Technical Protocol for Supplementary comparison between **PTB and VTT MIKES, Euramet project 1473**

Water flow: 30 m³/h … 200 m³/h

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Technical Protocol for SC supplementary comparison

Water flow within the range 30 m³/h … 200 m³/h

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1 Introduction

The purpose of the Supplementary Comparison SC for water flow measurement (Euramet ?) is to support the Calibration and Measurement Capabilities (CMC) entry of VTT MIKES, the National Metrology Institutes of Finland. For this goal a bilateral comparison between VTT MIKES and PTB Braunschweig will be realized. The laboratory “Hydrodynamic Test Field” of the department 1.5 “Liquid Flow” will act as the reference facility.

The special issues of SC comparisons have been outlined in “Guidelines for CIPM key comparisons” [] and comprise:

- Organization of a supplementary comparison;
- The technical protocol for a supplementary comparison;
- Circulation of the transfer standards;
- Reporting the results of a comparison;
- Preparation of the report on a supplementry comparison.

Note:

The official SCDB identifier will be updated after received from BIPM.

2 Administrative information

The transport of the equipment of the transfer package, which is packed in 2 metal cases (section 5.1), will be organized by VTT.

The sequence of the participating laboratories within the time schedule of the transfer meter round robin has been outlined in order to minimize the time requirements and under the aspect of customs efforts. The sequence is PTB-VTT-PTB.

3 Description of the transfer standard

The transfer standard used in SC comparison is the same transfer standard used in CCM.FF-K1.2015 key comparison. Within this document the transfer standard is referred with the identifier SC.

3.1 Quantities that are subject of the comparison measurements: Meter k-factors

Though there occur four measurands in fluid flow metering:

(Average) Volume/volumetric flow rate:

$$\overline{q_V} = V = \frac{V_{REF}}{T_{MEAS}} = \frac{m_{REF}}{\rho_{Water} \cdot T_{MEAS}}$$

(Average) Mass flow rate:

$$\overline{q_m} = m = \frac{m_{REF}}{T_{MEAS}}$$

Total(ized) volume flow measurement:

$$V_M = \int_0^{T_{MEAS}} V(t)\,dt = \overline{q_V} \cdot T_{MEAS}$$

Total(ized) mass flow measurement:

$$m_M = \int_0^{T_{MEAS}} m(t)\,dt = \overline{q_m} \cdot T_{MEAS}$$

In general, the **meter K-factor** of a flowmeter is the subject of flow calibration, regardless whether volumetric or gravimetric references are used in calibrating flowmeters, so it is in the SC water flow supplementary comparison.

T_{MEAS} represents the measurement time of one calibration run during which the reference standard is filled with the test fluid due to the diverter operation.

Under certain circumstances, even flow calibration standards whose operation principle relies on the standing-start-and-finish operation may be utilized for metering flowrates and meter K-factors.

Note:

The meter K-factor was the measurand in the CCM.FF-K1 for Water Flow in 2003/2004, too [2], which was the subject of the calibration measurements and also in the CCM.FF-K1.2015. This supplementary comparison uses same standard and measuring methods.

Depending on the operating principle of the flowmeters that are used in SC, following meter-K-factors are the subject of measurement and have to be determined in SC:

1) **Turbine flowmeter:** volume-related frequency output:
   $\boldsymbol{K_{Tur\_V}}$ [pulses/unit volume]
2) **Coriolis flowmeter:** mass-related frequency output:
   $\boldsymbol{K_{Cor\_m}}$ [pulses/unit mass]

3.2 Calculation of meter K-factors

For each single measurement a specific K-factor will be calculated by using equation 1, respectively, equation 2. The measurement error will be estimated by using equation 3 and 4. Both approaches are based on a specific nominal meter K-factor (Table 1 and Table 2). Finally, for each flow rate the mean measurement error $\bar{x}_{V,i}$ and $\bar{x}_{m,i}$ will be calculated by using equation 5, respectively, equation 6.

$$K_{Tur\_V,i} = \frac{Pulse_{Tur}}{V_{ref,i}} \qquad \text{Equ. 1}$$

with $Pulse_{Tur}$ - counted pulses of turbine meter (pulse)
$V_{ref,i}$ - reference volume (Liter)
i - laboratory

$$K_{Cor\_m,i} = \frac{Pulse_{Cor,m}}{m_{ref,i}} \qquad \text{Equ. 2}$$

with $Pulse_{Cor,m}$ - counted pulses of coriolis meter - mass output (pulse)
$m_{ref,i}$ - reference mass (kg)

$$x_{V,i} = \frac{K_{Tur\_V,i} - K_{Tur\_V,nom}}{K_{Tur\_V,nom}} \cdot 100\ \% \qquad \text{Equ. 3}$$

$$x_{m,i} = \frac{K_{Cor\_m,i} - K_{Cor\_m,nom}}{K_{Cor\_m,nom}} \cdot 100\ \% \qquad \text{Equ. 4}$$

$$\bar{x}_{V,i} = \frac{\sum_{j=1}^{n} x_{V,i}}{n} \qquad \text{Equ. 5}$$

$$\bar{x}_{m,i} = \frac{\sum_{j=1}^{n} x_{m,i}}{n} \qquad \text{Equ. 6}$$

with $K_{Tur\_V,nom}$ - nominal meter K-factor of turbine output (pulse/kg)
$K_{Cor\_m,nom}$ - nominal meter K-factor of coriolis mass output (pulse/kg)
$x_{V,i}$ - single value of measurement error turbine meter at one flow rate (%)
$x_{m,i}$ - single value of measurement error coriolis meter at one flow rate (%)

The installation of the transfer package comprising the above-mentioned transfer meters is shown in Figure 4.

Auxiliary measurands for diagnostic purposes:

These measurands are:

1) Water density (based on a signal delivered by the Coriolis flowmeter, see also Figure 2);
2) Pressure drop across the turbine meter (as an indicator for the proper operation of this meter)

They are acquired autonomously by the electronic equipment, which dedicated to the transfer package, during each calibration measurement **if electronic box 1 is used**. These devices and their arrangement in the calibration line are shown in Figure 3 and Figure 4, respectively.

3.3 Transfer meters

In addition to the transfer meters, all items that are necessary for installing the transfer meters are part of equipment provided by the pilot laboratory:

1) Pipework for meter installation: providing connectivity to both DIN and ANSI flanges Figure 3
2) Cables for connecting transfer meters and the auxiliary devices to the electronic boxes, respectively to the laptop computer
3) Electronic boxes 1 and 2 (Figure 9 and Figure 10)

The whole pipework consists of elements which were manufactured in stainless steel. The installation spacing of the meters and the KC pipework elements amounts to approx. 3,430 mm in total.

In order to provide optimum reproducibility conditions, the transfer package meters and the inter-connecting pipework are equipped with pin-in-hole alignment capabilities (see Figure 1 and Figure 3).

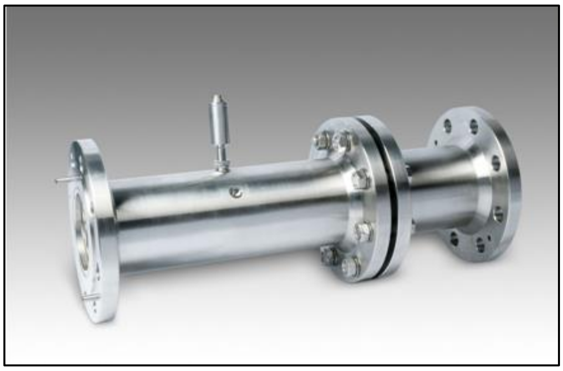


Figure 1: KC1 transfer meter - Turbine meter, DN 100, Manufacturer, KEM (Germany)

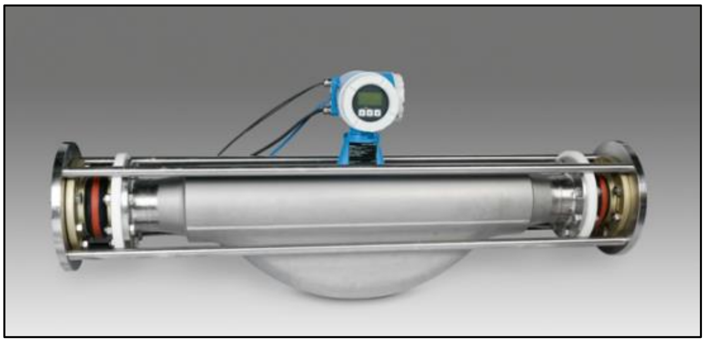


Figure 2: KC1 transfer meters - Coriolis flowmeter, DN 100, Manufacturer, E+H (Switzerland)

Transfer meter #1:

Table 1: Turbine flowmeter (Figure 1)

Manufacturer:	KEM Küppers Elektromechanik GmbH	Germany
Type:	HM 100.71.FDB40-TS15-P	For further details see manual
Serial No.:	010995521	
Pipe size:	DN 100	Nominal: 100 mm
Signal pick-up:	Type: VTE*/P-Ex Carrier-frequency pulse amplifier Serial No.: 02497623	Signal voltage: ca. 24 V
Output signal:	Frequency	(0 Hz) … 450 Hz (at 240 m³/h)
	Nominal meter K-factor: $K_{Tur\_V,nom}$	**6.633 Pulses/L**
Connecting cable:		Plug with green marker
Process connections:	Flanges	according to DIN standard
Additional equipment:	Tube-bundle flow conditioner	Permanently attached to meter
Special provision:	Pin-in-hole alignment	Steel pins located in precision holes on both ends

Transfer meter #2:

Table 2: Coriolis flowmeter (Figure 2)

Manufacturer:	ENDRESS + HAUSER	Switzerland
Type:	Proline Promass 83 F	For further details see manual
Serial No.:	D702C102000	
Pipe size:	DN 100	Nominal: 100 mm
Signal output #1:	Mass-flowrate related: frequency	0 kHz … 10 kHz
	Nominal meter K-factor: $K_{Cor\_m,nom}$	**100 Pulses/kg**
Signal output #2:	Fluid density: current signal	4 mA … 20 mA
Signal input:	Activate RE-ZERO of flowmeter	Binary signal:
Communication line:	Reading parameters from flowmeter	HART protocol (current output)
Connecting cable:	All signal lines are combined in a single cable	Plug with blue marker
Process connections:	Flanges	according DIN standard
Special adoptions:	A cage-like meter extension in order to isolate the meter from external forces and torques	With rubber damping elements included
Special provision:	Pin-in-hole alignment	Steel pins located in precision holes on both ends

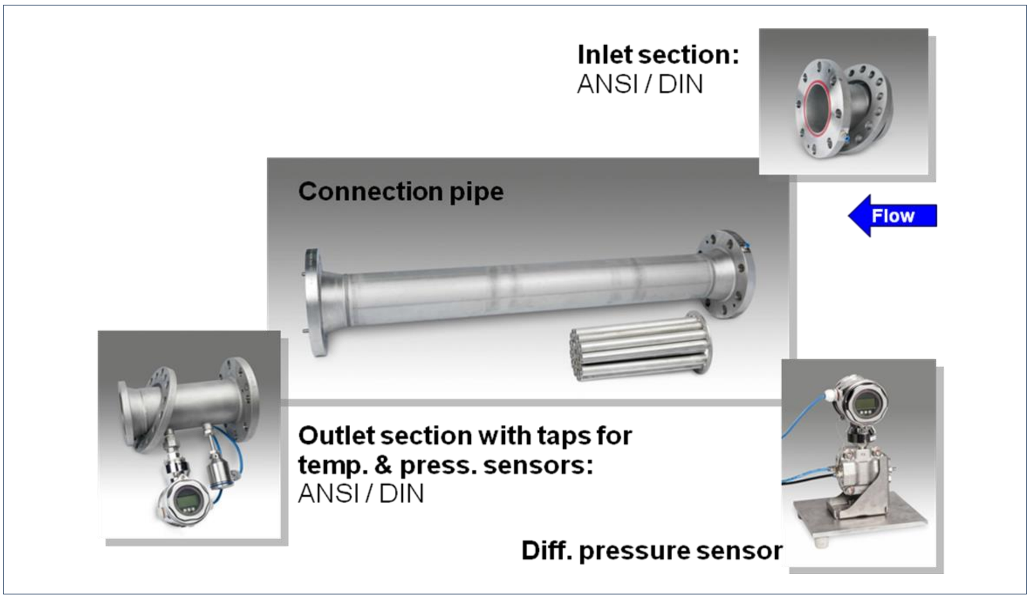


Figure 3: KC1 pipework

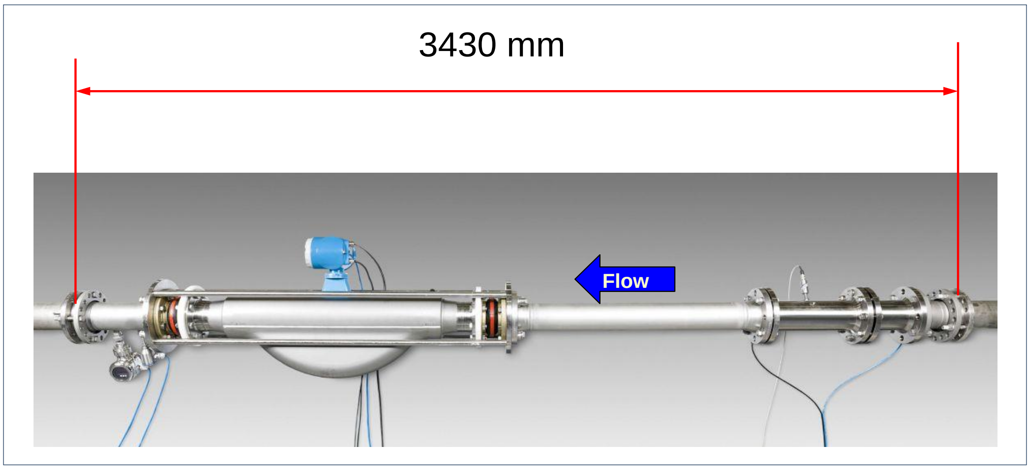


Figure 4: KC1 transfer meter package and pipework – Overview

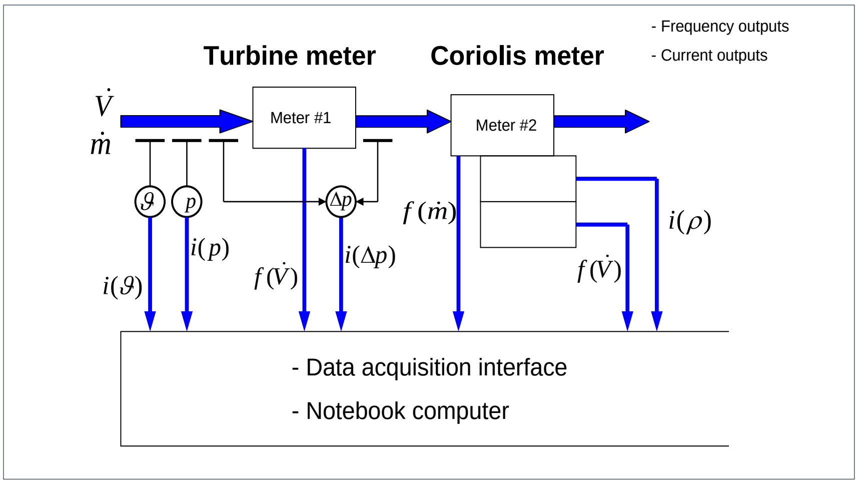


Figure 5: Electronic Box 1 - Signal acquisition during comparison measurements

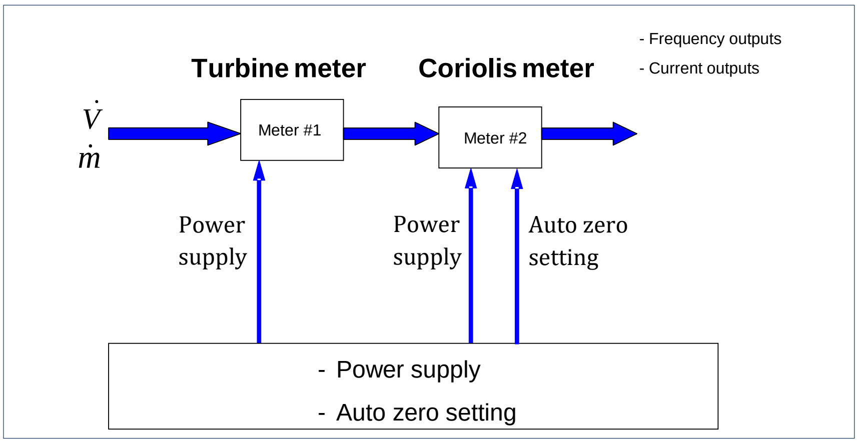


Figure 6: Electronic Box 2 – power supply and function of auto zero setting (for coriolis meter)

