REPORT TO THE EURAMET TC-F

EURAMET project 1325 (KCDB identifier EURAMET.M.FF-S10): Comparison for gas flow range 5 ml/min to 30 l/min

FINAL REPORT

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1. Introduction

At the EURAMET TC-F meeting at VSL in Delft on 12th to 14th of March 2013 it was proposed by MIKES to initiate an inter-comparison for low gas flows in the range 5 ml/min to 30 l/min. The comparison was motivated by the fact that the last wider comparison in the low flow range was performed in years 2005 to 2007, almost ten years ago. Based on discussions during and after the meeting, it was decided to initiate such a comparison. Twelve participants expressed their interest in participating and MIKES volunteered to coordinate the comparison and act as a pilot. The comparison is registered as EURAMET project number 1325 and as supplementary comparison EURAMET.M.FF-S10 in the BIPM database.

The aim of the project is to compare measurement capabilities of the participating laboratories in the gas flow range 5 ml/min to 30 l/min. Due to the high amount of participants the comparison was carried out in two parallel loops, with one circulating transfer standard in each loop. In order to link the results between the loops, PTB and INRIM performed measurement in both loops. The stability of the transfer standards was investigated at the end of the comparison by PTB and INRIM.

Mesa Laboratories Inc. loaned two sets of piston provers to be used as transfer standards in the comparison. The instruments were delivered to the pilot laboratory in August 2014. Based on initial tests on the transfer standards, the technical protocol (draft issued in June 2014) was revised. After this only minor revisions, which were mainly related to the comparison schedule and participants were made.

In an early phase of the comparison, instrument failure was observed, and as a result the comparison was terminated. The transfer standards were sent back to Mesa Labs for repair. After receiving the transfer standards back, the comparison was restarted in May 2015. This time, the comparison was successfully completed as planned. A detailed timeline of the comparison is given below (table 1).

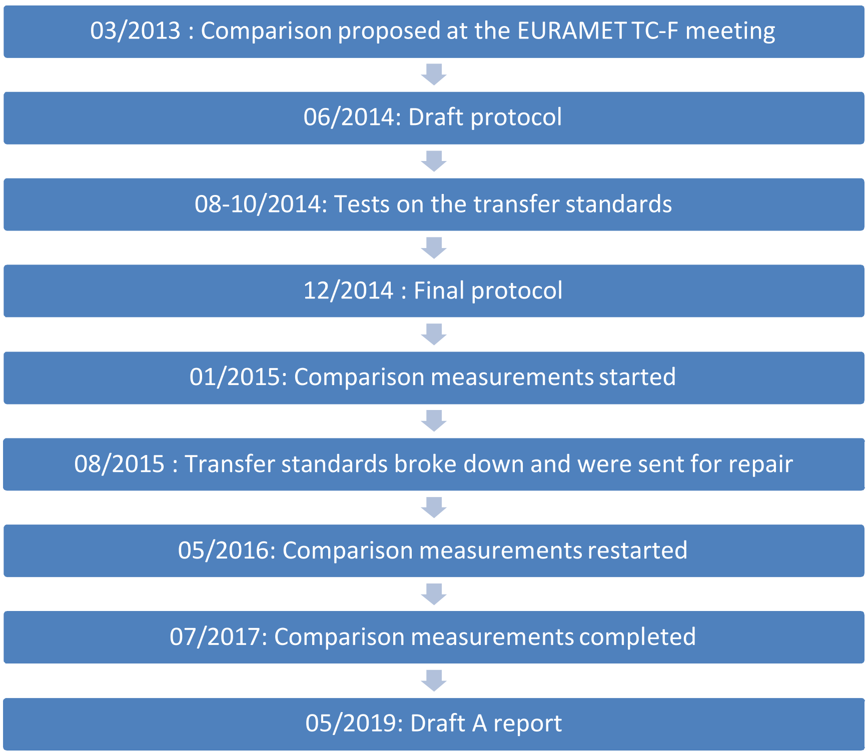

Figure 1. Timeline of the EURAMET1325 comparison.

2. Organization

2.1 Comparison scheme and participants

The comparison was carried out in two parallel loops (figure 2), such that one transfer standard circulated in each loop. Before the actual comparison measurements, MIKES conducted performance tests on the transfer standards. The aim of these tests was to find out the optimal measurement procedure, in which the influence of the transfer standard itself is as small as possible. In order to establish a link between the loops, INRIM and PTB performed measurements on both transfer standards. After the actual comparison measurements, INRIM and PTB performed additional measurements on the transfer standards of loops 1 and 2, respectively, in order to assess the long-term stability of the standards.

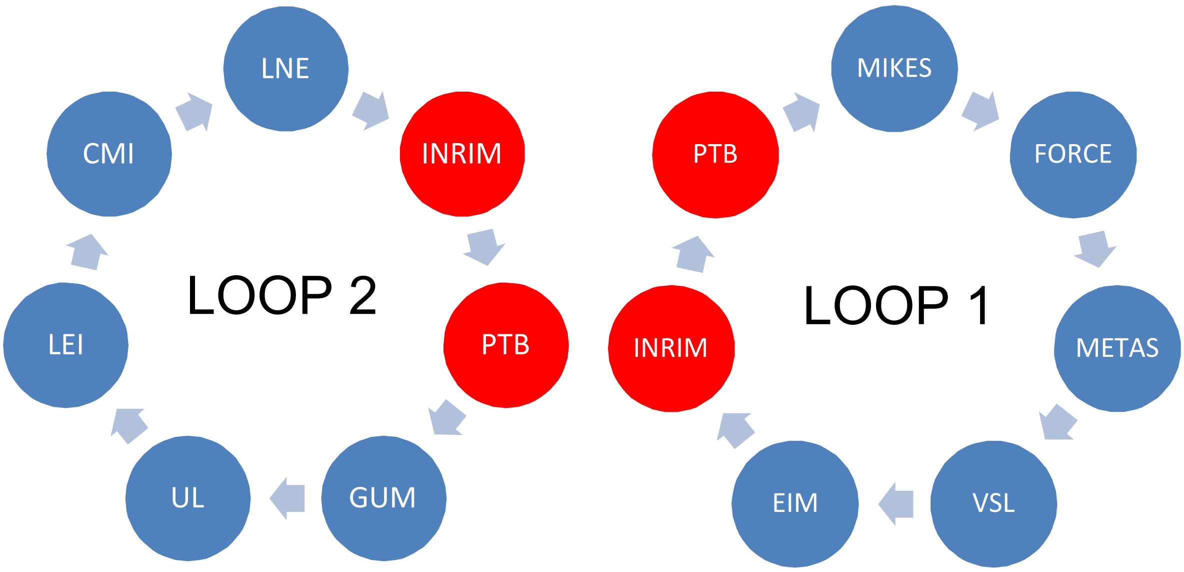

Figure 2. Scheme of the comparison. INRIM and PTB (in red) acted as linking laboratories.

A list of participating laboratories is presented in table 1. Detailed information of laboratories is given in Appendix 1. After the EURAMET project was registered, one participant decided not to participate and one new partner (UL) joined the comparison. The Norwegian Metrology Service (Justervesenet) withdrew themselves from the comparison because they do not provide calibration services in the range applicable to the comparison anymore.

Table 1. List of participants.

Participating laboratory		Country
MIKES	Centre for Metrology MIKES	Finland
CMI	Czech Metrology Institute	Czech Republic
UL	University of Ljubljana	Slovenia
PTB	Physikalisch-Technische Bundesanstalt	Germany
FORCE	FORCE Technology	Denmark
INRIM	Istituto Nazionale di Ricerca Metrologica	Italy
METAS	Federal Institute of Metrology METAS	Switzerland
VSL	VSL Dutch Metrology Institute	Netherlands
LNE	Laboratoire national de métrologie et d'essais	France
LEI	Lithuanian Energy Institute	Lithuania
EIM	Hellenic Institute of Metrology	Greece
GUM	Central Office of Measures / Glówny Urzad Miar	Poland

2.2 Comparison schedule

In the very beginning of the comparison, failure of both transfer standards was observed. Most probably, the transfer standards were damaged during transportation. The small flow cell of the transfer standard of loop 2 exhibited uneven movement of the piston and occasionally piston sticking. Clearly visible cracks were found on the flow cells glass tubes, indicating that the flow cells had experienced an impact. The pressure sensor of the other transfer standard was damaged during transportation and as a result, no pressure readings nor flow readings were displayed. Both transfer standards were returned to Mesa Labs for inspection and repair.

As a result of the extensive instrument failure, it was decided to start over the comparison. This was agreed with all the participants. In order to avoid similar problems from recurring, the packaging of the transfer standards was improved. A new timetable was drawn up and the protocol was updated accordingly. Table 4 in the Protocol (see Appendix 2) show the provisional timetables for both loops.

For each laboratory, four weeks was allowed for measurements and shipping to the next laboratory. The timetable was modified several times due to a number of delays and changes in the order of the participants in the loops. All changes were made in agreement with the participants. The delays were mainly caused by non-technical reasons, such as delays in customs clearance, other delays in transportation, summer and Christmas holidays, and other personal absences.

After completing the comparison measurements, stability measurements were carried out by INRIM and PTB to investigate the long-term stability and reproducibility of the transfer standards.

Table 2. Actual dates of measurements at the laboratories

Loop 1 Laboratory	**Date**	**Loop 2 Laboratory**	**Date**
INRIM1	05/2016	INRIM	05/2016
PTB	06/2016 - 07/2016	PTB1	06/2016 - 07/2016
MIKES	09/2016	GUM	10/2016, results withdrawn
FORCE	10/2016	UL	11/2016
METAS	01/2017	LEI	No results reported
VSL	02/2017 - 03/2017	CMI	01/2017
EIM	05/2017	LNE	02/2017 - 03/2017
INRIM2	06/2017	PTB2	05/2017 - 07/2017

3. Transfer standards

3.1 Description of the transfer standards

The transfer standards used in the comparison are commercially available Mesa Labs DryCal 800 equipped with three measuring cells covering the whole gas flow range of the comparison. The transfer standards serial numbers are shown in table 3. After the failure of the transfer standards, both bases were changed to the newest model (figure 3). The same flow cells were used throughout the project, only repair and verification at Mesa Labs was performed after instrument failure. After these service and repair measures, the stability of the instrument response cannot be guaranteed, and thus the comparison was decided to start over and the previously measured results were discarded.

Table 3. Transfer standards used for comparison measurements

LOOP 1 instrument			
Model	Unit	Serial number	Flow range
ML-800-B	Base	147457	
ML-800-10	Measurement cell	135207	5-500 ml/min
ML-800-24	Measurement cell	134909	50-5,000 ml/min
ML-800-44	Measurement cell	135198	500-50,000 ml/min
LOOP 2 instrument			
Model	Unit	Serial number	
ML-800-B	Base	147461	
ML-800-10	Measurement cell	135208	5-500 ml/min
ML-800-24	Measurement cell	134910	50-5,000 ml/min
ML-800-44	Measurement cell	135199	500-50,000 ml/min

Figure 3. Mesa Labs DryCal 800 system including base and flow cell. A set of three flow cells were used to cover the flow range of the comparison.

3.2 Operating principle

The operation of the transfer standards is based on the positive displacement principle, in which the volumetric flow is determined by measuring the time it takes for the gas flow to “displace” a graphite piston through a glass cylinder with known dimensions. By means of internal temperature and pressure measurements, actual flow readings are converted to standardized flow readings (0 °C and 101325 Pa). There is a small clearance between the piston and the cylinder to allow frictionless motion of the piston. This causes a small internal leak, which is corrected by the transfer standard. The leak rate depends on the viscosity of the calibration gas and therefore participants were advised to use nitrogen (at least grade 5.0 and 99.999% purity) in order to minimize uncertainties caused by the gas composition. All participants used nitrogen (at least grade 5.0 purity) as the calibration gas as advised.

3.3 Handling

Special care was taken in packaging and handling the transfer standards in order to avoid damage and/or contamination. The transfer standards were packed in custom-made tough pelican cases to ensure safe transportation. The packaging was further improved after the instrument failure, by including additional bubble wrap around the delicate flow cells. In this way a tighter fit of the flow cells inside the case was achieved to prevent movement of the parts during transport.

Additional guidelines on handling and operation of the instruments were provided to all participants. Special care needs to be taken to avoid particulate contamination from entering the flow cells. Any micrometer size particle will build up on the walls of the flow tube. The clearance between the piston and the cylinder is only a few micrometer, and thus even a small amount of particulate debris will influence the leakage between the piston and the cylinder. This will in turn have an influence on the response, i.e. stability, of the instrument and may eventually cause piston sticking. To minimize this effect, participants were advised to use a 5 micron filter at the inlet of the transfer standard.

4. Comparison method

4.1 Scope of the comparison

The purpose of the comparison was to compare the volumetric gas flow measurements of the participating laboratories in the range from 5 ml/min to 30 l/min. The transfer standard is able to measure both actual volumetric flow and standard flow. In this comparison, calibrations were performed in terms of standard readings at 0 °C and 101325 Pa. The instruments were pre-set to display standard readings at the aforementioned conditions.

4.2 Calibration points

The calibration flow rates and the associated flow cells are shown in table 4. The flow rates for each flow cell were chosen based on results of the initial performance tests at MIKES. In the overlapping flow range, the flow cell with the best performance in terms of reproducibility and repeatability was selected. In addition, measurement were performed with both flow cells at one calibration point in the overlapping range in order to check the consistency of the measurements results.

Participants were only presumed to measure at points included in their CMCs. However, measurements at other points was strongly encouraged to support future CMC entries. The participating laboratories were asked to match the flow reading indicated by the transfer standard as close as possible (at least within ±3 %) to the nominal flow in table 4 to allow good comparability between participants results. This is especially important for the low flow cell (-10), which experienced a non-linear response in the low end of the flow range.

Table 4. Calibration points and corresponding transfer standard flow cells.

Nominal flow rate (ml/min)	Transfer standard flow cell
5	ML-800-10
10	ML-800-10
20	ML-800-10
80	ML-800-10, ML-800-24
300	ML-800-24
600	ML-800-24
1250	ML-800-24, ML-800-44
5000	ML-800-44
10000	ML-800-44
20000	ML-800-44
30000	ML-800-44

4.3 Calibration procedure

The transfer standard was allowed to stabilize to laboratory conditions for at least 24 hours before starting measurements. After this, pressure and temperature readings of the transfer standard were compared against a participant’s calibrated laboratory reference. This allowed to check for damage or drift of the sensors.

Before starting actual comparison measurements, it is necessary to allow the flow cell temperature to stabilize by passing gas flow through the flow cell and continuously launching the piston for 180 min. Performance tests of the transfer standards showed that an initial “heating” is necessary for achieving consistent and comparable results, especially in the lower flow range of the measurement cells. When changing the flow rate, three minutes of continuous operation is sufficient for reaching a stable temperature.

At each nominal calibration point, four separate calibration measurements were performed. For a single calibration measurement, the flow rate of the transfer standard was obtained as the mean of at least ten (10) readings. As supporting measurements, temperature and pressure readings of the transfer standard were recorded for each measurement. Details of the recorded data can be seen from the results reported by the participants (Appendix 3).

5. Stability of the transfer standards

Measurements performed after the comparison (INRIM2 and PTB2) indicate that the response of the low flow cells (ML-800-10) have changed during the comparison (figures 4 and 5). The response of both flow cells have shifted about -0.02 ml/min (tables 5 and 6). The most obvious explanation would be a leakage in the instrument. However, according to the manufacturer, this rarely happens and no evidence of leakage was found when inspecting the instruments after the comparison. A possible reason for the shift is contamination, i.e. build up of particulate debris on the inner wall of the flow cell. Any contamination will affect the flow around the piston during measurements, and thus influence the response of the instrument. Also piston wear would have an influence on the leakage flow around the piston, but this is not likely considering the limited amount of measurements. According to the manufacturer, a typical value for the bypass flow, i.e. the piston tare value (PTV), is 0.1 ml/min, 0.2 ml/min and 1.4 ml/min for the low (ML-800-10), medium (ML-800-24) and high flow cell (ML-800-44), respectively. Thus, the low flow cell is most sensitive to contamination and even a small change in the PTV will affect the response.

A shift in the response was also observed for the medium flow cell of loop 1 (figure 4). Similar to the low flow cell, the relative change is larger in the lower end of the measurement range. In this case, however, the shift in the response is not constant and it is much larger than the typical PTV. The temperature and pressure sensors of the transfer standard were found stable during the comparison. Thus, the reasons for the observed instability remain unclear. The rest of the flow cells indicated a good stability, i.e. the change in the response was typically less than 0.05%, and thus much smaller than the measurement uncertainty (k=2) of about 0.2 %.

Although a shift was observed for some of the flow cells, no corrections to the participants' results were made. Instead, the change in the response was considered as an additional uncertainty when evaluating results (see section 6 for calculations). It was not possible to reliably determine a correction for the shift, because the stability measurements were only performed at the end of the comparison, and thus the trend of the response could not be determined. Also, based on the participants' results (e.g. figure 6 and 7) the trend cannot be reliably deduced.

Assuming that the shift in the response of the low flow cells is caused by contamination, it will depend on the measurement times (vary among participants) and the cleanliness of the calibration gas (filtration and gas purity vary among participants). Condensation of humid air inside the cell, caused by temperature variations during transportation, is also a possible source of contamination. In any case, a linear trend cannot be assumed. However, apart from flow rates below 20 ml/min, the uncertainties of stability (tables 5 and 6) are in most cases much smaller than the uncertainties reported by the participants.

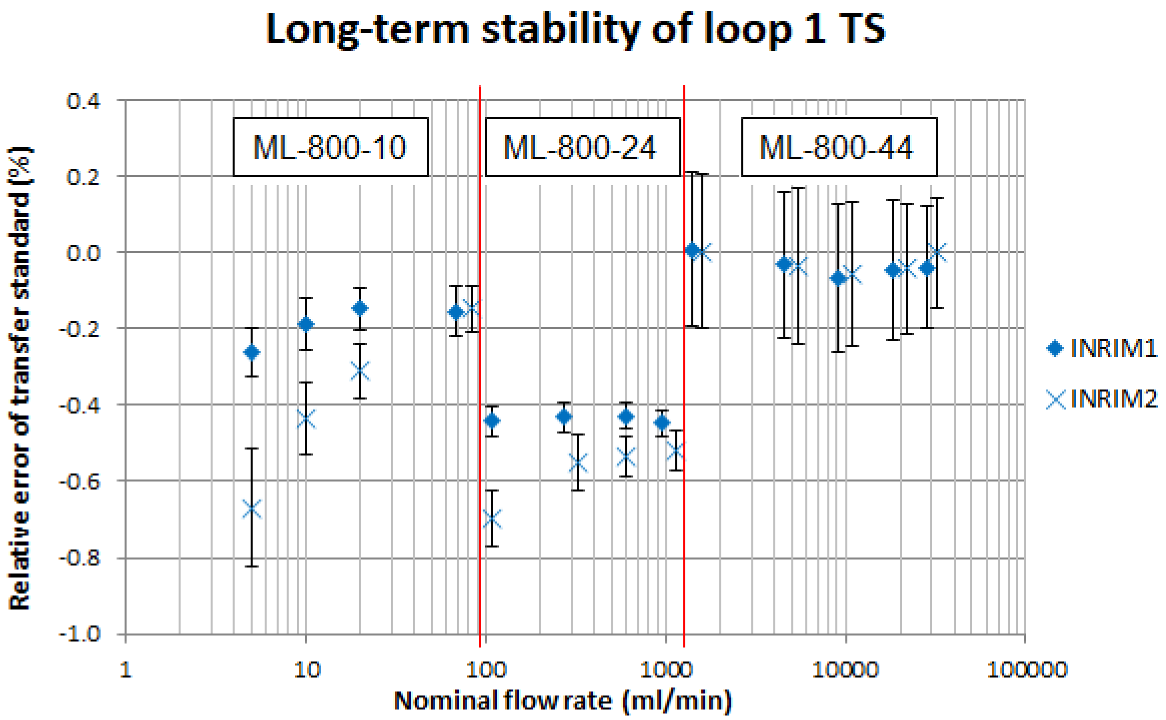

Figure 4. Measurements of loop 1 transfer standard (TS) relative error in the beginning (INRIM1) and at the end (INRIM2) of the comparison. Measurement uncertainties (k=2) are shown as error bars. Note that at some points, the flow rates are shifted for clarity.

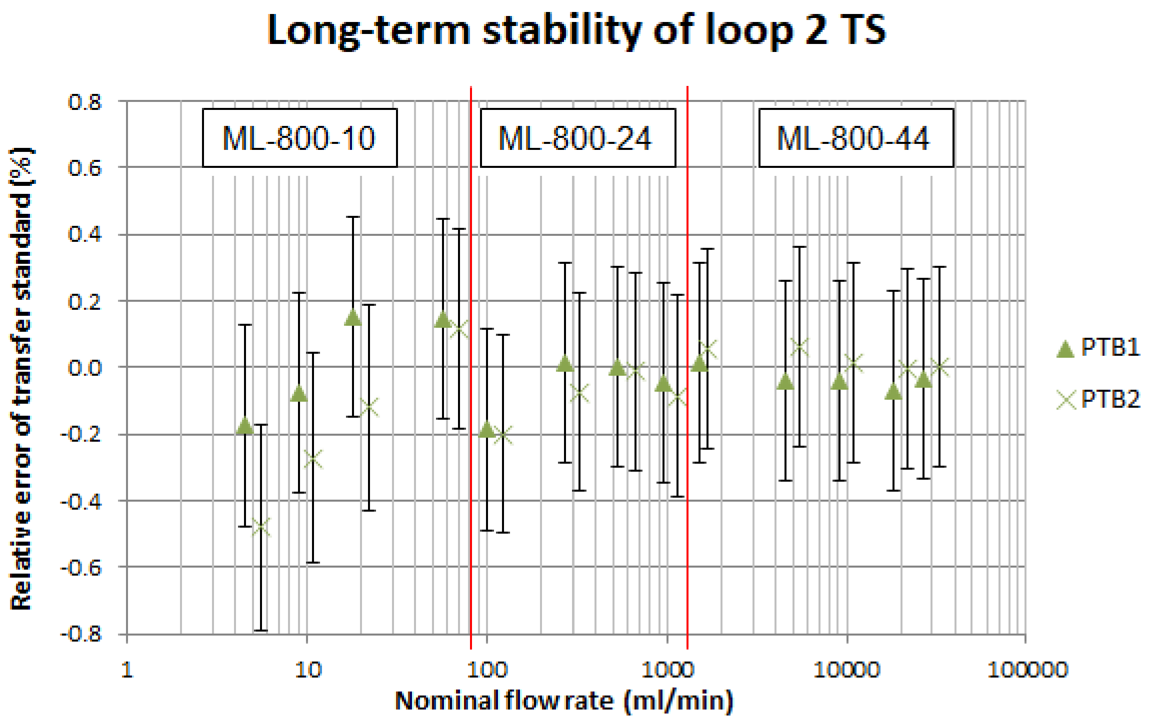

Figure 5. Measurements of loop 2 transfer standard (TS) relative error in the beginning (PTB1) and at the end (PTB2) of the comparison. Measurement uncertainties (k=2) are shown as error bars. Note that at some points, the flow rates are shifted for clarity.

Table 5. Stability and associated uncertainty of loop 1 transfer standard.

Nominal Flow Rate (std ml/min)	Transfer standard error (INRIM1) (%)	Transfer standard error (INRIM2) (%)	INRIM2 - INRIM1 (%)	INRIM2 - INRIM1 (ml/min)	Uncertainty due to stability (%)	Uncertainty due to stability (ml/min)
Flow cell:	*-10 (S/N: 135207)*					
5	-0.26	-0.67	-0.41	-0.02	0.24	0.01
10	-0.19	-0.44	-0.25	-0.02	0.14	0.01
20	-0.15	-0.31	-0.16	-0.03	0.09	0.02
80	-0.15	-0.15	0.01	0.01	0.004	0.003
Flow cell:	*-24 (S/N: 134909)*					
80	-0.44	-0.70	-0.26	-0.20	0.15	0.12
300	-0.43	-0.55	-0.12	-0.37	0.07	0.21
600	-0.43	-0.53	-0.10	-0.65	0.06	0.36
1250	-0.45	-0.52	-0.07	-0.92	0.04	0.51
Flow cell:	*-44 (S/N: 135198)*					
1250	0.01	0.00	0.00	-0.06	0.003	0.03
5000	-0.03	-0.04	0.00	-0.23	0.003	0.13
10000	-0.07	-0.06	0.01	1.26	0.007	0.73
20000	-0.05	-0.04	0.00	0.78	0.002	0.45
30000	-0.04	0.00	0.04	11.3	0.022	6.51

Table 6. Stability and associated uncertainty for of loop 2 transfer standard.

Nominal Flow Rate (std ml/min)	Transfer standard error (PTB1) (%)	Transfer standard error (PTB2) (%)	PTB2 - PTB1 (%)	PTB2 - PTB1 (ml/min)	Uncertainty due to stability (%)	Uncertainty due to stability (ml/min)
Flow cell:	*-10 (S/N: 135208)*					
5	-0.17	-0.48	-0.30	-0.02	0.18	0.01
10	-0.08	-0.27	-0.19	-0.02	0.11	0.01
20	0.15	-0.12	-0.27	-0.05	0.16	0.03
80	0.15	0.11	-0.03	-0.03	0.02	0.01
Flow cell:	*-24 (S/N: 134910)*					
80	-0.19	-0.20	-0.01	-0.01	0.01	0.01
300	0.01	-0.08	-0.09	-0.27	0.05	0.15
600	0.00	-0.01	-0.02	-0.10	0.01	0.06
1250	-0.05	-0.09	-0.04	-0.51	0.02	0.29
Flow cell:	*-44 (S/N: 135199)*					
1250	0.01	0.05	0.04	0.51	0.02	0.29
5000	-0.04	0.06	0.10	5.00	0.06	2.89
10000	-0.04	0.01	0.05	5.26	0.03	3.04
20000	-0.07	0.00	0.06	12.7	0.04	7.32
30000	-0.04	0.00	0.04	10.6	0.02	6.13

6. Measurement results

6.1 Summary of the results

Measurement results reported by the participants are given in Appendix 3. For each measurement, the laboratories calculated the relative error (*E*) of the transfer standard as:

$$E_i = \frac{\dot{V}_{ts,i} - \dot{V}_{ref,i}}{\dot{V}_{ref,i}} \times 100\%, \quad (1)$$

where $\dot{V}_{ts}$ and $\dot{V}_{ref}$ is the volumetric flow of the transfer standard and the laboratory flow standard, respectively. The result at each flow rate was calculated as the mean of four repeated measurements:

$$E_i = \frac{1}{4}\left(\sum_{j=1}^{4} E_j\right) + \delta_{stab,\,loop(i)}, \quad (2)$$

where $\delta_{stab,loop(i)}$ is the error due to the instability of the transfer standard.

The standard uncertainty of the error was calculated as follows:

$$u^2(E_i) = u^2(\dot{V}_{ref,i}) + u^2(\dot{V}_{ts,i}) + u^2(\delta_{stab,\,loop(i)}). \quad (3)$$

The uncertainty of the reference $u(\dot{V}_{ref,i})$ was calculated as the average uncertainty of the four repeated measurements. The uncertainty of the transfer standard $u(\dot{V}_{ts,i})$ was calculated from the spread of the error readings:

$$u(\dot{V}_{ts,i}) = \frac{1}{2\sqrt{3}}\left[max(E_j) - min(E_j)\right]. \quad (4)$$

The stability of the transfer standards was calculated as:

$$u(\delta_{stab,\,loop(i)}) = \frac{1}{\sqrt{3}}\left|E_{loop(i),2} - E_{loop(i),1}\right|, \quad (5)$$

where $E_{loop(i),1}$ and $E_{loop(i),2}$ is the transfer standard error measured at the beginning and at the end of the comparison, respectively.

The stability of the transfer standards was included in the uncertainty of the results for all laboratories as the full-width of the change in the response assuming a uniform distribution, i.e. type B uncertainty. This approach is justified due to the limited understanding of the reasons for the instability. Although the response of some of the flow cells appeared to have permanently shifted, a definite conclusion on the reasons for the change and the behaviour of the shift (linear or step-like) cannot be made based on the participants' results and the limited amount of stability data. In addition, initial tests on the transfer standards indicated that the reproducibility is inferior in the lower end of the measurement range, i.e. in the same range where a shift was noticed. Thus, the uncertainty derived from the stability measurements includes contributions from both long-term stability and short-term stability (reproducibility).

The results obtained with equations (2) to (5) are shown in figure 6 to 11. Error bars show the expanded uncertainty of the results. The expanded uncertainty was obtained by multiplying the standard uncertainty (equation 3) with 2. A summary of the results can be found in appendix 3. Note that the results are shifted in sake of clarity of presentation.

