Content

1. CLM vs traditional water meters

1.1. Installation

CLM consists of an electronic device (calculator and communication) and a sensor glued to an iron, copper or plastic pipe. There is no cutting of pipes necessary hence no risk for water leakage.

CLM water meter

Traditional water meter

Installation tool for CLM

Installation tools for traditional meters

CLM is glued to 12 to 108 mm pipes. No cutting of pipes and no need to closing the flow of water.

CLM is installed by the same technician who installs the communication network.

To install a traditional meter one have to cut the pipe, install valves and a wall mounting gear. The cost for the additional parts frequently exceeds the cost of the meter itself.

Installation shown in the picture above contains 8 potential leakage points.

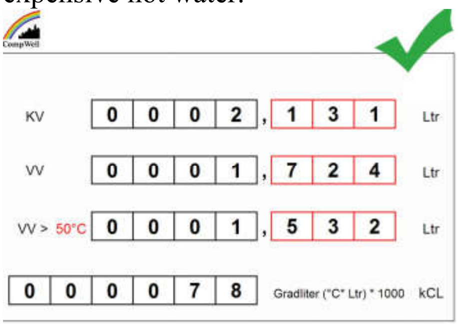
Installation is made by a plumber. Once that is done a network technician connects the meter to the building's communication network.

1.2. Metering of volume and temperature of water.

Traditional water meters report only the volume of water. CLM report the volume and the temperature of the water.

Fairness

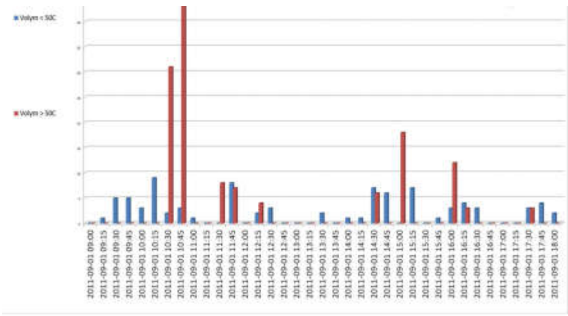
In many older apartment buildings there are no hot water re-circulation systems installed at all or are working poorly. A tenant needs to wait for a long time before the temperature of the delivered hot water reaches the required level between 50 and 65°C. Water is cold but it is charged as 3-4 times more expensive hot water.



CLM contains two separate counters. One counts the volume of water with temperatures below the threshold temperature (i.e. 45°C and one the volume of colder water. The system generates an alarm when the colder water exceeds for predefined portion (i.e. 20%) of the water that passed the meter.

Legionary disease

Poorly heated water creates a considerable health risk. In buildings with long water pipes, poor re-circulation of hot water and too low hot water temperature the heath threatening Legionary bacteria grows exponentially. It is estimated that over 500 people catches the disease and one in ten of them dies from the disease.



Picture above shows the use of water in an apartment. The blue bars represent volumes of hot water with temperatures below 50°C and red show the volumes of water that exceeded 50°C. If there are no red bars for more than 2 days the **system warns.**

Warning for leakage.
CLM can be used as a leakage sensor. A dripping faucet delivers 6 liters water per hour. Traditional mechanical meters start showing the flow at 20 liters. CLM detects flow of less than 3 liters per hour and can therefore be used as a **leakage detector.**

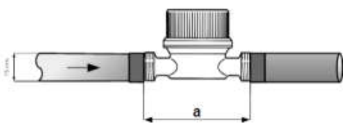
1.3. Data communication

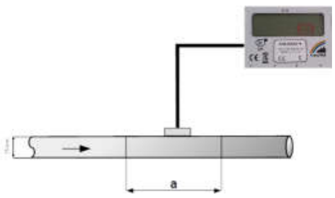
CLM delivers the state of the counter via **Wireless-MBUS** alt. via RS485. **MBUS, Bluetooth** and **TCP/IP** are supported by addition of the ComCard.

1.4. Power

CLM can be powered from a built in battery (6 years alt. 12 years lifecycle), MBUS network or a 12V supply.

2. CLM – principle of operation



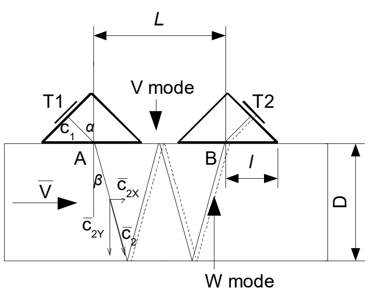


Invasive method.

