Final Report on the Key Comparison

Liquid Hydrocarbon Flow

(CCM.FF-K2.2015)

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1. Introduction

This key comparison, CCM.FF-K2.2015 for hydrocarbon flow measurement has been undertaken by CCM (Consultative Committee for Mass and related quantities) Working Group for Fluid Flow (CCM/WGFF), and was piloted by National Metrology Institute of Japan (NMIJ/AIST). The objective of this key comparison is to determine the key comparison reference values (KCRVs) for hydrocarbon flow measurement and to demonstrate the degree of equivalence among the participating National Metrology Institutes (NMIs). The participating NMIs calibrated a transfer standard and compared their calibration results. The identifier, CCM.FF-K2.2015 evolved from CCM.FF.K2.2.2011.

This Draft B report was prepared in accordance with some guidelines [1]~[4].

2. Participants and organization of the comparison

2.1. List of participants

The participants are listed in Table 1.

Table 1 List of the participating NMIs

	Participating NMI (Economy)	Contact Person and E-mail Address Phone Number Shipping Address
1	BEV (Austria)	Contact 1: Gerhard Baubinder, gerhard.baubinder@bev.gv.at Contact 2: Karin Bittner-Rohrhofer, karin.bittner-rohrhofer@bev.gv.at +43 1 21110 6518 Bundesamt für Eich- und Vermessungswesen A-1160 Vienna, Arltgasse 35, AUSTRIA
2	CENAM (México)	Contact 1: Víctor J. Medina López, vmedina@cenam.mx, Contact 2: Roberto Arias R., rarias@cenam.mx +52-442-211-05-00 Centro Nacional de Metrología Km 4.5 Carr. a los Cués El Marqués, Querétaro C.P. 76246, MEXICO
3	CMS/ITRI (Chinese Taipei)	Contact 1:Chun-Min Su, CMSu@itri.org.tw Contact 2: I-Cheng Chen, IchengChen@itri.org.tw +886-3-5741205 Center for Measurement Standards 30 Ta Hsueh Road, Hsinchu, TAIWAN
4	LNE-TRAPIL (France)	Fabien Ribere, fribere@trapil.com +33 1 47 92 48 23 / 48 20 Société des Transports Pétroliers par pipelines 14 route du Bassin n°5, 92230 Gennevilliers, FRANCE
5	NEL (UK)	Linda Rowan, lrowan@tuvnel.com 01355 593829 TUV NEL Ltd, East Kilbride, Glasgow G75 0QF, UK
6	NMIA (Australia)	Simon Dignan, simon.dignan@measurement.gov.au +61 2 8467 3514 National Measurement Institute, Australia Bradfield Road, West Lindfield, NSW, 2070, AUSTRTALA
7 Pilot	NMIJ/AIST (Japan)	Takashi Shimada, ff-k2-ml@aist.go.jp +81-29-861-4377 National Metrology Institute of Japan National Institute of Advanced Industrial Science and Technology AIST North site 14, 1497-1 Teragu, Tsukuba, Ibaraki, 300-4201, JAPAN

2.2. Comparison schedule

The actual testing dates at each participant are listed in Table 2.

Table 2 Participants and test schedule.

Participating NMI	From	To
NMIJ (#1)	July 1, 2014	August 5, 2014
BEV	September 22, 2014	September 24, 2014
LNE-TRAPIL	October 8, 2014	October 8, 2014
NEL	November 26, 2014	November 28, 2014
CENAM	January 27, 2015	January 28, 2015
NMIA	April 8, 2015	April 9, 2015
NMIJ (#2)	May 13, 2015	May 25, 2015
CMS/ITRI	June 18, 2015	June 29, 2015
NMIJ (#3)	July 27, 2015	September 9, 2015

3. Transfer standard and measurement instruction

3.1. Description of the transfer standard

A screw type positive displacement flow meter was used as a transfer standard. The specification of the flow meter is shown in Table 3. The schematic of the transfer package is shown in Fig. 1. The pictures of the flowmeter, the display, the strainer with pipe and the box for transportation are shown in Fig. 2 to Fig. 5.

Table 3 Specification of transfer package

Flow meter	Manufacturers	KRAL
	Type	OMG140
	Inlet diameter	150 mm
	Flange	6” ANSI 150lb RF
	Size	610 mm (L), 267 mm (D)
	Weight	180 kg
	Maximum flow rate (normal)	450 m^3/h (300 m^3/h)
	Converter type	BEG 47
	Class of protection	EEx ia IIC T6
Display with safety barrier	Pulse output type	TTL, Open corrector or 24V pulse
	Power supply	AC85 ~ 264V
	Size	160 mm X 230 mm X 260 mm
Upstream pipe	Flange	6” ANSI 150lb RF
	Pipe	6” Sch40
	Filter	10 mesh per inch
Box A	Size, L, W, H (mm)	630 mm X 990 mm X 755 mm
	Weight	280 kg in total
Box B (Reinforced cardboard box)	Size, L, W, H (mm)	380 mm X 380 mm X 410 mm
	Weight	45 kg in total

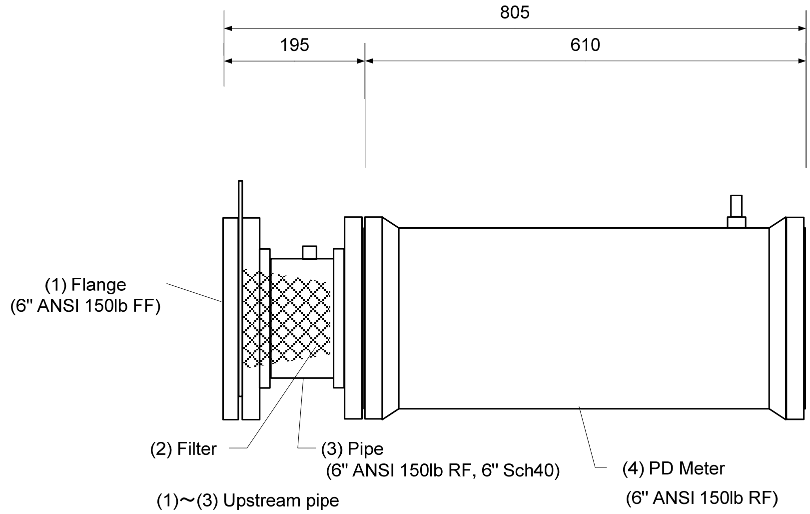


Fig. 1 Schematic of the package

Fig. 2 Flow meter

Fig. 3 Display with safety barrier

Fig. 4 Upstream pipe

Fig. 5 Box A for transport

3.2. Quantities to be measured and conditions of measurement

The participants calculated actual K factors at calibration condition. The K factors obtained at the participants were used to calculate a corrected K factor based on 20 ºC expressed as:

$$K_{f20} = K_f \left\{1 + 3\alpha\left(t - 20\right)\right\} \tag{1}$$

K_{f20} : Corrected K-factor (p/L)

K_f : K factor (p/L)

α : Coefficient of linear expansion of material. (Carbon steel for flow meter, =1.1 × 10^{-5} (ºC^{-1}))

t : Temperature at calibration condition (ºC)

The relative K factor against the nominal K factor of the transfer standard K is given by Equation (2).

$$K = \frac{K_{f20} - K_{fnom}}{K_{fnom}} \tag{2}$$

K : Relative K factor (-)

K_{fnom} : Nominal K factor (= 8.837 p/L)

The test points are listed in Table 4. The three cardinal points were the flow rates at Reynolds numbers of 70 000, 100 000 and 300 000. The participants calibrated the transfer standard at Re of 100 000 at least. The required flow rate was between 60 m^3/h and 300 m^3/h at the cardinal points. Some measurements out of the required flow rate range were regarded as informative results. The liquid temperature through the transfer standard at calibration condition was approximately between 20 ºC and 30 ºC. The kinematic viscosity of liquid at calibration condition was between 1.5 mm^2/s and 7.0 mm^2/s. The back pressure downstream of the flow meter was more than 0.1 MPa. The pressure at the flow meter was between 0.1 MPa and 0.6 MPa.

In NMIA a small volume prover is used as a reference standard. Therefore, the number of passes followed normal procedure at NMIA. The number of passes (strokes) was reported in the results data sheet.

Table 4 Flow rates and test sequence

Flowrate m^3/h (L/s)	Reynolds no	Recommended No of reputation measurements	Approx. Frequency (Hz)
60 (16.7)		2	150
120 (33.3)		2	290
180 (50.0)		2	440
240 (66.7)		2	590
300 (83.3)		2	740
Cardinal point	70 000	6	
Cardinal point	100 000	6	
Cardinal point	300 000	6	
Total No of points		28	

From the fluid properties and the flow rate, the Reynolds number at each flow rate was calculated. Reynolds number is expressed as

$$\mathrm{Re} = \frac{4\rho Q}{\pi \mu D} \tag{3}$$

Q : Volumetric flow rate (m^3/s)
ρ : Density (kg/m^3)
D : Package inlet diameter as given (= 0.15 m)
μ : Dynamic viscosity (Pa·s)

Reynolds number is based on the inlet diameter of the flow meter upstream pipe (= 0.15 m). The volumetric flow rate through the flow meter was used to set the Reynolds number. Difference of Reynolds number from the cardinal points was less than ± 5 %.

4. Methods of measurement

A summary of the calibration methods used by the participants is shown in Table 5. Details are given in Appendix B.

Table 5 Calibration method

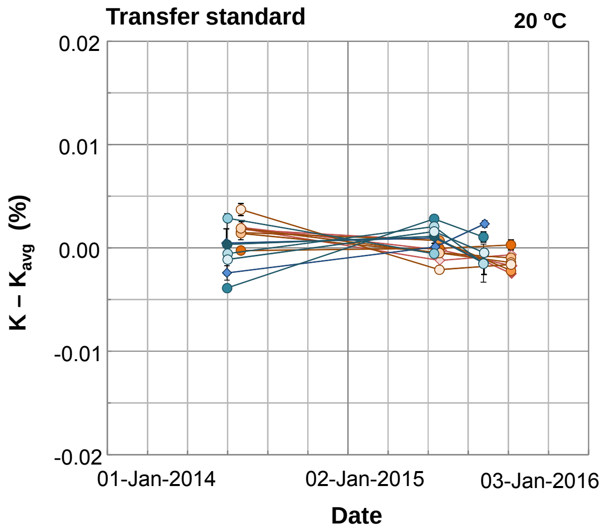
NMI	Calibration method	Reference standard
BEV	Volumetric method with flying start and stop	Volume tank
CENAM	Volumetric method with flying start and stop	Unidirectional Pipe prover
CMS	Static and gravimetric method with standing start and stop	Weighing scale
LNE-TRAPIL	Volumetric method with flying start and stop	Unidirectional Pipe prover
NEL	Static and gravimetric method with standing start and stop	Weighing scale
NMIA	Volumetric method with flying start and stop	Small volume prover
NMIJ	Static and gravimetric method with flying start and stop	Weighing scale

5. Repeated measurements at the pilot institute, behavior of the transfer standard

From the measurements at the pilot institute, NMIJ, the performance of the transfer standard and its stability was evaluated.

5.1. Reproducibility

The deviation of relative K factors against the averaged K factors obtained at 20 ºC in NMIJ during CCM.FF-K2.2015 is shown in Fig. 6. The maximum standard deviation of K factors during CCM.FF-K2.2015 is 0.003 5 % at a flow rate of 240 m^3/h in light oil. The standard uncertainty due to reproducibility of the transfer standard including transport effect is estimated to be 0.003 5 %.



Liquid	Flow rate	Marker	Standard deviation (%)
Kerosene	Re=300,000		0.0022
	Re=100,000		0.0016
	Re= 70,000		0.0019
	300 m³/h		0.0020
	240 m³/h		0.0003
	180 m³/h		0.0013
	120 m³/h		0.0017
	60 m³/h		0.0032
Light oil	Re=100,000		0.0013
	Re= 70,000		0.0024
	300 m³/h		0.0013
	240 m³/h		**0.0035**
	180 m³/h		0.0026
	120 m³/h		0.0019
	60 m³/h		0.0014

Fig. 6 Deviation of relative K factors against averaged relative K factors at NMIJ

5.2. Temperature and viscosity effect

The transfer standard was calibrated at different temperature in kerosene (KE) and light oil (LO) at NMIJ before the comparison in order to investigate the effect due to temperature and viscosity on the K factors. The calibration flow rates were between 60 m^3/h and 300 m^3/h. The calibration temperatures were 15 ºC, 20 ºC, 25 ºC, 30 ºC and 35 ºC. The relative K factor of the transfer standard at different temperature is shown in **Fig. 7**. The standard deviation due to temperature and viscosity at the cardinal points is shown in Table 6. The standard uncertainty due to the difference of temperature and viscosity between each pair of the participants is estimated to be 0.005 8 % at maximum.

Table 6 Standard deviation due to temperature and viscosity at the cardinal points

Re (-)	Maximum Viscosity (mm^2/s)	Minimum Viscosity (mm^2/s)	Standard deviation of K (%)
300 000	2.13	1.52	0.002 5
100 000	6.95	1.52	0.005 7
70 000	8.18	1.52	0.005 8

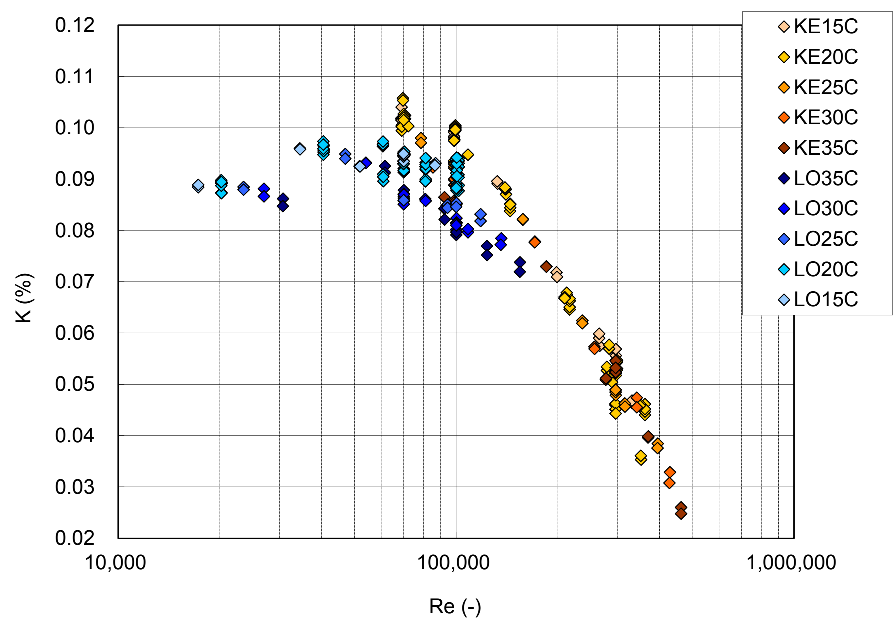


Fig. 7 Relative K factor of transfer standard at different temperature in NMIJ

5.3. Linearity

The corrected K factor, of which the flow rate is more than 60 m^3/h and Re is more than 50 000, was described by the quadratic function expressed by Equation(4).

$$K_{f20} = a\mathrm{Ln}^2(\mathrm{Re}) + \mathrm{b}\mathrm{Ln}(\mathrm{Re}) + c \tag{4}$$

a = -1.594998×10^{-3}, b = 3.527330×10^{-2}, c = 8.65029.

The sensitivity coefficient of the corrected K factors against Re is obtained by Equation(5).

$$\frac{\partial K_{f20}}{\partial \mathrm{Re}} = 2a\frac{\mathrm{Ln}(\mathrm{Re})}{\mathrm{Re}} + \frac{\mathrm{b}}{\mathrm{Re}} \tag{5}$$

The relative standard uncertainty of the K factors due to the uncertainty of Re is obtained by Equation(6), assumed that the uncertainty of Re is 5 % since the deviations of Reynolds number at the cardinal points are less than ± 5 %.

$$\left|\frac{\partial K_{f20}}{\partial \mathrm{Re}}\right| \frac{u(\mathrm{Re})}{K_{fnom}} = \frac{0.1a\mathrm{Ln}(\mathrm{Re}) + 0.05\mathrm{b}}{K_{fnom}} \tag{6}$$

The relative standard uncertainty due to the differences of Re at the cardinal points between each pair of the participants is estimated to be less than 0.002 8 % at Re of 300 000.

5.4. Pressure effect

The relative K factor of the transfer standard at different pressure is shown in Fig. 8. The calibration liquid was light oil and the liquid temperature was 35 ºC. The pressure effect on the relative K factors is less than 0.003 4 %/MPa, and the difference of liquid pressure between each pair of the participants is estimated to be less than ± 0.25 MPa. Therefore, the standard uncertainty due to the difference of the pressure between each pair of the participants is estimated to be 0.000 9 %.

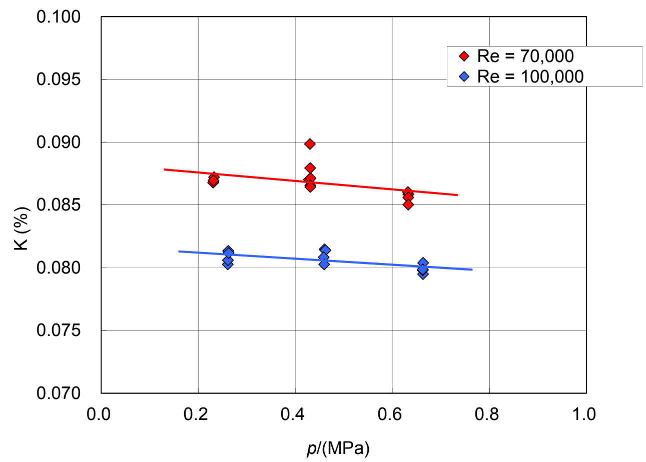


Fig. 8 Relative K factor of transfer standard at different pressure

5.5. Effect due to upstream condition

The strainer was set upstream of the transfer standard at calibration in the comparison and the PD meter was used as the transfer standard, indicating that the transfer package is hardly affected by the upstream condition in the test rig of the participants. The effect due to the upstream condition was estimated from the difference of the K factors with the strainer from those without the strainer. The relative difference of the K factors with the strainer from those without the strainer is shown in Fig. 9.

The calibration liquid was light oil and the temperature was 20 ºC. In addition, a PD meter, which is the same type as the transfer standard was also calibrated. From the results, the relative standard uncertainty due to the difference of the upstream condition between each pair of the participants u_{STR} is estimated to be 0.003 1 % by Equation (7).

$$u_{STR} = \overline{dK_{STR}} + u\left(\overline{dK_{STR}}\right) \quad (7)$$

$\overline{dK_{STR}}$ and $u\left(\overline{dK_{STR}}\right)$ indicate the mean of the relative differences and the standard deviation of the mean.

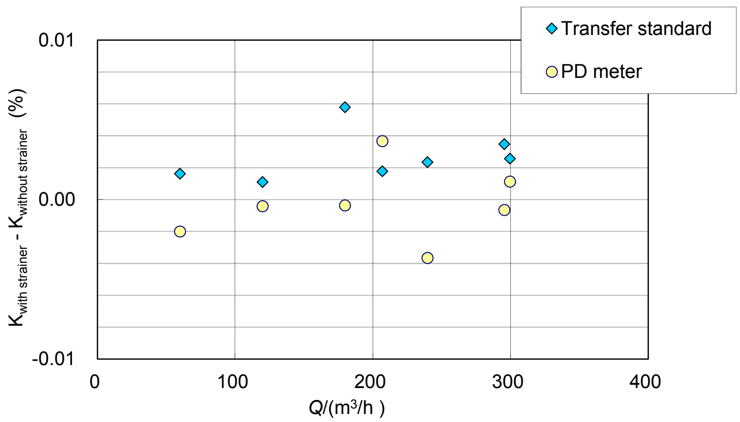


Fig. 9 Relative difference of K factor with the strainer from those without the strainer

6. Measurement results

6.1. Results of the participating institutes

The relative K factor reported from all participants is shown in Fig. 10. All of the reported values are listed in Appendix A, including the data reduction performed by the pilot lab.

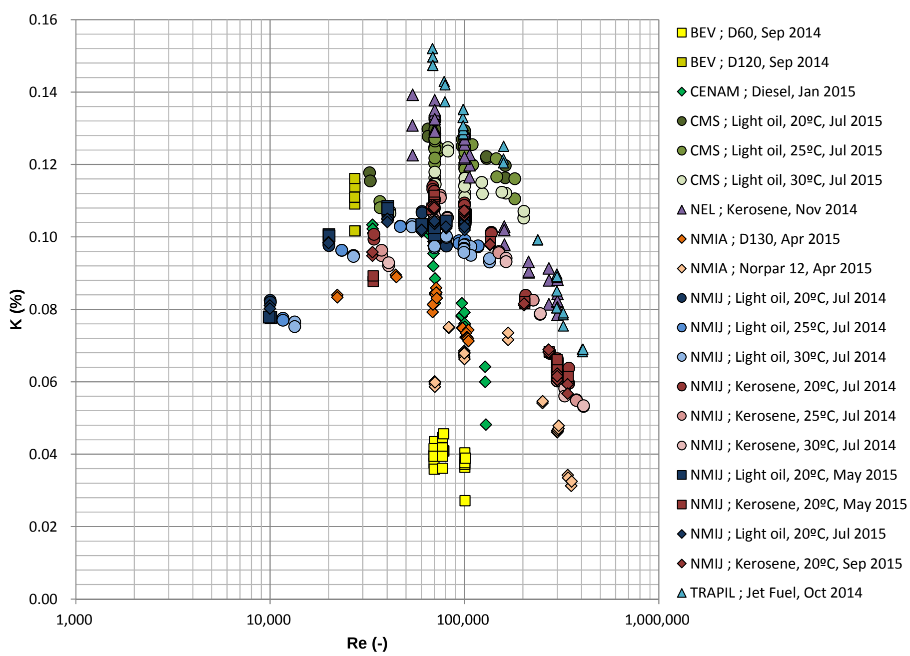


Fig. 10 Relative K factors obtained by the all participants.

6.2. Calculation of the reference value and its uncertainty

The analysis of the results was carried out according to the methods specified by

Cox[4].

At Reynolds numbers of 70 000, 100 000 and 300 000, the key comparison reference values (KCRV) of CCM.FF-K2.2015 K_{KCRV} are obtained as the weighted mean by Equation (8) using the relative K factor K_i and the standard uncertainty of the calibration results $u\left(K_i\right)$ at the participating laboratory i. The uncertainty of the KCRV of CCM.FF-K2.2015 $u\left(K_{\mathrm{KCRV}}\right)$ is expressed by Equation (9).

$$K_{\mathrm{KCRV}} = \frac{\sum_i^n \left(K_i / u^2\left(K_i\right)\right)}{\sum_i^n \left(1 / u^2\left(K_i\right)\right)} \tag{8}$$

$$\frac{1}{u^2\left(K_{\mathrm{KCRV}}\right)} = \sum_i^n \left(\frac{1}{u^2\left(K_i\right)}\right) \tag{9}$$

The expanded uncertainty of the KCRV of CCM.FF-K2.2015 $U\left(K_{\mathrm{KCRV}}\right)$ is obtained by Equation (10).

$$U\left(K_{\mathrm{KCRV}}\right) = k \cdot u\left(K_{\mathrm{KCRV}}\right) = 2u\left(K_{\mathrm{KCRV}}\right) \tag{10}$$

The standard uncertainty of the calibration results, that is the relative K factor at each participating laboratory, is expressed by Equation (11).

$$\begin{aligned} u^2\left(K_i\right) &= u_{f,i}{}^2 + u_{\mathrm{DUT},i}{}^2 + u_{TS}{}^2 \\ &= u_{f,i}{}^2 + u_{\mathrm{DUT},i}{}^2 + u_{REP}{}^2 + u_{vis}{}^2 + u_{\mathrm{Re}}{}^2 + u_p{}^2 + u_{upst}{}^2 \end{aligned} \tag{11}$$

$u_{f,i}$: Standard uncertainty due to calibration facility in the laboratory i, Base uncertainty

$u_{\mathrm{DUT},i}$: Standard uncertainty due to repeatability of transfer standard at calibration, DUT uncertainty

u_{TS} : Standard uncertainty due to the transfer standard

u_{REP} : Standard uncertainty due to reproducibility of the transfer standard

u_{vis} : Standard uncertainty due to the effect of viscosity and temperature differences between each pair of the participants on the transfer standard.

u_{Re} : Standard uncertainty due to the effect of differences of Re between each pair of the participants on the transfer standard.

u_p : Standard uncertainty due to the effect of pressure differences between each pair of the participants on the transfer standard.

u_{upst} : Standard uncertainty due to the effect of differences of upstream condition between each pair of the participants on the transfer standard.

The standard uncertainty due to the transfer standard u_{TS} is estimated to be 0.008 0 %. The expanded uncertainty of the relative K factor at each of the participating laboratories is obtained by Equation (12).

$$U(K_i) = k \cdot u(K_i) = 2u(K_i) \tag{12}$$

To obtain the KCRV of CCM.FF-K2.2015 and its uncertainties at the cardinal points, the calibration results from the participating laboratories were selected based on the following criteria;

a) The flow rate should be between 60 m^3/h and 300 m^3/h as specified in the technical protocol. In this flow range, the transfer standard shows very good dependency on Reynolds number. The calibration results out of the required flow range are regarded as “informative” results.

b) For the three participants (CMS, NMIA and NMIJ), which provided more than one calibration results at a single cardinal point, one result should be selected by each participant. The unselected calibration results are regarded as “additional” results.

The selected calculation results are shown in Table 7 and the chi-squared test was carried out for those data. The chi-squared value is calculated by Equation (13).

$$\chi_{obs}{}^2 = \sum_{i=1}^{n} \frac{\left(K_i - K_{\mathrm{KCRV}}\right)^2}{u(K_i)} \tag{13}$$

The observed chi-squared values at the cardinal points are shown in Table 7. The observed chi-squared values $\chi_{obs}{}^2$ at Reynolds number of 70 000 and 300 000 are less than the chi-squared values χ^2 of 9.49 and 6.00 for the 95 % confidence and the degrees of freedom (n – 1 = 5 and n – 1 = 2, respectively), indicating that the consistency check does not fail at the 95 % confidence level at Reynolds number of 70 000 and 300 000. However, the observed chi-squared value $\chi_{obs}{}^2$ of 13.21 at Reynolds number of 100 000 is larger than the chi-squared value χ^2 of 12.59 for the 95 % confidence and the degrees of freedom (n – 1 = 6). This result indicates that the consistency check at Re of 100 000 fails at the 95 % confidence level. Therefore the KCRV at Reynolds number of 100 000 was obtained as the median by using the Monte Carlo method according to the procedure B specified by Cox[4].

The KCRV of CCM.FF-K2.2015 and its uncertainties at Re of 100 000 using the Monte Carlo method are shown in Table 7.

Table 7 KCRV of CCM.FF-K2.2015, its uncertainty and chi-squared value

Re (-)	Name of NMI	Liquid, Temp	K_i (%)	$U(K_i)$ (%)	Procedure A (weighted mean) K_{KCRV} (%)	Procedure A (weighted mean) $U(K_{\mathrm{KCRV}})$ (%)	Procedure A (weighted mean) χ_{obs}	Procedure B (median) K_{KCRV} (%)	Procedure B (median) $U(K_{\mathrm{KCRV}})$ (%)
	CENAM	Diesel	0.0923	0.040					
	CMS	Light oil, 20 °C	0.1291	0.051					
70 000	NEL	Kerosene	0.1330	0.034	**0.1058**	**0.017**	5.59	-	-
	NMIA	D130	0.0844	0.034					
	NMIJ	Light oil, 20 °C	0.0992	0.034					
	BEV	D60	0.0363	0.066					
	CENAM	Diesel	0.0761	0.040					
	CMS	Light oil, 20 °C	0.1269	0.051					
100 000	NEL	Kerosene	0.1256	0.034	0.1001	0.015	**13.21** (>12.59)	**0.1025**	**0.025**
	NMIA	D130	0.0723	0.034					
	NMIJ	kerosene, 20 °C	0.1091	0.034					
	TRAPIL	Jet Fuel	0.1320	0.049					
	NMIA	Norpar 12	0.0468	0.034					
300 000	NMIJ	Kerosene, 20 °C	0.0656	0.034	**0.0622**	**0.022**	1.90	-	-
	TRAPIL	Jet Fuel	0.0871	0.049					

6.3. Degrees of equivalence

The degree of equivalence (d_i) of the calibration result selected to determine the KCRV and its standard uncertainty at Re of 70 000 and 300 000 $u(d_i)$ are expressed by Equations (14) and (15) according to the procedure A specified by Cox[4].

$$d_i = K_i - K_{\mathrm{KCRV}} \tag{14}$$

$$u^2(d_i) = u^2(K_i) - u^2(K_{\mathrm{KCRV}}) \tag{15}$$

The standard uncertainty of the degree of equivalence at Re of 100 000 was obtained by using the Monte Carlo method according to the procedure B[4].

The expanded uncertainty of the degree of equivalence $U(d_i)$ is obtained by Equation (16).

$$U(d_i) = k \cdot u(d_i) = 2u(d_i) \tag{16}$$

The En value (E_i), that is the standardized degree of equivalence at each laboratory selected to determine the KCRV, is obtained by Equation (17).

$$E_i = \left| \frac{d_i}{U(d_i)} \right| \tag{17}$$

The degree of equivalence of each participating laboratory to determine the KCRV is shown in Table 8 and Fig. 11.