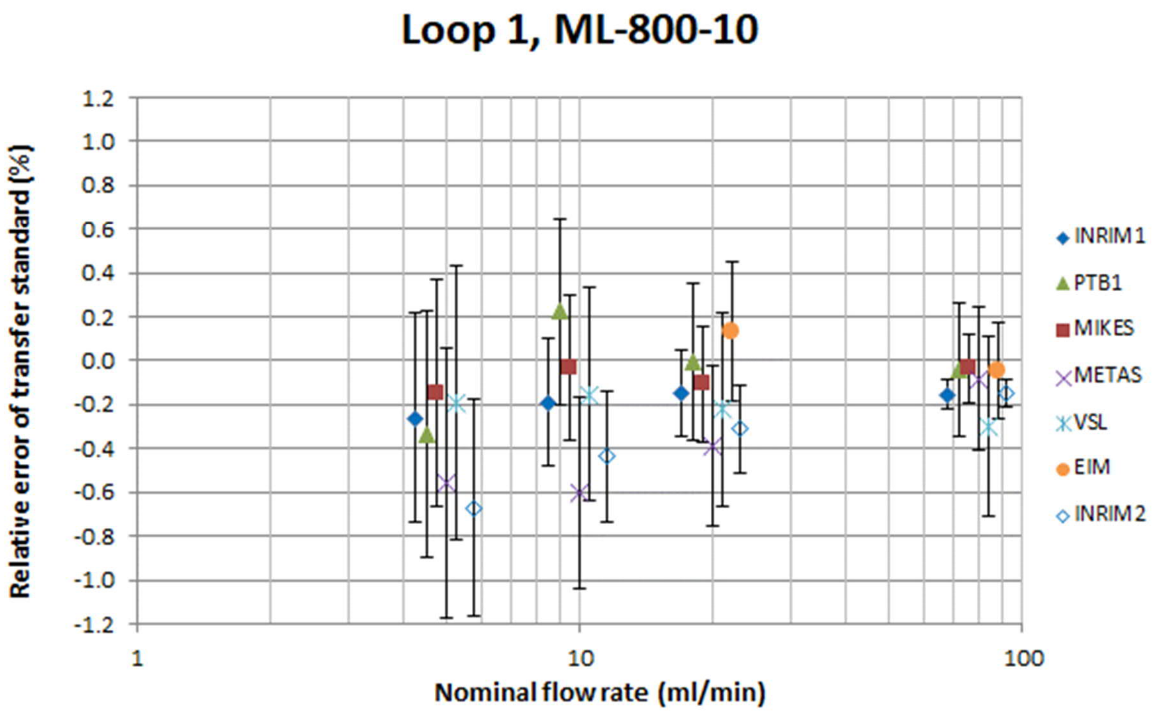

Figure 6. Measurements results of the participating laboratories in loop 1 for the low flow cell ML-800-10. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

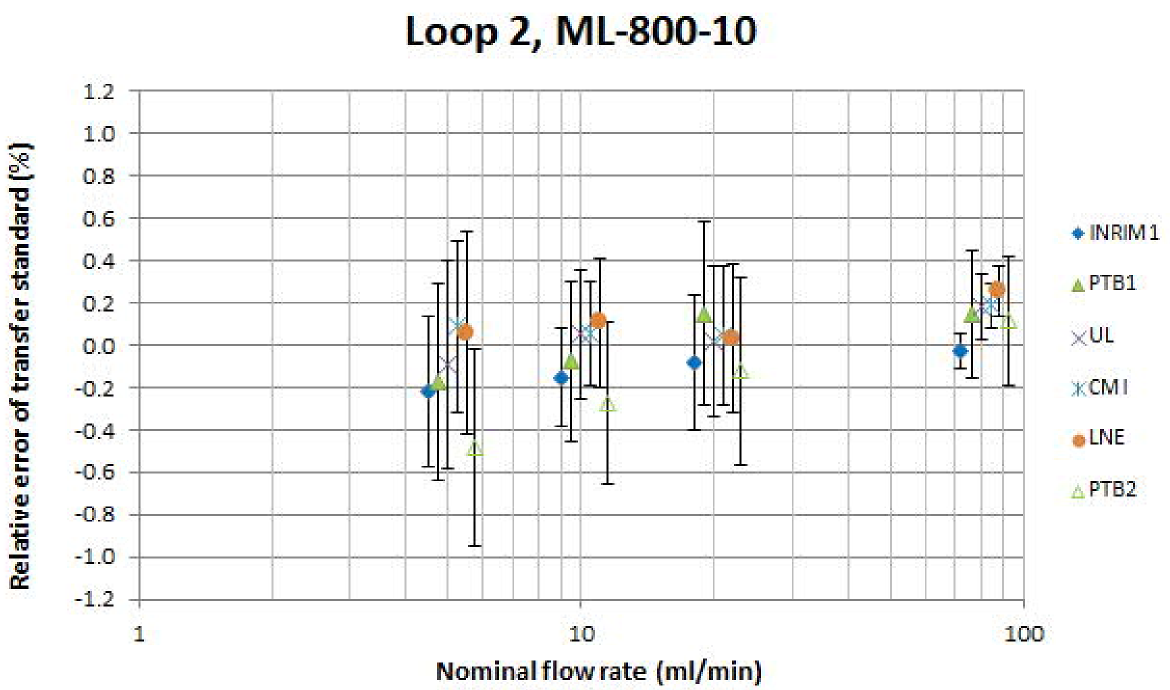

Figure 7. Measurements results of the participating laboratories in loop 2 for the low flow cell ML-800-10. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

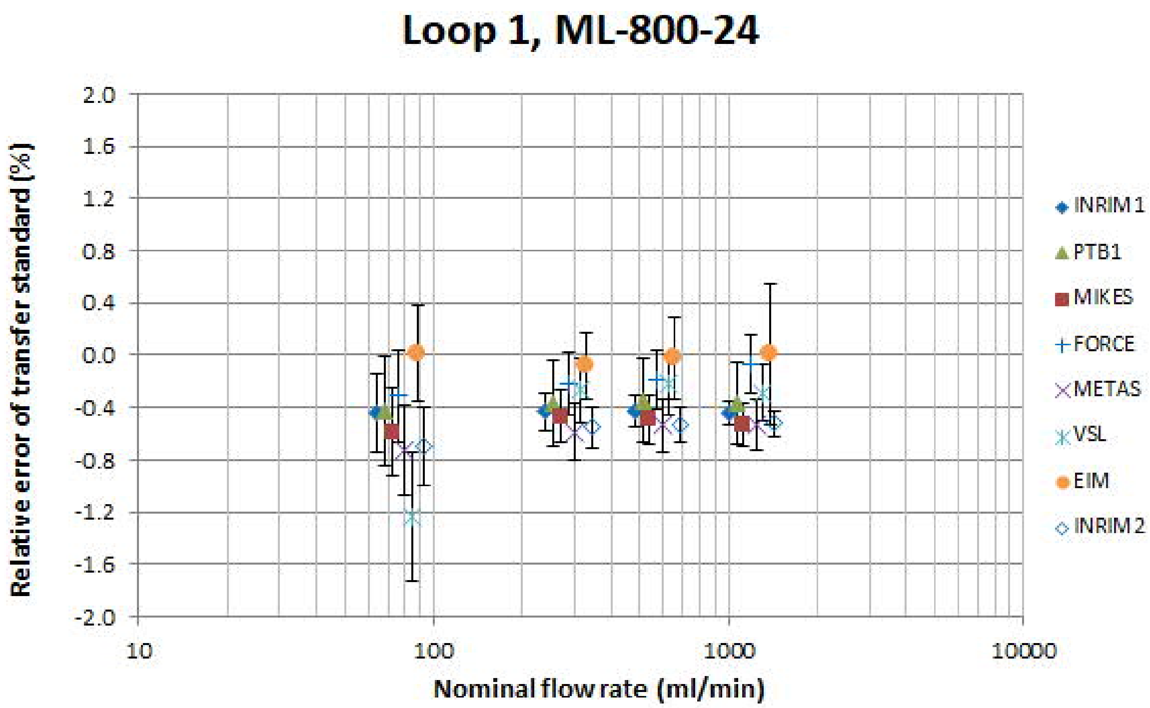

Figure 8. Measurements results of the participating laboratories in loop 1 for the medium flow cell ML-800-24. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

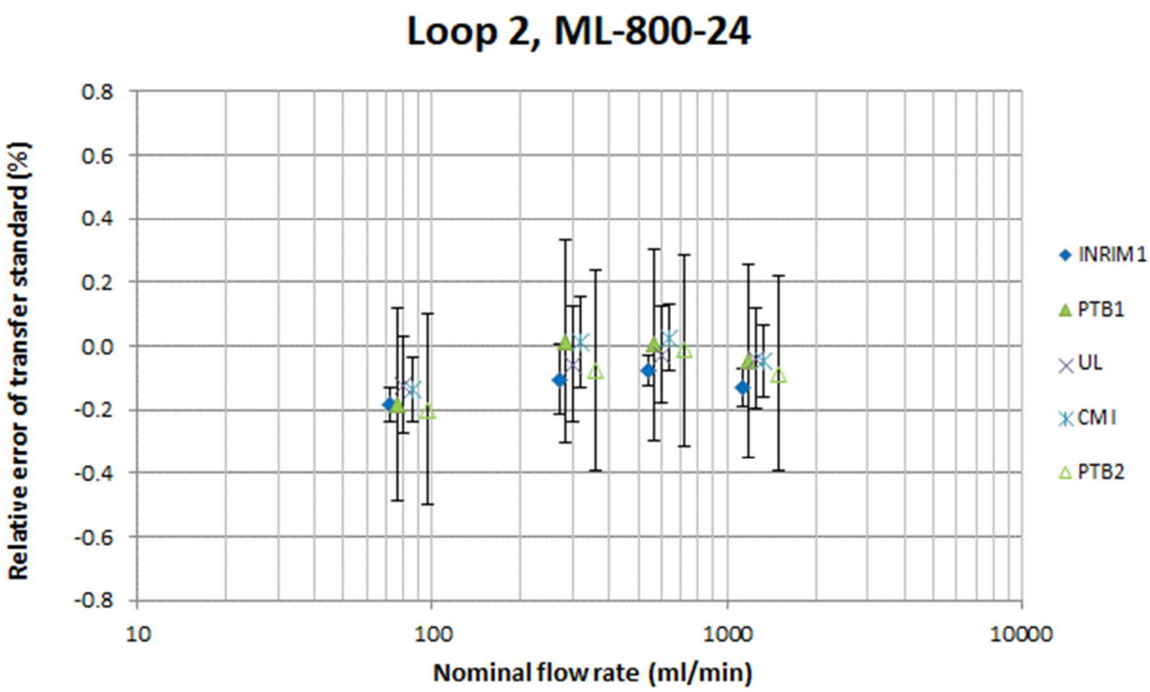

Figure 9. Measurements results of the participating laboratories in loop 2 for the medium flow cell ML-800-24. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

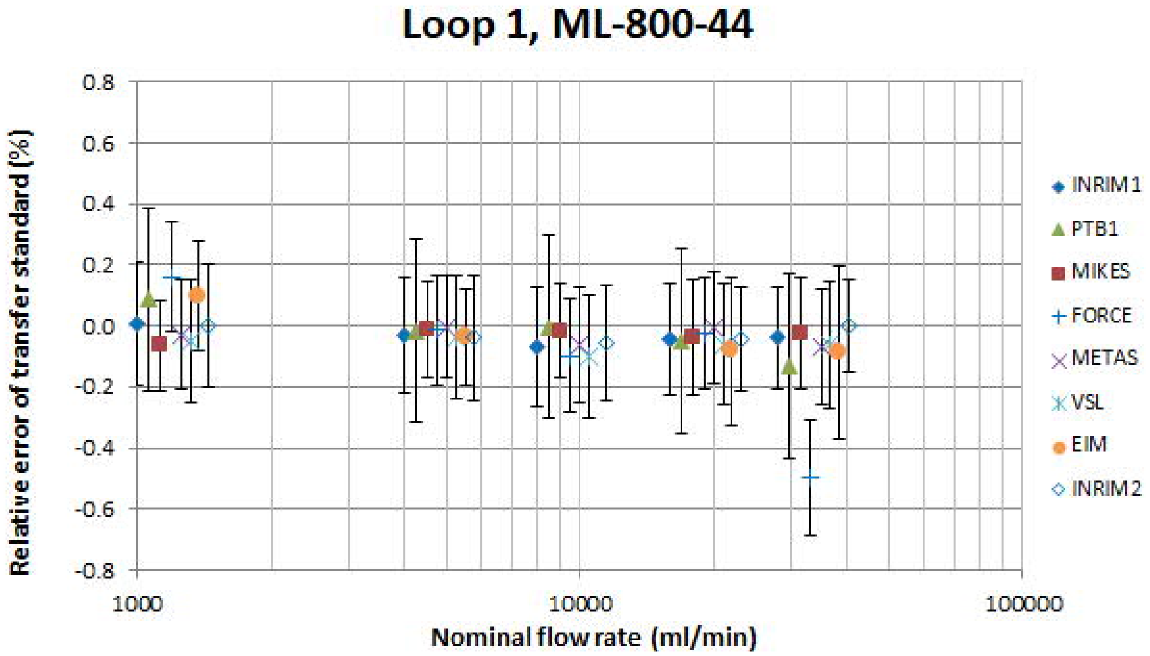

Figure 10. Measurements results of the participating laboratories in loop 1 for the medium flow cell ML-800-44. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

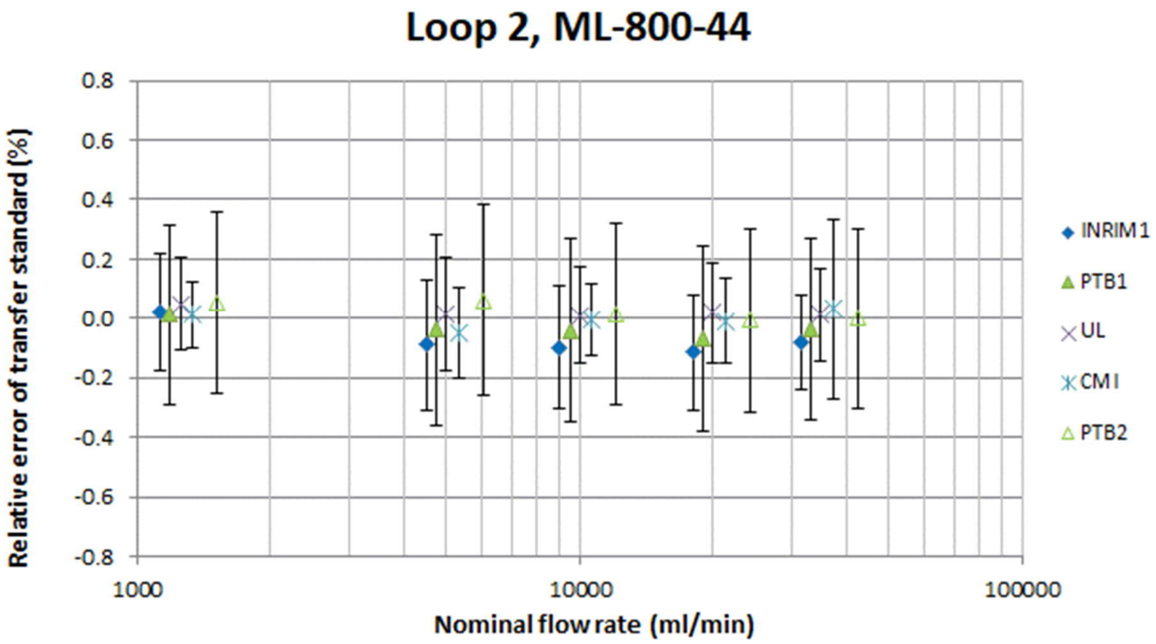

Figure 11. Measurements results of the participating laboratories in loop 2 for the medium flow cell ML-800-44. Error bars show expanded uncertainties (k=2) including stability of the transfer standard. Note that the x-axis values are shifted for clarity of presentation.

6.2 Notes on the results

The calibration points measured by the participating laboratories are summarized in table 7. Most of the laboratories performed measurements at all flow rates, or at the flow rates that were included in their calibration and measurement capabilities (CMCs). Exceptions to the measurement protocol and calibration scheme are listed below:

FORCE: At calibration points 600 ml/min and 1250 ml/min with the medium flow cell (ML-800-24) and at flow rate 30 000 ml/min with the high flow cell (ML-800-44), less than 10 flow indications from the transfer standard were recorded. The reason for this is that the reference standard of FORCE is a primary standard based on the displacement principle with fixed volume flow tubes. Thus, the number of flow indications during a calibration cycle depends on the flow rate and the volume of the selected flow tube. Anyhow, a minimum of 7 flow indications was recorded at these points, which is sufficient for obtaining a reliable result for the transfer standard (insignificant uncertainty due to repeatability of transfer standard reading). In addition, FORCE did not perform measurement with the small flow cell, because the pulsation induced by the transfer standard piston was found to influence the results of the primary standard. Therefore, FORCE decided not to participate in the comparison of the low flow cell (ML-800-10).

VSL: At calibration points 5 ml/min, 10 ml/min and 20 ml/min less repeated measurements were performed than advised in the protocol. Instead of four separate measurement, VSL performed three measurement at 5 ml/min and only two measurement at 10 ml/min and 20 ml/min. However, these measurements indicate good repeatability, and thus the results are considered to provide a reliable estimate of the error of the transfer standard.

EIM: Calibration points with flow rates 5 ml/min and 10 ml/min were not measured by EIM. The current CMCs of the laboratory start from 150 ml/min. In addition, at 10000 ml/min no measurements were made, because this flow rate corresponds to the lower limit of the laboratory bell prover reference standard.

GUM: Results were withdrawn from the comparison, because the measurements were not performed according to protocol. Actual volumetric flow readings were recorded instead of standardized readings as advised in the protocol. An attempt to convert the results to standardized readings based on pressure and temperature readings was unsuccessful.

LEI: Owing to technical reasons related to the laboratory flow standard, LEI was not able to provide measurement results according to the protocol.

LNE: LNE decided to participate the comparison only in the lower flow range.

Table 7. Comparison points measured by the laboratories.

	Flow cell	ML-800-10				ML-800-24				ML-800-44				
	Flow rate (ml/min)	5	10	20	80	80	300	600	1250	1250	5000	10000	20000	30000
LOOP 1	INRIM1	x	x	x	x	x	x	x	x	x	x	x	x	x
	PTB	x	x	x	x	x	x	x	x	x	x	x	x	x
	MIKES	x	x	x	x	x	x	x	x	x	x	x	x	x
	FORCE					x	x	x	x	x	x	x	x	x
	METAS	x	x	x	x	x	x	x	x	x	x	x	x	x
	VSL	x	x	x	x	x	x	x	x	x	x	x	x	x
	EIM			x	x	x	x	x	x	x	x		x	x
	INRIM2	x	x	x	x	x	x	x	x	x	x	x	x	x
LOOP 2	INRIM	x	x	x	x	x	x	x	x	x	x	x	x	x
	PTB1	x	x	x	x	x	x	x	x	x	x	x	x	x
	GUM													
	UL	x	x	x	x	x	x	x	x	x	x	x	x	x
	LEI													
	CMI	x	x	x	x	x	x	x	x	x	x	x	x	x
	LNE	x	x	x	x									
	PTB2	x	x	x	x	x	x	x	x	x	x	x	x	x

7. Bilateral equivalence

7.1 Analysis method

The applied method of linking results between laboratories in different loops is adapted from the method presented by Heinonen *et al*. [1]. In this case, however, there are only two loops and two linking laboratories, which simplifies the analysis.

The bilateral equivalence can be calculated as:

$$D_{ij} = E_i - E_j = E_{i,loop(i)} + B_{ij} + E_{j,loop(j)} \qquad (6)$$

where subscripts *i* and *j* identify the laboratories and *loop(i)* gives the loop number of the laboratory no. *i*.

The linking function *B* is determined based on the results of both linking laboratories as:

$$\begin{cases} B_{ij} = \dfrac{\frac{b_{INRIM}}{u^2[b_{INRIM}]}+\frac{b_{PTB}}{u^2[b_{PTB}]}}{\frac{1}{u^2[b_{INRIM}]}+\frac{1}{u^2[b_{PTB}]}} + \delta_B; & loop(i) \neq loop(j) \\ B_{ij} = 0; & loop(i) = loop(j) \end{cases} \qquad (7)$$

where the linking value *b* for respective linking laboratory is calculated as:

$$b_{INRIM} = -E_{INRIM,loop1} + E_{INRIM,loop2} \qquad (8)$$

$$b_{PTB} = -E_{PTB,loop1} + E_{PTB,loop2} \qquad (9)$$

The error in the linking function δ_B is assumed to be zero. However, due to the deviation of the linking values *b*, an uncertainty of the error needs to be included:

$$u(\delta_B) = \frac{1}{2\sqrt{3}} |b_{INRIM} - b_{PTB}| \qquad (10)$$

By following well-known principles of uncertainty estimation, the uncertainty of the linking function *B* can be given as:

$$\begin{cases} u^2[B_{ij}] = \left(\dfrac{1}{u^2[b_{INRIM}]} + \dfrac{1}{u^2[b_{PTB}]}\right)^{-1} + u^2(\delta_B); & loop(i) \neq loop(j) \\ u^2[B_{ij}] = 0; & loop(i) = loop(j) \end{cases} \qquad (11)$$

where:

$$u^2[b_{INRIM}] = u^2(E_{INRIM,loop1}) + u^2(E_{INRIM,loop2}) - 2 \cdot u(\dot{V}_{ref,INRIM,loop1})u(\dot{V}_{ref,INRIM,loop2}) \cdot r_{INRIM} \qquad (12)$$

$$u^2[b_{PTB}] = u^2(E_{PTB,\ loop1}) + u^2(E_{PTB,\ loop2}) - 2 \cdot u(\dot{V}_{ref,PTB,loop1})u(\dot{V}_{ref,PTB,loop2}) \cdot r_{PTB} \qquad (13)$$

and *r* is the correlation coefficient. The results obtained by the linking laboratories in both loops are correlated, because the same reference equipment was used. Based on the uncertainty budgets provided by the linking laboratories, a correlation coefficient of *r*=1 was used. This is justified, since the uncertainty of the laboratory references is dominated by non-random uncertainty sources. Anyhow, the influence of the correlation coefficient on the uncertainty of the bilateral equivalence was found insignificant.

As mentioned in section 6.1, the stability of the transfer standard is included in the uncertainties of each laboratory, and therefore it does not show up in the equations above. Table 8 shows the calculated estimates and uncertainties of *B*.

Table 8. Calculated estimates of the linking function B_{ij} when *loop(i) ≠ loop(j)*.

Nominal Flow Rate (std ml/min)	B_{ij} (%)	$u(B_{ij})$ (%)
Flow cell:	-10	
5	0.10	0.21
10	-0.13	0.16
20	0.11	0.13
80	0.18	0.02
Flow cell:	-24	
80	0.25	0.11
300	0.35	0.06
600	0.35	0.04
1250	0.32	0.03
Flow cell:	-44	
1250	-0.05	0.03
5000	-0.04	0.04
10000	-0.03	0.03
20000	-0.04	0.04
30000	0.06	0.05

The uncertainty of the bilateral equivalence is calculated as:

$$u^2(D_{ij}) = u^2(E_{i,\,loop(i)}) + u^2(B_{ij}) + u^2(E_{j,\,loop(j)}) \qquad (14)$$

In the case of linking laboratories the uncertainty is calculated as follows:

$$D_{ij} = E_i - E_j \qquad (15)$$

where:

$$E_i = \frac{1}{2}(E_{i,\,loop1} + E_{i,\,loop2}) \qquad (16)$$

The uncertainty can be expressed as:

$$u^2(E_i) = \left(\frac{1}{2}u(E_{i,\,loop1}) + \frac{1}{2}u(E_{i,\,loop2})\right)^2 \qquad (17)$$

7.2 Results of analysis

The bilateral degrees of equivalence (DoE) is determined as $(D_{ij}, U_{ij}) = (D_{ij}, 2 \cdot u_{ij})$ [2]. The DoE was calculated for each pair of participants at each nominal measurement point. The results are summarized in tables 9 to 21. The DoE of equivalence is expressed as the difference of the relative error of the transfer standard determined by the participants.

Table 9. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 5 ml/min with the low flow cell (-10). DoE are given as relative values (%).

j→ ↓i	*DoE ± U(DoE) @ 5 ml/min (flow cell: -10)*									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		0.01 ± 0.66	-0.12 ± 0.70		0.30 ± 0.78	-0.07 ± 0.79		-0.13 ± 0.61	-0.31 ± 0.54	-0.28 ± 0.60
PTB	-0.01 ± 0.66		-0.19 ± 0.77		0.23 ± 0.83	-0.14 ± 0.84		-0.09 ± 0.68	-0.26 ± 0.62	-0.23 ± 0.67
MIKES	0.12 ± 0.70	0.19 ± 0.77			0.41 ± 0.81	0.05 ± 0.81		0.04 ± 0.72	-0.13 ± 0.66	-0.11 ± 0.71
FORCE										
METAS	-0.30 ± 0.78	-0.23 ± 0.83	-0.41 ± 0.81			-0.37 ± 0.88		-0.37 ± 0.79	-0.55 ± 0.74	-0.52 ± 0.79
VSL	0.07 ± 0.79	0.14 ± 0.84	-0.05 ± 0.81		0.37 ± 0.88			0.00 ± 0.80	-0.18 ± 0.75	-0.15 ± 0.79
EIM										
UL	0.13 ± 0.61	0.09 ± 0.68	-0.04 ± 0.72		0.37 ± 0.79	0.00 ± 0.80			-0.18 ± 0.64	-0.15 ± 0.69
CMI	0.31 ± 0.54	0.26 ± 0.62	0.13 ± 0.66		0.55 ± 0.74	0.18 ± 0.75		0.18 ± 0.64		0.03 ± 0.63
LNE	0.28 ± 0.60	0.23 ± 0.67	0.11 ± 0.71		0.52 ± 0.79	0.15 ± 0.79		0.15 ± 0.69	-0.03 ± 0.63	

Table 10. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 10 ml/min with the low flow cell (-10). DoE are given as relative values (%).

j→ ↓i	*DoE ± U(DoE) @ 10 ml/min (flow cell: -10)*									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.24 ± 0.48	-0.16 ± 0.44		0.41 ± 0.53	-0.04 ± 0.57		-0.20 ± 0.39	-0.20 ± 0.34	-0.26 ± 0.39
PTB	0.24 ± 0.48		0.25 ± 0.54		0.82 ± 0.61	0.38 ± 0.65		-0.13 ± 0.48	-0.13 ± 0.45	-0.19 ± 0.48
MIKES	0.16 ± 0.44	-0.25 ± 0.54			0.57 ± 0.55	0.12 ± 0.59		-0.21 ± 0.45	-0.21 ± 0.41	-0.27 ± 0.45
FORCE										
METAS	-0.41 ± 0.53	-0.82 ± 0.61	-0.57 ± 0.55			-0.45 ± 0.66		-0.78 ± 0.54	-0.78 ± 0.50	-0.84 ± 0.54
VSL	0.04 ± 0.57	-0.38 ± 0.65	-0.12 ± 0.59		0.45 ± 0.66			-0.33 ± 0.58	-0.33 ± 0.55	-0.39 ± 0.58
EIM										
UL	0.20 ± 0.39	0.13 ± 0.48	0.21 ± 0.45		0.78 ± 0.54	0.33 ± 0.58			0.00 ± 0.39	-0.06 ± 0.43
CMI	0.20 ± 0.34	0.13 ± 0.45	0.21 ± 0.41		0.78 ± 0.50	0.33 ± 0.55		0.00 ± 0.39		-0.06 ± 0.39
LNE	0.26 ± 0.39	0.19 ± 0.48	0.27 ± 0.45		0.84 ± 0.54	0.39 ± 0.58		0.06 ± 0.43	0.06 ± 0.39	

Table 11. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 20 ml/min with the low flow cell (-10). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 20 ml/min (flow cell: -10)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.19 ± 0.47	-0.04 ± 0.33		0.24 ± 0.41	0.07 ± 0.48	-0.28 ± 0.37	-0.10 ± 0.48	-0.12 ± 0.46	-0.11 ± 0.47
PTB	0.19 ± 0.47		0.10 ± 0.44		0.39 ± 0.51	0.22 ± 0.57	-0.13 ± 0.48	0.13 ± 0.56	0.11 ± 0.55	0.12 ± 0.56
MIKES	0.04 ± 0.33	-0.10 ± 0.44			0.29 ± 0.45	0.11 ± 0.51	-0.24 ± 0.41	-0.02 ± 0.44	-0.04 ± 0.42	-0.03 ± 0.44
FORCE										
METAS	-0.24 ± 0.41	-0.39 ± 0.51	-0.29 ± 0.45			-0.17 ± 0.57	-0.52 ± 0.48	-0.30 ± 0.51	-0.32 ± 0.49	-0.31 ± 0.51
VSL	-0.07 ± 0.48	-0.22 ± 0.57	-0.11 ± 0.51		0.17 ± 0.57		-0.35 ± 0.54	-0.13 ± 0.57	-0.15 ± 0.55	-0.14 ± 0.56
EIM	0.28 ± 0.37	0.13 ± 0.48	0.24 ± 0.41		0.52 ± 0.48	0.35 ± 0.54		0.22 ± 0.48	0.20 ± 0.46	0.21 ± 0.47
UL	0.10 ± 0.48	-0.13 ± 0.56	0.02 ± 0.44		0.30 ± 0.51	0.13 ± 0.57	-0.22 ± 0.48		-0.02 ± 0.48	-0.01 ± 0.50
CMI	0.12 ± 0.46	-0.11 ± 0.55	0.04 ± 0.42		0.32 ± 0.49	0.15 ± 0.55	-0.20 ± 0.46	0.02 ± 0.48		0.01 ± 0.48
LNE	0.11 ± 0.47	-0.12 ± 0.56	0.03 ± 0.44		0.31 ± 0.51	0.14 ± 0.56	-0.21 ± 0.47	0.01 ± 0.50	-0.01 ± 0.48	