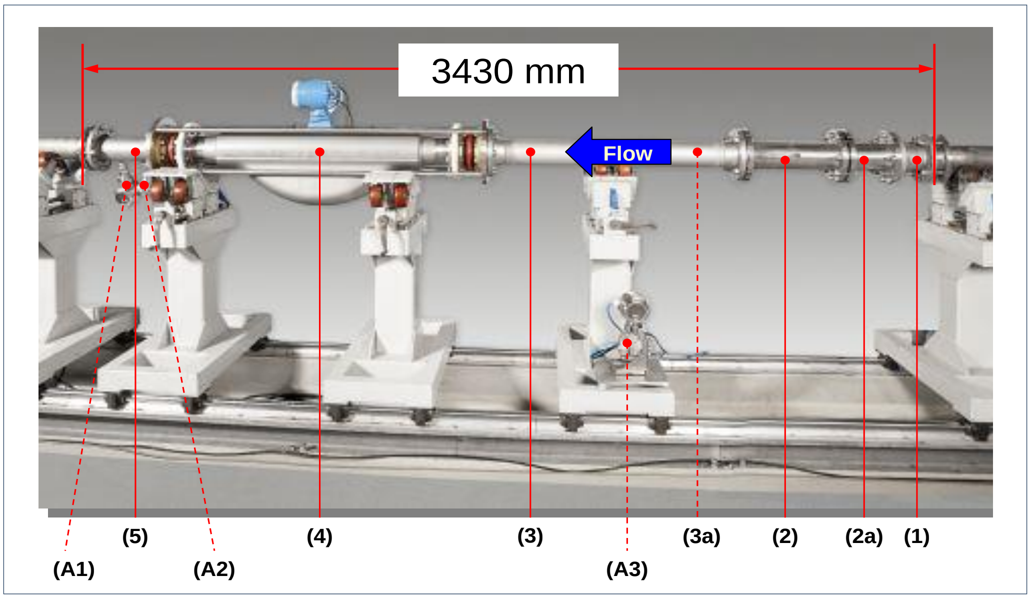


Figure 7: KC1 transfer meter package and pipework - **Sample installation**

(1) Inlet pipe section (adaptable to both ANSI and DIN flange connections)
(2) Turbine meter
(2a) Tube-bundle flow conditioner dedicated to the turbine
(3) Connecting pipe section with
(3a) Integrated tube-bundle flow conditioner
(4) Coriolis flowmeter
(5) Outlet pipe section (adaptable to both ANSI and DIN flange connections)

Auxiliary devices:

(A1) Pressure transmitter
(A2) Temperature transmitter
(A3) Differential pressure transmitter

In Figure 8, the operating characteristics of the transfer package as a function of pressure loss vs. flowrate (derating curve) is shown, which could be useful in order to estimate the operability of transfer package in a calibration facility.

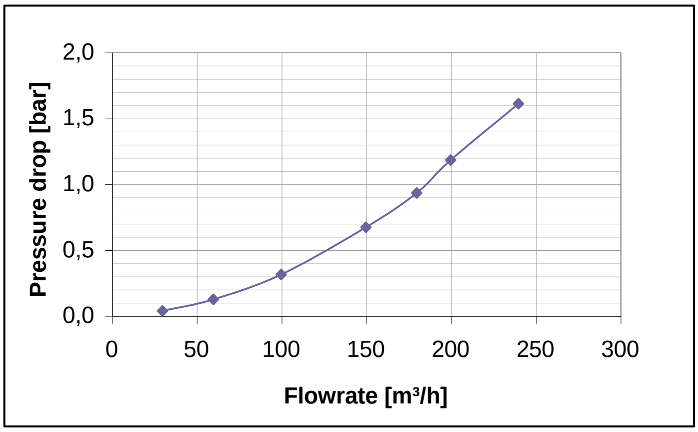


Figure 8: Pressure drop (pressure loss) across transfer meter package (derating curve)

<u>Inlet pipe section upstream meter #1:</u>

Table 3: Inlet section (Figure 3)

Material:	Stainless steel	
Length:	150 mm	
Pipe size/diameter:	Nominal: 100 mm	
Process connections:	Flanges: - Inlet side: - Outlet side:	- Connectable both to DIN and ANSI pipework - According to DIN standard
Special provisions:	Pin-in-hole alignment	On the outlet side: Flange connection to meter #1

<u>Interconnection pipe section between meter #1 and meter #2:</u>

Table 4: Connection pipe (Figure 3)

Material:	Stainless steel	
Length:	1,000 mm	
Pipe size/diameter:	Nominal: 100 mm	
Sub-item.:	Tube-bundle flow conditioner (inlet)	Fastened inside by screws
Process connections:	Flanges	According to DIN standard
Special provisions:	Pin-in-hole alignment	On either end

<u>Outlet pipe section downstream meter #2:</u>

Table 5: Outlet section (Figure 3)

Material:	Stainless steel	
Length:	300 mm	
Pipe size/diameter:	Nominal: 100 mm	
Process connections:	Flanges: - Inlet side: - Outlet side:	- According to DIN standard - Connectable both to DIN and ANSI pipework
Special provisions:	Pin-in-hole alignment	On the inlet side: connection to meter #2

3.4 Auxiliary devices

a) Temperature transmitter

Table 6: Temperature transmitter

Manufacturer:	ENDRESS + HAUSER	Switzerland
Type:	TR10 – ARA1CAR4H300L	For further details see manual
Serial No.:	D301FB14152	
Length of sensing element:	80 mm	
Process connections:	Male thread:	Permanently screwed to tap at outlet pipe section
Sensor head transmitter:	TMT182 - A	
Signal output:	Current signal	4 mA … 20 mA
Communication line:	Not in use	HART protocol (current output)
Connecting cable:		Plug with red marker

b) Pressure transmitter:

Table 7: Pressure transmitter

Manufacturer:	ENDRESS + HAUSER	Switzerland
Type:	Cerabar PMC71	For further details see manual
Serial No.:	D502B90109C	
Calibration label:	PTB 30295 14	
Process connections:	Male thread:	Permanently screwed to tap at outlet pipe section
Signal output:	Current signal	4 mA … 20 mA
Communication line:	Not in use	HART protocol (current output)
Connecting cable:		Plug with grey marker

c) Differential pressure transmitter:

Table 8: Differential pressure transmitter

Manufacturer:	ENDRESS + HAUSER	Switzerland
Type:	Deltabar PMD70 - ABR7HCAUA	For further details see manual
Serial No.:	H201CC0109D	
Calibration label:	PTB 30293 14	
Process connections:	Flexible hoses: - blue: "Pressure +" - black: "Pressure –"	Pluggable connections
Signal output:	Current signal	4 mA … 20 mA
Communication line:	Not in use	HART protocol (current output)
Connecting cable:		Plug with blue marker

d) Densitometer:

Signal is delivered by the Coriolis flowmeter:

- 4 mA … 20 mA; Measurement principle: See manual of Coriolis meter
- Signal connection: See Table 2

3.5 Electronic boxes 1 and 2

The transfer meters and the auxiliary devices have to be connected **to one** of the following electronical boxes. The electronic of both boxes was developed as a parallel working system, which does not affect the standard recording of the laboratories (impulse counting). Additionally, tests in the PTB-lab verified the use of both boxes. A negative influence of the electronics to the impulse counting itself was not detected.

a) **electronic box 1** - data logger system by National Instruments (Figure 9)

either

b) **electronic box 2** - power supply and auto zero setting (Figure 10)

In generally, all measurements should be done by using box 1. Only under special circumstances (see text below) it could be necessary to use box 2. In that case or if you are not sure about the next steps it is essential to contact a member of the pilot lab (For contact details see Page 1).

The main purpose of **electronic box 1** is to log impulses and process parameter during calibration. Additionally, power supply of the measurement instruments is provided by the box. The data of the box will be used for a long-term characterization of the transfer meters and an interpretation of the measurement conditions in the laboratories during the whole round-robin. Therefore the KC1 transfer package comprises special sensors and these extended measurement data acquisition electronics. For more detailed description of the logged data set see Appendix 2. The connectors and inlet/outlet sockets of electronic box 1 is given in Table 9.

Due to the diverse conditions of the laboratories (e.g. electronical compatibility) it was necessary to develop an alternative junction device for the transfer meters. For the scenario, if the use of electronic box 1 doesn't work in the intended function (power supply of the transfer meters and data logging) **electronic box 2** has to be used instead. The main purpose of **electronic box 2** is the power supply of the turbine and coriolis meter. Additionally, auto zero setting for the Coriolis meter can be activated. The connectors and inlet/outlet sockets of electronic box 2 are given in Table 10.

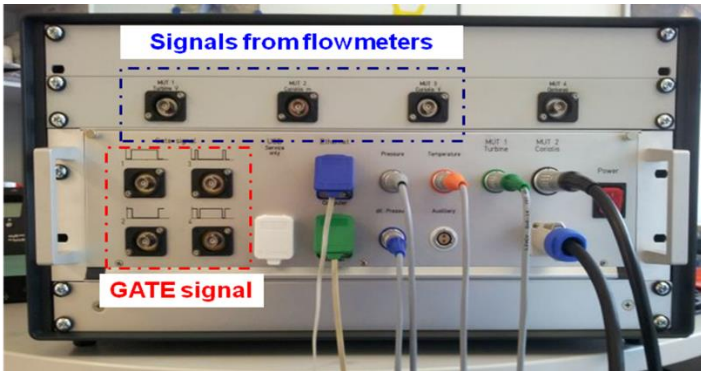


Figure 9: Front side of electronic box 1

Figure 10: Electronic box 2 (alternative junction) for power supply of both transfer meters and auto zero setting for coriolis meter

Table 9: Connectors and inlet/outlet sockets of electronic box 1 (Figure 10)

Item No.	Signal / power supply	Plug type	Signal type	Voltage / Signal level	Color code of connector
1	Mains switch	/	/	/	/
2	Mains connector input (on the rear side)	National adapters (*adequate types of adapters are part of the transfer package*)	AC mains	110 V … 240 V (50 Hz – 60 Hz)	/
3	Input signal from diverting device (1 of 4)	BNC socket (BNC cable & BNC-to-banana-plug adapter included)	Binary signal (TTL voltage level)	Digital logic levels: LOW: 0 to 0.8 V HIGH: 2 to 24 V 1)	black
4	Power supply to laptop computer	Mechanically coded		20 V (DC)	/
5	Computer-to-electronics interface	RJ45 socket (connecting cable included)	Ethernet	Ethernet	/
6	Line pressure	Mechanically coded	Current input	4 mA … 20 mA	grey
7	Differential pressure	Mechanically coded	Current input	4 mA … 20 mA	blue
8	Fluid temperature	Mechanically coded	Current input	4 mA … 20 mA	light red
9	MUT #1: Turbine meter - volume flowrate	Mechanically coded	Voltage input: pulse signal Supply voltage	ca. 24 V 24 V (DC)	green
10	MUT #2: Coriolis meter: - mass flowrate - volume flowrate - fluid density	Mechanically coded	Voltage input: pulse signal	ca. 18 V	black
11	Outlet socket: Power supply to Coriolis meter	Mechanically coded	Voltage (AC)	110 V … 240 V (AC)	blue
12	Outlet socket: - turbine meter	BNC socket (BNC cable & BNC-to-banana-plug adapter included)	Voltage input: pulse signal	ca. 22 V	/
13	Outlet socket: - Coriolis meter (mass)	BNC socket (ditto)	Voltage input: pulse signal	ca. 22 V	/
14	Outlet socket: - Coriolis meter (mass)	BNC socket (ditto)	Voltage input: pulse signal	ca. 22 V	/
15	Outlet socket: - NOT in use here	BNC socket	/	/	/
16	- USB socket: provides connectivity to laptop computer	USB socket	USB signal	USB voltage level	white cover

1) National Instruments, Inc.: NI 9411 - Operating instructions and specifications, 6-channel differential digital input module *[www.ni.com/manuals]*

Table 10: Connectors and inlet/outlet sockets of electronic box 2 (Alternative junction) **-** (Figure 10)

Item No.	Signal / power supply	Plug type	Signal type	Voltage / Signal level	Color code of connector
1	Mains switch	/	/	/	/
2	Mains connector input	National adapters (*adequate types of adapters are part of the transfer package*)	AC mains	110 V … 250 V (50 Hz – 60 Hz)	black
3	constant voltage power supply (24 V DC) input	Banana-plug	DC mains	24 V	Black: **-** Red: **+**
4	Outlet socket: - turbine meter MUT 1	BNC socket (BNC cable & BNC-to-banana-plug adapter included)	Voltage input: pulse signal	ca. 22 V	/
5	Outlet socket: - Coriolis meter (volume) MUT 2	BNC socket (ditto)	Voltage input: pulse signal	ca. 22 V	/
6	Outlet socket: - Coriolis meter (mass) MUT3	BNC socket (ditto)	Voltage input: pulse signal	ca. 22 V	/
7	Input socket: MUT #1: Turbine meter - volume flowrate	Mechanically coded	Voltage input: pulse signal Supply voltage	ca. 24 V 24 V (DC)	green
8	Input socket: MUT #2: Coriolis meter: - mass flowrate - volume flowrate	Mechanically coded	Voltage input: pulse signal	ca. 18 V	black
9	Outlet socket: Power supply to Coriolis meter	Mechanically coded	Voltage (AC)	110 V … 240 V (AC)	blue

3.6 Characterization of the transfer meters prior to SC

The two flowmeters were subjected to extensive test measurements. These calibrations were made under defined conditions (Table 11) during KC1 and included the following reference conditions of the SC. All measurements were made by installing the complete SC setup (Figure 4).

Reference conditions of SC:

- **Flowrate range**: 30 m³/h … 200 m³/h
- **Reference temperature**: 20 °C
- **Line gauge pressure**: 3 bar

For flowmeter characterization purposes, i.e. in order to analyze the temperature and pressure impacts on the meters' characteristics (error curves), the fluid temperature and the line gauge pressure had been subject of systematic variations (Table 12**)**. Due to short time period after the finish of the CCM.FF-K1.2015 and the beginning of the SC, there is no need to repeat the whole range of the characterization range. This assumption is valid for temperature and pressure characterization as well for additional measurement days at pilot laboratory (day#4 to day day#6). It is sufficient to measure only at the operation conditions i.e. the 20 °C and 3 bar.