Table 8 Degree of equivalence of each participating laboratory to determine the KCRV

Re (-)	NMI	Liquid, Temp.	d_i (%)	$U(d_i)$ (%)	E_i
70 000	CENAM	Diesel	-0.013 5	0.037	0.37
	CMS	Light oil, 20 ºC	0.023 3	0.048	0.49
	NEL	Kerosene	0.027 2	0.030	0.92
	NMIA	D130	-0.021 4	0.030	0.72
	NMIJ	Light oil, 20 ºC	-0.006 6	0.030	0.22
100 000	BEV	D60	-0.066 2	0.069	0.96
	CENAM	Diesel	-0.026 4	0.043	0.61
	CMS	Light oil, 20 ºC	0.024 4	0.048	0.50
	NEL	Kerosene	0.023 1	0.038	0.61
	NMIA	D130	-0.030 2	0.040	0.76
	NMIJ	kerosene, 20 ºC	0.006 6	0.029	0.23
	TRAPIL	Jet Fuel	0.029 5	0.049	0.60
300 000	NMIA	Norpar 12	-0.015 5	0.026	0.59
	NMIJ	Kerosene, 20 ºC	0.003 4	0.026	0.13
	TRAPIL	Jet Fuel	0.024 8	0.044	0.57

For the "additional" and “informative” calibration results those were not selected to determine the KCRV, the degree of equivalence between the KCRV and each of the participants d_i' and its standard uncertainty $u(d_i')$ are expressed by Equations (18) and (19).

$$d_i' = K_i - K_{\mathrm{KCRV}} \tag{18}$$

$$u^2(d_i') = u^2(K_i) + u^2(K_{\mathrm{KCRV}}) \tag{19}$$

The expanded uncertainty of the degree of equivalence $U(d_i')$ is obtained by Equation (20).

$$U(d_i') = k \cdot u(d_i') = 2u(d_i') \tag{20}$$

The En value, that is the standardized degree of equivalence, at each laboratory participated in CCM.FF-K2.2015 E_i' is obtained by Equation (21).

$$E_i' = \left| \frac{d_i'}{U(d_i')} \right| \tag{21}$$

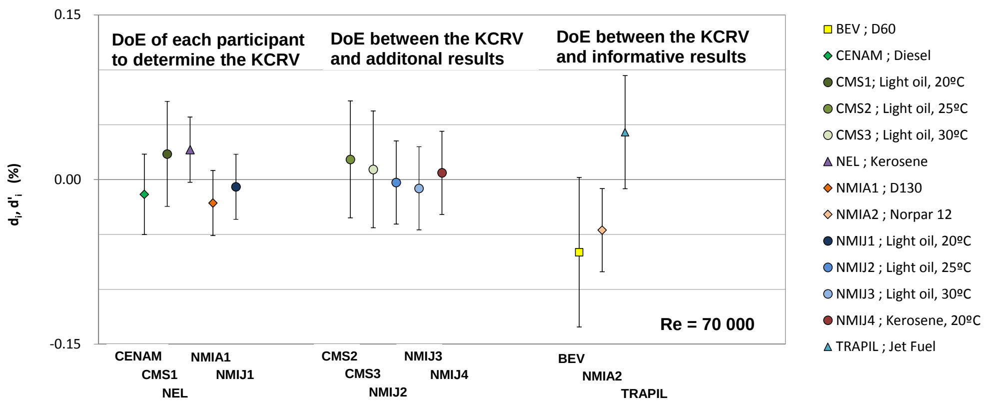
The degree of equivalence between the KCRV of CCM.FF-K2.2015 and the "additional" calibration results is shown in Table 9 and Fig. 11. The degree of equivalence between the KCRV and the "informative" calibration results is shown in Table 10 and Fig. 11.

Table 9 Degree of equivalence between the KCRV and "additional" results

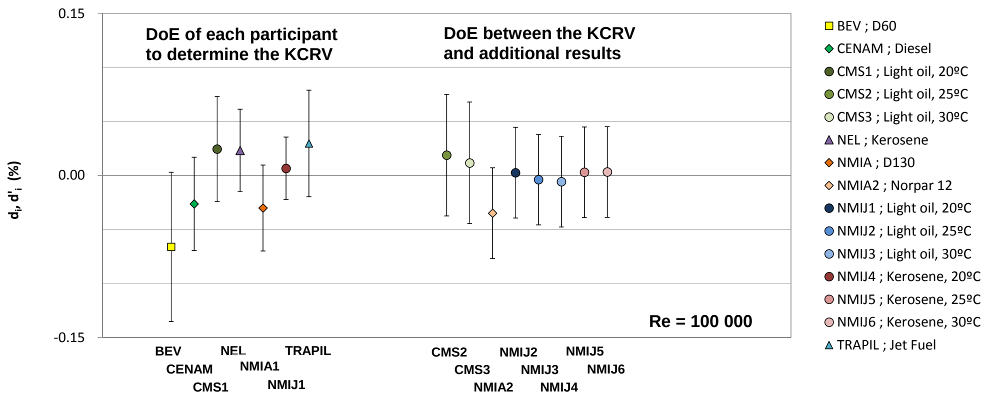
Re (-)	NMI	Liquid, Temp.	Flow rate (m³/h)	d_i' (%)	$U(d_i')$ (%)	E_i' (-)
70 000	CMS	Light oil, 25 °C	115.17	0.018 4	0.053	0.34
		Light oil, 30 °C	103.09	0.009 3	0.053	0.17
	NMIJ	Light oil, 25 °C	180.22	-0.002 7	0.038	0.07
		Light oil, 30 °C	156.25	-0.008 0	0.038	0.21
		Kerosene, 20 °C	60.53	0.006 1	0.038	0.16
100 000	CMS	Light oil, 25 °C	164.51	0.018 8	0.056	0.33
		Light oil, 30 °C	147.15	0.011 6	0.056	0.21
	NMIA	Norpar 12	68.75	-0.035 0	0.042	0.83
	NMIJ	Light oil, 20 °C	298.48	0.002 5	0.042	0.06
		Light oil, 25 °C	257.30	-0.003 9	0.042	0.09
		Light oil, 30 °C	221.39	-0.005 8	0.042	0.14
		Kerosene, 25 °C	79.13	0.002 9	0.042	0.07
		Kerosene, 30 °C	72.74	0.003 1	0.042	0.07
300 000	NMIJ	Kerosene, 25 °C	237.41	-0.001 5	0.040	0.04
		Kerosene, 30 °C	218.27	0.000 6	0.040	0.01

Table 10 Degree of equivalence between the KCRV and "informative" results

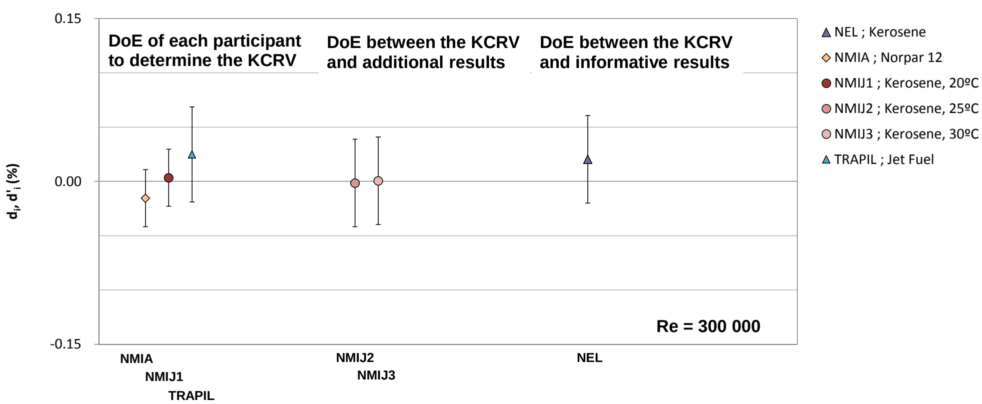
Re (-)	NMI	Liquid, Temp.	Flow rate (m³/h)	d_i' (%)	$U(d_i')$ (%)	E_i' (-)
70 000	BEV	D60	**53.42**	-0.066 2	0.068	0.97
	NMIA	Norpar 12	**48.86**	-0.046 1	0.038	**1.22**
	TRAPIL	Jet Fuel	**51.87**	0.043 1	0.051	0.84
300 000	NEL	Kerosene	**332.75**	0.020 4	0.040	0.51



(a) Re = 70 000



(b) Re = 100 000



(c) Re = 300 000

Fig. 11 Degree of Equivalence and its expanded uncertainty

The degree of equivalence between a laboratory i and a laboratory j in CCM.FF-K2.2015 and its standard uncertainty $u\left(d_{ij}\right)$ are expressed by Equations (22) and (23).

$$d_{ij} = K_i - K_j \tag{22}$$

$$\begin{aligned} u\left(d_{ij}\right) = & \, u_{f,i}{}^2 + u_{\mathrm{DUT},i}{}^2 \\ & + u_{f,j}{}^2 + u_{\mathrm{DUT},j}{}^2 \\ & + 2u_{REP}{}^2 + u_{vis}{}^2 + u_{\mathrm{Re}}{}^2 + u_p{}^2 + u_{upst}{}^2 \end{aligned} \tag{23}$$

The standard uncertainty of the degree of equivalence at Reynolds number of 100 000 was obtained by using the Monte Carlo method according to the procedure B specified by Cox[4].

The expanded uncertainty of the degree of equivalence between each pair of the participants in CCM.FF-K2.2015 $U\left(d_{ij}\right)$ is obtained by Equation (24).

$$U\left(d_{ij}\right) = k \cdot u\left(d_{ij}\right) = 2u\left(d_{ij}\right) \tag{24}$$

The En value between each pair of the participants in CCM.FF-K2.2015 E_{ij} is obtained by Equation (25).

$$E_{ij} = \left| \frac{d_{ij}}{U\left(d_{ij}\right)} \right| \tag{25}$$

The degree of equivalence between a laboratory i and a laboratory j in CCM.FF-K2.2015 is shown in Appendix A.4.

7. Summary and conclusions

Seven laboratories: BEV, CENAM, CMS, LNE-TRAPIL, NEL, NMIA and NMIJ, participated in the key comparison CCM.FF-K2.2015 for hydrocarbon flow measurement. A screw type positive displacement flow meter was selected as a transfer standard.

The performance of the transfer standard and its stability was evaluated from the measurements of the pilot institute, NMIJ. The transfer standard showed high performance and good stability since the uncertainty due to the transfer standard was less than quoted uncertainties in the participants.

The KCRVs at Reynolds number of 70 000 and 300 000 were obtained as the weighted mean from the calibration results, and the KCRV at Reynolds number of 100 000 was obtained as the median by using the Monte Carlo method according to the procedure B, since the consistency check at Reynolds number of 100 000 failed at the 95 % confidence level.

All calibration results selected to determine the KCRVs have En values which show consistency with the evaluated KCRVs.

Most of the En values of additional and informative calibration results between the KCRV and each of the participants show consistency with the KCRV.

8. References

[1] Comité International des Poids et Mesures (CIPM), Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates Issued by National Metrology Institutes, Paris, France, October, 1999.

[2] CCM-WGS, CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons, 29 August 2013.

[3] CCEM, CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons.

[4] Cox, M. G., The Evaluation of Key Comparison Data, Metrologia, 39, 589-595, 2002.

APPENDIX A

Tables of final results

A.1 BEV

Table A.1.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^{o}C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (k=2) [%]	Kf20 [p/L]	K [%]
70,000	Exxsol D60	1.805	788.60	53.42	20.25	0.094	8.8404	0.032	0.0011	0.064	8.84050	0.0396
100,000	Exxsol D60	1.788	788.18	76.25	20.82	0.125	8.8400	0.032	0.0020	0.064	8.84021	0.0363

Informative

Table A.1.b BEV, Exxsol D60, Sep. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	24-Sep-14	53.36	20.2458	0.094	19.84	1.81	788.603	8837	67.60	8.840246	0.9996328	69693		8.84032	0.0375	8.84050	0.0027	0.0011	69780	93
2	24-Sep-14	53.39	20.2713	0.093	19.86	1.80	788.584	8837	67.50	8.840429	0.9996122	69771		8.84051	0.0397					
3	24-Sep-14	53.51	20.2878	0.094	19.87	1.80	788.572	8837	67.50	8.840757	0.9995750	69941		8.84084	0.0435					
4	24-Sep-14	53.37	20.2954	0.094	19.87	1.80	788.566	8837	67.60	8.840581	0.9995949	69771		8.84067	0.0415					
5	24-Sep-14	53.49	20.2001	0.093	19.83	1.81	788.636	8837	67.50	8.840112	0.9996480	69816		8.84017	0.0359					
6	24-Sep-14	53.40	20.1998	0.093	19.81	1.81	788.637	8837	67.60	8.840428	0.9996122	69689		8.84049	0.0395					
7	24-Sep-14	59.14	20.2283	0.101	20.00	1.81	788.616	8837	61.20	8.840876	0.9995616	77231		8.84094	0.0446					
8	24-Sep-14	59.82	20.3148	0.101	19.89	1.80	788.552	8837	60.40	8.840520	0.9996018	78233		8.84061	0.0409					
9	24-Sep-14	59.39	20.2635	0.101	19.87	1.80	788.590	8837	60.60	8.840549	0.9995986	77602		8.84063	0.0410					
10	24-Sep-14	58.83	20.3661	0.098	20.25	1.80	788.515	8837	60.90	8.840585	0.9995945	77009		8.84069	0.0418					
11	24-Sep-14	59.60	20.3993	0.101	20.26	1.80	788.490	8837	60.60	8.840918	0.9995569	78055		8.84103	0.0457					
12	24-Sep-14	58.85	20.4448	0.101	20.12	1.80	788.457	8837	60.60	8.840062	0.9996536	77130		8.84019	0.0361					
13	24-Sep-14	58.78	20.4966	0.100	20.30	1.80	788.419	8837	61.40	8.840342	0.9996219	77116		8.84049	0.0395					
14	24-Sep-14	76.28	20.6505	0.126	20.39	1.79	788.306	8837	47.30	8.840376	0.9996181	100331		8.84057	0.0403	8.84021	0.0047	0.0019	100582	301
15	24-Sep-14	76.25	20.7511	0.126	20.29	1.79	788.232	8837	47.30	8.839999	0.9996608	100473		8.84022	0.0364					
16	24-Sep-14	76.24	20.7358	0.120	20.35	1.79	788.244	8837	49.50	8.840068	0.9996529	100428		8.84028	0.0372					
17	24-Sep-14	76.17	20.8136	0.125	20.63	1.79	788.187	8837	47.40	8.840088	0.9996507	100470		8.84033	0.0376					
18	24-Sep-14	76.14	20.9233	0.127	20.70	1.78	788.106	8837	47.20	8.839133	0.9997587	100623		8.83940	0.0272					
19	24-Sep-14	76.42	21.0218	0.124	20.74	1.78	788.034	8837	47.30	8.840142	0.9996446	101166		8.84044	0.0389					

Table A.1.b BEV, Exxsol D120, Sep. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	22-Sep-14	60.01	22.2714	0.111	22.26	5.17	828.586	8837	60.2000	8.8453	0.999	27352		8.84599	0.1017	8.84665	0.0056	0.0021	27266	57
2	22-Sep-14	59.82	22.2723	0.112	22.25	5.17	828.586	8837	60.3000	8.8453	0.999	27269		8.84598	0.1016					
3	22-Sep-14	59.96	22.1399	0.111	22.12	5.19	828.676	8837	60.1000	8.8460	0.999	27231		8.84664	0.1091					
4	22-Sep-14	59.92	22.2963	0.111	22.31	5.17	828.569	8837	60.2000	8.8464	0.999	27330		8.84706	0.1138					
5	22-Sep-14	60.08	22.1136	0.112	21.98	5.20	828.694	8837	60.0000	8.8466	0.999	27266		8.84727	0.1162					
6	22-Sep-14	59.92	22.1371	0.111	22.12	5.19	828.678	8837	60.3000	8.8462	0.999	27209		8.84680	0.1109					
7	22-Sep-14	59.88	22.1536	0.111	22.13	5.19	828.667	8837	60.2000	8.8462	0.999	27204		8.84681	0.1110					

A.2 CENAM

Table A.2.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^{o}C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (k=2) [%]	Kf20 [p/L]	K [%]
70,000	Diesel	4.259	829.46	125.82	21.80	0.130	8.8446	0.018	0.0026	0.037	8.84516	0.0923
100,000	Diesel	4.340	830.01	184.32	21.05	0.121	8.8434	0.018	0.0007	0.037	8.84372	0.0761

Table A.2.b CENAM, Diesel, Jan. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp., t_m	Pressure, p_m	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	28-Jan-15	239.82	20.2400	0.116	21.00	4.43	830.550	26540	45.0300	8.8426	3.001	127610		8.84267	0.0642					
2	28-Jan-15	239.82	20.3500	0.116	21.00	4.42	830.480	26539	45.0300	8.8422	3.001	127971		8.84230	0.0600					
3	28-Jan-15	240.00	20.5400	0.105	21.00	4.40	830.340	26536	45.0000	8.8411	3.000	128694		8.84126	0.0482					
4	28-Jan-15	179.70	20.6800	0.131	21.00	4.38	830.250	26540	60.1000	8.8437	2.999	96706		8.84390	0.0781					
5	28-Jan-15	179.70	20.7500	0.131	21.00	4.38	830.220	26540	60.0800	8.8437	2.999	96780		8.84392	0.0783					
6	28-Jan-15	179.70	20.7500	0.131	21.00	4.37	830.200	26540	60.1000	8.8440	2.999	96879		8.84422	0.0817					
7	28-Jan-15	120.30	20.7600	0.113	21.00	4.37	830.190	26542	89.7750	8.8457	2.999	64872		8.84592	0.1010					
8	28-Jan-15	120.40	20.7700	0.113	21.00	4.37	830.180	26542	89.7000	8.8458	2.999	64943		8.84602	0.1021					
9	28-Jan-15	120.30	20.7900	0.113	21.00	4.37	830.170	26542	89.7750	8.8458	2.999	64922		8.84603	0.1022					
10	28-Jan-15	62.22	20.8000	0.140	21.00	4.36	830.160	26541	173.6250	8.8459	2.999	33633		8.84613	0.1034					
11	28-Jan-15	62.58	20.8000	0.140	21.00	4.36	830.160	26540	172.6500	8.8457	2.999	33827		8.84593	0.1011					
12	28-Jan-15	62.34	20.8000	0.140	21.00	4.36	830.160	26540	173.3250	8.8458	2.999	33698		8.84603	0.1022					
13	27-Jan-15	184.32	20.9300	0.121	21.50	4.35	830.070	26539	58.6000	8.8433	2.999	99827		8.84357	0.0744	8.84372	0.0016	0.0007	100133	235
14	27-Jan-15	184.32	20.9800	0.121	21.50	4.35	830.180	26539	58.6040	8.8434	2.999	99955		8.84369	0.0757					
15	27-Jan-15	184.32	21.0200	0.121	21.50	4.34	830.010	26540	58.6000	8.8437	2.999	100056		8.84400	0.0792					
16	27-Jan-15	184.32	21.0700	0.121	21.50	4.34	829.970	26539	58.5750	8.8434	2.999	100184		8.84371	0.0760					
17	27-Jan-15	184.32	21.1200	0.121	21.50	4.33	829.940	26539	58.5750	8.8434	2.999	100311		8.84373	0.0761					
18	27-Jan-15	184.32	21.1800	0.121	21.50	4.33	829.890	26539	58.5750	8.8433	2.999	100464		8.84364	0.0752					
19	27-Jan-15	127.50	21.7800	0.128	22.00	4.26	829.470	26541	84.7000	8.8437	2.997	70555		8.84422	0.0817	8.84516	0.0064	0.0026	69655	698
20	27-Jan-15	127.50	21.7800	0.128	22.00	4.26	829.470	26541	84.6790	8.8443	2.997	70555		8.84482	0.0885					
21	27-Jan-15	124.98	21.7900	0.130	22.00	4.26	829.470	26541	86.4000	8.8446	2.996	69178		8.84512	0.0919					
22	27-Jan-15	124.98	21.8000	0.130	22.00	4.26	829.460	26542	86.3500	8.8451	2.996	69195		8.84563	0.0976					
23	27-Jan-15	124.98	21.8100	0.130	22.00	4.26	829.450	26542	86.3250	8.8452	2.996	69213		8.84573	0.0988					
24	27-Jan-15	124.98	21.8200	0.130	22.00	4.26	829.450	26541	86.2750	8.8449	2.996	69230		8.84543	0.0954					

A.3 CMS

Table A.3.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^{o}C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (*k*=2) [%]	Kf20 [p/L]	K [%]
70,000	Light oil	4.355	806.97	129.97	20.04	0.161	8.8484	0.023	0.0011	0.048	8.84841	0.1291
100,000	Light oil	4.353	806.97	184.70	20.05	0.182	8.8482	0.023	0.0007	0.048	8.84821	0.1269
70,000	Light oil	3.866	803.52	115.17	25.02	0.167	8.8465	0.023	0.0011	0.048	8.84797	0.1241
100,000	Light oil	3.870	803.55	164.51	24.98	0.175	8.8463	0.023	0.0011	0.048	8.84772	0.1213
70,000	Light oil	3.456	800.05	103.09	30.04	0.183	8.8442	0.023	0.0008	0.048	8.84717	0.1151
100,000	Light oil	3.459	800.08	147.15	30.01	0.167	8.8442	0.023	0.0009	0.048	8.84708	0.1141

Additional

Table A.3.b CMS, Light oil, 20 ºC, Jun. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	18-Jun-15	60.02	19.985	0.242	27.20	4.360	807.01	56012	379.71	8.8474	6.3309	32458		8.84741	0.1178					
2	18-Jun-15	60.25	20.115	0.241	27.21	4.346	806.92	56087	378.77	8.8472	6.3395	32689		8.84720	0.1155					
3	18-Jun-15	120.03	19.960	0.154	27.20	4.363	807.03	56835	192.65	8.8485	6.4231	64866		8.84847	0.1298					
4	18-Jun-15	120.11	19.980	0.154	27.16	4.361	807.01	57028	193.17	8.8483	6.4451	64944		8.84829	0.1278					
5	18-Jun-15	179.43	20.030	0.175	27.20	4.355	806.98	57560	130.52	8.8480	6.5054	97139		8.84805	0.1251					
6	18-Jun-15	179.69	20.040	0.175	27.20	4.354	806.97	57791	130.85	8.8482	6.5314	97305		8.84822	0.1270					
7	18-Jun-15	239.61	20.060	0.235	27.33	4.352	806.96	58158	98.76	8.8477	6.5732	129812		8.84776	0.1217					
8	18-Jun-15	239.02	20.095	0.235	27.36	4.348	806.93	58621	99.79	8.8478	6.6255	129608		8.84780	0.1222					
9	18-Jun-15	298.76	20.030	0.312	27.48	4.355	806.98	59274	80.73	8.8473	6.6997	161739		8.84728	0.1164					
10	18-Jun-15	298.80	20.090	0.312	27.52	4.349	806.94	59527	81.06	8.8476	6.7281	162005		8.84758	0.1197					
11	18-Jun-15	129.89	20.040	0.161	27.59	4.354	806.97	56851	178.08	8.8482	6.4251	70335		8.84822	0.1270	8.84844	0.0027	0.0011	70374	93
12	18-Jun-15	129.94	20.095	0.161	27.59	4.348	806.93	56917	178.21	8.8483	6.4325	70461		8.84836	0.1285					
13	18-Jun-15	129.97	20.025	0.161	27.55	4.356	806.98	56842	177.94	8.8485	6.4239	70351		8.84847	0.1298					
14	18-Jun-15	130.09	20.065	0.161	27.58	4.352	806.96	56932	178.05	8.8487	6.4340	70487		8.84869	0.1323					
15	18-Jun-15	129.87	19.985	0.161	27.55	4.360	807.01	57090	178.84	8.8488	6.4518	70230		8.84875	0.1329					
16	18-Jun-15	130.07	20.010	0.161	27.44	4.358	806.99	57116	178.66	8.8482	6.4551	70381		8.84816	0.1263					
17	18-Jun-15	184.51	20.070	0.182	27.44	4.351	806.95	57430	126.64	8.8483	6.4905	99986		8.84828	0.1276	8.84824	0.0016	0.0007	100039	77
18	18-Jun-15	184.79	20.075	0.182	27.41	4.350	806.95	57743	127.14	8.8481	6.5261	100150		8.84809	0.1255					
19	18-Jun-15	184.84	20.020	0.182	27.40	4.356	806.99	57753	127.12	8.8483	6.5270	100043		8.84834	0.1283					
20	18-Jun-15	184.73	20.045	0.182	27.43	4.354	806.97	57693	127.07	8.8482	6.5203	100042		8.84822	0.1269					
21	18-Jun-15	184.72	20.065	0.182	27.40	4.352	806.96	57624	126.92	8.8484	6.5124	100088		8.84843	0.1294					
22	18-Jun-15	184.63	20.020	0.182	27.39	4.356	806.99	57603	126.94	8.8481	6.5102	99928		8.84806	0.1252					

Table A.3.c CMS, Light oil, 25 ºC, Jun. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	24-Jun-15	60.13	24.970	0.253	27.18	3.871	803.56	56285	380.96	8.8453	6.3633	36629		8.84671	0.1098					
2	24-Jun-15	60.23	25.015	0.250	27.15	3.867	803.53	56251	380.09	8.8451	6.3596	36730		8.84655	0.1081					
3	24-Jun-15	119.87	24.950	0.159	27.16	3.872	803.57	57255	194.37	8.8465	6.4721	72986		8.84792	0.1236					
4	24-Jun-15	120.24	24.995	0.159	27.19	3.868	803.54	56937	192.70	8.8466	6.4361	73285		8.84801	0.1246					
5	24-Jun-15	180.49	24.980	0.177	27.08	3.870	803.55	57682	130.06	8.8461	6.5206	109969		8.84760	0.1199					
6	24-Jun-15	179.65	25.025	0.178	27.09	3.866	803.52	58093	131.59	8.8466	6.5667	109572		8.84809	0.1255					
7	24-Jun-15	239.23	24.945	0.232	27.14	3.873	803.58	58763	99.96	8.8463	6.6427	145645		8.84775	0.1216					
8	24-Jun-15	239.98	25.030	0.232	27.12	3.865	803.52	58708	99.56	8.8458	6.6368	146385		8.84731	0.1166					
9	24-Jun-15	297.08	25.020	0.312	27.14	3.866	803.53	59559	81.59	8.8458	6.7330	181175		8.84726	0.1161					
10	24-Jun-15	297.94	24.965	0.312	27.19	3.871	803.56	58959	80.54	8.8453	6.6656	181469		8.84677	0.1106					
11	24-Jun-15	114.94	25.055	0.167	27.19	3.863	803.50	56989	201.77	8.8465	6.4419	70151		8.84803	0.1248	8.84797	0.0026	0.0011	70243	116
12	24-Jun-15	114.97	25.025	0.167	27.31	3.866	803.52	56898	201.39	8.8465	6.4317	70123		8.84799	0.1243					
13	24-Jun-15	115.26	25.105	0.167	27.31	3.859	803.47	57000	201.24	8.8467	6.4431	70429		8.84818	0.1265					
14	24-Jun-15	115.12	25.000	0.167	27.39	3.868	803.54	57061	201.72	8.8462	6.4504	70172		8.84764	0.1204					
15	24-Jun-15	115.30	25.010	0.167	27.39	3.867	803.53	56973	201.09	8.8463	6.4403	70298		8.84776	0.1218					
16	24-Jun-15	115.46	24.940	0.167	27.36	3.873	803.58	57180	201.52	8.8468	6.4634	70286		8.84823	0.1271					
17	24-Jun-15	164.42	24.930	0.175	27.36	3.874	803.59	57530	142.39	8.8466	6.5031	100062		8.84802	0.1247	8.84772	0.0025	0.0010	100242	169
18	24-Jun-15	164.19	25.030	0.175	27.36	3.865	803.52	57624	142.83	8.8460	6.5141	100152		8.84751	0.1189					
19	24-Jun-15	164.38	24.995	0.175	27.32	3.868	803.54	57647	142.72	8.8461	6.5166	100188		8.84758	0.1197					
20	24-Jun-15	164.50	24.950	0.175	27.41	3.872	803.57	57601	142.50	8.8463	6.5113	100157		8.84779	0.1221					
21	24-Jun-15	164.78	24.975	0.175	27.41	3.870	803.56	57571	142.18	8.8465	6.5078	100386		8.84790	0.1234					
22	24-Jun-15	164.81	25.020	0.175	27.28	3.866	803.53	57781	142.68	8.8460	6.5319	100508		8.84749	0.1188					

