparison results between the two facilities are shown in Fig. 4. Measurement was conducted for kerosene and light oil at small hydrocarbon flow facility. Working liquid temperature was set at 25 °C at both facilities. The error bar in Fig. 4 indicates the expanded uncertainty of the measurement data. The measurement data shown here are the averages of all measurements performed at each flowrate point. The ordinate indicates the difference between the calibrated K factor of transfer meter and the nominal K factor of transfer meter. From Fig. 4, it can be observed that measurement data of kerosene, light oil and water agree well with one another, all falling within the expanded uncertainties of one another.

E_n values were also obtained for the two facilities. E_n value is a typical evaluation index for comparison of facilities and is calculated by the following equation.

$$E_n = \frac{|K_W - K_H|}{\sqrt{U_{K(W)}^2 + U_{K(H)}^2}} \quad (5)$$

where K_W , K_H are the measured K factors at water facility and hydrocarbon facility respectively. $U_{K(W)}$, $U_{K(H)}$ are the expanded uncertainties of the measured K factors at water and hydrocarbon facilities respectively. E_n is a non-dimensional value and relative value was actually being used for K_W , K_H , $U_{K(W)}$, $U_{K(H)}$ in

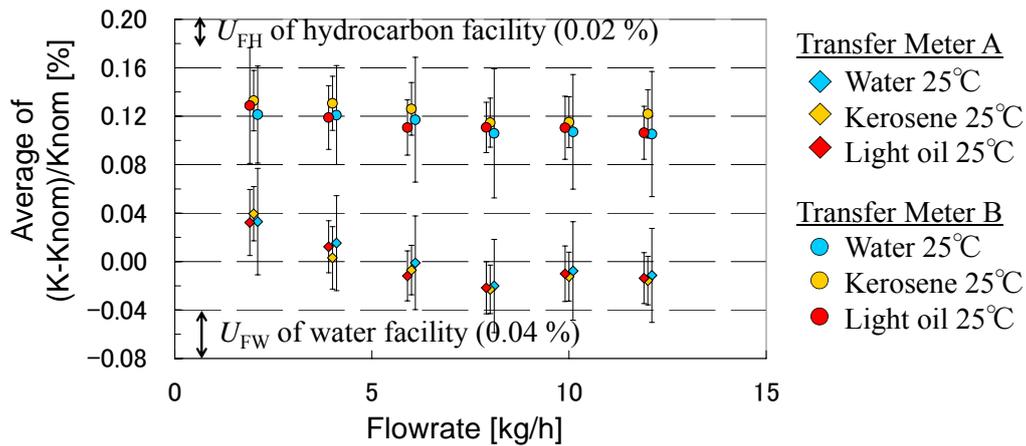


Fig. 4 Comparison between small hydrocarbon flow facility and small water flow facility.

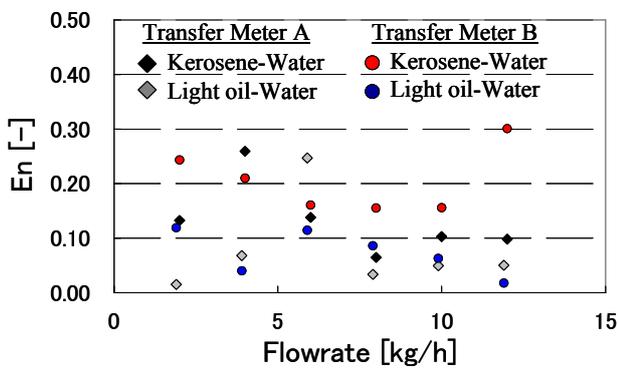


Fig. 5 E_n values for comparison.

Eq. (4). The calculation results for E_n is shown in Fig. 5. It can be observed that all E_n values are below 0.3.

The results in Figs. 4 and 5 indicate reasonably good agreement between the two facilities, hence justifying the calibration capability for the new flow range (1 L/h ~ 10 L/h) of small hydrocarbon flow facility.

Summary and Conclusion

Calibration flow range of small hydrocarbon flow facility has been expanded from the previous flow range of 10 L/h ~ 100 L/h to the new flow range of 1 L/h ~ 100 L/h. The working liquids are kerosene and light oil. To justify the calibration capability in the expanded flow range of 1 L/h ~ 10 L/h, an in-house comparison was conducted with the small water flow facility at NMIJ of which the calibration flow range is 2 L/h ~ 1200 L/h.

Two Coriolis flowmeters were used as the transfer meters. To alleviate the effect of zero instability of the flowmeters on measurements near zero flow range, compensation of zero point flowrate was applied. Reproducibility of

flowmeters also deteriorated near zero flowrate. To perform a reasonably meaningful comparison, uncertainty due to day-to-day reproducibility of transfer meters was reduced in relative to the uncertainty due to facility by making sufficient number of measurements.

The comparison results in terms of K factor and E_n value show a reasonably good agreement between the two facilities. Thus it can be concluded that the calibration capability of small hydrocarbon flow facility in the new flow range is well justified.

References

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