Non-invasive method

Traditional meter is screwed between two pipe

CLM is glued to an existing pipe



Metering principle

CLM measures the flow of water using ultrasonic signals. Electrical pulses sent to a piezo element T1 glued to a prism A which in turn is glued to the pipe filled with water flowing from A to B. T1 coverts the electrical signals to ultrasonic vibrations which travel through the prism, the wall of the pipe the water, the pipe under prism B, the prism B to the piezo element T2 where it converts to an electrical signal.

The measurement cycle has two phases. In the first phase the bean of ultrasound wave is travelling along the pipe according direction A->B. In the second phase the wave is travelling in the opposite direction, B->A.

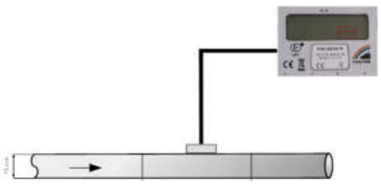
The time required to get from A to B and B to A (transit time) are equal when the water in the pipe does not move. If water flows from A to B the transit time from A to B will be shorter than from B to A. The time difference (TD) is proportional to the velocity of the flowing in the pipe. TD multiplied by a calibration factor (KF) gives the value of the flow in litres per hour.

At the low flow of the water molecules roll over each other, the ones closest to the walls of the pipe do not move forward at all. Such a flow is called the **laminar flow** (flow range Q1). When velocity of the water is high enough all molecules move forward at the same speed. Such flow is called the **turbulent flow** (flow range Q3).

Velocity diagram

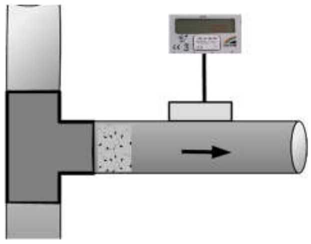
Laminar flow Q1 **Transition flow Q2** **Turbulent flow Q3**

Transition (Q2) between Q1 and Q3 depends on a number of factors like water temperature, water viscosity and the geometry of the piping system before, in and after the point where the metering device is located. A valve, a bend or branching (called “disturber”) disturbs the flow of water, creates whirls that have huge influence on the metering results for the flows lower than Q3. If the distance between the disturber and the meter is long the whirls fade away and has no influence on metering results.



Straight pipe. No whirls

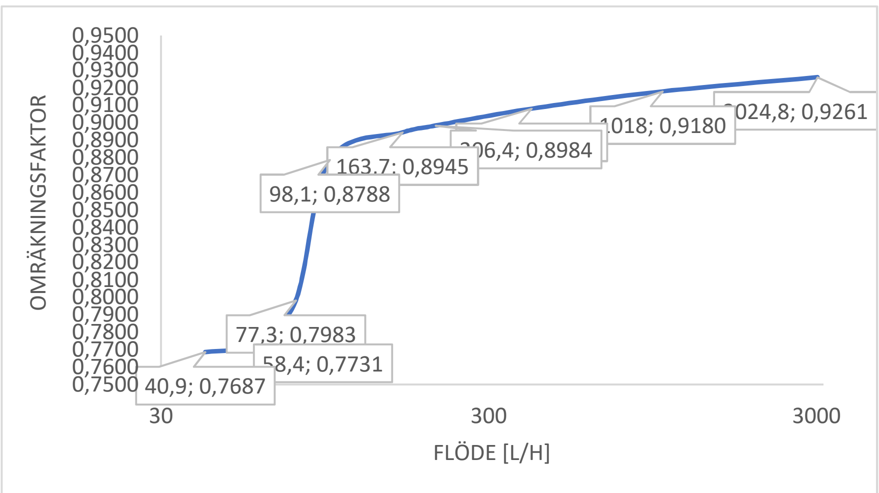
Valve. Whirls.



Branching. Whirls.

To calculate the volume of water passing the meter with required accuracy when the flow is in the laminar or in the turbulent range is not a major problem. To calculate it in the Q2 range is practically impossible.

The flow is calculated by multiplying the measured TD by the calibration factor KF. The picture below shows how KF (Omräkningsfaktor) changes within the flow (Flöde) range of 30 to 3000 liters per hours for a 15mm pipe.