Table A.3.d CMS, Light oil, 30 ºC, Jun. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	29-Jun-15	60.44	30.060	0.232	27.77	3.455	800.04	56555	380.91	8.8435	6.3951	41250		8.84647	0.1072					
2	29-Jun-15	60.68	30.025	0.230	27.79	3.457	800.06	56542	379.30	8.8435	6.3936	41384		8.84641	0.1065					
3	29-Jun-15	120.47	29.960	0.157	27.73	3.462	800.11	57448	194.09	8.8451	6.4949	82038		8.84802	0.1247					
4	29-Jun-15	120.46	30.020	0.157	27.75	3.458	800.07	57343	193.75	8.8450	6.4831	82141		8.84793	0.1237					
5	29-Jun-15	181.48	29.985	0.175	27.77	3.460	800.09	58024	130.15	8.8440	6.5608	123651		8.84689	0.1120					
6	29-Jun-15	179.89	29.985	0.175	27.83	3.460	800.09	58266	131.84	8.8443	6.5880	122572		8.84717	0.1151					
7	29-Jun-15	239.22	30.010	0.230	27.83	3.459	800.07	59221	100.77	8.8440	6.6962	163087		8.84691	0.1121					
8	29-Jun-15	228.19	30.005	0.230	27.90	3.459	800.08	58890	105.05	8.8440	6.6587	155550		8.84693	0.1124					
9	29-Jun-15	295.82	30.015	0.311	27.86	3.458	800.07	60068	82.66	8.8434	6.7924	201697		8.84630	0.1052					
10	29-Jun-15	296.28	30.040	0.311	27.83	3.456	800.05	59288	81.46	8.8435	6.7041	202118		8.84647	0.1071					
11	29-Jun-15	103.07	30.065	0.183	27.92	3.454	800.04	57131	225.61	8.8443	6.4596	70355		8.84728	0.1164	8.84717	0.0021	0.0008	70327	163
12	29-Jun-15	102.93	30.065	0.183	27.87	3.454	800.04	57107	225.84	8.8442	6.4570	70255		8.84716	0.1150					
13	29-Jun-15	102.95	30.030	0.183	27.76	3.457	800.06	57057	225.61	8.8440	6.4515	70213		8.84688	0.1118					
14	29-Jun-15	102.97	30.025	0.183	27.76	3.457	800.06	57158	225.94	8.8442	6.4628	70225		8.84713	0.1146					
15	29-Jun-15	103.52	30.055	0.183	27.83	3.455	800.04	57145	224.70	8.8442	6.4613	70643		8.84712	0.1146					
16	29-Jun-15	103.07	30.010	0.183	27.83	3.459	800.07	57147	225.67	8.8445	6.4613	70270		8.84742	0.1179					
17	29-Jun-15	147.41	29.990	0.167	27.90	3.460	800.09	57502	158.78	8.8442	6.5017	100452		8.84713	0.1146	8.84708	0.0021	0.0009	100310	164
18	29-Jun-15	147.36	30.025	0.167	27.83	3.457	800.06	57498	158.82	8.8444	6.5011	100496		8.84728	0.1163					
19	29-Jun-15	147.13	30.005	0.167	27.88	3.459	800.08	57695	159.62	8.8440	6.5236	100294		8.84692	0.1122					
20	29-Jun-15	147.19	30.010	0.167	27.83	3.459	800.07	57557	159.17	8.8444	6.5078	100344		8.84727	0.1162					
21	29-Jun-15	147.05	30.005	0.167	27.82	3.459	800.08	57680	159.67	8.8439	6.5220	100238		8.84681	0.1110					
22	29-Jun-15	146.74	30.010	0.167	27.80	3.459	800.07	57589	159.75	8.8442	6.5115	100038		8.84708	0.1140					

A.4. NEL

Table A.4.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [°C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (*k*=2) [%]	Kf20 [p/L]	K [%]
70,000	Kerosene	2.627	801.01	78.30	30.11	0.148	8.8458	0.015	0.0013	0.030	8.84875	0.1330
100,000	Kerosene	2.623	800.95	111.37	30.20	0.149	8.8451	0.015	0.0013	0.030	8.84810	0.1256
300,000	Kerosene	2.607	800.80	332.75	30.52	0.157	8.8412	0.015	0.0013	0.030	8.84430	0.0826

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Table A.4.b NEL, Kerosene, Nov. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	26-Nov-14	300.76	30.4627	0.160	17.95	2.610	800.83	64324	87.0848	8.8411	7.276	271740		8.84419	0.0814					
2	26-Nov-14	300.81	30.4920	0.159	18.07	2.608	800.81	63966	86.5784	8.8420	7.234	271933		8.84507	0.0913					
3	26-Nov-14	300.88	30.5751	0.160	18.12	2.604	800.75	64069	86.6991	8.8417	7.246	272429		8.84478	0.0880					
4	26-Nov-14	236.85	30.4679	0.157	18.35	2.610	800.80	64029	110.0698	8.8419	7.242	214004		8.84497	0.0902					
5	26-Nov-14	236.95	30.4290	0.158	18.37	2.611	800.83	63995	109.9626	8.8420	7.238	213940		8.84500	0.0905					
6	26-Nov-14	236.83	30.3689	0.158	18.32	2.614	800.87	63916	109.8807	8.8422	7.229	213586		8.84523	0.0931					
7	26-Nov-14	177.75	30.4069	0.149	18.38	2.613	800.82	49514	113.4098	8.8426	5.599	160414		8.84565	0.0979					
8	26-Nov-14	177.77	30.3314	0.149	18.42	2.616	800.87	49437	113.2121	8.8431	5.590	160206		8.84609	0.1029					
9	26-Nov-14	177.83	30.3202	0.149	18.48	2.617	800.88	49572	113.4821	8.8430	5.606	160229		8.84600	0.1019					
10	26-Nov-14	117.82	30.2748	0.153	18.53	2.619	800.90	31815	109.9154	8.8443	3.597	106062		8.84730	0.1165					
11	26-Nov-14	118.03	30.2436	0.152	18.62	2.621	800.92	31855	109.8564	8.8446	3.602	106186		8.84759	0.1198					
12	26-Nov-14	118.12	30.2255	0.152	18.71	2.622	800.93	31987	110.2163	8.8449	3.616	106238		8.84784	0.1227					
13	26-Nov-14	59.96	30.2656	0.150	19.13	2.620	800.90	32054	217.5763	8.8456	3.624	53965		8.84856	0.1308					
14	26-Nov-14	60.17	30.2024	0.150	18.98	2.623	800.94	32095	217.1129	8.8449	3.629	54089		8.84783	0.1226					
15	26-Nov-14	60.24	30.1849	0.150	18.92	2.624	800.95	32070	216.6610	8.8463	3.625	54133		8.84931	0.1393					
16	28-Nov-14	332.80	30.5716	0.159	18.84	2.604	800.77	63928	78.2176	8.8412	7.231	301308		8.84425	0.0820	8.84430	0.0033	0.0014	300977	334
17	28-Nov-14	332.80	30.5770	0.158	18.67	2.604	800.76	63995	78.2980	8.8414	7.238	301338		8.84444	0.0842					
18	28-Nov-14	332.76	30.5373	0.156	17.81	2.606	800.79	64386	78.7827	8.8417	7.282	301075		8.84479	0.0882					
19	28-Nov-14	332.75	30.5017	0.155	17.49	2.608	800.81	63519	77.7315	8.8409	7.185	300864		8.84393	0.0784					
20	28-Nov-14	332.69	30.5024	0.155	17.23	2.608	800.81	63924	78.2365	8.8412	7.230	300820		8.84428	0.0823					
21	28-Nov-14	332.72	30.4345	0.156	17.09	2.611	800.86	63571	77.8001	8.8411	7.190	300456		8.84412	0.0806					
22	28-Nov-14	111.26	30.2660	0.149	17.60	2.620	800.90	31980	116.9944	8.8448	3.616	100139		8.84775	0.1217	8.84810	0.0032	0.0013	100109	43
23	28-Nov-14	111.32	30.1973	0.149	17.88	2.623	800.95	31861	116.4854	8.8451	3.602	100068		8.84809	0.1255					
24	28-Nov-14	111.38	30.1948	0.149	18.00	2.623	800.95	32077	117.2098	8.8452	3.626	100117		8.84822	0.1269					
25	28-Nov-14	111.39	30.1868	0.149	18.02	2.624	800.96	32127	117.3815	8.8454	3.632	100110		8.84835	0.1284					
26	28-Nov-14	111.42	30.1459	0.149	18.11	2.626	800.99	31906	116.5580	8.8448	3.607	100052		8.84778	0.1220					
27	28-Nov-14	111.44	30.1943	0.149	18.23	2.623	800.95	31966	116.7435	8.8454	3.614	100166		8.84842	0.1292					
28	28-Nov-14	78.28	30.1058	0.148	16.94	2.628	801.01	31931	166.0036	8.8455	3.610	70246		8.84846	0.1297	8.84875	0.0033	0.0013	70261	41
29	28-Nov-14	78.28	30.0916	0.148	17.90	2.628	801.02	31902	165.8485	8.8459	3.606	70226		8.84884	0.1340					
30	28-Nov-14	78.29	30.1035	0.148	18.40	2.628	801.01	32019	166.4504	8.8455	3.620	70248		8.84841	0.1291					
31	28-Nov-14	78.30	30.0794	0.148	18.73	2.629	801.03	31916	165.8821	8.8462	3.608	70224		8.84917	0.1378					
32	28-Nov-14	78.30	30.1472	0.148	18.94	2.626	800.98	31949	166.0527	8.8460	3.612	70317		8.84893	0.1350					
33	28-Nov-14	78.32	30.1270	0.148	19.08	2.627	800.99	32056	166.5720	8.8457	3.624	70307		8.84871	0.1325					

A.5. NMIA

Table A.5.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^{o}C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (*k*=2) [%]	Kf20 [p/L]	K [%]
70,000	D130	5.507	816.04	166.36	28.87	0.213	8.8419	0.015	0.0006	0.030	8.84446	0.0844
100,000	D130	5.243	814.90	229.00	30.55	0.197	8.8403	0.015	0.0009	0.030	8.84339	0.0723
300,000	Norpar 12	1.593	743.97	204.24	27.74	0.210	8.8389	0.015	0.0004	0.030	8.84113	0.0468
70,000	Norpar 12	1.635	745.19	48.86	26.07	0.212	8.8405	0.015	0.0002	0.030	8.84227	0.0596
100,000	Norpar 12	1.624	744.87	68.75	26.51	0.242	8.8411	0.015	0.0004	0.030	8.84297	0.0675

Additional
Informative

Table A.5.b NMIA, Norpar 12, Apr. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	09-Apr-15	60.12	23.31	0.196	19	1.71	747.197			8.8427		82943	1000L/min run 1	8.84362	0.0749					
2	09-Apr-15	60.14	23.35	0.196	19	1.71	747.172			8.8427		83024	1000L/min run 2	8.84364	0.0751					
3	09-Apr-15	120.73	23.63	0.205	19	1.70	746.966			8.8423		167428	2000L/min run 1	8.84333	0.0716					
4	09-Apr-15	120.74	23.72	0.206	19	1.70	746.901			8.8424		167682	2000L/min run 2	8.84350	0.0735					
5	09-Apr-15	180.05	24.20	0.208	19	1.68	746.554			8.8406		252017	3000L/min run 1	8.84179	0.0542					
6	09-Apr-15	180.09	24.38	0.208	19	1.68	746.422			8.8405		252829	3000L/min run 2	8.84183	0.0546					
7	09-Apr-15	240.55	24.73	0.204	19	1.67	746.168			8.8386		339665	4000L/min run 1	8.84002	0.0342					
8	09-Apr-15	240.55	25.01	0.205	19	1.66	745.959			8.8385		341290	4000L/min run 2	8.83996	0.0335					
9	09-Apr-15	247.69	25.52	0.194	19	1.65	745.589			8.8382		354141	Qmax run 1	8.83976	0.0313					
10	09-Apr-15	247.93	25.80	0.193	19	1.64	745.388			8.8382		355998	Qmax run 2	8.83987	0.0325					
11	09-Apr-15	48.86	25.97	0.211	19	1.64	745.265			8.8406		70340	Re=70k run1	8.84231	0.0601	8.84227	0.0005	0.0002	70448	95
12	09-Apr-15	48.84	26.00	0.212	19	1.64	745.238			8.8405		70346	Re=70k run2	8.84225	0.0594					
13	09-Apr-15	48.85	26.06	0.212	19	1.64	745.199			8.8404		70421	Re=70k run3	8.84218	0.0586					
14	09-Apr-15	48.87	26.09	0.212	19	1.63	745.172			8.8405		70495	Re=70k run4	8.84229	0.0599					
15	09-Apr-15	48.85	26.13	0.212	19	1.63	745.145			8.8405		70507	Re=70k run5	8.84230	0.0600					
16	09-Apr-15	48.87	26.17	0.212	19	1.63	745.116			8.8405		70576	Re=70k run6	8.84229	0.0599					
17	09-Apr-15	68.75	26.35	0.242	19	1.63	744.986			8.8411		99562	Re=100k run 1	8.84295	0.0674	8.84297	0.0008	0.0003	99806	138
18	09-Apr-15	68.78	26.45	0.243	19	1.63	744.912			8.8412		99769	Re=100k run 2	8.84306	0.0685					
19	09-Apr-15	68.75	26.50	0.243	19	1.62	744.878			8.8411		99787	Re=100k run 3	8.84302	0.0681					
20	09-Apr-15	68.76	26.54	0.242	19	1.62	744.847			8.8410		99872	Re=100k run 4	8.84291	0.0669					
21	09-Apr-15	68.76	26.59	0.243	19	1.62	744.811			8.8409		99952	Re=100k run 5	8.84286	0.0663					
22	09-Apr-15	68.67	26.63	0.242	19	1.62	744.777			8.8411		99894	Re=100k run 6	8.84300	0.0679					
23	09-Apr-15	204.38	27.17	0.211	19	1.61	744.384			8.8390		299819	Re=300k run1	8.84107	0.0461	8.84113	0.0006	0.0003	302322	2034
24	09-Apr-15	204.35	27.39	0.210	19	1.60	744.227			8.8390		300800	Re=300k run2	8.84111	0.0465					
25	09-Apr-15	204.09	27.59	0.211	19	1.60	744.078			8.8389		301383	Re=300k run3	8.84109	0.0463					
26	09-Apr-15	204.19	27.82	0.210	19	1.59	743.908			8.8389		302650	Re=300k run4	8.84113	0.0468					
27	09-Apr-15	204.26	28.13	0.210	19	1.58	743.688			8.8388		304206	Re=300k run5	8.84116	0.0471					
28	09-Apr-15	204.20	28.32	0.210	19	1.58	743.546			8.8388		305073	Re=300k run6	8.84123	0.0478					

K factor based on average of 5 strokes of 60L piston prover

Table A.5.c NMIA, D130, Apr. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	08-Apr-15	60.37	23.79	0.216	20	6.43	819.478			8.8433		22133	1000L/min run 1	8.84442	0.0840					
2	08-Apr-15	60.31	23.83	0.216	20	6.42	819.451			8.8432		22142	1000L/min run 2	8.84436	0.0833					
3	08-Apr-15	119.99	24.01	0.225	20	6.38	819.328			8.8437		44313	2000L/min run 1	8.84491	0.0895					
4	08-Apr-15	120.34	24.16	0.206	20	6.35	819.228			8.8436		44651	2000L/min run 2	8.84486	0.0889					
5	08-Apr-15	180.21	24.93	0.205	20	6.20	818.709			8.8426		68577	3000L/min run 1	8.84400	0.0793					
6	08-Apr-15	180.13	25.10	0.204	20	6.16	818.593			8.8427		68910	3000L/min run 2	8.84419	0.0813					
7	08-Apr-15	240.09	27.01	0.198	20	5.83	817.298			8.8416		97079	4000L/min run 1	8.84362	0.0749					
8	08-Apr-15	240.16	27.31	0.198	20	5.78	817.096			8.8415		97976	4000L/min run 2	8.84361	0.0748					
9	08-Apr-15	249.92	27.76	0.194	20	5.70	816.787			8.8411		103376	Qmax run 1	8.84337	0.0721					
10	08-Apr-15	250.12	28.12	0.193	20	5.64	816.546			8.8412		104594	Qmax run 2	8.84356	0.0743					
11	08-Apr-15	166.44	28.54	0.214	20	5.57	816.260			8.8420		70520	Re=70k run1	8.84447	0.0845	8.84446	0.0009	0.0004	71226	554
12	08-Apr-15	166.40	28.67	0.213	20	5.54	816.170			8.8419		70796	Re=70k run2	8.84443	0.0841					
13	08-Apr-15	166.27	28.80	0.212	20	5.52	816.082			8.8419		71027	Re=70k run3	8.84442	0.0840					
14	08-Apr-15	166.44	28.93	0.213	20	5.50	815.992			8.8420		71401	Re=70k run4	8.84459	0.0859					
15	08-Apr-15	166.16	29.06	0.212	20	5.47	815.904			8.8418		71576	Re=70k run5	8.84448	0.0846					
16	08-Apr-15	166.45	29.21	0.213	20	5.45	815.804			8.8417		72037	Re=70k run6	8.84434	0.0831					
17	08-Apr-15	229.27	29.87	0.198	20	5.33	815.360			8.8405		101342	Re=100k run 1	8.84339	0.0723	8.84339	0.0007	0.0003	103000	1307
18	08-Apr-15	228.86	30.15	0.197	20	5.29	815.166			8.8405		101973	Re=100k run 2	8.84349	0.0735					
19	08-Apr-15	229.04	30.39	0.196	20	5.26	815.005			8.8404		102636	Re=100k run 3	8.84339	0.0723					
20	08-Apr-15	228.76	30.66	0.197	20	5.23	814.821			8.8403		103181	Re=100k run 4	8.84338	0.0722					
21	08-Apr-15	228.89	30.95	0.196	20	5.19	814.627			8.8402		103957	Re=100k run 5	8.84336	0.0719					
22	08-Apr-15	229.16	31.28	0.196	20	5.15	814.405			8.8400		104911	Re=100k run 6	8.84330	0.0712					

K factor based on average of 5 strokes of 60L piston prover

A.6 NMIJ

Table A.6.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^{o}C]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	DUT uncertainty u [%]	Expanded Uncertainty of K factor U (*k*=2) [%]	Kf20 [p/L]	K [%]
70,000	Light oil	7.020	837.25	208.95	20.11	0.482	8.8457	0.015	0.0003	0.030	8.84576	0.0992
100,000	Kerosene	2.043	795.32	86.52	19.92	0.413	8.8467	0.015	0.0001	0.030	8.84664	0.1091
300,000	Kerosene	2.039	795.31	259.70	20.03	0.509	8.8428	0.015	0.0003	0.030	8.84280	0.0656
70,000	Light oil	6.050	833.83	180.22	25.10	0.459	8.8446	0.015	0.0002	0.030	8.84611	0.1031
70,000	Light oil	5.267	830.43	156.25	30.09	0.443	8.8427	0.015	0.0004	0.030	8.84564	0.0978
70,000	Kerosene	2.044	795.33	60.53	19.91	0.405	8.8469	0.015	0.0004	0.030	8.84689	0.1119
100,000	Light oil	7.002	837.18	298.48	20.20	0.460	8.8462	0.015	0.0006	0.030	8.84628	0.1050
100,000	Light oil	6.039	833.83	257.30	25.17	0.521	8.8442	0.015	0.0002	0.030	8.84571	0.0986
100,000	Light oil	5.259	830.42	221.39	30.15	0.493	8.8426	0.015	0.0003	0.030	8.84554	0.0967
100,000	Kerosene	1.868	791.72	79.13	24.92	0.409	8.8449	0.015	0.0001	0.030	8.84631	0.1054
100,000	Kerosene	1.717	788.15	72.74	29.91	0.408	8.8434	0.015	0.0005	0.030	8.84633	0.1056
300,000	Kerosene	1.865	791.70	237.41	25.01	0.492	8.8409	0.015	0.0002	0.030	8.84237	0.0608
300,000	Kerosene	1.715	788.13	218.27	29.99	0.476	8.8396	0.015	0.0001	0.030	8.84255	0.0628

Additional

Table A.6.b NMIJ, Light oil, 20 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	01-Jul-14	298.60	20.1894	0.459	22.81	7.00	837.179	100216	136.5785	8.8464	11.328	100534	Re = 100,000	8.84647	0.1072	8.84628	0.0014	0.0006	100513	37
2	01-Jul-14	298.37	20.1891	0.459	23.00	7.00	837.180	100172	136.6273	8.8461	11.324	100457	Re = 100,000	8.84614	0.1035					
3	01-Jul-14	298.57	20.1966	0.460	23.24	7.00	837.175	100159	136.5176	8.8461	11.322	100548	Re = 100,000	8.84618	0.1039					
4	01-Jul-14	298.43	20.1970	0.461	23.38	7.00	837.176	100157	136.5789	8.8462	11.322	100501	Re = 100,000	8.84630	0.1052					
5	01-Jul-14	298.43	20.2131	0.460	23.58	7.00	837.164	100057	136.4425	8.8462	11.311	100551	Re = 100,000	8.84622	0.1044					
6	01-Jul-14	298.47	20.1889	0.460	23.74	7.00	837.180	100115	136.5032	8.8463	11.317	100488	Re = 100,000	8.84636	0.1060					
7	02-Jul-14	208.98	20.0950	0.483	23.15	7.02	837.258	99630	194.0237	8.8456	11.263	70157	Re = 70,000	8.84565	0.0979	8.84576	0.0007	0.0003	70185	35
8	02-Jul-14	208.98	20.1193	0.480	23.36	7.02	837.240	99595	193.9563	8.8457	11.259	70209	Re = 70,000	8.84574	0.0989					
9	02-Jul-14	209.04	20.1226	0.483	23.55	7.02	837.239	99651	194.0074	8.8458	11.265	70236	Re = 70,000	8.84582	0.0998					
10	02-Jul-14	208.93	20.1225	0.484	23.73	7.02	837.240	99599	194.0071	8.8458	11.260	70199	Re = 70,000	8.84581	0.0996					
11	02-Jul-14	208.89	20.1030	0.482	23.85	7.02	837.252	99529	193.9096	8.8458	11.252	70143	Re = 70,000	8.84580	0.0995					
12	02-Jul-14	208.87	20.1173	0.483	23.90	7.02	837.243	99549	193.9669	8.8457	11.254	70168	Re = 70,000	8.84577	0.0992					
13	02-Jul-14	240.01	20.1497	0.509	24.04	7.01	837.238	99763	169.1687	8.8456	11.278	80708		8.84564	0.0978					
14	02-Jul-14	239.67	20.1458	0.508	24.21	7.01	837.240	99793	169.4574	8.8456	11.282	80586		8.84562	0.0975					
15	02-Jul-14	299.77	20.1898	0.457	24.31	7.00	837.183	100118	135.9183	8.8462	11.318	100928		8.84621	0.1043					
16	02-Jul-14	299.43	20.2063	0.456	24.35	7.00	837.171	100082	136.0189	8.8463	11.313	100867		8.84638	0.1062					
17	03-Jul-14	179.98	20.0909	0.461	23.01	7.02	837.248	99451	224.8604	8.8464	11.242	60414		8.84646	0.1071					
18	03-Jul-14	179.99	20.0910	0.460	23.32	7.02	837.247	99410	224.7616	8.8464	11.237	60416		8.84643	0.1067					
19	03-Jul-14	119.90	20.0659	0.427	23.41	7.03	837.243	99128	336.4458	8.8463	11.206	40215		8.84637	0.1060					
20	03-Jul-14	120.01	20.0665	0.426	23.48	7.03	837.242	99098	336.0497	8.8463	11.202	40252		8.84628	0.1050					
21	03-Jul-14	59.91	20.0145	0.405	23.60	7.04	837.264	98820	671.2952	8.8456	11.172	20063		8.84565	0.0979					
22	03-Jul-14	59.90	20.0252	0.406	23.62	7.04	837.258	98793	671.2746	8.8456	11.169	20064		8.84563	0.0977					
23	03-Jul-14	29.86	20.0125	0.401	23.62	7.04	837.267	98612	1344.1035	8.8443	11.150	10000		8.84429	0.0825					
24	03-Jul-14	29.87	20.0231	0.401	23.58	7.04	837.259	98609	1343.8689	8.8442	11.150	10005		8.84424	0.0820					

Table A.6.c NMIJ, Light oil, 25 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	07-Jul-14	239.98	25.1500	0.505	22.15	6.04	833.823	100111	169.8053	8.8442	11.319	93651		8.84575	0.0990					
2	07-Jul-14	239.89	25.1730	0.505	22.24	6.04	833.808	100140	169.9206	8.8442	11.323	93677		8.84568	0.0982					
3	07-Jul-14	299.91	25.2334	0.459	22.28	6.03	833.736	100520	136.4316	8.8441	11.366	117319		8.84560	0.0973					
4	07-Jul-14	299.82	25.2094	0.459	22.36	6.03	833.753	100564	136.5304	8.8441	11.371	117204		8.84562	0.0976					
5	07-Jul-14	180.04	25.0690	0.460	22.41	6.06	833.849	99819	225.6684	8.8446	11.286	70096		8.84603	0.1022					
6	07-Jul-14	179.89	25.1020	0.462	22.45	6.05	833.828	99901	226.0359	8.8446	11.295	70106		8.84606	0.1025					
7	07-Jul-14	120.02	25.0647	0.428	22.51	6.06	833.831	99519	337.5027	8.8446	11.252	46722		8.84610	0.1030					
8	07-Jul-14	120.00	25.0705	0.427	22.56	6.06	833.827	99516	337.5532	8.8446	11.252	46722		8.84610	0.1029					
9	07-Jul-14	59.94	25.0404	0.400	22.63	6.06	833.839	99197	673.6705	8.8440	11.216	23317		8.84551	0.0963					
10	07-Jul-14	59.97	25.0331	0.404	22.66	6.06	833.847	99174	673.1043	8.8440	11.214	23326		8.84551	0.0963					
11	08-Jul-14	257.60	25.1749	0.520	23.05	6.04	833.822	100311	158.5090	8.8442	11.342	100598	Re = 100,000	8.84571	0.0985	8.84571	0.0004	0.0002	100467	73
12	08-Jul-14	257.37	25.1647	0.521	23.27	6.04	833.829	100272	158.5859	8.8442	11.337	100481	Re = 100,000	8.84573	0.0988					
13	08-Jul-14	257.24	25.1672	0.521	23.44	6.04	833.828	100289	158.6936	8.8442	11.339	100437	Re = 100,000	8.84569	0.0983					
14	08-Jul-14	257.27	25.1748	0.521	23.68	6.04	833.823	100150	158.4519	8.8442	11.324	100473	Re = 100,000	8.84572	0.0987					
15	08-Jul-14	257.12	25.1648	0.522	23.91	6.04	833.830	100268	158.7336	8.8443	11.337	100383	Re = 100,000	8.84576	0.0991					
16	08-Jul-14	257.19	25.1708	0.522	24.04	6.04	833.826	100318	158.7695	8.8441	11.343	100429	Re = 100,000	8.84566	0.0980					
17	08-Jul-14	29.87	25.0159	0.402	24.33	6.07	833.852	98995	1349.4133	8.8424	11.195	11611		8.84386	0.0776					
18	08-Jul-14	29.87	25.0289	0.403	24.57	6.06	833.844	98998	1349.3233	8.8423	11.196	11616		8.84381	0.0770					
19	09-Jul-14	180.10	25.1009	0.459	22.72	6.05	833.830	99844	225.6427	8.8447	11.289	70186	Re = 70,000	8.84618	0.1038	8.84611	0.0004	0.0002	70233	36
20	09-Jul-14	180.29	25.1017	0.457	22.75	6.05	833.828	99812	225.3430	8.8446	11.285	70259	Re = 70,000	8.84610	0.1030					
21	09-Jul-14	180.23	25.0988	0.460	22.83	6.05	833.832	99807	225.4067	8.8446	11.284	70230	Re = 70,000	8.84609	0.1028					
22	09-Jul-14	180.33	25.1052	0.459	22.92	6.05	833.827	99805	225.2731	8.8446	11.284	70283	Re = 70,000	8.84611	0.1030					
23	09-Jul-14	180.21	25.1080	0.458	22.99	6.05	833.825	99816	225.4522	8.8446	11.286	70241	Re = 70,000	8.84606	0.1026					
24	09-Jul-14	180.16	25.0986	0.459	23.10	6.05	833.835	99849	225.5900	8.8446	11.289	70202	Re = 70,000	8.84612	0.1032					

Table A.6.d NMIJ, Light oil, 30 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	10-Jul-14	240.24	30.1514	0.507	23.30	5.26	830.428	100548	170.3899	8.8426	11.371	107726		8.84560	0.0973					
2	10-Jul-14	240.19	30.1644	0.506	23.54	5.26	830.419	100502	170.3523	8.8424	11.366	107741		8.84539	0.0949					
3	10-Jul-14	299.65	30.2256	0.460	23.65	5.25	830.346	100858	137.0379	8.8422	11.406	134631		8.84523	0.0931					
4	10-Jul-14	299.61	30.2082	0.461	23.84	5.25	830.358	100976	137.2116	8.8423	11.420	134554		8.84531	0.0941					
5	10-Jul-14	179.97	30.0720	0.462	24.01	5.27	830.452	100156	226.5616	8.8429	11.326	80528		8.84583	0.0999					
6	10-Jul-14	180.02	30.1134	0.461	24.13	5.26	830.423	100263	226.7383	8.8429	11.338	80640		8.84586	0.1002					
7	10-Jul-14	119.91	30.0772	0.426	24.15	5.27	830.424	99898	339.1655	8.8432	11.297	53659		8.84615	0.1035					
8	10-Jul-14	120.05	30.0705	0.425	24.19	5.27	830.428	99865	338.6542	8.8431	11.293	53713		8.84608	0.1028					
9	10-Jul-14	59.91	30.0485	0.404	24.16	5.27	830.427	99572	676.7048	8.8425	11.261	26788		8.84539	0.0950					
10	10-Jul-14	59.91	30.0331	0.402	24.13	5.28	830.436	99584	676.6947	8.8424	11.262	26781		8.84536	0.0946					
11	11-Jul-14	221.69	30.1427	0.493	23.73	5.26	830.423	100404	184.3865	8.8427	11.354	99383	Re = 100,000	8.84564	0.0978	8.84554	0.0007	0.0003	99260	73
12	11-Jul-14	221.39	30.1556	0.492	24.31	5.26	830.413	100469	184.7536	8.8426	11.362	99285	Re = 100,000	8.84556	0.0969					
13	11-Jul-14	221.35	30.1457	0.493	24.73	5.26	830.420	100470	184.7924	8.8426	11.362	99238	Re = 100,000	8.84557	0.0969					
14	11-Jul-14	221.40	30.1507	0.493	24.81	5.26	830.417	100462	184.7391	8.8425	11.361	99273	Re = 100,000	8.84550	0.0961					
15	11-Jul-14	221.28	30.1353	0.493	24.92	5.26	830.428	100530	184.9638	8.8426	11.369	99178	Re = 100,000	8.84554	0.0966					
16	11-Jul-14	221.27	30.1458	0.493	25.13	5.26	830.421	100352	184.6453	8.8425	11.349	99202	Re = 100,000	8.84546	0.0957					
17	11-Jul-14	29.86	30.0197	0.400	25.52	5.28	830.445	99373	1355.1380	8.8408	11.240	13342		8.84376	0.0766					
18	11-Jul-14	29.88	30.0402	0.400	25.75	5.27	830.431	99382	1354.3875	8.8407	11.241	13358		8.84365	0.0753					
19	14-Jul-14	156.22	30.0774	0.444	23.95	5.27	830.436	100108	260.8733	8.8429	11.321	69913	Re = 70,000	8.84583	0.0999	8.84564	0.0011	0.0004	69952	29
20	14-Jul-14	156.26	30.1121	0.444	24.17	5.26	830.413	100079	260.7425	8.8427	11.318	69995	Re = 70,000	8.84560	0.0973					
21	14-Jul-14	156.24	30.0995	0.442	24.37	5.27	830.420	100081	260.7762	8.8427	11.318	69963	Re = 70,000	8.84562	0.0975					
22	14-Jul-14	156.26	30.0843	0.442	24.55	5.27	830.431	100092	260.7762	8.8426	11.319	69943	Re = 70,000	8.84557	0.0970					
23	14-Jul-14	156.31	30.0878	0.442	24.61	5.27	830.428	100061	260.6219	8.8427	11.316	69969	Re = 70,000	8.84561	0.0974					
24	14-Jul-14	156.20	30.0924	0.443	24.63	5.27	830.425	100073	260.8247	8.8427	11.317	69931	Re = 70,000	8.84561	0.0974					