Table 12. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 80 ml/min with the low flow cell (-10). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 80 ml/min (flow cell: -10)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.14 ± 0.31	-0.12 ± 0.17		-0.07 ± 0.33	0.14 ± 0.41	-0.11 ± 0.23	-0.21 ± 0.18	-0.22 ± 0.13	-0.28 ± 0.14
PTB	0.14 ± 0.31		0.00 ± 0.34		0.04 ± 0.44	0.26 ± 0.51	0.01 ± 0.37	-0.04 ± 0.34	-0.04 ± 0.32	-0.11 ± 0.32
MIKES	0.12 ± 0.17	0.00 ± 0.34			0.05 ± 0.36	0.26 ± 0.44	0.01 ± 0.27	-0.04 ± 0.22	-0.05 ± 0.19	-0.11 ± 0.20
FORCE										
METAS	0.07 ± 0.33	-0.04 ± 0.44	-0.05 ± 0.36			0.21 ± 0.52	-0.04 ± 0.39	-0.09 ± 0.36	-0.09 ± 0.34	-0.16 ± 0.35
VSL	-0.14 ± 0.41	-0.26 ± 0.51	-0.26 ± 0.44		-0.21 ± 0.52		-0.25 ± 0.46	-0.30 ± 0.44	-0.31 ± 0.42	-0.38 ± 0.42
EIM	0.11 ± 0.23	-0.01 ± 0.37	-0.01 ± 0.27		0.04 ± 0.39	0.25 ± 0.46		-0.05 ± 0.27	-0.06 ± 0.24	-0.12 ± 0.25
UL	0.21 ± 0.18	0.04 ± 0.34	0.04 ± 0.22		0.09 ± 0.36	0.30 ± 0.44	0.05 ± 0.27		0.00 ± 0.19	-0.07 ± 0.19
CMI	0.22 ± 0.13	0.04 ± 0.32	0.05 ± 0.19		0.09 ± 0.34	0.31 ± 0.42	0.06 ± 0.24	0.00 ± 0.19		-0.07 ± 0.16
LNE	0.28 ± 0.14	0.11 ± 0.32	0.11 ± 0.20		0.16 ± 0.35	0.38 ± 0.42	0.12 ± 0.25	0.07 ± 0.19	0.07 ± 0.16	

Table 13. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 80 ml/min with the medium flow cell (-24). DoE are given as relative values (%).

j→ / ↓i	DoE ± U(DoE) @ 80 ml/min (flow cell: -24)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.01 ± 0.40	0.14 ± 0.45	-0.13 ± 0.46	0.29 ± 0.46	0.80 ± 0.58	-0.45 ± 0.47	-0.06 ± 0.16	-0.04 ± 0.11	
PTB	0.01 ± 0.40		0.16 ± 0.53	-0.11 ± 0.55	0.31 ± 0.54	0.82 ± 0.65	-0.43 ± 0.56	-0.06 ± 0.34	-0.05 ± 0.32	
MIKES	-0.14 ± 0.45	-0.16 ± 0.53		-0.27 ± 0.48	0.15 ± 0.48	0.65 ± 0.60	-0.60 ± 0.50	-0.22 ± 0.36	-0.20 ± 0.35	
FORCE	0.13 ± 0.46	0.11 ± 0.55	0.27 ± 0.48		0.42 ± 0.49	0.93 ± 0.61	-0.32 ± 0.51	0.06 ± 0.38	0.08 ± 0.37	
METAS	-0.29 ± 0.46	-0.31 ± 0.54	-0.15 ± 0.48	-0.42 ± 0.49		0.51 ± 0.61	-0.74 ± 0.50	-0.36 ± 0.38	-0.34 ± 0.36	
VSL	-0.80 ± 0.58	-0.82 ± 0.65	-0.65 ± 0.60	-0.93 ± 0.61	-0.51 ± 0.61		-1.25 ± 0.62	-0.87 ± 0.52	-0.85 ± 0.51	
EIM	0.45 ± 0.47	0.43 ± 0.56	0.60 ± 0.50	0.32 ± 0.51	0.74 ± 0.50	1.25 ± 0.62		0.38 ± 0.40	0.40 ± 0.38	
UL	0.06 ± 0.16	0.06 ± 0.34	0.22 ± 0.36	-0.06 ± 0.38	0.36 ± 0.38	0.87 ± 0.52	-0.38 ± 0.40		0.02 ± 0.18	
CMI	0.04 ± 0.11	0.05 ± 0.32	0.20 ± 0.35	-0.08 ± 0.37	0.34 ± 0.36	0.85 ± 0.51	-0.40 ± 0.38	-0.02 ± 0.18		
LNE										

Table 14. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 300 ml/min with the medium flow cell (-24). DoE are given as relative values (%).

j→ / ↓i	DoE ± U(DoE) @ 300 ml/min (flow cell: -24)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.09 ± 0.35	0.04 ± 0.25	-0.21 ± 0.27	0.15 ± 0.26	-0.16 ± 0.29	-0.35 ± 0.29	-0.05 ± 0.21	-0.12 ± 0.18	
PTB	0.09 ± 0.35		0.11 ± 0.39	-0.14 ± 0.40	0.22 ± 0.39	-0.09 ± 0.41	-0.28 ± 0.41	0.07 ± 0.37	0.00 ± 0.35	
MIKES	-0.04 ± 0.25	-0.11 ± 0.39		-0.25 ± 0.31	0.11 ± 0.30	-0.20 ± 0.32	-0.39 ± 0.32	-0.06 ± 0.27	-0.13 ± 0.25	
FORCE	0.21 ± 0.27	0.14 ± 0.40	0.25 ± 0.31		0.37 ± 0.32	0.05 ± 0.34	-0.13 ± 0.34	0.19 ± 0.30	0.12 ± 0.27	
METAS	-0.15 ± 0.26	-0.22 ± 0.39	-0.11 ± 0.30	-0.37 ± 0.32		-0.32 ± 0.33	-0.50 ± 0.33	-0.18 ± 0.28	-0.25 ± 0.26	
VSL	0.16 ± 0.29	0.09 ± 0.41	0.20 ± 0.32	-0.05 ± 0.34	0.32 ± 0.33		-0.18 ± 0.35	0.14 ± 0.31	0.07 ± 0.29	
EIM	0.35 ± 0.29	0.28 ± 0.41	0.39 ± 0.32	0.13 ± 0.34	0.50 ± 0.33	0.18 ± 0.35		0.32 ± 0.31	0.25 ± 0.29	
UL	0.05 ± 0.21	-0.07 ± 0.37	0.06 ± 0.27	-0.19 ± 0.30	0.18 ± 0.28	-0.14 ± 0.31	-0.32 ± 0.31		-0.07 ± 0.23	
CMI	0.12 ± 0.18	0.00 ± 0.35	0.13 ± 0.25	-0.12 ± 0.27	0.25 ± 0.26	-0.07 ± 0.29	-0.25 ± 0.29	0.07 ± 0.23		
LNE										

Table 15. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 600 ml/min with the medium flow cell (-24). DoE are given as relative values (%).

j→ / ↓i	DoE ± U(DoE) @ 600 ml/min (flow cell: -24)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.08 ± 0.32	0.06 ± 0.23	-0.25 ± 0.26	0.11 ± 0.24	-0.21 ± 0.27	-0.41 ± 0.34	-0.05 ± 0.16	-0.10 ± 0.11	
PTB	0.08 ± 0.32		0.15 ± 0.38	-0.16 ± 0.39	0.19 ± 0.38	-0.12 ± 0.40	-0.32 ± 0.45	0.03 ± 0.34	-0.02 ± 0.32	
MIKES	-0.06 ± 0.23	-0.15 ± 0.38		-0.31 ± 0.29	0.04 ± 0.28	-0.27 ± 0.30	-0.47 ± 0.36	-0.11 ± 0.24	-0.17 ± 0.22	
FORCE	0.25 ± 0.26	0.16 ± 0.39	0.31 ± 0.29		0.35 ± 0.30	0.04 ± 0.32	-0.16 ± 0.38	0.20 ± 0.27	0.14 ± 0.25	
METAS	-0.11 ± 0.24	-0.19 ± 0.38	-0.04 ± 0.28	-0.35 ± 0.30		-0.31 ± 0.31	-0.52 ± 0.37	-0.16 ± 0.25	-0.21 ± 0.23	
VSL	0.21 ± 0.27	0.12 ± 0.40	0.27 ± 0.30	-0.04 ± 0.32	0.31 ± 0.31		-0.20 ± 0.39	0.16 ± 0.28	0.10 ± 0.26	
EIM	0.41 ± 0.34	0.32 ± 0.45	0.47 ± 0.36	0.16 ± 0.38	0.52 ± 0.37	0.20 ± 0.39		0.36 ± 0.35	0.30 ± 0.33	
UL	0.05 ± 0.16	-0.03 ± 0.34	0.11 ± 0.24	-0.20 ± 0.27	0.16 ± 0.25	-0.16 ± 0.28	-0.36 ± 0.35		-0.05 ± 0.18	
CMI	0.10 ± 0.11	0.02 ± 0.32	0.17 ± 0.22	-0.14 ± 0.25	0.21 ± 0.23	-0.10 ± 0.26	-0.30 ± 0.33	0.05 ± 0.18		
LNE										

Table 16. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 1250 ml/min with the medium flow cell (-24). DoE are given as relative values (%).

j→ / ↓i	DoE ± U(DoE) @ 1250 ml/min (flow cell: -24)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.08 ± 0.32	0.08 ± 0.19	-0.38 ± 0.25	0.08 ± 0.21	-0.16 ± 0.23	-0.46 ± 0.55	-0.09 ± 0.17	-0.08 ± 0.13	
PTB	0.08 ± 0.32		0.16 ± 0.35	-0.30 ± 0.39	0.16 ± 0.37	-0.08 ± 0.38	-0.38 ± 0.62	-0.01 ± 0.34	0.00 ± 0.32	
MIKES	-0.08 ± 0.19	-0.16 ± 0.35		-0.47 ± 0.28	0.00 ± 0.26	-0.24 ± 0.27	-0.54 ± 0.57	-0.17 ± 0.23	-0.16 ± 0.20	
FORCE	0.38 ± 0.25	0.30 ± 0.39	0.47 ± 0.28		0.47 ± 0.30	0.22 ± 0.31	-0.08 ± 0.59	0.30 ± 0.28	0.30 ± 0.25	
METAS	-0.08 ± 0.21	-0.16 ± 0.37	0.00 ± 0.26	-0.47 ± 0.30		-0.24 ± 0.29	-0.54 ± 0.58	-0.17 ± 0.25	-0.16 ± 0.22	
VSL	0.16 ± 0.23	0.08 ± 0.38	0.24 ± 0.27	-0.22 ± 0.31	0.24 ± 0.29		-0.30 ± 0.58	0.07 ± 0.27	0.08 ± 0.24	
EIM	0.46 ± 0.55	0.38 ± 0.62	0.54 ± 0.57	0.08 ± 0.59	0.54 ± 0.58	0.30 ± 0.58		0.37 ± 0.56	0.38 ± 0.55	
UL	0.09 ± 0.17	0.01 ± 0.34	0.17 ± 0.23	-0.30 ± 0.28	0.17 ± 0.25	-0.07 ± 0.27	-0.37 ± 0.56		0.01 ± 0.19	
CMI	0.08 ± 0.13	0.00 ± 0.32	0.16 ± 0.20	-0.30 ± 0.25	0.16 ± 0.22	-0.08 ± 0.24	-0.38 ± 0.55	-0.01 ± 0.19		
LNE										

Table 17. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 1250 ml/min with the high flow cell (-44). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 1250 ml/min (flow cell: -44)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.03 ± 0.36	0.07 ± 0.25	-0.15 ± 0.27	0.04 ± 0.27	0.06 ± 0.29	-0.09 ± 0.27	-0.03 ± 0.25	0.01 ± 0.23	
PTB	0.03 ± 0.36		0.15 ± 0.33	-0.07 ± 0.35	0.11 ± 0.35	0.14 ± 0.36	-0.01 ± 0.35	-0.04 ± 0.34	0.00 ± 0.32	
MIKES	-0.07 ± 0.25	-0.15 ± 0.33		-0.22 ± 0.23	-0.04 ± 0.23	-0.01 ± 0.25	-0.16 ± 0.23	-0.17 ± 0.22	-0.13 ± 0.19	
FORCE	0.15 ± 0.27	0.07 ± 0.35	0.22 ± 0.23		0.19 ± 0.26	0.21 ± 0.27	0.06 ± 0.25	0.06 ± 0.24	0.09 ± 0.21	
METAS	-0.04 ± 0.27	-0.11 ± 0.35	0.04 ± 0.23	-0.19 ± 0.26		0.02 ± 0.27	-0.13 ± 0.25	-0.13 ± 0.24	-0.10 ± 0.21	
VSL	-0.06 ± 0.29	-0.14 ± 0.36	0.01 ± 0.25	-0.21 ± 0.27	-0.02 ± 0.27		-0.15 ± 0.27	-0.16 ± 0.26	-0.12 ± 0.23	
EIM	0.09 ± 0.27	0.01 ± 0.35	0.16 ± 0.23	-0.06 ± 0.25	0.13 ± 0.25	0.15 ± 0.27		-0.01 ± 0.24	0.03 ± 0.21	
UL	0.03 ± 0.25	0.04 ± 0.34	0.17 ± 0.22	-0.06 ± 0.24	0.13 ± 0.24	0.16 ± 0.26	0.01 ± 0.24		0.03 ± 0.19	
CMI	-0.01 ± 0.23	0.00 ± 0.32	0.13 ± 0.19	-0.09 ± 0.21	0.10 ± 0.21	0.12 ± 0.23	-0.03 ± 0.21	-0.03 ± 0.19		
LNE										

Table 18. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 5000 ml/min with the high flow cell (-44). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 5000 ml/min (flow cell: -44)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.03 ± 0.37	-0.02 ± 0.25	-0.02 ± 0.26	-0.03 ± 0.25	0.00 ± 0.28	0.00 ± 0.25	-0.10 ± 0.29	-0.04 ± 0.27	
PTB	0.03 ± 0.37		0.00 ± 0.34	0.00 ± 0.35	-0.01 ± 0.34	0.02 ± 0.36	0.02 ± 0.34	-0.05 ± 0.37	0.01 ± 0.36	
MIKES	0.02 ± 0.25	0.00 ± 0.34		0.00 ± 0.24	-0.01 ± 0.23	0.03 ± 0.25	0.02 ± 0.22	-0.06 ± 0.25	0.00 ± 0.22	
FORCE	0.02 ± 0.26	0.00 ± 0.35	0.00 ± 0.24		-0.01 ± 0.25	0.03 ± 0.27	0.02 ± 0.24	-0.06 ± 0.26	0.00 ± 0.24	
METAS	0.03 ± 0.25	0.01 ± 0.34	0.01 ± 0.23	0.01 ± 0.25		0.04 ± 0.26	0.03 ± 0.23	-0.05 ± 0.25	0.01 ± 0.23	
VSL	0.00 ± 0.28	-0.02 ± 0.36	-0.03 ± 0.25	-0.03 ± 0.27	-0.04 ± 0.26		0.00 ± 0.26	-0.09 ± 0.28	-0.03 ± 0.25	
EIM	0.00 ± 0.25	-0.02 ± 0.34	-0.02 ± 0.22	-0.02 ± 0.24	-0.03 ± 0.23	0.00 ± 0.26		-0.08 ± 0.25	-0.02 ± 0.22	
UL	0.10 ± 0.29	0.05 ± 0.37	0.06 ± 0.25	0.06 ± 0.26	0.05 ± 0.25	0.09 ± 0.28	0.08 ± 0.25		0.06 ± 0.24	
CMI	0.04 ± 0.27	-0.01 ± 0.36	0.00 ± 0.22	0.00 ± 0.24	-0.01 ± 0.23	0.03 ± 0.25	0.02 ± 0.22	-0.06 ± 0.24		
LNE										

Table 19. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 10000 ml/min with the high flow cell (-44). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 10 000 ml/min (flow cell: -44)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.06 ± 0.36	-0.05 ± 0.25	0.03 ± 0.27	0.00 ± 0.27	0.03 ± 0.28	-0.07 ± 0.20	-0.11 ± 0.26	-0.09 ± 0.24	
PTB	0.06 ± 0.36		0.01 ± 0.34	0.09 ± 0.35	0.06 ± 0.36	0.10 ± 0.36	0.00 ± 0.30	-0.05 ± 0.35	-0.04 ± 0.33	
MIKES	0.05 ± 0.25	-0.01 ± 0.34		0.08 ± 0.24	0.05 ± 0.25	0.08 ± 0.25	-0.02 ± 0.16	-0.06 ± 0.22	-0.05 ± 0.20	
FORCE	-0.03 ± 0.27	-0.09 ± 0.35	-0.08 ± 0.24		-0.03 ± 0.27	0.00 ± 0.28	-0.10 ± 0.19	-0.14 ± 0.25	-0.13 ± 0.22	
METAS	0.00 ± 0.27	-0.06 ± 0.36	-0.05 ± 0.25	0.03 ± 0.27		0.04 ± 0.28	-0.06 ± 0.19	-0.11 ± 0.25	-0.09 ± 0.22	
VSL	-0.03 ± 0.28	-0.10 ± 0.36	-0.08 ± 0.25	0.00 ± 0.28	-0.04 ± 0.28		-0.10 ± 0.20	-0.14 ± 0.26	-0.13 ± 0.23	
EIM	0.07 ± 0.20	0.00 ± 0.30	0.02 ± 0.16	0.10 ± 0.19	0.06 ± 0.19	0.10 ± 0.20		-0.04 ± 0.16	-0.03 ± 0.12	
UL	0.11 ± 0.26	0.05 ± 0.35	0.06 ± 0.22	0.14 ± 0.25	0.11 ± 0.25	0.14 ± 0.26	0.04 ± 0.16		0.01 ± 0.20	
CMI	0.09 ± 0.24	0.04 ± 0.33	0.05 ± 0.20	0.13 ± 0.22	0.09 ± 0.22	0.13 ± 0.23	0.03 ± 0.12	-0.01 ± 0.20		
LNE										

Table 20. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 20000 ml/min with the high flow cell (-44). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 20 000 ml/min (flow cell: -44)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		-0.02 ± 0.36	-0.01 ± 0.26	-0.02 ± 0.26	-0.04 ± 0.26	0.01 ± 0.27	0.04 ± 0.30	-0.13 ± 0.25	-0.11 ± 0.24	
PTB	0.02 ± 0.36		-0.02 ± 0.36	-0.03 ± 0.35	-0.05 ± 0.35	0.01 ± 0.36	0.03 ± 0.39	-0.09 ± 0.35	-0.06 ± 0.34	
MIKES	0.01 ± 0.26	0.02 ± 0.36		-0.01 ± 0.26	-0.03 ± 0.26	0.02 ± 0.27	0.05 ± 0.31	-0.09 ± 0.25	-0.07 ± 0.24	
FORCE	0.02 ± 0.26	0.03 ± 0.35	0.01 ± 0.26		-0.02 ± 0.26	0.04 ± 0.27	0.06 ± 0.30	-0.08 ± 0.25	-0.05 ± 0.23	
METAS	0.04 ± 0.26	0.05 ± 0.35	0.03 ± 0.26	0.02 ± 0.26		0.05 ± 0.27	0.08 ± 0.30	-0.06 ± 0.25	-0.04 ± 0.23	
VSL	-0.01 ± 0.27	-0.01 ± 0.36	-0.02 ± 0.27	-0.04 ± 0.27	-0.05 ± 0.27		0.02 ± 0.31	-0.12 ± 0.26	-0.09 ± 0.25	
EIM	-0.04 ± 0.30	-0.03 ± 0.39	-0.05 ± 0.31	-0.06 ± 0.30	-0.08 ± 0.30	-0.02 ± 0.31		-0.14 ± 0.29	-0.11 ± 0.28	
UL	0.13 ± 0.25	0.09 ± 0.35	0.09 ± 0.25	0.08 ± 0.25	0.06 ± 0.25	0.12 ± 0.26	0.14 ± 0.29		0.03 ± 0.22	
CMI	0.11 ± 0.24	0.06 ± 0.34	0.07 ± 0.24	0.05 ± 0.23	0.04 ± 0.23	0.09 ± 0.25	0.11 ± 0.28	-0.03 ± 0.22		
LNE										

Table 21. Degree of equivalence (D_{ij}) between the participants of EURAMET1325 at the flow rate of 30000 ml/min with the high flow cell (-44). DoE are given as relative values (%).

j→ ↓i	DoE ± U(DoE) @ 30 000 ml/min (flow cell: -44)									
	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
INRIM		0.02 ± 0.34	-0.01 ± 0.25	0.46 ± 0.25	0.03 ± 0.25	0.02 ± 0.27	0.05 ± 0.33	-0.10 ± 0.22	-0.12 ± 0.34	
PTB	-0.02 ± 0.34		-0.11 ± 0.35	0.36 ± 0.36	-0.07 ± 0.36	-0.07 ± 0.37	-0.05 ± 0.41	-0.05 ± 0.34	-0.07 ± 0.43	
MIKES	0.01 ± 0.25	0.11 ± 0.35		0.47 ± 0.26	0.04 ± 0.26	0.04 ± 0.28	0.06 ± 0.34	0.02 ± 0.24	0.00 ± 0.35	
FORCE	-0.46 ± 0.25	-0.36 ± 0.36	-0.47 ± 0.26		-0.43 ± 0.27	-0.43 ± 0.28	-0.41 ± 0.34	-0.45 ± 0.25	-0.47 ± 0.36	
METAS	-0.03 ± 0.25	0.07 ± 0.36	-0.04 ± 0.26	0.43 ± 0.27		0.00 ± 0.28	0.02 ± 0.34	-0.02 ± 0.24	-0.04 ± 0.36	
VSL	-0.02 ± 0.27	0.07 ± 0.37	-0.04 ± 0.28	0.43 ± 0.28	0.00 ± 0.28		0.02 ± 0.35	-0.02 ± 0.26	-0.04 ± 0.37	
EIM	-0.05 ± 0.33	0.05 ± 0.41	-0.06 ± 0.34	0.41 ± 0.34	-0.02 ± 0.34	-0.02 ± 0.35		-0.04 ± 0.32	-0.06 ± 0.41	
UL	0.10 ± 0.22	0.05 ± 0.34	-0.02 ± 0.24	0.45 ± 0.25	0.02 ± 0.24	0.02 ± 0.26	0.04 ± 0.32		-0.02 ± 0.34	
CMI	0.12 ± 0.34	0.07 ± 0.43	0.00 ± 0.35	0.47 ± 0.36	0.04 ± 0.36	0.04 ± 0.37	0.06 ± 0.41	0.02 ± 0.34		
LNE										

8. EURAMET comparison reference values (ERV)

8.1 ERV calculation method

In this project, the calculation of the EURAMET comparison reference value (ERV) is carried out according to Heinonen [1], which is based on the principles presented by M. Cox [2, 3]. Because there was no common transfer standard for all participants, absolute ERV values were not determined. Only the difference between ERVs and the results of each laboratory were calculated.

The calculations were carried out using the weighed mean of the results normalised to the loop of the laboratory under study (*i*). The normalisation was realised using the linking function *B* defined by equation (7):

$$\Delta E_i = E_i - E_{ERV} = E_i - \frac{\sum_{j=1}^{N} \frac{E'_j}{u^2(E'_j)}}{\sum_{j=1}^{N} u^{-2}(E'_j)} = E_i - \frac{\sum_{j=1}^{N} \frac{E_j + B_{ij}}{u^2(E_j)+u^2(B_{ij})}}{\sum_{j=1}^{N}\left[u^2(E_j)+u^2(B_{ij})\right]^{-1}} \qquad (18)$$

$$u^2(\Delta E_i) = \left(\sum_{j=1}^{N}\left[u^2(E_j) + u^2(B_{ij})\right]^{-1}\right)^{-1} + u^2(E_i) \qquad (19)$$

where *N* is the number of participants contributing to the ERV and E_j is the result of *j*th laboratory included in the ERV calculation.

Due to participation in both loops, the link laboratories form a special case, where results are combined in the following way:

$$\Delta E_i = \frac{1}{2}\left(\Delta E_{i,\,loop1} + \Delta E_{i,\,loop2}\right) + \delta\Delta E_i \qquad (20)$$

$$u^2(\Delta E_i) = \left[\frac{1}{2}u\left(\Delta E_{i,\,loop1}\right) + \frac{1}{2}u\left(\Delta E_{i,\,loop2}\right)\right]^2 + u^2(\delta\Delta E_i) \qquad (21)$$

where $\delta\Delta E_i = 0$ and

$$u(\delta\Delta E_i) = \frac{1}{2\sqrt{3}}\left|\Delta E_{i,\,loop1} - \Delta E_{i,\,loop2}\right| \qquad (22)$$

Note that the results of the stability measurements were not included in the calculations, because the linking laboratories performed stability measurements only for one transfer standard.

8.2 Consistency check

The consistency of the participating laboratories results was evaluated by performing a chi-square test applying principles presented by M. Cox [2, 3]. As a first step, the chi-squared value was calculated as:

$$x_{obs}^2 = \sum_{i=1}^{n} \frac{(E_i - E_{ERV})^2}{u^2(\Delta E_i)} = \sum_{i=1}^{n} \frac{(\Delta E_i)^2}{u^2(\Delta E_i)} \qquad (23)$$

where *n* is the number of laboratories contributing the reference value. The results were evaluated against the 95 % confidence interval. The consistency test was performed for each flow rate separately. In cases where the consistency check failed, outliers were identified as results deviating more than two times the standard uncertainty:

$$|\Delta E_i| > 2 \cdot u(\Delta E_i) \quad (24)$$

As a next step, the outlier deviating the most is removed from the calculation of the ERV at that specific flow rate and the chi-square test described above is repeated. This iterative process is repeated until a consistent subset is achieved. The outcome of the consistency check including chi-square values is summarized in table 22.

Table 22. Outcome of consistency check including chi-square values.

Chi-square value for each participant $(\Delta E_i)^2/u^2(\Delta E_i)$										Chi-square value (sum)	Degrees of freedom	Chi-square citeria	Laboratories excluded from ERV calculations
INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE				
(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	χ^2_{obs}	n-1	$\chi^2_{0.050}$	
Flow cell: -10													
0.13	0.12	0.07		1.10	0.01		0.00	0.70	0.38	2.5	7	14.1	
0.66	0.30	0.00		6.00	0.21		0.47	0.73	1.10	9.5	7	14.1	
0.16	0.40	0.01		2.01	0.19	2.31	0.00	0.04	0.02	5.1	8	15.6	
5.43	0.05	0.22		0.00	1.19	0.06	0.76	1.65	5.23	14.6	8	15.6	
Flow cell: -24													
0.06	0.01	1.04	0.28	3.19	10.50	4.74	0.36	0.32		10.0	7	14.1	VSL
0.75	0.03	0.80	1.64	3.42	0.69	4.91	0.05	0.40		12.7	8	15.6	
0.84	0.05	1.61	2.46	2.59	1.39	4.69	0.04	1.65		15.3	8	15.6	
0.32	0.14	1.48	9.22	1.19	1.45	2.52	0.69	1.00		8.8	7	14.1	FORCE
Flow cell: -44													
0.00	0.04	1.75	1.58	0.52	0.76	0.38	0.41	0.09		5.5	8	15.6	
0.08	0.00	0.00	0.00	0.02	0.05	0.06	0.39	0.00		0.6	8	15.6	
0.18	0.01	0.01	0.54	0.15	0.50		0.51	0.53		2.4	7	14.1	
0.22	0.03	0.04	0.01	0.01	0.17	0.27	0.61	0.31		1.7	8	15.6	
0.08	0.10	0.08	18.84	0.02	0.01	0.05	0.10	0.09		0.5	7	14.1	FORCE

8.3 Final results of the ERV analysis

The results of all laboratories are compared to the ERV according to the analysis described in the previous sections. The results are summarized below in figures 12 to 14 and table 23. All uncertainties are at the 95 % confidence level (k=2). Table 24 summarizes the ERVs. The ERVs are shown for each laboratory because they depend on the loop. Also, the ERVs for the link laboratories differ from the others (as seen from eq. 21).

