EURAMET Project no. 1369

Bi-lateral comparison using Transfer Standard of Key-Comparison CCM-FF.K2.2011 for Water and Hydrocarbon flow between 10 and 60 kg/min

VSL (F.M. Smits) – Pilot and coordinator of the comparison
VSL (D.M. Standiford) – Author of this Euramet report
Measurement Canada (René Magnan) – Coordinator of the comparison

December 2019

Contents

1. Introduction

Euramet Project no. 1369 compares the flow measurement results of MC (Measurement Canada) and VSL (The Netherlands). The artifact that is used for this comparison is a special designed reference meter skid (IKS-SKID). The advantage of the IKS-SKID is that influences due to building in the meters and/or operators are eliminated as much as possible. This leads to a comparison of the realization of the references of the participating labs. The transfer standard (IKS-SKID) has been designed in such a way that it can be used for both water and hydrocarbon flows and a cleaning procedure is put in place. The results of VSL are verified during the CIPM-CCM.FF-K2 comparison and are consistent with the CMC claim of VSL. The CMC claim of VSL in the CIPM-MRA database is 0.02% @ k=2 (water) and 0.04% @ k=2 (hydrocarbons) for liquid mass flow. At the writing of this report, VSL no longer has a CMC listed at BIPM for hydrocarbon.

The participants in the bilateral comparison are:

VSL B.V.
Liquid Flow and Volume
Thijsseweg 11
2629 JA Delft
The Netherlands

and

Measurement Canada
Standards Building
151 Tunney's Pasture Driveway
Ottawa, Ontario K1Y 1G9
Canada

The comparison was performed in conjunction with the CCM.FF-K2 CIPM key comparison which started in August 2013 with the determination of the mass flow rate error of the IKS-SKID by VSL. The IKS-SKID was shipped to Measurement Canada during the key comparison and they also determined the mass flow rate error in turn. At the completion by all participants, the IKS-SKID was shipped back to VSL for a final calibration to demonstrate the stability of the IKS-SKID.

2. The transfer standard (TS)

The transfer standard is a skid with two Coriolis mass flow meters and auxiliary equipment. The piping and ball valves in the skid are placed in a so-called X-configuration. This makes it possible to place the mass flow meters upstream or downstream of each other just by opening and closing valves. Furthermore, it is possible to test each mass flow meter individually and in parallel if needed. This was a very nice option during the commissioning tests at the pilot laboratory to prove that the mass flow meters do not interact with each other.

A detailed description of the transfer standard can be found in the technical protocol of CCM.FF-K2.1.2011.

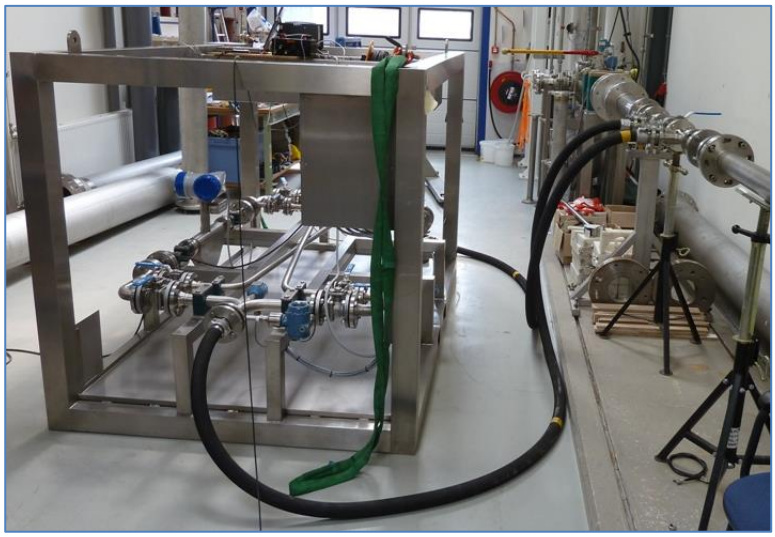
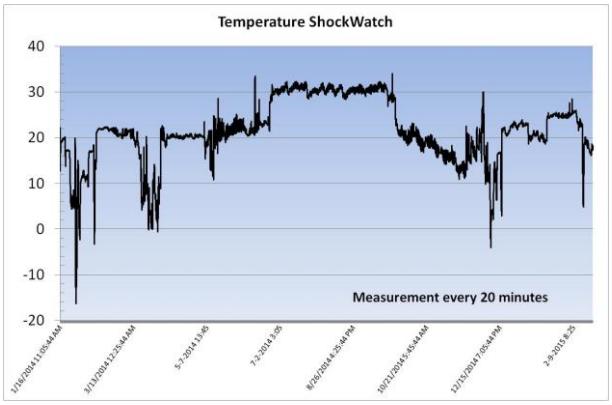


Figure 1 - Picture of the IKS-SKID connected to a calibration facility (VSL Water Flow)

A ShockWatch® was connected to the IKS-SKID which monitored the movements of the IKS-SKID during transportation. The position of the ShockWatch® is shown in Figure 2.

Figure 2 - Position of the ShockWatch® on the IKS-SKID

Three events are reported in the logfile. Details of the events can be seen in the reports of the ShockWatch® from which an example can be seen in Figure 3 and Figure 4. A registration of the temperatures during the two years of the comparison can be seen in Figure ***5***. If necessary, it is possible to zoom in on specific time frames. There was no need to do so.



The most severe shock was event #2. It registered an acceleration in the z-direction of 24 g which could have been caused e.g. by a lift truck bumping into the IKS-SKID. The force is exerted only for a very short period of approximately 10ms.
No visual damage was reported by any of the participating laboratories. So, it is assumed that no damage was inflicted on the IKS-SKID.

Figure 3 - Report of the ShockWatch®

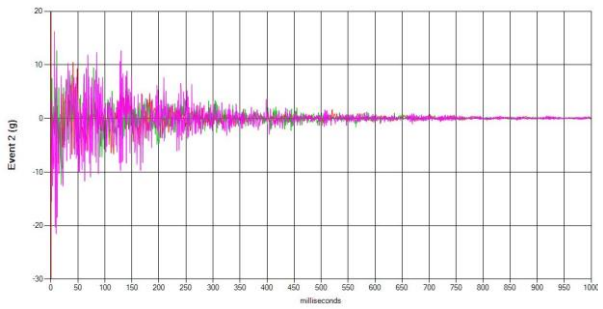


Figure 4 - Detail of event #2

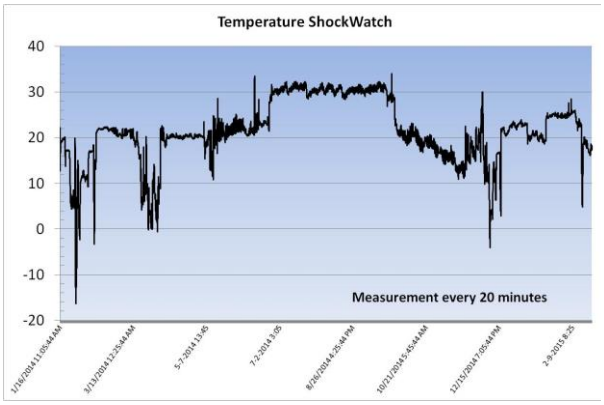


Figure 5 - Temperature registered by the ShockWatch® during the time of the comparison

3. Measurement procedure

The reference value and flows

In this bilateral comparison, VSL is the traceable link to the CCM.FF-K2.2011 key comparison reference value (KCRV) that is compared to Measurement Canada. As Measurement Canada was an unofficial participant in the CCM.FF-K2.2011 comparison, their results have also been compared directly to the KCRV. The reference value for this comparison is defined as:

“The mass quantity of a flowing liquid passing through the transfer standard at given flow rates.”

The measured flows ranged from 10 to 60 kg/min.

The results of this comparison are the measurement errors of the reference flows at the MUT as determined by Measurement Canada and VSL. The measurement errors are calculated for each mass flow meter making use of the pulse output of the meter or the display reading. During the commissioning tests of the IKS-SKID no difference was found between display reading and pulse counting. Therefore, either indication can be used to calculate the measurement error. The mass flow meters are set up with a base k-factor (set to 1000 pulses per kilogram so 1 pulse is equal to 1 gram).

Each laboratory performed the tests according to their own procedures. For this comparison both Standing Start Finish (SSF) and Flying Start Finish (FSF) methods could be used. The different methods should not lead to differences in the errors as both mass flow meters are setup with a low flow cutoff to avoid that pulses are missed at the start and end of one single test when using SSF method. (or mass reading on the display is too low) It should be noted that when using the SSF method, each measurement should be at least one minute.

Test liquids

Water

VSL and Measurement Canada both tested with water.

Hydrocarbon

VSL and Measurement Canada both tested with hydrocarbon in a viscosity range from 1.5 up to 2.8 mm^2/s. According to the measurement principle of Coriolis mass flow meters it should make no difference in measurement results for this viscosity range.

Methods used for calibration

Measurement Canada provided VSL with a description and a simplified P&ID drawing to show how the IKS-SKID is connected to their test facilities. The facilities are described in Annex 3.. The method of FSF and/or SSF is described in Annex 3. as well. Measurement Canada has an independent traceability in the realization of their standards.

