Inter-Laboratory Comparisons between NMIJ and Accredited Laboratories for Water Flow in Japan

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Abstract

Inter-laboratory comparisons between NMIJ and four JCSS accredited laboratories in Japan for water flow are carried out for wide flowrate range from 0.005 m^3/h to 5000 m^3/h using five type transfer flowmeters. The deviations of test results between NMIJ and the accredited labs are within approximately 0.1% and the averages of the deviations for each accredited labs are within 0.025%. These results indicate a high capability of the calibration facilities in the accredited labs. To investigate the reason of the deviations in the comparisons, influences of temperature, density and measurement time are observed.

Introduction

There are four accredited laboratories under JCSS system (Japan Calibration Service System) for water flow in Japan as of March 2013, which are Azbil Corporation (hereafter, Azbil), Endress+Hauser Japan Co. Ltd. (E+H Japan), Shimadzu System Solutions Co. Ltd. (Shimadzu) and Yokogawa Electric Co. Ltd. (Yokogawa). The calibration method of them is a static gravimetric method using weighing tanks except a part and flowrate range is from 0.002 m^3/h to 1200 m^3/h. According to JCSS system, proficiency tests must be conducted generally at the maximum flowrate for the test line, the maximum and minimum flowrate for the weighing tank system [1]. The test at maximum flowrate of a weighing tank is to check a diverter system and minimum flowrate is to check the influence of leak and vaporization. The test at maximum flowrate for the test line means to check the influence of the velocity profile. The validity of the calibration facility in accredited lab is decided by En value which is obtained by the comparison between NMIJ and accredited lab. This proficiency test is one of the strictest one all over the world. The proficiency tests using a turbine or Coriolis flowmeter for all accredited labs were carried out and the validities of the calibration facilities in them have been confirmed.

Turbine or Coriolis flowmeters which were also used in WGFF/CCM.K1 [2] and APMP comparison [3] are most suitable transfer meters for the comparison of water flow calibration facilities since these flowmeters have high stability. To evaluate the weighing tank system including characteristics of the diverter system, a high stability and high repeatability are essential for transfer flowmeters. On the other hand, the calibration test for other flowmeters such as electromagnetic and ultrasonic flowmeters does not guarantee the result without a meaningful difference among the accredited labs even if the validity was confirmed by the comparison using the turbine or Coriolis flowmeter. Because the influential factor to the other flowmeters is different with turbine and Coriolis flowmeters. In general, it is difficult to carry out the comparison under complete same flow field condition such as temperature, pressure, density and velocity profile. Therefore, it is very important to carry out the comparison using many types of the flowmeter to conduct the actual evaluation of the calibration facility.

As mentioned above, the comparison between NMIJ and accredited laboratories carried out as the proficiency test. In addition of the proficiency tests, we carried out the comparison using larger number of transfer meters not only turbine and Coriolis but also orifice, electromagnetic and ultrasonic flowmeters to establish reliability of the calibration for each flowmeters. In this presentation, the comparison result and evaluation of these flowmeters are described for wide flowrate range from 0.005 m^3/h to 5000 m^3/h. In the evaluation of the flowmeter, meter characteristics for influential factors to the flowmeters are discussed using the flow field data in the comparison.

Table 1 Specifications of calibration facility in NMIJ

System	Method	Flowrate range (m^3/h)	Pipe diameter (mm)	Uncertainty (k=2)
High Reynolds number	Comparison	750 ~ 12000	200 ~ 600	0.081 %
Large flowrate (50 t)	Weighing	50 ~ 3000	100 ~ 400	0.060 %
Medium flowrate (5 t)	Weighing	5 ~ 300	15 ~ 400	0.040 %
Medium flowrate (500 kg)	Weighing	0.3 ~ 30	15 ~ 250	0.042 %
Small flowrate (10 kg)	Weighing	0.002 ~ 1.2	≤ 25	0.039 %

Experimental facility

Facility in NMIJ

NMIJ has five calibration systems to supply the wide range flowrate standard as shown in Table 1. Flowrate range is from 0.002 m^3/h to 12000 m^3/h. Except the high Reynolds number rig, the reference standard of flowrate is given by the static gravimetric method using weighing tanks. In these rigs, water is supplied to the test section from the over flow head tank whose height is 30 m and capacity is 150 m^3. In the high Reynolds number calibration rig, water is supplied by four pumps and the calibration is normally carried out by the comparison method. Details of these calibration rigs are described in the previous papers [4][5].