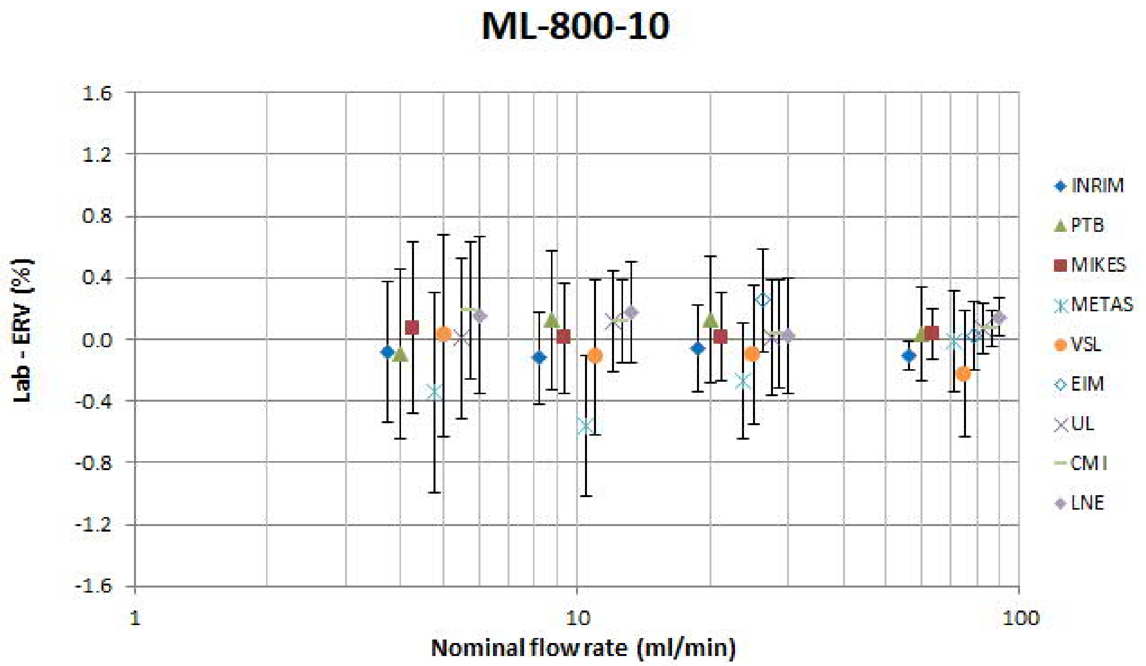

Figure 12. Difference between the ERV and the results of the laboratories for the low flow cell ML-800-10. Error bars show expanded uncertainties (k=2). Note that the x-axis values are shifted for clarity of presentation.

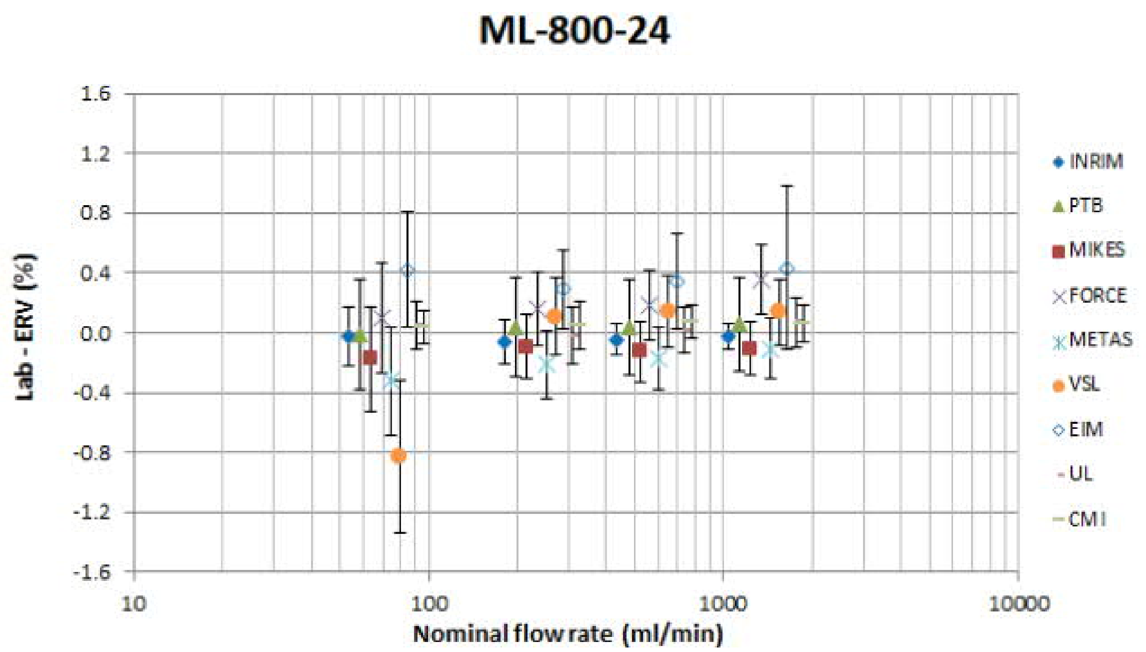

Figure 13. Difference between the ERV and the results of the laboratories for the medium flow cell ML-800-24. Error bars show expanded uncertainties (k=2). Note that the x-axis values are shifted for clarity of presentation.

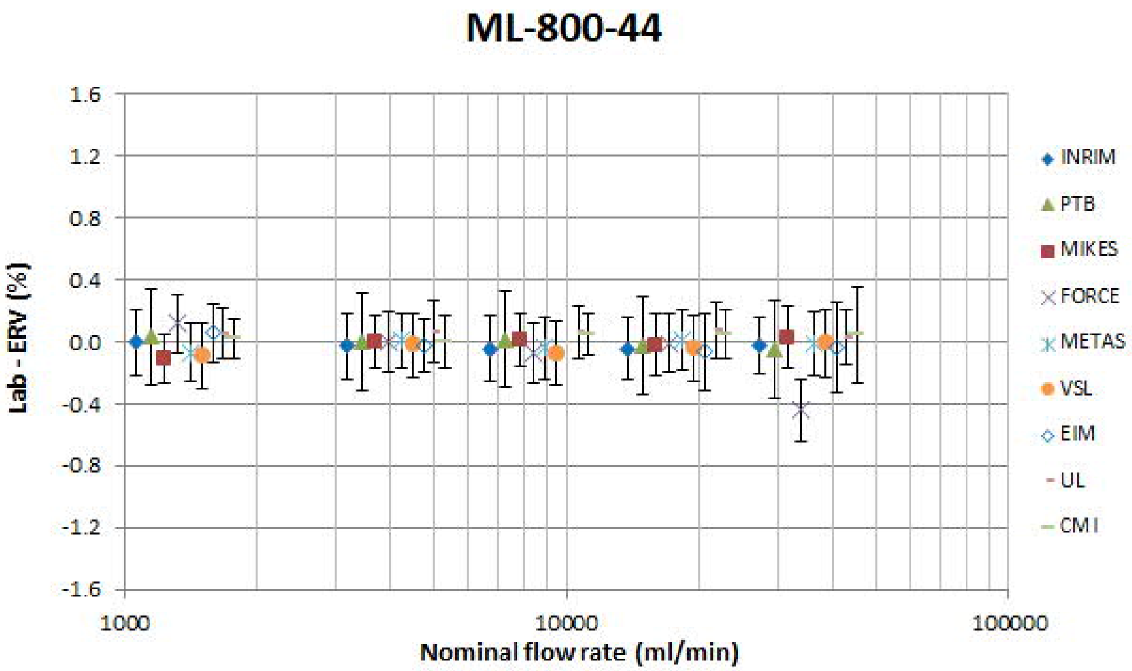

Figure 14. Difference between the ERV and the results of the laboratories for the high flow cell ML-800-44. Error bars show expanded uncertainties (k=2). Note that the x-axis values are shifted for clarity of presentation.

Table 23. Estimates of the difference between the ERVs and the results of the laboratories expressed as relative values (%). Uncertainties are given as expanded uncertainties (*k*=2).

Nominal Flow Rate	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
(std ml/min)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Flow cell:	-10									
5	-0.08 ± 0.46	-0.10 ± 0.55	0.07 ± 0.56		-0.34 ± 0.65	0.03 ± 0.66		0.01 ± 0.52	0.18 ± 0.44	0.16 ± 0.51
10	-0.12 ± 0.30	0.12 ± 0.45	0.01 ± 0.36		-0.56 ± 0.46	-0.12 ± 0.51		0.11 ± 0.33	0.12 ± 0.27	0.17 ± 0.33
20	-0.06 ± 0.28	0.13 ± 0.41	0.02 ± 0.28		-0.27 ± 0.38	-0.10 ± 0.45	0.25 ± 0.33	0.01 ± 0.38	0.04 ± 0.35	0.02 ± 0.37
80	-0.11 ± 0.09	0.03 ± 0.30	0.04 ± 0.17		-0.01 ± 0.33	-0.22 ± 0.41	0.03 ± 0.22	0.07 ± 0.16	0.08 ± 0.12	0.14 ± 0.13
Flow cell:	-24									
80	-0.02 ± 0.19	-0.02 ± 0.37	-0.18 ± 0.35	0.10 ± 0.37	-0.32 ± 0.36	-0.83 ± 0.51	0.42 ± 0.38	0.05 ± 0.16	0.03 ± 0.11	
300	-0.06 ± 0.14	0.03 ± 0.33	-0.10 ± 0.21	0.16 ± 0.24	-0.21 ± 0.23	0.11 ± 0.26	0.29 ± 0.26	-0.02 ± 0.19	0.05 ± 0.16	
600	-0.05 ± 0.10	0.03 ± 0.32	-0.13 ± 0.20	0.18 ± 0.23	-0.17 ± 0.21	0.14 ± 0.24	0.34 ± 0.32	0.02 ± 0.16	0.07 ± 0.11	
1250	-0.03 ± 0.09	0.06 ± 0.31	-0.11 ± 0.18	0.36 ± 0.24	-0.11 ± 0.20	0.13 ± 0.22	0.43 ± 0.54	0.07 ± 0.16	0.06 ± 0.12	
Flow cell:	-44									
1250	0.00 ± 0.21	0.03 ± 0.31	-0.11 ± 0.16	0.12 ± 0.19	-0.07 ± 0.19	-0.09 ± 0.21	0.06 ± 0.19	0.05 ± 0.17	0.02 ± 0.13	
5000	-0.03 ± 0.21	0.00 ± 0.32	0.00 ± 0.17	0.00 ± 0.19	0.01 ± 0.18	-0.02 ± 0.21	-0.02 ± 0.17	0.06 ± 0.20	0.00 ± 0.17	
10000	-0.04 ± 0.21	0.02 ± 0.31	0.01 ± 0.17	-0.07 ± 0.20	-0.04 ± 0.20	-0.07 ± 0.21		0.06 ± 0.17	0.05 ± 0.13	
20000	-0.05 ± 0.20	-0.03 ± 0.31	-0.02 ± 0.20	-0.01 ± 0.19	0.01 ± 0.19	-0.04 ± 0.21	-0.07 ± 0.25	0.07 ± 0.18	0.04 ± 0.16	
30000	-0.03 ± 0.18	-0.05 ± 0.31	0.03 ± 0.20	-0.44 ± 0.20	-0.01 ± 0.20	-0.01 ± 0.22	-0.03 ± 0.29	0.03 ± 0.17	0.05 ± 0.31	

Table 24. ERVs and associated expanded uncertainties (*k*=2) for each participant expressed as relative values (%).

Nominal Flow Rate	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
(std ml/min)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Flow cell:	*-10*									
5	-0.16 ± 0.19	-0.16 ± 0.19	-0.22 ± 0.20		-0.22 ± 0.20	-0.22 ± 0.20		-0.10 ± 0.17	-0.10 ± 0.17	-0.10 ± 0.17
10	-0.05 ± 0.13	-0.05 ± 0.13	-0.04 ± 0.14		-0.04 ± 0.14	-0.04 ± 0.14		-0.06 ± 0.12	-0.06 ± 0.12	-0.06 ± 0.12
20	-0.06 ± 0.12	-0.06 ± 0.12	-0.12 ± 0.12		-0.12 ± 0.12	-0.12 ± 0.12	-0.12 ± 0.12	0.01 ± 0.13	0.01 ± 0.13	0.01 ± 0.13
80	0.02 ± 0.05	0.02 ± 0.05	-0.07 ± 0.05		-0.07 ± 0.05	-0.07 ± 0.05	-0.07 ± 0.05	0.11 ± 0.05	0.11 ± 0.05	0.11 ± 0.05
Flow cell:	*-24*									
80	-0.29 ± 0.08	-0.29 ± 0.08	-0.41 ± 0.11	-0.41 ± 0.11	-0.41 ± 0.11	-0.41 ± 0.11	-0.41 ± 0.11	-0.17 ± 0.04	-0.17 ± 0.04	
300	-0.21 ± 0.07	-0.21 ± 0.07	-0.37 ± 0.07	-0.37 ± 0.07	-0.37 ± 0.07	-0.37 ± 0.07	-0.37 ± 0.07	-0.04 ± 0.06	-0.04 ± 0.06	
600	-0.20 ± 0.05	-0.20 ± 0.05	-0.36 ± 0.06	-0.36 ± 0.06	-0.36 ± 0.06	-0.36 ± 0.06	-0.36 ± 0.06	-0.04 ± 0.04	-0.04 ± 0.04	
1250	-0.26 ± 0.05	-0.26 ± 0.05	-0.42 ± 0.06	-0.42 ± 0.06	-0.42 ± 0.06	-0.42 ± 0.06	-0.42 ± 0.06	-0.11 ± 0.04	-0.11 ± 0.04	
Flow cell:	*-44*									
1250	0.02 ± 0.06	0.02 ± 0.04	0.04 ± 0.06	0.04 ± 0.06	0.04 ± 0.06	0.04 ± 0.06	0.04 ± 0.06	0.00 ± 0.06	0.00 ± 0.06	
5000	-0.03 ± 0.06	-0.03 ± 0.05	-0.01 ± 0.06	-0.01 ± 0.06	-0.01 ± 0.06	-0.01 ± 0.06	-0.01 ± 0.06	-0.05 ± 0.07	-0.05 ± 0.07	
10000	-0.04 ± 0.06	-0.04 ± 0.05	-0.02 ± 0.06	-0.02 ± 0.06	-0.02 ± 0.06	-0.02 ± 0.06		-0.05 ± 0.06	-0.05 ± 0.06	
20000	-0.03 ± 0.06	-0.03 ± 0.05	-0.02 ± 0.06	-0.02 ± 0.06	-0.02 ± 0.06	-0.02 ± 0.06	-0.02 ± 0.06	-0.05 ± 0.07	-0.05 ± 0.07	
30000	-0.03 ± 0.07	-0.03 ± 0.06	-0.05 ± 0.07	-0.05 ± 0.07	-0.05 ± 0.07	-0.05 ± 0.07	-0.05 ± 0.07	0.00 ± 0.07	-0.01 ± 0.07	

9. Conclusion and discussion

9.1 General

The comparison had a rough start as the transfer standards broke down in the very beginning. The instruments were sent for repair, and as a result, the comparison had to be re-started. This time, the comparison was successfully completed, without any significant problems reported by the participants.

Past EURAMET comparisons [4, 5, 6], Molbloc flow standards (sonic nozzles and laminar flow elements) have been used as high-precision transfer standards. This time it was decided to use high-end piston provers, instead. The nominal accuracy of such gas flow meters is similar to the Molblocs. The main reasons for this choice was to gain experience of using such flow meters for inter-comparisons, and to investigate the laboratories competence in calibrating this type of flow meters.

Based on the experience and the results of this comparison, the transfer standards were found suitable for high-level inter-comparisons with some reservations. Special care should be taken when handling and transporting these delicate instruments to avoid damage and to minimize possible shifts in the response. Especially, the low flow cell indicated a change in the response at flow rates below 20 ml/min. To reduce the risks of such an event, the amount of participants in each loop should be reduced, or alternatively intermediate stability measurements should be performed to better characterize and compensate for the shift. Anyway, the uncertainty caused by the transfer standards was in many cases smaller than the participating laboratories calibration uncertainties, and thus it had only a small effect on the overall uncertainty.

The comparison method applied in this project was found successful, and the results can be used for reviewing the CMCs of the participants. Uncertainty estimations carried out by the participants seem to be realistic.

9.2 Identified discrepancies in the results

Generally a good agreement between laboratories was found, with only a few exceptions. It was concluded that the observed discrepancies are in most cases not caused by stability problems of the transfer standards. Discrepant results were identified as results deviating more than the estimated expanded uncertainty (see tables 23 and 25, and figures 12 - 14). Results with normalized error values $|E_n| > 1$ are considered discrepant and highlighted in red in table 25. Results where the standard uncertainty of the transfer standard is larger than the reported measurement uncertainty (k=2) is highlighted in orange. In these cases, the results are inconclusive for evaluating the validity of reported measurement uncertainties. Such results were mainly found for the low flow cell.

Table 25. Normalized error values E_n for each participant. Discrepant results ($|E_n| > 1$) are shown in red and inconclusive results in orange.

Normalized error values E_n $E_n = \Delta E_i / U(\Delta E_i)$										
Nominal Flow Rate	INRIM	PTB	MIKES	FORCE	METAS	VSL	EIM	UL	CMI	LNE
(std ml/min)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Flow cell:	-10									
5	-0.2	-0.2	0.1		-0.5	0.0		0.0	0.4	0.3
10	-0.4	0.3	0.0		-1.2	-0.2		0.3	0.4	0.5
20	-0.2	0.3	0.1		-0.7	-0.2	0.8	0.0	0.1	0.1
80	-1.2	0.1	0.2		0.0	-0.5	0.1	0.4	0.6	1.1
Flow cell:	-24									
80	-0.1	0.0	-0.5	0.3	-0.9	-1.6	1.1	0.3	0.3	
300	-0.4	0.1	-0.4	0.6	-0.9	0.4	1.1	-0.1	0.3	
600	-0.5	0.1	-0.6	0.8	-0.8	0.6	1.1	0.1	0.6	
1250	-0.3	0.2	-0.6	1.5	-0.5	0.6	0.8	0.4	0.5	
Flow cell:	-44									
1250	0.0	0.1	-0.7	0.6	-0.4	-0.4	0.3	0.3	0.2	
5000	-0.1	0.0	0.0	0.0	0.1	-0.1	-0.1	0.3	0.0	
10000	-0.2	0.1	0.1	-0.4	-0.2	-0.4		0.4	0.4	
20000	-0.2	-0.1	-0.1	0.0	0.1	-0.2	-0.3	0.4	0.3	
30000	-0.1	-0.2	0.1	-2.2	-0.1	0.0	-0.1	0.2	0.1	

A detailed description of identified discrepancies is given below:

- INRIM - Discrepant results were found at flow rate 80 ml/min with the low flow cell (-10). The result was, however, well in-line with the rest of the INRIM results with the low flow cell (-10), but due to the very low uncertainty it was classified as discrepant. On the other hand, a good agreement was found at 80 ml/min with the medium flow cell (-24).
- FORCE - Discrepant results were found at flow rate 1250 ml/min with the medium flow cell (-24) and at flow rate 30 000 ml/min with the high flow cell (-44). Interestingly, the results at 1250 ml/min with the high flow cell (-44) was found consistent. The laboratory suspects that the pressure pulsation of the transfer standard might have influenced the results of the primary standard, especially at the higher flow rates, similar to what was observed with the low flow cell (-10). In addition, FORCE did not perform measurement with the low flow cell, because the pulsation induced by the transfer standard piston was found to influence the results of the primary standard. Therefore, FORCE decided not to participate in the comparison of the low flow cell (ML-800-10).
- METAS - A discrepant results was found at flow rate 10 ml/min with the low flow cell (-10).
- VSL - The results at flow rate 80 ml/min with the medium flow cell (-24) was found discrepant. However, a good agreement was found with the low flow cell (-10) at the same flow rate.
- EIM - Slightly discrepant results were found at flow rates 80 ml/min, 300 ml/min and 600 ml/min with the medium flow cell (-24). Again, at flow rate 80 ml/min the results with the low flow cell (-10) show a good agreement. Discussion on redundant measurements performed with different flow cells is given in the next section.
- LNE - The results at flow rate 80 ml/min with the low flow cell (-10) was found slightly discrepant. As with INRIM, the result was well in-line with the rest of the LNE results, but due to the very low uncertainty it was classified as discrepant. LNE performed

measurement only with the low flow cell (-10), and therefore a comparison at redundant measurement point with the medium flow cell (-24) could not be made.

9.3 Discussion

Redundant measurement were performed at 80 ml/min and 1250 ml/min in order to investigate the influence of the transfer standard on the measurement results. Clear differences in the results for the different flow cells were found for many laboratories in loop 1, whereas the results were consistent for laboratories in loop 2 (see table 23 and figures 12, 13 and 14). At flow rate 80 ml/min MIKES, METAS, VSL and EIM got clearly different results with the low (-10) and medium flow cells (-24). Similar findings were made at flow rate 1250 ml/min with the medium (-24) and high flow cells (-44), but this time only FORCE, VSL and EIM got inconsistent results.

These findings are discussed in more detail below for each laboratory:

- EIM - At 80 ml/min and 1250 ml/min the result with the medium flow cell (-24) are inconsistent with the other laboratories, whereas results with the low flow cell (-10) at 80 ml/min and with the high flow cell (-44) at 1250 ml/min show good agreement. Comparing the results of EIM for all flow cells, it seems that there is an offset of +0.3% to +0.4 % in the results of the medium flow cell (-24).

- VSL - The result at flow rate 80 ml/min with the medium flow cell (-24) was found discrepant and inconsistent with the rest of the VSL results. At 1250 ml/min there is a clear difference in the VSL results of the medium (-24) and high flow cell (-44). Similar to the EIM results, it seems that, apart from the 80 ml/min measurement point, there is an offset of +0.2 % to +0.3 % in the results of the medium flow cell (-24) compared to the other flow cells. In this case, however, the results with the medium flow cell (-24) were found to agree within estimated expanded uncertainties, except for the 80 ml/min measurement point.

- METAS - The result at 80 ml/min with the medium flow cell (-24) was lower than the results of other laboratories but still within estimated expanded uncertainties, while the result at 80 ml/min with the low flow cell (-10) shows good agreement. However, all METAS results, also the discrepant result at 10 ml/min with the low flow cell (-10), are perfectly concordant with the INRIM2 results. This could lead to the interpretation, that METAS was already subject to the equal shift of medium and low flow cells of the transfer standard as measured by INRIM at the end of the loop (see figures 4, 6 and 8). Therefore, the discrepancies found may not be real but caused by the shift of the transfer standard.

- FORCE - The results at 1250 ml/min with the medium flow cell was found discrepant, while the results at the same flow rate with the high flow cell (-44) agree with the other laboratories. As with EIM and VSL, there seems to be an offset of about +0.2 % in the results of the medium flow cell.

- MIKES - At flow rate 80 ml/min there is a deviation in the results of the low (-10) and medium flow cells (-24). Also in the MIKES results, a small offset of about -0.1 % can be seen in the medium flow cell (-24) results when comparing to the other flow cells. This time, however, the offset is opposite to what was observed in the results of EIM, VSL and FORCE. Anyhow, the deviation is rather small and all results were found to agree within estimated expanded uncertainties.

The spread of the laboratories results was larger for the low (-10) and medium flow cells (-24) than for the high flow cell (-44). Also the instability of these flow cells was larger, especially in the lower end of the measurement range. It can be clearly seen from the results of the low flow cells (-10) (figures 6 and 7) that the spread of the results is larger at low flow rates where the instability was found larger. However, a clear trend in response cannot be seen from the results (laboratories are placed in measurement order in the figures 6 to 11). The measured shift in the response of the transfer standards is probably also to some extent influenced by random effects caused by unideal reproducibility of the flow cell indications.

Initial tests on the transfer standards and previous studies [5] indicate that piston prover measurements are sensitive to the heat exchange effect that results from differences between the piston-cylinder temperature and the gas temperature. This effect is larger for the low (-10) and medium (-24) flow cells that require long time for temperature stabilization, because of small gas flow rates. Due to these effects, a long stabilization time of 180 min was included in the measurement protocol. However, if the surrounding temperature conditions are not stable enough, such temperature differences could occur during measurement even with long stabilization period; e.g., the cylinder with a high thermal capacity is stabilized at different temperature than the inlet gas flow, which temperature mainly depends on the temperature of the connection lines. Such temperature related effects might explain to some extent the observed spread of result for the low (-10) and medium (-24) flow cells.

The reasons for the constant offset in the results of some laboratories for the medium flow cell (-24) remains unclear. As this observation was only made for laboratories in loop 1, the possibility of an instrument malfunction cannot be completely ruled out. However, this seems unlikely based on the measurements performed after the comparison. An alternative explanation for the deviations could be an interference between the calibration system and the transfer standard. Launching the piston introduces a pressure pulse that might influence the flow stability and thus the operation of the calibration system depending on the design. Anyhow, further investigations are necessary to understand the reasons for the deviations.

This comparison provided valuable experience of using piston provers as high precision transfer standards. Such an extensive inter-comparison using piston provers has not been done before. As such, it gives a good overview on the capabilities of European laboratories of calibrating such instruments that are commonly used in industrial calibration laboratories worldwide.

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Appendix 1: Detailed information of participants

Table A1. Updated contact information

Name of the laboratory	Country	Address	Contact	E-mail
Istituto Nazionale di Ricerca Metrologica (INRIM)	Italy	Strada delle Cacce, 91, I-10135 Torino	Pier Giorgio Spazzini	piergiorgio.spazzini@polito.it
Physikalisch-Technische Bundesanstalt (PTB)	Germany	Bundesallee 100, 38116 Braunschweig	Rainer Kramer	rainer.kramer@ptb.de
VTT Technical Research Centre of Finland Ltd, Centre for Metrology MIKES (MIKES)	Finland	Tekniikantie 1, 02150 Espoo	Richard Högström	richard.hogstrom@vtt.fi
FORCE Technology (FORCE)	Denmark	Navervej 1, 6600 Vejen	Jesper Busk	jrb@force.dk
Federal Institute of Metrology (METAS)	Switzerland	Lindenweg 50, CH-3003 Bern-Wabern	Bernhard Niederhauser	bernhard.niederhauser@metas.ch
Hellenic Institute of Metrology (EIM)	Greece	Industrial Area of Thessaloniki, Block 45, GR 57 022, Sindos, Thessaloniki	Zoe Metaxiotou	zoe@eim.gr
VSL (VSL)	Netherlands	Thijsseweg 11, 2629 JA Delft	Gerard Blom	gblom@vsl.nl
Central Office of Measures (GUM)	Poland	ul. Elektoralna 2, 00-139 Warszawa	Arkadiusz Zadworny	a.zadworny@gum.gov.pl

University of Ljubljana (UL)	Slovenia	Askerceva 6, SI-1000 Ljubljana	Joze Kutin	joze.kutin@fs.uni-lj.si
Lithuanian Energy Institute (LEI)	Lithuania	Breslaujos str. 3, 44403 Kaunas	Arūnas Stankevičius	arunas.stankevicius@lei.lt
Czech Metrology Institute (CMI)	Czech Republic	Okruzni 31, Brno 638 00	Zdenek Krajicek	zkrajicek@cmi.cz
Laboratoire national de métrologie et d'essais (LNE)	France	1, rue Gaston Boissier, 75724 Paris Cedex 15	Jean Barbe	jean.barbe@lne.fr

Table A2. Detailed information on the measurement standards used by the participants in EURAMET1325

Name of the laboratory	**Country**	**Type of standards**	**Identification of the standard**
Istituto Nazionale di Ricerca Metrologica (INRIM)	Italy	Piston prover (MICROGas) Bell prover (BELLGas)	MICROGas test rig: used for calibrating the low (ML-800-10) and medium flow cells (ML-800-24). BELLGas test rig: used for calibrating the high flow cells (ML-800-44).
Physikalisch-Technische Bundesanstalt (PTB)	Germany	3 mercury sealed piston provers with interferomertric distance/velocity measurement	The flow cells were calibrated by critical nozzles installed upstream to the flow cells. The critical nozzles were recalibrated with the mercury sealed primary standard meter immediately before the calibration. By constant pressure and temperature upstream to the critical nozzles the flow rate was stabilised during the calibration of the flow cells and the comparison with the mercury sealed piston prover.

VTT Technical Research Centre of Finland Ltd, Centre for Metrology MIKES (MIKES)	Finland	Dynamic gravimetric weighing (DWS1 and DWS2)	DWS1: used for calibrating flow rates up to 300 ml/min. DWS2: used for calibrating flow rates above 300 ml/min
FORCE Technology (FORCE)	Denmark	Piston prover (Cal-bench no C02-006)	Cal-bench with flow tubes GT001, GT002, GT003.
Federal Institute of Metrology (METAS)	Switzerland	Piston prover	Three flow tubes with following ranges: 3 to 180 ml/min No. 3 (small) used for cell -10 20 to 2000 ml/min No. 2 (medium) used for cell -24 200 to 30000 ml/min No. 1 (large) used for cell -44
Hellenic Institute of Metrology (EIM)	Greece	Piston prover (Brooks VOL-U-METER, 2 units) Sierra Bell Prover	Brooks 1064: used for flow rates 20 - 600 ml/min Brooks 1066: used for flow rates 1250 - 5000 ml/min Bell Prover: used for flow rates 20 000 - 30 000 ml/min
VSL (VSL)	Netherlands	Piston prover (mercury sealed)	Tube 1 (range 3.7 to 45 ml/min): used for cell 10 and cell -24 Tube 2 (range 45 to 385 ml/min): used for cell -24 Tube 3 (range 440 to 3500 ml/min): used for cell -44 Tube 4 (range 5000 to 13000 ml/min): used for cell -44
University of Ljubljana (UL)	Slovenia	Piston prover (3 flow cells)	Cell A: used for calibrating the low flow cell (ML-800-10). Cell B: used for calibrating the medium flow cell (ML-800-24).

			Cell C: used for calibrating the high flow cell (ML-800-44).
Czech Metrology Institute (CMI)	Czech Republic	Dynamic gravimetric flow standard GFS DHI Fluke upgraded for operation under vacuum and hermetic modes	GFS used for calibrating all flow rates from 5 ml/min to 30 000 ml/min. Except for the 30 000 ml/min calibration point which was measured using a molbloc-S sonic nozzle traceable to Gravimetric Flow Standard in vacuum.
Laboratoire national de métrologie et d'essais (LNE)	France	Set of 2 Molblocs calibrated with the dynamic gravimetric method	1E1 : 5 and 10 ml/min 1E2 : 20 and 80 ml/min

Appendix 2: Technical protocol

EURAMET PROJECT 1325

Comparison for gas flow range 5 ml/min to 30 l/min

Technical Protocol

Version 5.0 (17 May 2016)

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1. INTRODUCTION

At the EURAMET TC-F meeting at VSL in Delft on 12th to 14th of March 2013 it was proposed by MIKES to initiate an inter-comparison for low gas flows in the range 5 ml/min to 30 l/min. The comparison was motivated by the fact that the last wider comparison in the low flow range was performed in years 2005 to 2007, almost ten years ago.