Test points

The following flow rates were used for the comparison for each liquid. Both laboratories were able to generate the requested flow rates. The tests are performed in the given order. The repeatability based on the test at 40 kg/min is used to calculate the uncertainty as presented by each laboratory.

Table 1 - Flow rates and number of repeats for the comparison tests

Flow-rate (kg/min)	Number of Repeats	Remarks
20	5	--
40	10	5 extra test for repeatability
60	5	--
50	5	--
30	5	--
10	5	--

4. Data Analysis

The standardized Degree of Equivalence (E_n) will be determined for each flow rate separately. The data have been processed using procedure B of the recommended approaches for processing bi-lateral comparison data described by Cox [4].

No distinction has been made between the results of the meters in the upstream or downstream position since there was no significant difference between the results in the upstream and downstream position. The results of the two positions are considered as one set of results. This implies that there are 4 sets of results to be presented. The results of two fluids through each of the two meters.

The difference d_i between the result of Measurement Canada and VSL and the corresponding uncertainty $U(d_i)$ are calculated to form the Degree of Equivalence (DoE) which is the combination (d_i, $U(d_i)$). (see section 0) The standardized Degree of Equivalence (E_n) has been used to indicate whether Measurement Canada's result is consistent with VSL. Consistency is demonstrated when E_n<1. If 1< E_n<1.2 a warning level is defined. With E_n>1.2 the results are inconsistent with the reference laboratory.

The determination of the difference "Lab to Lab" (DoE)

The differences between the results of Measurement Canada and VSL were calculated according to

$$d_i = x_i - x_{ref} \qquad (1)$$

The expanded uncertainty was computed as the half-width of the 95% coverage interval. The coverage factor was computed as the ratio of the expanded and standard uncertainty.

Based on these differences and the corresponding uncertainties the standardized Degree of Equivalence (or normalized deviation) can be calculated according to:

$$E_n = \left|\frac{d_i}{U(d_i)}\right| \qquad (2)$$

The standardized *DoE* E_n is a measure for the consistency of the results of Measurement Canada with VSL. The limit for demonstrating equivalence is that the difference between the measurement error of the Measurement Canada and VSL is equal to the expanded uncertainty of the difference d_i:

- The results of Measurement Canada will be considered consistent (passed) if $E_n \leq 1$.
- Measurement Canada will be considered as not consistent (failed) if $E_n > 1.2$.
- For values of *DoE* in the range $1 < E_n \leq 1.2$ the "warning level" is defined. In this case actions to check are recommended.

The calculation of the *DoE* needs the information about the uncertainty of the difference d_i (equation (1) and (2)). To make statements about the uncertainty of the difference d_i, it is necessary to consider first the general problem of the difference of two values x_1 and x_2. If we look to the pure propagation of (standard) uncertainty, we find:

$$u^2_{x_1-x_2} = \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} & \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} \begin{pmatrix} u_1^2 & cov \\ cov & u_2^2 \end{pmatrix} \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} \\ \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} = u_1^2 + u_2^2 - 2 \times cov \qquad (3)$$

The (standard) uncertainty of the difference is the quadratic sum of the uncertainties of the inputs (u_1 and u_2). The results between Measurement Canada and VSL are considered independent. In this case, the covariance (*cov*) is considered zero leading to:

$$u_{x_1-x_2}^2 = u_1^2 + u_2^2 \qquad (4)$$

Equation (3) uses the standard uncertainties. The expanded uncertainty $U(d_i)$ is determined by

$$U(d_i) = 2.u(d_i) \qquad (5)$$

5. Measurement results

The IKS-SKID gave the possibility to use two different configurations for the test by changing the order of the two travel standards. Either Meter 1 is upstream, or Meter 2 is upstream. Each configuration results in two sets of data. For each fluid (water and hydrocarbon) four sets of measurement errors are reported each related to the configuration of the meter setup:

1. Configuration 1
   - Measurement error of Meter 1 in the upstream position
   - Measurement error of Meter 2 in the downstream position

2. Configuration 2
   - Measurement error of Meter 2 in the upstream position
   - Measurement error of Meter 1 in the downstream position

From the CCM.FF-K2.2011 Draft B report, it was decided that there was no significant difference between the results with a meter in the upstream position or in the downstream position. Likewise, for this comparison the results of a meter in upstream and downstream position are considered as one set of results.

Stability of the transfer standard meters

The stability of the transfer standard meters has been determined based on three tests with water as the calibration liquid performed by VSL during the CCM.FF-K2.2011 key comparison. Water was used since the uncertainty of the facility of VSL is lowest for this liquid. The tests were performed before the start of the comparisons, approximately in the middle of the comparisons and after the IKS-SKID was returned from the last comparison laboratory. The stability of the meters has been calculated using the maximum difference between the three measurement errors determined by VSL on three different occasions for each flow rate assuming a rectangular distribution.

$$u_{drift} = \left(\frac{\mathcal{E}_{max} - \mathcal{E}_{min}}{2\sqrt{3}} \right) \quad (6)$$

The maximum average of the results has been used as the contribution to the uncertainty for drift of the transfer standard. The contribution u_{drift} to the uncertainty of the laboratory results is determined to be 0.003% for Meter 1 and 0.006% for Meter 2.

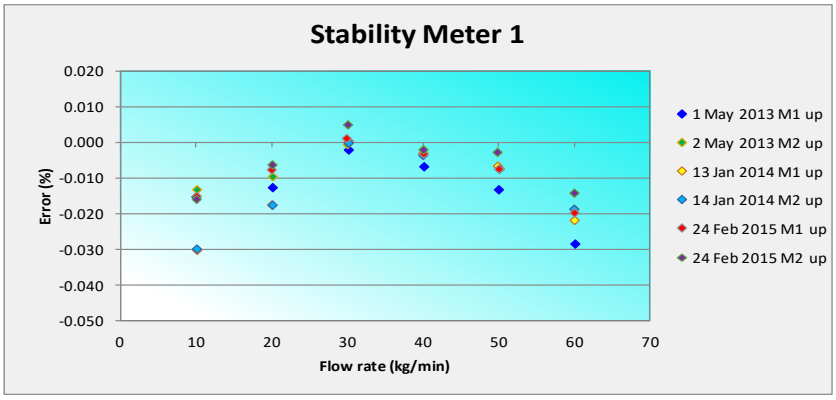


Figure 6: Meter 1 Test results to determine the stability of the transfer standards

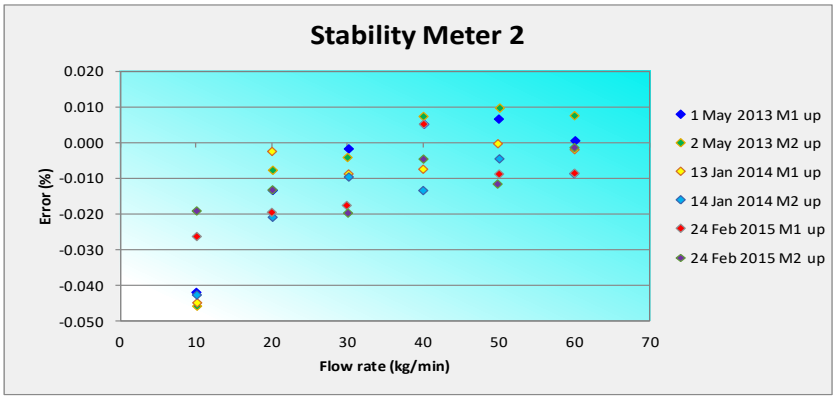


Figure 7: Meter 2 Test results to determine the stability of the transfer standards

Based on calculations performed by NMIJ during the CCM.FF-K2.2011 comparison, an additional contribution to the long-term stability of one of the transfer standards is incorporated in the calculations of the KCRV for the hydrocarbon measurements. Based on the average value of the coefficients and the temperature difference among the hydrocarbon laboratories, the temperature effect on the transfer meters is estimated to be 0.0015% for Meter 1 and 0.034% for Meter 2, respectively. (see Annex 2 of the CCM.FF-K2.2011 key comparison final report for details) The total contribution u_{drift} to the uncertainty of the laboratory results is determined to be 0.003% for Meter 1 and 0.006% for Meter 2 on water and 0.003% for Meter 1 and 0.018% for Meter 2 on hydrocarbons.

Results of the tests with water

The results presented in the following charts are from the water data collected during the CCM.FF-K2.2011 comparison. Measurement Canada and VSL both participated in the CCM.FF-K2.2011 comparison, however Measurement Canada's results were not included in the determination of the key comparison reference value (KCRV) as they are not a national metrology institute. The charts show Measurement Canada's comparison to VSL and the linkage of Measurement Canada's results to the KCRV through this comparison. The 'Results' chart compares the average errors (with uncertainties) between Measurement Canada and VSL and includes the KCRV data determined from the CCM.FF-K2.2011 as a reference. The degrees of equivalence ('DoE') chart shows the DoE between Measurement Canada and VSL and includes the DoE of VSL to the KCRV data.

Meter 1.