Facility in accredited laboratories

Schematic diagrams of the calibration facility in the accredited laboratories are shown in Fig.1 and flowrate range, available pipe diameter and uncertainty for each accredited laboratory are listed in Table 2. Fig.1(a) and (d) are one part of the all calibration facility and the drawing rigs in the figures are the parts accredited. Table 2 also only show the specifications accredited. Water is supplied to the test section from over flow head tank and the upstream straight pipe length is over 50D except E+H Japan. Reference flowrate of all accredited laboratories is given by the static weighing tank method expect a part. Only for lower flowrate in E+H Japan, the reference flowrate is given by the volumetric method using the cylinder.

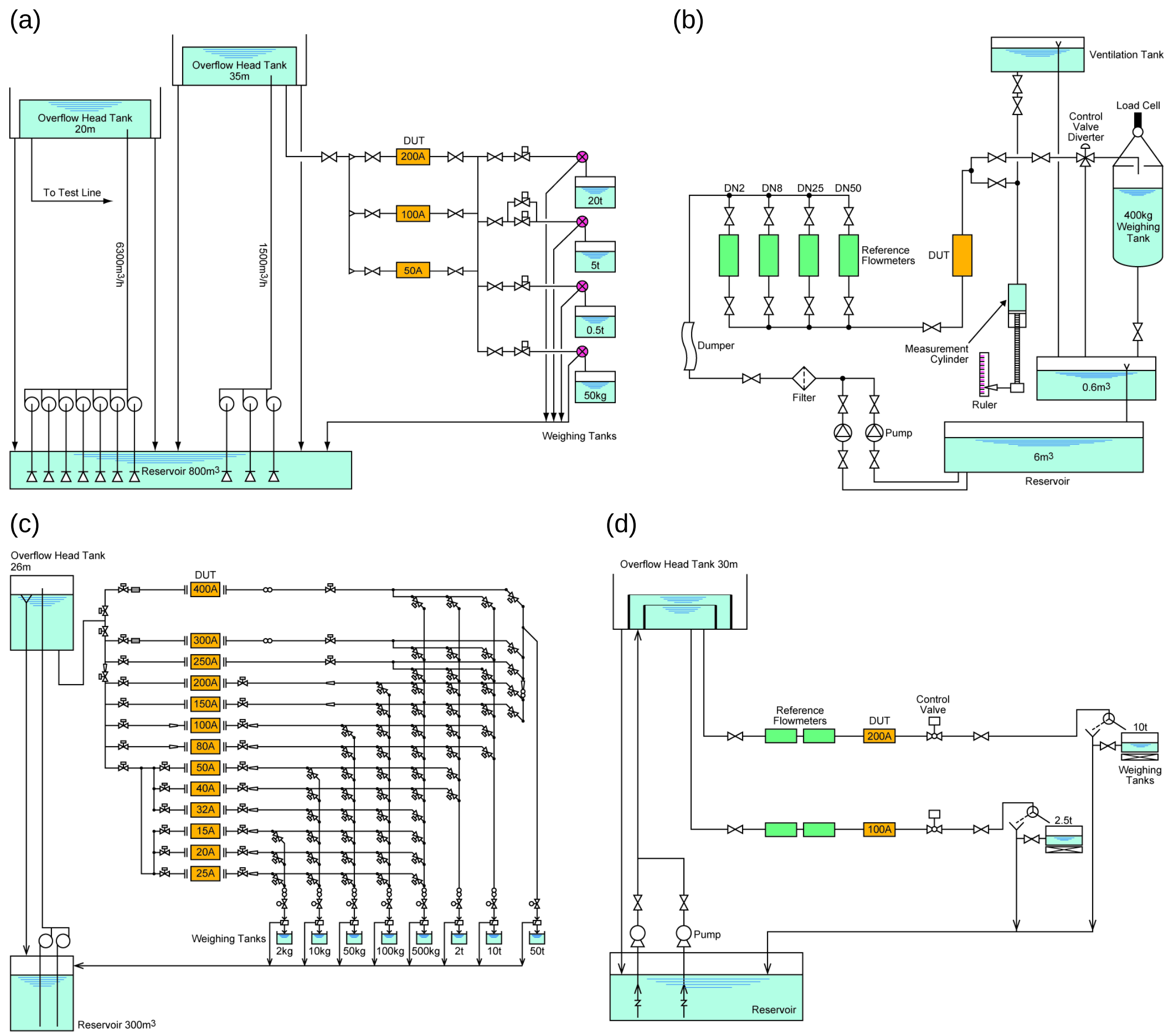

Fig.1 Schematic diagrams of water calibration facility in accredited laboratories
(a) Azbil, (b) E+H Japan, (c) Shimadzu, (d) Yokogawa

Table.2 Specifications of calibration facility in accredited laboratories

Lab.	Method	Flowrate range (m^3/h)	Pipe diameter (mm)	Uncertainty (k=2)
Azbil	Weighing	0.09 ~ 650	50 ~ 200	0.10 %
E+H Japan	Weighing and Cylinder	0.002 ~ 40	4 ~ 80	0.050 %
Shimadzu	Weighing	0.008 ~ 1200	15 ~ 400	0.13%～0.23%
Yokogawa	Weighing	50 ~ 630	50 ~ 200	0.13%～0.17%