Table A.6.e NMIJ, Kerosene, 20 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No [-]	Date [dd/mm/yy]	Flowrate [m3/h]	Temp. [°C]	Pressure [MPa]	Ambient Temp. [°C]	Kinematic Viscosity [×10⁻⁶ m²/s]	Density [kg/m³]	Pulses [P]	Time [s]	K factor [p/L]	Volume [m³]	Re [-]		Kf20 [p/L]	K [%]	Kf20avg [p/L]	S. D. of K [%]	uDUT [%]	Reavg [-]	S.D. of Re [-]
1	23-Jul-14	238.02	20.0334	0.493	24.04	2.04	795.285	104857	179.3473	8.8430	11.858	275235		8.84299	0.0678					
2	23-Jul-14	238.06	19.9890	0.493	24.26	2.04	795.317	104911	179.4066	8.8430	11.864	275059		8.84302	0.0681					
3	23-Jul-14	297.36	20.0743	0.509	24.30	2.04	795.266	105239	144.0837	8.8426	11.901	344119		8.84264	0.0638					
4	23-Jul-14	297.38	20.0701	0.508	24.35	2.04	795.268	105118	143.9153	8.8422	11.888	344114		8.84227	0.0596					
5	23-Jul-14	178.46	19.9334	0.452	24.56	2.04	795.331	104563	238.4844	8.8444	11.822	205991		8.84439	0.0836					
6	23-Jul-14	178.48	19.9741	0.452	24.71	2.04	795.302	104562	238.4639	8.8444	11.822	206161		8.84442	0.0839					
7	23-Jul-14	118.94	19.9327	0.422	24.83	2.04	795.314	104244	356.6704	8.8460	11.784	137288		8.84595	0.1013					
8	23-Jul-14	118.98	19.9486	0.423	24.80	2.04	795.303	104245	356.5763	8.8459	11.785	137366		8.84593	0.1010					
9	23-Jul-14	59.43	19.9165	0.404	24.85	2.04	795.313	103958	711.7575	8.8471	11.751	68578		8.84707	0.1140					
10	23-Jul-14	59.44	19.9252	0.404	24.76	2.04	795.307	103959	711.6373	8.8470	11.751	68602		8.84700	0.1132					
11	24-Jul-14	259.69	20.0124	0.510	24.01	2.04	795.318	104972	164.5620	8.8429	11.871	300181	Re = 300,000	8.84287	0.0664	8.84280	0.0007	0.0003	300272	120
12	24-Jul-14	259.78	20.0455	0.509	24.19	2.04	795.293	105036	164.6046	8.8428	11.878	300472	Re = 300,000	8.84282	0.0658					
13	24-Jul-14	259.78	20.0202	0.510	24.33	2.04	795.312	105027	164.5904	8.8428	11.877	300333	Re = 300,000	8.84277	0.0653					
14	24-Jul-14	259.76	20.0187	0.508	24.54	2.04	795.316	105018	164.5890	8.8428	11.876	300300	Re = 300,000	8.84282	0.0659					
15	24-Jul-14	259.57	20.0329	0.510	24.69	2.04	795.307	105013	164.7027	8.8427	11.876	300161	Re = 300,000	8.84270	0.0644					
16	24-Jul-14	259.60	20.0317	0.509	24.85	2.04	795.307	105025	164.7018	8.8428	11.877	300186	Re = 300,000	8.84283	0.0659					
17	24-Jul-14	86.48	19.9207	0.411	25.01	2.04	795.322	104088	489.8118	8.8467	11.766	99790	Re = 100,000	8.84665	0.1092	8.84664	0.0002	0.0001	99846	32
18	24-Jul-14	86.53	19.9243	0.414	25.02	2.04	795.321	104078	489.4730	8.8467	11.765	99856	Re = 100,000	8.84665	0.1092					
19	24-Jul-14	86.51	19.9253	0.413	24.88	2.04	795.320	104098	489.6805	8.8466	11.767	99835	Re = 100,000	8.84663	0.1089					
20	24-Jul-14	86.52	19.9226	0.414	24.90	2.04	795.323	104088	489.5808	8.8466	11.766	99841	Re = 100,000	8.84663	0.1089					
21	24-Jul-14	86.54	19.9293	0.414	24.93	2.04	795.319	104124	489.6170	8.8467	11.770	99880	Re = 100,000	8.84667	0.1094					
22	24-Jul-14	86.55	19.9219	0.414	24.89	2.04	795.325	104088	489.4163	8.8466	11.766	99874	Re = 100,000	8.84661	0.1088					
23	25-Jul-14	60.51	19.8801	0.406	24.22	2.04	795.351	103935	698.9068	8.8468	11.748	69780	Re = 70,000	8.84673	0.1101	8.84689	0.0010	0.0004	69840	32
24	25-Jul-14	60.54	19.9081	0.405	24.44	2.04	795.330	103949	698.7018	8.8469	11.750	69845	Re = 70,000	8.84687	0.1116					
25	25-Jul-14	60.53	19.9144	0.405	24.71	2.04	795.329	103953	698.8375	8.8470	11.750	69841	Re = 70,000	8.84696	0.1127					
26	25-Jul-14	60.55	19.9220	0.405	24.93	2.04	795.323	103939	698.5289	8.8469	11.749	69873	Re = 70,000	8.84691	0.1122					
27	25-Jul-14	60.53	19.9311	0.406	25.10	2.04	795.317	103966	698.9515	8.8469	11.752	69861	Re = 70,000	8.84690	0.1121					
28	25-Jul-14	60.53	19.9101	0.406	25.14	2.04	795.333	103926	698.6272	8.8470	11.747	69839	Re = 70,000	8.84695	0.1126					
29	25-Jul-14	29.61	19.9072	0.401	25.24	2.04	795.334	103771	1426.4357	8.8458	11.731	34157		8.84578	0.0994					
30	25-Jul-14	29.63	19.8893	0.401	25.40	2.04	795.347	103780	1425.2520	8.8459	11.732	34176		8.84590	0.1007					

Table A.6.f NMIJ, Kerosene, 25 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	28-Jul-14	238.10	25.0135	0.492	23.63	1.87	791.693	105335	180.1469	8.8409	11.914	301006		8.84239	0.0610					
2	28-Jul-14	238.12	25.0071	0.493	23.79	1.87	791.698	105304	180.0715	8.8410	11.911	301007		8.84249	0.0621					
3	28-Jul-14	297.45	25.0646	0.507	24.07	1.86	791.666	105670	144.6673	8.8404	11.953	376377		8.84186	0.0550					
4	28-Jul-14	297.56	25.0671	0.508	24.28	1.86	791.665	105739	144.7074	8.8404	11.961	376535		8.84185	0.0549					
5	28-Jul-14	178.58	24.9436	0.453	24.31	1.87	791.716	104966	239.2877	8.8429	11.870	225494		8.84430	0.0826					
6	28-Jul-14	178.55	24.9716	0.453	24.52	1.87	791.696	104964	239.3202	8.8428	11.870	225569		8.84430	0.0826					
7	28-Jul-14	118.94	24.9337	0.423	24.72	1.87	791.704	104709	358.3450	8.8440	11.840	150161		8.84548	0.0960					
8	28-Jul-14	118.99	24.9365	0.423	24.86	1.87	791.702	104712	358.2142	8.8440	11.840	150228		8.84545	0.0957					
9	28-Jul-14	59.44	24.9076	0.404	24.82	1.87	791.712	104384	714.7050	8.8454	11.801	75010		8.84686	0.1115					
10	28-Jul-14	59.47	24.9065	0.404	24.84	1.87	791.712	104385	714.4231	8.8454	11.801	75039		8.84679	0.1108					
11	29-Jul-14	237.46	25.0184	0.491	23.68	1.86	791.698	105328	180.6159	8.8410	11.914	300229	Re = 300,000	8.84243	0.0615	8.84237	0.0006	0.0002	300127	131
12	29-Jul-14	237.47	25.0221	0.491	23.85	1.86	791.696	105245	180.4706	8.8409	11.904	300257	Re = 300,000	8.84233	0.0603					
13	29-Jul-14	237.43	25.0135	0.491	24.04	1.87	791.702	105389	180.7424	8.8409	11.921	300169	Re = 300,000	8.84237	0.0608					
14	29-Jul-14	237.29	25.0047	0.494	24.24	1.87	791.710	105286	180.6754	8.8410	11.909	299939	Re = 300,000	8.84243	0.0615					
15	29-Jul-14	237.46	25.0086	0.493	24.45	1.87	791.707	105270	180.5187	8.8409	11.907	300178	Re = 300,000	8.84232	0.0602					
16	29-Jul-14	237.34	25.0025	0.494	24.61	1.87	791.715	105319	180.6955	8.8409	11.913	299991	Re = 300,000	8.84233	0.0603					
17	29-Jul-14	79.14	24.9190	0.409	24.78	1.87	791.714	104487	537.4071	8.8449	11.813	99880	Re = 100,000	8.84632	0.1055	8.84631	0.0003	0.0001	99878	16
18	29-Jul-14	79.14	24.9079	0.408	24.85	1.87	791.724	104501	537.4210	8.8449	11.815	99872	Re = 100,000	8.84632	0.1055					
19	29-Jul-14	79.13	24.9263	0.410	24.79	1.87	791.712	104471	537.3663	8.8449	11.811	99885	Re = 100,000	8.84634	0.1057					
20	29-Jul-14	79.13	24.9220	0.409	24.94	1.87	791.716	104500	537.5287	8.8449	11.815	99875	Re = 100,000	8.84633	0.1056					
21	29-Jul-14	79.12	24.9106	0.409	24.87	1.87	791.724	104483	537.4672	8.8448	11.813	99851	Re = 100,000	8.84627	0.1050					
22	29-Jul-14	79.15	24.9220	0.409	25.00	1.87	791.716	104511	537.4527	8.8449	11.816	99901	Re = 100,000	8.84629	0.1051					
23	30-Jul-14	55.38	24.9064	0.405	23.80	1.87	791.735	104379	767.0952	8.8453	11.801	69883	Re = 70,000	8.84673	0.1101	8.84675	0.0002	0.0001	69911	16
24	30-Jul-14	55.40	24.9139	0.404	24.03	1.87	791.729	104381	766.8665	8.8453	11.801	69914	Re = 70,000	8.84676	0.1104					
25	30-Jul-14	55.40	24.9114	0.405	24.31	1.87	791.731	104358	766.6002	8.8453	11.798	69920	Re = 70,000	8.84674	0.1102					
26	30-Jul-14	55.41	24.9077	0.405	24.52	1.87	791.733	104363	766.5373	8.8453	11.799	69924	Re = 70,000	8.84674	0.1102					
27	30-Jul-14	55.39	24.9152	0.405	24.73	1.87	791.728	104384	767.0221	8.8453	11.801	69903	Re = 70,000	8.84676	0.1104					
28	30-Jul-14	55.40	24.9139	0.405	24.92	1.87	791.729	104369	766.6883	8.8453	11.799	69922	Re = 70,000	8.84677	0.1106					
29	30-Jul-14	29.64	24.8975	0.400	25.13	1.87	791.738	104218	1431.3569	8.8439	11.784	37394		8.84538	0.0948					
30	30-Jul-14	29.64	24.9016	0.399	25.30	1.87	791.734	104229	1431.6334	8.8441	11.785	37393		8.84551	0.0964					

Table A.6.g NMIJ, Kerosene, 30 ºC, Jul. 2014

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^-6 m²/s]	[kg/m³]	[P]	[s]	[p/L]	[m³]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	31-Jul-14	237.96	30.0670	0.492	24.25	1.71	788.050	105872	181.2071	8.8392	11.978	327580		8.84214	0.0582					
2	31-Jul-14	238.00	30.0082	0.493	24.47	1.71	788.093	105806	181.0631	8.8390	11.970	327327		8.84196	0.0561					
3	31-Jul-14	297.39	30.0730	0.507	24.69	1.71	788.069	106195	145.4402	8.8388	12.015	409445		8.84170	0.0532					
4	31-Jul-14	297.38	30.0568	0.508	24.89	1.71	788.081	106099	145.3163	8.8388	12.004	409314		8.84172	0.0534					
5	31-Jul-14	178.47	29.9239	0.451	25.13	1.72	788.136	105448	240.5849	8.8411	11.927	245117		8.84395	0.0786					
6	31-Jul-14	178.52	29.9642	0.451	25.32	1.72	788.109	105471	240.5780	8.8411	11.930	245339		8.84396	0.0788					
7	31-Jul-14	118.92	29.9254	0.420	25.86	1.72	788.121	105160	360.0348	8.8424	11.893	163325		8.84532	0.0942					
8	31-Jul-14	118.95	29.9281	0.421	25.94	1.72	788.120	105169	359.9687	8.8423	11.894	163378		8.84524	0.0932					
9	01-Aug-14	59.46	29.9369	0.406	24.33	1.72	788.106	104840	717.7785	8.8434	11.855	81680		8.84632	0.1055					
10	01-Aug-14	59.46	29.9300	0.405	24.72	1.72	788.110	104866	717.8886	8.8434	11.858	81679		8.84630	0.1052					
11	01-Aug-14	29.63	29.9015	0.398	24.98	1.72	788.123	104678	1438.2573	8.8422	11.838	40682		8.84514	0.0921					
12	01-Aug-14	29.59	29.9043	0.397	25.26	1.72	788.120	104681	1440.3407	8.8423	11.839	40626		8.84521	0.0929					
13	04-Aug-14	218.16	30.0063	0.476	24.53	1.71	788.123	105697	197.3128	8.8396	11.957	300032	Re = 300,000	8.84254	0.0627	8.84255	0.0003	0.0001	300100	99
14	04-Aug-14	218.21	29.9840	0.475	24.76	1.72	788.138	105663	197.2050	8.8397	11.953	299987	Re = 300,000	8.84260	0.0633					
15	04-Aug-14	218.25	29.9893	0.475	24.94	1.71	788.129	105693	197.2254	8.8396	11.957	300069	Re = 300,000	8.84254	0.0627					
16	04-Aug-14	218.29	29.9821	0.476	25.10	1.72	788.136	105695	197.1880	8.8396	11.957	300097	Re = 300,000	8.84251	0.0624					
17	04-Aug-14	218.33	29.9819	0.476	25.18	1.72	788.136	105663	197.0963	8.8396	11.953	300144	Re = 300,000	8.84254	0.0627					
18	04-Aug-14	218.40	29.9879	0.477	25.29	1.71	788.135	105665	197.0362	8.8397	11.954	300270	Re = 300,000	8.84257	0.0630					
19	04-Aug-14	72.72	29.9287	0.409	25.42	1.72	788.127	104914	587.2854	8.8433	11.864	99888	Re = 100,000	8.84616	0.1037	8.84633	0.0011	0.0005	99876	13
20	04-Aug-14	72.76	29.8994	0.409	25.65	1.72	788.148	104894	586.8812	8.8435	11.861	99887	Re = 100,000	8.84638	0.1061					
21	04-Aug-14	72.75	29.9022	0.408	25.75	1.72	788.149	104903	586.9595	8.8435	11.862	99887	Re = 100,000	8.84636	0.1059					
22	04-Aug-14	72.74	29.9012	0.408	25.74	1.72	788.150	104895	587.0681	8.8434	11.861	99860	Re = 100,000	8.84634	0.1057					
23	04-Aug-14	72.73	29.9049	0.408	25.69	1.72	788.149	104900	587.1128	8.8434	11.862	99863	Re = 100,000	8.84631	0.1054					
24	04-Aug-14	72.74	29.9036	0.407	25.64	1.72	788.149	104938	587.2701	8.8436	11.866	99869	Re = 100,000	8.84646	0.1070					
25	05-Aug-14	50.92	29.9301	0.404	24.77	1.72	788.136	104797	837.7876	8.8436	11.850	69941	Re = 70,000	8.84654	0.1080	8.84631	0.0014	0.0006	69914	29
26	05-Aug-14	50.93	29.9249	0.404	25.16	1.72	788.139	104803	837.6154	8.8435	11.851	69955	Re = 70,000	8.84636	0.1059					
27	05-Aug-14	50.92	29.9021	0.405	25.39	1.72	788.159	104785	837.6368	8.8434	11.849	69916	Re = 70,000	8.84625	0.1047					
28	05-Aug-14	50.91	29.8984	0.405	25.65	1.72	788.163	104789	837.8617	8.8434	11.849	69896	Re = 70,000	8.84625	0.1047					
29	05-Aug-14	50.90	29.9023	0.406	25.85	1.72	788.161	104800	838.0934	8.8434	11.851	69888	Re = 70,000	8.84625	0.1047					
30	05-Aug-14	50.91	29.9004	0.408	26.07	1.72	788.164	104788	837.9651	8.8433	11.849	69889	Re = 70,000	8.84621	0.1042					

Table A.6.h NMIJ, Light oil, 20 ºC, May. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No [-]	Date [dd/mm/yy]	Flowrate [m3/h]	Temp. [ºC]	Pressure [MPa]	Ambient Temp. [ºC]	Kinematic Viscosity [$\times10^{-6}$ m^2/s]	Density [kg/m^3]	Pulses [P]	Time [s]	K factor [p/L]	Volume [m^3]	Re [-]		Kf20 [p/L]	K [%]	Kf20avg [p/L]	S. D. of K [%]	uDUT [%]	Reavg [-]	S.D. of Re [-]
1	13-May-15	238.94	20.1745	0.511	21.98	7.01	837.536	99722	169.8427	8.8462	11.273	80419		8.84622	0.1043					
2	13-May-15	239.03	20.1408	0.511	22.23	7.01	837.559	99795	169.9022	8.8462	11.281	80366		8.84622	0.1044					
3	13-May-15	299.78	20.2037	0.461	22.51	7.00	837.484	100080	135.8582	8.8463	11.313	100986		8.84638	0.1061					
4	13-May-15	299.89	20.2082	0.461	22.76	7.00	837.481	100054	135.7711	8.8463	11.310	101039		8.84636	0.1059					
5	13-May-15	179.54	20.0814	0.459	22.94	7.03	837.566	99447	225.4192	8.8461	11.242	60252		8.84614	0.1034					
6	13-May-15	179.64	20.1098	0.457	23.06	7.02	837.545	99465	225.3265	8.8461	11.244	60341		8.84615	0.1035					
7	13-May-15	119.95	20.0717	0.426	23.15	7.03	837.551	99092	336.1662	8.8466	11.201	40244		8.84658	0.1085					
8	13-May-15	120.02	20.0632	0.424	23.31	7.03	837.556	99115	336.0547	8.8465	11.204	40257		8.84653	0.1078					
9	13-May-15	59.87	20.0311	0.406	23.42	7.04	837.573	98764	671.3074	8.8459	11.165	20063		8.84590	0.1007					
10	13-May-15	59.91	20.0347	0.406	23.56	7.04	837.570	98760	670.8396	8.8459	11.165	20078		8.84586	0.1003					
11	14-May-15	298.05	20.2257	0.469	22.07	6.99	837.480	100116	136.6982	8.8463	11.317	100470	Re = 100,000	8.84634	0.1057	8.84632	0.0005	0.0002	100341	85
12	14-May-15	297.85	20.2162	0.468	22.32	7.00	837.486	100095	136.7578	8.8463	11.315	100376	Re = 100,000	8.84637	0.1061					
13	14-May-15	297.93	20.1967	0.469	22.61	7.00	837.500	99965	136.5470	8.8462	11.300	100341	Re = 100,000	8.84628	0.1050					
14	14-May-15	297.78	20.2071	0.469	22.79	7.00	837.493	100086	136.7817	8.8462	11.314	100322	Re = 100,000	8.84626	0.1048					
15	14-May-15	297.82	20.2044	0.470	23.02	7.00	837.495	100102	136.7827	8.8463	11.316	100328	Re = 100,000	8.84635	0.1058					
16	14-May-15	297.52	20.1981	0.469	23.16	7.00	837.499	100063	136.8663	8.8463	11.311	100208	Re = 100,000	8.84634	0.1057					
17	14-May-15	30.04	20.0262	0.401	23.51	7.04	837.575	98574	1335.9208	8.8439	11.146	10063		8.84388	0.0778					
18	14-May-15	29.42	20.0256	0.404	23.69	7.04	837.577	98561	1363.4905	8.8439	11.145	9858		8.84389	0.0779					
19	15-May-15	208.29	20.1062	0.484	22.38	7.02	837.572	99581	194.5623	8.8459	11.257	69957	Re = 70,000	8.84596	0.1014	8.84599	0.0008	0.0003	69993	27
20	15-May-15	208.40	20.1118	0.484	22.67	7.02	837.568	99567	194.4304	8.8460	11.256	70006	Re = 70,000	8.84605	0.1024					
21	15-May-15	208.30	20.1192	0.483	22.87	7.02	837.563	99553	194.5020	8.8459	11.254	69988	Re = 70,000	8.84591	0.1009					
22	15-May-15	208.38	20.1202	0.485	23.02	7.02	837.563	99524	194.3701	8.8460	11.251	70016	Re = 70,000	8.84602	0.1021					
23	15-May-15	208.30	20.1101	0.484	23.23	7.02	837.568	99557	194.5136	8.8459	11.255	69967	Re = 70,000	8.84589	0.1006					
24	15-May-15	208.39	20.1229	0.484	23.32	7.02	837.560	99547	194.4078	8.8460	11.253	70024	Re = 70,000	8.84607	0.1026					

Table A.6.i NMIJ, Kerosene, 20 ºC, May 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No [-]	Date [dd/mm/yy]	Flowrate [m3/h]	Temp. [°C]	Pressure [MPa]	Ambient Temp. [°C]	Kinematic Viscosity [×10^-6 m²/s]	Density [kg/m³]	Pulses [P]	Time [s]	K factor [p/L]	Volume [m³]	Re [-]		Kf20 [p/L]	K [%]	Kf20avg [p/L]	S. D. of K [%]	uDUT [%]	Reavg [-]	S.D. of Re [-]
1	21-May-15	238.46	20.0786	0.491	21.64	2.06	795.587	104801	178.9148	8.8430	11.851	273437		8.84302	0.0681					
2	21-May-15	238.39	20.0213	0.492	21.72	2.06	795.629	104876	179.0997	8.8430	11.860	273060		8.84304	0.0683					
3	21-May-15	297.86	20.0800	0.509	21.92	2.06	795.599	105161	143.7399	8.8423	11.893	341555		8.84234	0.0605					
4	21-May-15	298.03	20.0798	0.509	22.14	2.06	795.597	105174	143.6757	8.8424	11.894	341745		8.84243	0.0614					
5	21-May-15	178.71	19.9346	0.453	22.39	2.06	795.664	104489	237.9885	8.8442	11.814	204378		8.84422	0.0817					
6	21-May-15	178.73	19.9709	0.453	22.55	2.06	795.638	104559	238.1283	8.8443	11.822	204531		8.84426	0.0821					
7	21-May-15	119.14	19.9368	0.424	22.74	2.06	795.643	104219	355.9985	8.8457	11.782	136258		8.84573	0.0988					
8	21-May-15	119.12	19.9463	0.423	22.88	2.06	795.635	104236	356.1145	8.8457	11.784	136260		8.84573	0.0988					
9	21-May-15	59.50	19.9015	0.406	23.00	2.06	795.658	103911	710.6986	8.8466	11.746	68001		8.84654	0.1080					
10	21-May-15	59.49	19.9060	0.406	23.16	2.06	795.655	103904	710.7764	8.8465	11.745	67995		8.84650	0.1075					
11	22-May-15	261.93	20.0268	0.514	21.72	2.06	795.648	104987	163.1810	8.8426	11.873	300058	Re = 300,000	8.84265	0.0640	8.84270	0.0010	0.0004	300060	37
12	22-May-15	261.93	20.0272	0.513	21.90	2.06	795.647	104914	163.0661	8.8428	11.864	300059	Re = 300,000	8.84277	0.0653					
13	22-May-15	261.91	20.0378	0.513	22.04	2.06	795.638	105080	163.3381	8.8426	11.883	300098	Re = 300,000	8.84260	0.0634					
14	22-May-15	261.87	20.0370	0.515	22.21	2.06	795.640	105076	163.3535	8.8427	11.883	300051	Re = 300,000	8.84268	0.0643					
15	22-May-15	261.89	20.0415	0.515	22.38	2.06	795.637	105009	163.2378	8.8427	11.875	300098	Re = 300,000	8.84266	0.0641					
16	22-May-15	261.86	20.0310	0.513	22.56	2.06	795.645	104902	163.0904	8.8428	11.863	299999	Re = 300,000	8.84284	0.0661					
17	22-May-15	87.32	19.8970	0.413	22.83	2.06	795.672	104068	485.0167	8.8464	11.764	99786	Re = 100,000	8.84637	0.1061	8.84637	0.0006	0.0002	99829	29
18	22-May-15	87.31	19.9152	0.413	22.93	2.06	795.662	104024	484.8489	8.8465	11.759	99811	Re = 100,000	8.84645	0.1069					
19	22-May-15	87.34	19.9256	0.413	22.86	2.06	795.654	104025	484.6907	8.8464	11.759	99865	Re = 100,000	8.84639	0.1062					
20	22-May-15	87.32	19.9160	0.413	22.80	2.06	795.660	104041	484.9028	8.8463	11.761	99820	Re = 100,000	8.84630	0.1052					
21	22-May-15	87.33	19.9257	0.413	22.80	2.06	795.653	104034	484.7913	8.8464	11.760	99853	Re = 100,000	8.84635	0.1058					
22	22-May-15	87.34	19.9132	0.413	22.78	2.06	795.664	104033	484.7434	8.8464	11.760	99839	Re = 100,000	8.84636	0.1059					
23	25-May-15	61.16	19.8976	0.404	22.25	2.06	795.684	103889	691.1866	8.8468	11.743	69899	Re = 70,000	8.84679	0.1108	8.84669	0.0012	0.0005	69925	14
24	25-May-15	61.19	19.9006	0.403	22.35	2.06	795.681	103910	691.0620	8.8469	11.745	69929	Re = 70,000	8.84685	0.1115					
25	25-May-15	61.18	19.9057	0.403	22.55	2.06	795.666	103903	691.0998	8.8467	11.745	69928	Re = 70,000	8.84668	0.1096					
26	25-May-15	61.18	19.9050	0.403	22.52	2.06	795.666	103904	691.1468	8.8467	11.745	69924	Re = 70,000	8.84663	0.1089					
27	25-May-15	61.19	19.9068	0.403	22.50	2.06	795.667	103915	691.0733	8.8466	11.746	69941	Re = 70,000	8.84662	0.1088					
28	25-May-15	61.19	19.8989	0.403	22.61	2.06	795.673	103908	691.0293	8.8466	11.745	69931	Re = 70,000	8.84657	0.1083					
29	25-May-15	29.65	19.9033	0.399	22.68	2.06	795.670	103725	1423.7861	8.8448	11.727	33891		8.84475	0.0877					
30	25-May-15	29.65	19.9066	0.399	22.62	2.06	795.668	103729	1423.8155	8.8449	11.728	33893		8.84489	0.0892					