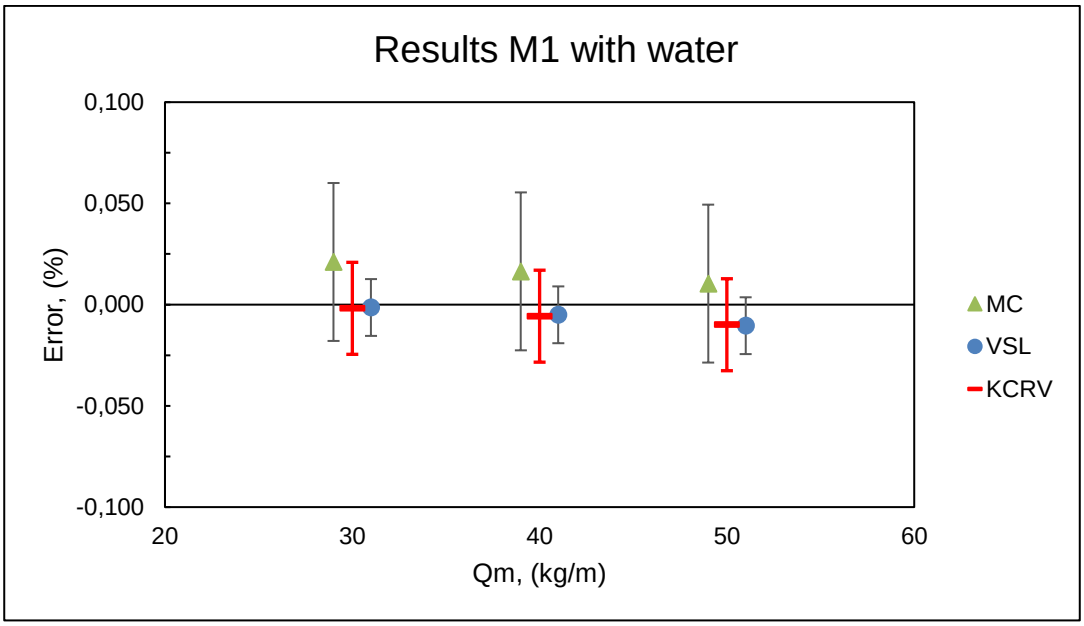


Figure 8: Meter 1 measurement error with uncertainty. (Error bars represent worst case for all rates.)

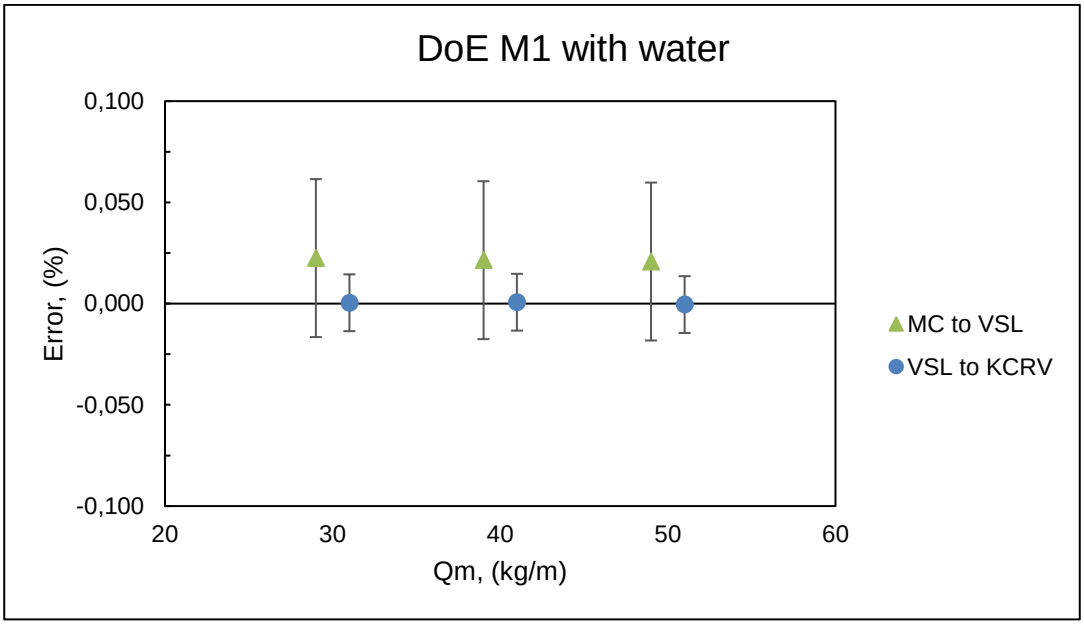


Figure 9: Meter 1 degree of equivalence with uncertainty. (Error bars represent worst case for all rates.)

Meter 2.

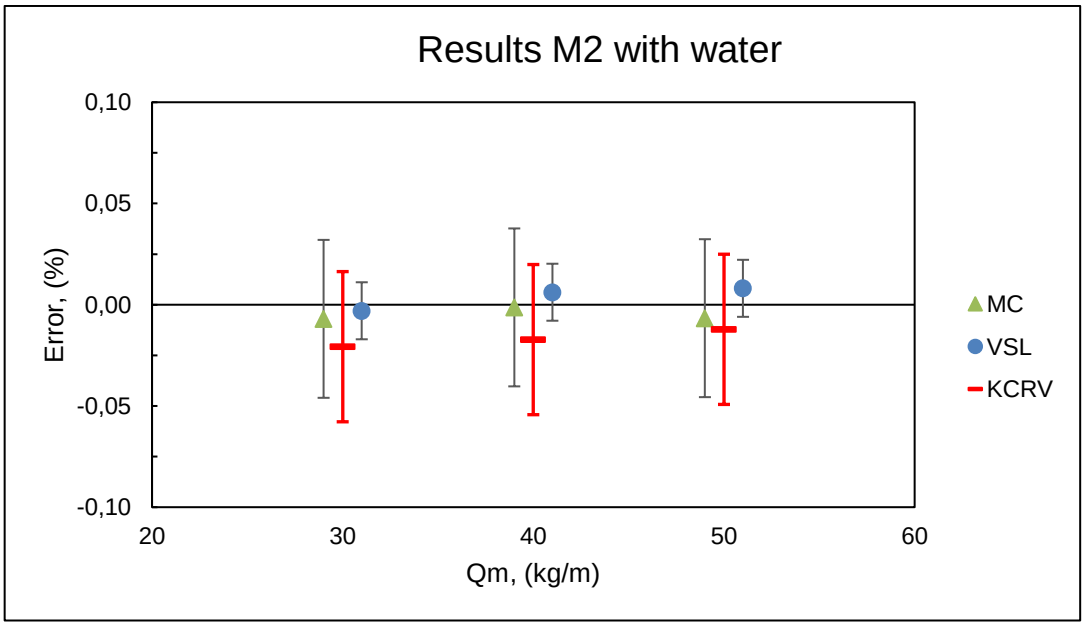


Figure 10: Meter 2 measurement error with uncertainty. (Error bars represent worst case for all rates.)

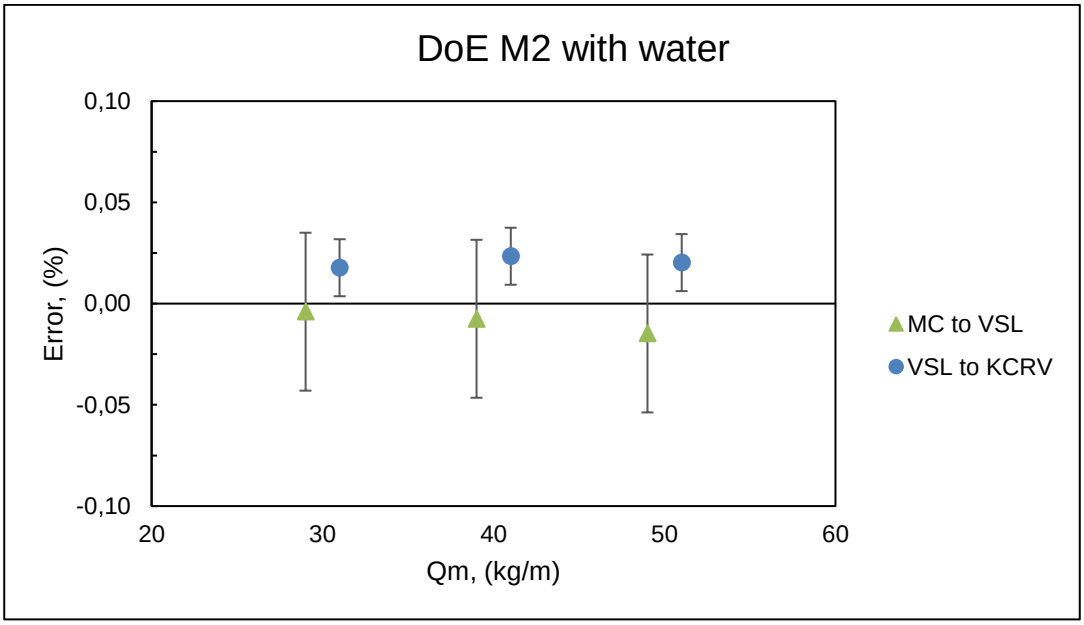


Figure 11: Meter 2 degree of equivalence with uncertainty. (Error bars represent worst case for all rates.)

Results of the tests with hydrocarbon

The results presented in the following charts are from the hydrocarbon data collected during the CCM.FF-K2.2011 comparison. Measurement Canada and VSL both participated in the CCM.FF-K2.2011 comparison, however Measurement Canada's results were not included in the determination of the key comparison reference value (KCRV) as they are not a national metrology institute. The charts show Measurement Canada's comparison to VSL and the linkage of Measurement Canada's results to the KCRV through this comparison. The 'Results' chart compares the average errors (with uncertainties) between Measurement Canada and VSL and includes the KCRV data determined from the CCM.FF-K2.2011 as a reference. The degrees of equivalence ('DoE') chart shows the DoE between Measurement Canada and VSL and includes the DoE of VSL to the KCRV data.