Table 11: Measurement and reference conditions

1) Meters under test applied:

			Measurands that are subject of the comparison:	
1)	**Turbine flowmeter**, DN100		K_{Turb_Vol}	[Pulses per unit volume]
2)	**Coriolis flowmeter**, DN100			
	a)	Mass-flow related output	K_{Cor_Mass}	[Pulses per unit mass]
	b)	Volume-flow related output	K_{Cor_Vol}	[Pulses per unit volume]
	c)		**Water density**	[0 … 20 mA]

2) Flow range:

		Flowrate [kg/min]	Flowrate [kg/s]	Flowrate [m³/h]	
Q_{MIN}	Q_1	499	8	**30,0**	$Q_{1.1}$ - $Q_{1.5}$
	Q_2	999	17	**60,0**	
	Q_3	1664	28	**100,0**	
	Q_4	2330	39	**140,0**	
	Q_5	2996	50	**180,0**	
	Q_6	3329	55	**200,0**	$Q_{6.1}$ - $Q_{6.5}$
Q_{MAX}	Q_7	3994	67	240,0	$Q_{7.1}$ - $Q_{7.5}$

SC flow range: Q_1 … Q_6; Characterization: Q_1 … Q_7

3) Reference conditions:

Pressure:

		Pressure [bar]
p_{MIN}	p_1	2,0
p_{REF}	**p_2**	**3,0**
p_{MAX}	p_3	4,0

Temperature:

		Temperature [°C]
	T_1	10,0
	T_2	15,0
T_{REF}	**T_3**	**20,0**
	T_4	25,0
	T_5	30,0
	T_6	35,0

Table 12: Characterization of the transfer meters

Investigation: Effects of temperature and pressure

1) Program: ***Effect of temperature*** ***(Repeatability)***

Pressure: ***3,0 bar***

Temperature:	**10 °C**	**15 °C**	**20 °C**	**25 °C**	**30 °C**	**35 °C**	
	$Q_{1.5}$	$Q_{1.5}$	$Q_{1.5}$	$Q_{1.5}$	$Q_{1.5}$	$Q_{1.5}$	
	$Q_{2.5}$	$Q_{2.5}$	$Q_{2.5}$	$Q_{2.5}$	$Q_{2.5}$	$Q_{2.5}$	
	$Q_{3.5}$	$Q_{3.5}$	$Q_{3.5}$	$Q_{3.5}$	$Q_{3.5}$	$Q_{3.5}$	
	$Q_{4.5}$	$Q_{4.5}$	$Q_{4.5}$	$Q_{4.5}$	$Q_{4.5}$	$Q_{4.5}$	
	$Q_{5.5}$	$Q_{5.5}$	$Q_{5.5}$	$Q_{5.5}$	$Q_{5.5}$	$Q_{5.5}$	
	$Q_{6.5}$	$Q_{6.5}$	$Q_{6.5}$	$Q_{6.5}$	$Q_{6.5}$	$Q_{6.5}$	
	$Q_{7.5}$	$Q_{7.5}$	$Q_{7.5}$	$Q_{7.5}$	$Q_{7.5}$	$Q_{7.5}$	in total
Count of measurements:	*35*	*35*	*35*	*35*	*35*	*35*	***210***

2) Program: Effect of pressure (Tapping for pressure sensing: downstream)

Temperature: 20 °C

Pressure:	**2,0 bar**	**3,0 bar**	**4,0 bar**	
	$Q_{1.5}$	$Q_{1.5}$	$Q_{1.5}$	
	$Q_{2.5}$	$Q_{2.5}$	$Q_{2.5}$	
	$Q_{3.5}$	$Q_{3.5}$	$Q_{3.5}$	
	$Q_{4.5}$	$Q_{4.5}$	$Q_{4.5}$	
	$Q_{5.5}$	$Q_{5.5}$	$Q_{5.5}$	
	$Q_{6.5}$	$Q_{6.5}$	$Q_{6.5}$	
	$Q_{7.5}$	$Q_{7.5}$	$Q_{7.5}$	in total
Count of measurements:	*35*	*(35)*	*35*	**70**

3) Investigation: Reproduceability
- Repeated removal and reinstallation: *at reference conditions*

3.7 Data acquisition and operating software

<u>If using electronical box 1</u>, the data acquisition and operating software relies on a LabVIEW application program (National Instruments, Inc.) that is run on a Windows 7-based laptop computer.

The LabVIEW program comprises a HMI (human machine interface) which run as a Virtual Instrument (VI) on the Windows computer as well as the operating part which was downloaded to be run on the FPGA-based process interface, realized in a CompactRIO subsystem from National Instruments, Inc.

In order to start the measurement program, do start up the laptop's Windows 7 operating system and log in:

User: ***.\Lab#XX*** (placeholder: XX, stands for sequence number of NMI)

Password: ***Lab#XX*** (default; password **should be changed** under Windows 7)

To start the measurement program, double click on the NI (National Instrument) icon and LabVIEW's welcome VI window will appear.

Please follow the instructions, which are described in Appendix 2.

<u>If using electronical box 2</u>, no data acquisition and operating software is running. It is not necessary to start the SC laptop.

4 Measurement procedure

4.1 Calibration method

The flow calibration facilities of PTB and MIKES are operating by practicing the calibration method of Flying-start-and-finish in combination with diverter-operated static weighing. This method provides the highest accuracy in liquid flow calibration. The set of transfer meters and the auxiliary electronics are prepared to be run in this operation mode.

The manual data input during each single flow point, when calibrating the transfer meter is described in Appendix 1

The **main objective of the measurement program** during SC is to verify and confirm the future CMC entries of the National Metrology Institute (NMI) of Finland.

The test and measurement program(s) for SC Water Flow has been derived under this special aspect.

4.2 Measurement program: SC participating laboratories

The SC calibration measurements of the participating laboratories provide following data and information:

1) **Lab-to-lab reproducibility**: Meter error drifts of the transfer meters during the SC meter round robin from lab to lab (measurements on the 1st day).

   Of course, these values inherently comprise both meter and laboratory related effects.

   In order to isolated meter and laboratory related effects, the PTB's SC program comprises a more extended calibration and test program part.

2) **Flowmeter calibration capabilities** of the labs under "normal" operation conditions in order to prove the CMC entries in BIPM's CMC data base (2nd day).

   These measurement results represent the basis to determine The **Supplementary Comparison Reference Value** (SCRV).

   As the transfer meter package comprises flowmeters based on both volume-flow metering:

   a) through the turbine meter volume flow output signal;

   and mass-flow metering principles:

   b) through the Coriolis meter's mass flow output signal;

Both participating labs have to prove their mass flow as well their volume flow calibration capabilities, regardless whether a participating laboratory's calibration facility primarily relies on a gravimetric or a volumetric reference system.

3) **Repeatability** of the laboratories' calibration measurements: For this purpose, meter calibration is run at selected flowrates:

   flow flowrate: 30 m^3/h, medium flowrate: 100 m^3/h, high flowrate: 200 m^3/h;

   with a higher number of 10 repeated measurements.

Behind this background, the SC measurement program for both laboratories has been derived as follows:

1) <u>1st day of calibration measurements</u>

Reproducibility	**(Lab-to-lab reproducibility)**		
Preparations:	Installation of transfer meters		
	Coriolis meter: re-zero **YES** (flowrate = 0)		
Start-up	(flowrate > 0)		
Calibration:	at 6 flowrates (according to Table 11: 30 m³/h, 60 m³/h, 100 m³/h, 140 m³/h 180 m³/h 200 m³/h) with 5 repeated measurements		
Finish:	Shutdown of calibration facility		
	Transfer package **remains in calibration line**		

2) <u>2nd day of calibration measurements:</u> **Main measurement of SC**

Day-to-day repeatability

Preparations:	Coriolis meter: re-zero **NO**
Start-up	(flowrate > 0)
Calibration:	at 6 flowrates (according to Table 11: 30 m³/h, 60 m³/h, 100 m³/h, 140 m³/h 180 m³/h 200 m³/h) with 5 repeated measurements
Finish:	Shutdown of calibration facility
	Transfer package **remains in calibration line**

3) <u>3rd day of calibration measurements</u>

Repeatability

Start-up:	1st flowrate:	30 m³/h	(10x repeated measurements)
	2nd flowrate:	100 m³/h	(ditto)
	3rd flowrate:	200 m³/h	(ditto)
Finish:	Shutdown of calibration facility		
	Transfer package is removed from calibration line and prepared for shipment.		

4) <u>Shipment of transfer package</u>

5 Shipping the transfer standard

5.1 Packing and unpacking the transfer standard

An overview how the elements of the transfer package, the electronic hardware and the laptop computer are arranged in their transport case for shipment can be seen in **Figure 11.**

The two shipment cases, destined for shipping the SC transfer package meters, data acquisition electronics and laptop computer, have following sizes and weights (Mass):

Case #1:	Transfer package meters		
	Size:	Length x Width x Height	**(1700 x 800 x 860) mm**
	Weight / mass:		**351 kg**
Case #2:	Electronic devices, computer		
	Size:	Length x Width x Height	**(800 x 600 x 410) mm**
	Weight / mass:		**45 kg**

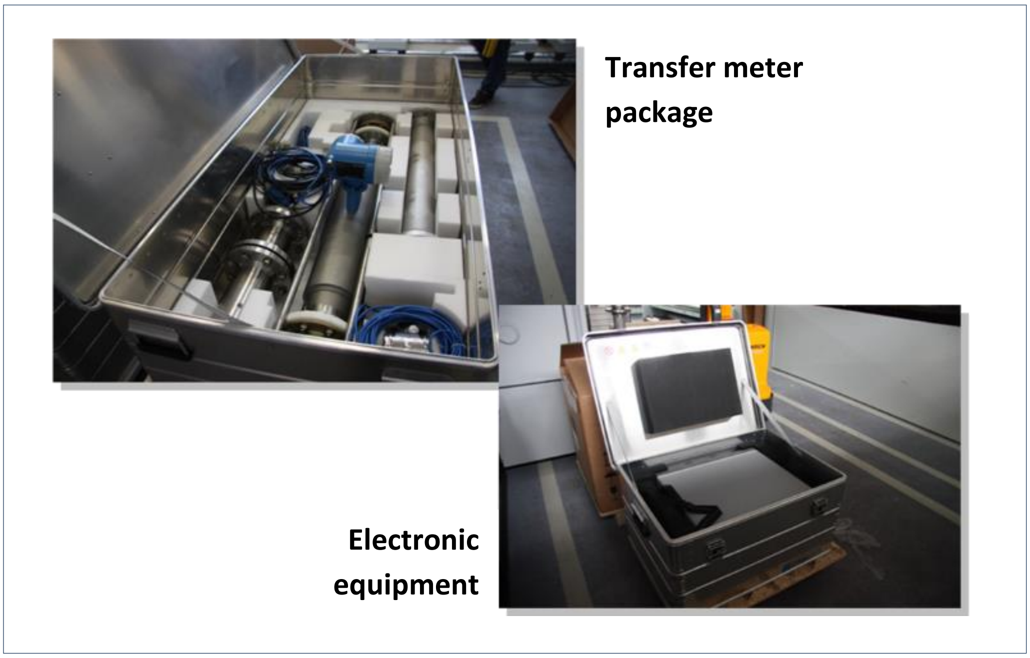


Figure 11: Transfer standard, shipping conditions (two metal boxes)

5.2 Mounting and dismounting the transfer package

The elements of the SC flow instruments and connecting pipework were prepared for high-reproducibility installation by means of pin-and-hole design as a mounting aid for a precise alignment of the flowmeters and connecting pipe segments.

A description how to proceed when mounting the transfer package hardware will be placed in the shipment case - in addition to a list of all parts of the transfer package.

Prior to installation works, the completeness of the contents of the shipment boxes should be checked.

In case of missing parts or damaged devices (due to visual inspection) the co-ordinator or another representative of the PTB laboratory is to be informed.

For smaller parts such as screws or electrical connectors, spare parts were added to the equipment.

5.3 Cleaning

It is a prerequisite that the transfer package meters will be run in a flow calibration standard facility where no pollutant occurs. It is not necessary to apply a special cleaning procedure to the transfer meters after having finalized the SC measurement program.

Before preparing the flowmeters for shipment again, be sure that the inner surfaces of these meters, which were wetted during measurement, are dry. Otherwise, dried carbonate remainders could be deposited in the flowmeters. Especially in case of the turbine meter, these carbonate deposits could cause an effect to the meter characteristics. Additionally, damages due to frost could occur if wet meters will be transported.

5.4 Packing

Before packing the transfer meters and other equipment, make a visual check whether any damages occurred to SC component parts. Please check the whole equipment is complete when being shipped.

6 Reporting the measurement results

6.1 Acquisition of the measurement results

For reporting calibration results of the laboratories, in addition to the approach generally practiced in a participating laboratory, following ways of data acquisition and collection will be applied.

6.1.1 Primary measurement data acquisition and collection

An EXCEL spreadsheet has been developed for reporting calibration results. Please enter here results of the calibration facility. An example of the EXCEL sheet is shown in Appendix 1; it comprises following data and information:

<u>1) Measurement configuration:</u>	Meter K-factors of the transfer meters; and type of reference standard
<u>2) Density coefficients:</u>	Depending on the density calculation/approximation which is used in the laboratory
<u>3) Pipe / flow conditions:</u>	Serve to calculation the Reynolds number(s)
<u>4) Ambient conditions:</u>	Ambient air density for buoyancy correction purposes;
<u>5) Measurement data:</u>	According to the numbers of tests/calibrations, in the positions of the main part (shaded light green), **30 data sets** have to be entered.

The example EXCEL sheet in **Appendix 1** contains **dummy data**, which were placed there, in order to avoid that the main table indicates a greater number of **Error codes**.

The EXCEL spreadsheet which is destined to be used for collecting and acquiring the measurement data in KC1 comprise 3 tables which tabbed (named) as follows:

1) **Day #1** - Acquisition of calibration data on the first day of the laboratory's SC measurements (Lab-to-lab reproducibility)

2) **Main_Day #2** - Acquisition of calibration data on the second day of the laboratory's SC measurements;

   These measurement results represent those values that will be used to determine the **Supplementary Comparison Reference Values** SCRV), which are:

   - SCRV(mass flow): acquired data from Coriolis meter output
   - SCRV(volume flow): acquired data from turbine meter output
   - SCRV(volume flow): acquired data from Coriolis meter output

3) **Day #3_Repeatability -** Acquisition of calibration data on the third day of the laboratory's KC1 measurements;

In addition to the calibration data of the transfer meters during the comparison measurements, which are represented by the measurement values of the second, here meter characteristics are determined which provides a greater emphasis on the repeatability behavior or flow standard.

4) **Density_Water** - This table contains an example how the water density, which is needed in the tables #1 through #3, might be determined. The laboratories will apply their own approaches and algorithms to determine water density and will modify and adapt this table in accordance with their practices in this issue.

5) **Auto zero values** – The table has to be completed in case of using electronic box 2 and to minute the set values of Auto zero.

6.1.2 Real-time acquisition of additional measurement and process data

In order to provide information concerning the long-term characteristics of the transfer meters and the measurement conditions in the laboratories, the SC transfer package comprises special sensors and measurement data acquisition electronics (see also chapter 3.5). The handling and the Human Machine Interface (HMI) of the LabVIEW-based software, which is dedicated to this auxiliary measurement equipment, is described in Appendix 2. During the SC, measurements flowmeter output signals and measured values of process variables will be measured and acquired in real time.

After the successful completion of the whole measurement program in a laboratory, the compilation of data files will be generated on the operator's demand. A detailed description of this data handling procedure is given in Appendix 3.

Note:

The recorded data of the SC electronic will be used for an internal interpretation of the calibrations and for a bilateral discussion with the related laboratory. The data will not be forwarded to any third party.

The generated data sets comprise follow data files:

File name **:=** *user_flowrate_run_***General**.txt

File name **:=** *user_flowrate_run_***LabDATA**.csv

File name **:=** *user_flowrate_run_***Meters**.csv

File name **:=** *user_flowrate_run_***ProcessValues***.csv*

File name **:=** *user_flowrate_run_***Transition***.csv*

File name **:=** *user_flowrate_run_***Zeroing**.*txt*

6.2 Utilization and dissemination of the measurement results

The calibration data **taken during the second day** of the SC measurements will be applied for calculating the meter K-factors of the transfer meters. These data will be used for determining the corresponding SCRVs of the three measurands which are subjects of SC:

1) **Turbine flowmeter:** - volume-related frequency output:

K_{Tur_V} [pulses/unit volume]

2) **Coriolis flowmeter:**

- mass-related frequency output:

K_{Cor_m} [pulses/unit mass]

7 Data and information provided by the participating laboratories

- **Piping & instrumentation diagram and description of the calibration facility**

  For preparing the report on SC, the participating laboratories are asked to deliver a short description of their water flow standards. This description should refer to a classification of the calibration principle as it is given in **Fehler! Verweisquelle konnte nicht gefunden werden.** and contain a simplified piping and instrumentation diagram.

- **Photos of the transfer package when installed in the calibration rig**

  In addition to the measurement data, the situation of the experimental setup is to be documented by photographs. The pictures should show at least the installed transfer meters in the calibration line, the complete inlet section to the transfer standard and the outlet section of the calibration line.