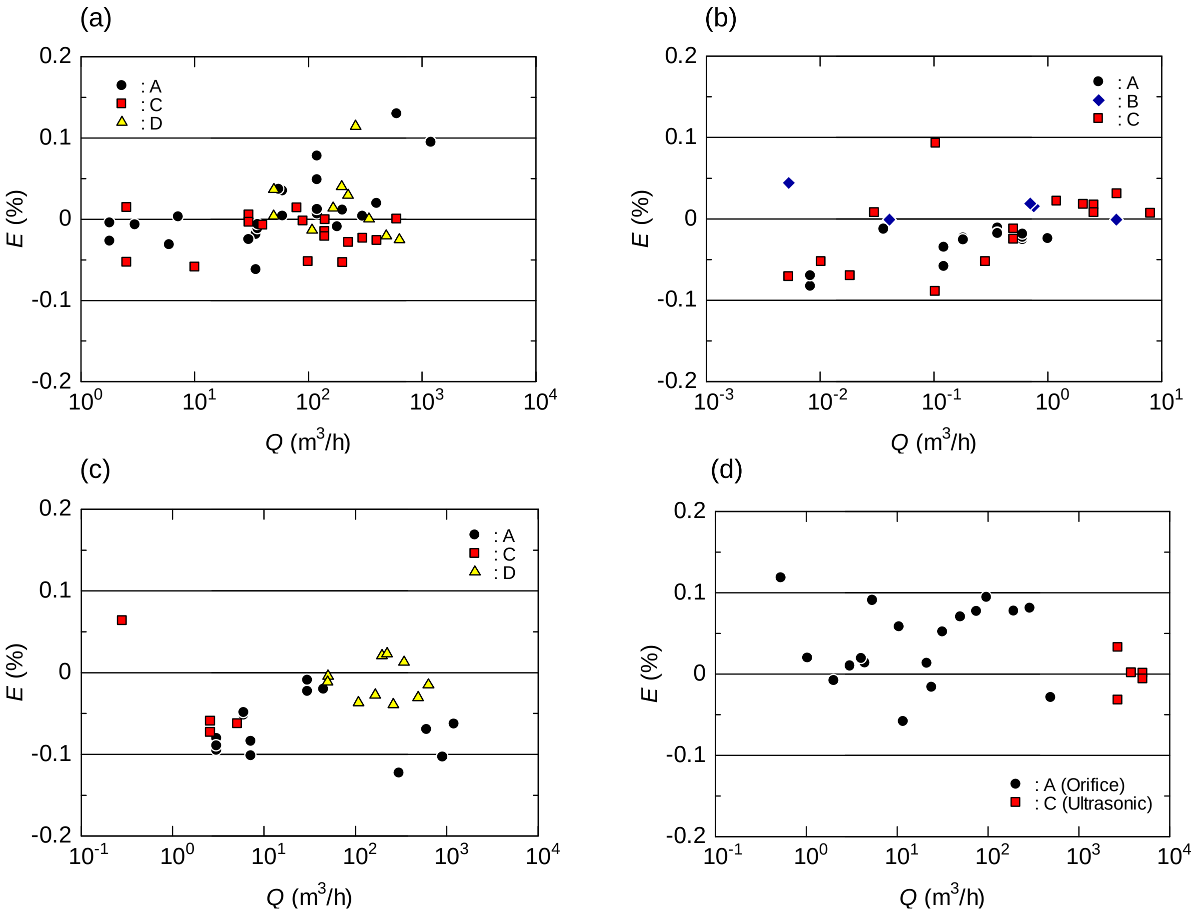

Fig.2 Comparison results using (a) turbine, (b) Coriolis, (c) electromagnetic, (d) orifice and ultrasonic flowmeters

Transfer meters and condition

In this comparison test, 8 turbine flowmeters (T-1~T-8) whose diameter is from 25 mm to 400 mm, 5 Coriolis flowmeters (C-1~C-5) whose diameter is from 2 mm to 50 mm, 5 electromagnetic flowmeters (E-1~E-5) whose diameter is form 15 mm to 300mm, 4 orifice flowmeters (O-1~O-4) whose diameter is from 20 mm to 200 mm and 1 ultrasonic flowmeter (U-1) whose diameter is 600 mm are used to cover the wide flowrate range. Reproducibility of them are checked mainly by the several calibration results under different condition in NMIJ. The reproducibility is 0.01%~0.07% for turbine, 0.01%~0.03% for Coriolis, 0.03%~0.08% for electromagnetic, 0.05%~0.2%

Flowrate range in this comparison is from 0.005 m^3/h to 5000 m^3/h. Temperature of the water and ambient air surrounding of the test meter is not strictly controlled and temperature range in this comparison is from 11 °C to 31 °C and from 9 °C to 33 °C, respectively. Pressure depends on flowrate and it is from 0.1 MPa to 0.5 MPa.

Comparison results

The evaluation of the comparisons is conducted by K factor except the orifice flowmeters. The K factor is calculated by volumetric flowrate except Coriolis flowmeter. For Coriolis flowmeter, mass flowrate is used to the comparisons. Only for the turbine flowmeters, the K factor is corrected to one at 20 °C for the thermal expansion. For the orifice flowmeters, the evaluation of the comparisons is conducted by the discharge coefficient under same Reynolds number.

The comparison results for each flowmeter are shown in Fig.2. A to D in the explanatory note mean the accredited labs. It should be noted that the actual names of the accredited labs are blinded and they are not corresponding to Fig.1. As shown in these figures, the deviations are approximately within 0.1% for all flowmeters and it is difficult to find any dependency of the accredited labs and experimental flowrate. In the international comparison WGFF/CCM-K1, the deviation from the degree of equivalence is from -0.079% to 0.065% (NMIJ: -0.007%) for the turbine transfer flowmeter and from -0.069% to 0.065% (NMIJ: 0.019%) for the Coriolis transfer flowmeter[2]. The range of the deviations in this paper is equivalent level with the international comparison, especially, for the turbine and Coriolis transfer meter. Moreover, En value of all results is under 1 in this comparison. These results indicate the high capability of the calibration facilities in each accredited lab.