Table A.6.j NMIJ, Light oil, 20 ºC, Jul. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	27-Jul-15	239.65	20.2401	0.507	24.74	7.02	837.524	99779	169.4444	8.8460	11.280	80528		8.84605	0.1024					
2	27-Jul-15	239.64	20.1443	0.508	24.94	7.04	837.589	99788	169.4645	8.8460	11.281	80287		8.84608	0.1028					
3	27-Jul-15	299.45	20.2161	0.461	25.10	7.02	837.510	100128	136.0778	8.8461	11.319	100549		8.84612	0.1032					
4	27-Jul-15	299.43	20.2267	0.460	25.26	7.02	837.502	100133	136.0906	8.8461	11.319	100577		8.84615	0.1036					
5	27-Jul-15	179.90	20.0727	0.462	25.50	7.05	837.609	99428	224.9239	8.8459	11.240	60140		8.84596	0.1014					
6	27-Jul-15	179.70	20.1161	0.463	25.62	7.04	837.580	99400	225.1161	8.8460	11.237	60152		8.84601	0.1019					
7	27-Jul-15	119.77	20.0870	0.428	25.68	7.05	837.577	99069	336.6233	8.8463	11.199	40055		8.84628	0.1050					
8	27-Jul-15	119.81	20.0625	0.432	25.71	7.06	837.591	99128	336.6916	8.8462	11.206	40041		8.84620	0.1041					
9	28-Jul-15	298.11	20.2244	0.466	23.75	7.02	837.500	100068	136.6071	8.8460	11.312	100126	Re = 100,000	8.84607	0.1026	8.84611	0.0011	0.0005	100111	29
10	28-Jul-15	298.10	20.2139	0.465	23.92	7.02	837.506	100134	136.6993	8.8462	11.319	100089	Re = 100,000	8.84627	0.1049					
11	28-Jul-15	298.06	20.2187	0.465	24.19	7.02	837.504	100101	136.6739	8.8461	11.316	100090	Re = 100,000	8.84620	0.1041					
12	28-Jul-15	298.12	20.2157	0.466	24.43	7.02	837.506	100056	136.5853	8.8460	11.311	100103	Re = 100,000	8.84605	0.1024					
13	28-Jul-15	298.27	20.2189	0.465	24.52	7.02	837.503	100063	136.5267	8.8459	11.312	100163	Re = 100,000	8.84601	0.1019					
14	28-Jul-15	298.11	20.2137	0.465	24.64	7.02	837.507	100054	136.5868	8.8460	11.311	100093	Re = 100,000	8.84608	0.1028					
15	28-Jul-15	59.84	20.0219	0.405	25.00	7.06	837.608	98764	671.6978	8.8457	11.165	19973		8.84571	0.0986					
16	28-Jul-15	59.85	20.0428	0.403	25.13	7.06	837.592	98778	671.7405	8.8457	11.167	19988		8.84569	0.0983					
17	29-Jul-15	208.97	20.1136	0.481	24.13	7.04	837.588	99530	193.8314	8.8461	11.251	69946	Re = 70,000	8.84616	0.1037	8.84618	0.0003	0.0001	70034	104
18	29-Jul-15	209.13	20.1191	0.480	24.30	7.04	837.584	99530	193.6785	8.8461	11.251	70013	Re = 70,000	8.84617	0.1038					
19	29-Jul-15	209.71	20.1351	0.480	24.23	7.04	837.573	99620	193.3236	8.8461	11.261	70240	Re = 70,000	8.84616	0.1036					
20	29-Jul-15	208.97	20.1301	0.482	24.29	7.04	837.577	99535	193.8430	8.8461	11.252	69981	Re = 70,000	8.84616	0.1037					
21	29-Jul-15	209.06	20.1342	0.482	24.37	7.04	837.574	99580	193.8435	8.8462	11.257	70021	Re = 70,000	8.84622	0.1043					
22	29-Jul-15	208.93	20.1471	0.481	24.55	7.04	837.565	99564	193.9349	8.8462	11.255	70004	Re = 70,000	8.84622	0.1044					
23	29-Jul-15	29.84	20.0380	0.400	24.63	7.06	837.590	98566	1344.5732	8.8442	11.145	9965		8.84416	0.0810					
24	29-Jul-15	29.84	20.0351	0.400	24.74	7.06	837.592	98560	1344.5357	8.8441	11.144	9963		8.84409	0.0802					

Table A.6.k NMIJ, Kerosene, 20 ºC, Sep. 2015

Calibration condition								PD meter			Others		Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor	Volume	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m3/h]	[°C]	[MPa]	[°C]	[×10^{-6} m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	07-Sep-15	238.08	20.0210	0.492	22.03	2.07	795.831	104741	179.0991	8.8430	11.844	271020		8.84303	0.0682					
2	07-Sep-15	237.96	20.0260	0.493	22.03	2.07	795.828	104787	179.2671	8.8431	11.850	270908		8.84309	0.0689					
3	07-Sep-15	297.43	20.0804	0.509	22.03	2.07	795.795	105221	144.0309	8.8422	11.900	338956		8.84224	0.0593					
4	07-Sep-15	297.48	20.0775	0.508	22.03	2.07	795.797	105106	143.8558	8.8420	11.887	338988		8.84201	0.0567					
5	07-Sep-15	178.51	19.9298	0.452	22.03	2.07	795.864	104526	238.3454	8.8442	11.819	202862		8.84417	0.0812					
6	07-Sep-15	178.48	19.9576	0.453	22.03	2.07	795.844	104507	238.3393	8.8442	11.816	202935		8.84421	0.0816					
7	07-Sep-15	119.00	19.9350	0.424	22.03	2.07	795.842	104171	356.2660	8.8457	11.776	135247		8.84564	0.0977					
8	07-Sep-15	118.98	19.9373	0.424	22.03	2.07	795.840	104148	356.2341	8.8457	11.774	135234		8.84566	0.0980					
9	07-Sep-15	59.43	19.9097	0.404	22.03	2.08	795.848	103857	711.1184	8.8466	11.740	67515		8.84656	0.1082					
10	07-Sep-15	59.45	19.9051	0.409	22.03	2.08	795.855	103878	711.0103	8.8466	11.742	67533		8.84658	0.1084					
11	08-Sep-15	263.38	20.0329	0.514	22.03	2.07	795.835	105032	162.3582	8.8423	11.878	299885	Re = 300,000	8.84234	0.0604	8.84242	0.0007	0.0003	299992	91
12	08-Sep-15	263.49	20.0337	0.514	22.03	2.07	795.835	104988	162.2181	8.8424	11.873	300020	Re = 300,000	8.84242	0.0613					
13	08-Sep-15	263.42	20.0384	0.514	22.03	2.07	795.831	105011	162.3022	8.8423	11.876	299959	Re = 300,000	8.84235	0.0606					
14	08-Sep-15	263.55	20.0450	0.514	22.03	2.07	795.828	104952	162.1300	8.8425	11.869	300142	Re = 300,000	8.84247	0.0619					
15	08-Sep-15	263.39	20.0374	0.513	22.03	2.07	795.833	104952	162.2246	8.8425	11.869	299923	Re = 300,000	8.84250	0.0622					
16	08-Sep-15	263.56	20.0210	0.513	22.03	2.07	795.845	104875	162.0047	8.8424	11.860	300020	Re = 300,000	8.84244	0.0615					
17	08-Sep-15	87.86	19.9228	0.412	22.03	2.08	795.843	104006	481.7338	8.8464	11.757	99832	Re = 100,000	8.84634	0.1057	8.84642	0.0007	0.0003	99838	35
18	08-Sep-15	87.88	19.9231	0.412	22.03	2.08	795.843	103997	481.5848	8.8464	11.756	99855	Re = 100,000	8.84639	0.1062					
19	08-Sep-15	87.90	19.9289	0.412	22.03	2.07	795.839	104034	481.6408	8.8464	11.760	99890	Re = 100,000	8.84637	0.1061					
20	08-Sep-15	87.85	19.9052	0.412	22.03	2.08	795.867	104030	481.9055	8.8465	11.759	99786	Re = 100,000	8.84644	0.1068					
21	08-Sep-15	87.87	19.9263	0.411	22.03	2.07	795.851	104000	481.6659	8.8465	11.756	99846	Re = 100,000	8.84648	0.1073					
22	08-Sep-15	87.84	19.9291	0.412	22.03	2.07	795.850	104013	481.8646	8.8465	11.758	99822	Re = 100,000	8.84648	0.1073					
23	09-Sep-15	61.52	19.9017	0.405	22.03	2.08	795.867	103874	687.1352	8.8465	11.742	69873	Re = 70,000	8.84649	0.1074	8.84656	0.0005	0.0002	69874	15
24	09-Sep-15	61.53	19.9039	0.404	22.03	2.08	795.866	103863	686.8818	8.8466	11.740	69893	Re = 70,000	8.84659	0.1086					
25	09-Sep-15	61.51	19.8942	0.405	22.03	2.08	795.875	103872	687.1775	8.8466	11.741	69856	Re = 70,000	8.84659	0.1085					
26	09-Sep-15	61.53	19.9000	0.405	22.03	2.08	795.870	103862	686.8828	8.8466	11.740	69887	Re = 70,000	8.84659	0.1085					
27	09-Sep-15	61.52	19.9006	0.404	22.03	2.08	795.868	103855	686.9710	8.8466	11.740	69875	Re = 70,000	8.84653	0.1078					
28	09-Sep-15	61.51	19.8951	0.408	22.03	2.08	795.874	103872	687.1615	8.8466	11.741	69860	Re = 70,000	8.84655	0.1081					
29	09-Sep-15	29.61	19.9009	0.402	22.03	2.08	795.869	103690	1425.4238	8.8454	11.722	33627		8.84537	0.0948					
30	09-Sep-15	29.60	19.9018	0.402	22.03	2.08	795.868	103692	1425.7222	8.8455	11.723	33620		8.84547	0.0958					

A.7 TRAPIL

Table A.7.a Averaged data

Reynolds number [-]	Liquid [-]	Kinematic viscosity [×10^{-6} m^2/s]	Density [kg/m^3]	Flow rate [m^3/h]	Temperature [^oC]	Pressure [MPa]	K factor [p/L]	Base uncertainty u [%]	uncertainty due to repeatability u [%]	Expanded Uncertainty of K factor U (k=2) [%]	Kf20 [p/L]	K [%]
68,669	Jet Fuel (JP)	1.781	813.36	51.87	20.44	0.500	8.8500	0.023	0.0008	0.046	8.85016	0.1489
98,443	Jet Fuel (JP)	1.778	813.30	74.25	20.52	0.500	8.8485	0.023	0.0012	0.046	8.84867	0.1320
298,936	Jet Fuel (JP)	1.771	813.11	224.48	20.78	0.500	8.8445	0.023	0.0015	0.046	8.84469	0.0871

Informative

Table A.7.b TRAPL, Jet Fuel, Sep. 2015

Calibration condition								PD meter			Others				Comments	Data analysis by the Pilot Lab						
No	Date	Flowrate	Temp.	Pressure	Ambient Temp.	Kinematic Viscosity	Density	Pulses	Time	K factor @ t °C	Prover Volume	PD meter Volume	Meter Factor	Re		Kf20	K	Kf20avg	S. D. of K	uDUT	Reavg	S.D. of Re
[-]	[dd/mm/yy]	[m³/h]	[°C]	[MPa]	[°C]	[$\times 10^{-6}$ m^2/s]	[kg/m^3]	[P]	[s]	[p/L]	[m^3]	[m³]	[-]	[-]		[p/L]	[%]	[p/L]	[%]	[%]	[-]	[-]
1	08-Oct-14	51.7	20.46	0.50	18.4	1.780	813.34	22160	174.2706	8.8503	2.50386	2.50768	0.99848	68477		8.85043	0.1520	8.85016	0.0019	0.0008	68669	94
2	08-Oct-14	51.9	20.43	0.50	18.4	1.781	813.36	22159	173.5758	8.8499	2.50388	2.50756	0.99853	68707		8.85003	0.1474					
3	08-Oct-14	51.9	20.42	0.50	18.4	1.781	813.37	22159	173.8043	8.8499	2.50388	2.50756	0.99853	68695		8.85002	0.1474					
4	08-Oct-14	51.9	20.43	0.50	18.4	1.781	813.36	22160	173.7808	8.8501	2.50392	2.50767	0.99850	68707		8.85023	0.1497					
5	08-Oct-14	51.9	20.44	0.50	18.4	1.781	813.36	22160	173.8034	8.8501	2.50392	2.50767	0.99850	68719		8.85023	0.1497					
6	08-Oct-14	51.9	20.43	0.50	18.4	1.781	813.36	22159	173.8002	8.8499	2.50388	2.50756	0.99853	68707		8.85003	0.1474					
7	08-Oct-14	59.4	20.44	0.50	18.4	1.781	813.36	22158	151.7432	8.8495	2.50388	2.50745	0.99858	78649		8.84963	0.1429					
8	08-Oct-14	59.9	20.46	0.50	18.4	1.780	813.34	22157	150.4428	8.8490	2.50391	2.50734	0.99863	79338		8.84913	0.1373					
9	08-Oct-14	60.0	20.49	0.50	18.4	1.779	813.32	22158	150.3487	8.8494	2.50391	2.50745	0.99859	79511		8.84954	0.1419					
10	08-Oct-14	74.0	20.52	0.50	18.4	1.778	813.30	22156	121.8653	8.8486	2.50391	2.50723	0.99868	98114		8.84875	0.1330	8.84867	0.0029	0.0012	98443	162
11	08-Oct-14	74.3	20.53	0.50	18.4	1.778	813.29	22155	121.3929	8.8482	2.50389	2.50712	0.99871	98529		8.84835	0.1285					
12	08-Oct-14	74.3	20.53	0.50	18.4	1.778	813.29	22155	121.3978	8.8483	2.50387	2.50712	0.99870	98529		8.84845	0.1296					
13	08-Oct-14	74.3	20.52	0.50	18.4	1.778	813.30	22155	121.3489	8.8484	2.50385	2.50712	0.99870	98512		8.84855	0.1307					
14	08-Oct-14	74.3	20.51	0.50	18.4	1.779	813.31	22156	121.3689	8.8488	2.50385	2.50723	0.99865	98495		8.84895	0.1352					
15	08-Oct-14	74.3	20.50	0.50	18.4	1.779	813.31	22156	121.3680	8.8488	2.50385	2.50723	0.99865	98478		8.84895	0.1352					
16	08-Oct-14	119.9	20.48	0.50	18.4	1.780	813.33	22153	75.2038	8.8476	2.50384	2.50689	0.99878	158863		8.84774	0.1215					
17	08-Oct-14	119.9	20.50	0.50	18.4	1.779	813.31	22153	75.1654	8.8475	2.50387	2.50689	0.99880	158917		8.84765	0.1205					
18	08-Oct-14	119.9	20.52	0.50	18.4	1.778	813.30	22154	75.1648	8.8479	2.50387	2.50700	0.99875	158971		8.84805	0.1251					
19	08-Oct-14	179.2	20.55	0.50	18.4	1.777	813.28	22148	50.2958	8.8456	2.50385	2.50633	0.99901	237716		8.84576	0.0991					
20	08-Oct-14	179.7	20.57	0.50	18.4	1.777	813.26	22148	50.1486	8.8456	2.50386	2.50633	0.99901	238461		8.84577	0.0992					
21	08-Oct-14	179.8	20.57	0.50	18.4	1.777	813.26	22148	50.1359	8.8456	2.50383	2.50633	0.99900	238593		8.84577	0.0992					
22	08-Oct-14	224.5	20.64	0.50	18.4	1.775	813.21	22146	40.1456	8.8447	2.50386	2.50611	0.99910	298265		8.84489	0.0892	8.84469	0.0037	0.0015	298936	556
23	08-Oct-14	224.4	20.69	0.50	18.4	1.773	813.17	22144	40.1722	8.8439	2.50387	2.50588	0.99920	298385		8.84410	0.0804					
24	08-Oct-14	224.5	20.75	0.50	18.4	1.771	813.13	22145	40.1584	8.8443	2.50388	2.50600	0.99915	298822		8.84452	0.0851					
25	08-Oct-14	224.5	20.80	0.50	18.4	1.770	813.09	22146	40.1467	8.8447	2.50386	2.50612	0.99910	299076		8.84493	0.0898					
26	08-Oct-14	224.5	20.86	0.50	18.4	1.768	813.05	22146	40.1596	8.8446	2.50389	2.50613	0.99911	299380		8.84485	0.0888					
27	08-Oct-14	224.5	20.92	0.50	18.4	1.766	813.01	22146	40.1485	8.8446	2.50390	2.50613	0.99911	299685		8.84487	0.0890					
28	08-Oct-14	240.2	21.15	0.50	18.4	1.759	812.84	22144	37.5345	8.8436	2.50395	2.50592	0.99921	321893		8.84394	0.0785					
29	08-Oct-14	240.3	21.25	0.50	18.4	1.756	812.77	22143	37.5075	8.8433	2.50394	2.50582	0.99925	322571		8.84366	0.0754					
30	08-Oct-14	240.2	21.32	0.50	18.4	1.754	812.71	22144	37.5268	8.8436	2.50395	2.50594	0.99921	322818		8.84399	0.0790					
31	08-Oct-14	298.7	21.69	0.50	18.4	1.744	812.44	22142	30.1778	8.8426	2.50402	2.50574	0.99931	403946		8.84309	0.0690					
32	08-Oct-14	298.9	21.84	0.50	18.4	1.739	812.34	22142	30.1602	8.8425	2.50404	2.50575	0.99932	405236		8.84304	0.0683					
33	08-Oct-14	298.9	22.06	0.50	18.4	1.733	812.17	22142	30.1613	8.8425	2.50405	2.50577	0.99931	406731		8.84310	0.0690					

A.4 The degree of equivalence between a laboratory *i* and a laboratory *j*

(1) Re = 70 000

Lab j		BEV, informative			CENAM			CMS			NEL			NMIA			NMIJ			TRAPIL, informative		
		Exxsol D60			Diesel			Light oil,20C			Kerosene			D130			Light oil,20C			Jet Fuel		
Lab i		dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij
BEV	Exxsol D60				-0.0527	0.075	0.70	-0.0895	0.081	**1.10**	-0.0934	0.072	**1.29**	-0.0448	0.072	0.62	-0.0596	0.072	0.83	-0.1093	0.080	**1.36**
CENAM	Diesel	0.0527	0.075	0.70				-0.0368	0.062	0.59	-0.0407	0.050	0.82	0.0079	0.050	0.16	-0.0069	0.050	0.14	-0.0566	0.061	0.93
CMS	Light oil, 20 ºC	0.0895	0.081	**1.10**	0.0368	0.062	0.59				-0.0039	0.058	0.07	0.0447	0.058	0.77	0.0300	0.058	0.51	-0.0198	0.068	0.29
NEL	Kerosene	0.0934	0.072	**1.29**	0.0407	0.050	0.82	0.0039	0.058	0.07				0.0486	0.045	**1.08**	0.0338	0.045	0.75	-0.0159	0.057	0.28
NMIA	D130	0.0448	0.072	0.62	-0.0079	0.050	0.16	-0.0447	0.058	0.77	-0.0486	0.045	**1.08**				-0.0148	0.045	0.33	-0.0645	0.057	**1.14**
NMIJ	Light oil, 20 ºC	0.0596	0.072	0.83	0.0069	0.050	0.14	-0.0300	0.058	0.51	-0.0338	0.045	0.75	0.0148	0.045	0.33				-0.0498	0.057	0.88
TRAPIL	Jet Fuel	0.1093	0.080	**1.36**	0.0566	0.061	0.93	0.0198	0.068	0.29	0.0159	0.057	0.28	0.0645	0.057	**1.14**	0.0498	0.057	0.88			

(2) Re = 100 000

Lab j		BEV			CENAM			CMS			NEL			NMIA			NMIJ			TRAPIL		
		Exxsol D60			Diesel			Light oil,20 °C			Kerosene			D130			Kerosene,20 °C			Jet Fuel		
Lab i		dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij
BEV	Exxsol D60				-0.0398	0.077	0.52	-0.0906	0.083	**1.09**	-0.0893	0.074	**1.20**	-0.0360	0.074	0.48	-0.0728	0.074	0.98	-0.0958	0.082	**1.16**
CENAM	Diesel	0.0398	0.077	0.52				-0.0508	0.064	0.79	-0.0495	0.053	0.94	0.0038	0.052	0.07	-0.0330	0.052	0.63	-0.0560	0.063	0.89
CMS	Light oil	0.0906	0.083	**1.09**	0.0508	0.064	0.79				0.0013	0.061	0.02	0.0546	0.061	0.90	0.0178	0.061	0.29	-0.0051	0.070	0.07
NEL	Kerosene,20 °C	0.0893	0.074	**1.20**	0.0495	0.053	0.94	-0.0013	0.061	0.02				0.0534	0.048	**1.11**	0.0165	0.048	0.34	-0.0064	0.060	0.11
NMIA	D130	0.0360	0.074	0.48	-0.0038	0.052	0.07	-0.0546	0.061	0.90	-0.0534	0.048	**1.11**				-0.0368	0.048	0.77	-0.0598	0.060	**1.00**
NMIJ	Kerosene,20 °C	0.0728	0.074	0.98	0.0330	0.052	0.63	-0.0178	0.061	0.29	-0.0165	0.048	0.34	0.0368	0.048	0.77				-0.0230	0.059	0.39
TRAPIL	Jet Fuel	0.0958	0.082	**1.16**	0.0560	0.063	0.89	0.0051	0.070	0.07	0.0064	0.060	0.11	0.0598	0.060	**1.00**	0.0230	0.059	0.39			

(3) Re = 300 000

Lab j		NEL, informative			NMIA			NMIJ			TRAPIL		
		Kerosene			Norpar 12			Kerosene,20 °C			Jet Fuel		
Lab i		dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij	dij	U(dij)	Eij
NEL	Kerosene				0.0359	0.045	0.80	0.0170	0.045	0.38	-0.0044	0.057	0.08
NMIA	Norpar 12	-0.0359	0.045	0.80				-0.0189	0.045	0.42	-0.0403	0.057	0.71
NMIJ	Kerosene,20 °C	-0.0170	0.045	0.38	0.0189	0.045	0.42				-0.0214	0.057	0.38
TRAPIL	Jet Fuel	0.0044	0.057	0.08	0.0403	0.057	0.71	0.0214	0.057	0.38			

APPENDIX B

Methods of measurement

B.1 BEV

1. Calibration test rig

The BEV has 2 identical test benches for hydrocarbons. One for low viscosity fluids similar to gasoline (Exxsol D60, 2 mm^2/s) and the other for higher viscosity fluids similar to diesel oil (Exxsol D120, 6.6 mm^2/s). The flow rate Q is settable from 0.1 l/min (operation with standard capacity tank) respectively up to 1500 L/min (operation with master meter). The pressure range is 0.5 – 6 bar (settable) and the temperature range which is not settable is 14 – 20 °C. The test benches are automatically controlled (preset quantity, flow rate, pressure) by a storage programmed control (SPC).

Path of the liquid flow: The liquid is sucked in from the underground supply tank by a frequency controlled pump. Then it is pumped over a gas separator to the devices under test. Furthermore the liquid is pumped over the selected master meter then either to the fixed / mobile standard, or over the diverter either into the fixed standards tanks or back to the supply tank. Test benches are used for type approval of meters / measuring systems (e.g. fuel dispensers), calibration of meters, 1st stage of a 2-stage verification of a measuring system and test of air elimination devices by metered addition of air.

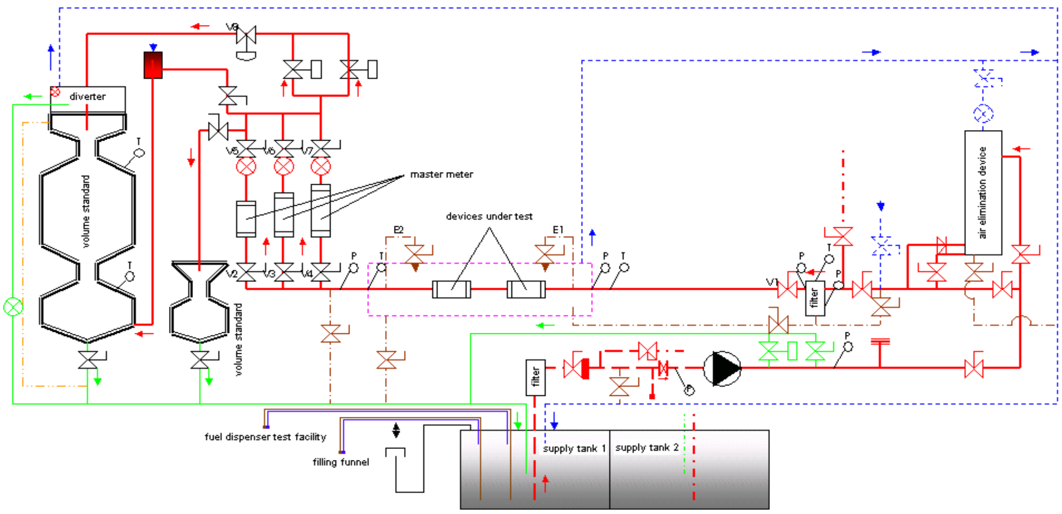


Fig. B-1-1Test rig for liquids other than water

Fig. B-1-2 a) Test rig, b) installation of the TS

2. Method and Equation

Method used: Flying or standing start method used:

Equation:

$$F(Q) = A - \left(V_{\mathrm{Re}\,f} - \Delta V_1 - \Delta V_2 + \Delta V_3\right) \cdot \left(1 + \left(T_M - T_{\mathrm{Re}\,f\,20°C}\right) \cdot \gamma\right) \cdot \frac{\left(T_M - T_{\mathrm{Re}\,f\,20°C}\right) \cdot \gamma \cdot e^{-\alpha\left(T_M - T_{\mathrm{Re}\,f\,15°C}\right)\cdot\left(1+0{,}8\cdot\alpha\cdot\left(T_M - T_{\mathrm{Re}\,f\,15°C}\right)\right)} \cdot \frac{1}{1 - P_M \cdot \kappa}}{\left(T_m - T_{\mathrm{Re}\,f\,20°C}\right) \cdot \gamma \cdot e^{-\alpha\left(T_m - T_{\mathrm{Re}\,f\,15°C}\right)\cdot\left(1+0{,}8\cdot\alpha\cdot\left(T_m - T_{\mathrm{Re}\,f\,15°C}\right)\right)} \cdot \frac{1}{1 - P_m \cdot \kappa}}$$

$$\alpha = \frac{K_0}{\rho_0^{\,2}} + \frac{K_1}{\rho_0}$$

F(Q) … measurement error

A … measurement value (device under test)

VRef … volume standard

Δ V1 … reading error

Δ V2 … wetting

Δ V3 … evaporation

TM … temperature (volume standard)

TRef20°C … reference temperature 20°C

γ … gamma - coefficient of expansion (stainless steel)

Tm … temperature (device under test)

α … alpha – coefficient of expansion (liquid)

TRef15°C … reference temperature 15°C

PM … pressure (valume standard) = Patm atmospheric pressure

Pm … pressure (device under test)

κ … kappa – pressure-coefficient of expansion of liquids

r0 …density at 15°C

K0 … constant for alpha

K1 … constant for alpha

Density:

The density determinations of samples D60 and D120 were performed by using the standard density meter “DMA 5000”, inventory number M01554. The density meter itself is traced back by hydrostatic weighing to the Fundamental Apparatus of Liquid Density (primary density standard of the BEV).
Each densitiy of the fluids was determined at temperatures of 15 °C, 20 °C and 30 °C. The given density values are mean values of 3 measurements at each temperature.

The measurement uncertainty was estimated from the standard uncertainty of the measurements and the uncertainty of the national standard DMA 5000. Possible temperature effects and drift effects were not determined, but also considered in the given uncertainty.

Budget:

$$U = 2 \cdot \sqrt{u_{Normal}{}^2 + s^2 + u_{Temp}{}^2 + u_{Visko}{}^2 + u_H{}^2}$$

u_{Normal} = uncertainty of the standard density meter

s = standard deviation of the measurements, multiplied by student factor

u_{Temp} = influence due to stability of the measurement temperature (α = 8 * 10^{-4})

u_{Visko} = influence due to the stability of the viscosity of the test substance

u_H = influence due to homogeneity of the test substance

Viscosity:

The determination of viscosity for the samples D60 and D120 was carried out with two standard viscometer of type Ubbelohde, inventory number M01603 and M01633, at a gravitational force of g = 9,8084 ms^{-2}. The standard viscometer are traceable to PTB.
The given values are mean values of three fills at each viscometer and each temperature.

The measurement uncertainty was determined according to DIN 51562-1 (1999).

Budget:

$$U = 2 \cdot \sqrt{u_{Normal}{}^2 + s^2 + u_{Temp}{}^2 + u_{Time}{}^2 + u_{Neigung}{}^2 + u_{Gravi}{}^2}$$

u_{Normal} = uncertainty of the standard viscometer, determined for the measured viscosity of the test substance

s = standard deviation of the measurements, multiplied by student factor

u_{Temp} = influence due to stability of the measurement temperature, determined according to the viscosity of the test substance

u_{Time} = influence, based on the capillary constant of the standard viscometer and the uncertainty on determining the “measurement time”

$u_{Neigung}$ = influence due to orientation of the standard viscometer

u_{Gravi} = influence due to the force of gravity

3. Expression of uncertainty

Table Uncertainty budget

Symbol	Source of uncertainty	Input uncertainty	Probability distribution	Divisor	Standard uncertainty	Sensitivity coefficient	Contribution to overall uncertainty
$U(_{K0})$	constant	0	-	-	-	-	0.00E+00
$U(_{K1})$	constant	0	-	-	-	-	0.00E+00
$U(_{Gamma})$	constant	0	-	-	-	-	0.00E+00
$U(_{kappa})$	constant	0	-	-	-	-	0.00E+00
$U_{P\_M}(_{P\_Atm})$	estimation	0,04 bar	Normal	2	2.00E-02	7.90E-07	1.58E-08
$U(_{rho0})$	calibration	0,1 kg/m³	Normal	2	5.00E-02	9.30E-05	4.65E-06
$U(_{T\_M})$	calibration	0,010 °C	Normal	2	5.00E-03	4.40E-02	2.20E-04
$U(_{T\_M\_drift})$	calibration	0,010 °C	Normal	2	5.00E-03	4.40E-02	2.20E-04
$U(_{T\_M\_digit})$	resolution	0,001 °C	Rectangular	√3	5.77E-04	4.40E-02	2.54E-05
$U(_{T\_m})$	calibration	0,010 °C	Normal	2	5.00E-03	4.60E-02	2.30E-04
$U(_{T\_m\_drift})$	calibration	0,010 °C	Normal	2	5.00E-03	4.60E-02	2.30E-04
$U(_{T\_m\_digit})$	resolution	0,001 °C	Rectangular	√3	5.77E-04	4.60E-02	2.66E-05
$U(_{P\_m})$	calibration	0,0011 bar	Normal	2	5.50E-04	4.00E-07	2.20E-10
$U(_{P\_m\_drift})$	calibration	0,0011 bar	Normal	2	5.50E-04	4.00E-07	2.20E-10
$U(P_{\_m\_digit})$	resolution	0,0001 bar	Rectangular	√3	5.77E-05	4.00E-07	2.31E-11
$U(_{VRef\_calib})$	calibration	0,015 L	Normal	2	7.50E-03	1.00E+00	7.50E-03
$U(_{VRef\_drift})$	calibration	0,0025 L	Normal	2	1.25E-03	1.00E+00	1.25E-03
$U_{\Delta V1}(_{reading\ error})$	estimation	0,004 L	Normal	2	2.00E-03	1.00E+00	2.00E-03
$U_{\Delta V2}(_{wetting})$	estimation	0 L	-	-	-	-	0.00E+00
$U_{\Delta V3}\ (_{evaporation})$	estimation	0,0001 L	Normal	2	5.00E-05	1.00E+00	5.00E-05
u_C	Combined uncertainty	-	-	-			0.0079 L
U	Expanded uncertainty	-	Normal	2	-	-	0.0158 L
U	Expanded uncertainty	-	Normal	2	-	-	0.032%

B.2 CENAM

1. Reference system

A uni-directional pipe prover is used as the reference system. The main characteristics:

Maximum Trip Volume:	3000 L
Pipe diameter:	202.7 mm
Thickness:	8.18 mm
Elasticity Modulus:	193 100 MPa
Sphere:	nitrile
Sensors:	four electro-mechanical type
Pre-run volume:	400 L
Manufacturer:	Maloney

The pipe prover was calibrated in 2014 by the Water Draw Method, using a single 3000 L proving tank; following is the calibration result:

$V_{20\ °C}$ = (3000.02 ± 0.72) L, k = 2

The proving tank was also calibrated at CENAM by the volume transfer technique, using a 500 L reference tank; origin of the relevant traceability chain is the 21st copy of the International Prototype, maintained at CENAM.