Meter 1.

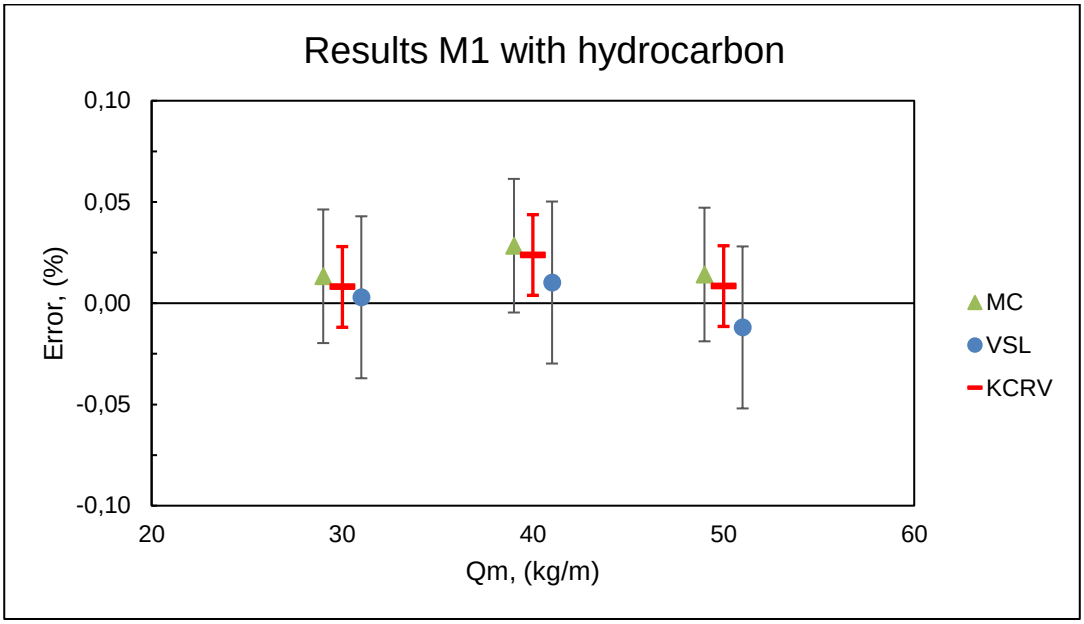


Figure 12: Meter 1 measurement error with uncertainty. (Error bars represent worst case for all rates.)

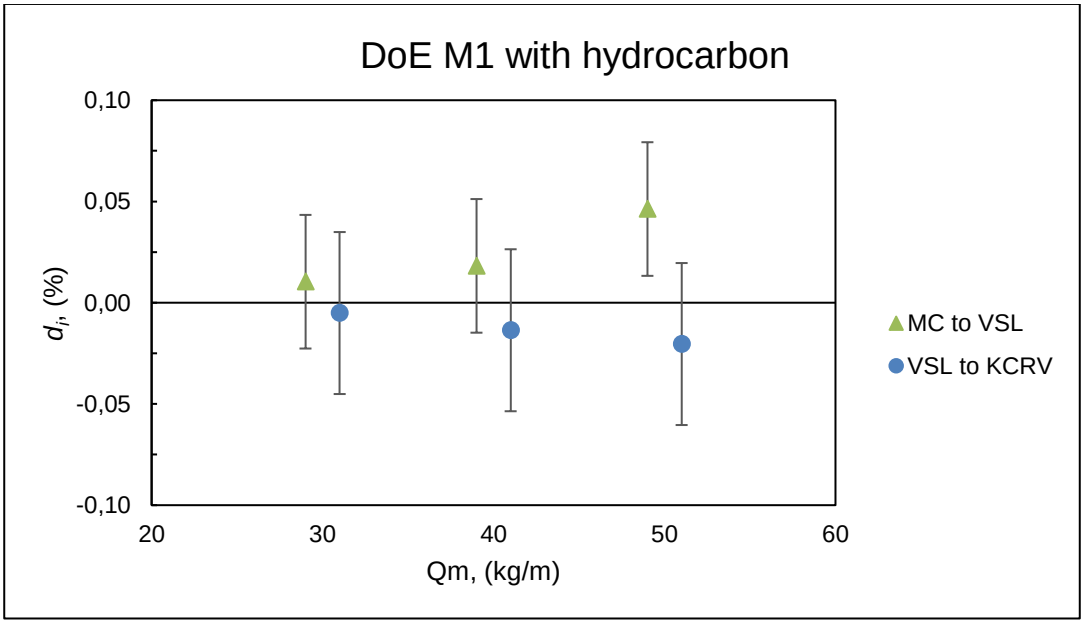


Figure 13: Meter 1 degree of equivalence with uncertainty. (Error bars represent worst case for all rates.)

Meter 2.

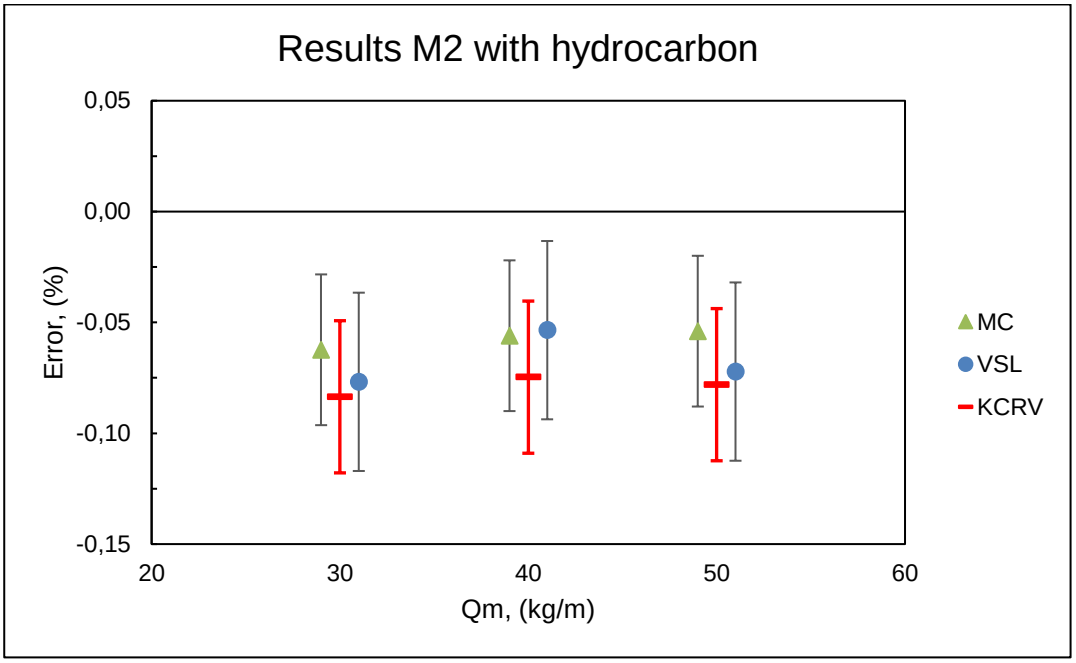


Figure 14: Meter 2 measurement error with uncertainty. (Error bars represent worst case for all rates.)

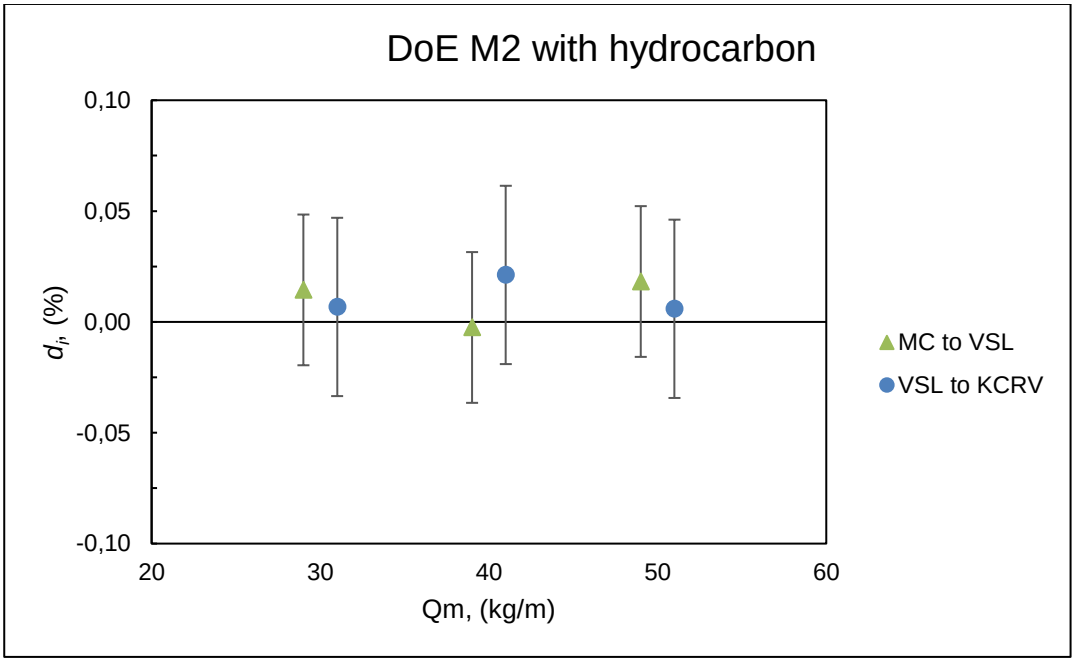


Figure 15: Meter 2 degree of equivalence with uncertainty. (Error bars represent worst case for all rates.)