As shown in Fig.2, the deviations depend on each measurement. As one of the index to indicate the capability of the accredited labs, the average of the deviations is calculated and the averaged deviations are shown in Fig.3. The averaged deviations are from -0.068% to 0.038%. It should be made an attention to the differences depend on the flowmeters in this figure. The white large circles in Fig.3 mean the averaged deviations for each flowmeter. The averaged deviation for the turbine flowmeters and the ultrasonic flowmeters are very small. The test results by accredited labs are

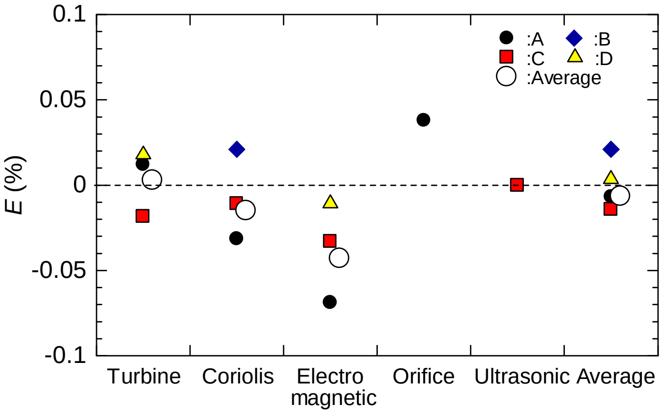

Fig.3 Averaged deviation

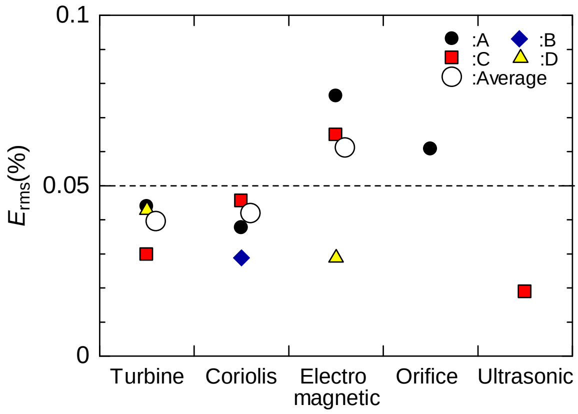

Fig.4 Root mean square of deviation

approximately equal to NMIJs. Also, the comparison result for Coriolis flowmeter is in good agreement. On the other hand, electromagnetic and Orifice flowmeters are relatively larger than other meters although it is within 0.05%. As mentioned in the introduction, the result in comparison might be difference for different flowmeters. To establish the reliable evaluation of the calibration facility, a comparison should be conducted using many types of flowmeter.

The averaged deviations for each accredited lab are within 0.025% as shown in the rightest hand in Fig.3. In the international comparison by WGFF/CCM.K1, the averaged deviation for each lab is from -0.063% to 0.046% (NMIJ : 0.006%). Compared with the result in the international comparison, the result of the presented comparison shows a high equivalency. This indicates that un-expected deviation is possible to observe in the case of that measurement points are a few and unique transfer flowmeters are used. Finally, the averaged deviation for all experiment is -0.006%. This result indicates also high ability of the measurement in NMIJ.

To investigate the dispersion of the measurement result, the root mean square of the deviation is obtained and the result for each transfer flowmeters is shown in Fig.4. The dispersion of the comparison result of turbine and Coriolis flowmeters is approximately 0.04%. Compared with these meters, one of the electromagnetic flowmeters is large, approximately 0.06%. These values are equivalent level of the reproducibility of the transfer meters. Moreover, Fig.4 also indicates that the dependency of the dispersion is small among the accredited labs. This result obviously indicates that the most of the deviation in the comparison is contributed by the reproducibility of the transfer flowmeters. In the next section, the influence factor to the test meter is investigated using the field data in the comparisons.

Meter characteristics

As mentioned in the previous section, the most of the deviations in the comparison between NMIJ and the accredited labs are caused by the reproducibility of the transfer flowmeters. Flowmeters are generally influenced by field conditions such as temperature, pressure, density and so on and they relate to the reproducibility. To achieve a reliable comparison and to know the reason of the deviation of each measurement in this comparison, it is very important to investigate the meter characteristics for the field conditions. In this section, the meter characteristics for measurement time, temperature and density is investigated using the flow field data in the comparison. Since the validities of the calibration facilities in each accredited lab have already established, this investigations for the meter characteristics can supply reliable information for comparison tests.