Temperature measurements are performed by using Rosemount 100 Ω platinum resistance sensors, all calibrated internally at CENAM temperature laboratory. Expanded uncertainty for the calibration of the temperature sensors is quoted as 0.052 °C, k = 2.

As for pressure measurements, absolute pressure sensor (Rosemount 3051S) are used; those sensors are calibrated at CENAM pressure laboratory. Calibration uncertainties ranges (0.15 to 0.015) % for pressure range 100 < p/kPa < 1000.

Figure B-2-1 a) Images of the reference system at CENAM, b) installation of the K2 TS at CENAM.

2. Density Characterization

Several samples from the oil Diesel reservoirs were sent to the CENAM density laboratory, in order to determine the equation of state that relate density to temperature. Density measurements were performed by using an Anton Paar DMA 5000M density meter; which measurement results are traceable to CENAM national standards. Table B-2-1 shows measurement results

Table B-2-1 Density measurement results for the working fluid (Diesel)

t/°C	ρ/(kg/m^3)	$U(\rho)$/(kg/m^3)
15	834.26	0.04
18	832.11	0.04
20	830.70	0.04
22	829.36	0.04
24	827.94	0.04
26	826.52	0.04

By least squares methodology, the following equation was determined to relate density to temperature,

$$\rho = \exp(-0.168\,580\,77 - 0.000\,843\,980\,93t) \qquad (1)$$

3. Viscosity Characterization

Several samples from the oil Diesel reservoirs were sent to the CENAM viscosity laboratory, in order to determine the equation of state that relate viscosity to temperature. Viscosity measurements were performed by using Ubbelohde type viscometers; which measurement results are traceable to CENAM Viscosity Scale.

Table B-2-2 shows measurement results

Table B-2-2 Viscosity measurement results for the working fluid (Diesel)

t/°C	ν/(mm²/s)	$U(\nu)$/(mm²/s)
18	4.669	0.012
20	4.459	0.011
22	4.237	0.011
24	4.034	0.009 7
26	3.846	0.009 3

By least squares methodology, the following equation was determined to relate density to temperature,

$$\nu = (-11.123\ 3 + 72.658\ 918/\ln t - 77.827\ 26/(\ln t)^2) \qquad (2)$$

4. Calculation equation and uncertainty

MF, meter correction factor was determined by using the following math model,

$$MF = \frac{V_{\text{ref}} \cdot CTS_{\text{p}} \cdot CPS_{\text{p}} \cdot \rho_{\text{p}} \cdot [1 + F \cdot (p_{\text{p}} - p_{\text{m}})]}{\frac{N}{K} \cdot \rho_{\text{m}}}$$

Where:

V_{ref}: Volume of the unidirectional pipe prover

CTS_{p}: Correction factor due to thermal expansion; $CTS_{\text{p}} = 1 + \alpha \cdot (t_{\text{p}} - 20)$

CPS_{p}: Correction factor due to elastic deformation; $CPS_{\text{p}} = 1 + p_{\text{p}} \cdot D/(E \cdot t)$

ρ_{p}, ρ_{m}: density of the working fluid at prover and meter temperatures.

N: number of pulses during a single sphere travel

K: K-factor of the flow meter, as provided in the Technical Protocol ; K = 8.837 pulses/L

F: Isothermal compressibility of the fluid, calculates as per API-MPMS 11.1 $F = 0.000\ 787\ \text{MPa}^{-1}$

p_{p}, p_{m}: pressure of the fluid at prover and meter locations.

Table B-2-3 Uncertainty budget for measurements at *Re* = 100 000 for *MF* as the measurand

	x_i	u	c_i	$u_i(y)$	%
V_{20}/L	3000.02	0.36	0.00033309	0.000120	43
α/°C^{-1}	0.0000518	0.00000259	0.799389014	0.000002	0
t_p/°C	20.80	0.1	-0.000791599	–0.000079	19
p_p/MPa	0.20136	0.001	0.000821998	0.000001	0
D/m	0.2027474	0.001	0.000127402	0.000000	0
e/m	0.0081788	0.001	-0.003158217	–0.000003	0
E/MPa	193100	19310	-1.33767E-10	–0.000003	0
ρ_{15}/(kg/m^3)	834.26	0.02	-1.66702E-07	0.000000	0
t_m/°C	21.05	0.1	0.000843371	0.000084	21
p_m/MPa	0.1213	0.0006	-0.000693718	0.000000	0
N/pulsos	26539.2	2	-3.76529E-05	–0.000075	17
K/(pulsos/L)	8.837				
C_{rep}[1]	0	0.000009	1	0.000009	0
F/MPa^{-1}	0.000 694 3				
CTS	1.000 041				
CPS	1.000 026				
ρ_p	0.830 16				
ρ_m	0.829 99				
				3.35318E-08	
MF	0.999 28		$u(MF)$	0.000183	
			$U(MF)$, k = 2	0.00037	
			$U(MF)$/%, k = 2	0.037	

[1] Contribution due to the repeatability of the calibrations results; calculated as the standard deviation of the mean for *MF* values.

Table B-2-4 Uncertainty budget for measurements at *Re* = 100 000 for *K* as the measurand

	x_i	u	c_i	$u_i(y)$	%
V_{20}/L	3000.02	0.36	-0.002947776	-0.001061	43
α/°C^{-1}	0.0000518	0.00000259	-7.074417048	-1.83E-05	0
t_p/°C	20.80	0.1	0.007005476	0.0007005	19
p_p/MPa	0.20136	0.001	-0.007275186	-7.32E-06	0
D/m	0.2027474	0.001	-0.00112748	-1.13E-06	0
e/m	0.0081788	0.001	0.027949529	2.795E-05	0
E/MPa	193100	19310	1.18381E-09	2.286E-05	0
ρ_{15}/(kg/m^3)	834.26	0.02	1.47544E-06	2.951E-08	0
t_m/°C	21.05	0.1	-0.007463651	-0.000746	21
p_m/MPa	0.12126	0.0006	0.006139937	3.723E-06	0
N/pulsos	26539.2	2	0.00033322	0.0006664	17
C_{rep}[2]	0	0.00006	1	0.00006	0
F/MPa^{-1}	0.0006942				
CTS	1.000034706				
CPS	1.000025852				
ρ_p	0.830252128				
ρ_m	0.830069961				
				2.623E-06	
K/(pulsos/L)	8.843 4		$u(K)$	0.00162	
			$U(K)$, k = 2	0.0033	
			$U(K)$/%, k = 2	0.037	

[2] Contribution due to the repeatability of the calibrations results; calculated as the standard deviation of the mean for *MF* values.

B.3 CMS

1. Calibration test rig

The transfer standard (TS) is calibrated by the low viscosity oil flow calibration system. A solvent oil of Exxon D110 is used as the working fluid. Meanwhile, the standing-start-and-finish mode with static weighing method is used to calibrate flowmeters.

The low viscosity oil flow facility is a circulating system. The working fluid is pumped from a reservoir and flows through the meter under test, a flowrate control valve, an on-off valve, and a constant level device. Then the liquid falls freely into the weightank. After being weighed, the liquid in the weightank flows back to the main reservoir by opening a valve on the outlet pipe of the weightank. The process flow diagram is shown as Figure B-3-1. A photograph of the calibration setup is shown in Figure B-3-2.

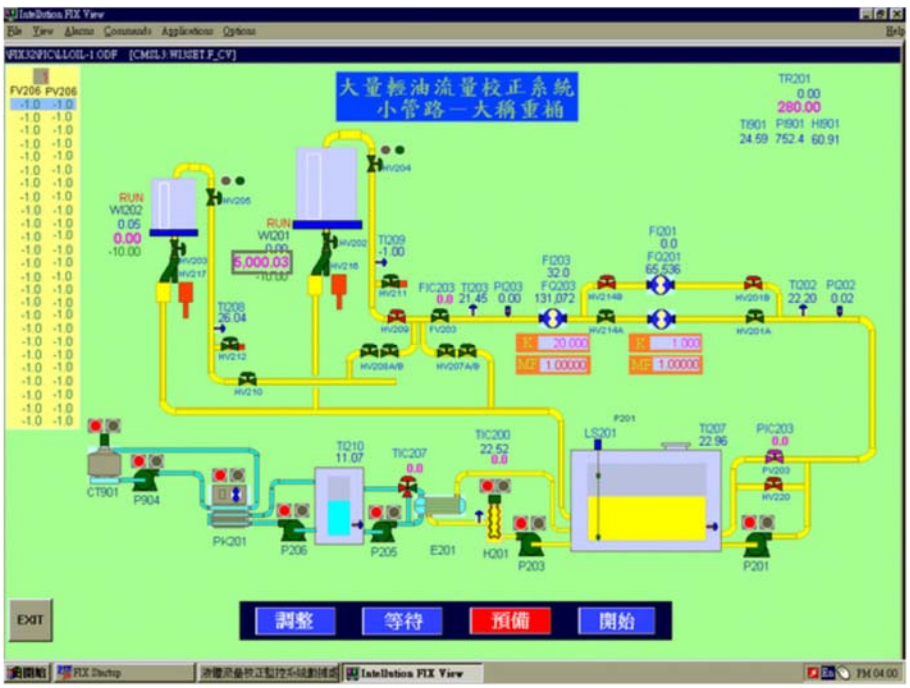


Figure B-3-1 Process diagram of the low viscosity oil flow facility

Figure B-3-2 Photograph of the calibration setup

The test rig includes 75 mm, 100 mm, 150 mm, and 200 mm pipelines, the TS was installed on the 150 mm pipeline, the sketch drawing of the TS and its upstream and downstream is shown on Figure B-3-3.

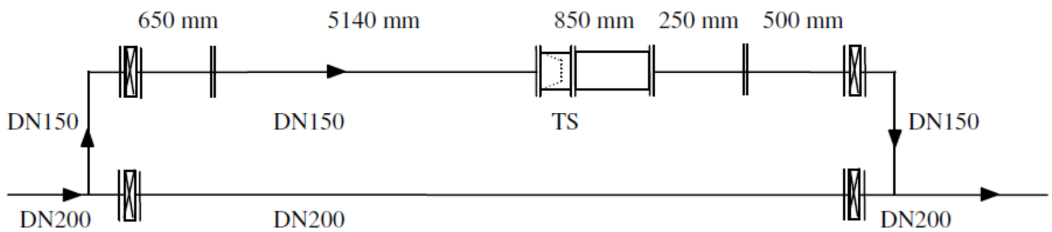


Figure B-3-3 Sketch drawing of the TS installation

2. Calculation equation and uncertainty

The following equations were used in the calculation of the *K* factors:

$$V_a = \frac{W(1+\varepsilon)}{\rho_l(1+P_m \times f)} \quad , \quad K = \frac{N}{V_a}$$

where V_a = actual volume transferred from the collected weight

W = net weight measured by weighing scale

ρ_l = oil density corresponding to the average temperature passing through TS meter during test

P_m = average pressure passing through meter during test

f = compressibility coefficient (f = 0.00009 cm^2/kg)

$\varepsilon = \rho_\alpha(\frac{1}{\rho_l} - \frac{1}{\rho_w})$ = air buoyancy, where ρ_a and ρ_w are the densities of air and deadweight, respectively

N = number of TS meter output pulses

The combined standard uncertainty of *K* factor at any flowrate for a single calibration is defined as

$$u_c(K_{ij}) = \left\{ \left[\frac{-N_{ij}}{V_{a,ij}{}^2} u(V_{a,ij}) \right]^2 + \left[\frac{1}{V_{a,ij}} u(N_{ij}) \right]^2 \right\}^{1/2}$$

Where i and *j* represent i^{th} flowrate and j^{th} test,

$u(V_{a,ij})/V_{a,ij}$ = Base uncertainty, standard uncertainty of actual volume, 0.023 %

$u(N_{ij})$ = resolution uncertainty of TS meter, 0.001 %

$$K_i = \sum_{j=1}^{n} K_{ij} \Big/ n$$

Where K_i is the average *K* factor at i^{th} flowrate, used for reporting the comparison test results.

$$u_c(K_i) = \{ [u^2(K_{ij})] + u^2(R_i) \}^{1/2}$$

where

$u(R_i)$ = repeatability uncertainty of TS meter at *i*th flowrate, evaluated from the standard deviation (*s*) of repeated measurements.

$$u(R_i) = s / \sqrt{j}$$

DUT uncertainty = $\left\{ \left[\frac{1}{V_{a,ij}} u(N_{ij}) \right]^2 + [u(R_i)]^2 \right\}^{1/2}$

The expand uncertainty is the combined standard uncertainty multiplied by the coverage factor (*k*=2).

$$U = 2 \times u_c(K_i)$$

The equation of oil density

$\rho_l(T) = 0.820389 + 0.0006914 \times T$ (°C)

$u(\rho_l) = 0.00005$ (g/cm^3)

The equation of oil viscosity

$v = 6.983 - 0.16553 \times T + 0.0014979 \times T^2$ (mm^2/s)

B.4 NEL

1. Description of facility and simplified P&ID

The UK National Standards Oil Flow Facility, located at NEL in East Kilbride, Scotland, consists of two separate flow circuits (A and B), each with a high capacity and a low capacity flow line. These can accommodate nominal pipe sizes from 0.5 to 8 inches, and can operate at line pressures up to 10 bar. Test fluids can be delivered at flowrates up to 720 m^3/hr.

The figure above provides a schematic diagram of one of the flow circuits. The oil for each circuit is drawn from a 30 m^3 supply tank into the suction stream of the main pumps, from where it is discharged to the test lines. A conditioning circuit, linked to each tank, maintains the oil temperature to within ±1 ºC of a pre-selected value (itself set in the range 5 – 60 ºC). Each test line can accommodate up to 30 m of horizontal straight lengths or alternative configurations as required. At the outlet of each test section, a manifold directs the fluid back to the storage tank or to one of the calibrated weigh tanks. Line temperature and pressure are monitored both upstream and downstream of the test section.

The flow lines share a common primary standard weighbridge system consisting of four separate weightanks of 150, 600, 1500 and 6000 kg capacity. The facility is fully traceable to National Standards and is accredited by the United Kingdom Accreditation Service (UKAS).

For ‘primary’ calibrations, a gravimetric ‘standing-start-and-finish’ method is used to determine the quantity of fluid (volume or mass) which has passed through the flowmeter under test and into the selected weightank.

The gravimetric weightanks constitute the primary reference standard of the NEL oil flow facility. Using the above technique, the overall uncertainty in the reference flowrate, expressed at the 95% confidence level is approximately ±0.03 % (k = 2).

For a ‘secondary’ calibration, the quantity of oil passing through the test meter is measured using a pre-calibrated reference meter, installed in series. The reference meters used at NEL have a history of previous calibrations and typical uncertainties of the order of ±0.08 % (k = 2).

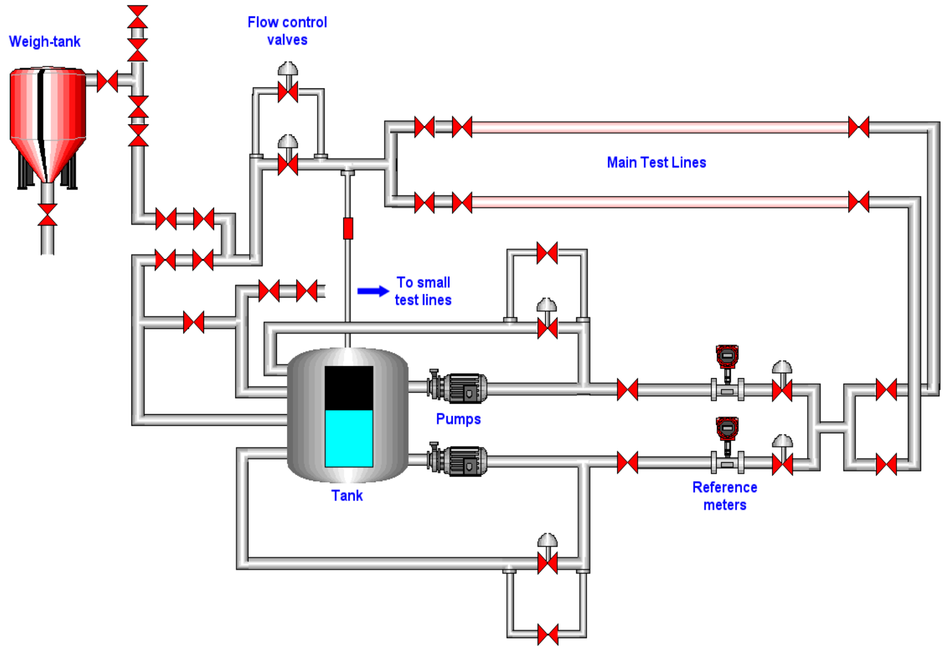


Figure B-4-1 NEL Oil flow facility schematic diagram

2. Viscosity and density measurement

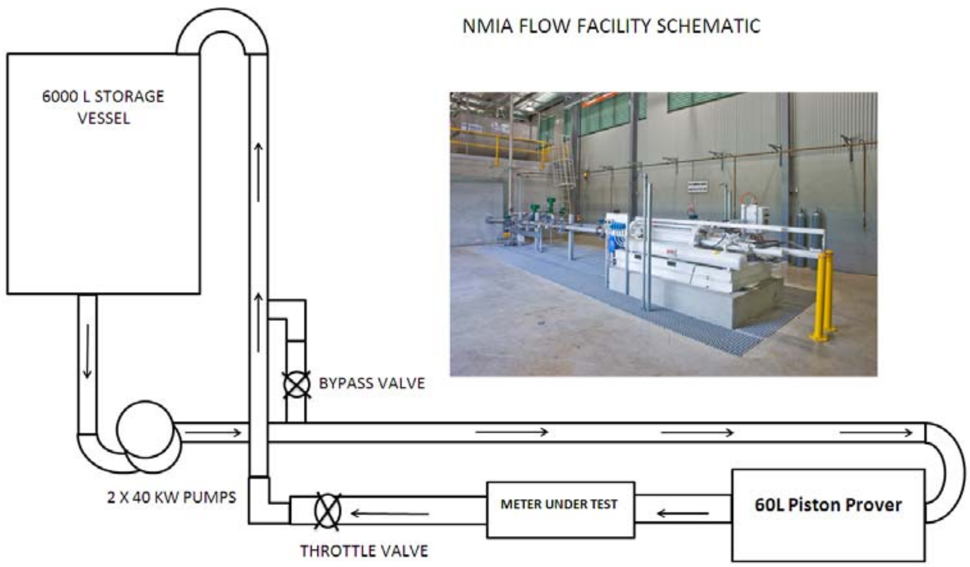
For the viscosity and density measurement the procedure is to take a sample of the test fluid prior to the start of a new calibration. The density of the fluid is then determined off line by an Anton Paar DMA 5000 densitometer for the density values and an Anton Paar SVM viscometer for the viscosity values.

Estimated Viscosity Uncertainty: 2 %
Estimated Density Uncertainty: 0.015%

NOTE: The final density of the fluid in the test line is corrected for compressibility due to the test line pressure by calculating the compressibility and then through the correction factor Cpl. An isothermal expansion is assumed. The algorithm used is taken from ISO 9770, and modified in IP PPM Part 10. Section 3.

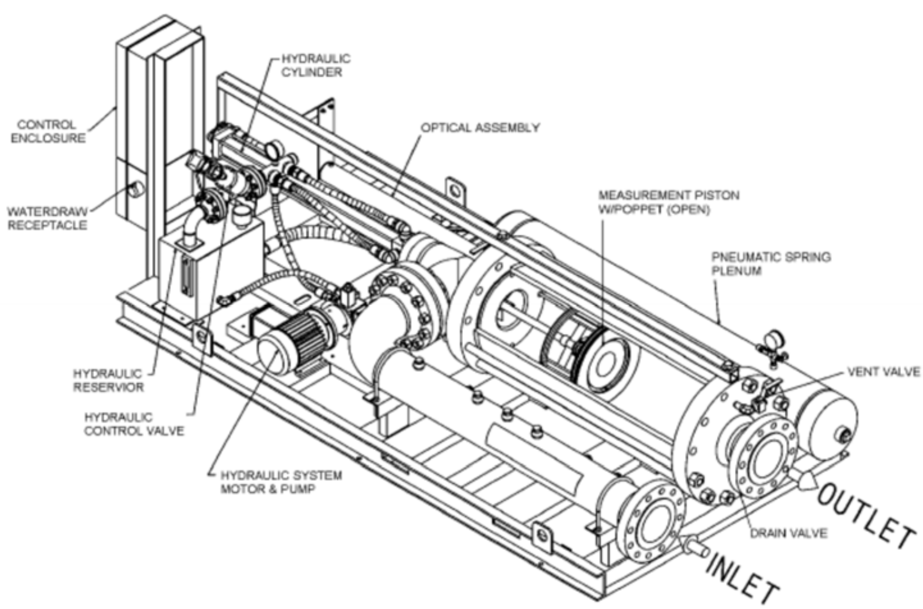
B.5 NMIA

1. Flow facility



2. Equipment

The volumetric standard used is a 60L piston prover (see below)



3. Test method

The method involves:

1) Establish the desired flow rate and pressure conditions within a closed (approx. 6000L) loop using pump speed, pump bypass valves and meter throttle valves;
2) Launch piston prover and determine KF;
3) Repeat step 2 4 times, giving 5 values of KF;
4) Determine average of KF and report
5) Repeat steps 1 to 4 as many time as necessary to charaterise the performance of the meter

4. Equations

KF = (n x CPLM x CTLM) / (Vp x CPLP x CTLP x CPSP x CTSP)

Where: n = Number of pulses [Pulses]

CPLM = Correction for Pressure on the Liquid in MUT [dimless]

CTLM = Correction for Temperature on the Liquid in the MUT [dimless]

Vp = Volume of the Prover at known conditions of temperature and pressure, [L]

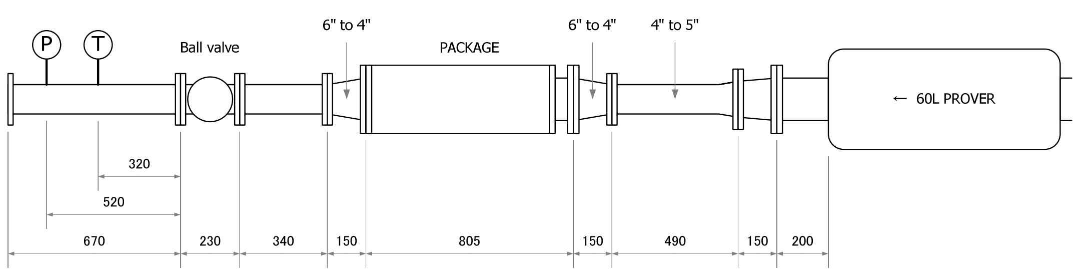
CPLP = Correction for Pressure on the Liquid in Prover [dimless]

CTLP = Correction for Temperature on the Liquid in Prover [dimless]

CPSP = Correction for Pressure on the Steel of the Prover [dimless]

CTSP = Correction for Temperaure on the Steel of the Prover [dimless]

5. Pipework



6. Uncertainty

NFF BFR UNCERTAINTY ANALYSIS

Australian Government
National Measurement Institute

RN131392 PREPARED BY: SIMON DIGNAN DATE: 23/08/2013

i	COMPONENTS	U_i	U_i units	k_i	u_i	ν_i	c_i	c_i units	$c_i.u_i$	ν_i
1	Prover calibration	0.0056	L	2.00	0.003	60	0.0167	per L	0.005%	7.90E-20
2	Prover stability	0.003	L/yr	1.73	0.002	100	0.0167	per L	0.003%	6.98E-21
3	Prover leakage	0.1	mm	2.00	0.050	30	0.13%	per mm	0.007%	5.95E-19
4	Prover fluid temperature measurement, T1	0.128	°C	2.09	0.061	20	0.12%	per °C	0.007%	1.47E-18
5	MUT fluid temperature measurement, T2	0.128	°C	2.18	0.059	12	0.12%	per °C	0.007%	2.06E-18
6	Temperature uniformity	0.10	°C	1.73	0.058	30	0.12%	per °C	0.007%	7.68E-19
7	ΔT time constant (T1 - T2)	0.000	°C	1.73	0.000	30	0.12%	per °C	0.000%	0.00E+00
8	MUT fluid pressure measurement, P1	3.6	kPa	2.31	1.58	9	0.001%	per 100kPa	0.00002%	7.02E-29
9	Prover fluid pressure measurement, P2	3.6	kPa	2.23	1.63	11	0.001%	per 100kPa	0.00002%	6.75E-29
10	Prover steel thermal expansion correction (CTSP)	2	°C	1.73	1.16	30	22	ppm/C	0.0025%	1.39E-20
11	Prover steel pressure correction (CPSP)	0.0001%	%	2.00	0.00005%	75	1	dimless	0.00005%	8.33E-28
12	Fluid Density measurement effect on CTL	0.05	kg/m³	2.00	0.025	60	0.0009%	% per kg/m³	0.00002%	4.27E-29
13	Fluid Density measurement effect on CPL	0.05	kg/m³	2.00	0.025	60	0.000049%	% per kg/m³	0.00000%	3.75E-34
14	API Correction table rounding (to 0.00001)	0.000005	dimless	1.73	0.000003	100	1	dimless	0.00001%	2.71E-31
15	Invar rod thermal expansion	2	°C	1.73	1.15	30	1.44	ppm/C	0.00017%	2.55E-25
16	Rounding for report (to 0.001 P/L in Kind)	0.00566%	%	1.73	0.00327%	100	1	dimless	0.00327%	1.14E-20
17	MUT Repeatability (SAMPLE)	0.001%	%	2.24	0.001%	4	1	dimless	0.001%	2.07E-22
18	MUT Data deviation from fitted curve (SAMPLE)	0.000%	%	1.73	0.000%	10	1	dimless	0.000%	0.00E+00

u_c	0.016%
ν_{eff}	116.8
k_{95}	2.0
U_{95}	0.031%

RATE of Change of temperature (°C/hr):	
Temperature probe time constant (τ, sec):	41
Correlation between T_{MUT} and T_{PROV}:	0.9 (Scale 0 --> 1, 0 = no correlation; 1 = correlated)

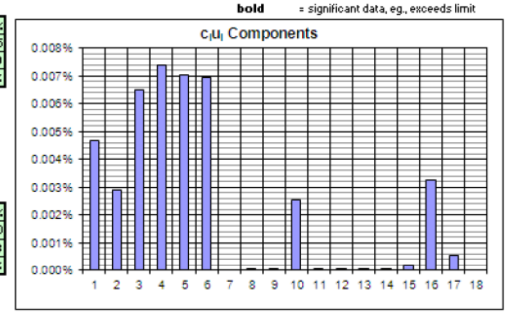
REFERENCE

u_c	0.016%
ν_{eff}	116.5
k_{95}	2.0
U_{95}	0.03%

MUT

u_c	0.001%
ν_{eff}	4.0
k_{95}	2.8
U_{95}	0.00%

KEY:
- (yellow) = Input data changes each time
- (purple) = Input data changes rarely
- (green) = Hard coded data or calculated field
- (blue) = Output data to be reported
- normal = general data
- **bold** = significant data, eg., exceeds limit



Some of the main contributions include:

1. **<u>Calibration of Prover Volume</u>**: Uncertainty from NMI calibration report where value is determined gravimetrically using water, where the measured volume is converted to an equivalent volume at standard condition of 15 °C and 0 kPag. Typical uncertainty is 0.006L in 60 L (or 0.01%).
2. **<u>Prover Volume Stability</u>**: Drift in value of prover volume over time. Prover calibrated every 2 years, so use rectangular distribution semi-range equal to expected drift over 2 years.

17. **<u>Repeatability of MUT</u>**: This is a measure of the short term repeatability of the MUT and is defined as:

u_{repeat} = STDEV(k_i …k_n) / SQRT(n_{passes})

Where: k_i = MUT k factor (Pul / L) averaged over n passes (ie., strokes) of piston.

n = Number of prover runs, typically n = 5.

n_{passes} = Number of passes (ie., strokes) of the piston per run, typically n_{passes}= 1

Resolution of MUT pulses per litre is not a component of uncertainty as the S600 controller applies dual double chronometry to increase pulse resolution beyond a single pulse.

<u>18 Deviation of MUT calibration data from fitted curve</u>: Typically a curve is fitted to the data for the meter and this component is the difference between the fitted and actual value, rectangular distribution semi-range equal to the difference. For this calibration calibration points only were reported and no curve fitting done.