6. Determination of the Evaluation Number (E_n value)

The determination of E_n values is performed at the same flow rates used in the CCM.FF-K2.2011 key comparison final report. The formula used to calculate the E_n values is as follows:

$$E_{\mathrm{n}} = \frac{x_{MC} - X_{VSL}}{k\sqrt{u_{MC}^2 + u_{VSL}^2}} \qquad (7)$$

With: E_{n} = performance characteristic including the stated uncertainty,

k = the coverage factor,

u_{MC}^2 = the uncertainty given by Measurement Canada,

u_{VSL}^2 = the uncertainty given by VSL,

x_{MC} = the results from Measurement Canada,

X_{VSL} = the results from VSL.

Table 2 – E_n Values

Fluid	Flow Rate (kg/min)	Meter 1 E_n	Meter 2 E_n		Fluid	Flow Rate (kg/min)	Meter 1 E_n	Meter 2 E_n
water	30	0.61	-0.11		hydrocarbon	30	0.20	0.28
water	40	0.58	-0.20		hydrocarbon	40	0.35	-0.05
water	50	0.50	-0.36		hydrocarbon	50	0.57	0.39

7. Tables with KCRV and Doe

In tables 3 and 4 the results of Measurement Canada (compared to VSL) and the results from VSL (CCM.FF-K2.2011) are presented together with the KCRV and U(KCRV) (CCM.FF-K2.2011). The columns show respectively the laboratory, the error as determined by the laboratory (Error), the expanded uncertainty of the error (U), the uncertainty of the transfer standard, the difference with the reference value (VSL or KCRV) (di), the expanded uncertainty of the difference (U(di)) and the En-value (En).

Table 3 expanded uncertainties for the results with water

Water Meter 1

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.021	0.034	0.003	0.022	0.037	0.611
VSL	-0.001	0.014	0.003	0.000	0.024	0.018

	KCRV (%)	$U_{(KCRV)}$ (%)
30 kg/min	-0.002	0.023

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.016	0.034	0.003	0.021	0.037	0.583
VSL	-0.005	0.014	0.003	0.001	0.024	0.028

	KCRV (%)	$U_{(KCRV)}$ (%)
40 kg/min	-0.006	0.023

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.010	0.039	0.003	0.021	0.042	0.501
VSL	-0.010	0.014	0.003	0.000	0.024	0.020

	KCRV (%)	$U_{(KCRV)}$ (%)
50 kg/min	-0.010	0.023

Water Meter 2

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.007	0.034	0.006	-0.004	0.037	-0.108
VSL	-0.003	0.014	0.006	0.018	0.038	0.471

	KCRV (%)	$U_{(KCRV)}$ (%)
30 kg/min	-0.021	0.035

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.001	0.034	0.006	-0.007	0.037	-0.204
VSL	0.006	0.014	0.006	0.023	0.040	0.586

	KCRV (%)	$U_{(KCRV)}$ (%)
40 kg/min	-0.017	0.037

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.007	0.039	0.006	-0.015	0.041	-0.356
VSL	0.008	0.014	0.006	0.020	0.039	0.524

	KCRV (%)	$U_{(KCRV)}$ (%)
50 kg/min	-0.012	0.036

Table 4 expanded uncertainties for the results with hydrocarbon

Hydrocarbon Meter 1

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.013	0.033	0.003	0.010	0.052	0.200
VSL	0.003	0.040	0.003	-0.005	0.038	0.134

	KCRV (%)	$U_{(KCRV)}$ (%)
30 kg/min	0.008	0.020

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.028	0.033	0.003	0.018	0.052	0.351
VSL	0.010	0.040	0.003	-0.014	0.039	0.351

	KCRV (%)	$U_{(KCRV)}$ (%)
40 kg/min	0.024	0.019

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	0.014	0.023	0.003	0.026	0.046	0.565
VSL	-0.012	0.040	0.003	-0.020	0.040	0.507

	KCRV (%)	$U_{(KCRV)}$ (%)
50 kg/min	0.008	0.020

Hydrocarbon Meter 2

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.062	0.033	0.018	0.014	0.052	0.278
VSL	-0.077	0.040	0.018	0.007	0.051	0.134

	KCRV (%)	$U_{(KCRV)}$ (%)
30 kg/min	-0.084	0.034

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.056	0.034	0.018	-0.003	0.053	-0.048
VSL	-0.053	0.040	0.018	0.021	0.055	0.384

	KCRV (%)	$U_{(KCRV)}$ (%)
40 kg/min	-0.075	0.034

Laboratory	Error (%)	$U_{(xi\_lab)}$ (%)	u_{ts} (%)	di (%)	$U_{(di)}$ (%)	En (-)
MC_{VSL}	-0.054	0.025	0.018	0.018	0.047	0.385
VSL	-0.072	0.040	0.018	0.006	0.051	0.115

	KCRV (%)	$U_{(KCRV)}$ (%)
50 kg/min	-0.078	0.034

8. Conclusion

Euramet Project no.1369 compares the calibration results of Measurement Canada (Canada) and VSL (The Netherlands). This comparison was performed in conjunction with the CCM.FF-K2 CIPM key comparison which started in August 2013 with the determination of the mass flow rate error of the IKS-SKID by VSL. The IKS-SKID was shipped to Measurement Canada during the key comparison and they also determined the mass flow rate error in turn.

The results of the comparison comply with the requirement that the Degree of Equivalence between participants should be smaller than 1 and show Measurement Canada's comparison to VSL and the linkage to the KCRV through VSL.

Conclusion with water

The results of the comparison with Meter 1 and Meter 2 with water as the calibration liquid show good agreement with VSL and the KCRV. The results of Measurement Canada with Meter 1 and Meter 2 are within the limits regarding the standardized DoE with respect to VSL. The results in this bilateral comparison will be used by Measurement Canada to substantiate their testing facility's capabilities and could be used to establish a CMC for CLAS or the BIPM (if designation is authorized by the NRC) in the future.

Temperature effects are not included in the uncertainties of to the transfer standards.

Conclusion with hydrocarbon

The results of the comparison with Meter 1 and Meter 2 with hydrocarbon as the calibration liquid show good agreement with VSL and the KCRV. The results of Measurement Canada with Meter 1 and Meter 2 are within the limits regarding the standardized DoE with respect to VSL. The results in this bilateral comparison will be used by Measurement Canada to substantiate their testing facility's capabilities and could be used to establish a CMC for CLAS or the BIPM (if designation is authorized by the NRC) in the future.

The influence of the temperature on the performance of the Meter 2 has been incorporated in the uncertainty of Meter 2. (see Annex 2 of the CCM.FF-K2.1.2011 final report)

9. References

1. Template for WGFF-KCs Technical Protocol for CIPM Key Comparison, Version 1, 2009.8
2. JCGM 100:2008, Evaluation of measurement data – Guide to the expression of uncertainty in measurement, 2008 (GUM 1995 with minor corrections)
3. BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, and OIML. Supplement 1 to the 'Guide to the Expression of Uncertainty in Measurement' – Propagation of distributions using a Monte Carlo method, JCGM 101:2008. BIPM, 2008.
4. Cox M.G., Evaluation of key comparison data. Metrologia, 2002, 39, 589-595
5. Cox M.G., The evaluation of key comparison data: determining the largest consistent subset, Metrologia, 2007, 44, 187-200
6. R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
7. JCGM 200:2012, International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM), 3rd edition, 2012
8. WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty, February 8, 2013
9. Transfer standard uncertainty can cause inconclusive inter-laboratory comparisons, John Wright et al., Metrologia 53 (2016) 1243-1258
10. Measurement comparisons in the CIPM MRA, CIPM MRA-D-05, Version 1.5
11. Guidelines for CIPM key comparisons (Appendix F to the "Mutual recognition of national measurements standards and of measurement certificates issued by national metrology institutes" (MRA)), 1 March 1999
12. CIPM key comparison CCM.FF-K2.2011, Draft B., Erik Smits, Gerard Blom, VSL BV., 2019.