The characteristics of the transfer meters are shown in Fig.5-Fig.7 for several parameters. Figures (a) show influences of the duration time t_d. This evaluation is to investigate the time responsibility of the transfer flowmeters. Figures (b) show influences of the temperature difference between NMIJ and the accredited labs. *Tn* and *Ta* is an averaged water temperature of the measurement in NMIJ and the accredited labs, respectively. Normally, general flowmeters has a temperature dependency which is caused by the thermal expansion and velocity profile depending on Reynolds number. Although K factor is corrected for the turbine and ultrasonic transfer flowmeter for the thermal expansion, it is very important to investigate the temperature dependency. Figures (c) show influences of the temperature difference between water and outside temperature. *Tw* and *To* are water and air temperature surrounding the transfer flowmeters, respectively. Finally, figures (d) show influences of the density of water, namely difference of density. In here, the evaluation is performed by the correction value of density ρ_c.

For the turbine transfer flowmeters, the results for all factors are shown. For the Coriolis and electromagnetic flowmeters, the results for influential factors are only shown in this paper. In these figures, the fitting lines are drawn if the influence is observed over 0.03% within the measurement range.

Figure 5 shows the meter characteristics of the turbine transfer flowmeters. An influence of the temperature difference is observed in this comparison. The dotted line in Fig.5(b) is a fitting curve for all experimental deviations. The weak influence of the temperature difference between labs is observed although the correction for the thermal expansion of the meter body is conducted. The influence of the temperature difference for the turbine transfer flowmeter is approximately ±0.02% for ±10 °C in this comparison.

Figure 6 shows the meter characteristics of the Coriolis transfer flowmeters. A weak influence of the temperature difference between NMIJ and the accredited labs and the difference of density can be observed in Fig.6(b) and Fig.6(d). For the temperature difference, the