B.6 NMIJ

1. Calibration test rig and calibration method

A schematic of the primary standard for hydrocarbon flow is shown in Fig. B-6-1. Light oil and kerosene are used as working liquids; each oil has a separate test line. As they share a heat exchanger, however, the two lines cannot be operated at the same time. The flow rate range of the facility capacity is from 3 to 300 m^3/h. This primary standard is based on static and gravimetric methods with a flying start and finish, i.e., the total mass of fluid passing through the flowmeter via the diverter in a given time is measured. It consists of a 10 t weighing scale, a 1 t weighing scale, a density meter and the diverter system, which has double diverting wings.

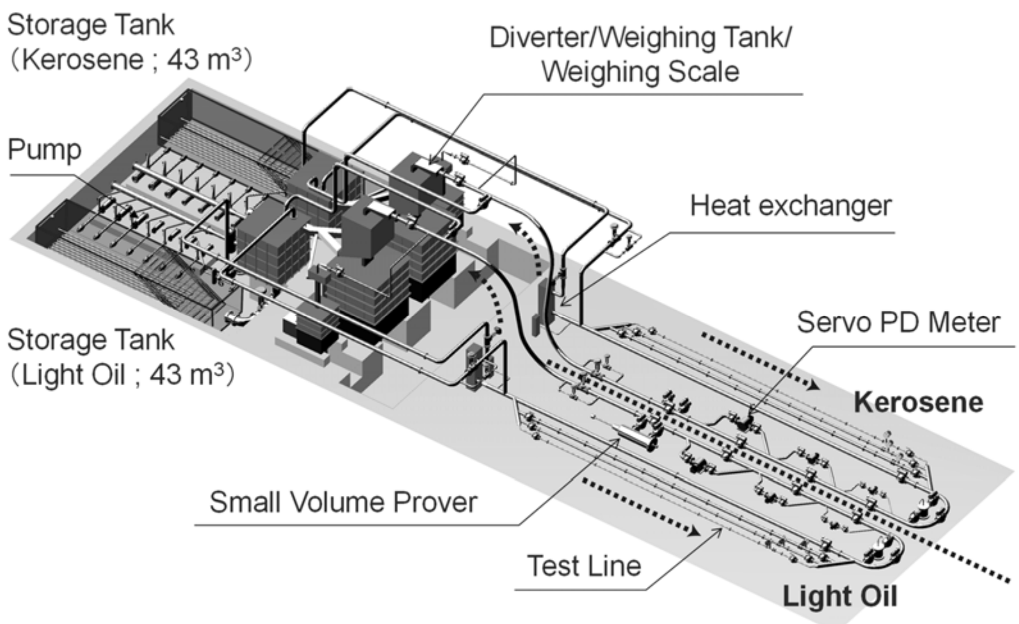


Fig. B-6-1 Schematic of the facility

2. Installation of the meter

The picture of the transfer standard in the test line is shown in Fig. B-6-2. The schematic of pipes upstream and downstream of the package are shown in Table B-6-1.

Fig. B-6-2 (a) Test lines (b) TS in the calibration test rig

Table B-6-1 Pipe size and lengths

	Pipe		Flange	Length (mm)	Diameter (mm)	Material
Upstream	Ball Valve	6"	ANSI 150lb			
	Pipe	6" Sch 20	ANSI 150lb	2000	155.2	SUS304
	Pipe	6" Sch 20	ANSI 150lb	590	155.2	SUS304
	Pipe	6" Sch 20	ANSI 150lb/ JIS10K	1500	155.2	SUS304
	Pipe	6" Sch 40	JIS10K	500	151.0	SUS304
	Flowmeter (OMG140)	6”	JIS 10K	610		
	Pipe	6" Sch 40	JIS 10K/ ANSI 150lb	500	151.0	SUS304
	Pipe	6" Sch 20	ANSI 150lb/ JIS10K	1500	155.2	SUS304
	Pipe	6" Sch 40	JIS10K	1500	151.0	SUS304
	Pipe	6” Sch 40	JIS10K	2000	151.0	SUS304
	Pipe	6” Sch 40	JIS10K	1000	151.0	SUS304
	Pipe	6” Sch 40	JIS10K	1000	151.0	SUS304
	Pipe	6” Sch 40	JIS10K	1000	151.0	SUS304
	Pipe	6" Sch 40	JIS10K/ ANSI 150lb	165	151.0	SUS304
	Package			805		
	Pipe	6" Sch 40	ANSI 150lb/ JIS10K	500	151.0	SUS304
Downstream	Pipe	6" Sch 40	JIS10K	210	151.0	SUS304

3. Explanation of calculations of K-factors at NMIJ

The following formulas are used in the calculation of the K-factor:

$$K_f = \frac{I_P}{1000}\frac{t_P}{t_D}\frac{\overline{\rho_{LFM}}}{M_L} \quad \text{(pulse/L)}$$

I_P (pulse) = the number of pulses generated by the flowmeter

t_P (s) = The duration for which flowmeter pulses are counted

t_D (s) = diversion time

M_L (kg) = the mass of oil accumulating in the weighing tank

$\overline{\rho_{LFM}}$ (kg/m^3) = Time-averaged oil density through the flowmeter under calibration

(1) Time-averaged oil density through the flowmeter under calibration $\overline{\rho_{LFM}}$

$$\overline{\rho_{LFM}} = \left\{\rho_{LREF} + \alpha_L\left(T_{FMm} - T_{REF}\right)\right\}\left\{1 + F_L\frac{\left(p_{FMmU} + p_{FMmD}\right)}{2}\right\}$$

ρ_{LREF} (kg/m^3) = The oil density measured by the off-line density meter at temperature T_{REF} (ºC)

α_L (kg/(m^3 K)) = Thermal coefficient of oil density

T_{FMm} (ºC) = Measured temperature downstream the flowmeter during calibration

F_L (MPa^{-1}) = Compressibility of oil

p_{FMmU} (MPa) = Measured pressure upstream the flowmeter during calibration

p_{FMmD} (MPa) = Measured pressure downstream the flowmeter during calibration

(2) Thermal coefficient of oil α_L

$$\alpha_L = \frac{\left(\rho_{L35} - \rho_{L15}\right)}{T_{35} - T_{15}}$$

ρ_{L35} (kg/m^3) = oil density measured by the off-line density meter at temperature $T_{35} \approx 35$ (ºC)

ρ_{L15} (kg/m^3) = oil density measured by the off-line density meter at temperature $T_{15} \approx 15$ (ºC)

(3) Compressibility coefficient of oil F_L

$$F_L = 0.001 \times \exp\left(-1.6208 + 0.00021592 T_{FMm} + \frac{0.87096}{\left(\rho_{15}/1000\right)^2} + \frac{0.0042092 T_{FMm}}{\left(\rho_{15}/1000\right)^2}\right)$$

ρ_{15} (kg/m^3) = oil density at 15 ºC obtained from ρ_{LREF} , α_L and T_{REF}

(4) Mass oil weight M_L

$$M_L = \frac{k_{mL} \cdot m_L}{\left(1 - \rho_{Gm} / \rho_{LW}\right)}$$

k_{mL} (-) = the calibration factor of the weighing scale corresponding to m_L
m_L (kg) = the reading from the weighing scale
ρ_{Gm} (kg/m^3) = the density of the air around the weighing scale
ρ_{LW} (kg/m^3) = the density of the oil in the weighing tank

(5) Calibration factor of the weighing scale
(a) 10 t weighing scale

$$k_{mL} = \frac{k_{MS=10,000} - k_{MS=9,000}}{M_S(10,000) - M_S(9,000)}\left(m_L - M_S(9,000)\right) + k_{MS=9,000}$$

$k_{MS=10,000}$ (-) = The calibration factor corresponding to the dead weight

$$M_S(10,000) \approx 10000 \text{ kg}$$

$k_{MS=9,000}$ (-) = The calibration factor corresponding to the dead weight

$$M_S(9,000) \approx 9000 \text{ kg}$$

(b) Calibration factor

$$k_S = \frac{M_S}{m_{CAL}}\left(1 - \frac{\rho_{GCAL}}{8000}\right)$$

M_S (kg) = Conventional value of dead weights
m_{CAL} (kg) = The reading from weighing scale during calibration of weighing scale
ρ_{GCAL} (kg/m^3) = The density of air during calibration of weighing scale

(6) Density of the air

$$\rho_{Gm} = \frac{1.2932}{\left(1 + 0.00367 T_{atm}\right)}\left(\frac{p_{atm}}{101.325} \text{-} 0.006\right)$$

T_{atm} (ºC) = the temperature in the weighing room
p_{atm} (kPa) = the atmospheric pressure

(7) Density of oil in the weighing tank

$$\rho_{LW} = \rho_{LREF} + \alpha_L \left(T_{FMm} - T_{REF} \right)$$

2. Uncertainty

The uncertainty budget as a base uncertainty is shown in Table B-6-2. The combined relative standard uncertainty for volumetric flow at the calibration facility is simplified to be 0.015 %. The relative combined standard uncertainty of the K-factor is estimated in combination with the uncertainty of the experimental standard deviation of the mean due to the random effect, which normally is negligible. Accordingly, the relative expanded uncertainty of the K-factor for volumetric flow is estimated to be 0.030 % (coverage factor k = 2).

4. Fluid Property

1) Density

The density of the liquid was measured using the oscillating U-tube density meter, DMA5000 or DMA5000M, which were manufactured by Anton Paar. This is based on the principle of a U-tube which has a resonant frequency that is inversely proportional to the square root of its mass. The density meter was calibrated using the standard density liquids of water, whose expanded uncertainty (k = 2) is 0.030 kg/m^3. The standard uncertainty of the density measurement was estimated to be 0.052 kg/m^3, because the uncertainty due to the viscosity effect was estimated to be 0.050 kg/m^3.

2) Viscosity

Viscosity of liquid was measured using the Viscometer, AMVn or SVM3000, which was manufactured by Anton Paar.

The Viscometers were calibrated using standard viscosity liquids, whose expanded uncertainty (k = 2) is less than 0.1 %. However the measurement uncertainty of viscosity is dominant on the linearity and the reproducibility of the device. The Expanded uncertainty of viscosity was roughly estimated to be 3 %. The uncertainty of the density is negligible against that of the viscosity. Therefore, the uncertainty of Reynolds Number is estimated to be 3 %.

Table B-6-2 Relative combined standard uncertainty of volumetric flow rate calibration in large hydrocarbon flow calibration facilities.

Uncertainty Sources		Relative standard uncertainty × 10^{-5}			
		Kerosene		Light oil	
Number of pulses			~ 0		~ 0
Duration of pulse counting			1.4		1.4
	Resolution	< 0.1		< 0.1	
	Correction	1.0		1.0	
	Reproducibility	1.0		1.0	
Dead volume			0.4		0.4
Fluctuation of flow rate and density			< 0.1		< 0.1
Mass of liquid			2.8 ~ 7.7		2.9 ~ 4.0
	Calibration factor	2.2		2.4	
	Resolution	0.1		0.1	
	Buoyancy correction	0.8		0.8	
	Vapor and mist	1.5 ~ 7.3		1.4 ~ 3.1	
Density of liquid			9.6 ~ 10.4		8.5 ~ 9.2
	Density meter	6.6		6.2	
	Thermal coefficient	0.3		0.3	
	Temperature measurement	6.6		5.8	
	Compressibility	0.3 ~ 1.5		0.3 ~ 1.5	
	Pressure measurement	0.9 ~ 3.9		0.8 ~ 3.2	
	Reproducibility of working liquid	2.2		0.7	
Duration of installation			1.4 ~ 2.5		1.4 ~ 2.6
	Timer	1.4		1.4	
	Correction time (Diverter timing error)	0.2 ~ 2.1		0.2 ~ 2.2	
Combined relative standard uncertainty		10.4 ~ 13.1		9.5 ~ 10.2	

B.7 TRAPIL

1. Calibration test rig

The calibration laboratory has two prover loops, each consisting of a prover tube, of a spheroid launcher, a regulated pump for the flow, a control valve, a pressurizing pump and a compensation tank. A standard diagram is given in appendix 1.

The characteristics of the prover loops are the following:

Prover Loop reference	Diameter (inch)	Pipe Prover Calibrated Nominal Volume (m^3)	Loop total Volume (m^3)	Flow Meter Diameter range (inch)	Minimum Flow (m^3/h)	Maximum Flow (m^3/h)
1	20”	10.0	26	6” up to 16”	40	2500
2	10”	2.5	6	2” up to 6”	10	600

Many types of flow meters (Ultrasonic, Turbine, Mass, Coriolis, PD meter, orifice plate, dP meter...) can be installed on the prover loops, whatever the type of flanges (ANSI 150#, 300#, 400#, 600#...), the diameter (from 2" to 6" on loop 2 and from 6" to 16" on loop 1) and the length of the meter.

Our calibration laboratory has permanently 6 petroleum products of different viscosities and densities whose characteristics are the following :

Product	Product code	Kinematic Viscosity Range at +20 °C and P_{atm} (mm^2/s)	Density Range at +15 °C and P_{atm} (kg/m^3)
Unleaded gasoline	ES/SP	0.5 - 0.8	720 - 785
Kerosene	JP	1.2 - 2.0	790 - 830
Heating-oil	FD	3.5 - 8.0	840 - 870
Light crude	BR	10 - 30	880 - 930
Heavy crude	BT	30 - 70	905 - 940
Oil	HU	70 - 400	920 - 980

Moreover, every two years, the benches are filled with water from the fire fighting network. Any request for calibration with water may be realised if the reservation is made in time. Every time the circuits are filled, the viscosity and density are determined by our analysis Laboratory located in POISSY. A sample of product can be taken more often, on request of the customer.

At the time of the installation of the meter on the line of prover loop, at the request of the customer, a straightening vane can be mounted upstream at the desired distance. During the calibration, the liquid can be pressurized between 0.1 MPa and 1.2 MPa (1 and 12 bar g) and the heating of the temperature is limited with our cooling system. The prover loops are buried to obtain thermal stability.

The volume of the prover tubes are determined periodically using vessels with full traceability of measurement to recognised national standards and to the International System of units.
The associated measuring instruments listed below, are also traceable to recognised national standards and to the International System of units.

Prover loop temperature sensors and transmitters
Flow meter temperature sensors and transmitters
Double timing electronics
Pulse counter

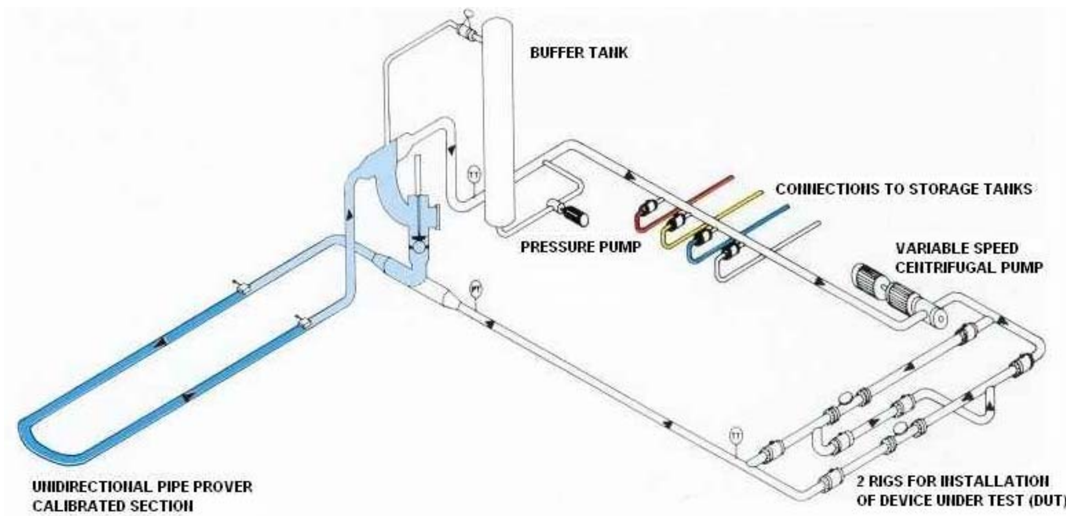


Fig. B-7-1 TRAPIL Prover loop drawing

Fig. B-7-2 Meter in calibration test rig with inlet outlet

2. Principle of calculations

The object of the calibration consists in comparing the volume indicated by the meter under test with the volume which really passed the meter. One determines as follows:

The coefficient of correction Meter Factor

$$\text{M.F. by: } MF = \frac{Vm}{Vl}$$

The Factor K of the apparatus to the flow considered by:

$$K = \frac{n'}{V_m} \qquad \text{Or Factor 1/K}$$

With :

Vm : Conventionally true volume which crossed the apparatus:

Vl : Volume indicated by the apparatus:

n' Numbers interpolated impulses (see ISO 7278-3)

To determine the result, one calculates volume VM of the tube standard brought back to the conditions of the meter:

$$Vm = Vp \times CTSp \times CPSp \times \frac{CTLp \times CPLp}{CTLm \times CPLm}$$

One determines in the same way Vl volume, indicated by the meter:

$$Vl = n' \times v \times CTSm \times CPSm$$

With:

Vp :	Volume of the tube standard at +20 °C and atmospheric pressure (101325 Pa)
CTS_P :	Thermal expansion coefficient of the pipe prover
CPS_P :	Pressure coefficient of the pipe prover
CTS_M :	Thermal expansion coefficient of the flow meter
CPS_M :	Pressure coefficient of the flow meter
CTL_P :	Thermal expansion coefficient of liquid in the prover
CPL_P :	Pressure coefficient of liquid in the prover
CTLm :	Thermal expansion coefficient of liquid in the flow meter
CPLm :	Pressure coefficient of liquid in the flow meter
v :	Theoretical weight of a pulse
T1 :	Time between the first pulse detected after the first sphere detector and the next pulse after the second sphere detector
T2 :	Time between the 2 sphere detectors
n :	Number of pulses acquired by the calculator (integer)

n' : n' = n, if n ≥ 10 000 pulses

$$n' = n \times \frac{T2}{T1}, \text{ if } n < 10\,000 \text{ pulses (float)}$$

This calculation complies with the pulse interpolation technique described in the international standard ISO 7278-3.

APPENDIX C

Comparison protocol

Technical Protocol for Key Comparison

Hydrocarbon Liquid Flow

(CCM.FF-K2.2.2011)

Draft Ver.1 April 15, 2014
Ver.2 June 3, 2014

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1. Purpose

This key comparison, CCM.FF-K2.2.2011 is performed by CCM (Consultative Committee for Mass and related quantities) Working Group for Fluid Flow (CCM/WGFF) for the purpose of determining the degree of equivalence of the National Standards for hydrocarbon flow measurement among the participating National Metrology Institutes (NMIs). The participating NMIs will test a transfer standard and compare their calibration results. National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology (NMIJ/AIST) has been assigned as the pilot laboratory.

This protocol has been prepared to perform the key comparison in accordance with the Guidelines for CIPM Key Comparisons [1].

A positive displacement flow meter (KRAL meter) is to be used as the transfer standard. It will be tested by each participating laboratory at Reynolds number of 100,000 and at Reynolds numbers selected from 70,000, and 300,000.

After the measurement is completed, the degree of equivalence (DoE) between the participating NMIs will be obtained at every cardinal point, at Reynolds number of 70,000, 100,000 and 300,000. The key comparison reference value (KCRV) and the DoE between the KCRV and each of the participating NMIs will be also obtained.

2. Administrative information

2.1. Package of the Transfer Standard

The transfer standard (TS) will be shipped using an ATA Carnet[3] . The TS shall be shipped in two transportation boxes. Box A measures 630 mm (depth) × 990 mm (width) × 755 mm (height) and weighs 280 kg including the TS. Box B measures 380 mm (depth) × 380 mm (width) × 410 mm (height) and weighs 35 kg including the pipe.

2.2. Participating NMIs, test schedule and transportation

A list of the participating labs, their shipping addresses and contact information is provided in Table 1. Each lab has been allotted three weeks for testing and two weeks are reserved for shipping. Each participating NMI must ship the TS by fastest and safest way and the TS should be insured during shipment for at least 30,000USD. Each participating NMI shall pay the shipping and the insurance cost derived from delivery to the next participating NMI.

2.3. Keeping test schedule

After the comparison starts, the participating NMIs must send the TS to the next participating NMI on the schedule to prevent disruptions in the KC schedule even if their measurements are not completed. Participating NMIs, who cannot complete their measurements, will be assigned a new test date by the pilot after the entire original test schedule is accomplished.

[3] For transportation between Taiwan and Japan, a SCC Carnet will be used.

2.4. Loss or damage of TS

The transfer standard is robust and it is contained in a strong shipping container, however if the TS is damaged or a participating NMI finds it to be malfunctioning, they should consult the pilot lab for advice. The pilot will have a backup TS if a replacement is needed and spare parts that might be used to repair the entire TS. In the event of total loss, results from the backup TS would be normalized with data from calibrations at the pilot lab.

2.5. Special mailing address for the pilot lab

E-mail messages being sent to NMIJ regarding this key comparison should be addressed to "ff-k2-ml@aist.go.jp". Then the message will be distributed to the NMIJ personnel in charge.

Table 11 List of the participating NMIs

	Participating NMI (Economy)	Contact Person and E-mail Address Phone Number Shipping Address
1	BEV (Austria)	Contact 1: Gerhard Baubinder, gerhard.baubinder@bev.gv.at Contact 2: Karin Bittner-Rohrhofer, karin.bittner-rohrhofer@bev.gv.at +43 1 21110 6518 Bundesamt für Eich- und Vermessungswesen A-1160 Vienna, Arltgasse 35, Austria
2	CENAM (México)	Contact 1: Victor J. Medina Lopez, vmedina@cenam.mx, Contact 2: Roberto Arias R., rarias@cenam.mx +52-442-211-05-00 Centro Nacional de Metrología Km 4.5 Carr. a los Cués El Marqués, Querétaro C.P. 76246, Mexico
3	CMS/ITRI (Chinese Taipei)	Contact 1:Chun-Min Su, CMSu@itri.org.tw Contact 2: I-Cheng Chen, IchengChen@itri.org.tw +886-3-5741205 Center for Measurement Standards 30 Ta Hsueh Road, Hsinchu, CHINESE TAIPEI
4	LNE-TRAPIL (France)	Fabien RIBERE, fribere@trapil.com +33 1 47 92 48 23 / 48 20 Société des Transports Pétroliers par pipelines 14 route du Bassin n°5, 92230 GENNEVILLIERS, FRANCE
5	NEL (UK)	Linda Rowan, lrowan@tuvnel.com 01355 593829 TUV NEL Ltd, East Kilbride, Glasgow G75 0QF
6	NMIA (Australia)	SIMON DIGNAN, simon.dignan@measurement.gov.au +61 2 8467 3514 National Measurement Institute, Australia Bradfield Road, West Lindfield, NSW, 2070, AUSTRTALA
7 Pilot	NMIJ/AIST (Japan)	Takashi Shimada, ff-k2-ml@aist.go.jp +81-29-861-4377 National Metrology Institute of Japan National Institute of Advanced Industrial Science and Technology AIST North site 14, 1497-1 Teragu, Tsukuba, Ibaraki, 300-4201, JAPAN

3. Description of Transfer Standard

The screw type positive displacement flow meter will be used as a transfer standard. The specification of the flow meter is shown in Table 3. The pictures of the flowmeter, the display, the strainer with pipe and the boxes for transportation are shown in Fig. 2 to Fig. 5.

Table 12 Specification of transfer package

Flow meter	Manufacturers	KRAL
	Type	OMG140
	Inlet diameter	150 mm
	Flange	6" ANSI 150lb RF
	Size	610 mm (L), 267 mm (D)
	Weight	180 kg
	Maximum flow rate (normal)	450 m^3/h (300 m^3/h)
	Converter type	BEG 47
	Class of protection	EEx ia IIC T6
Display with safety barrier	Pulse output type	TTL, Open corrector or 24V pulse
	Power supply	AC85 ~ 264V
	Size	160 mm X 230 mm X 260 mm
Upstream pipe	Flange	6" ANSI 150lb RF
	Pipe	6" Sch40
	Filter	10 mesh per inch
Box A	Size, L, W, H (mm)	630 mm X 990 mm X 755 mm
	Weight	280 kg in total
Box B (Plastic box)	Size, L, W, H (mm)	380 mm X 380 mm X 410 mm
	Weight	45 kg in total

Fig. 12 Flow meter

Fig. 13 Display with safety barrier

Fig. 14 Upstream pipe

Fig. 15 Box A for transport

Fig. 5 Box B

4. Preparation at a participating lab

Prior to receiving the transfer standard, each participating NMI should prepare pipes and signal cables for its calibration facility to accommodate the flowmeter. The schematic of the package is shown in Appendix 1.

Each laboratory should be notified of the actual arrival date of the package by the previous laboratory. If no notification is received when expected, please check with the previous laboratory. Please inform the Pilot laboratory immediately if a problem has arisen.

If during the testing, a problem arises, please inform the Pilot for advice. Inform the next laboratory if a delay in completion is expected.

5. Unpacking the Transfer Standard

5.1. Receiving check list

When the transfer standard arrives at a participating lab, Form 1 "Receiving Checklist" (see, Appendix 2) must be filled out and emailed to the pilot lab (ff-k2-ml@aist.go.jp). The procedure of the receiving check is described in the following sections.

5.2. External examination of Transportation box

Make a visual check of the external of the transportation boxes.

5.3. Checking the contents

Take out all the items from the boxes and inspect them visually one by one. Take some pictures of the inlet and outlet of the flow meter and then the pictures should be emailed to the pilot lab (ff-k2-ml@aist.go.jp). Report any damage or missing parts to the pilot and the previous laboratory.

5.4. Reporting the receiving check result

After the check is completed, the Form 1 "Receiving check list" should be e-mailed to the pilot lab (ff-k2-ml@aist.go.jp). If problems are found, the participant should describe them in detail on a separate sheet (preferably in a MS-Word file), and send it along with the Form 1.

6. Measurement Procedure

6.1. Preliminaries

1) The required test liquid is clean hydrocarbons such as kerosene, light fuel oil and so on.
2) Prior to the start of testing, measure viscosity and density of the oil across the expected temperature range. Prepare density and viscosity equation coefficients.
3) Density equation should be in the form of a linear fit to data collected across a temperature range at least 20 to 30 ºC. Density should be quoted as kg/m^3.
4) Viscosity should be measured over the same temperature range. Viscosity should be quoted as mPa·s.
5) The equations should be used for a dynamic calculation of Reynolds number during measurement.
6) The fluid density and viscosity data should be provided as the report and include an estimated uncertainty. The data should also be provided in the reporting spreadsheet.

6.2. Installation and filling

1) The meter package should initially be assembled according to the configuration (See Appendix 1).
2) The installation should be carried out according to normal best practice adopted for a normal client flow meter calibration. No specification has been given as to the nature, length or type of pipework up or downstream of the package.
3) Set lab's pressure gauges at the two pressure taps of the upstream pipe if necessary. Pressure drop at the upstream pipe is approximately 20 kPa at the flow rate of 300 m^3/h and the kinematic viscosity of 7.0 cSt.
4) Connect up the meter signal instrumentation. The wiring and connection

specifications are provided in Appendix 1.

5) Gently allow the package to fill with oil and bleed out all air. When filling the package and establishing flow, ensure the upstream and downstream valves are closed to prevent air from over-speeding the meter.

6.3. Choice of test points

1) Carry out the test procedure as given in Table 13. The three cardinal points are the flow rates at Reynolds numbers of 70,000, 100,000 and 300,000. The participants should calibrate the transfer standard at Re of 100,000 at least. Flow rate should be between 60 and 300 m^3/h at the cardinal points.
2) The liquid temperature through the transfer standard at calibration condition should be approximately between 20 ºC and 30 ºC. The viscosity of liquid at calibration condition should be between 1.5 cSt (mm^2/s) and 7.0 cSt. Back pressure downstream of the flow meter should be more than 0.1 MPa. Pressure at the flow meter should be between 0.1 MPa and 0.6 MPa.
3) The number of reputation measurements at the cardinal points should be the same as that at normal calibration. If the number of reputation measurements is not specified, the recommended number is 6 as shown in Table 13.
4) If a small volume prover is used as a reference standard, the number of passes should follow normal procedure at each lab. The number of passes should be reported in the results data sheet.
5) From the fluid properties and the flow rate, the Reynolds number at each flow rate will be calculated. Reynolds number is expressed as

$$\mathrm{Re} = \frac{4\rho Q}{\pi\mu D} \qquad (26)$$

Q : Volumetric flow rate (m^3/s)
ρ : Density (kg/m^3)
D : package inlet diameter as given (=0.15 m)
μ : Dynamic viscosity (Pa·s)

6) The cardinal flow point has been specified by Reynolds number and not by flow rate. Reynolds number is based on the inlet diameter of the flow meter upstream pipe(=0.15 m). The volumetric flow rate through the flow meter is used to set the Reynolds number. Difference of Reynolds number from the cardinal points should be less than ±5 %.

6.4. Limited flow range

Where the laboratory can not reach the maximum flow rate, the maximum achievable flow rate may be reported on the summary sheet in place of the next highest specified point. Cavitation must be avoided at all times.

6.5. Timescales

Tests should be carried out within consecutive working days as possible. Durations of more than one day should be reported in the final report.

The laboratory should not have the package longer than three weeks.

6.6. Draining the package

Drain the package carefully ensuring the meters do not exceed the maximum flow rate during draining. After draining, immediately perform the anti-rust treatment (6.7) and do not leave the meter package with the emptied test line.

6.7. Uninstallation and dispatch

1) Safely disconnect and pack instrument cables and connectors.
2) Remove the package from the test line. Drain all residual oil from the meters and filter. Clean or re-install the filter.
3) Give the anti-rust treatment (ex. anti-rust spray) to the wetted part of the PD meter as soon as possible. Close the inlet and the outlet of the flow meter using the blind flanges.
4) Take pictures of the inlet and outlet of the flow meter in order to confirm condition of the flow meter and the pictures should be emailed to the Pilot before packing.
5) Re-assemble for dispatch.