10 Terms and abbreviations

BIPM = Bureau International des Poids et Mesures (the International Bureau of Weights and Measures)
CCM = Consultative Committee for Mass and Related Quantities
CIPM = Comité International des Poids et Mesures (International Committee for Weights and Measures)
CMC = Calibration and Measurement Capabilities
DI = Designated Institute
DoE = Degree of Equivalence
FF = Fluid Flow
FSF = Flying Start Finish method
GUM = Guide to the Expression of Uncertainty in Measurement
KC = Key Comparison
KCRV = Key Comparison Reference Value
MRA = Mutual Recognition Arrangement
NMI = National Metrology Institute

RTD = Resistive Temperature Device

SSF = Standing Start Finish method

TS = Transfer Standard

VIM = Vocabulaire International de Metrologie

VSL = The National Metrology Institute of the Netherlands

WGFF = Working Group for Fluid Flow

Annex 1. Data of the stability tests

KC Set Water 1 Meter 1 upstream Meter 2 downstream

1 May 2013		13 January 2014		24 February 2015			
Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Max Δ Error mtr 1 [%]	u drift WGFF [%]
20.06	-0.013	19.96	-0.017	19.93	-0.008	0.010	0.003
40.09	-0.007	39.95	-0.003	40.04	-0.003	0.004	0.001
60.08	-0.028	59.99	-0.022	59.98	-0.020	0.009	0.003
49.97	-0.013	49.85	-0.007	50.00	-0.007	0.007	0.002
30.12	-0.002	30.09	0.000	29.84	0.001	0.003	0.001
9.95	-0.015	10.06	-0.030	10.00	-0.015	0.015	0.004
						Average u	0.003

KC Set Water Meter 2 upstream Meter 1 downstream

2 May 2013		14 January 2014		24 February 2015			
Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Ref. flow rate [kg/min]	Error mtr 1 mass [%]	Max Δ Error mtr 1 [%]	u drift WGFF [%]
20.07	-0.010	20.04	-0.018	20.02	-0.006	0.011	0.003
40.00	-0.003	39.96	-0.004	40.00	-0.002	0.002	0.000
59.98	-0.019	59.93	-0.019	59.97	-0.014	0.005	0.001
50.10	-0.007	50.04	-0.007	49.80	-0.003	0.005	0.001
29.95	-0.001	30.12	0.000	30.01	0.005	0.006	0.002
10.05	-0.013	10.02	-0.030	9.99	-0.016	0.017	0.005
						Average u	0.003

KC Set Water Meter 1 upstream Meter 2 downstream

1 May 2013		13 January 2014		24 February 2015			
Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Max Δ Error mtr 2 [%]	u drift WGFF [%]
20.06	-0.013	19.96	-0.002	19.93	-0.019	0.017	0.005
40.09	0.005	39.95	-0.007	40.04	0.005	0.013	0.004
60.08	0.001	59.99	-0.002	59.98	-0.008	0.009	0.003
49.97	0.007	49.85	0.000	50.00	-0.009	0.015	0.004
30.12	-0.002	30.09	-0.009	29.84	-0.018	0.016	0.005
9.95	-0.042	10.06	-0.045	10.00	-0.026	0.019	0.005
						Average u	0.005

KC Set Water Meter 2 upstream Meter 1 downstream

2 May 2013		14 January 2014		24 February 2015			
Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Ref. flow rate [kg/min]	Error mtr 2 mass [%]	Max Δ Error mtr 2 [%]	u drift WGFF [%]
20.07	-0.008	20.04	-0.021	20.02	-0.013	0.013	0.004
40.00	0.007	39.96	-0.013	40.00	-0.005	0.021	0.006
59.98	0.008	59.93	-0.009	59.97	-0.001	0.016	0.005
50.10	0.010	50.04	-0.004	49.80	-0.012	0.021	0.006
29.95	-0.004	30.12	-0.010	30.01	-0.020	0.016	0.004
10.05	-0.046	10.02	-0.043	9.99	-0.019	0.027	0.008
						Average u	0.006

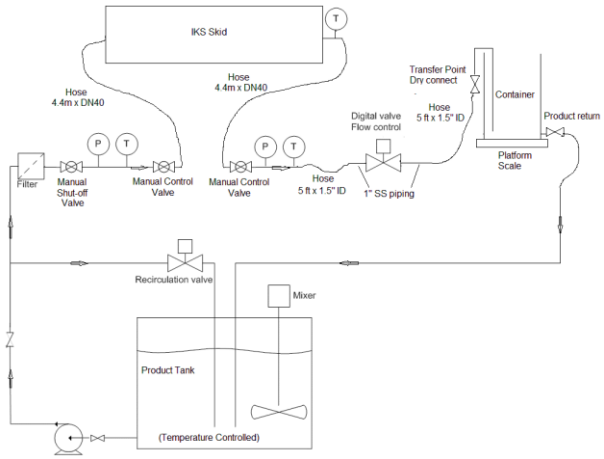
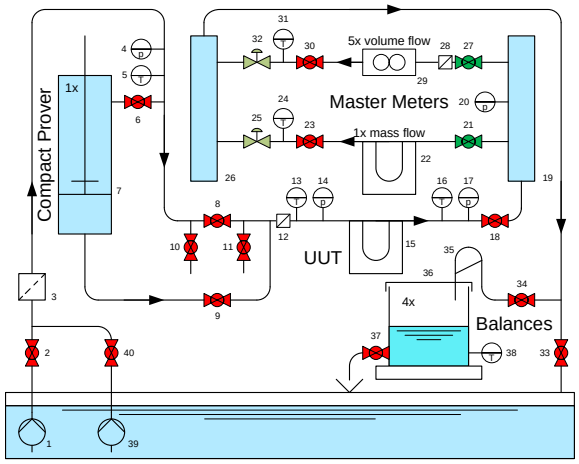
Annex 2. Schedule

Participant	Country	Latest arrival [dd-mm-yyyy]	Dispatch before [dd-mm-yyyy]	Number of weeks at NMI
VSL(1)	The Netherlands	--	19-08-2013	--
VSL(2)	The Netherlands	06-01-2014	20-01-2014	2
MC	Canada	01-04-2014	30-04-2014	3
VSL(3)	The Netherlands	01-02-2015	--	--

1) First measurements at VSL that will be the results presented for the KCRV values
2) Check measurements at VSL before IKS-SKID is send outside Europe water measurements only
3) Final measurements at VSL

Annex 3. Test facilities

Canada	Measurement Canada Standards Building 151 Tunney's Pasture Driveway Ottawa, Ontario K1Y 1G9 Canada
The Netherlands [pilot]	VSL B.V. Water Flow Hugo de Grootplein 1 3314 EG Dordrecht The Netherlands

Measurement Canada  	**Method used:** Gravimetric measurement of delivered product into an open container **Flying or standing start method used:** Standing start method **1)** Take sample of liquid and measure density from 5 to 35 °C; establish density vs temperature equation **2)** Measure balance linearity error across measurement range using certified mass standards **3)** Weigh empty container (Ie, conventional mass) **4)** Deliver product into container, measure average flowing pressure and temperature at the meter **5)** Weigh full container (If, conventional mass) **6)** Correct the empty and full container weighings (We and Wf) by applying scale linearity correction factor calculated in step (2) **7)** Obtain conventional mass of liquid passed through the meter from the difference between the full and empty weighing **8)** Convert the liquid conventional mass to absolute mass (M_abs) by applying buoyancy correction **9)** Calculate the liquid volume from liquid mass and liquid density
VSL the Netherlands  	VSL installation has several possibilities to determine the reference flow. Reference can be a weigh scale, a small volume prover or a master meter. For the Key Comparison the procedure with the lowest uncertainty has been chosen: the weigh scale. Results with the weigh scale are always compared with results from master meters. The Standing Start Finish method is used.

Annex 4. Calibration data

VSL

30 kg/min																	
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
6.01	13:33	30.1	45.521	45.524	17.31	17.35	3.83	3.13					30.11	45.5227	999.22	-0.004	0.002
6.02	13:39	30.1	46.218	46.219	17.35	17.42	3.83	3.13					30.12	46.2190	999.22	-0.001	0.000
6.03	13:45	30.1	45.662	45.661	17.37	17.44	3.83	3.13					30.08	45.6625	999.21	-0.001	-0.004
6.04	13:51	30.1	45.879	45.878	17.40	17.45	3.83	3.13					30.13	45.8799	999.21	-0.003	-0.005
6.05	13:57	30.2	46.360	46.360	17.41	17.46	3.83	3.13					30.15	46.3603	999.21	-0.001	-0.001
reversed order of the transfer standards																	
6.01	12:56	29.9	45.994	45.992	17.76	17.79	3.67	2.99					29.92	45.9948	999.14	-0.002	-0.007
6.02	13:03	30.0	45.948	45.949	17.79	17.82	3.67	2.99					30.03	45.9481	999.13	-0.001	0.002
6.03	13:09	29.9	46.120	46.118	17.80	17.85	3.67	2.99					29.92	46.1197	999.13	0.000	-0.003
6.04	13:20	29.9	46.484	46.482	17.78	17.90	3.67	2.99					29.87	46.4848	999.13	-0.001	-0.006
6.05	13:26	30.0	46.061	46.058	17.80	17.87	3.67	2.99					30.02	46.0610	999.13	0.001	-0.007