Based on discussions during and after the meeting, it was decided to initiate such a comparison. Twelve participants expressed their interest in participating and MIKES volunteered to coordinate the comparison and act as a pilot. The comparison is registered as EURAMET project number 1325.

The aim of the project is to compare measurement capabilities of the participating laboratories in the gas flow range 5 ml/min to 30 l/min. The comparison will be carried out using commercially available piston provers as high precision transfer standards. Due to the high amount of participants the comparison will be carried out in two parallel loops, with one circulating transfer standard in each loop. MIKES will perform initial tests on the transfer standards and based on this experience the measurement protocol (this document) will be refined before the actual comparison measurements.

This document serves as the technical protocol for the comparison and includes e.g. specific instructions for calibrating the transfer standards and timetables for a successful and timely completion of the project.

2. PARTICIPANTS

There are twelve participants in the comparison, as showed in table 1. The details of all participants are reported in Appendix 1.

Table 1 - NMIs participating in the comparison.

Participating NMI		**Country**
MIKES	Centre for Metrology and Accreditation	Finland
CMI	Czech Metrology Institute	Czech Republic
UL	University of Ljubljana	Slovenia
PTB	Physikalisch-Technische Bundesanstalt	Germany
FORCE	FORCE Technology	Denmark
INRIM	Istituto Nazionale di Ricerca Metrologica	Italy
METAS	Federal Institute of Metrology METAS	Switzerland
VSL	VSL	Netherlands
LNE	Laboratoire national de métrologie et d'essais	France
JV	Justervesenet - Norwegian Metrology Service	Norway
LEI	Lithuanian Energy Institute	Lithuania
EIM	Hellenic Institute of Metrology	Greece
GUM	Central Office of Measures / Glówny Urzad Miar	Poland

MIKES is the coordinator and pilot of the comparison and supplies the transfer standards.

3. METHOD OF COMPARISON

The purpose of the comparison is to compare the volumetric gas flow measurements of the participating NMIs in the range from 5 ml/min to 30 l/min using two transfer standards. The instruments loaned by the manufacturer will be thoroughly tested at the pilot laboratory before actual comparison measurements. Nitrogen (grade 5.0 with purity at least 99.999 %) should be used as the calibration gas. The comparison is carried out in two parallel loops (see Table 4), such that one transfer standard circulates in each loop. Before measurements in any other laboratory, MIKES as the pilot will test both transfer. INRIM and PTB will perform calibrations with both transfer standards and thus establish a link between the loops. After the actual comparison measurements, INRIM and PTB will perform additional measurements on the transfer standards of loops 1 and 2, respectively, in order to assess the long-term stability of the standards including stability of pressure and temperature sensors.

4. HANDLING AND TRANSPORT

The transfer standard is supplied with its shipping box, which is sufficiently robust to ensure safe transportation. The transfer standard should be opened by authorised persons upon receipt at the laboratory.

On receipt:

- Inform the sending laboratory, next laboratory in the chain and the pilot laboratory to confirm receipt. Inform the pilot laboratory and the next laboratory of your expected measurement schedule to confirm planned dispatch time
- check the package casing for damage and on opening the package check the contents against the packing list. Check the transfer standard for damage. Report any damage or missing items to the pilot laboratory and the previous laboratory.

On completion:

- Pack all items (including manuals) into the shipping box in a similar way as received
- check the contents against the packing list
- check that all paperwork is available to the carrier
- inform the next laboratory and the pilot laboratory on the day of dispatch.

For shipment:

- Co-ordinate the shipping with the recipient: Obtain the recipient's exact shipping address. The sending laboratory should provide the recipient with the carrier, the exact travel mode, and the estimated time of arrival
- the recipient should be aware of any customs issues in their country that may cause problems at the customs
- the shipping laboratory must be aware of any national regulations covering the travelling standard to be exported
- mark the shipping box with "FRAGILE SCIENTIFIC INSTRUMENTS", “TO BE OPENED ONLY BY LABORATORY STAFF”
- each laboratory is responsible for the cost of shipping to the next participant including any customs charges and insurance. The insurance should be sufficient to cover the costs of the travelling standards (**about 15 000 Euro per transfer standard**) and any damages that could occur
- **for shipment to METAS and JV only**: The travelling standard will be accompanied by a customs ATA Carnet for temporary import/export and uniquely identifying the instrument.

Report:

- Complete within 3 weeks of measurements and send the results to the pilot laboratory.

Timing:

- Allow 3 weeks for measurements and 1 week for transport to the next laboratory.

4.1 In the case of failure of the transfer standard

If a participant suspects failure of the transfer standard it shall be reported immediately to the pilot laboratory. The pilot laboratory shall decide if repair is required and make arrangements for any repairs. The total costs for repairing (including shipping) will be shared equally among all participants.

4.2 In the case of an unexpected delay at a participant laboratory

With their agreement the laboratories will be allotted a time slot (see section 9), within the schedule, to conduct the comparison measurements. If a laboratory is unable to keep to the schedule, then it will be allowed to perform the measurements at the end of the comparison schedule, but it will be responsible for any additional transport costs.

Inform the pilot laboratory immediately if a problem or delay occurs.

5. DESCRIPTION OF THE TRANSFER STANDARD

The travelling standards are commercially available BIOS Met Lab ML-800 equipped with three measuring cells covering the whole gas flow range of the comparison. The travelling standards serial numbers are shown in table 2. The operating manuals will accompany the transfer standard. A complete packing list of all items included with the transfer standard is given in appendix 2.

Table 2 – Transfer standards used for comparison measurements

LOOP 1 instrument		
Model	Unit	Serial number
ML-800-B	Base	147457
ML-800-10	Measurement cell	135207
ML-800-24	Measurement cell	134909
ML-800-44	Measurement cell	135198
LOOP 2 instrument		
Model	Unit	Serial number
ML-800-B	Base	147461
ML-800-10	Measurement cell	135208
ML-800-24	Measurement cell	134910
ML-800-44	Measurement cell	135199

The instrument type is based on the positive displacement principle, in which the volumetric flow is determined by measuring the time it takes for the gas flow to “displace” a graphite piston through a glass cylinder with known dimensions. By means of internal temperature and pressure measurements, actual flow readings are converted to standardized flow readings (0 °C and 101325 Pa). There is a small clearance between the piston and the cylinder to allow frictionless motion of the piston. This causes a small internal leak, which is corrected by the transfer standard. The leak rate depends on the viscosity of the calibration gas and therefore comparison measurements should preferably be performed using the same gas, in this case nitrogen (at least grade 5.0 and 99.999% purity).

Figure 2 – Met Lab ML-800 travelling standard

6. MEASUREMENT PROCESS

All participants should refer to the operating manuals for instructions of use of the travelling standard. Participant laboratories may perform any initial checks of the operation of the transfer standard that would be performed for a normal calibration. In case of an unexpected instrument failure, the coordinator should be informed as soon as possible.

The gas flow is connected to the transfer standard inlet using Swagelok ¼” ID compression fittings. Flow direction is depicted on top of the measurement cell with an arrow pointing in the flow direction. **The flow cell should not be pressurized since it might result in damaging the instrument**. This can be easily avoided by leaving the outlet open to atmosphere. The instrument is able to measure both actual volumetric flow and standard flow. In this comparison, **calibrations are performed in terms of standard readings at 0 °C and 101325 Pa.** The instruments are pre-set to display standard readings at the aforementioned conditions and therefore no configuration of the settings is necessary.

The calibration points of the comparison and the associated transfer standard flow cells to be used are shown in table 3. Participants are only presumed to measure at points included in their CMCs. However, measurements at other points are strongly encouraged to support future CMCs entries. The flow reading indicated by the transfer standard should be matched as exactly as possible (at least within ±3 %) to the nominal flows in table 3 to allow good comparability between participants results. The flow ranges of the transfer standard flow cells are partially overlapping, which allows checking the consistency of the measurements results obtained with different flow cells at the same nominal flow. Any drift in a flow cell can therefore be detected and taken into account when evaluating the final comparison results.

Table 3 – Calibration points and corresponding flow cells to be used as transfer standard.

Nominal flow rate (ml/min)	Transfer standard flow cell
5	ML-800-10
10	ML-800-10
20	ML-800-10
80	ML-800-10, ML-800-24[1]
300	ML-800-24
600	ML-800-24
1250	ML-800-24, ML-800-44[1]
5000	ML-800-44
10000	ML-800-44
20000	ML-800-44
30000	ML-800-44

[1] Measurements are performed with both cells for consistency checking

The transfer standard should be allowed to stabilize to laboratory conditions for at least 24 hours before starting measurements. After this, the transfer standard pressure and temperature sensor readings are checked against participant’s temperature measurement at the transfer standard and laboratory ambient pressure (no flow through transfer standard). This allows considering any drifts in temperature and pressure sensors when evaluating the comparison results.

Before starting actual comparison measurements, it is necessary to allow the flow cell temperature to settle by passing gas flow through the flow cell and continuously launching the piston for 180 min (referred to in the manual as continuous auto-read mode). This initial “heating” is necessary for achieving consistent and comparable results, especially in the lower flow range of the measurement cells. When changing the flow rate, three minutes of continuous measurements is sufficient for reaching a stable temperature. For each nominal calibration point, four separate calibrations are performed. For a single calibration at a nominal point, the flow rate of the transfer standard is obtained as the mean of at least ten (10) consecutive single readings. As supporting measurements, temperature and pressure readings of the transfer standard are recorded for each measurement.

7. REPORTING MEASUREMENT RESULTS

The following data shall be recorded and reported:

1. A description and identification of the laboratory flow standard and traceability including an uncertainty budget of the flow standard. An estimate of the connection tubing (between reference and transfer standard) inner volume as this might influence the results.
2. A short description of the applied calibration method including a schematic drawing indicating the position of the transfer standard.
3. Prior to any calibration measurements for each flow cell: Temperature and pressure indicated by transfer standard and temperature at the transfer standard and laboratory pressure.
4. Required data for each measurement (four per calibration point):
    a. Mean volume flow of transfer standard at standard conditions.
    b. Mean volume flow at standard conditions realized by laboratory flow standard and the associated standard uncertainty.
    c. Standard deviation of transfer standard flow readings.
    d. Number of transfer standard flow readings contributing to the mean value.
    e. Temperature and pressure readings indicated by the transfer standard.
    f. Laboratory temperature, pressure and relative humidity.

An excel spreadsheet will be provided to the participants for recording and reporting results.

Participants shall report their measurement results to the coordinator within three weeks of completion of measurements. If not reported on time as requested, the laboratory results may be excluded from the comparison.

8. ANALYSIS OF THE COMPARISON RESULTS

The coordinator will be responsible for analysing the comparison results.

The parameter to be compared is the difference found at each laboratory between the transfer standard and the laboratory flow standard and it is calculated as:

$$E = \frac{\dot{V}_t - \dot{V}_r}{\dot{V}_r} \times 100, \tag{1}$$

where $\dot{V}_t$ and $\dot{V}_r$ is the volumetric flow of the transfer standard and laboratory flow standard, respectively.

The uncertainty of the comparison results will be derived from:

- the quoted uncertainty of the flow rate realisation
- the estimated uncertainty from the standard deviation of four flow measurements with the transfer standard
- the estimated uncertainty from the short-term stability of the transfer standard at the time of measurements derived from the standard deviation of transfer standard flow readings
- the estimated uncertainty due to any drift of the travelling standard in the comparison period
- any other components of uncertainty that might be significant, such as stability of temperature and pressure sensors of the transfer standard

The outputs of the comparison are expected to be:

- differences between the realisations of volume flow rate of the participants at each calibration point evaluated with reference to a comparison reference value calculated as the uncertainty weighted mean
- estimates of bilateral equivalence between every pair of participants at each calibration point.

9. TENTATIVE SCHEDULE OF COMPARISON

Each participant will be allowed three weeks for performing the comparison measurements, after which the traveling standard is shipped to the next institute (see table 4). One week is reserved for shipping of the transfer standard to the next institute. After all institutes in both loops have performed their measurements, the travelling standards will return to INRIM and PTB for evaluation of possible drifts during the comparison. Based on the data reported by the participants, the comparison results will be evaluated and a comparison report will be prepared by the co-ordinator and circulated to the participants by the end of May 2017.

Table 4 – Tentative schedule for comparison measurements.

Date	**Loop 1**	**Loop 2**	**TASK**
April 2016 – May/June 2016	INRIM		Comparison measurements
June 2016 – July 2016	PTB		Comparison measurements
September 2016	EIM	VSL	Comparison measurements
October 2016	FORCE	GUM	Comparison measurements
November 2016	MIKES	UL	Comparison measurements
December 2016		LEI	Comparison measurements
January 2017	METAS	CMI	Comparison measurements
February 2017	JV	LNE	Comparison measurements
March 2017	INRIM	PTB	Evaluation of possible drifts in transfer standards
May 2017	MIKES		Draft A of comparison report

APPENDIX 1. DETAILS OF PARTICIPATING NMIs

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APPENDIX 2. PACKING LIST OF TRANSFER STANDARD

The contents of the transfer standard packages for loops 1 and 2 are listed in tables A1 and A2, respectively

Table A1 – Loop 1 transfer standard package content

Item number	Description	Model	Serial number
1	Base	ML-800-B	147457
2	Low flow cell	ML-800-10	135207
3	Medium flow cell	ML-800-24	134909
4	High flow cell	ML-800-44	135198
5	RS-232 Serial cable		
6	USB-cable		
7	Power supply		
8	Power supply adapter		
9	ML-800 user manual		
10	Serial communication manuals		
11	Additional instruction for debug and handling		
12	Certificate of calibration		

Table A2 – Loop 2 transfer standard package content

Item number	Description	Model	Serial number
1	Base	ML-800-B	147461
2	Low flow cell	ML-800-10	135208
3	Medium flow cell	ML-800-24	134910
4	High flow cell	ML-800-44	135199
5	RS-232 Serial cable		
6	USB-cable		
7	Power supply		
8	Power supply adapter		
9	ML-800 user manual		
10	Serial communication manuals		
11	Additional instruction for debug and handling		
12	Certificate of calibration		

Appendix 3: Results reported by the participants

INRIM loop1 results

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
19.84	97.987	19.96	97.978

COMPARISON MEASUREMENTS

Flow cell: *-10 (S/N: 135207)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	19.05.2016	19.903	98034	54	20.462	98.1312	5.01	0.00	10	1	5.0296	0.0011
5	2	19.05.2016	19.907	98020	54	20.558	98.1188	5.01	0.00	10	2	5.0207	0.0011
5	3	19.05.2016	19.902	98016	54	20.554	98.1191	5.01	0.00	10	3	5.0241	0.0012
5	4	19.05.2016	19.917	98003	54	20.596	98.1073	5.00	0.00	10	4	5.0182	0.0014
							Average=	5.01			Average=	5.02	
Change Flow Rate						Stabilization 3 minutes							
10	1	19.05.2016	19.908	98028	54	20.49	98.1272	10.01	0.01	10	1	10.023	0.002
10	2	19.05.2016	19.906	98023	54	20.538	98.1227	9.99	0.00	10	2	10.018	0.002
10	3	19.05.2016	19.915	98018	54	20.55	98.1184	9.99	0.00	10	3	10.010	0.002
10	4	19.05.2016	19.912	97998	54	20.596	98.0985	9.99	0.00	10	4	10.007	0.002
							Average=	10.00			Average=	10.01	
Change Flow Rate						Stabilization 3 minutes							
20	1	19.05.2016	19.912	98021	54	20.504	98.1246	19.99	0.00	10	1	20.017	0.004
20	2	19.05.2016	19.910	98025	54	20.522	98.1263	19.96	0.00	10	2	20.001	0.004
20	3	19.05.2016	19.910	98018	54	20.548	98.1153	19.97	0.00	10	3	19.998	0.005
20	4	19.05.2016	19.914	98012	54	20.588	98.1122	19.95	0.01	10	4	19.980	0.004
							Average=	19.97			Average=	20.00	
Change Flow Rate						Stabilization 3 minutes							
80	1	19.05.2016	19.905	98023	54	20.514	98.1325	79.84	0.02	10	1	80.011	0.017
80	2	19.05.2016	19.911	98020	54	20.516	98.1261	79.84	0.03	10	2	79.945	0.017
80	3	19.05.2016	19.911	98016	54	20.56	98.1271	79.80	0.03	10	3	79.908	0.017
80	4	19.05.2016	19.913	98012	54	20.578	98.1183	79.79	0.01	10	4	79.893	0.017
							Average=	79.82			Average=	79.94	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
19.54	97.049	19.98	97.045

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134909)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	12.05.2016	19.919	97167	59.5	20.658	97.2741	79.54	0.02	10	1	79.893	0.013
80	2	12.05.2016	19.921	97148	59.5	20.78	97.2549	79.40	0.02	10	2	79.755	0.013
80	3	12.05.2016	19.918	97135	59.5	20.776	97.2439	79.41	0.02	10	3	79.745	0.014
80	4	12.05.2016	19.926	97099	59.5	20.878	97.206	79.30	0.01	10	4	79.664	0.013
							Average=	79.41			Average=	79.76	
Change Flow Rate						Stabilization 3 minutes							
300	1	12.05.2016	19.920	97166	59.5	20.684	97.2968	298.17	0.04	10	1	299.45	0.05
300	2	12.05.2016	19.927	97155	59.5	20.726	97.2842	298.63	0.03	10	2	299.97	0.05
300	3	12.05.2016	19.920	97122	59.5	20.782	97.2519	298.79	0.02	10	3	300.12	0.05
300	4	12.05.2016	19.927	97107	59.5	20.86	97.2355	298.58	0.03	10	4	299.80	0.05
							Average=	298.54			Average=	299.84	
Change Flow Rate						Stabilization 3 minutes							
600	1	12.05.2016	19.917	97166	59.5	20.68	97.3246	596.42	0.04	10	1	598.92	0.10
600	2	12.05.2016	19.918	97160	59.5	20.706	97.3179	595.99	0.05	10	2	598.64	0.10
600	3	12.05.2016	19.918	97121	59.5	20.782	97.2787	596.39	0.05	10	3	598.90	0.10
600	4	12.05.2016	19.923	97106	59.5	20.832	97.2656	596.22	0.04	10	4	598.81	0.10
							Average=	596.25			Average=	598.82	
Change Flow Rate						Stabilization 3 minutes							
1250	1	12.05.2016	19.918	97163	59.5	20.668	97.4172	1245.09	0.14	10	1	1250.73	0.20
1250	2	12.05.2016	19.923	97162	59.5	20.682	97.4153	1244.60	0.13	10	2	1250.38	0.20
1250	3	12.05.2016	19.917	97118	59.5	20.778	97.3742	1245.11	0.13	10	3	1250.65	0.20
1250	4	12.05.2016	19.922	97113	59.5	20.802	97.3702	1245.18	0.04	10	4	1250.64	0.20
							Average=	1245.00			Average=	1250.60	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
19.9	98.422	19.96	98.411

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135198)*			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(Pa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	25.05.2016	19.685	98563	50.5	20.477	98.7117	1247.4	0.5	80.000	1	1246.8	1.1
1250	2	25.05.2016	19.720	98562	50.5	20.784	98.7119	1237.5	2.2	70.000	2	1237.8	1.2
1250	3	25.05.2016	19.745	98567	50.5	20.738	98.7189	1242.8	1.1	70.000	3	1243.6	1.2
1250	4	25.05.2016	19.750	98555	50.5	20.843	98.7103	1236.2	2.6	70.000	4	1235.3	1.2
							Average=	**1240.97**			Average=	**1240.88**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	25.05.2016	19.685	98563	50.5	20.816	98.7363	5005.3	3.3	60	1	5009.4	4.6
5000	2	25.05.2016	19.700	98563	50.5	20.944	98.7411	4972.3	1.6	50	2	4974.1	4.6
5000	3	25.05.2016	19.715	98561	50.5	20.824	98.7398	5008.2	2.5	60	3	5008.1	4.5
5000	4	25.05.2016	19.740	98555	50.5	21.040	98.7370	4969.9	3.0	60	4	4970.7	4.6
							Average=	**4988.91**			Average=	**4990.57**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	25.05.2016	19.695	98557	50.5	21.156	98.7945	10009.7	3.4	50	1	10022.3	8.8
10000	2	25.05.2016	19.695	98562	50.5	21.050	98.7958	9950.2	5.5	40	2	9956.1	9.2
10000	3	25.05.2016	19.695	98557	50.5	21.179	98.8058	10001.1	5.0	40	3	10009.0	9.4
10000	4	25.05.2016	19.715	98550	50.5	21.101	98.7762	9951.0	4.9	40	4	9951.7	9.3
							Average=	**9978.01**			Average=	**9984.79**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	25.05.2016	19.680	98561	50.5	21.255	98.9757	19999.9	9.7	30	1	20013.0	17.9
20000	2	25.05.2016	19.695	98558	50.5	21.105	98.9910	19926.4	9.5	30	2	19942.7	17.6
20000	3	25.05.2016	19.695	98557	50.5	21.215	99.0073	20006.8	11.1	30	3	20014.7	17.7
20000	4	25.05.2016	19.710	98551	50.5	21.116	99.0150	19917.4	11.2	30	4	19916.9	17.4
							Average=	**19962.62**			Average=	**19971.85**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	25.05.2016	19.685	98559	50.5	21.162	99.1954	29989.9	17.5	30	1	30016.2	22.0
30000	2	25.05.2016	19.695	98556	50.5	21.121	99.2060	29947.1	14.6	20	2	29963.6	20.9
30000	3	25.05.2016	19.700	98558	50.5	21.161	99.2282	30008.6	19.5	30	3	29998.2	21.3
30000	4	25.05.2016	19.705	98551	50.5	21.103	99.2151	29945.9	18.6	30	4	29960.5	21.6
End of measurements							Average=	**29972.86**			Average=	**29984.63**	

INRIM loop2 results

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
19.84	98.768	20.14	98.79

COMPARISON MEASUREMENTS

Flow cell: -10 (S/N: 135208)

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	18.05.2016	19.897	98743	50.5	20.814	98.8859	5.04	0.00	10	1	5.0489	0.0011
5	2	18.05.2016	19.908	98704	50.5	20.836	98.8446	5.02	0.00	10	2	5.0279	0.0012
5	3	18.05.2016	19.906	98683	50.5	20.79	98.8239	5.01	0.00	10	3	5.0221	0.0014
5	4	18.05.2016	19.909	98613	50.5	20.738	98.7553	5.01	0.00	10	4	5.0199	0.0012
							Average=	**5.02**			Average=	**5.03**	
Change Flow Rate						Stabilization 3 minutes							
10	1	18.05.2016	19.902	98742	50.5	20.84	98.884	10.03	0.01	10	1	10.040	0.002
10	2	18.05.2016	19.901	98715	50.5	20.884	98.8581	10.01	0.00	10	2	10.028	0.002
10	3	18.05.2016	19.908	98661	50.5	20.76	98.8052	10.00	0.01	10	3	10.012	0.002
10	4	18.05.2016	19.911	98630	50.5	20.754	98.7747	9.99	0.01	10	4	10.008	0.002
							Average=	**10.01**			Average=	**10.02**	
Change Flow Rate						Stabilization 3 minutes							
20	1	18.05.2016	19.902	98733	50.5	20.844	98.8752	20.02	0.01	10	1	20.038	0.005
20	2	18.05.2016	19.908	98720	50.5	20.89	98.8626	19.98	0.01	10	2	19.995	0.004
20	3	18.05.2016	19.915	98654	50.5	20.76	98.8017	19.99	0.00	10	3	19.999	0.004
20	4	18.05.2016	19.906	98640	50.5	20.76	98.7883	19.96	0.01	10	4	19.984	0.005
							Average=	**19.99**			Average=	**20.00**	
Change Flow Rate						Stabilization 3 minutes							
80	1	18.05.2016	19.901	98724	50.5	20.86	98.8755	79.90	0.01	10	1	79.961	0.016
80	2	18.05.2016	19.901	98722	50.5	20.874	98.8725	79.88	0.01	10	2	79.941	0.017
80	3	18.05.2016	19.909	98652	50.5	20.764	98.8076	79.92	0.02	10	3	79.899	0.017
80	4	18.05.2016	19.909	98646	50.5	20.76	98.8023	79.87	0.01	10	4	79.870	0.017
							Average=	**79.90**			Average=	**79.92**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
19.67	98.795	20.42	98.818

COMPARISON MEASUREMENTS

Flow cell: ***-24 (S/N: 134910)***

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	17.05.2016	19.904	98942	45.8	20.468	99.0871	80.433	0.02	10	1	80.600	0.013
80	2	17.05.2016	19.899	98931	45.8	20.616	99.0752	80.451	0.03	10	2	80.603	0.013
80	3	17.05.2016	19.899	98928	45.8	20.634	99.0723	80.481	0.02	10	3	80.595	0.013
80	4	17.05.2016	19.904	98894	45.8	20.748	99.0397	80.027	0.02	10	4	80.184	0.013
							Average=	**80.35**			Average=	**80.50**	
Change Flow Rate						Stabilization 3 minutes							
300	1	17.05.2016	19.896	98939	45.8	20.48	99.1029	299.33	0.04	10	1	299.75	0.05
300	2	17.05.2016	19.897	98935	45.8	20.58	99.0998	301.36	0.03	10	2	301.62	0.05
300	3	17.05.2016	19.901	98919	45.8	20.66	99.0846	299.11	0.02	10	3	299.37	0.05
300	4	17.05.2016	19.900	98899	45.8	20.72	99.0647	298.85	0.03	10	4	299.16	0.05
							Average=	**299.66**			Average=	**299.97**	
Change Flow Rate						Stabilization 3 minutes							
600	1	17.05.2016	19.898	98942	45.8	20.488	99.1346	600.05	0.02	10	1	600.70	0.10
600	2	17.05.2016	19.899	98934	45.8	20.552	99.1297	599.83	0.03	10	2	600.31	0.10
600	3	17.05.2016	19.901	98916	45.8	20.66	99.1109	599.72	0.03	10	3	600.06	0.10
600	4	17.05.2016	19.900	98903	45.8	20.674	99.0985	599.55	0.04	10	4	599.89	0.10
							Average=	**599.79**			Average=	**600.24**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	17.05.2016	19.894	98938	45.8	20.496	99.2262	1250.48	0.12	10	1	1252.10	0.20
1250	2	17.05.2016	19.898	98934	45.8	20.51	99.223	1250.22	0.09	10	2	1251.73	0.20
1250	3	17.05.2016	19.902	98913	45.8	20.664	99.2058	1249.44	0.09	10	3	1251.28	0.20
1250	4	17.05.2016	19.900	98905	45.8	20.668	99.1974	1249.51	0.07	10	4	1251.15	0.20
							Average=	**1249.91**			Average=	**1251.56**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
19.62	98.751	19.6	98.775

COMPARISON MEASUREMENTS

Flow cell: ***-44 (S/N: 135199)***

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	26.05.2016	19.710	98805	62.3	20.475	98.9865	1245.0	0.6	70.000	1	1244.5	1.2
1250	2	26.05.2016	19.740	98787	62.3	20.799	98.9707	1234.8	2.8	70.000	2	1234.9	1.2
1250	3	30.05.2016	19.655	98109	66.0	20.433	98.2879	1249.8	0.5	70.000	3	1249.5	1.2
1250	4	26.05.2016	19.750	98776	62.3	20.874	98.9625	1254.3	2.9	70.000	4	1253.9	1.2
							Average=	1245.99			Average=	1245.70	
Change Flow Rate						Stabilization 3 minutes							
5000	1	26.05.2016	19.715	98820	62.3	20.761	99.0235	5002.9	2.5	60	1	5007.8	4.6
5000	2	26.05.2016	19.715	98802	62.3	21.005	99.0097	4968.0	2.1	60	2	4970.9	4.6
5000	3	30.05.2016	19.675	98107	66.0	20.741	98.3001	5010.7	2.3	50	3	5015.3	4.8
5000	4	26.05.2016	19.735	98786	62.3	21.053	98.9912	4965.0	2.3	60	4	4970.0	4.5
							Average=	4986.63			Average=	4991.00	
Change Flow Rate						Stabilization 3 minutes							
10000	1	26.05.2016	19.695	98825	62.3	21.234	99.0770	9971.4	5.7	50	1	9978.9	9.0
10000	2	26.05.2016	19.720	98813	62.3	21.127	99.0862	9931.4	2.5	40	2	9934.4	9.3
10000	3	30.05.2016	19.670	98105	66.0	21.189	98.3550	9999.6	4.3	40	3	10013.2	9.4
10000	4	26.05.2016	19.715	98791	62.3	21.132	99.0536	9919.1	3.9	40	4	9934.0	9.4
							Average=	9955.38			Average=	9965.12	
Change Flow Rate						Stabilization 3 minutes							
20000	1	26.05.2016	19.695	98822	62.3	21.368	99.2069	20011.2	13.2	40	1	20041.7	15.9
20000	2	26.05.2016	19.715	98820	62.3	21.175	99.1936	19879.6	10.8	30	2	19899.8	17.2
20000	3	30.05.2016	19.680	98106	66.0	21.280	98.4873	19976.0	13.1	30	3	19989.9	17.4
20000	4	26.05.2016	19.720	98787	62.3	21.157	99.1757	19855.5	14.0	30	4	19882.2	17.7
							Average=	19930.56			Average=	19953.40	
Change Flow Rate						Stabilization 3 minutes							
30000	1	26.05.2016	19.695	98828	62.3	21.255	99.3876	29974.6	19.7	30	1	29999.7	21.9
30000	2	26.05.2016	19.705	98827	62.3	21.163	99.3970	29944.3	16.6	30	2	29962.4	21.9
30000	3	30.05.2016	19.675	98102	66.0	21.149	98.6915	29987.2	15.0	30	3	30002.3	21.6
30000	4	26.05.2016	19.715	98786	62.3	21.177	99.3715	29912.1	20.5	30	4	29952.4	22.0
End of measurements							Average=	29954.57			Average=	29979.18	