Table 13 Flow rates and test sequence

Flowrate m^3/h (L/s)	Reynolds no	Recommended No of reputation measurements	Approx. Frequency (Hz)
60 (16.7)		2	150
120 (33.3)		2	290
180 (50.0)		2	440
240 (66.7)		2	590
300 (83.3)		2	740
Cardinal point			
	70,000	6	
	100,000	6	
	300,000	6	
Total No of points		28	

7. Shipping the Transfer Standard

1) Please pack the transfer standard in the transportation box properly and fill the Form 3 "Shipping Checklist" (see Appendix 2). The information needed for packing is provided in Appendix 1.
2) Each participating lab is responsible to select an appropriate transportation company and to ship the transfer standards as precision instruments. All transportation cost are to be afforded by the participating laboratory. The TS should be insured for at least 30,000USD.
3) After shipment, the completed Form 3 "Shipping Checklist" should be e-mailed to "ff-k2-ml@aist.go.jp" and to the next participating lab.

8. Reporting the measurement result

8.1. Test data to be reported

1) A description of the calibration test rig, including a P&I sketch drawing indicating the general principle of the test rig and the installation of the meter including pipe sizes and lengths immediately upstream and downstream of the package.
2) Some pictures of the meter in the calibration test rig and the pictures of the inlet and outlet of the flow meter (See 5.3 and 6.7).
3) A brief description of the measurement method used and of the calculation equation used.
4) A summary of the main uncertainty components for the measurement as an uncertainty budget (See 8.2).
5) Fluid property data as previously specified. This is to be in the report and should indicate the density and viscosity measurements across the temperature range used to establish the fluid property equations. A brief description of the measurement method, uncertainty and fluid property equations should be given. Data should be reported in the “Density and Viscosity (liquid)” sheet in Form2 (See Appendix 2).
6) Required data in Form2: The following data may be considered as a minimum requirement for each test point:-.

    Point number, Date, flow rate through the flow meter, mean temperature at the flow meter, mean pressure at the flow meter, ambient temperature, kinematic viscosity and density at the flow meter, meter pulses collected, measured time, and fluid volume passed through the package at test conditions.
7) The participants should calculate actual K factors under calibration condition. This K factor should not be corrected to standard conditions.
8) The following results at the cardinal points should be calculated and reported in the "Summary" sheet in Form 2.

    Type of liquid, kinematic viscosity (X10^{-6} m^2/s = cSt), Density (kg/m^3), flow rate (m^3/h), liquid temperature at the flow meter (ºC), pressure at the flow meter (MPa), K-factor (P/L), base uncertainty (%), uncertainty due to repeatability (%) and expanded uncertainty of K factor (%).

9) If the participants carry out extra calibration, all results should be reported.

8.2. Expression of uncertainty

1) The standard uncertainty of K factor is combined with the base uncertainty of the reference standard based on the GUM [2] and the standard uncertainty due to the repeatability of calibration results in according to WGFF Guidelines [3]. The expanded uncertainties of K factors should be quoted in percentage term at 95 % confidence level. Each quoted value should be rounded up to two decimal places.
2) A summary of the main uncertainty components for the measurement should be provided as an uncertainty budget.
3) To allow a calculation of the uncertainty in Reynolds number, an uncertainty estimate of the measured viscosity and density should be provided.

8.3. Sending the result to the pilot

1) The completed Form 2 (see Appendix 2) and the report on calibration test rig etc. should be emailed to ff-k2-ml@aist.go.jp.

9. Data Analysis by the Pilot Lab

1) The K-factor is used to calculate a corrected K factor based on 20 ºC expressed as:

$$K_{f20} = K_f \left\{1 + 3\alpha\left(T - 20\right)\right\} \tag{27}$$

K_{f20} : Corrected K-factor (p/L)

K_f : K-factor (p/L)

α : Coefficient of linear expansion of material. (Carbon steel for flow meter, =1.1X10^{-5} (K^{-1}))

T : Temperature at calibration condition (ºC)

2) At Reynolds number of 70,000, 100,000 and 300,000, the key comparison reference values (KCRV) will be obtained based on the method proposed by Cox [4][5]. Then the degree of equivalence (DoE) between the KCRV and each of the participant, and DoE between each pair of the participants will be calculated.
3) At Reynolds number of 70,000, 100,000 and 300,000, the DoE among the participants will be calculated.
4) Draft A and Draft B will be distributed to the participants in accordance with the Guidelines [6].

10. References

[1] Guidelines for CIPM key comparisons, October 2003.

[2] ISO/IEC GUIDE 98-3:2008, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).

[3] WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty, October 21, 2013

[4] Cox, M. G., The Evaluation of Key Comparison Data, Metrologia, 39, 589-595, 2002.

[5] Cox, M. G., The evaluation of key comparison data: determining the largest consistent subset, Metrologia, 2007, 44, 187-200

[6] CCM-WGS, CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons, 29 August 2013.

Appendix 1 Assembly Manual for Package

1. Schematic of the meter package

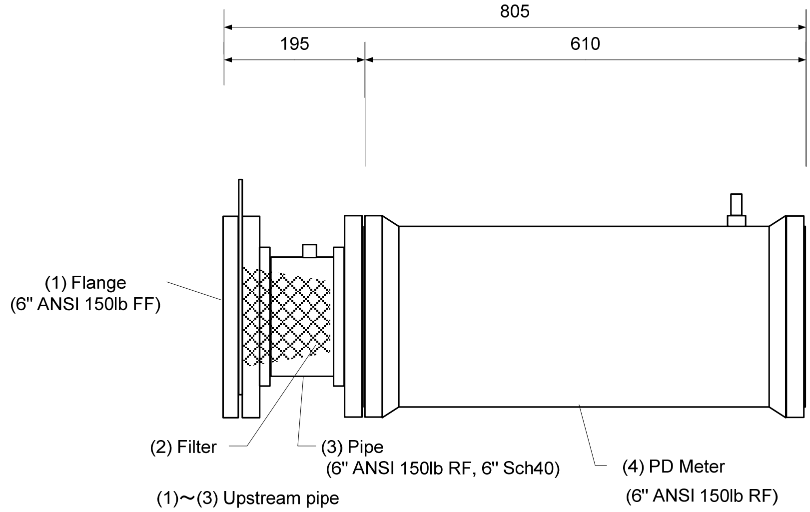

Fig. A1-1 Schematic of the package

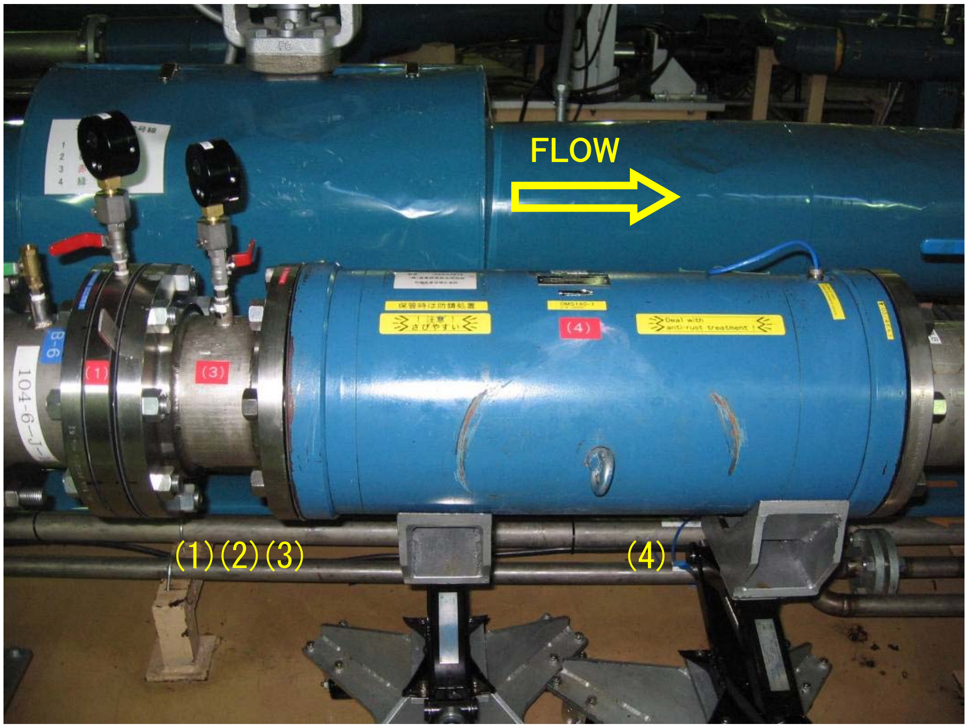

Fig. A1-2 A picture of the package

2. Unpacking and packing

2.1. Box A

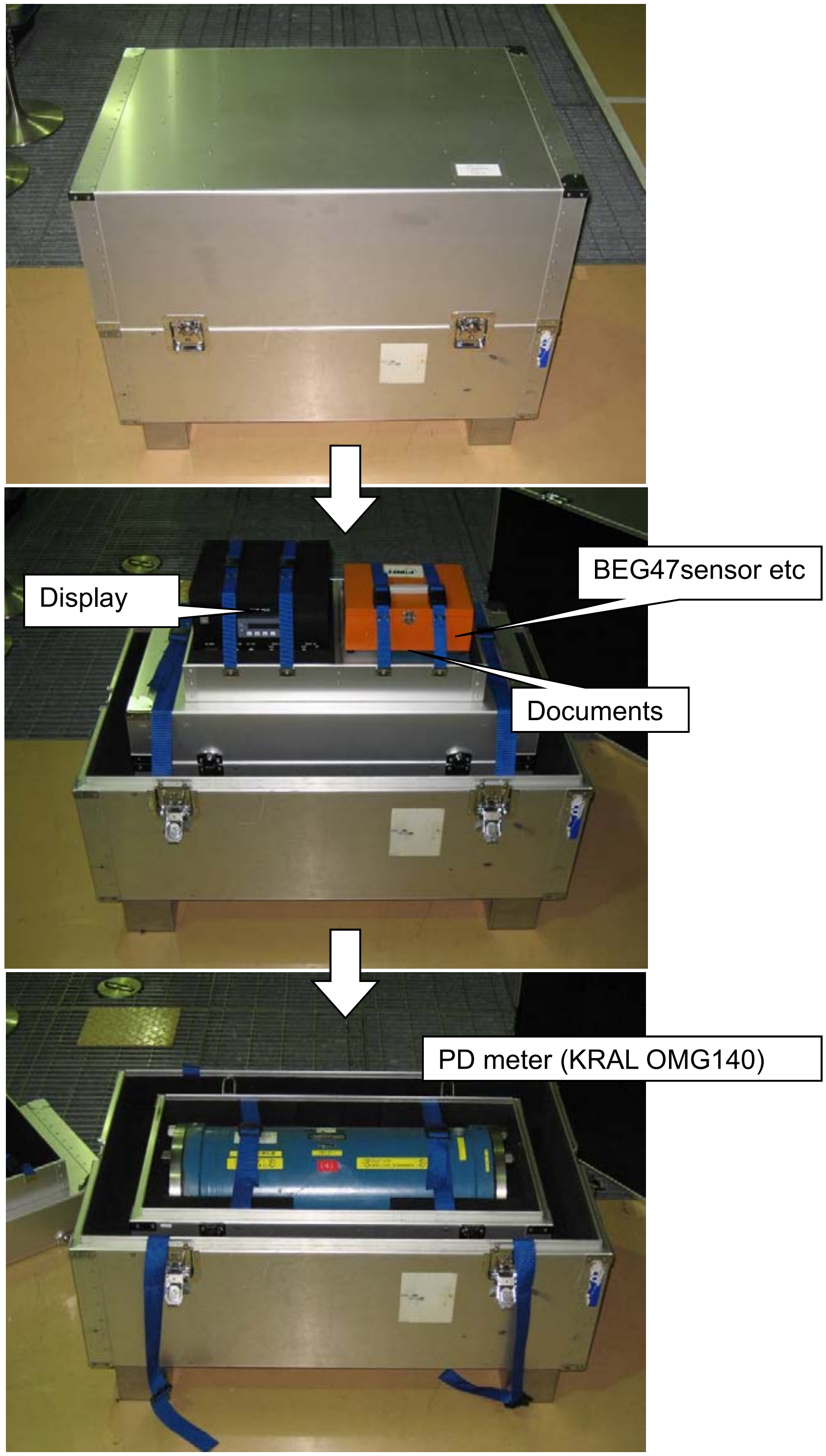

Fig. A1-3 Box A : Flow meter and display (990 X 630 X 755, 280 kg)

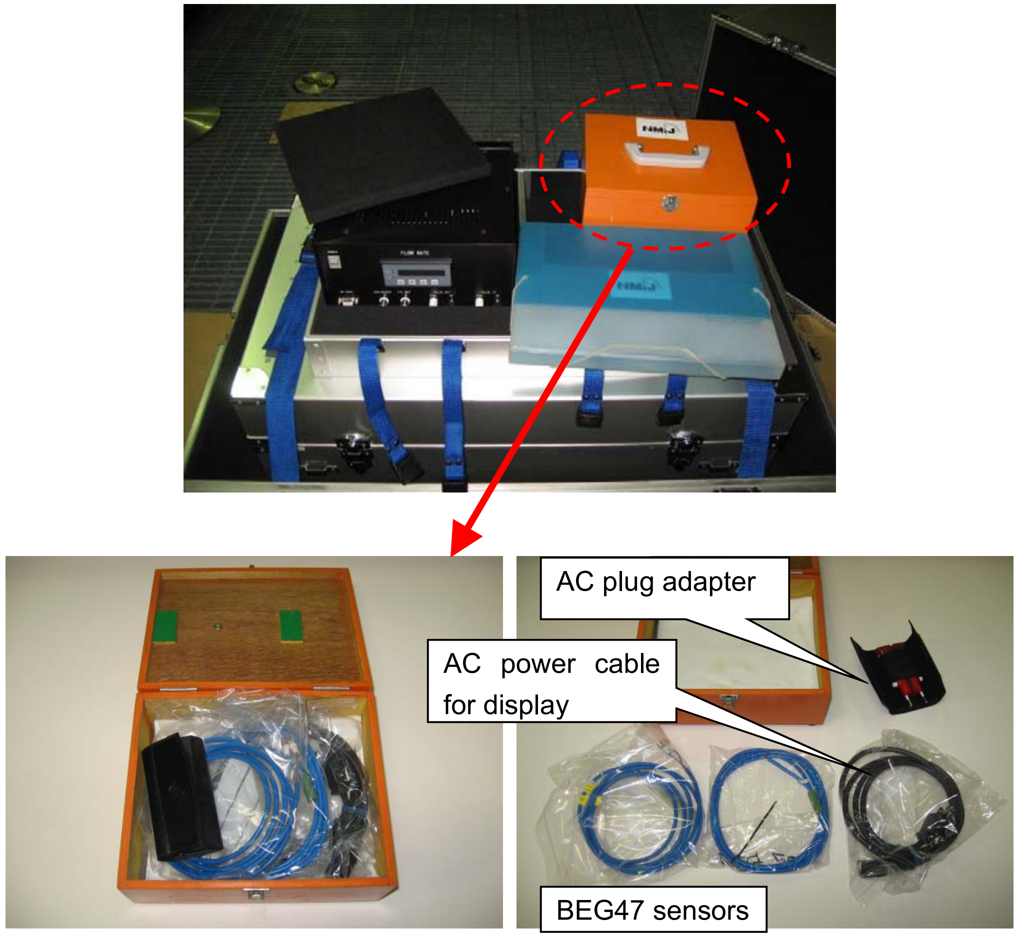

Fig. A1-4 Display and sensors.

Fig. A1-5 Projecting guides of a rotary lock should appear when a box is closed.

2.2. Box B

Fig. A1-6 Box B : Upstream pipe (380 X 380 X 410, 45 kg)

3. PD meter

Table A1-1 Specification of PD meter

Manufacturer	KRAL	Nominal size	150 mm(6 inch)
Model	OMG140.6052947	Flanges	ANSI 150lb RF
S/N	136565	Length	610 mm
K factor	8.837 P/L	Max. Press.	10 bar
Flow Range Q_nom(max)	300(450)m^3/h 5000(7500)L/min	Max Temp.	100 °C

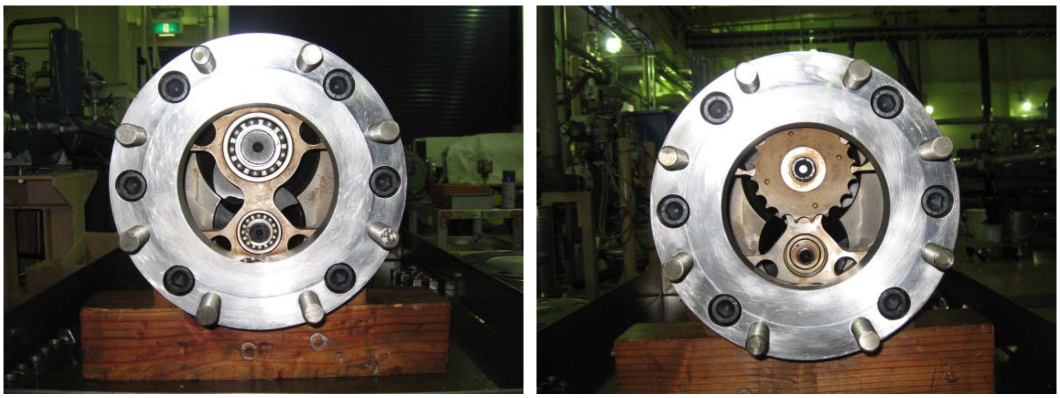

Fig. A1-7 Pictures of the inlet and outlet of the PD meter.

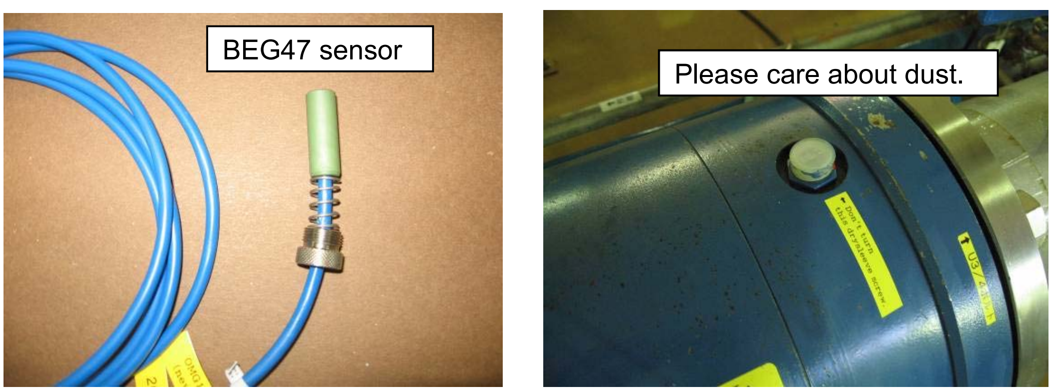

Fig. A1-8 Pictures of the sensor

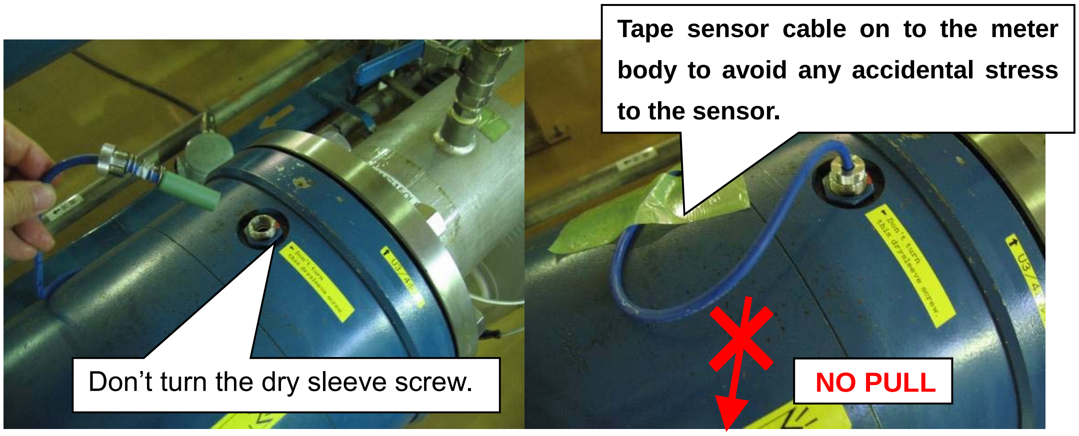

Fig. A1-9 Connecting instruction for BEG47sensor

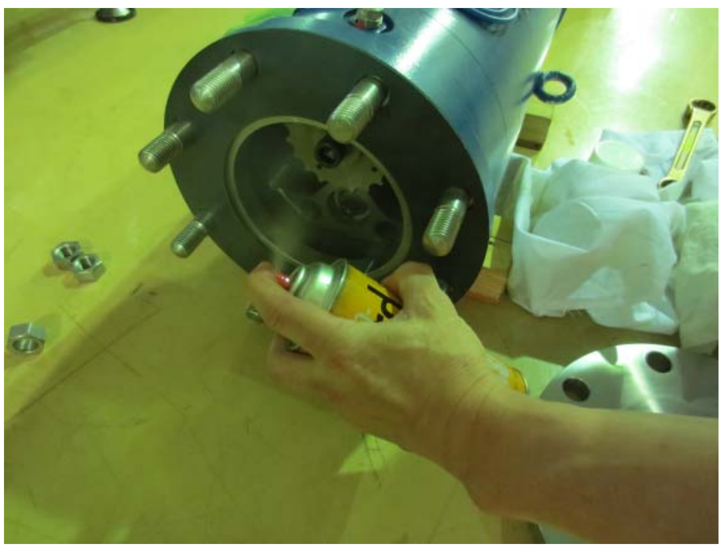

Fig. A1-10 Give the anti-rust treatment (ex. anti-rust spray) to the wetted part of the PD meter.

Note: Cover the inlet and the outlet of the flow meter with the blind flanges except during measurement in order to prevent rust.

Note : Remove the package from the test line and deal with anti-rust treatment (6.7) remove right after draining. Cover the inlet and the outlet of the flow meter using the blind flanges as soon as possible.

Note : Before packing the all components into the transportation boxes, please make sure no liquid remained inside the components and anti-rust treatment (ex. anti-rust spray) has been given to the wetted part of the PD meter.

4. Wiring of PD meter signal

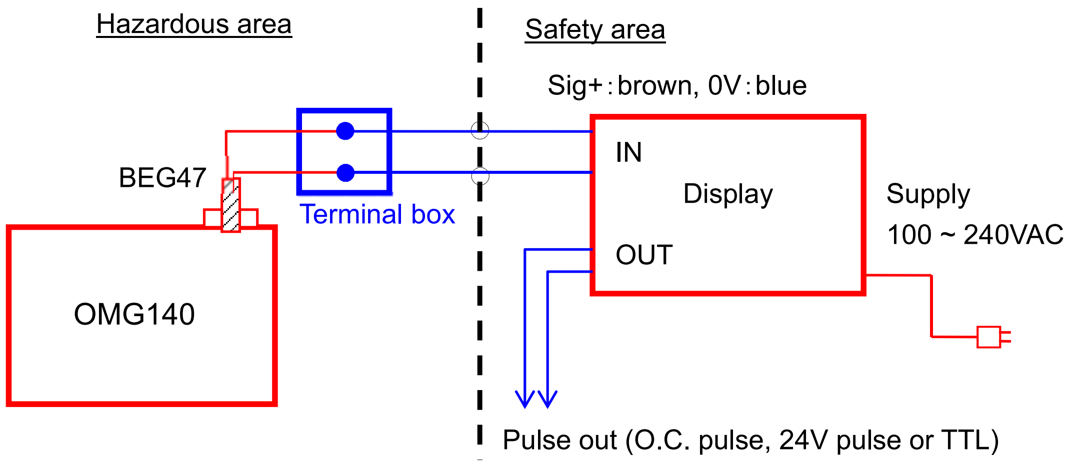

Fig. A1-11 Wiring of PD meter signal transmission. Red : Components sent from NMIJ, Blue : Connecting wires, cable glands and a terminal box should be prepared by the participants.

Fig. A1-12 Example : Increased Safety–Explosion Proof Terminal box and Cable glands.

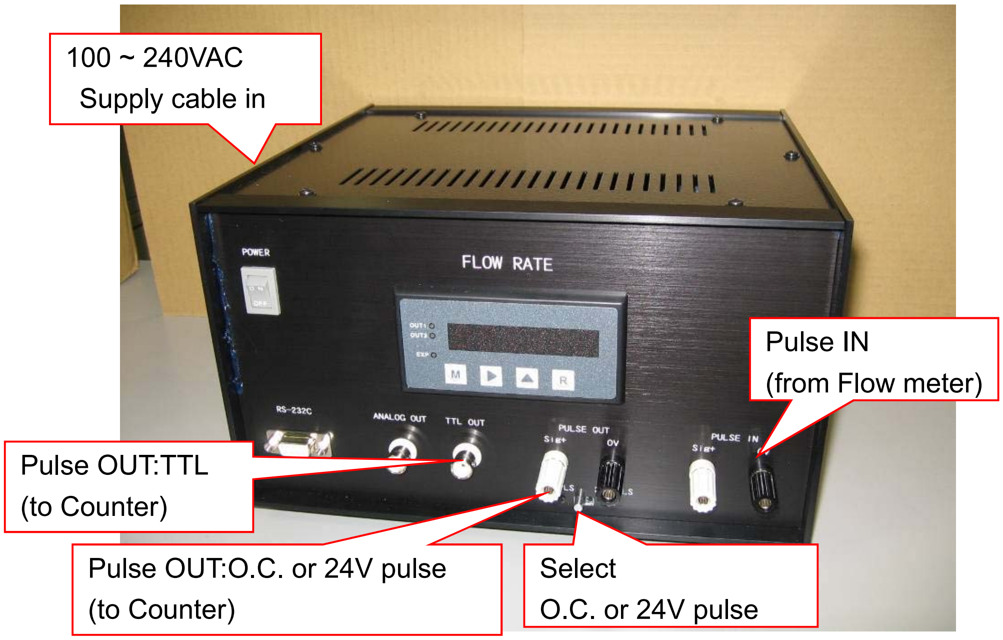

Fig. A1-13 Display with a built-in Isolated barrier for PD meter

Note : Don’t change any settings provided in the display.

5. Upstream pipe

Fig. A1-14 Upstream pipe

Fig. A1-15 Properly align the filter with the pipe center.

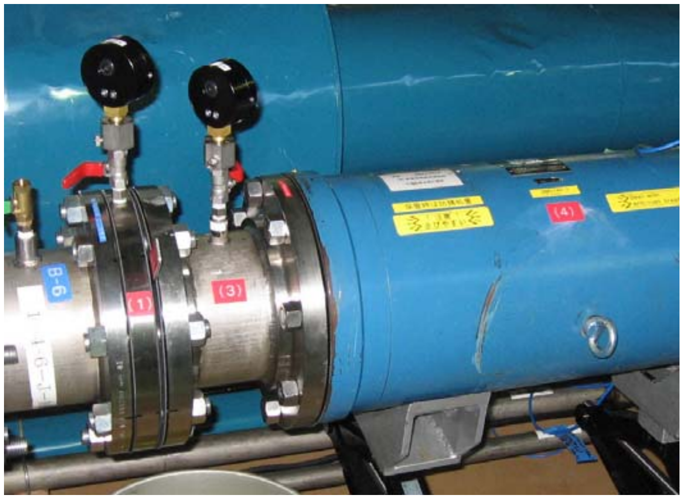

Fig. A1-16 Pressure measurement at the two pressure taps of the upstream pipe with the filter if necessary.

Appendix 2 Forms to be used in KC

	Title	File name
Form 1	Receiving Checklist	Form1(Rcv_ChkLst).xlsx
Form 2	Report of measurement result	Form2(Report).xlsx
Form 3	Shipping Checklist	Form3(Shpng_ChkLst).xlsx

The MS-Excel files of these forms are available in the CD-R, which is stored in the document binder.

Appendix 3 Test Schedule

#	Beginning of Week	Participating NMI	#	Beginning of Week	Participating NMI
1	14 July 2014	NMIJ	26	5 January 2015	Shipping
2	21 July 2014	NMIJ	27	12 January 2015	CENAM
3	28 July 2014	NMIJ	28	19 January 2015	CENAM
4	4 August 2014	-	29	26 January 2015	CENAM
5	11 August 2014	-	30	2 February 2015	Shipping
6	18 August 2014	NMIJ	31	9 February 2015	Shipping
7	25 August 2014	Shipping	32	16 February 2015	Shipping
8	1 September 2014	Shipping	33	23 February 2015	NMIA
9	8 September 2014	Shipping	34	2 March 2015	NMIA
10	15 September 2014	BEV	35	9 March 2015	NMIA
11	22 September 2014	BEV	36	16 March 2015	Shipping
12	29 September 2014	BEV	37	23 March 2015	Shipping
13	6 October 2014	Shipping	38	30 March 2015	Shipping
14	13 October 2014	Shipping	39	6 April 2015	NMIJ
15	20 October 2014	LNE-TRAPIL	40	13 April 2015	NMIJ
16	27 October 2014	LNE-TRAPIL	41	20 April 2015	Shipping
17	3 November 2014	LNE-TRAPIL	42	27 April 2015	Shipping
18	10 November 2014	Shipping	43	4 May 2015	CMS
19	17 November 2014	Shipping	44	11 May 2015	CMS
20	24 November 2014	NEL	45	18 May 2015	CMS
21	1 December 2014	NEL	46	25 May 2015	Shipping
22	8 December 2014	NEL	47	1 June 2015	Shipping
23	15 December 2014	Shipping	48	8 June 2015	NMIJ
24	22 December 2014	Shipping	49	15 June 2015	NMIJ
25	29 December 2014	Shipping	50	22 June 2015	NMIJ

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