VSL

40 kg/min																	
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
3.01	10:23	40.0	61.312	61.318	17.17	17.25	3.76	2.60					40.04	61.3158	999.25	-0.006	0.004
3.02	10:26	40.1	62.329	62.338	17.26	17.32	3.76	2.60					40.08	62.3326	999.23	-0.006	0.009
3.03	10:32	40.2	61.619	61.627	17.27	17.35	3.76	2.60					40.24	61.6241	999.23	-0.008	0.005
3.04	10:39	40.0	61.698	61.706	17.30	17.35	3.76	2.60					40.02	61.7007	999.22	-0.004	0.008
3.05	10:46	40.1	59.403	59.413	17.32	17.37	3.76	2.60					40.10	59.4069	999.22	-0.007	0.010
3.06	10:52	40.1	60.776	60.785	17.36	17.41	3.76	2.60					40.06	60.7813	999.21	-0.009	0.005
3.07	10:59	40.0	60.742	60.748	17.36	17.43	3.76	2.60					40.04	60.7472	999.21	-0.008	0.001
3.08	11:06	40.1	62.324	62.329	17.36	17.44	3.76	2.60					40.13	62.3283	999.21	-0.007	0.001
3.09	11:13	40.1	61.064	61.070	17.41	17.48	3.76	2.60					40.06	61.0685	999.20	-0.007	0.002
3.10	11:20	40.1	60.960	60.967	17.44	17.50	3.76	2.60					40.13	60.9645	999.20	-0.007	0.005
reversed order of the transfer standards																	
3.01	09:33	39.7	61.382	61.390	17.18	17.25	3.59	2.45					39.73	61.3843	999.24	-0.003	0.009
3.02	09:43	40.5	61.467	61.474	17.25	17.31	3.59	2.45					40.53	61.4687	999.22	-0.003	0.008
3.03	09:47	39.9	60.847	60.855	17.29	17.35	3.59	2.45					39.91	60.8498	999.22	-0.005	0.009
3.04	09:54	39.9	61.223	61.231	17.27	17.36	3.59	2.45					39.90	61.2249	999.22	-0.003	0.009
3.05	10:01	40.1	61.342	61.347	17.35	17.40	3.59	2.45					40.07	61.3430	999.21	-0.002	0.007
3.06	10:07	39.9	61.051	61.057	17.33	17.39	3.59	2.45					39.90	61.0530	999.21	-0.004	0.006
3.07	10:14	40.0	60.630	60.638	17.38	17.43	3.59	2.45					40.02	60.6320	999.20	-0.003	0.009
3.08	10:21	40.1	61.890	61.894	17.41	17.49	3.59	2.45					40.14	61.8912	999.19	-0.002	0.005
3.09	10:28	39.9	61.142	61.149	17.44	17.51	3.59	2.45					39.93	61.1445	999.19	-0.004	0.007
3.10	10:34	39.9	73.211	73.216	17.48	17.56	3.59	2.45					39.87	73.2135	999.18	-0.003	0.004

VSL

50 kg/min																	
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
5.01	12:52	50.0	66.751	66.764	17.24	17.33	3.68	1.94					50.00	66.7594	999.23	-0.013	0.007
5.02	13:00	50.0	71.332	71.346	17.26	17.36	3.68	1.94					49.95	71.3420	999.23	-0.013	0.006
5.03	13:08	50.0	71.619	71.635	17.24	17.36	3.68	1.94					49.99	71.6281	999.23	-0.013	0.009
5.04	13:14	50.0	71.921	71.936	17.25	17.34	3.68	1.94					49.95	71.9309	999.23	-0.014	0.007
5.05	13:20	50.0	71.559	71.572	17.27	17.36	3.68	1.94					49.97	71.5688	999.22	-0.014	0.004
reversed order of the transfer standards																	
5.01	11:41	50.1	67.978	67.988	17.68	17.73	3.51	1.78					50.10	67.9800	999.14	-0.003	0.012
5.02	11:48	50.1	70.069	70.080	17.71	17.79	3.51	1.78					50.12	70.0740	999.14	-0.008	0.009
5.03	11:55	50.1	69.260	69.274	17.70	17.80	3.51	1.78					50.12	69.2678	999.14	-0.010	0.009
5.04	12:01	50.0	69.706	69.718	17.70	17.78	3.51	1.78					50.03	69.7131	999.14	-0.010	0.007
5.05	12:12	50.1	71.904	71.916	17.69	17.77	3.51	1.78					50.12	71.9087	999.14	-0.006	0.011

VSL

30 kg/min																		
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
6.01	14:58	30.3	79.724	79.664	22.10	22.20	4.25	3.35					30.30	79.7209	1.581	797.27	0.004	-0.071
6.02	15:06	30.5	79.425	79.359	22.00	22.10	4.25	3.35					30.50	79.4233	1.583	797.35	0.003	-0.081
6.03	15:16	29.8	79.695	79.633	21.90	22.00	4.25	3.35					29.80	79.6914	1.586	797.42	0.004	-0.073
6.04	15:23	30.3	79.657	79.593	21.90	22.00	4.25	3.35					30.30	79.6544	1.586	797.42	0.003	-0.077
6.05	15:32	30.1	79.666	79.604	21.90	22.00	4.25	3.35					30.10	79.6650	1.586	797.42	0.002	-0.076
reversed order of the transfer standards																		
6.01	13:33	30.0	79.329	79.267	22.80	22.90	4.24	3.36					30.03	79.3266	1.562	796.75	0.003	-0.075
6.02	13:41	30.4	79.642	79.580	22.70	22.80	4.24	3.36					30.40	79.6389	1.565	796.83	0.004	-0.073
6.03	13:49	30.4	80.024	79.957	22.70	22.70	4.24	3.36					30.40	80.0226	1.565	796.83	0.002	-0.083
6.04	13:57	30.4	79.988	79.919	22.60	22.60	4.24	3.36					30.40	79.9848	1.567	796.90	0.004	-0.082
6.05	14:05	30.2	79.744	79.682	22.50	22.60	4.24	3.36					30.20	79.7426	1.570	796.98	0.001	-0.076

VSL

40 kg/min																		
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
3.01	11:33	39.8	79.906	79.858	19.70	19.80	4.24	2.77					39.82	79.8957	1.645	799.06	0.013	-0.047
3.02	11:40	39.8	80.091	80.043	19.70	19.80	4.24	2.77					39.80	80.0817	1.645	799.06	0.012	-0.048
3.03	11:48	39.7	79.631	79.583	19.70	19.80	4.24	2.77					39.70	79.6213	1.645	799.06	0.012	-0.048
3.04	11:56	39.5	79.797	79.749	19.70	19.80	4.24	2.77					39.50	79.7880	1.645	799.06	0.011	-0.049
3.05	12:04	40.0	79.714	79.670	19.80	19.90	4.24	2.77					40.00	79.7059	1.642	798.99	0.010	-0.044
3.06	12:11	40.5	79.610	79.561	19.80	19.90	4.24	2.77					40.50	79.6022	1.642	798.99	0.009	-0.052
3.07	12:19	40.4	80.238	80.189	19.80	19.90	4.24	2.77					40.40	80.2301	1.642	798.99	0.010	-0.051
3.08	12:28	39.6	79.556	79.506	19.80	19.90	4.24	2.77					39.60	79.5488	1.642	798.99	0.009	-0.053
3.09	12:35	39.5	80.050	80.000	19.80	19.90	4.24	2.77					39.50	80.0412	1.642	798.99	0.011	-0.051
3.10	12:43	39.4	80.089	80.041	19.80	19.90	4.24	2.77					39.40	80.0812	1.642	798.99	0.009	-0.050
reversed order of the transfer standards																		
3.01	10:13	40.1	79.708	79.649	21.00	21.10	4.24	2.75					40.10	79.6988	1.610	798.09	0.012	-0.063
3.02	10:21	40.4	79.767	79.712	21.00	21.10	4.24	2.75					40.40	79.7598	1.610	798.09	0.009	-0.060
3.03	10:28	40.5	79.310	79.258	21.00	21.00	4.24	2.75					40.50	79.3024	1.610	798.09	0.009	-0.056
3.04	10:35	40.4	80.008	79.953	21.00	21.00	4.24	2.75					40.40	79.9976	1.610	798.09	0.013	-0.055
3.05	10:42	40.2	79.322	79.265	21.00	21.00	4.24	2.75					40.20	79.3136	1.610	798.09	0.011	-0.062
3.06	10:50	40.5	79.854	79.799	21.00	21.00	4.24	2.75					40.50	79.8463	1.610	798.09	0.010	-0.060
3.07	10:57	40.6	79.916	79.858	20.90	21.00	4.24	2.75					40.60	79.9079	1.613	798.17	0.010	-0.062
3.08	11:05	40.7	79.879	79.825	20.90	21.00	4.24	2.75					40.70	79.8687	1.613	798.17	0.012	-0.055
3.09	11:12	40.7	80.054	80.009	20.90	21.00	4.24	2.75					40.70	80.0501	1.613	798.17	0.005	-0.052
3.10	11:19	40.7	80.070	80.025	20.90	21.00	4.24	2.75					40.70	80.0656	1.613	798.17	0.006	-0.051