- **Instruments used by the laboratory in the comparison measurements**

  The laboratories are expected to deliver information (technical specifications etc.) relating to instruments whose measuring properties contribute to the measurement uncertainty of the flow standard facility (claimed as CMC entry).

- **Measurement model (i.e. equations) applied for uncertainty analysis purposes**

  An essential contribution of the laboratories of SC will be the measurement model, which describes the calibration of the water calibration facility individually. In order to provide a better comparability of the single uncertainty figures of the laboratories the recommendation is given to enter all uncertainty relevant information into an uncertainty calculation spreadsheet which has been prepared.

- **Measurement uncertainty results (CMCs) based upon a unified EXCEL spreadsheet (which will be provided by the pilot lab)**

  For a most effective evaluation of the laboratories' SC measurement data, the laboratories are expected to finish their calibration results to fit into the unified EXCEL spreadsheet shown in Appendix 1.

8 Data analysis by the pilot laboratory

8.1 Calculation of the comparison reference value *y* and the uncertainty *U*(*y*)

The following analysis are based on [3, 4, 5, 6]. The reference value of the comparison will be estimated by using Equ. 7.

$$y = \frac{\left(\frac{\overline{x_1}}{u^2(\overline{x_1})} + \frac{\overline{x_2}}{u^2(\bar{x}_2)} + \cdots \frac{\bar{x}_i}{u^2(\bar{x}_i)}\right)}{\left(\frac{1}{u^2(\bar{x}_1)} + \frac{1}{u^2(\bar{x}_2)} + \cdots \frac{1}{u^2(\bar{x}_i)}\right)} \qquad \text{Equ. 7}$$

with y - Reference value of the comparison (in %)
$\bar{x}_i$ - Mean of measurement error at one flow rate (in %)
i - Participating laboratory

The standard uncertainty *u*(y) is:

$$\frac{1}{u^2(y)} = \frac{1}{u^2(\bar{x}_1)} + \frac{1}{u^2(\bar{x}_2)} + \cdots \frac{1}{u^2(\bar{x}_i)} \qquad \text{Equ. 8}$$

with *u(y)* - Standard uncertainty of the comparison reference value *y* with *k* = 1 (in %)

The extended uncertainty U(y) is:

$$U(y) = 2 \cdot u(y) \qquad \text{Equ. 9}$$

with $U(y)$ - Extended uncertainty of the comparison reference value y with k = 2 (in %)

8.2 Differences „Lab to SCRV“ and „Lab to Lab“

When the SCRV was determined, the differences between the participating laboratories and the SCRV will be calculated according to

$$d_i = \bar{x}_i - y \qquad \text{Equ. 9}$$

$$d_{i,j} = \bar{x}_i - \bar{x}_{i,j} \qquad \text{Equ. 10}$$

$$d_k = \bar{x}_i - KCRV \qquad \text{Equ. 11}$$

with d_i - deviation of $\bar{x}_i$ to SCRV (in %)

$d_{i,j}$ - deviation of $\bar{x}_i$ to reference laboratory (in %)

d_k - deviation of $\bar{x}_i$ to KCRV (in %)

Based on these differences, the normalized Degree of Equivalence will be calculated according to:

$$E_{N,i} = \left|\frac{d_i}{U(d_i)}\right| \qquad \text{Equ. 12}$$

$$E_{N,ij} = \left|\frac{d_{ij}}{U\left(d_{i,j}\right)}\right| \qquad \text{Equ. 13}$$

$$E_{N,k} = \left|\frac{d_k}{U(d_k)}\right| \qquad \text{Equ. 14}$$

with $E_{N,i}$ - normalized Degree of Equivalence of a single laboratory (-)

$E_{N,i,j}$ - normalized Degree of Equivalence between the laboratories (-)

$E_{N,k}$ - normalized Degree of Equivalence of a single laboratory to KCRV (-)

a) Differences to the SCRV (independent laboratories with contribution to the SCRV)

The covariance between the result of a laboratory (with contribution to the SCRV) and the SCRV is the variance of the SCRV itself:

$$u(d_i) = \sqrt{u(x_i)^2 + u(y)^2 - 2 \cdot u(y)^2} = \sqrt{u(x_i)^2 - u(y)^2} \qquad \text{Equ. 15}$$

b) Lab to Lab Differences

All of the participants in this comparison have independent traceability chains. There is no covariance between the results of two independent laboratories i and j and the uncertainty of the difference between two labs is:

$$u\left(d_{i,j}\right) = \sqrt{u(x_i)^2 + u\left(x_j\right)^2} \qquad \text{Equ. 16}$$

c) Linkage to the KCRV

Results of this Suplementary Comparison could be linked to CCM.FF-K1.2015 Key Comparison. The uncertainty between lab and KCRV is:

$$u(d_k) = \sqrt{u(x_i)^2 + u(KCRV)^2} \qquad \text{Equ. 17}$$

Equations 15 to 17 use the standard uncertainties. The expanded uncertainties *$U(d_i)$, $U(d_{i,j})$ and $U(d_k)$* are determined by using a coverage factor of 2 to obtain an approximately 95 % confidence level value.

8.3 Final criteria for the evaluation of the comparison

a) Chi²-Test

This test will not be applied because of the bilateral character of the measurements.

b) Criteria A – the E_N-value

- the results of a laboratory were equivalent (passed) if Eni or Enij ≤ 1.
- the laboratory was determined as not equivalent (failed) if Eni or Enij >1.

c) Criteria B – the ratio between u_{Comp} und u_{Lab}

The ratio between ucomp and ulab ≤ 2,0 verifies the capability of the transfer standard for a confirmation of the aimed CMC values.

9 References

[1] BIPM: Measurement comparisons in the CIPM MRA, CIPM MRA-D-05, Version 1.6, March 2016, https://www.bipm.org/en/cipm-mra/cipm-mra-documents/

[2] Paik J.S. et al: Final report on CCM.FF-K1 for water. In: Metrologia, Volume 44, 2007

[3] Cox M. G., Evaluation of key comparison data, Metrologia, 39, 589 to 595, 2002.

[4] WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty, Working Group for Fluid Flow, October 21, 2013, http://www.bipm.org/utils/en/pdf/ccm-wgff-guidelines.pdf.

[5] WRIGHT, J. et al. (2016): Transfer standard uncertainty can cause inconclusive inter-laboratory comparisons. In: Metrologia 53 (2016)

[6] Benková, M., Makovnik, S.: Final report on CIPM key comparison CCM.FF-K6.2011: Comparison of the primary (national) standards of low-pressure gas flow In: Metrologia 51 (2014)

Appendices

Appendix 1 - EXCEL spreadsheet for primary acquisition of SC calibration data

Table A 1: Excel sheet – example for Day #1 and Day #2

1. Measurement Configuration

	Grav. reference	Vol. reference	Prover	Meter K-factor [Pulses/L]	Meter K-factor [Pulses/kg]	Mass flowrate
Referenc	X					
MUT #1				66,540		
MUT #2					6,654	X
MUT #3				200000,000		
MUT #4						

2. Density Coefficients

(due to measurment)

a0	a1	a2	a3
0,999953565	4,56891E-05	-7,33E-06	3,41E-08

3. Pipe / flow conditions

Diameter [m]	Pipe cross-section area [m²]
0,101	0,008011847

4. Ambient conditions

Ambient air density [kg/m³]
1,2

PCS = Process control system

References – Gravimetric standard / Reference values

Test No.	Date [dd.mm.yyyy]	Time [h : min]	Nominal flowrate [m³/h]	Flowrate (PCS) [m³/h]	Mass flowrate (PCS) [t/h]	Measurement time [s]	Balance reading [kg]	True mass [kg]	Buoy. factor	Standard mass flowrate [t/h]	Standard volume flowrate [m³/h]	Reynolds No. [/]	Mass (true mass) [kg]	Volume [m³]
1	18.01.2011	07:28	30,0	29,978		302,0766	2712,029	2715,293	1,00120	32,3595	32,417	104449	2715,293	2,72013
2	18.01.2011	07:42	30,0	30,027		324,2519	2713,626	2716,892	1,00120	30,1642	30,218	104664	2716,892	2,72174
3	18.01.2011	07:56	30,0	29,995		324,2509	2712,696	2715,961	1,00120	30,1540	30,208	104524	2715,961	2,72080
4	18.01.2011	08:10	30,0	29,999		324,2810	2713,489	2716,755	1,00120	30,1600	30,214	104531	2716,755	2,72160
5	18.01.2011	08:24	30,0	30,022		324,2809	2714,517	2717,785	1,00120	30,1714	30,225	104620	2717,785	2,72263
		MIN		29,978		302,0766	2712,0291	2715,293	1,00120	30,1540	30,208	104449	2715,2933	2,72013
		AVG		30,004		319,8283	2713,2715	2716,537	1,00120	30,6018	30,656	104558	2716,5372	2,72138
		MAX		30,027		324,2810	2714,5174	2717,785	1,00120	32,3595	32,417	104664	2717,7846	2,72263
		MAX-MIN		0,049		22,2044	2,4883	2,491	0,00000	2,2055	2,209	214,47	2,4913	0,00250
		relSTD		6,709E-04		3,103E-02	3,497E-04	3,497E-04	1,488E-08	3,211E-02	3,211E-02	8,104E-04	3,497E-04	3,503E-04
6	18.01.2011	08:47	60,0	60,101		162,2583	2714,770	2718,037	1,00120	60,3047	60,485	209524	2721,3085	2,7262
7	18.01.2011	08:58	60,0	60,087		162,2583	2714,426	2717,693	1,00120	60,2971	60,477	209474	2720,9642	2,7258
8	18.01.2011	09:10	60,0	60,056		162,2573	2713,821	2717,087	1,00120	60,2840	60,464	209365	2720,3577	2,7252
9	18.01.2011	09:21	60,0	60,078		162,2543	2714,001	2717,267	1,00120	60,2891	60,469	209443	2720,5380	2,7254
10	18.01.2011	09:32	60,0	60,041		162,2802	2713,850	2717,117	1,00120	60,2761	60,456	209318	2720,3871	2,7252
		MIN		60,041		162,2543	2713,8211	2717,087	1,00120	60,2761	60,456	209318	2720,3577	2,7252
		AVG		60,073		162,2617	2714,1736	2717,440	1,00120	60,2902	60,471	209425	2720,7111	2,7256
		MAX		60,101		162,2802	2714,7696	2718,037	1,00120	60,3047	60,485	209524	2721,3085	2,7262
		MAX-MIN		0,060		0,0259	0,9485	0,950	0,00000	0,0286	0,029	206,63	0,9508	0,0010
		relSTD		4,020E-04		6,469E-05	1,516E-04	1,516E-04	1,488E-08	1,845E-04	1,845E-04	3,972E-04	1,516E-04	1,516E-04
11	18.01.2011	09:53	100,0	96,810		97,4858	2626,970	2630,132	1,00120	97,1267	97,4177	337633	2633,2973	2,6380
12	18.01.2011	10:03	100,0	99,560		97,4879	2701,624	2704,875	1,00120	99,8847	100,1836	347098	2708,1309	2,7130
13	18.01.2011	10:14	100,0	99,517		97,4379	2700,063	2703,303	1,00120	99,8779	100,1768	346934	2706,5567	2,7114
14	18.01.2011	10:24	100,0	99,502		97,4859	2700,422	2703,672	1,00120	99,8424	100,1413	346964	2706,9262	2,7118
15	18.01.2011	10:34	100,0	99,523		97,4859	2700,637	2703,887	1,00120	99,8503	100,1495	347129	2707,1415	2,7120
		MIN		96,810		97,4379	2626,9699	2630,132	1,00120	97,1267	97,4177	337633	2633,2973	2,6380
		AVG		98,982		97,4767	2685,9411	2689,174	1,00120	99,3164	99,6138	345152	2692,4105	2,6972
		MAX		99,560		97,4879	2701,6237	2704,875	1,00120	99,8847	100,1836	347129	2708,1309	2,7130
		MAX-MIN		2,750		0,0500	74,6537	74,744	0,00000	2,7580	2,7660	9496,54	74,8335	0,0750
		relSTD		1,227E-02		2,226E-04	1,228E-02	1,228E-02	2,105E-08	1,233E-02	1,233E-02	1,218E-02	1,228E-02	1,227E-02
16	18.01.2011	11:00	140,0	139,960		69,7075	2715,281	2718,549	1,00120	140,3978	140,8179	487926	2721,8213	2,7267
17	18.01.2011	11:10	140,0	140,527		69,6866	2724,795	2728,075	1,00120	140,9322	141,3539	489903	2731,3583	2,7362
18	18.01.2011	11:20	140,0	140,480		69,6615	2724,112	2727,390	1,00120	140,9474	141,3691	489738	2730,6731	2,7356
19	18.01.2011	11:30	140,0	140,435		69,6845	2724,499	2727,778	1,00120	140,9209	141,3425	489583	2731,0612	2,7359
20	18.01.2011	11:40	140,0	140,934		69,7115	2735,654	2738,946	1,00120	141,4431	141,8664	491321	2742,2430	2,7471
		MIN		139,960		69,6615	2715,2812	2718,549	1,00120	140,3978	140,8179	487926	2721,8213	2,7267
		AVG		140,467		69,6903	2724,8682	2728,148	1,00120	140,9263	141,3500	489694	2731,4314	2,7363
		MAX		140,934		69,7115	2735,6538	2738,946	1,00120	141,4431	141,8664	491321	2742,2430	2,7471
		MAX-MIN		0,974		0,0499	20,3726	20,397	0,00000	1,0454	1,0485	3394,66	20,4217	0,0205
		relSTD		2,465E-03		2,888E-04	2,652E-03	2,652E-03	1,488E-08	2,624E-03	2,624E-03	2,465E-03	2,652E-03	2,652E-03
21	18.01.2011	11:56	180,0	180,274		54,2750	2723,711	2726,989	1,00120	180,8780	181,4192	628470	2730,2711	2,7351
22	18.01.2011	12:06	180,0	179,907		54,2971	2718,475	2721,746	1,00120	180,4569	180,9969	627189	2725,0223	2,7299
23	18.01.2011	12:15	180,0	181,076		54,2751	2734,038	2737,329	1,00120	181,5636	182,1068	631266	2740,6233	2,7455
24	18.01.2011	12:25	180,0	180,903		54,2481	2731,267	2734,554	1,00120	181,4700	182,0130	630660	2737,8456	2,7427
25	18.01.2011	12:34	180,0	180,960		54,2731	2733,247	2736,537	1,00120	181,5178	182,0609	630859	2739,8303	2,7447
		MIN		179,907		54,2481	2718,4745	2721,746	1,00120	180,4569	180,9969	627189	2725,0223	2,7299
		AVG		180,624		54,2737	2728,1474	2731,431	1,00120	181,1772	181,7194	629689	2734,7185	2,7396
		MAX		181,076		54,2971	2734,0380	2737,329	1,00120	181,5636	182,1068	631266	2740,6233	2,7455
		MAX-MIN		1,169		0,0490	15,5635	15,582	0,00000	1,1066	1,1100	4076,36	15,6010	0,0156
		relSTD		2,811E-03		3,203E-04	2,484E-03	2,484E-03	1,488E-08	2,703E-03	2,703E-03	2,811E-03	2,484E-03	2,484E-03
26	18.01.2011	12:49	200,0	202,001		48,8709	2723,711	2726,989	1,00120	200,8795	201,4806	704213	2730,2711	2,7351
27	18.01.2011	12:59	200,0	202,179		48,8739	2718,475	2721,746	1,00120	200,4812	201,0811	704835	2725,0223	2,7299
28	18.01.2011	13:08	200,0	202,322		48,8489	2734,038	2737,329	1,00120	201,7321	202,3357	705331	2740,6233	2,7455
29	18.01.2011	13:18	200,0	202,644		48,8729	2731,267	2734,554	1,00120	201,4285	202,0312	706453	2737,8456	2,7427
30	18.01.2011	13:27	200,0	202,566		48,8449	2733,247	2736,537	1,00120	201,6899	202,2934	706182	2739,8303	2,7447
		MIN		202,001		48,8449	2718,4745	2721,746	1,00120	200,4812	201,0811	704213	2725,0223	2,7299
		AVG		202,342		48,8623	2728,1474	2731,431	1,00120	201,2422	201,8444	705403	2734,7185	2,7396
		MAX		202,644		48,8739	2734,0380	2737,329	1,00120	201,7321	202,3357	706453	2740,6233	2,7455
		MAX-MIN		0,642		0,0289	15,5635	15,582	0,00000	1,2509	1,2547	2239,39	15,6010	0,0156
		relSTD		1,317E-03		2,897E-04	2,484E-03	2,484E-03	1,488E-08	2,706E-03	2,706E-03	1,317E-03	2,484E-03	2,484E-03