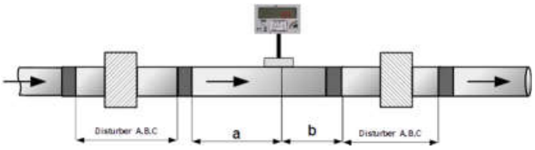


KF changes 14% within the range 60 to 120 liters per hour (Q2) but only 0.6% within the Q1 range (below 60 l/h) and Q3 (above 120 l/h). A small TD change within Q2 influences the estimation of the flow 23 times more within Q2 than within Q1 or Q3.

The range defined by MID covers the Q2 range. For example the required accuracy for a cold water meter for a 15 mm pipe must be better than +/-5% within 65 – 105 l/h and better than +/-2% within 105 – 3 125 l/h. The 2% requirement applies to the Q2 range.

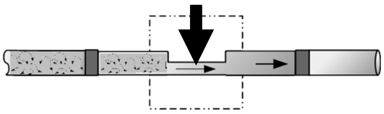
The Irish engineer Osborne Reynolds wrote a formula for calculation of the transition pint from Q1 to Q3 in a straight pipe.The form is called the **Reynolds number**. Wikipedia https://en.wikipedia.org/wiki/Reynolds_number *The Reynolds number (Re) is an important dimensionless quantity in fluid mechanics used to help predict flow patterns in different fluid flow situations… The Reynolds number is used to predict the transition from laminar to turbulent flow, and used in the scaling of similar but different-sized flow situations,…*One can use the Re to calculate the flow in a straight pipe. If there are whirls in the water passing the meter the Q2 can't be defined in a general way.

The MID-norm defined 3 different flow disturbers, (left swirl, right swirl and half-blocked pipe). The MID certified meter must be able to achieve the required accuracy when installed x cm before and y cm after each one the disturbers

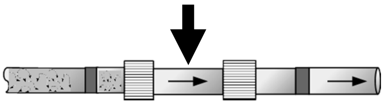


To be able to pass all of these tests one has to use one of the methods listed below:

Alt 1. Make sure that the flow is within the Q3 range across the whole by MID defined range.
It is done by reducing the diameter of the pipe inside the meter.



Alt 2. Install a "rectifier" in front of the meter to eliminate the whirls.



3. MID certification of CLM - background

3.1. Goal

Our goal is to design and manufacture a flow meter which after a non-invasive installation on an existing pipe fulfills all by the MID specification defined requirements. These requirement can be broadly divided as follows:

(a) **Environment** – the meter must pass temperature, humidity and vibration tests.
(b) **Life expectancy** – the meter must pass the longevity test
(c) **EC and EMC** – the meter must pass electrical safety and electromagnetic tests
(d) **Software** – the software powering the meter must fulfill the WELMEC standard
(e) **Accuracy** – the accuracy must be within the limits in the presence of disturbers as defined by the MID norm

3.2. Problems to solve:

To fulfil the goals listed in 3.1 one will have to solve two "unsolvable" problem:

Problem 1:
None of the European MID certification institutes will issue a MID certificate for the meter mounted on a pipe installed in an apartment in Stockholm without receiving the part of the pipe with the mounted meter to its test laboratory. The pipe is treated as part of the meter and without it the meter does not function.
But the whole point with CLM that it will mounted on a pipe without cutting it.

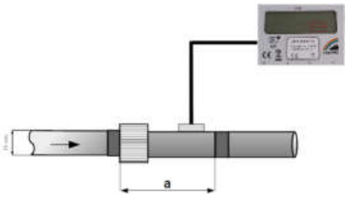
Problem 2:

As discussed under 2.2 above there are no mathematical methods to calculate the flow of water in systems with disturbers without correcting the flow within the meter itself which in the case of CLM means “invading” the pipe. But the whole point with CLM is that it will mounted on a pipe without cutting it.

3.3. 3-step solution

The idea about how to solve these problems came from SP Techincal Research Institute of Sweden in Borås: ”meters for petrol are certified on site”.
Petrol is approximately 1 000 time more expensive than cold water. If one can certify petrol meters on site it must be possible to certify water meters on site.
After reviewing the idea with SP we decided on a 3-stage strategy:

Step 1. MID-certify CLM with “flow corrector”



Certificate will prove that:
- CLM cleared Environment, Life cycle, EC/EMC, WELMEC tests.
- Accuracy test passed but with the help of the flow corrector.