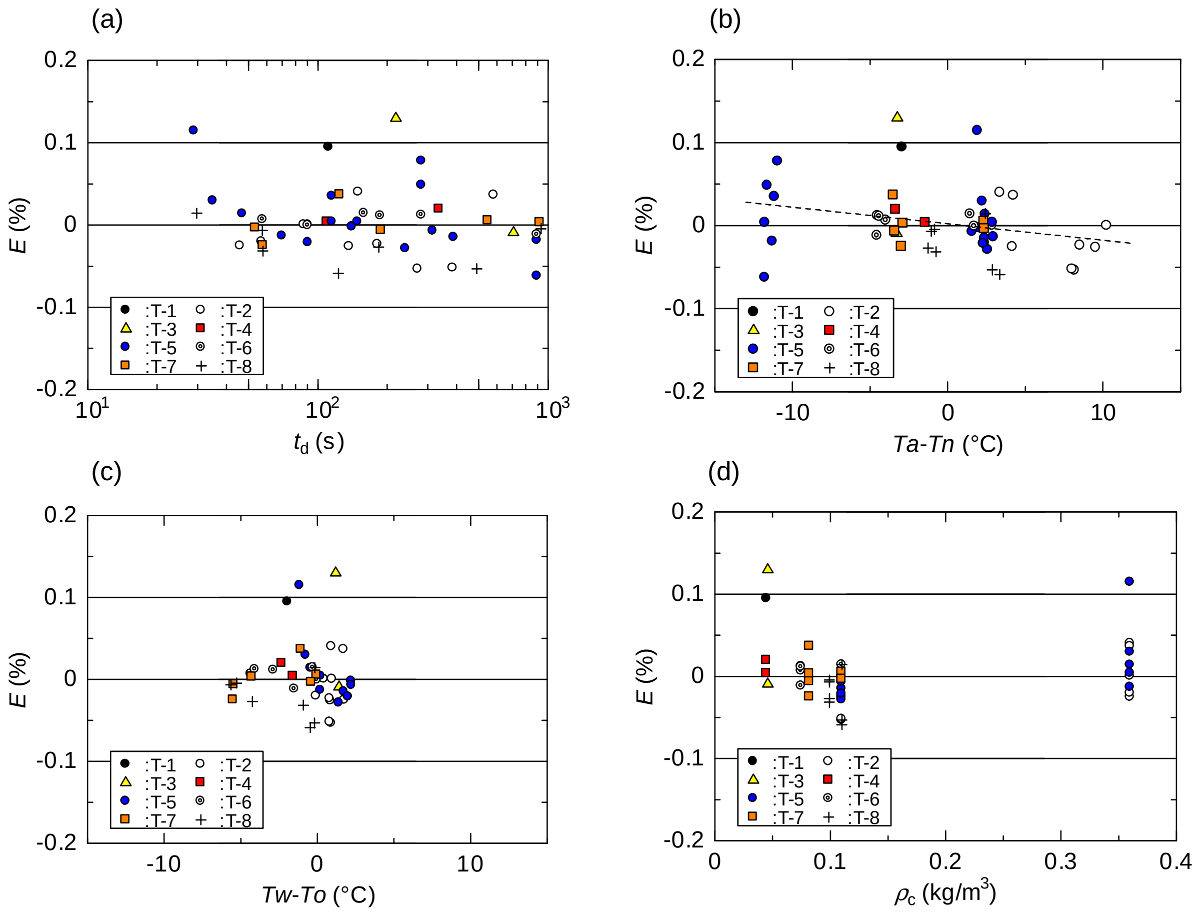

Fig.5 Meter characteristics of turbine transfer flowmeters in comparisons

influence observed by the linear fitting line is very weak for the all measurement temperature. However, compared with the influences of other factors, it seems that the dependency of the temperature is clear. Although additional measurements are necessary for the temperature influence to clarify it, the temperature difference has a possibility to be a one of error factor in this comparison. The influence of the difference of density is also weak. Although measurement data is not sufficient to conclude the influence of the density, the difference of density has also possibility to be a one of error factor in this comparison.

Figure 7 shows the meter characteristics of the electromagnetic and ultrasonic transfer flowmeters. The fitting line is obtained only for the electromagnetic flowmeters. As shown in Fig.7(c), the influence of the temperature difference between water and air surrounding the test meter is observed clearly in this comparison and it is approximately 0.1% in the experimental range of air temperature. Since the influences by other factors are relatively small than the temperature difference between water and air, this effect might be dominant factor to the deviation in the comparison for the electromagnetic flowmeter. As shown in Fig.3, the deviation of the electromagnetic flowmeter is larger than other transfer flowmeters. There is possibility to reduce the deviation by reducing the temperature difference between water and air. By the correction according to the fitting line in Fig.7(c), the averaged deviation can be reduced to -0.015% and it is equivalent level with the other transfer flowmeters.