Test fluid / Ambient conditions / **Meters under test**: Meter under Test #1 (Turbine meter), Meter under Test #2 (Coriolis flowmeter: Mass), Meter under Test #3 (Coriolis flowmeter: Volume)

Test No.	Time	Water density [kg/m³]	Kinematic Viscosity [m²/s]	Line pressure [bar]	Water temp. [°C]	Air temp. [°C]	Air pressure [bar]	#1 Pulse count (Volume) [Puls count]	#1 K-factor [Pulses/Liter]	#1 Meter output frequency [Hz]	#1 Meter error [%]	#2 Pulse count (Mass) [Puls count]	#2 K-factor [Pulses/kg]	#2 Meter output frequency [Hz]	#2 Meter error [%]	#3 Pulse count (Volume) [Puls count]	#3 K-factor [Pulses/Liter]	#3 Meter output frequency [Hz]	#3 Meter error [%]
1	07:28	998,221	1,00504E-06	3,040	19,932	21,847	1012,597	18137	66,6769	60,0411	0,2058	18124	6,6748	59,998	0,3124	543517	199812,784	1799,269	-0,094
2	07:42	998,218	1,00461E-06	3,037	19,950	21,820	1012,735	18134	66,6264	55,9257	0,1299	18134	6,6745	55,926	0,3087	543768	199786,681	1676,992	-0,107
3	07:56	998,220	1,00490E-06	3,038	19,938	21,829	1012,893	18129	66,6311	55,9104	0,1369	18142	6,6798	55,950	0,3873	543594	199791,746	1676,461	-0,104
4	08:10	998,221	1,00494E-06	3,038	19,936	21,827	1013,044	18133	66,6263	55,9176	0,1297	18236	6,7124	56,235	0,8780	543770	199798,066	1676,848	-0,101
5	08:24	998,220	1,00487E-06	3,036	19,939	21,824	1013,170	18139	66,6231	55,9361	0,1248	18236	6,7099	56,235	0,8397	543977	199798,298	1677,487	-0,101
	MIN	998,218	1,00461E-06	3,036	19,932	21,820	1012,597	18129	66,6231	55,9104	0,1248	18124	6,6745	55,9257	0,3087	543517	199786,681	1676,461	-0,1067
	AVG	998,220	1,00487E-06	3,038	19,939	21,829	1012,888	18134,400	66,6368	56,7462	0,1454	18174,400	6,6903	56,8689	0,5452	543725,200	199797,515	1701,412	-0,1012
	MAX	998,221	1,00504E-06	3,040	19,950	21,847	1013,170	18139	66,6769	60,0411	0,2058	18236	6,7124	59,9980	0,8780	543977	199812,784	1799,269	-0,0936
	MAX-MIN	0,0036	4,32114E-10	0,005	0,018	0,027	0,573	10	0,0539	4,1307	0,0810	112	0,0379	4,0724	0,5693	460	26,103	122,808	0,0131
	relSTD	1,360E-06	1,601E-04	5,759E-04	3,303E-04	4,822E-04	2,272E-04	2,121E-04	3,397E-04	3,246E-02		3,114E-03	2,868E-03	3,087E-02		3,287E-04	4,908E-05	3,215E-02	
6	08:47	998,217	1,00447E-06	3,134	19,956	21,810	1013,431	18160	66,6136	111,9203	0,1106	18236	6,7012	112,389	0,7092	543910	199514,316	3352,125	-0,243
7	08:58	998,217	1,00447E-06	3,131	19,956	21,796	1013,617	18158	66,6147	111,9080	0,1122	18236	6,7020	112,389	0,7219	543836	199512,413	3351,669	-0,244
8	09:10	998,217	1,00447E-06	3,130	19,956	21,787	1013,668	18153	66,6112	111,8779	0,1070	18236	6,7035	112,389	0,7444	543693	199504,422	3350,807	-0,248
9	09:21	998,217	1,00447E-06	3,129	19,956	21,783	1013,557	18154	66,6104	111,8861	0,1059	18236	6,7031	112,391	0,7377	543711	199497,804	3350,981	-0,251
10	09:32	998,216	1,00445E-06	3,127	19,956	21,764	1013,653	18153	66,6105	111,8621	0,1059	18236	6,7035	112,374	0,7433	543683	199498,565	3350,273	-0,251
	MIN	998,216	1,00445E-06	3,127	19,956	21,764	1013,431	18153	66,6104	111,8621	0,1059	18236	6,7012	112,3735	0,7092	543683	199497,804	3350,273	-0,2511
	AVG	998,217	1,00446E-06	3,130	19,956	21,788	1013,585	18155,600	66,6121	111,8909	0,1083	18236,000	6,7027	112,3864	0,7313	543766,600	199505,504	3351,171	-0,2472
	MAX	998,217	1,00447E-06	3,134	19,956	21,810	1013,668	18160	66,6147	111,9203	0,1122	18236	6,7035	112,3915	0,7444	543910	199514,316	3352,125	-0,2428
	MAX-MIN	0,0001	1,49297E-11	0,006	0,001	0,047	0,236	7	0,0042	0,0583	0,0064	0	0,0023	0,0180	0,0352	227	16,512	1,852	0,0083
	relSTD	5,720E-08	6,647E-06	7,756E-04	1,370E-05	7,898E-04	9,469E-05	1,768E-04	2,924E-05	2,088E-04		0,000E+00	1,516E-04	6,469E-05		1,859E-04	3,834E-05	2,179E-04	
11	09:53	998,213	1,00406E-06	3,340	19,972	21,750	1013,712	17605	66,7359	180,5904	0,2944	18236	6,9252	187,063	4,0751	526204	199469,982	5397,749	-0,265
12	10:03	998,216	1,00443E-06	3,340	19,957	21,790	1013,757	18109	66,7497	185,7564	0,3152	18236	6,7338	187,059	1,1992	541154	199469,215	5550,986	-0,265
13	10:14	998,217	1,00447E-06	3,341	19,956	21,792	1013,806	18099	66,7517	185,7491	0,3181	18236	6,7377	187,155	1,2581	540842	199470,221	5550,634	-0,265
14	10:24	998,215	1,00423E-06	3,339	19,965	21,784	1013,948	18101	66,7498	185,6782	0,3153	18236	6,7368	187,063	1,2443	540916	199469,889	5548,661	-0,265
15	10:34	998,212	1,00397E-06	3,339	19,976	21,766	1014,095	18218	67,1758	186,8784	0,9555	18236	6,7363	187,063	1,2362	540980	199477,171	5549,318	-0,261
	MIN	998,212	1,00397E-06	3,339	19,956	21,750	1013,712	17605	66,7359	180,5904	0,2944	18236	6,7338	187,0591	1,1992	526204	199469,215	5397,749	-0,2654
	AVG	998,215	1,00423E-06	3,340	19,965	21,776	1013,864	18026,400	66,8326	184,9305	0,4397	18236,000	6,7739	187,0807	1,8026	538019,200	199471,296	5519,470	-0,2644
	MAX	998,217	1,00447E-06	3,341	19,976	21,792	1014,095	18218	67,1758	186,8784	0,9555	18236	6,9252	187,1551	4,0751	541154	199477,171	5550,986	-0,2614
	MAX-MIN	0,0042	5,01742E-10	0,001	0,021	0,042	0,383	613	0,4399	6,2880	0,6611	0	0,1914	0,0960	2,8759	14950	7,955	153,236	0,0040
	relSTD	1,866E-06	2,194E-04	1,873E-04	4,522E-04	8,353E-04	1,548E-04	1,336E-02	2,872E-03	1,339E-02		0,000E+00	1,248E-02	2,226E-04		1,228E-02	1,657E-05	1,233E-02	
16	11:00	998,217	1,00447E-06	3,637	19,956	21,776	1013,974	18218	66,8138	261,3493	0,4114	18236	6,6999	261,607	0,6902	543899	199472,690	7802,591	-0,264
17	11:10	998,217	1,00447E-06	3,635	19,956	21,790	1013,938	18281	66,8107	262,3320	0,4068	18233	6,6754	261,643	0,3221	545789	199466,926	7832,063	-0,267
18	11:20	998,217	1,00447E-06	3,635	19,956	21,808	1013,846	18277	66,8128	262,3687	0,4101	18236	6,6782	261,780	0,3638	545670	199473,476	7833,164	-0,263
19	11:30	998,217	1,00447E-06	3,633	19,956	21,810	1013,860	18279	66,8107	262,3108	0,4068	18238	6,6780	261,722	0,3605	545742	199471,444	7831,611	-0,264
20	11:40	998,217	1,00447E-06	3,632	19,956	21,810	1013,728	18354	66,8112	263,2853	0,4076	18236	6,6500	261,593	-0,0597	547987	199475,293	7860,789	-0,262
	MIN	998,217	1,00447E-06	3,632	19,956	21,776	1013,728	18218	66,8107	261,3493	0,4068	18233	6,6500	261,5926	-0,0597	543899	199466,926	7802,591	-0,2665
	AVG	998,217	1,00447E-06	3,635	19,956	21,799	1013,869	18281,800	66,8118	262,3292	0,4085	18235,800	6,6763	261,6692	0,3354	545817,400	199471,966	7832,044	-0,2640
	MAX	998,217	1,00447E-06	3,637	19,956	21,810	1013,974	18354	66,8138	263,2853	0,4114	18238	6,6999	261,7802	0,6902	547987	199475,293	7860,789	-0,2624
	MAX-MIN	0,0000	0,00000E+00	0,005	0,000	0,034	0,246	136	0,0031	1,9360	0,0046	5	0,0499	0,1876	0,7498	4088	8,367	58,198	0,0042
	relSTD	1,529E-08	0,000E+00	5,014E-04	0,000E+00	6,939E-04	9,378E-05	2,640E-03	2,077E-05	2,611E-03		9,810E-05	2,654E-03	3,051E-04		2,657E-03	1,576E-05	2,628E-03	
21	11:56	998,217	1,00447E-06	4,027	19,956	21,814	1013,754	18271	66,8008	336,6372	0,3919	18236	6,6792	335,992	0,3786	545553	199460,073	10051,636	-0,270
22	12:06	998,217	1,00447E-06	4,029	19,956	21,825	1013,699	18236	66,8012	335,8559	0,3926	18236	6,6921	335,856	0,5719	544547	199475,745	10029,025	-0,262
23	12:15	998,217	1,00447E-06	4,021	19,956	21,832	1013,627	18341	66,8034	337,9265	0,3958	18420	6,7211	339,382	1,0084	547648	199469,707	10090,222	-0,265
24	12:25	998,217	1,00447E-06	4,022	19,956	21,839	1013,643	18323	66,8055	337,7632	0,3991	18470	6,7462	340,473	1,3853	547095	199470,456	10085,060	-0,265
25	12:34	998,217	1,00447E-06	4,020	19,956	21,839	1013,564	18335	66,8009	337,8285	0,3920	18470	6,7413	340,316	1,3119	547493	199470,969	10087,742	-0,265
	MIN	998,217	1,00447E-06	4,020	19,956	21,814	1013,564	18236	66,8008	335,8559	0,3919	18236	6,6792	335,8559	0,3786	544547	199460,073	10029,025	-0,2700
	AVG	998,217	1,00447E-06	4,024	19,956	21,830	1013,657	18301,200	66,8023	337,2023	0,3943	18366,400	6,7160	338,4038	0,9312	546467,200	199469,390	10068,737	-0,2653
	MAX	998,217	1,00447E-06	4,029	19,956	21,839	1013,754	18341	66,8055	337,9265	0,3991	18470	6,7462	340,4730	1,3853	547648	199475,745	10090,222	-0,2621
	MAX-MIN	0,0000	0,00000E+00	0,008	0,000	0,025	0,191	105	0,0048	2,0706	0,0072	234	0,0670	4,6171	1,0068	3101	15,673	61,197	0,0078
	relSTD	1,529E-08	0,000E+00	9,766E-04	0,000E+00	4,728E-04	7,162E-05	2,499E-03	3,111E-05	2,719E-03		6,576E-03	4,408E-03	6,803E-03		2,483E-03	2,868E-05	2,701E-03	
26	12:49	998,217	1,00447E-06	4,233	19,956	21,846	1013,448	18427	67,3711	377,0548	1,2490	18471	6,7653	377,955	1,6721	550227	201168,938	11258,789	0,584
27	12:59	998,217	1,00447E-06	4,231	19,956	21,850	1013,368	18448	67,5778	377,4615	1,5597	18469	6,7776	377,891	1,8569	550868	201787,559	11271,015	0,894
28	13:08	998,217	1,00447E-06	4,227	19,956	21,849	1013,240	18470	67,2732	378,1050	1,1020	18470	6,7393	378,105	1,2826	551442	200851,595	11288,738	0,426
29	13:18	998,217	1,00447E-06	4,226	19,956	21,858	1013,382	18493	67,4253	378,3896	1,3306	18475	6,7480	378,021	1,4128	552157	201316,058	11297,814	0,658
30	13:27	998,217	1,00447E-06	4,225	19,956	21,860	1013,324	18480	67,3291	378,3401	1,1860	18480	6,7449	378,340	1,3667	551783	201033,967	11296,626	0,517
	MIN	998,217	1,00447E-06	4,225	19,956	21,846	1013,240	18427	67,2732	377,0548	1,1020	18469	6,7393	377,8912	1,2826	550227	200851,595	11258,789	0,4258
	AVG	998,217	1,00447E-06	4,228	19,956	21,853	1013,352	18463,600	67,3953	377,8702	1,2854	18473,000	6,7550	378,0625	1,5182	551293,400	201231,623	11282,596	0,6158
	MAX	998,217	1,00447E-06	4,233	19,956	21,860	1013,448	18493	67,5778	378,3896	1,5597	18480	6,7776	378,3401	1,8569	552157	201787,559	11297,814	0,8938
	MAX-MIN	0,0000	0,00000E+00	0,007	0,000	0,014	0,208	66	0,3046	1,3349	0,4577	11	0,0382	0,4489	0,5743	1930	935,965	39,025	0,4680
	relSTD	1,529E-08	0,000E+00	7,227E-04	0,000E+00	2,713E-04	7,586E-05	1,422E-03	1,725E-03	1,553E-03		2,451E-04	2,352E-03	4,609E-04		1,386E-03	1,763E-03	1,514E-03	

Table A 2: Excel sheet – example for Day #3

1. Measurement Configuration

	Grav. reference	Vol. reference	Prover	Meter K-factor [Pulses/L]	Meter K-factor [Pulses/kg]	Mass flowrate
Referenc	X					
MUT #1				66,540		
MUT #2					6,654	X
MUT #3				200000,000		
MUT #4						