INRIM loop1 stability results (INRIM2)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Initial

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.1	98.716	20.9	98.709

Final

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.5	98.61	21.09	98.73

COMPARISON MEASUREMENTS

Flow cell: *-10 (S/N: 135207)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	13.06.2017	19.938	98724	71	20.924	98.83	5.01	0.00	10	1	5.0525	0.0022
5	2	13.06.2017	19.975	98687	71	21.048	98.7945	5.01	0.00	10	2	5.0456	0.0022
5	3	13.06.2017	19.978	98676	71	21.054	98.7856	5.01	0.00	10	3	5.0421	0.0022
5	4	13.06.2017	19.957	98631	71	21.1	98.7383	5.01	0.00	10	4	5.0429	0.0022
							Average=	5.01			Average=	5.05	
Change Flow Rate						Stabilization 3 minutes							
10	1	13.06.2017	19.958	98719	71	20.968	98.8224	10.00	0.00	10	1	10.055	0.003
10	2	13.06.2017	19.969	98697	71	21.04	98.8076	10.00	0.01	10	2	10.044	0.003
10	3	13.06.2017	19.962	98676	71	21.064	98.7816	10.00	0.00	10	3	10.046	0.003
10	4	13.06.2017	19.968	98646	71	21.108	98.7522	10.00	0.01	10	4	10.039	0.003
							Average=	10.00			Average=	10.05	
Change Flow Rate						Stabilization 3 minutes							
20	1	13.06.2017	19.962	98714	71	20.988	98.8217	20.00	0.00	10	1	20.072	0.005
20	2	13.06.2017	19.964	98702	71	21.027	98.8112	19.99	0.00	10	2	20.052	0.005
20	3	13.06.2017	19.962	98670	71	21.07	98.7799	20.00	0.00	10	3	20.055	0.005
20	4	13.06.2017	19.961	98651	71	21.096	98.763	19.99	0.00	10	4	20.051	0.005
							Average=	19.99			Average=	20.06	
Change Flow Rate						Stabilization 3 minutes							
80	1	13.06.2017	19.962	98709	71	21	98.8251	79.99	0.01	10	1	80.117	0.02
80	2	13.06.2017	19.956	98705	71	21.018	98.8205	80.00	0.01	10	2	80.097	0.02
80	3	13.06.2017	19.966	98662	71	21.074	98.7788	79.98	0.01	10	3	80.089	0.02
80	4	13.06.2017	19.959	98654	71	21.088	98.7693	79.99	0.02	10	4	80.132	0.02
							Average=	79.99			Average=	80.11	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Initial

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.5	98.822	20.8	99.091

Final

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
21.31	98.792	21.51	98.913

COMPARISON MEASUREMENTS

Flow cell: *-24 (S/N: 134909)*			**ENVIRONMENTAL PARAMETERS**			**TRANSFER STANDARD PARAMETERS**					**REFERENCE PARAMETERS**		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (Pa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	16.06.2017	19.962	98841	71.1	21.29	98.9526	79.43	0.01	10	1	80.011	0.020
80	2	16.06.2017	19.965	98805	71.1	21.404	98.9153	79.17	0.03	10	2	79.742	0.020
80	3	16.06.2017	19.963	98813	71.1	21.428	98.9237	79.36	0.01	10	3	79.866	0.020
80	4	16.06.2017	19.965	98804	71.1	21.508	98.9155	78.88	0.07	10	4	79.445	0.020
							Average=	**79.21**			Average=	**79.77**	
Change Flow Rate						Stabilization 3 minutes							
300	1	16.06.2017	19.954	98839	71.1	21.312	98.97	300.00	0.02	10	1	301.81	0.075
300	2	16.06.2017	19.963	98819	71.1	21.374	98.95	299.75	0.02	10	2	301.28	0.075
300	3	16.06.2017	19.963	98816	71.1	21.43	98.9444	299.92	0.03	10	3	301.67	0.075
300	4	16.06.2017	19.971	98804	71.1	21.47	98.9345	299.73	0.01	10	4	301.28	0.075
							Average=	**299.85**			Average=	**301.51**	
Change Flow Rate						Stabilization 3 minutes							
600	1	16.06.2017	19.958	98839	71.1	21.3	98.999	599.75	0.05	10	1	603.01	0.15
600	2	16.06.2017	19.960	98825	71.1	21.352	98.985	599.38	0.04	10	2	602.50	0.15
600	3	16.06.2017	19.963	98811	71.1	21.426	98.9737	599.70	0.07	10	3	602.99	0.15
600	4	16.06.2017	19.968	98807	71.1	21.45	98.9681	599.51	0.04	10	4	602.69	0.15
							Average=	**599.59**			Average=	**602.80**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	16.06.2017	19.957	98833	71.1	21.304	99.0952	1249.97	0.13	10	1	1256.63	0.31
1250	2	16.06.2017	19.959	98827	71.1	21.32	99.0951	1249.42	0.12	10	2	1255.92	0.31
1250	3	16.06.2017	19.967	98810	71.1	21.41	99.0772	1249.83	0.10	10	3	1256.50	0.31
1250	4	16.06.2017	19.967	98810	71.1	21.428	99.0808	1249.70	0.09	10	4	1255.97	0.31
							Average=	**1249.73**			Average=	**1256.25**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
19.45	98.978	20.84	99.555

Initial

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
19.56	98.916	20.92	99.494

Final

COMPARISON MEASUREMENTS

Flow cell: *-44 (S/N: 135198)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(Pa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	09.06.2017	19.420	98979	62.2	20.855	99.5568	1246.6	0.4	70	1	1247.3	1.2
1250	2	09.06.2017	19.475	98952	62.2	21.109	99.5310	1246.6	2.1	80	2	1246.4	1.2
1250	3	09.06.2017	19.515	98940	62.2	21.002	99.5167	1250.9	0.5	80	3	1251.1	1.2
1250	4	09.06.2017	19.590	98913	62.2	20.954	99.4932	1248.3	2.4	80	4	1247.5	1.2
							Average=	**1248.09**			Average=	**1248.06**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	09.06.2017	19.435	98987	62.2	21.176	99.5843	5014.8	2.0	60	1	5020.2	4.9
5000	2	09.06.2017	19.455	98954	62.2	21.323	99.5472	4981.6	2.1	60	2	4981.7	4.8
5000	3	09.06.2017	19.440	98931	62.2	21.167	99.5269	5007.0	3.3	60	3	5006.7	4.9
5000	4	09.06.2017	19.585	98913	62.2	21.156	99.5083	4983.6	2.3	60	4	4985.8	4.8
							Average=	**4996.73**			Average=	**4998.61**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	09.06.2017	19.420	98983	62.2	21.562	99.6370	10016.2	3.2	50	1	10025.4	9.2
10000	2	09.06.2017	19.485	98958	62.2	21.388	99.6057	9950.4	4.2	50	2	9953.3	9.3
10000	3	09.06.2017	19.445	98931	62.2	21.493	99.5716	10007.3	3.0	50	3	10013.1	9.2
10000	4	09.06.2017	19.565	98916	62.2	21.266	99.5586	9967.0	5.7	50	4	9971.1	9.2
							Average=	**9985.21**			Average=	**9990.73**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	09.06.2017	19.450	98977	62.2	21.636	99.7594	20007.4	11.2	40	1	20014.2	16.6
20000	2	09.06.2017	19.495	98964	62.2	21.420	99.7468	19923.0	15.1	40	2	19929.7	17.1
20000	3	09.06.2017	19.465	98929	62.2	21.614	99.7028	20001.0	12.0	40	3	20014.5	17.1
20000	4	09.06.2017	19.575	98912	62.2	21.311	99.6795	19974.2	13.9	40	4	19981.1	17.0
							Average=	**19976.42**			Average=	**19984.88**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	09.06.2017	19.475	98977	62.2	21.487	99.9346	29965.3	21.3	40	1	29962.3	21.7
30000	2	09.06.2017	19.485	98970	62.2	21.424	99.9261	29976.2	16.3	40	2	29977.6	21.8
30000	3	09.06.2017	19.500	98928	62.2	21.507	99.8922	29972.4	22.5	40	3	29977.2	21.7
30000	4	09.06.2017	19.585	98911	62.2	21.232	99.8608	30051.6	20.1	40	4	30050.4	21.1
End of measurements							Average=	**29991.36**			Average=	**29991.86**	

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PTB loop1 results

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
21.85	1010.3	21.75	1010.2

COMPARISON MEASUREMENTS

***Flow cell:** -10 (S/N: 135207)*			**ENVIRONMENTAL PARAMETERS**			**TRANSFER STANDARD PARAMETERS**					**REFERENCE PARAMETERS**		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	09-08-2016	21.76	100.99		22.72	101.12	4.96	0.00	10	1	4.978	0.0075
5	2	09-08-2017	21.77	100.99		22.72	101.12	4.96	0.00	10	2	4.978	0.0075
5	3	09-08-2018	21.67	100.98		22.70	101.11	4.96	0.00	10	3	4.979	0.0075
5	4	09-08-2019	21.64	101.00		22.66	101.11	4.96	0.00	10	4	4.980	0.0075
							Average=	**4.96**			Average=	**4.98**	
Change Flow Rate						Stabilization 3 minutes							
10	1	09-08-2019	21.60	100.98		22.66	101.11	10.01	0.00	10	1	9.981	0.015
10	2	09-08-2020	21.60	100.99		22.66	101.12	10.01	0.00	10	2	9.982	0.015
10	3	09-08-2021	21.63	100.99		22.66	101.12	10.00	0.00	10	3	9.981	0.015
10	4	09-08-2022	21.66	100.99		22.68	101.12	9.99	0.00	10	4	9.980	0.015
							Average=	**10.00**			Average=	**9.98**	
Change Flow Rate						Stabilization 3 minutes							
20	1	19.7.2016	22.02	101.06		22.62	101.17	19.85		10	1	19.848	0.03
20	2	19.7.2016	22.02	101.06		22.62	101.17	19.85		10	2	19.847	0.03
20	3	19.7.2016	22.02	101.06		22.62	101.17	19.85		10	3	19.848	0.03
20	4	19.7.2016	22.02	101.06		22.64	101.18	19.85		10	4	19.850	0.03
							Average=	**19.85**			Average=	**19.85**	
Change Flow Rate						Stabilization 3 minutes							
80	1	28.7.2016	22.37	100.64		23.13	100.76	80.19		10	1	80.222	0.12
80	2	28.7.2016	22.40	100.64		23.13	100.76	80.19		10	2	80.219	0.12
80	3	28.7.2016	22.40	100.64		23.13	100.76	80.19		10	3	80.220	0.12
80	4	28.7.2016	22.40	100.64		23.15	100.76	80.19		10	4	80.222	0.12
							Average=	**80.19**			Average=	**80.22**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.02	1010.3	21.91	1010.2

COMPARISON MEASUREMENTS

Flow cell: -24 (S/N: 134909)

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	28.7.2016	22.37	100.39		23.03	100.52	79.91		10	1	80.248	0.12
80	2	29.7.2016	22.39	100.38		23.09	100.51	79.90		10	2	80.232	0.12
80	3	30.7.2016	22.39	100.38		23.11	100.51	79.88		10	3	80.218	0.12
80	4	31.7.2016	22.40	100.38		23.11	100.50	79.87		10	4	80.211	0.12
							Average=	**79.89**			Average=	**80.23**	
Change Flow Rate						Stabilization 3 minutes							
300	1	13.7.2016	22.03	100.66		22.86	100.78	303.07		10	1	304.2118	0.46
300	2	13.7.2016	22.03	100.66		22.88	100.79	303.09		10	2	304.1972	0.46
300	3	13.7.2016	22.03	100.66		22.88	100.79	303.10		10	3	304.1842	0.46
300	4	13.7.2016	22.03	100.66		22.90	100.79	303.09		10	4	304.1644	0.46
							Average=	**303.09**			Average=	**304.19**	
Change Flow Rate						Stabilization 3 minutes							
600	1	14.7.2016	22.03	100.67		22.80	100.80	599.76		10	1	601.780	0.90
600	2	14.7.2016	22.03	100.67		22.80	100.80	599.72		10	2	601.823	0.90
600	3	14.7.2016	22.02	100.67		22.82	100.80	599.74		10	3	601.827	0.90
600	4	14.7.2016	22.02	100.67		22.82	100.80	599.71		10	4	601.829	0.90
							Average=	**599.73**			Average=	**601.81**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	14.7.2016	22.14	100.61		22.63	100.75	1250.70		10	1	1255.406	1.88
1250	2	14.7.2016	22.14	100.61		22.64	100.75	1249.50		10	2	1254.173	1.88
1250	3	14.7.2016	22.14	100.61		22.64	100.75	1249.50		10	3	1253.782	1.88
1250	4	14.7.2016	22.14	100.61		22.66	100.77	1248.80		10	4	1253.577	1.88
							Average=	**1249.63**			Average=	**1254.23**	1.88
Change Flow Rate						Stabilization 3 minutes							
1000	1	14.7.2016	22.07	100.67		22.72	100.82	1003.70		10	1	1007.111	1.51
1000	2	14.7.2016	22.07	100.67		22.72	100.81	1003.60		10	2	1007.117	1.51
1000	3	14.7.2016	22.07	100.67		22.74	100.82	1003.60		10	3	1007.123	1.51
1000	4	14.7.2016	22.07	100.67		22.74	100.81	1003.40		10	4	1007.146	1.51
							Average=	**1003.58**			Average=	**1007.12**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
23.74	101.01	23.45	100.85

COMPARISON MEASUREMENTS

Flow cell: ***-44 (S/N: 135198)***

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	14.7.2016	22.08	100.63		22.24	100.8	1254.90		10	1	1253.866	1.88
1250	2	14.7.2016	22.08	100.64		22.26	100.8	1255.00		10	2	1253.908	1.88
1250	3	14.7.2016	22.07	100.64		22.28	100.8	1255.00		10	3	1253.914	1.88
1250	4	14.7.2016	22.07	100.64		22.28	100.81	1255.00		10	4	1253.875	1.88
							Average=	**1254.98**			Average=	**1253.89**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	22.6.2016	22.00	101.44	49.14	22.66	101.58	5004.19	0.62	10	1	5005.397	7.51
5000	2	22.6.2016	22.00	101.44	49.16	22.63	101.58	5004.86	0.49	10	2	5005.628	7.51
5000	3	22.6.2016	22.00	101.44	49.10	22.62	101.59	5005.22	0.34	10	3	5005.805	7.51
5000	4	22.6.2016	22.00	101.44	49.01	22.62	101.59	5005.30	0.43	10	4	5006.075	7.51
							Average=	**5004.89**			Average=	**5005.73**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	22.6.2016	22.04	101.43	48.60	22.49	101.62	9992.29	1.70	10	1	9992.807	14.99
10000	2	22.6.2016	22.00	101.43	48.60	22.46	101.62	9991.86	1.27	10	2	9992.122	14.99
10000	3	22.6.2016	22.00	101.43	48.60	22.45	101.62	9991.15	1.32	10	3	9991.389	14.99
10000	4	22.6.2016	22.00	101.43	48.60	22.45	101.62	9990.22	0.96	10	4	9990.681	14.99
							Average=	**9991.38**			Average=	**9991.75**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	22.6.2016	22.10	101.43	48.64	22.47	101.74	20058.50	8.73	10	1	20077.09	30.12
20000	2	22.6.2016	22.10	101.43	48.54	22.41	101.73	20064.10	7.00	10	2	20074.03	30.11
20000	3	22.6.2016	22.10	101.43	48.47	22.40	101.73	20069.00	4.40	10	3	20078.00	30.12
20000	4	22.6.2016	22.10	101.43	48.40	22.40	101.73	20073.20	4.87	10	4	20078.01	30.12
							Average=	**20066.20**			Average=	**20076.78**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	23.6.2016	22.50	100.94	49.52	22.64	101.34	29942.78	9.74	10	1	29983.77	44.98
30000	2	23.6.2016	22.50	100.94	49.32	22.57	101.33	29949.90	9.59	10	2	29991.51	44.99
30000	3	23.6.2016	22.50	100.94	49.26	22.56	101.33	29953.00	10.71	10	3	29993.86	44.99
30000	4	23.6.2016	22.50	100.94	49.14	22.55	101.33	29961.20	8.64	10	4	29998.27	45.00
End of measurements							Average=	**29951.72**			Average=	**29991.85**	

PTB loop2 results

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
21.85	1010.3	21.81	1010.5

COMPARISON MEASUREMENTS

***Flow cell:** -10 (S/N: 135208)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	08.08.2016	21.69	100.88		22.62	101.05	4.9739	0.0013	10	1	4.982	0.0075
5	2	08.08.2017	21.78	100.87		22.68	101.04	4.9703	0.0023	10	2	4.979	0.0075
5	3	08.08.2018	21.76	100.87		22.66	101.03	4.9699	0.0010	10	3	4.980	0.0075
5	4	08.08.2019	21.77	100.86		22.68	101.03	4.9712	0.0010	10	4	4.980	0.0075
							Average=	**4.97**			Average=	**4.98**	
Change Flow Rate						Stabilization 3 minutes							
10	1	08.08.2019	21.77	100.83		22.64	100.99	9.9972	0.0035	10	1	10.005	0.015
10	2	08.08.2019	21.76	100.83		22.64	101.00	9.9978	0.0030	10	2	10.006	0.015
10	3	08.08.2019	21.76	100.83		22.64	101.00	9.9978	0.0025	10	3	10.006	0.015
10	4	08.08.2019	21.75	100.83		22.64	101.00	10	0.0015	10	4	10.006	0.015
							Average=	**10.00**			Average=	**10.01**	
Change Flow Rate						Stabilization 3 minutes							
20	1	19.7.2016	21.64	101.244		22.4	101.41	19.945		10	1	19.916	0.03
20	2	19.7.2016	21.64	101.25		22.36	101.41	19.952		10	2	19.922	0.03
20	3	19.7.2016	21.64	101.248		22.38	101.40	19.946		10	3	19.918	0.03
20	4	19.7.2016	21.64	101.248		22.38	101.41	19.95		10	4	19.918	0.03
							Average=	**19.95**			Average=	**19.92**	
Change Flow Rate						Stabilization 3 minutes							
80	1	28.7.2016	22.41	100.549		23.19	100.71	80.318		10	1	80.198	0.12
80	2	28.7.2016	22.41	100.549		23.19	100.71	80.318		10	2	80.198	0.12
80	3	28.7.2016	22.4	100.547		23.21	100.71	80.317		10	3	80.200	0.12
80	4	28.7.2016	22.41	100.549		23.21	100.71	80.314		10	4	80.200	0.12
							Average=	**80.32**			Average=	**80.20**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.02	1010.3	21.97	1010.5

COMPARISON MEASUREMENTS

Flow cell: *-24 (S/N: 134910)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	28.7.2016	22.34	100.43		22.99	100.58	80.10		10	1	80.232	0.12
80	2	28.7.2016	22.34	100.42		23.01	100.58	80.06		10	2	80.224	0.12
80	3	28.7.2016	22.38	100.414		23.03	100.58	80.04		10	3	80.211	0.12
80	4	28.7.2016	22.38	100.414		23.05	100.58	80.08		10	4	80.200	0.12
							Average=	80.07			Average=	80.22	
Change Flow Rate						Stabilization 3 minutes							
300	1	13.7.2016	22.09	100.282		22.5	100.44	303.21		10	1	303.122	0.45
300	2	13.7.2016	22.13	100.284		22.54	100.44	303.12		10	2	303.081	0.45
300	3	13.7.2016	22.13	100.284		22.54	100.44	303.11		10	3	303.076	0.45
300	4	13.7.2016	22.13	100.29		22.54	100.44	303.10		10	4	303.100	0.45
							Average=	303.14			Average=	303.09	
Change Flow Rate						Stabilization 3 minutes							
600	1	13.7.2016	22.05	100.281		22.56	100.43	600.90		10	1	600.889	0.90
600	2	13.7.2016	22.05	100.281		22.58	100.44	600.93		10	2	600.927	0.90
600	3	13.7.2016	22.05	100.284		22.58	100.44	600.82		10	3	600.791	0.90
600	4	13.7.2016	22.05	100.292		22.6	100.45	600.88		10	4	600.831	0.90
							Average=	600.88			Average=	600.86	
Change Flow Rate						Stabilization 3 minutes							
1250	1	14.7.2016	22.05	100.711		22.62	100.88	1255.40		10	1	1256.060	1.88
1250	2	14.7.2016	22.05	100.714		22.62	100.89	1255.30		10	2	1255.942	1.88
1250	3	14.7.2016	22.07	100.714		22.62	100.89	1255.30		10	3	1255.840	1.88
1250	4	14.7.2016	22.07	100.714		22.64	100.9	1255.30		10	4	1255.757	1.88
							Average=	1255.33			Average=	1255.90	
Change Flow Rate						Stabilization 3 minutes							
1000	1	13.7.2016	22.04	100.342		22.62	100.53	1002.60		10	1	1003.222	1.50
1000	2	13.7.2016	22.04	100.342		22.64	100.51	1002.60		10	2	1003.185	1.50
1000	3	13.7.2016	22.04	100.345		22.66	100.51	1002.60		10	3	1003.140	1.50
1000	4	13.7.2016	22.05	100.348		22.66	100.53	1002.70		10	4	1003.100	1.50
							Average=	1002.63			Average=	1003.16	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.66	101.17	22.74	101.04

COMPARISON MEASUREMENTS

Flow cell: ***-44 (S/N: 135199)***

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	18.7.2016	21.34	1010.58		22.07	1012.5	1255.10		10	1	1255.045	1.88
1250	2	18.7.2016	21.34	1010.6		22.07	1012.5	1255.00		10	2	1254.762	1.88
1250	3	18.7.2016	21.35	1010.63		22.07	1012.7	1254.70		10	3	1254.61	1.88
1250	4	18.7.2016	21.37	1010.65		22.09	1012.5	1254.70		10	4	1254.468	1.88
							Average=	**1254.88**			Average=	**1254.72**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	28.6.2016	21.63	101.04	38.48	22.7	101.22	5003.85	0.72	10	1	5006.223	7.51
5000	2	28.6.2016	21.61	101.05	38.40	22.6	101.22	5005.06	0.72	10	2	5006.636	7.51
5000	3	28.6.2016	21.69	101.05	38.37	22.6	101.22	5005.34	0.47	10	3	5006.874	7.51
5000	4	28.6.2016	21.70	101.05	38.34	22.6	101.22	5004.78	0.47	10	4	5006.9	7.51
							Average=	**5004.76**			Average=	**5006.66**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	28.6.2016	21.70	101.03	37.93	22.4	101.27	9996.81	3.25	10	1	10002.78	15.00
10000	2	28.6.2016	21.70	101.03	37.93	22.3	101.26	9999.92	2.67	10	2	10002.74	15.00
10000	3	28.6.2016	21.70	101.03	37.91	22.3	101.25	9998.82	1.59	10	3	10002.97	15.00
10000	4	28.6.2016	21.70	101.03	37.99	22.3	101.26	10000.50	3.74	10	4	10003.26	15.00
							Average=	**9999.01**			Average=	**10002.94**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	28.6.2016	21.70	100.89	37.50	22.1	101.20	20071.70	6.13	10	1	20080.65	30.12
20000	2	28.6.2016	21.70	100.89	37.50	22.0	101.18	20064.10	4.18	10	2	20080.4	30.12
20000	3	28.6.2016	21.70	100.89	37.44	22.0	101.18	20066.70	4.69	10	3	20080.89	30.12
20000	4	28.6.2016	21.70	100.89	37.40	22.0	101.18	20064.90	10.30	10	4	20080.24	30.12
							Average=	**20066.85**			Average=	**20080.54**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	28.6.2016	21.70	100.88	36.86	22.0	101.27	29944.00	11.34	10	1	29955.96	44.93
30000	2	28.6.2016	21.70	100.88	36.90	21.9	101.27	29950.60	8.41	10	2	29956.11	44.93
30000	3	28.6.2016	21.70	100.88	36.90	21.9	101.27	29939.70	12.35	10	3	29955.81	44.93
30000	4	28.6.2016	21.70	100.88	36.94	21.9	101.28	29946.30	8.04	10	4	29955.11	44.93
End of measurements							Average=	**29945.15**			Average=	**29955.75**	

PTB loop2 stability results (PTB2)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
21.85	101.03	21.8	101.05

COMPARISON MEASUREMENTS (LOOP2)

Base: *S/N: 135516*

Flow cell: *-10 (S/N: 135208)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(kPa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate							Stabilization 180 minutes						
5	1	21.7.2017	21.97	100.45	45	22.62	100.58	5.029	0.0010	10	1	5.050	0.008
5	2	21.7.2017	21.92	100.42	45	22.66	100.58	5.029	0.0011	10	2	5.051	0.008
5	3	21.7.2017	21.92	100.40	45	22.74	100.55	5.025	0.0017	10	3	5.050	0.008
5	4	21.7.2017	21.97	100.39	45	22.74	100.55	5.021	0.0007	10	4	5.050	0.008
							Average=	5.03			Average=	5.05	
Change Flow Rate							Stabilization 3 minutes						
10	1	24.7.2017	21.94	99.79	45	22.46	99.925	10.342	0.0021	10	1	10.365	0.016
10	2	24.7.2017	21.96	99.76	45	22.52	99.918	10.339	0.0037	10	2	10.363	0.016
10	3	24.7.2017	21.96	99.75	45	22.56	99.91	10.333	0.0021	10	3	10.362	0.016
10	4	24.7.2017	21.96	99.75	45	22.6	99.908	10.326	0.0030	10	4	10.362	0.016
							Average=	10.34			Average=	10.36	
Change Flow Rate							Stabilization 3 minutes						
20	1	3.7.2017	21.85	100.81	48	22.76	101	19.915	0.0050	10	1	19.952	0.030
20	2	3.7.2017	21.85	100.81	48	22.76	101	19.927	0.0031	10	2	19.952	0.030
20	3	3.7.2017	21.85	100.80	48	22.76	100.97	19.932	0.0049	10	3	19.952	0.030
20	4	3.7.2017	21.85	100.80	48	22.76	100.97	19.938	0.0032	10	4	19.952	0.030
							Average=	19.93			Average=	19.95	
Change Flow Rate							Stabilization 3 minutes						
80	1	30.6.2017	21.88	99.33	43	22.56	99.5	80.442	0.0064	10	1	80.350	0.121
80	2	30.6.2017	21.88	99.33	43	22.58	99.49	80.442	0.0075	10	2	80.350	0.121
80	3	30.6.2017	21.88	99.33	43	22.58	99.49	80.440	0.0092	10	3	80.350	0.121
80	4	30.6.2017	21.88	99.33	43	22.58	99.49	80.445	0.0068	10	4	80.349	0.121
							Average=	80.44			Average=	80.35	
Change Flow Rate							Stabilization 3 minutes						
50	1	3.7.2017	21.85	100.80	48	22.66	100.99	49.719	0.0066	10	1	49.753	0.075
50	2	3.7.2017	21.85	100.80	48	22.66	100.99	49.717	0.0037	10	2	49.752	0.075
50	3	3.7.2017	21.85	100.80	48	22.68	101	49.715	0.0045	10	3	49.752	0.075
50	4	3.7.2017	21.85	100.80	48	22.7	101	49.711	0.0039	10	4	49.752	0.075
							Average=	49.72			Average=	49.75	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (^{o}C)	Laboratory pressure (kPa)	BIOS temperature (^{o}C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.02	1010.3	21.97	1010.5

COMPARISON MEASUREMENTS (LOOP2)