VSL

50 kg/min																		
General		Meter 1 - MM upstream		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[°C]	[°C]	[bar(g)][Pa^5(g)]	[bar(g)][Pa^5(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
5.01	14:05	50.4	80.282	80.243	21.60	21.80	4.22	1.95					50.40	80.2984	1.594	797.64	-0.020	-0.069
5.02	14:13	50.4	79.673	79.631	21.50	21.70	4.22	1.95					50.40	79.6827	1.597	797.72	-0.012	-0.065
5.03	14:22	50.5	80.503	80.458	21.50	21.60	4.22	1.95					50.50	80.5125	1.597	797.72	-0.012	-0.068
5.04	14:30	50.5	80.040	79.986	21.50	21.60	4.22	1.95					50.50	80.0475	1.597	797.72	-0.009	-0.077
5.05	14:37	50.3	79.769	79.723	21.40	21.50	4.22	1.95					50.30	79.7803	1.599	797.79	-0.014	-0.072
reversed order of the transfer standards																		
5.01	12:46	50.2	79.990	79.938	22.40	22.50	4.22	1.98					50.20	79.9899	1.573	797.05	0.000	-0.065
5.02	12:53	50.1	80.088	80.030	22.30	22.40	4.22	1.98					50.10	80.0992	1.575	797.12	-0.014	-0.087
5.03	13:00	50.2	79.529	79.476	22.20	22.30	4.22	1.98					50.20	79.5375	1.578	797.20	-0.011	-0.077
5.04	13:06	50.3	79.873	79.829	22.20	22.30	4.22	1.98					50.30	79.8859	1.578	797.20	-0.016	-0.071
5.05	13:13	50.5	79.515	79.468	22.20	22.30	4.22	1.98					50.50	79.5246	1.578	797.20	-0.012	-0.071

MC

30 kg/min

General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
6.01		30.0	121.0727	121.0320	20.08	20.16	2.77	2.09	20.04	20.13	NA	NA	30.00	121.0420	998.4141	0.0254	-0.0082
6.02		30.0	121.1819	121.1403	20.07	20.11	2.76	2.09	20.06	20.12	NA	NA	30.00	121.1513	998.4098	0.0253	-0.0091
6.03		30.0	121.1719	121.1306	20.11	20.17	2.77	2.09	20.10	20.16	NA	NA	30.00	121.1418	998.4022	0.0249	-0.0092
6.04		30.0	121.2108	121.1721	20.14	20.19	2.77	2.09	20.15	20.20	NA	NA	30.00	121.1835	998.3923	0.0225	-0.0086
6.05		30.0	121.1064	121.0659	20.20	20.24	2.77	2.09	20.19	20.24	NA	NA	30.00	121.0767	998.3843	0.0245	-0.0089

MC

40 kg/min

General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
3.01		40.0	121.4988	121.4698	20.09	20.18	2.76	1.61	19.96	20.11	NA	NA	40.00	121.4697	998.4239	0.0239	0.0001
3.02		40.0	121.3561	121.3281	19.96	20.03	2.75	1.61	19.93	20.00	NA	NA	40.00	121.3277	998.4295	0.0234	0.0003
3.03		40.0	121.4891	121.4603	19.98	20.04	2.76	1.61	19.97	20.03	NA	NA	40.00	121.4604	998.4220	0.0237	-0.0001
3.04		40.0	121.5802	121.5537	20.01	20.08	2.76	1.61	20.01	20.06	NA	NA	40.00	121.5548	998.4141	0.0209	-0.0009
3.05		40.0	121.5909	121.5623	20.06	20.12	2.76	1.60	20.04	20.09	NA	NA	40.00	121.5660	998.4080	0.0205	-0.0030
3.06		40.0	121.4253	121.4003	20.14	20.15	2.74	1.59	20.08	20.13	NA	NA	40.00	121.4019	998.3992	0.0193	-0.0013
3.07		40.0	121.4126	121.3823	20.12	20.14	2.75	1.61	20.10	20.15	NA	NA	40.00	121.3826	998.3959	0.0247	-0.0002
3.08		40.0	121.4900	121.4629	20.14	20.18	2.76	1.61	20.13	20.18	NA	NA	40.00	121.4637	998.3903	0.0217	-0.0006
3.09		40.0	121.5308	121.5001	20.20	20.23	2.74	1.60	20.17	20.22	NA	NA	40.00	121.5054	998.3815	0.0209	-0.0044
3.10		40.0	121.3930	121.3675	20.20	20.26	2.75	1.60	20.20	20.24	NA	NA	40.00	121.3681	998.3758	0.0205	-0.0005

MC

50 kg/min

General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values			Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[kg/m^3]	[%]	[%]
5.01		50.0	101.6381	101.6221	20.15	20.21	2.73	1.02	20.11	20.17	NA	NA	50.00	101.6152	998.3863	0.0225	0.0068
5.02		50.0	101.6624	101.6453	20.17	20.22	2.73	1.02	20.14	20.21	NA	NA	50.00	101.6392	998.3803	0.0228	0.0060
5.03		50.0	101.6541	101.6341	20.34	20.40	2.73	1.02	20.29	20.36	NA	NA	50.00	101.6379	998.3503	0.0159	-0.0038
5.04		50.0	101.9207	101.8967	20.21	20.37	2.73	1.02	20.28	20.34	NA	NA	50.00	101.8978	998.3523	0.0225	-0.0011
5.05		50.0	101.7660	101.7467	20.31	20.38	2.73	1.02	20.29	20.35	NA	NA	50.00	101.7508	998.3503	0.0150	-0.0040

MC

30 kg/min																			
General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
6.01		30.0	121.1883	121.0907	21.72	21.71	2.72	1.79	21.81	21.76	NA	NA	30.0	121.1714	2.63	815.3572	0.0140	-0.0666
6.02		30.0	121.1874	121.0916	21.81	21.82	2.72	1.79	21.91	21.85	NA	NA	30.0	121.1706	2.63	815.2851	0.0139	-0.0652
6.03		30.0	121.2913	121.1926	21.76	21.80	2.72	1.79	21.72	21.74	NA	NA	30.0	121.2732	2.63	815.4220	0.0149	-0.0665
6.04		30.0	121.2531	121.1629	21.20	21.35	2.72	1.79	21.01	21.12	NA	NA	30.0	121.2330	2.68	815.9338	0.0165	-0.0579
6.05		30.0	121.3185	121.2289	20.92	21.00	2.72	1.79	20.93	20.97	NA	NA	30.0	121.3034	2.68	815.9915	0.0124	-0.0614

MC

40 kg/min																			
General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
3.01		40.0	121.5301	121.4284	21.61	21.74	2.70	1.12	21.44	21.66	NA	NA	40.0	121.4882	2.65	815.6115	0.0345	-0.0492
3.02		40.0	121.4642	121.3601	20.98	21.16	2.70	1.12	20.92	20.85	NA	NA	40.0	121.4203	2.68	815.9864	0.0362	-0.0496
3.03		40.0	121.6641	121.5480	20.92	20.96	2.69	1.12	21.14	21.11	NA	NA	40.0	121.6271	2.68	815.8273	0.0304	-0.0651
3.04		40.0	121.6467	121.5252	21.44	21.49	2.70	1.12	21.59	21.57	NA	NA	40.0	121.6062	2.65	815.5034	0.0333	-0.0666
3.05		40.0	121.5196	121.4115	21.50	21.55	2.70	1.13	21.29	21.49	NA	NA	40.0	121.4797	2.65	815.7198	0.0329	-0.0561
3.06		40.0	121.4419	121.3407	20.91	21.09	2.70	1.12	20.98	20.90	NA	NA	40.0	121.4031	2.68	815.9359	0.0320	-0.0514
3.07		40.0	121.4941	121.3778	21.05	21.08	2.70	1.12	21.33	21.29	NA	NA	40.0	121.4579	2.65	815.6908	0.0298	-0.0660
3.08		40.0	121.5619	121.4597	21.10	21.28	2.70	1.12	21.36	20.97	NA	NA	40.0	121.5208	2.65	815.9287	0.0338	-0.0503
3.09		40.0	121.4792	121.3694	20.79	20.86	2.70	1.13	20.99	20.97	NA	NA	40.0	121.4456	2.68	815.9361	0.0277	-0.0627
3.10		40.0	121.6665	121.5571	21.17	21.27	2.70	1.12	21.12	21.20	NA	NA	40.0	121.6254	2.68	815.8422	0.0337	-0.0562

MC

50 kg/min																			
General		Meter 1 - MM		Meter 2 - Kr.	IKS-SKID temperatures and pressures				Facility temperatures and pressures				Calculated values				Meter 1 MM	Meter 2 Kr
Test no.	Start time	Flow rate	Mass total	Mass total	T Upstream	T Downstream	P Upstream	P Downstream	T Upstream	T Downstream	P Upstream	P Downstream	Ref. flow rate	Reference mass	Viscosity Upstream	Density Upstream	Error mass	Error mass
[--]	[u:mm]	[kg/min]	[kg]	[kg]	[°C]	[°C]	[bar(g)]	[bar(g)]	[°C]	[°C]	[bar(g)]	[bar(g)]	[kg/min]	[kg]	[mm^2/s]	[kg/m^3]	[%]	[%]
5.01		50.0	201.9230	201.7723	21.40	21.48	2.68	0.30	21.44	21.50	NA	NA	50.0	201.8952	2.65	815.5966	0.0137	-0.0609
5.02		50.0	201.9087	201.7752	20.92	21.14	2.68	0.30	20.96	20.85	NA	NA	50.0	201.8663	2.68	815.9427	0.0210	-0.0451
5.03		50.0	201.8646	201.7034	20.64	20.73	2.68	0.30	20.78	20.83	NA	NA	50.0	201.8210	2.68	816.0725	0.0216	-0.0583
5.04		50.0	201.9805	201.8266	21.21	21.30	2.68	0.31	21.35	21.39	NA	NA	50.0	201.9420	2.65	815.6617	0.0191	-0.0571
5.05		50.0	202.0081	201.8756	20.96	21.17	2.67	0.30	20.94	20.91	NA	NA	50.0	201.9640	2.68	815.9566	0.0218	-0.0438