2. Density Coefficients

(due to measurment)

a0	a1	a2	a3
0,999953565	4,56891E-05	-7,33E-06	3,41E-08

3. Pipe / flow conditions

Diameter [m]	Pipe cross-section area [m²]
0,101	0,008011847

4. Ambient conditions

Ambient air density [kg/m³]
1,2

PCS = Process control system

						References								
						Gravimetric standard							Reference values	
Test No.	Date	Time	Nominal flowrate	Flowrate (PCS)	Mass flowrate (PCS)	Measurement time	Balance reading	True mass	Buoy. factor	Standard mass flowrate	Standard volume flowrate	Reynolds No.	Mass (true mass)	Volume
	[dd.mm.yyyy]	[h : min]	[m³/h]	[m³/h]	[t/h]	[s]	[kg]	[kg]		[t/h]	[m³/h]	[/]	[kg]	[m³]
1	18.01.2011	07:28	30,0	29,978		302,0766	2712,029	2715,293	1,00120	32,3595	32,417	104449	2715,293	2,72013
2	18.01.2011	07:42	30,0	30,027		324,2519	2713,626	2716,892	1,00120	30,1642	30,218	104664	2716,892	2,72174
3	18.01.2011	07:56	30,0	29,995		324,2509	2712,696	2715,961	1,00120	30,1540	30,208	104524	2715,961	2,72080
4	18.01.2011	08:10	30,0	29,999		324,2810	2713,489	2716,755	1,00120	30,1600	30,214	104531	2716,755	2,72160
5	18.01.2011	08:24	30,0	30,022		324,2809	2714,517	2717,785	1,00120	30,1714	30,225	104620	2717,785	2,72263
6	18.01.2011	08:47	30,0	29,999		324,2810	2714,770	2718,037	1,00120	30,1742	30,265	104580	2721,3085	2,7262
7	18.01.2011	08:58	30,0	30,022		324,2810	2714,426	2717,693	1,00120	30,1704	30,261	104613	2720,9641	2,7258
8	18.01.2011	09:10	30,0	29,999		324,2810	2713,821	2717,087	1,00120	30,1637	30,254	104538	2720,3576	2,7252
9	18.01.2011	09:21	30,0	30,022		324,2810	2714,001	2717,267	1,00120	30,1657	30,256	104662	2720,5380	2,7254
10	18.01.2011	09:32	30,0	30,022		324,2509	2713,850	2717,117	1,00120	30,1668	30,257	104664	2720,3871	2,7252
		MIN		29,978		302,0766	2712,0291	2715,293	1,00120	30,1540	30,208	104449	2715,2933	2,7201
		AVG		30,008		322,0516	2713,7226	2716,989	1,00120	30,3850	30,457	104584	2718,6241	2,7235
		MAX		30,027		324,2810	2714,7696	2718,037	1,00120	32,3595	32,417	104664	2721,3085	2,7262
		MAX-MIN		0,049		22,2044	2,7404	2,744	0,00000	2,2055	2,209	214,47	6,0152	0,0060
		relSTD		5,511E-04		2,179E-02	3,086E-04	3,086E-04	0,000E+00	2,283E-02	2,262E-02	6,951E-04	8,481E-04	8,492E-04
11	18.01.2011	09:53	100,0	96,810		97,4858	2626,970	2630,132	1,00120	97,1267	97,4177	337633	2633,2973	2,6380
12	18.01.2011	10:03	100,0	99,560		97,4879	2701,624	2704,875	1,00120	99,8847	100,1836	347098	2708,1309	2,7130
13	18.01.2011	10:14	100,0	99,517		97,4379	2700,053	2703,303	1,00120	99,8779	100,1768	346934	2706,5567	2,7114
14	18.01.2011	10:24	100,0	99,502		97,4859	2700,422	2703,672	1,00120	99,8424	100,1413	346964	2706,9262	2,7118
15	18.01.2011	10:34	100,0	99,523		97,4859	2700,637	2703,887	1,00120	99,8503	100,1495	347129	2707,1415	2,7120
16	18.01.2011	11:00	100,0	99,523		97,4859	2715,281	2718,549	1,00120	100,3918	100,6922	346956	2721,8213	2,7267
17	18.01.2011	11:10	100,0	99,523		97,4859	2724,795	2728,075	1,00120	100,7435	101,0450	346956	2731,3583	2,7362
18	18.01.2011	11:20	100,0	99,523		97,4859	2724,112	2727,390	1,00120	100,7183	101,0196	346956	2730,6731	2,7356
19	18.01.2011	11:30	100,0	99,523		97,4859	2724,499	2727,778	1,00120	100,7326	101,0340	346956	2731,0612	2,7359
20	18.01.2011	11:40	100,0	99,517		97,4379	2735,654	2738,946	1,00120	101,1948	101,4976	346934	2742,2430	2,7471
		MIN		96,810		97,4379	2626,9699	2630,132	1,00120	97,1267	97,418	337633	2633,2973	2,6380
		AVG		99,252		97,4765	2705,4046	2708,661	1,00120	100,0363	100,336	346052	2711,9210	2,7168
		MAX		99,560		97,4879	2735,6538	2738,946	1,00120	101,1948	101,498	347129	2742,2430	2,7471
		MAX-MIN		2,750		0,0500	108,6839	108,815	0,00000	4,0681	4,080	9496,54	108,9456	0,1091
		relSTD		8,647E-03		2,087E-04	1,126E-02	1,126E-02	1,403E-08	1,130E-02	1,130E-02	8,550E-03	1,126E-02	1,125E-02
21	18.01.2011	11:56	200,0	202,644		48,8739	2723,711	2726,989	1,00120	200,8673	201,4684	706453	2730,2711	2,7351
22	18.01.2011	12:06	200,0	202,322		48,8709	2718,475	2721,746	1,00120	200,4933	201,0933	705331	2725,0223	2,7299
23	18.01.2011	12:15	200,0	202,322		48,8709	2734,038	2737,329	1,00120	201,6412	202,2446	705331	2740,6233	2,7455
24	18.01.2011	12:25	200,0	202,322		48,8489	2731,267	2734,554	1,00120	201,5276	202,1307	705331	2737,8456	2,7427
25	18.01.2011	12:34	200,0	202,322		48,8729	2733,247	2736,537	1,00120	201,5745	202,1777	705331	2739,8303	2,7447
26	18.01.2011	12:49	200,0	202,001		48,8489	2723,711	2726,989	1,00120	200,9701	201,5714	704213	2730,2711	2,7351
27	18.01.2011	12:59	200,0	202,179		48,8739	2718,475	2721,746	1,00120	200,4812	201,0811	704835	2725,0223	2,7299
28	18.01.2011	13:08	200,0	202,322		48,8489	2734,038	2737,329	1,00120	201,7321	202,3357	705331	2740,6233	2,7455
29	18.01.2011	13:18	200,0	202,644		48,8729	2731,267	2734,554	1,00120	201,4285	202,0312	706453	2737,8456	2,7427
30	18.01.2011	13:27	200,0	202,566		48,8449	2733,247	2736,537	1,00120	201,6899	202,2934	706182	2739,8303	2,7447
		MIN		202,001		48,8449	2718,4745	2721,746	1,00120	200,4812	201,081	704213	2725,0223	2,7299
		AVG		202,364		48,8627	2728,1474	2731,431	1,00120	201,2406	201,843	705479	2734,7185	2,7396
		MAX		202,644		48,8739	2734,0380	2737,329	1,00120	201,7321	202,336	706453	2740,6233	2,7455
		MAX-MIN		0,642		0,0289	15,5635	15,582	0,00000	1,2509	1,255	2239,39	15,6010	0,0156
		relSTD		1,004E-03		2,625E-04	2,342E-03	2,342E-03	1,984E-08	2,446E-03	2,446E-03	1,004E-03	2,342E-03	2,342E-03

							Meters under test											
							Meter under Test #1				Meter under Test #2				Meter under Test #3			
	Test fluid				Ambient conditions		Turbine meter				Coriolis flowmeter: Mass				Coriolis flowmeter: Volume			
Test No.	Water density	Kinematic Viscosity	Line pressure	Water temp.	Air temp.	Air pressure	Pulse count (Volume)	K-factor	Meter output frequency	Meter error	Pulse count (Mass)	K-factor	Meter output frequency	Meter error	Pulse count (Volume)	K-factor	Meter output frequency	Meter error
	[kg/m³]	[m²/s]	[bar]	[°C]	[°C]	[bar]	[Puls count]	[Pulses/Liter]	[Hz]	[%]	[Puls count]	[Pulses/kg]	[Hz]	[%]	[Puls count]	[Pulses/Liter]	[Hz]	[%]
1	998,221	1,00504E-06	3,040	19,932	21,847	1012,597	18137	66,6769	60,0411	0,2058	18124	6,6748	59,998	0,3124	543517	199812,784	1799,269	-0,094
2	998,218	1,00461E-06	3,037	19,950	21,820	1012,735	18134	66,6264	55,9257	0,1299	18134	6,6745	55,926	0,3087	543768	199786,681	1676,992	-0,107
3	998,220	1,00490E-06	3,038	19,938	21,829	1012,893	18129	66,6311	55,9104	0,1369	18142	6,6798	55,950	0,3873	543594	199791,746	1676,461	-0,104
4	998,221	1,00494E-06	3,038	19,936	21,827	1013,044	18133	66,6263	55,9176	0,1297	18236	6,7124	56,235	0,8780	543770	199798,066	1676,848	-0,101
5	998,220	1,00487E-06	3,036	19,939	21,824	1013,170	18139	66,6231	55,9361	0,1248	18236	6,7099	56,235	0,8397	543977	199798,298	1677,487	-0,101
6	998,217	1,00447E-06	3,134	19,956	21,810	1013,431	18160	66,6136	56,0008	0,1106	18236	6,7012	56,235	0,7092	543910	199514,316	1677,280	-0,243
7	998,221	1,00494E-06	3,131	19,936	21,796	1013,617	18158	66,6150	55,9947	0,1126	18236	6,7020	56,235	0,7219	543836	199513,213	1677,052	-0,243
8	998,220	1,00487E-06	3,130	19,939	21,787	1013,668	18153	66,6114	55,9792	0,1073	18236	6,7035	56,235	0,7444	543693	199505,108	1676,611	-0,247
9	998,217	1,00447E-06	3,129	19,956	21,783	1013,557	18154	66,6104	55,9823	0,1059	18236	6,7031	56,235	0,7377	543711	199497,804	1676,666	-0,251
10	998,216	1,00445E-06	3,127	19,956	21,764	1013,653	18153	66,6105	55,9844	0,1059	18236	6,7035	56,240	0,7433	543683	199498,565	1676,735	-0,251
MIN	998,216	1,00445E-06	3,036	19,932	21,764	1012,597	18129	66,6104	55,9104	0,1059	18124	6,6745	55,9257	0,3087	543517	199497,8044	1676,4610	-0,2511
AVG	998,219	1,00476E-06	3,084	19,944	21,788	1013,236	18145,000	66,6245	56,3672	0,1269	18205,200	6,6965	56,5526	0,6382	543745,900	199651,6582	1689,1402	-0,1742
MAX	998,221	1,00504E-06	3,134	19,956	21,810	1013,668	18160	66,6769	60,0411	0,2058	18236	6,7124	59,9980	0,8780	543977	199812,7841	1799,2690	-0,0936
MAX-MIN	0,0049	5,86008E-10	0,098	0,024	0,047	1,071	31	0,0665	4,1307	0,0999	112	0,0379	4,0724	0,5693	460	314,9797	122,8080	0,1575
relSTD	1,944E-06	2,289E-04	1,578E-02	4,721E-04	7,898E-04	3,980E-04	6,427E-04	2,992E-04	2,291E-02		2,734E-03	2,147E-03	2,152E-02		2,550E-04	7,712E-04	2,291E-02	
11	998,213	1,00406E-06	3,340	19,972	21,750	1013,712	17605	66,7359	180,5904	0,2944	18236	6,9252	187,063	4,0751	526204	199469,982	5397,749	-0,265
12	998,216	1,00443E-06	3,340	19,957	21,790	1013,757	18109	66,7497	185,7564	0,3152	18236	6,7338	187,059	1,1992	541154	199469,215	5550,986	-0,265
13	998,217	1,00447E-06	3,341	19,956	21,792	1013,806	18099	66,7517	185,7491	0,3181	18236	6,7377	187,155	1,2581	540842	199470,221	5550,634	-0,265
14	998,215	1,00423E-06	3,339	19,965	21,784	1013,948	18101	66,7498	185,6782	0,3153	18236	6,7368	187,063	1,2443	540916	199469,889	5548,661	-0,265
15	998,212	1,00397E-06	3,339	19,976	21,766	1014,095	18218	67,1758	186,8784	0,9555	18236	6,7363	187,063	1,2362	540980	199477,171	5549,318	-0,261
16	998,217	1,00447E-06	3,637	19,956	21,776	1013,974	18218	66,8138	186,8784	0,4114	18236	6,6999	187,063	0,6902	543899	199472,690	5579,261	-0,264
17	998,217	1,00447E-06	3,635	19,956	21,790	1013,938	18281	66,8107	187,5246	0,4068	18233	6,6754	187,032	0,3221	545789	199466,926	5598,648	-0,267
18	998,217	1,00447E-06	3,635	19,956	21,808	1013,846	18277	66,8128	187,4836	0,4101	18236	6,6782	187,063	0,3638	545670	199473,476	5597,428	-0,263
19	998,217	1,00447E-06	3,633	19,956	21,810	1013,860	18279	66,8107	187,5041	0,4068	18238	6,6780	187,084	0,3605	545742	199471,444	5598,166	-0,264
20	998,217	1,00447E-06	3,632	19,956	21,810	1013,728	18354	66,8112	188,3662	0,4076	18236	6,6500	187,155	-0,0597	547987	199475,293	5623,962	-0,262
MIN	998,217	1,00397E-06	3,339	19,956	21,750	1013,712	17605	66,7359	180,5904	0,2944	18233	6,6500	187,0323	-0,0597	526204	199466,9257	5397,7494	-0,2665
AVG	998,217	1,00435E-06	3,487	19,956	21,788	1013,866	18154,100	66,8222	186,2409	0,4241	18235,900	6,7251	187,0800	1,0690	541918,300	199471,6306	5559,4813	-0,2642
MAX	998,217	1,00447E-06	3,637	19,956	21,810	1014,095	18354	67,1758	188,3662	0,9555	18238	6,9252	187,1551	4,0751	547987	199477,1705	5623,9624	-0,2614
MAX-MIN	0,0000	5,01742E-10	0,298	0,000	0,060	0,383	749	0,4399	7,7758	0,6611	5	0,2751	0,1229	4,1348	21783	10,2449	226,2129	0,0051
relSTD	1,529E-08	1,913E-04	4,454E-02	0,000E+00	9,078E-04	1,207E-04	1,168E-02	1,922E-03	1,171E-02		6,565E-05	1,148E-02	2,215E-04		1,126E-02	1,535E-05	1,130E-02	
21	998,217	1,00447E-06	4,027	19,956	21,814	1013,754	18271	66,8008	373,8399	0,3919	18236	6,6792	373,124	0,3786	545553	199460,073	11162,471	-0,270
22	998,217	1,00447E-06	4,029	19,956	21,825	1013,699	18236	66,8012	373,1465	0,3926	18236	6,6921	373,147	0,5719	544547	199475,745	11142,565	-0,262
23	998,217	1,00447E-06	4,021	19,956	21,832	1013,627	18341	66,8034	375,2950	0,3958	18420	6,7211	376,912	1,0084	547648	199469,707	11206,017	-0,265
24	998,217	1,00447E-06	4,022	19,956	21,839	1013,643	18323	66,8055	375,0957	0,3991	18470	6,7462	378,105	1,3853	547095	199470,456	11199,749	-0,265
25	998,217	1,00447E-06	4,020	19,956	21,839	1013,564	18335	66,8009	375,1567	0,3920	18470	6,7413	377,919	1,3119	547493	199470,969	11202,383	-0,265
26	998,217	1,00447E-06	4,233	19,956	21,846	1013,448	18427	67,3711	377,2247	1,2490	18471	6,7653	378,125	1,6721	550227	201168,938	11263,865	0,584
27	998,217	1,00447E-06	4,231	19,956	21,850	1013,368	18448	67,5778	377,4615	1,5597	18469	6,7776	377,891	1,8569	550858	201787,559	11271,015	0,894
28	998,217	1,00447E-06	4,227	19,956	21,849	1013,240	18470	67,2732	378,1050	1,1020	18470	6,7393	378,105	1,2826	551442	200851,595	11288,738	0,426
29	998,217	1,00447E-06	4,226	19,956	21,858	1013,382	18493	67,4253	378,3896	1,3306	18475	6,7480	378,021	1,4128	552157	201316,058	11297,814	0,658
30	998,217	1,00447E-06	4,225	19,956	21,860	1013,324	18480	67,3291	378,3401	1,1860	18480	6,7449	378,340	1,3667	551783	201033,967	11296,626	0,517
MIN	998,217	1,00447E-06	4,020	19,956	21,814	1013,240	18236	66,8008	373,1465	0,3919	18236	6,6792	373,1238	0,3786	544547	199460,0726	11142,5646	-0,2700
AVG	998,217	1,00447E-06	4,126	19,956	21,841	1013,505	18382,400	67,0988	376,2055	0,8398	18419,700	6,7355	376,9689	1,2247	548880,300	200350,5067	11233,1242	0,1753
MAX	998,217	1,00447E-06	4,233	19,956	21,860	1013,754	18493	67,5778	378,3896	1,5597	18480	6,7776	378,3401	1,8569	552157	201787,5593	11297,8142	0,8938
MAX-MIN	0,0000	0,00000E+00	0,212	0,000	0,046	0,514	257	0,7770	5,2431	1,1678	244	0,0984	5,2163	1,4783	7610	2327,4867	155,2496	1,1637
relSTD	1,529E-08	1,334E-08	2,616E-02	0,000E+00	6,606E-04	1,732E-04	5,034E-03	4,799E-03	5,141E-03		5,333E-03	4,516E-03	5,455E-03		5,005E-03	4,784E-03	5,112E-03	