Base: *(S/N: 135516)*

Flow cell: *-24 (S/N: 134910)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (^{o}C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (^{o}C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	30.6.2017	21.50	99.31	43	22.32	99.47	80.231	0.0130	10	1	80.380	0.12
80	2	30.6.2017	21.56	99.30	43	22.34	99.46	80.225	0.0100	10	2	80.377	0.12
80	3	30.6.2017	21.60	99.30	43	22.38	99.47	80.205	0.0180	10	3	80.370	0.12
80	4	30.6.2017	21.62	99.30	43	22.44	99.47	80.187	0.0190	10	4	80.363	0.12
							Average=	**80.21**			Average=	**80.37**	
Change Flow Rate						Stabilization 3 minutes							
300	1	22.5.2017	20.85	100.94	45	21.81	101.09	302.880		10	1	303.130	0.45
300	2	22.5.2017	20.85	100.94	45	21.83	101.09	302.880		10	2	303.120	0.45
300	3	22.5.2017	20.87	100.94	45	21.85	101.09	302.880		10	3	303.099	0.45
300	4	22.5.2017	20.88	100.94	45	21.85	101.09	302.890		10	4	303.099	0.45
							Average=	**302.88**			Average=	**303.11**	
Change Flow Rate						Stabilization 3 minutes							
600	1	22.5.2017	20.88	100.94	45	21.95	101.08	601.810		10	1	601.838	0.90
600	2	22.5.2017	20.88	100.94	45	21.93	101.08	601.780		10	2	601.859	0.90
600	3	22.5.2017	20.86	100.94	45	21.93	101.08	601.790		10	3	601.880	0.90
600	4	22.5.2017	20.88	100.94	45	21.93	101.08	601.760		10	4	601.880	0.90
							Average=	**601.79**			Average=	**601.86**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	22.5.2017	21.08	100.89	42	21.97	101.07	1253.500		10	1	1255.218	1.88
1250	2	22.5.2017	21.08	100.89	42	21.99	101.07	1253.400		10	2	1254.272	1.88
1250	3	22.5.2017	21.11	100.89	42	21.99	101.07	1253.500		10	3	1254.315	1.88
1250	4	22.5.2017	21.11	100.89	42	21.99	101.07	1253.400		10	4	1254.337	1.88
							Average=	**1253.45**			Average=	**1254.54**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			

COMPARISON MEASUREMENTS (LOOP2)

Base: *(S/N: 135516)*

Flow cell: *-44 (S/N: 135199)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	11.5.2017	21.6	99.19	37.36	22.57	99.44	1250.39	0.12	10	1	1249.747	1.87
1250	2	11.5.2017	21.6	99.18	37.31	22.56	99.43	1250.42	0.13	10	2	1249.689	1.87
1250	3	11.5.2017	21.6	99.19	37.30	22.55	99.43	1250.34	0.15	10	3	1249.689	1.87
1250	4	11.5.2017	21.6	99.20	37.42	22.56	99.43	1250.28	0.21	10	4	1249.655	1.87
							Average=	**1250.36**			Average=	**1249.70**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	12.5.2017	21.7	99.33	40.95	22.46	99.63	4999.70	0.62	10	1	4996.92	7.50
5000	2	12.5.2017	21.7	99.33	41.03	22.42	99.63	5000.40	0.11	10	2	4997.15	7.50
5000	3	12.5.2017	21.7	99.33	41.11	22.42	99.63	5000.37	0.07	10	3	4997.20	7.50
5000	4	12.5.2017	21.7	99.33	41.09	22.42	99.63	5000.26	0.45	10	4	4997.08	7.50
							Average=	**5000.18**			Average=	**4997.08**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	12.5.2017	21.5	99.32	41.63	22.39	99.71	9990.61	2.43	10	1	9990.07	14.99
10000	2	12.5.2017	21.6	99.33	41.60	22.33	99.71	9991.54	1.31	10	2	9990.28	14.99
10000	3	12.5.2017	21.6	99.33	41.60	22.33	99.70	9991.96	1.13	10	3	9989.94	14.98
10000	4	12.5.2017	21.6	99.33	41.60	22.32	99.71	9990.96	0.45	10	4	9989.42	14.98
							Average=	**9991.27**			Average=	**9989.93**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	15.5.2017	21.5	101.95	44.10	21.95	102.56	19984.90	3.41	10	1	19988.02	29.98
20000	2	15.5.2017	21.5	101.95	44.42	21.93	102.56	19988.30	4.08	10	2	19987.17	29.98
20000	3	15.5.2017	21.5	101.95	44.57	21.93	102.55	19985.20	6.53	10	3	19985.68	29.98
20000	4	15.5.2017	21.5	101.95	44.55	21.93	102.56	19983.00	4.64	10	4	19984.34	29.98
							Average=	**19985.35**			Average=	**19986.30**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	24.5.2017	21.7	101.92	41.52	22.07	102.62	29993.20	3.26	10	1	29990.43	44.99
30000	2	24.5.2017	21.7	101.93	41.38	22.04	102.62	29986.70	12.06	10	2	29989.86	44.98
30000	3	24.5.2017	21.7	101.92	41.34	22.03	102.62	29991.00	11.77	10	3	29988.85	44.98
30000	4	24.5.2017	21.7	101.93	41.26	22.03	102.62	29984.10	10.55	10	4	29985.88	44.98
End of measurements							Average=	**29988.75**			Average=	**29988.75**	

MIKES results (loop1)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
23.7	102.00	24.3	101.98

COMPARISON MEASUREMENTS

Flow cell: ***-10 (S/N: 135207)***

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	28.9.2016	23.6	101.1	35.9	24.40	101.1	4.981	0.002	37	1	4.982	0.004
5	2	28.9.2016	23.6	100.9	35.6	24.41	100.9	4.978	0.002	37	2	4.989	0.004
5	3	28.9.2016	23.6	100.7	36.0	24.39	100.7	4.975	0.001	37	3	4.981	0.004
5	4	29.9.2016	23.6	99.8	35.4	24.47	99.8	4.971	0.001	38	4	4.982	0.004
							Average=	**4.976**			Average=	**4.984**	
Change Flow Rate						Stabilization 3 minutes							
10	1	28.9.2016	23.6	100.0	36.3	24.36	100.1	9.984	0.001	37	1	9.982	0.007
10	2	28.9.2016	23.6	100.0	35.4	24.36	100.1	9.984	0.001	38	2	9.994	0.007
10	3	28.9.2016	23.6	99.9	35.5	24.36	100.0	9.984	0.001	38	3	9.980	0.007
10	4	30.9.2016	23.6	98.7	35.4	24.47	98.8	9.986	0.002	38	4	9.994	0.007
							Average=	**9.984**			Average=	**9.987**	
Change Flow Rate						Stabilization 3 minutes							
20	1	28.9.2016	23.6	99.9	35.4	24.37	100.0	19.954	0.002	36	1	19.984	0.015
20	2	28.9.2016	23.6	99.9	35.3	24.38	100.0	19.954	0.001	36	2	19.987	0.015
20	3	28.9.2016	23.6	99.9	35.5	24.38	100.0	19.954	0.001	36	3	19.949	0.015
20	4	28.9.2016	23.6	99.9	35.3	24.39	100.0	19.954	0.002	36	4	19.980	0.015
							Average=	**19.954**			Average=	**19.975**	
Change Flow Rate						Stabilization 3 minutes							
80	1	30.9.2016	23.6	98.9	34.8	24.59	99.0	78.693	0.046	81	1	78.678	0.057
80	2	30.9.2016	23.6	99.0	34.6	24.59	99.1	78.615	0.031	81	2	78.663	0.057
80	3	30.9.2016	23.6	99.0	34.7	24.59	99.1	79.995	0.027	81	3	80.004	0.058
80	4	30.9.2016	23.6	99.1	34.8	24.59	99.2	80.002	0.045	81	4	80.074	0.058
							Average=	**79.326**			Average=	**79.355**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
23.6	101.48	23.7	101.46

COMPARISON MEASUREMENTS

Flow cell: *-24 (S/N: 134909)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	20.9.2016	23.6	101.8	34.7	24.51	101.9	79.49	0.04	13	1	79.95	0.06
80	2	20.9.2016	23.6	101.9	34.6	24.53	101.9	79.42	0.01	13	2	79.89	0.06
80	3	20.9.2016	23.6	101.9	34.6	24.53	101.9	79.40	0.03	13	3	79.86	0.06
80	4	20.9.2016	23.6	101.9	34.7	24.55	101.9	79.43	0.03	13	4	79.92	0.06
							Average=	79.44			Average=	79.90	
Change Flow Rate						Stabilization 3 minutes							
300	1	20.9.2016	23.6	101.8	34.7	24.57	101.9	299.97	0.02	33	1	301.30	0.22
300	2	20.9.2016	23.6	101.8	34.5	24.58	101.9	299.97	0.02	33	2	301.47	0.22
300	3	20.9.2016	23.6	101.8	34.4	24.58	101.9	299.97	0.02	33	3	301.49	0.22
300	4	20.9.2016	23.6	101.8	34.5	24.59	101.9	299.97	0.02	33	4	301.31	0.22
							Average=	299.97			Average=	301.39	
Change Flow Rate						Stabilization 3 minutes							
600	1	15.9.2016	23.6	101.3	35.2	24.56	101.4	599.85	0.06	50	1	602.78	0.44
600	2	15.9.2016	23.6	101.3	35.3	24.57	101.4	599.81	0.04	50	2	602.81	0.44
600	3	15.9.2016	23.6	101.3	35.5	24.57	101.4	599.78	0.05	50	3	602.82	0.44
600	4	15.9.2016	23.6	101.3	35.4	24.57	101.4	599.77	0.05	50	4	602.65	0.44
							Average=	599.80			Average=	602.77	
Change Flow Rate						Stabilization 3 minutes							
1250	1	15.9.2016	23.6	101.3	35.6	24.57	101.4	1249.88	0.19	72	1	1256.63	0.92
1250	2	15.9.2016	23.6	101.3	35.3	24.57	101.4	1249.77	0.17	72	2	1256.42	0.92
1250	3	15.9.2016	23.6	101.3	35.3	24.57	101.4	1249.66	0.24	72	3	1256.35	0.92
1250	4	15.9.2016	23.6	101.7	34.8	24.53	101.8	1249.46	0.22	72	4	1255.95	0.92
							Average=	1249.69			Average=	1256.34	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
23.6	100.79	23.6	100.76

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135198)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	9.9.2016	24.0	101.5	35.2	24.49	101.7	1250.56	0.18	15	1	1251.35	0.91
1250	2	9.9.2016	24.0	101.5	35.0	24.50	101.7	1250.45	0.10	15	2	1250.94	0.91
1250	3	9.9.2016	24.0	101.5	35.0	24.51	101.7	1250.54	0.11	15	3	1251.52	0.91
1250	4	9.9.2016	24.0	101.5	34.8	24.51	101.7	1250.55	0.10	15	4	1251.55	0.91
							Average=	**1250.53**			Average=	**1251.34**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	9.9.2016	24.0	101.5	34.8	24.41	101.7	4983.95	3.20	24	1	4984.00	3.65
5000	2	9.9.2016	24.0	101.5	34.7	24.41	101.7	4984.10	4.79	24	2	4987.45	3.65
5000	3	9.9.2016	24.0	101.5	34.7	24.42	101.7	4990.03	1.52	24	3	4990.20	3.66
5000	4	9.9.2016	24.0	101.5	34.5	24.42	101.7	4993.18	1.91	24	4	4992.08	3.66
							Average=	**4987.81**			Average=	**4988.43**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	9.9.2016	24.0	101.5	34.5	24.37	101.7	9984.00	2.17	33	1	9989.53	7.31
10000	2	9.9.2016	24.0	101.5	34.5	24.37	101.7	9987.45	2.87	33	2	9990.62	7.31
10000	3	9.9.2016	24.0	101.5	34.4	24.37	101.7	9987.12	2.29	33	3	9987.98	7.31
10000	4	9.9.2016	24.0	101.5	34.4	24.37	101.7	9987.96	2.70	33	4	9984.55	7.31
							Average=	**9986.63**			Average=	**9988.17**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	9.9.2016	24.0	101.5	34.3	24.44	101.8	20032.04	4.95	24	1	20014.44	14.77
20000	2	9.9.2016	24.0	101.5	34.3	24.45	101.8	20022.63	6.03	24	2	20045.23	14.74
20000	3	9.9.2016	24.0	101.5	34.2	24.45	101.8	20021.04	5.73	24	3	20035.48	14.73
20000	4	9.9.2016	24.0	101.5	34.3	24.44	101.8	20019.46	6.34	24	4	20029.16	14.73
							Average=	**20023.79**			Average=	**20031.08**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	9.9.2016	23.7	101.5	34.8	24.34	101.9	30135.88	28.40	24	1	30147.04	22.17
30000	2	9.9.2016	23.7	101.5	34.7	24.36	101.9	30079.38	53.25	24	2	30059.59	22.10
30000	3	9.9.2016	23.7	101.5	34.9	24.35	102.0	30009.46	17.74	24	3	30042.36	22.07
30000	4	9.9.2016	23.7	101.5	34.8	24.36	102.0	30059.00	14.96	24	4	30065.32	22.09
End of measurements							Average=	**30070.93**			Average=	**30078.58**	

FORCE results (loop1)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.29	101.143	20.6	102.15

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134909)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	21.10.2016	20.35	101.10	42	21.45	101.60	79.823	0.05	10	1	80.061	0.076
80	2	21.10.2016	20.38	101.10	42	21.49	101.60	79.858	0.02	10	2	80.078	0.076
80	3	21.10.2016	20.43	101.10	42	21.55	101.60	79.881	0.04	10	3	80.151	0.076
80	4	21.10.2016	20.44	101.09	42	21.58	101.59	79.853	0.02	10	4	80.118	0.076
							Average=	79.85			Average=	80.10	
Change Flow Rate						Stabilization 3 minutes							
300	1	21.10.2016	20.48	101.07	42	21.75	101.57	301.018	0.12	10	1	301.652	0.287
300	2	21.10.2016	20.47	101.06	41	21.75	101.57	300.801	0.11	10	2	301.467	0.286
300	3	21.10.2016	20.45	101.06	42	21.75	101.57	301.126	0.12	10	3	301.757	0.287
300	4	21.10.2016	20.43	101.06	42	21.75	101.57	301.108	0.10	10	4	301.811	0.287
							Average=	301.01			Average=	301.67	
Change Flow Rate						Stabilization 3 minutes							
600	1	21.10.2016	20.47	101.06	42	21.8	101.58	607.661	0.13	9	1	608.769	0.578
600	2	21.10.2016	20.46	101.07	42	21.8	101.58	608.584	0.15	9	2	609.734	0.579
600	3	21.10.2016	20.47	101.06	42	21.8	101.58	609.003	0.19	9	3	610.054	0.580
600	4	21.10.2016	20.47	101.06	42	21.8	101.58	609.104	0.20	9	4	610.243	0.580
							Average=	608.59			Average=	609.70	
Change Flow Rate						Stabilization 3 minutes							
1250	1	21.10.2016	20.45	101.05	42	21.8	101.57	1248.586	8.63	7	1	1248.516	1.186
1250	2	21.10.2016	20.45	101.05	42	21.8	101.57	1251.600	12.02	7	2	1252.227	1.190
1250	3	21.10.2016	20.46	101.05	42	21.8	101.57	1252.614	9.81	7	3	1254.639	1.192
1250	4	21.10.2016	20.46	101.05	42	21.8	101.57	1247.171	5.78	7	4	1247.784	1.185
							Average=	1249.99			Average=	1250.79	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.29	101.369	20.36	101.37

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135198)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate								Stabilization 180 minutes					
1250	1	25.10.2016	20.35	101.45	38	21.51	101.96	1261.73	3.48	24	1	1259.88	1.13
1250	2	25.10.2016	20.39	101.45	38	21.53	101.96	1222.16	3.54	25	2	1220.20	1.10
1250	3	25.10.2016	20.41	101.45	38	21.56	101.96	1235.81	3.56	25	3	1233.61	1.11
1250	4	25.10.2016	20.39	101.46	38	21.57	101.97	1251.13	3.28	24	4	1249.23	1.12
							Average=	**1242.71**			Average=	**1240.73**	
Change Flow Rate								Stabilization 3 minutes					
5000	1	24.10.2016	20.39	101.50	38	21.49	102.08	4998.36	1.85	21	1	4999.53	4.50
5000	2	24.10.2016	20.41	101.50	38	21.50	102.09	5003.98	1.29	20	2	5004.31	4.50
5000	3	24.10.2016	20.45	101.50	38	21.48	102.08	5013.42	1.60	19	3	5014.33	4.51
5000	4	24.10.2016	20.45	101.49	39	21.50	102.07	5033.79	1.59	19	4	5033.92	4.53
							Average=	**5012.39**			Average=	**5013.03**	
Change Flow Rate								Stabilization 3 minutes					
10000	1	24.10.2016	20.44	101.49	39	21.41	102.24	9936.65	1.56	14	1	9945.92	8.95
10000	2	24.10.2016	20.44	101.50	39	21.41	102.25	9942.17	2.01	15	2	9946.33	8.95
10000	3	24.10.2016	20.45	101.50	39	23.42	102.25	9946.49	2.67	15	3	9959.26	8.96
10000	4	24.10.2016	20.46	101.50	39	21.42	102.26	9963.58	1.72	13	4	9976.10	8.98
							Average=	**9947.22**			Average=	**9956.90**	
Change Flow Rate								Stabilization 3 minutes					
20000	1	25.10.2016	20.34	101.83	37	20.69	103.12	20144.83	6.37	12	1	20147.12	18.13
20000	2	25.10.2016	20.34	101.83	37	20.72	103.10	20157.58	9.13	12	2	20163.33	18.15
20000	3	25.10.2016	20.33	101.83	37	20.73	103.10	20176.67	7.29	12	3	20178.12	18.16
20000	4	25.10.2016	20.31	101.83	37	20.73	103.09	20190.25	9.27	12	4	20200.32	18.18
							Average=	**20167.33**			Average=	**20172.22**	
Change Flow Rate								Stabilization 3 minutes					
30000	1	24.10.2016	20.53	101.48	39	21.15	103.50	30217.11	20.36	9	1	30380.72	27.34
30000	2	24.10.2016	20.55	101.47	39	21.17	103.52	30425.67	17.31	9	2	30574.36	27.52
30000	3	24.10.2016	20.56	101.48	39	21.13	103.51	30340.33	14.21	9	3	30487.88	27.44
30000	4	24.10.2016	20.56	101.47	39	21.11	103.47	29913.56	11.47	9	4	30055.90	27.05
		End of measurements					Average=	**30224.17**			Average=	**30374.72**	

METAS results (loop1)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.118	95.995	20.56	95.987

COMPARISON MEASUREMENTS

Flow cell: -10 (S/N: 135207)			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS				
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)	Reference mean temperature (°C)	Reference mean pressure (kPa)
Set Flow Rate						Stabilization 180 minutes									
5	1	18.1.2017	20.095	96.017	46.5	20.61	96.162	4.9944	0.0012	10	1	5.008	0.008	20.113	96.047
5	2	18.1.2017	20.111	96.044	46.4	20.65	96.184	4.9984	0.0013	10	2	5.028	0.008	20.114	96.104
5	3	18.1.2017	20.098	96.111	46.7	20.66	96.216	4.9998	0.0015	10	3	5.035	0.008	20.103	96.109
5	4	18.1.2017	20.099	96.125	46.7	20.69	96.220	4.9963	0.0013	10	4	5.031	0.008	20.092	96.128
							Average=	**4.9972**			Average=	**5.025**			
Change Flow Rate						Stabilization 3 minutes									
10	1	18.1.2017	20.093	96.160	46.8	20.64	96.262	10.114	0.002	10	1	10.185	0.016	20.072	96.161
10	2	18.1.2017	20.063	96.161	47.2	20.65	96.257	10.104	0.003	10	2	10.153	0.016	20.128	96.162
10	3	18.1.2017	20.125	96.157	46.6	20.65	96.259	10.089	0.002	10	3	10.151	0.016	20.128	96.156
10	4	18.1.2017	20.073	96.152	46.8	20.66	96.251	10.090	0.002	10	4	10.152	0.016	20.064	96.151
							Average=	**10.099**			Average=	**10.160**			
Change Flow Rate						Stabilization 3 minutes									
20	1	18.1.2017	20.063	96.142	46.6	20.63	96.227	20.069	0.002	10	1	20.162	0.031	20.062	96.140
20	2	18.1.2017	20.072	96.130	46.7	20.63	96.225	20.074	0.002	10	2	20.149	0.031	20.114	96.130
20	3	18.1.2017	20.036	96.124	46.7	20.64	96.220	20.065	0.008	10	3	20.138	0.031	20.121	96.126
20	4	18.1.2017	20.111	96.113	46.7	20.64	96.208	20.064	0.003	10	4	20.139	0.031	20.092	96.111
							Average=	**20.068**			Average=	**20.147**			
Change Flow Rate						Stabilization 3 minutes									
80	1	18.1.2017	20.085	96.114	47.1	20.60	96.203	80.006	0.004	10	1	80.09	0.13	20.087	96.114
80	2	18.1.2017	20.114	96.104	47.2	20.60	96.203	79.989	0.015	10	2	80.05	0.13	20.117	96.106
80	3	18.1.2017	20.120	96.102	47.0	20.60	96.200	79.978	0.006	10	3	80.04	0.13	20.119	96.105
80	4	18.1.2017	20.105	96.108	47.1	20.61	96.202	79.958	0.014	10	4	80.02	0.13	20.102	96.104
							Average=	**79.983**			Average=	**80.05**			

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)	
Stabilization 24 hours in laboratory (no flow)				Date
20.109	95.138	20.60	95.134	11.1.2017
20.077	96.346	20.74	96.341	19.1.2017

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134909)*			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS				
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)	Reference mean temperature (°C)	Reference mean pressure (kPa)
Set Flow Rate						Stabilization 180 minutes									
80	1	19.1.2017	20.105	96.384	46.5	20.68	96.475	80.035	0.008	10	1	80.65	0.07	20.105	96.381
80	2	19.1.2017	20.093	96.391	46.8	20.69	96.473	80.055	0.003	10	2	80.60	0.07	20.094	96.396
80	3	19.1.2017	20.093	96.402	46.5	20.70	96.490	80.008	0.005	10	3	80.60	0.07	20.093	96.401
80	4	19.1.2017	20.102	96.394	46.6	20.71	96.485	80.013	0.006	10	4	80.61	0.07	20.103	96.395
							Average=	**80.028**			Average=	**80.62**			
Change Flow Rate						Stabilization 3 minutes									
300	1	19.1.2017	20.100	96.401	46.6	20.70	96.493	300.07	0.01	10	1	301.92	0.25	20.100	96.400
300	2	19.1.2017	20.097	96.410	47.0	20.70	96.495	300.10	0.01	10	2	301.86	0.25	20.096	96.404
300	3	19.1.2017	20.105	96.415	46.6	20.69	96.496	300.07	0.01	10	3	301.80	0.25	20.104	96.407
300	4	19.1.2017	20.125	96.397	46.6	20.70	96.488	300.07	0.01	10	4	301.81	0.25	20.128	96.398
							Average=	**300.08**			Average=	**301.84**			
Change Flow Rate						Stabilization 3 minutes									
600	1	11.1.2017	20.026	95.184	46.9	20.59	95.297	599.94	0.02	10	1	603.32	0.49	20.027	95.183
600	2	11.1.2017	20.043	95.145	46.8	20.59	95.284	600.06	0.07	10	2	603.32	0.49	20.044	95.141
600	3	11.1.2017	20.054	95.123	46.7	20.59	95.237	599.90	0.10	10	3	603.18	0.49	20.047	95.130
600	4	11.1.2017	20.055	95.114	46.9	20.59	95.234	600.09	0.04	10	4	603.13	0.49	20.056	95.112
							Average=	**600.00**			Average=	**603.24**			
Change Flow Rate						Stabilization 3 minutes									
1250	1	11.1.2017	20.054	95.104	46.9	20.56	95.224	1250.8	0.1	10	1	1257.4	1.1	20.054	95.107
1250	2	11.1.2017	20.044	95.084	47.0	20.56	95.224	1251.0	0.1	10	2	1257.6	1.1	20.044	95.085
1250	3	11.1.2017	20.041	95.065	46.9	20.59	95.201	1250.6	0.1	10	3	1257.4	1.1	20.043	95.072
1250	4	11.1.2017	20.037	95.073	46.9	20.58	95.202	1250.6	0.1	10	4	1257.4	1.1	20.037	95.071
							Average=	**1250.8**			Average=	**1257.4**			

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.008	95.301	20.44	95.300

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135198)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS				
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)	Reference mean temperature (°C)	Reference mean pressure (kPa)
Set Flow Rate						Stabilization 180 minutes									
1250	1	12.1.2017	20.068	95.257	46.7	20.63	95.402	1244.3	0.1	10	1	1245.5	1.0	20.071	95.254
1250	2	12.1.2017	20.071	95.254	46.8	20.63	95.391	1244.8	0.1	10	2	1245.3	1.0	20.068	95.231
1250	3	12.1.2017	20.071	95.234	46.9	20.63	95.374	1245.9	0.1	10	3	1245.3	1.0	20.068	95.229
1250	4	12.1.2017	20.066	95.223	47.0	20.62	95.377	1245.1	0.2	10	4	1245.5	1.0	20.065	95.218
							Average=	**1245.0**			Average=	**1245.4**			
Change Flow Rate						Stabilization 3 minutes									
5000	1	12.1.2017	20.046	95.224	46.9	20.59	95.405	4988.7	2.2	10	1	4989.8	4.0	20.046	95.229
5000	2	12.1.2017	20.044	95.229	47.0	20.58	95.401	4987.0	2.5	10	2	4989.0	4.0	20.043	95.200
5000	3	12.1.2017	20.045	95.204	46.9	20.59	95.388	4989.1	1.2	10	3	4988.4	4.0	20.044	95.198
5000	4	12.1.2017	20.042	95.216	47.0	20.57	95.386	4990.8	2.0	10	4	4989.0	4.0	20.040	95.206
							Average=	**4988.9**			Average=	**4989.0**			
Change Flow Rate						Stabilization 3 minutes									
10000	1	12.1.2017	20.038	95.199	46.8	20.56	95.342	9985.7	6.6	10	1	9986	8	20.037	95.140
10000	2	12.1.2017	20.042	95.128	47.0	20.58	95.339	9982.7	5.1	10	2	9986	8	20.045	95.123
10000	3	12.1.2017	20.058	95.118	47.0	20.58	95.317	9968.4	3.8	10	3	9986	8	20.054	95.120
10000	4	12.1.2017	20.062	95.116	47.0	20.60	95.314	9980.2	3.4	10	4	9985	8	20.064	95.117
							Average=	**9979.3**			Average=	**9986**			
Change Flow Rate						Stabilization 3 minutes									
20000	1	12.1.2017	20.095	94.897	46.5	20.54	95.188	20154	4	10	1	20142	17	20.095	94.898
20000	2	12.1.2017	20.091	94.891	46.7	20.56	95.186	20156	5	10	2	20166	17	20.092	94.886
20000	3	12.1.2017	20.091	94.882	46.5	20.58	95.174	20173	5	10	3	20169	17	20.092	94.881
20000	4	12.1.2017	20.081	94.865	46.5	20.60	95.175	20170	3	10	4	20181	17	20.081	94.865
							Average=	**20163**			Average=	**20165**			
Change Flow Rate						Stabilization 3 minutes									
30000	1	12.1.2017	20.078	94.844	46.3	20.59	95.274	30105	12	10	1	30149	25	20.078	94.846
30000	2	12.1.2017	20.081	94.830	46.4	20.60	95.278	30113	13	10	2	30132	25	20.081	94.829
30000	3	12.1.2017	20.090	94.805	46.3	20.62	95.243	30096	7	10	3	30112	25	20.084	94.824
30000	4	12.1.2017	20.096	94.787	46.4	20.62	95.242	30100	3	10	4	30103	25	20.096	94.787
End of measurements							Average=	**30104**			Average=	**30124**			

VSL results (loop1)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			

COMPARISON MEASUREMENTS

Flow cell: *-10 (S/N: 135207)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	14.03.2017	20.12	103.109	45	20.40	103.19	4.968	0.003	10	1	4.981	0.010
5	2	14.03.2017	20.11	103.125	45	20.48	103.20	4.972	0.002	10	2	4.979	0.010
5	3	14.03.2017	20.14	103.128	45	20.52	103.21	4.971	0.003	10	3	4.980	0.010
5	4										4		
							Average=	4.97			Average=	4.98	
Change Flow Rate						Stabilization 3 minutes							
10	1	14.03.2017	20.14	103.136	45	20.66	103.21	10.141	0.005	10	1	10.155	0.020
10	2	14.03.2017	20.14	103.136	45	20.68	103.22	10.141	0.008	10	2	10.159	0.020
10	3										3		
10	4										4		
							Average=	10.14			Average=	10.16	
Change Flow Rate						Stabilization 3 minutes							
20	1	14.03.2017	20.14	103.126	45	20.72	103.21	20.252	0.004	10	1	20.29	0.04
20	2	14.03.2017	20.15	103.126	45	20.7	103.21	20.248	0.009	10	2	20.30	0.04
20	3										3		
20	4										4		
							Average=	20.25			Average=	20.30	
Change Flow Rate						Stabilization 3 minutes							
80	1	13.03.2017	20.19	102.894	45	20.60	102.98	79.336	0.016	10	1	79.50	0.16
80	2	13.03.2017	20.19	102.894	45	20.62	102.98	79.333	0.023	10	2	79.60	0.16
80	3	13.03.2017	20.17	102.902	45	20.64	102.98	79.319	0.039	10	3	79.60	0.16
80	4	13.03.2017	20.17	102.902	45	20.64	103.00	79.331	0.020	10	4	79.57	0.16
							Average=	79.33			Average=	79.57	