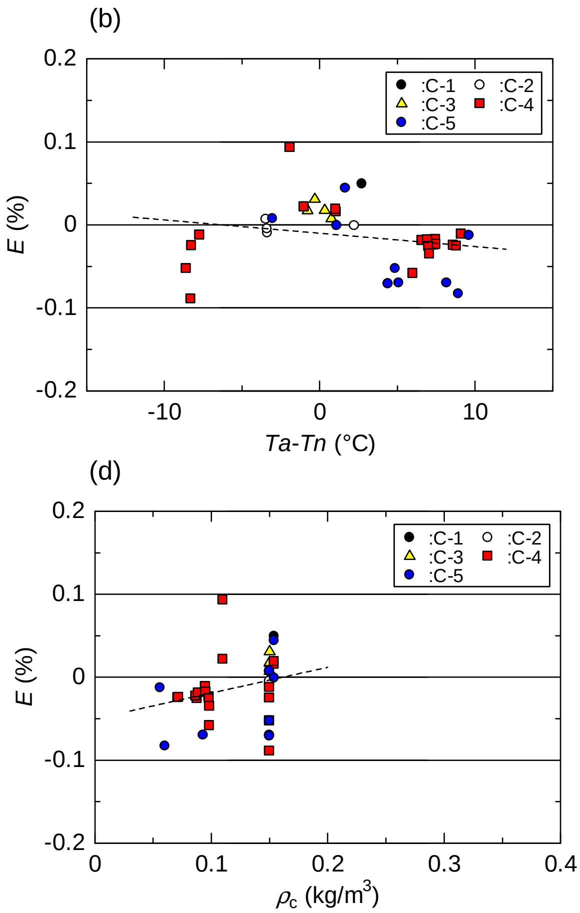

Fig.6 Meter characteristics of Coriolis transfer flowmeters in comparisons

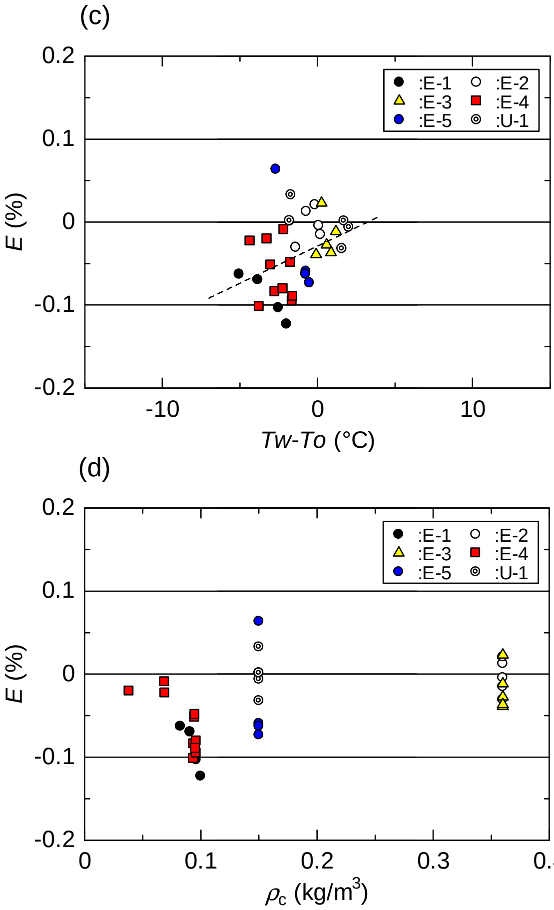

Fig.7 Meter characteristics of electromagnetic and ultrasonic transfer flowmeters in comparisons

Conclusion

The inter-laboratory comparisons are carried out between NMIJ and four JCSS accredited laboratories in Japan for wide flowrate range from 0.005 m^3/h to 5000 m^3/h. The transfer flowmeters used in this comparison are turbine, Coriolis, electromagnetic, ultrasonic and orifice. The deviation of the test results by the accredited labs from by NMIJ is within approximately 0.1% and En values for all measurements are less than 1. The averages of the deviations are within 0.025% for all accredited labs. These results indicate a high capability of the calibration facilities in the accredited labs.

On the other hand, the trends of the deviations for each transfer flowmeter show difference. The test results of the turbine flowmeters and Coriolis flowmeters are in good agreement between NMIJ and the accredited labs and that is less than 0.02% as the average. However, the deviations of electromagnetic flowmeter are larger than other transfer flowmeters although that is approximately 0.05%. To investigate the reason of the deviation in detail, the influences of the temperature, density and measurement time are observed. The relation between the deviation in the comparison and the measurement time, the temperature difference of water between NMIJ and the accredited labs, the temperature difference between water and air surrounding the test meter and the density correction are obtained. For the turbine flowmeter and Coriolis transfer flowmeters, a weak influence of the temperature difference between NMIJ and accredited labs are observed. For the Coriolis transfer flowmeters, a weak influence of the density is also observed. On the other hand, the large influence of the temperature difference between water and air surrounding the test meter is observed for the electromagnetic transfer flowmeter. This result is not general one, however, it should be regarded that this factor is one of the influenced factor to the comparison.

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