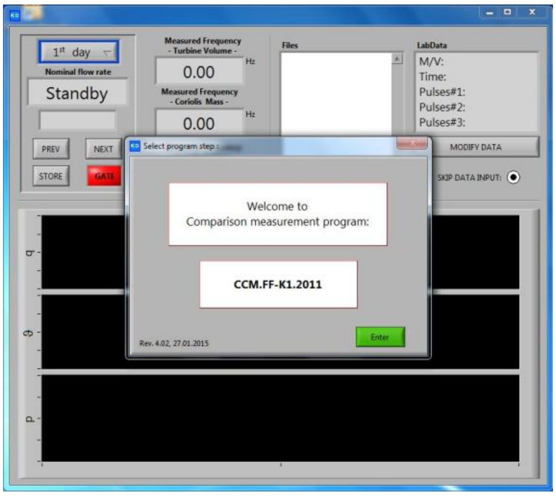
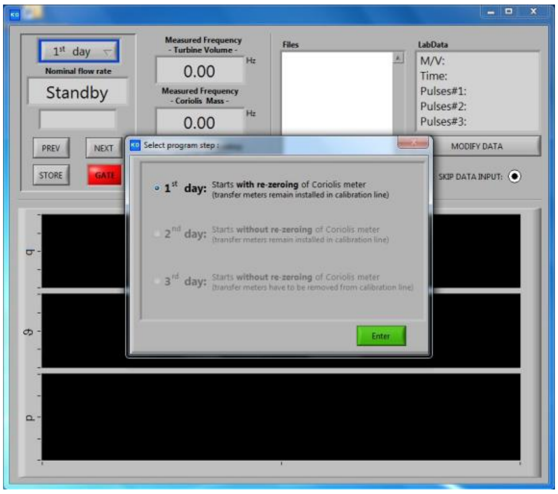
Appendix 2 - Stepping through SC data acquisition for using electronic box 1

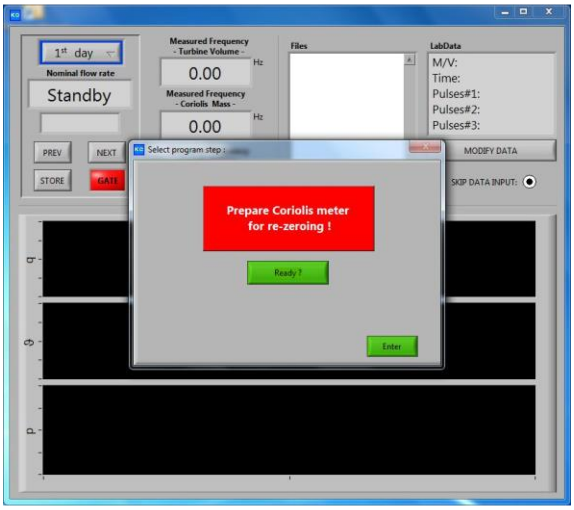
This section is only valid if electronic box 1 is used. In case of connecting box 2 please follow the instructions of Appendix 4

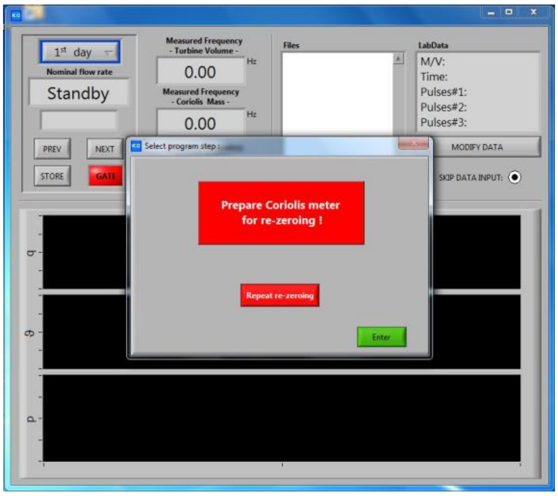
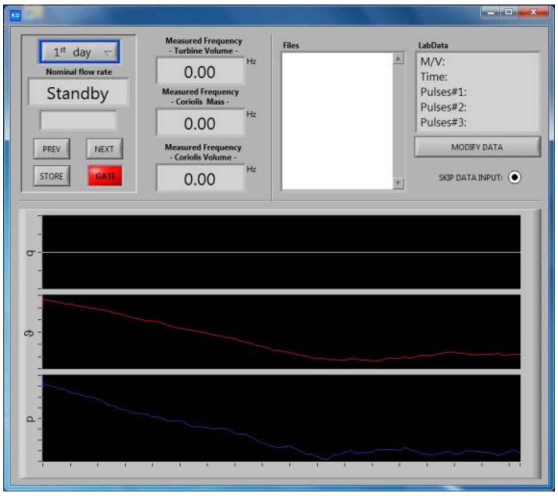
- **Before connecting the GATE signal cable** to the data acquisition electronics (Figure 5), check - by means of an appropriate measurement device (e.g., a scope – that the signal levels of this signal, definitely, corresponds to the specification (TTL signal specification), in accordance with the **logic level OFF** and **ON**.
- The **GATE signal** may be defined both LOW active (**logic voltage < 3.0 V** corresponds to **ON**) and **HIGH active** (**logic voltage > 3.0 V** corresponds to **ON**).
- After this checking operation, the GATE signal cable can be connected to the electronic box.
- Now the LabVIEW KC1 software can be started as described in Table A 3.
- During the start-up of the LabVIEW program, the GATE signal, definitely, must be logically OFF, for the software derives the definition of the logic states of the GATE signal from this initial signal condition.
- In order to guarantee the correct gating function of the GATE signal, it is absolutely necessary that this functionality is being verified during the software operations: **Step #5** in Table A 3 .
- **As the computer shuts down after a longer period of non-operation, it "loses" connectivity to the external data acquisition electronics.**
- **To reestablish the LAN connection between laptop computer and external data acquisition electronics**, do switch off the electronics and restart it again on the second and on third day before starting the calibration measurements.

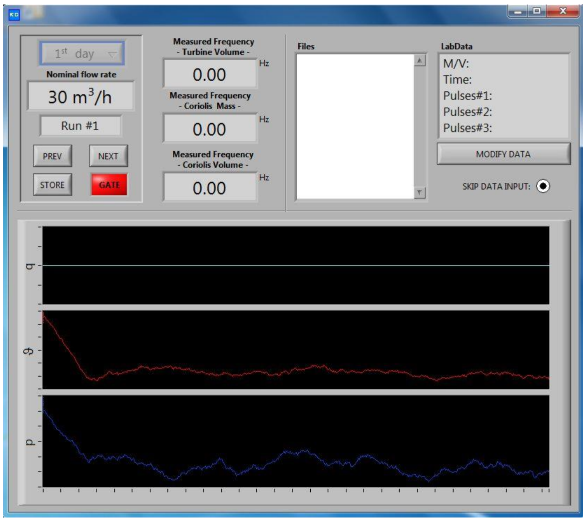
Table A 3: Stepping through the KC1 measurement program

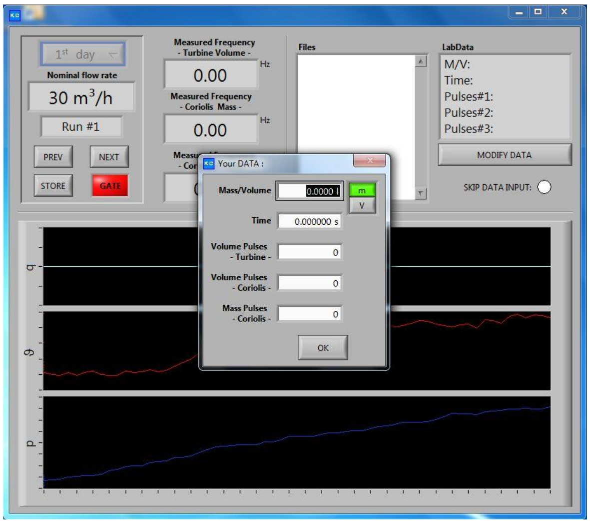
Step No.	Screen display	Activity
1		Initial screen of Windows 7: **Double-click on LabVIEW icon** in centre position. Check before clicking to start KC1 software that **GATE** signal is **OFF** : - **Positive logics**: GATE level is **LOW**; - **Negated logics**: GATE level is **HIGH**.
1a		If this message appears, no networkconnection to the box could be established. After confirmation of the <OK>-button the program will be closed. Switch the box off and on again (by using the powerswitch on frontpanel of the box), then restart program.

<table>
<tr>
<td>2</td>
<td>
</td>
<td>Welcome screen:
Just click on <ENTER> to proceed.</td>
</tr>
<tr>
<td>3</td>
<td>
</td>
<td>Program indicates that the program part of the 1st day is going to be started.

Click on <ENTER> to proceed.</td>
</tr>
<tr>
<td>4a</td>
<td>
</td>
<td>The program stops here, so that the calibration personnel can establish zero-flow process conditions:
- Adjust control valve to OFF position.
- Run fluid pumps at a speed/ flowrate that a line gauge pressure magnitude is established which corresponds to the pressure level during calibration (e.g. 3 bar).
- Hold these conditions for approx. 10 minutes and observe the flow condition that no leakage passes through the control valve.
- Click on <READY> to start re-zeroing meter.
In case of a failed re-zeroing operation, the above procedure may be repeated.</td>
</tr>
</table>

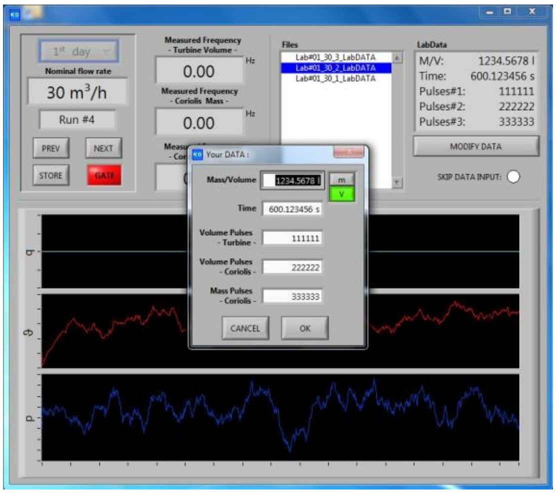
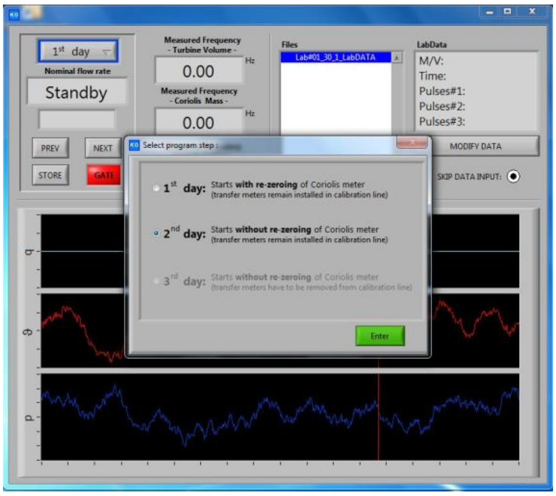
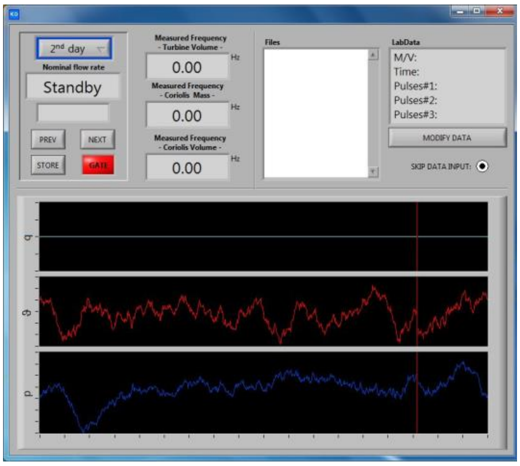
4b		The re-zero operation of the Coriolis meter has shown to be successful: - **Click on <ENTER>** to proceed and step into the data acquisition part of the program. **Alternative decisions:** - **<ENTER>**: Re-zeroing has been successful. - **<REPEAT>**: If the operator recognizes that rezeroing the Coriolis meter has **not** been successful (e.g.: process conditions had been instable during autozero operation), the re-zero action may be repeated.
5	 **<u>Input options:</u>** **<PREV>** Skip backward to prevous data series **<NEXT>** Initially: Selection of 1st measurement point **<STORE>** Store measurement data after the completion of the SC measurement data acquisition program **<u>Status indicator:</u>** **<GATE>** Indication of GATE signal status: <red> inactive <green> active	**1st day:** SC program is in **STAND-BY** mode: - **Click on <NEXT>** to proceed and step into data acquisition part of the program. **<u>Attention:</u>** In order to guarantee the correct gating function of the GATE signal, it is absolutely necessary that this functionality is being verified during the software operations. The GATE indicator will change from RED to GREEN if the GATE signal is operating properly.

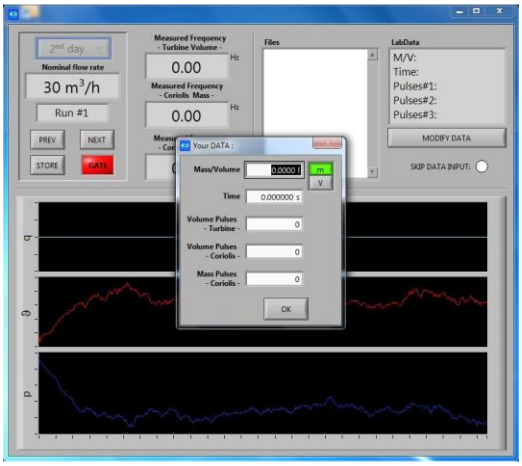
<table>
<tr>
<td>6a</td>
<td>
</td>
<td>Measurement program: 1st day:

- 6 flowrates: 30 m³/h ... 200 m³/h, with 5 repeated measurements each;
The program is automatically passing through all measurement points according to the lab's part of SC as described in Chapter 4.2</td>
</tr>
<tr>
<td>6b</td>
<td>
</td>
<td>At first, dial <Radio button> whether the lab's reference standard is either VOLUMETRIC (Select: V) or GRAVIMETRIC (Select: m)
Once made this choice at the very beginning, it is valid for KC1 program's total running time and needs no further re-activation during the following program steps).
<u>Remark:</u>
<Radio button>: - Default: Variant B
Click on, in order to toggle from Variant B to Variant A

- Measurement data to be entered at each measurement point:

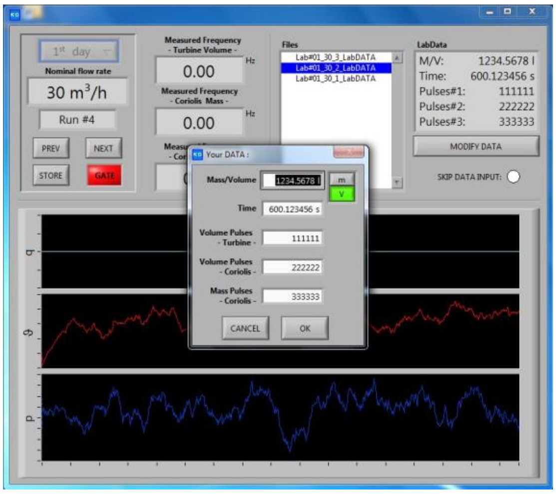
1) Volume or mass (incl. buoyancy correction) (Variant A) or skip this part of data entry (Variant B)
2) Time of diversion (measurement time)
3) Pulse count from turbine meter
4) Pulse count #1 from Coriolis meter (mass-flow-related output signal)
5) Pulse count #2 from Coriolis meter (volume-flow-related output signal)</td>
</tr>
<tr>
<td>6c</td>
<td></td>
<td>Variant B:
Option to enter the measurement values delivered from the respective reference standard (V or m), made in a consecutive series, one reference value after another.</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>End of program for the 1st day:
<u>Remark:</u> Program may be shut down.</td>
</tr>
</table>

7+		**<u>Option:</u>** Opportunity to apply a final modification of measurement data (relating to a day's measurement results) before proceeding in the SC program steps or before storing data at end the of SC measurement program.
8		Initial program step: 2nd day Program indicates that the program part of the **2nd day** is going to be started. **Click on <ENTER>** to proceed. (**Optionally:** Measurements of the 1st day can be repeated).
9		**2nd day:** SC program is in **STAND-BY** mode: - **Click on <NEXT>** to proceed and step into data acquisition part of the program.