EURAMET VTT

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			

COMPARISON MEASUREMENTS

Flow cell: *-24 (S/N: 134909)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(kPa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	21.2.2017	20.71	101.607	45	20.92	101.69	79.95	0.04	10	1	80.89	0.16
80	2	21.2.2017	20.66	101.607	45	20.96	101.65	79.92	0.03	10	2	80.94	0.16
80	3	21.2.2017	20.59	101.607	45	20.96	101.65	79.91	0.02	10	3	80.95	0.16
80	4	21.2.2017	20.55	101.607	45	20.98	101.65	79.88	0.03	10	4	80.88	0.16
							Average=	79.91			Average=	80.92	
Change Flow Rate						Stabilization 3 minutes							
300	1	21.2.2017	20.48	101.553	45	20.86	101.68	300.32	0.14	10	1	301.2	0.3
300	2	21.2.2017	20.48	101.553	45	20.88	101.69	300.41	0.09	10	2	301.2	0.3
300	3	21.2.2017	20.46	101.553	45	20.9	101.69	300.44	0.12	10	3	301.1	0.3
300	4	21.2.2017	20.43	101.598	45	20.88	101.7	300.44	0.15	10	4	301.4	0.3
							Average=	300.40			Average=	301.21	
Change Flow Rate						Stabilization 3 minutes							
600	1	21.2.2017	20.47	101.532	45	20.74	101.63	600.36	0.3	10	1	601.7	0.6
600	2	21.2.2017	20.47	101.532	45	20.74	101.63	600.36	0.26	10	2	601.7	0.6
600	3	21.2.2017	20.48	101.532	45	20.78	101.63	600.36	0.24	10	3	601.8	0.6
600	4	21.2.2017	20.49	101.532	45	20.78	101.63	600.41	0.25	10	4	601.6	0.6
							Average=	600.37			Average=	601.71	
Change Flow Rate						Stabilization 3 minutes							
1250	1	20.2.2017	20.52	101.43	45	20.88	101.54	1248.2	0.75	10	1	1251.7	1.3
1250	2	20.2.2017	20.46	101.43	45	20.86	101.54	1247.7	0.49	10	2	1251.2	1.3
1250	3	20.2.2017	20.45	101.43	45	20.86	101.55	1247.4	0.37	10	3	1251.1	1.3
1250	4	20.2.2017	20.47	101.43	45	20.86	101.54	1247.3	0.38	10	4	1250.9	1.3
							Average=	1247.65			Average=	1251.24	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			

COMPARISON MEASUREMENTS

Flow cell: *-44 (S/N: 135198)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(kPa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	16.2.2017	20.38	102.78	45	20.80	102.93	1249.4		10	1	1249.8	1.2
1250	2	16.2.2017	20.38	102.78	45	20.80	102.92	1248.9		10	2	1249.9	1.2
1250	3	16.2.2017	20.38	102.78	45	20.80	102.92	1249.3		10	3	1250.1	1.3
1250	4	16.2.2017	20.39	102.78	45	20.80	102.92	1249.2		10	4	1249.6	1.2
							Average=	**1249.20**			Average=	**1249.84**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	16.2.2017	20.42	102.83	45	20.72	102.98	4992.8		10	1	4994	5
5000	2	16.2.2017	20.46	102.83	45	20.68	102.97	4992.9		10	2	4994	5
5000	3	16.2.2017	20.36	102.822	45	20.66	102.97	4993.1		10	3	4996	5
5000	4	16.2.2017	20.39	102.822	45	20.68	102.96	4992.9		10	4	4995	5
							Average=	**4992.93**			Average=	**4994.81**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	16.2.2017	20.47	102.87	45	20.72	103.03	10014		10	1	10024	10
10000	2	16.2.2017	20.47	102.87	45	20.7	103.03	10016		10	2	10025	10
10000	3	16.2.2017	20.45	102.87	45	20.7	103.02	10015		10	3	10027	10
10000	4	16.2.2017	20.48	102.87	45	20.7	103.02	10017		10	4	10027	10
							Average=	**10015.50**			Average=	**10025.43**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	16.2.2017	20.56	102.884	45	20.76	103.14	20083		10	1	20092	20
20000	2	16.2.2017	20.52	102.884	45	20.78	103.14	20083		10	2	20097	20
20000	3	16.2.2017	20.53	102.884	45	20.76	103.14	20083		10	3	20097	20
20000	4	16.2.2017	20.55	102.884	45	20.74	103.14	20084		10	4	20095	20
							Average=	**20083.25**			Average=	**20095.40**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	16.2.2017	20.66	102.899	45	20.76	103.25	29935		10	1	29958	30
30000	2	16.2.2017	20.55	102.899	45	20.82	102.85	29947		10	2	29967	30
30000	3	16.2.2017	20.61	102.899	45	20.78	103.26	29934		10	3	29959	30
30000	4	16.2.2017	20.65	102.899	45	20.78	103.26	29946		10	4	29954	30
End of measurements							Average=	**29940.50**			Average=	**29959.44**	

EIM results (loop1)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
21.9	1012.5	21.99	1013.5

COMPARISON MEASUREMENTS

Flow cell: *-10 (S/N: 135207)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(kPa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1										1		
5	2										2		
5	3										3		
5	4										4		
							Average=	#DIV/0!			Average=	#DIV/0!	
Change Flow Rate						Stabilization 3 minutes							
10	1										1		
10	2										2		
10	3										3		
10	4										4		
							Average=	#DIV/0!			Average=	#DIV/0!	
Change Flow Rate						Stabilization 3 minutes							
20	1	07.05.2017	23.2	1005	42.8	23.74	1007.2	19.960	0.017	10	1	19.963	0.020
20	2					23.80	1006.5	19.755	0.012	10	2	19.743	0.020
20	3					23.83	1006.3	19.618	0.008	10	3	19.570	0.020
20	4					23.90	1005.6	19.497	0.014	10	4	19.451	0.019
							Average=	19.707			Average=	19.682	
Change Flow Rate						Stabilization 3 minutes							
80	1	18.05.2017	23.9	1015	52	24.02	1016.6	82.756	0.058	10	1	82.879	0.083
80	2		23.9	1015	52	24.03	1016.4	82.621	0.133	10	2	82.619	0.083
80	3		23.9	1015	52	24.06	1016.4	82.474	0.047	10	3	82.483	0.082
80	4		23.9	1015	52	24.06	1016.4	82.347	0.052	10	4	82.372	0.082
							Average=	82.550			Average=	82.588	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
24	1021.1	23.78	1021.4

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134909)*

Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	ENVIRONMENTAL PARAMETERS: Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	TRANSFER STANDARD PARAMETERS: BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	REFERENCE PARAMETERS: RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	16.05.2017	23.9	1021.2	58.9	23.96	1022.9	78.967	0.105	10	1	79.008	0.079
80	2					24.02	1022.7	78.226	0.057	10	2	78.208	0.078
80	3					24.10	1022.5	79.143	0.900	10	3	79.147	0.079
80	4					24.18	1022.3	78.910	0.143	10	4	78.846	0.079
							Average=	78.812			Average=	78.802	
Change Flow Rate						Stabilization 3 minutes							
300	1	17.05.2017	23.2	1014.7	55.3	23.86	1015.9	300.58	0.27	10	1	300.89	0.30
300	2					23.90	1015.7	302.07	0.55	10	2	302.40	0.30
300	3					24.00	1015.3	299.74	0.21	10	3	299.75	0.30
300	4					24.05	1015.1	302.98	0.49	10	4	303.35	0.30
							Average=	301.34			Average=	301.60	
Change Flow Rate						Stabilization 3 minutes							
600	1	17.05.2017	23.2	1014.7	55.3	24.32	1014.5	609.17	1.12	10	1	609.67	0.61
600	2					24.32	1014.4	610.27	0.41	10	2	609.00	0.61
600	3					24.24	1014.0	609.82	0.73	10	3	610.73	0.61
600	4					24.28	1014.5	609.21	1.70	10	4	609.60	0.61
							Average=	609.62			Average=	609.75	
Change Flow Rate						Stabilization 3 minutes							
1250	1	08.05.2017	23.6	1001.8	39.5	24.13	1004.0	1242.11	0.28	10	1	1239.93	0.93
1250	2					24.19	1004.0	1234.56	0.13	10	2	1237.59	0.93
1250	3					24.22	1003.9	1254.99	0.53	10	3	1248.75	0.94
1250	4					24.26	1004.0	1242.49	0.10	10	4	1247.31	0.94
							Average=	1243.54			Average=	1243.40	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature	Laboratory pressure	BIOS temperature	BIOS pressure
(°C)	(kPa)	(°C)	(kPa)
Stabilization 24 hours in laboratory (no flow)			
23	1013	22.9	1013.5
12.05.2017			

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135198)*			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate	RUN	Date	Laboratory temperature	Laboratory pressure	Laboratory relative humidity	BIOS mean temperature	BIOS mean pressure	Mean Indicated Flow Rate	Standard deviation of indication	Number of flow indications in mean	RUN	Reference Flow Rate	Standard uncertainty of reference
(std ml/min)		(dd.mm.yyy)	(°C)	(kPa)	(%rh)	(°C)	(kPa)	(std ml/min)	(std ml/min)			(std ml/min)	(std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	12.05.2017	23.4	1012.8	54	24.04	1015.4	1255.54	1.08	10	1	1255.27	0.94
1250	2					24.06	1015.2	1247.81	1.01	10	2	1245.48	0.93
1250	3					24.04	1015.4	1250.08	0.78	10	3	1248.15	0.94
1250	4					24.04	1015.5	1244.80	1.55	10	4	1244.41	0.93
							Average=	**1249.56**			Average=	**1248.33**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	12.05.2017	23.4	1012.8	54	23.07	1015.4	5071.6	1.1	10	1	5071.7	3.8
5000	2					23.05	1015.5	5066.5	1.1	10	2	5066.1	3.8
5000	3					23.1	1015.2	5069.4	1.1	10	3	5073.2	3.8
5000	4					23.12	1015	5043.3	3.5	10	4	5046.6	3.8
							Average=	**5062.7**			Average=	**5064.4**	
Change Flow Rate						Stabilization 3 minutes							
Change Flow Rate						Stabilization 3 minutes							
20000	1	12.05.2017	23.4	1012.8	54	22.65	1017.3	19976	5	10	1	19959	20
20000	2					22.65	1017.2	19858	7	10	2	19888	20
20000	3					22.71	1016.6	20041	7	10	3	20061	20
20000	4					22.67	1016.7	20225	7	10	4	20238	20
20000	5					22.72	1016.8	20354	9	10	5	20382	20
20000	6					22.72	1017	20588	9	10	6	20614	21
							Average=	**20174**			Average=	**20190**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	11.05.2017	23.4	1012.8	54	23.01	1020	29943	17	10	1	29992	30
30000	2					23.02	1020.2	30139	15	10	2	30141	30
30000	3					23.02	1020.2	29602	20	10	3	29696	30
30000	4					22.91	1020.3	30391	12	10	4	30401	30
30000	5					23.03	1020.4	30046	11	10	5	30039	30
30000	6					23.06	1020.4	30234	12	10	6	30244	30
End of measurements							Average=	**30059**			Average=	**30085**	

UL results (loop2)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.50	98.895	22.72	98.925

COMPARISON MEASUREMENTS

Flow cell: -10 (S/N: 135208)			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	18.11.2016	22.8	98.051	38	23.49	98.193	5.0417	0.0019	10	1	5.0403	0.0083
5	2	18.11.2016	22.8	98.041	38	23.44	98.174	5.0431	0.0008	10	2	5.0473	0.0083
5	3	18.11.2016	22.8	97.998	38	23.64	98.152	5.0400	0.0016	10	3	5.0484	0.0083
5	4	18.11.2016	22.8	97.996	38	23.90	98.142	5.0354	0.0015	10	4	5.0423	0.0083
							Average=	**5.0401**			Average=	**5.0446**	
Change Flow Rate						Stabilization 3 minutes							
10	1	21.11.2016	22.6	98.248	37	23.32	98.400	9.983	0.002	10	1	9.975	0.010
10	2	21.11.2016	22.6	98.248	37	23.33	98.400	9.985	0.003	10	2	9.978	0.010
10	3	21.11.2016	22.6	98.266	37	23.33	98.436	9.986	0.003	10	3	9.980	0.010
10	4	21.11.2016	22.6	98.290	37	23.34	98.443	9.984	0.003	10	4	9.985	0.010
							Average=	**9.984**			Average=	**9.979**	
Change Flow Rate						Stabilization 3 minutes							
20	1	21.11.2016	22.3	98.192	40	23.13	98.337	20.005	0.005	10	1	19.993	0.016
20	2	21.11.2016	22.3	98.200	40	23.13	98.335	19.999	0.006	10	2	19.998	0.016
20	3	21.11.2016	22.3	98.179	40	23.12	98.326	19.998	0.005	10	3	20.001	0.016
20	4	21.11.2016	22.3	98.186	40	23.13	98.334	20.005	0.004	10	4	19.999	0.016
							Average=	**20.002**			Average=	**19.998**	
Change Flow Rate						Stabilization 3 minutes							
80	1	21.11.2016	22.5	98.247	40	23.32	98.388	80.024	0.009	10	1	79.877	0.060
80	2	21.11.2016	22.5	98.236	40	23.33	98.380	80.026	0.012	10	2	79.877	0.060
80	3	21.11.2016	22.5	98.229	40	23.33	98.374	80.017	0.011	10	3	79.871	0.060
80	4	21.11.2016	22.5	98.227	40	23.32	98.378	80.001	0.015	10	4	79.857	0.060
							Average=	**80.017**			Average=	**79.871**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.51	98.895	22.64	98.925

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134910)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	25.11.2016	22.9	98.172	45	23.79	98.310	79.864	0.009	10	1	79.963	0.060
80	2	25.11.2016	22.9	98.166	45	23.82	98.291	79.868	0.011	10	2	79.964	0.060
80	3	25.11.2016	22.9	98.143	45	23.84	98.279	79.857	0.008	10	3	79.963	0.060
80	4	25.11.2016	22.9	98.129	45	23.84	98.271	79.858	0.010	10	4	79.948	0.060
							Average=	**79.862**			Average=	**79.959**	
Change Flow Rate						Stabilization 3 minutes							
300	1	24.11.2016	22.7	98.350	50	23.51	98.498	299.86	0.04	10	1	300.03	0.23
300	2	24.11.2016	22.7	98.354	50	23.53	98.492	299.82	0.02	10	2	300.01	0.23
300	3	24.11.2016	22.7	98.344	50	23.53	98.488	299.84	0.02	10	3	300.02	0.23
300	4	24.11.2016	22.7	98.341	50	23.54	98.486	299.85	0.02	10	4	299.99	0.22
							Average=	**299.84**			Average=	**300.01**	
Change Flow Rate						Stabilization 3 minutes							
600	1	24.11.2016	22.8	98.453	46	23.59	98.591	599.66	0.05	10	1	599.83	0.45
600	2	24.11.2016	22.8	98.447	46	23.60	98.587	599.65	0.05	10	2	599.83	0.45
600	3	24.11.2016	22.8	98.440	46	23.59	98.580	599.71	0.03	10	3	599.85	0.45
600	4	24.11.2016	22.8	98.438	46	23.59	98.579	599.71	0.04	10	4	599.89	0.45
							Average=	**599.68**			Average=	**599.85**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	24.11.2016	23.0	98.487	44	23.53	98.646	1250.03	0.14	10	1	1250.56	0.94
1250	2	24.11.2016	23.0	98.481	44	23.53	98.644	1250.06	0.14	10	2	1250.54	0.94
1250	3	24.11.2016	23.0	98.482	44	23.52	98.647	1250.06	0.12	10	3	1250.59	0.94
1250	4	24.11.2016	23.0	98.482	44	23.52	98.643	1250.15	0.10	10	4	1250.62	0.94
							Average=	**1250.08**			Average=	**1250.58**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
22.46	98.895	22.62	98.925

COMPARISON MEASUREMENTS

Flow cell: *-44 (S/N: 135199)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	23.11.2016	22.6	98.572	40	23.59	98.772	1250.26	0.15	10	1	1249.60	0.94
1250	2	23.11.2016	22.6	98.576	40	23.62	98.772	1250.07	0.11	10	2	1249.55	0.94
1250	3	23.11.2016	22.6	98.581	40	23.62	98.778	1250.22	0.17	10	3	1249.59	0.94
1250	4	23.11.2016	22.6	98.583	40	23.63	98.775	1250.25	0.22	10	4	1249.59	0.94
							Average=	**1250.20**			Average=	**1249.58**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	23.11.2016	22.6	98.607	40	22.86	98.821	4996.1	1.0	10	1	4995.8	3.7
5000	2	23.11.2016	22.6	98.599	40	22.84	98.820	4996.9	0.8	10	2	4996.1	3.7
5000	3	23.11.2016	22.6	98.597	40	22.84	98.824	4997.1	1.3	10	3	4996.3	3.7
5000	4	23.11.2016	22.6	98.595	40	22.82	98.814	4997.4	0.4	10	4	4996.5	3.7
							Average=	**4996.9**			Average=	**4996.2**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	23.11.2016	22.6	98.665	40	23.01	98.950	10005.4	1.1	10	1	10004.3	7.5
10000	2	23.11.2016	22.6	98.666	40	23.02	98.949	10006.6	1.7	10	2	10005.4	7.5
10000	3	23.11.2016	22.6	98.666	40	23.03	98.947	10005.9	1.0	10	3	10005.0	7.5
10000	4	23.11.2016	22.6	98.663	40	23.03	98.945	10005.2	1.7	10	4	10004.5	7.5
							Average=	**10005.8**			Average=	**10004.8**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	23.11.2016	22.4	98.692	39	23.10	99.055	20001	6	10	1	20000	15
20000	2	23.11.2016	22.4	98.689	39	23.09	99.055	20005	5	10	2	20000	15
20000	3	23.11.2016	22.4	98.687	39	23.09	99.062	20005	5	10	3	20000	15
20000	4	23.11.2016	22.4	98.685	39	23.07	99.057	20006	4	10	4	20001	15
							Average=	**20004**			Average=	**20000**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	23.11.2016	22.6	98.695	40	23.05	99.193	30024	7	10	1	30023	23
30000	2	23.11.2016	22.6	98.679	40	23.02	99.186	30028	14	10	2	30023	23
30000	3	23.11.2016	22.6	98.676	40	23.01	99.190	30032	15	10	3	30024	23
30000	4	23.11.2016	22.6	98.673	40	23.00	99.189	30031	14	10	4	30028	23
End of measurements							Average=	**30029**			Average=	**30025**	

CMI results (loop2)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.76	97.42	22.07	97.45

COMPARISON MEASUREMENTS

***Flow cell:** -10 (S/N: 135208)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	17.01.2017	20.46	99.016	53	21.59	99.155	5.0045	0.0002	10	1	5.0000	0.0050
5	2	17.01.2017	20.45	99.018	53	21.61	99.159	5.0043	0.0002	10	2	5.0000	0.0050
5	3	17.01.2017	20.48	98.024	53	21.61	99.164	5.0040	0.0002	10	3	5.0000	0.0050
5	4	17.01.2017	20.51	99.023	53	21.63	99.167	5.0045	0.0002	10	4	4.9999	0.0050
							Average=	5.0043			Average=	5.0000	
Change Flow Rate						Stabilization 3 minutes							
10	1	09.01.2017	20.76	98.536	21	22.11	98.699	10.0055	0.0006	10	1	10.0007	0.0050
10	2	09.01.2017	20.82	98.532	21	22.09	98.697	10.0062	0.0009	10	2	10.0007	0.0050
10	3	09.01.2017	20.83	98.533	21	22.09	98.7	10.0056	0.0018	10	3	10.0007	0.0050
10	4	09.01.2017	20.84	98.532	21	22.09	98.701	10.0068	0.0012	10	4	10.0007	0.0050
							Average=	10.0060			Average=	10.0007	
Change Flow Rate						Stabilization 3 minutes							
20	1	13.1.2017	20.71	95.833	24	22.07	95.986	20.004	0.001	10	1	19.999	0.010
20	2	13.1.2017	20.72	95.839	24	22.07	95.985	20.008	0.002	10	2	19.999	0.010
20	3	13.1.2017	20.72	95.841	24	22.09	95.987	20.009	0.001	10	3	19.999	0.010
20	4	13.1.2017	20.66	95.828	25	22.09	95.975	20.009	0.001	10	4	19.999	0.010
							Average=	20.008			Average=	19.999	
Change Flow Rate						Stabilization 3 minutes							
80	1	18.01.2017	20.52	99.636	57.7	21.87	99.79	80.164	0.003	10	1	80.012	0.040
80	2	18.01.2017	20.54	99.632	58.7	21.87	99.787	80.163	0.003	10	2	80.012	0.040
80	3	18.01.2017	20.52	99.633	58.7	21.87	99.787	80.160	0.002	10	3	80.012	0.040
80	4	18.01.2017	20.54	99.622	58.9	21.89	99.776	80.160	0.002	10	4	80.012	0.040
							Average=	80.162			Average=	80.012	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.7	99.809	21.89	99.887

COMPARISON MEASUREMENTS

***Flow cell:** -24 (S/N: 134910)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
80	1	19.01.2017	20.57	99.78	60	21.87	99.926	79.893	0.005	10	1	80.002	0.040
80	2	19.01.2018	20.6	99.76	60	21.88	99.904	79.896	0.004	10	2	80.002	0.040
80	3	19.01.2019	20.63	99.758	60	21.89	99.904	79.889	0.004	10	3	80.004	0.040
80	4	19.01.2020	20.63	99.76	60	21.89	99.904	79.893	0.002	10	4	80.004	0.040
							Average=	**79.893**			Average=	**80.003**	
Change Flow Rate						Stabilization 3 minutes							
300	1	20.01.2017	20.75	99.675	62	21.63	99.824	300.229	0.008	10	1	300.171	0.150
300	2	20.01.2017	20.7	99.679	62	21.65	99.826	300.220	0.009	10	2	300.171	0.150
300	3	20.01.2017	20.74	99.679	62	21.65	99.826	300.198	0.010	10	3	300.171	0.150
300	4	20.01.2017	20.74	99.679	62	21.65	99.826	300.204	0.011	10	4	300.171	0.150
							Average=	**300.213**			Average=	**300.171**	
Change Flow Rate						Stabilization 3 minutes							
600	1	23.01.2017	20.95	98.794	62	21.87	98.93	600.71	0.03	10	1	600.60	0.30
600	2	23.01.2017	20.95	98.793	62	21.89	98.93	600.78	0.06	10	2	600.60	0.30
600	3	23.01.2017	20.95	98.795	62	21.89	98.932	600.77	0.10	10	3	600.57	0.30
600	4	23.01.2017	20.93	98.796	62	21.89	98.932	600.68	0.07	10	4	600.57	0.30
							Average=	**600.73**			Average=	**600.58**	
Change Flow Rate						Stabilization 3 minutes							
1250	1	23.01.2017	20.75	98.804	63	21.99	98.959	1250.59	0.06	10	1	1251.10	0.63
1250	2	23.01.2017	20.76	98.803	63	21.99	98.954	1250.75	0.07	10	2	1251.10	0.63
1250	3	23.01.2017	20.76	98.803	63	21.99	98.94	1250.41	0.10	10	3	1251.10	0.63
1250	4	23.01.2017	20.79	98.801	63	21.99	98.952	1250.28	0.15	10	4	1251.10	0.63
							Average=	**1250.51**			Average=	**1251.10**	

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
20.81	99.09	22.05	99.11

COMPARISON MEASUREMENTS

***Flow cell:** -44 (S/N: 135199)*			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
1250	1	23.1.2017	20.64	98.636	63	21.79	98.8	1250.93	0.10	10	1	1250.85	0.63
1250	2	23.1.2018	20.63	98.636	63	21.81	98.81	1251.18	0.14	10	2	1250.85	0.63
1250	3	23.1.2019	20.63	98.637	63	21.81	98.796	1251.02	0.17	10	3	1250.79	0.63
1250	4	23.1.2020	20.63	98.636	63	21.81	98.815	1250.87	0.13	10	4	1250.79	0.63
							Average=	**1251.00**			Average=	**1250.82**	
Change Flow Rate						Stabilization 3 minutes							
5000	1	24.1.2017	20.68	98.667	63	22.2	98.87	5002.4	0.5	10	1	5004.7	2.5
5000	2	24.1.2017	20.68	98.667	63	22.21	98.81	5003.4	0.5	10	2	5004.9	2.5
5000	3	24.1.2017	20.68	98.669	63	22.22	98.87	5002.2	0.3	10	3	5005.3	2.5
5000	4	24.1.2017	20.68	98.67	63	22.24	98.87	5002.6	0.2	10	4	5005.3	2.5
							Average=	**5002.7**			Average=	**5005.0**	
Change Flow Rate						Stabilization 3 minutes							
10000	1	24.1.2017	20.62	98.817	62	21.69	99.058	10001.1	1.2	10	1	10002.0	5.0
10000	2	24.1.2017	20.62	98.817	62	21.69	99.052	9998.4	1.0	10	2	10000.0	5.0
10000	3	24.1.2017	20.62	98.819	62	21.69	99.058	9999.7	0.9	10	3	9999.8	5.0
10000	4	24.1.2017	20.62	98.819	62	21.71	99.054	10001.1	1.1	10	4	9999.8	5.0
							Average=	**10000.0**			Average=	**10000.4**	
Change Flow Rate						Stabilization 3 minutes							
20000	1	26.1.2016	20.78	99.528	62	21.77	99.531	20043.4	1.8	10	3	20046.6	12.5
20000	2	26.1.2016	20.78	99.528	62	21.77	99.531	20034.3	2.0	10	4	20037.0	12.5
20000	3	25.1.2017	20.81	99.09	63	22.03	99.436	20005.1	2.5	10	1	20004.6	12.4
20000	4	25.1.2017	20.8	99.092	63	22.01	99.435	19997.8	0.9	10	2	19998.6	12.4
							Average=	**20020.2**			Average=	**20021.7**	
Change Flow Rate						Stabilization 3 minutes							
30000	1	25.1.2017	20.76	98.057	62	21.75	99.53	30020	2	10	1	30009	45
30000	2	25.1.2017	20.76	98.057	62	21.73	99.524	30016	3	10	2	30006	45
30000	3	25.1.2017	20.77	98.057	62	21.71	99.534	30009	2	10	3	30000	45
30000	4	25.1.2017	20.77	98.057	62	21.73	99.544	30005	3	10	4	29996	45
End of measurements							Average=	**30013**			Average=	**30003**	

LNE results (loop2)

INITIAL TESTS

Compare BIOS temperature and pressure readings wtih calibrated temperature and ambient pressure instrument readings.

Laboratory temperature (°C)	Laboratory pressure (kPa)	BIOS temperature (°C)	BIOS pressure (kPa)
Stabilization 24 hours in laboratory (no flow)			
21.8	100.97	22.05	101.09

COMPARISON MEASUREMENTS (LOOP2)

Base: *S/N: 147461*

Flow cell: *-10 (S/N: 135208)*

			ENVIRONMENTAL PARAMETERS			TRANSFER STANDARD PARAMETERS					REFERENCE PARAMETERS		
Nominal Flow Rate (std ml/min)	RUN	Date (dd.mm.yyy)	Laboratory temperature (°C)	Laboratory pressure (kPa)	Laboratory relative humidity (%rh)	BIOS mean temperature (°C)	BIOS mean pressure (kPa)	Mean Indicated Flow Rate (std ml/min)	Standard deviation of indication (std ml/min)	Number of flow indications in mean	RUN	Reference Flow Rate (std ml/min)	Standard uncertainty of reference (std ml/min)
Set Flow Rate						Stabilization 180 minutes							
5	1	24.2.2017	21.4	100.91	43	22.34	101.04	5.0180	0.0015	10	1	5.0138	0.0076
5	2	27.2.2017	21.7	99.08	46	22.54	99.21	5.0128	0.0017	10	2	5.0078	0.0079
5	3	1.3.2017	21.0	99.27	45	22.68	99.39	5.0141	0.0018	10	3	5.0173	0.0081
5	4	2.3.2017	21.2	100.85	43	22.48	100.97	5.0180	0.0014	10	4	5.0121	0.0078
							Average=	**5.0157**			Average=	**5.0128**	
Change Flow Rate						Stabilization 3 minutes							
10	1	24.2.2017	21.4	100.91	46	22.46	101.09	10.022	0.001	10	1	10.017	0.010
10	2	27.2.2017	21.2	99.14	42	22.44	99.26	10.012	0.003	10	2	9.997	0.010
10	3	1.3.2017	21.5	99.31	43	22.60	99.41	10.034	0.001	10	3	10.022	0.010
10	4	2.3.2017	20.8	100.85	44	22.64	100.97	10.016	0.003	10	4	10.004	0.010
							Average=	**10.021**			Average=	**10.010**	
Change Flow Rate						Stabilization 3 minutes							
20	1	24.2.2017	21.4	100.91	43	22.34	101.04	20.053	0.003	10	1	20.044	0.014
20	2	27.2.2017	21.8	98.79	42	22.46	98.91	20.048	0.007	10	2	20.039	0.019
20	3	1.3.2017	20.8	99.33	45	22.52	99.46	20.019	0.005	10	3	20.017	0.014
20	4	2.3.2017	21.4	100.82	43	22.58	100.94	20.016	0.003	10	4	20.010	0.014
							Average=	**20.034**			Average=	**20.028**	
Change Flow Rate						Stabilization 3 minutes							
80	1	24.2.2017	21.5	100.91	45	22.48	101.03	80.097	0.010	10	1	79.885	0.040
80	2	27.2.2017	21.5	98.81	41	22.64	98.92	80.064	0.017	10	2	79.834	0.042
80	3	1.3.2017	21.2	99.33	44	22.52	99.46	80.078	0.008	10	3	79.902	0.041
80	4	2.3.2017	21.7	100.82	45	22.68	100.95	80.093	0.006	10	4	79.895	0.040
							Average=	**80.083**			Average=	**79.879**	