<table>
<tr>
<td>10</td>
<td>
</td>
<td>Measurement program: 2nd day:

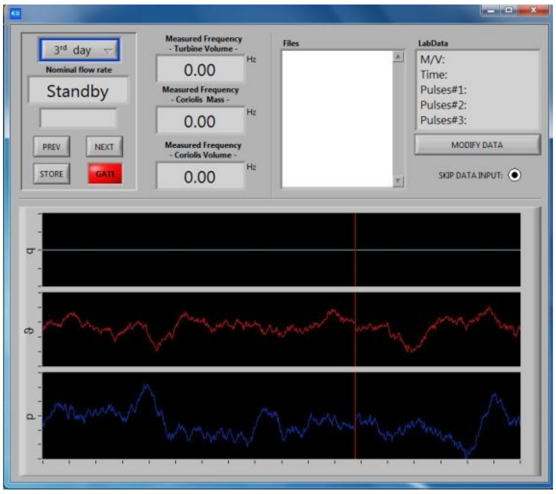
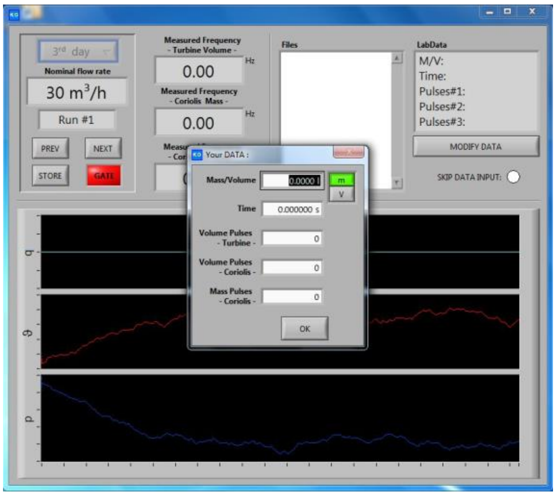
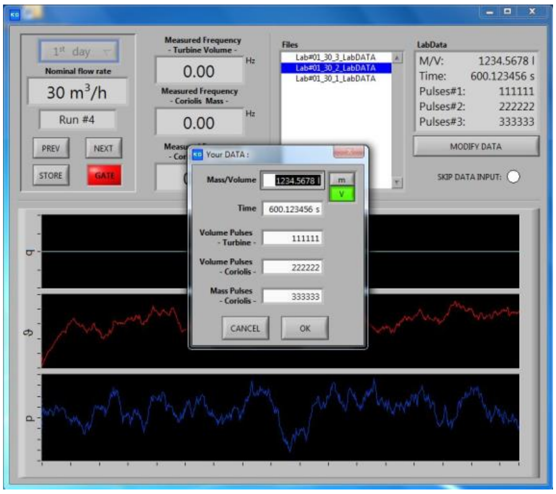
- 6 flowrates: 30 m³/h ... 200 m³/h,
with 5 repeated measurements each;

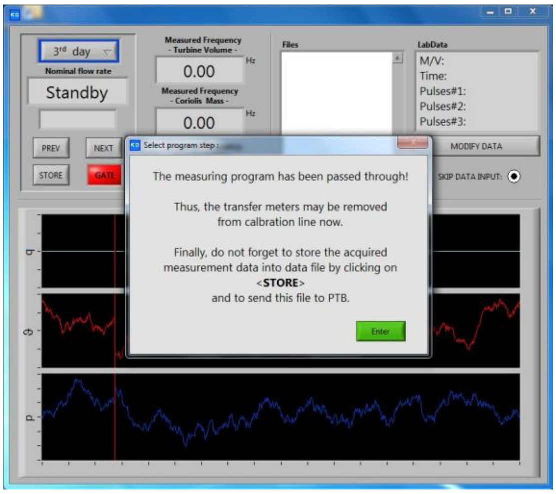
See Steps #6a and #6b.</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>End of program for the 2nd day:

<u>Remark:</u> Program may be shut down.</td>
</tr>
<tr>
<td>11
+</td>
<td>
</td>
<td><u>Option:</u>

Opportunity to apply a final modification of measurement data (relating to a day's measurement results) before proceeding in the SC program steps or before storing data at end the of SC measurement program.</td>
</tr>
<tr>
<td>12</td>
<td>
</td>
<td>Program indicates that the program part of the 3rd day is going to be started.

Click on <ENTER> to proceed.</td>
</tr>
</table>

12a		**3rd day:** SC program is in **STAND-BY** mode: - **Click on <NEXT>** to proceed and step into data acquisition part of the program.
13		**Measurement program: 3rd day:** - **3 flowrates: 30 m³/h, 100 m³/h, 200 m³/h**, with **10 repeated measurements** each; - Measurement data to be entered at each measurement point: See **Steps #4a** and **#4b**.
13 +		**<u>Option:</u>** Opportunity to apply a final modification of measurement data (relating to a day's measurement results) before storing data at end the of SC measurement program.

14		Store measurement data to an external memory device (memory stick) and send these measurement data to the Pilot Laboratory by e-mail: **Click on <STORE>** button in MAIN WINDOW (#13)
14a		Data file will be generated automatically by SC program: - Just do **Click on <OK>** button. <u>**Default:**</u> **Standard storage location i**s the desktop of Windows 7. Please do not modify this parameter.
15	<u>Annotations:</u> - In case of incomplete measurement data sets, **no decoded** (i.e. readable by calibration personnel) will be generated. - Only if the whole measurement program has been completed successfully a decoded file will be generated which is accessible by the lab's personnel.	- Copy data file onto an external storage media (e.g. memory stick). - Send data file to Pilot Laboratory by e-mail. - Measurement data can be extracted from data file (unzipped) and decoded for laboratory-internal purposes.
16		Log off from laptop computer and shut down operating system, Switch off the electronic box and disconnect mains power supply.
17		Remove transfer meter package from the calibration line.
18		Drain and dry transfer meters. <u>Remark:</u> Be careful when applying air flow for drying in order to avoid any damage to the turbine meter.
19		Prepare the transfer package, auxiliary equipment, and computer for shipment.

Appendix 3 - Data files generated by the SC LabVIEW

In the description following below, the file names comprise placeholders, which stand for:

- *user*	<Lab#*number*>	(e.g.: <Lab#01>)
- *flowrate*	<Nominal flowrate>	(e.g. <30>)
- *run*	<No. of measurement at a certain flowrate>	(e.g.: <1>)

Example: File name := **Lab#01_30_1_General**.csv

In an analogous way, the sample file names can be formed as follows:

Lab#01_30_1_LabDATA.csv
Lab#01_30_1_Meters.csv
Lab#01_30_1_ProcessValues.csv
Lab#01_30_1_Transition.csv
Lab#01_30_1_Zeroing.csv

File name := *user_flowrate_run*_**General**.txt

--- The measurement data represent summarized values each which were derived from the corresponding files: *user_flowrate_run*_**ProcessValues**.csv
*user_flowrate_run*_**Meters**.csv ---

Gate time: Time of diversion (Measurement time) [µs]
T_mean :
delta T:
P_mean:
delta P:
Meas.density:

--- Coriolis volume flow ---
Pulse count:
f_mean:
delta f:

--- Coriolis mass flow ---
Pulse count:
f_mean:
delta f:

--- Turbine volume flow ---
Pulse count:
f_mean:
delta f:
mean_flow:

File name := *user_flowrate_run*_**LabDATA**.csv

Volume [L] or **mass** [kg] (incl. buoyancy correction)
Time of diversion (measurement time) [s]
Pulse count from turbine meter
Pulse count #1 from **Coriolis meter** (mass-flow-related output signal)
Pulse count #2 from **Coriolis meter** (volume-flow-related output signal)

File name := *user_flowrate_run*_**Meters**.csv

1st row of values: Represents the periods of time between the active edge of the diverter's START signal and the first active edge each of the meter signals which are dedicated to rows #1 through #3, as described below;

1st column of values: Pulse-interspacing period of the Coriolis meter's volume-flow output signal;

2nd column of values: Pulse-interspacing period of the Coriolis meter's mass-flow output signal;

3rd column of values: Pulse-interspacing period of the turbine meter's flow signal;

All periods of time are measured in **microseconds [µs]**.

File name **:=** *user_flowrate_run_***ProcessValues***.csv*

Logging file of measurement data:

- **Sampling time:** 200ms

- 256 sampled values (>51,2 s) prior to the diverter's transition to measurement position (into weigh tank),

- These pre-measurement logged values are followed by a zero-value row.

- The rows of "regularly" logged measurement values follow now.

- Data logging will be stopped when, after measurement, the diverter returns to its initial position again.

T	:	Temperature	[°C]
P	:	Gauge pressure	[bar]
Dm	:	Fluid density (Coriolis meter)	[kg/L]
P_diff	:	Differential pressure across turbine	[mbar]

File name **:=** *user_flowrate_run_***Transition***.csv*

Logging file of measurement data from turbine output**:**

- Logging pulse-interspacing periods of time (*1/frequency*): [µs]

- Logging starts 512 data samples prior to diverter actuation into measurement position.

- Signal logging is stopped until the diverter actuation redirects the fluid stream from measurement position back to flow-bypass position; then another 512 data samples will be acquired and stored.

File name **:=** **Zeroing.***txt*

File contains data (device parameter) which refer to re-zeroing of Coriolis flowmeter as follows (sample data set):

4.08.2016-13:36:23 ++ PIPO: -11.0000 ++ CALIF: 1.6614 ++TEMP: 23.46 ++ PRESS: 1.23 ++ <read>

04.08.2016-13:38:51 ++ PIPO: -11.0000 ++ CALIF: 1.6614 ++TEMP: 20.00 ++ PRESS: 3.00 ++ <set>

04.08.2016-13:40:10 ++ PIPO: -11.0000 ++ CALIF: 1.6614 ++TEMP: 23.44 ++ PRESS: 1.23 ++ <set> ***((To be continued automatically by LabVIEW measurement program))***

Appendix 4 - Instructions for using electronical box 2

This section is only valid if electronic box 2 is used. In case of connecting box 1 please follow the instructions of Appendix 2.

If you have any problems or suggestions for using the electronical box please contact the SC staff at PTB (see page 1)

Instructions for start-up box 2:

- Connect all relevant cable (see Table 10) to the alternative junction box.
- Connect a constant voltage power supply (24 V DC) to the box and switch on.
- Switch on the main power button.
- The system is ready for calibration if the following requirements are achieved:
    - The display of Coriolis meter is at the status “On” and the screen display is like the example in step #1 of Table A 4.
    - If the flow rate at the meters under test is > 0 m^3/s you should record impulses with your impulse counting system.

Setting Autozero

- Before starting measurements of day #1 it is necessary to set Auto zero of the coriolis meter.
- Please use only the intended key at the box 2. **Don’t try to set auto zero directly at the coriolis display.**
- After installing the setup und refilling the pipe line be sure of all air is excluded from the water.
- Adjust control valve to OFF position.
- Run fluid pumps at a flowrate that a line gauge pressure magnitude is established which corresponds to the pressure level during calibration (e.g. 3 bar).
- Hold these conditions for approx. 10 minutes and observe the flow condition that no leakage passes through the control valve.
- **Before** setting auto zero please note the current value. The procedure for identifying the value is described in Table A 4.
- Insert the Auto zero key into box 2 and turn the key shortly to the right. The key will turn back to starting position automatically.
- Read out and note the new Auto zero.
- Please repeat this procedure of zero setting at least 3 times.
- If the value doesn’t chance significant (differences < 3) the Auto zero setting is finished successfully.
- Please use for reporting zero values the provided EXCEL spreadsheet (Table “Auto zero values”), see also Section 6.1.1

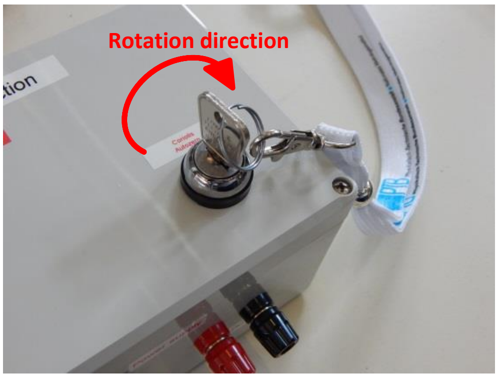
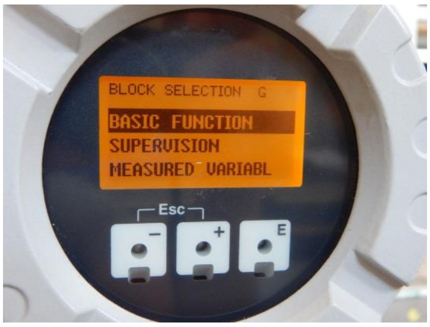


Figure A 1: Electronic box 2 and the plugged key for setting Auto zero of coriolis meter

Table A 4: Stepping through the auto zero process if using electronic box 2

Step No.	Coriolis display	Activity
1		- Standard display of the Coriolis meter (if switched on) - Press “E” to go to step 2
2		- Main menu of the Coriolis meter - Press “+” six times to select “Basic Function” - Press “E” to go to step 3
3		- Basic function menu of the Coriolis meter - Press “+” three times to select “Sensor Data” - Press “E” to go to step 4
4		- Sensor data menu of the Coriolis meter - select “Configuration” - Press “E” to go to step 5
5		- Configuration menu of the Coriolis meter - Press “E” three times to select “Zeropoint” - Please note the current value of Auto zero

Appendix 5 - List of participants

Table A 5: List of participants

1	**Germany** (EURAMET)	**PTB Braunschweig** Contact: **Enrico Frahm** **Shipping address:** Physikalisch-Technische Bundesanstalt Department Liquid Flow Bundesallee 100 38116 Braunschweig Germany	Email: enrico.frahm@ptb.de Phone: +49-531-592 1333
2	**Finland** (EURAMET)	**VTT MIKES Kajaani** Contact: **Mika Huovinen** **Shipping address:** VTT MIKES Kajaani Sokajärventie 9 Puristamo 9D3 87100 Kajaani Finland	Email: mika.huovinen@vtt.fi Phone: +358-50-4155 974

Appendix 6 - Current time schedule of the SC

Table A 6: Time schedule of SC (03/2019)

Date	Country	NMI	Measurement Status
05/2018	Germany	PTB	done
08 – 12 /2018	Finland	VTT MIKES	done
04/2019	Germany	PTB	estimated