Step 2. Prove that CLM without the flow corrector:

(1) **Clears the MID requirement for Environment, Life expectancy, EC/EMC, WELMEC**

(2) **Clears Accuracy requirement when tested in piping system with a known geometry**.
CLM is calibrated in the factory to pass the test with a specific disturber, i.e. specific geometry.
The Institute verifies the results. Tests are repeated for all 3 disturbers placed before and after the CLM.

(3) **Clears Accuracy requirement with known pipe geometry mounted on pipes from various manufactures.**
CLM is calibrated in the factory on the Reference Pipe to pass tests with a specific disturber but mounted on pipes with the same specifications (catalogue data) from a number of suppliers.
The Institute verifies the results. Tests are repeated for all 3 disturbers placed before and after the CLM and 3 deferent, randomly selected, pipe manufacturers.

(4) **Clears Accuracy requirement with known pipe dimensions and unknown geometry of the piping system geometry after it was calibrated by a Mobile Calibration Station, MCS.**
The Institute verifies the results.

Step 3. Mobile Calibration Station, MCS.
Design, manufacture and certify a portable calibration instrument, the **Mobile Calibration Station, MCS.**
Prove that CLM mounted on pipes of unknown dimensions installed in an unknwon piping system and calibrated with MCS meets MID accuracy requirements.
The Institute verifies the results.

4. Step 1. MID certification of CLM equipped with flow corrector

Pass the MID certification and solve the flow correction issue in next phase.

- Glue the CLM-sensor to a pipe purchased at the local distributor
- Connect by CompWell designed and manufactured flow corrector in front of the meter. The total lengths must be as defined by MID.

Flow corrector
Flow sensor

- Deliver 25 units to the Test Institute

On the 11th of August 2014 CLM with flow corrector as shown on the picture above received MID certificat number TCM 142/14-5216 for metering the flow of cold water T30 and the flow of hot water T30/70.

Český metrologický institut
Okružní 31, 638 00 Brno
tel. +420 545 555 111, fax +420 545 222 728, www.cmi.cz

V 3112
Notified Body No. 1383

EC-TYPE EXAMINATION CERTIFICATE

Number: TCM 142/14 - 5216

Page 1 from 10 pages

In accordance: with Directive 2004/22/EC of the European Parliament and of the Council as amended implemented in Czech Republic by Government Order No. 464/2005 Coll. as amended that lays down technical requirements on measuring instruments.

Manufacturer: CompWell AB
Strandvägen 57C
SE-104 51 Stockholm
Sweden

For: ultrasonic water meter
type: CLM
Accuracy class: 2
Temperature class: T30 or T30/70

Valid until: 10 August 2024

Document No: 0511-CS-A054-14

Description: Essential characteristics, approved conditions and special conditions, if any, are described in this certificate.

Date of issue: 11 August 2014

Certificate approved by:

Český metrologický institut NOTIFIKOVANÁ OSOBA 1383 AO 250 1

RNDr. Pavel Klenovský

This certificate was issued according to module B - type examination according to annex B to Directive 2004/22/EC of the European Parliament and of the Council or point 3 of annex 2 to Government Order No. 464/2005 Coll., respectively.

5. Step 2. CLM non-invasively added to an existing piping system

The certified CLM mounted on commonly available pipe and equipped with the flow corrected passed all 5 required tests. The only difference between the CLM delivered for certification to the Test Institute and the CLM installed on a pipe previously installed in a building is the that first unit included the flow corrector and the second did not. That means the all the tests which were not involved in measuring the accuracy of the meter must apply to both meters.

a. Environment, Life Expectancy, EC/EMC, Software

(a) Environment - (the meter must pass temperature, humidity and vibration tests.

Electronic circuitry as well as sensor are manufactured by the same manufacturing process independently of where they will be installed, on pipe being sent for certification or a pipe installed in a apartment. The installation process (attaching to a pipe by glue) is exactly the same in both cases.

Statement: The CLM glued to a preinstalled pipe in a building meets the MID environmental requirements.

(b) Life Expectancy (the meter must pass the longevity test of min 6 years)

As in (a) above. Electronic circuitry, sensor and the installation process are identical in both cases and pass the required test exactly the same way.
A pilot series of 500 CLM meters have been installed since 2008 in apartments in Botkyrka and Lund in Sweden. Every 15 minutes the meters deliver the meter reading to a data collection system.
Statement: The CLM glued to a preinstalled pipe in a building meets and by far exceeds the MID life expectancy requirement.

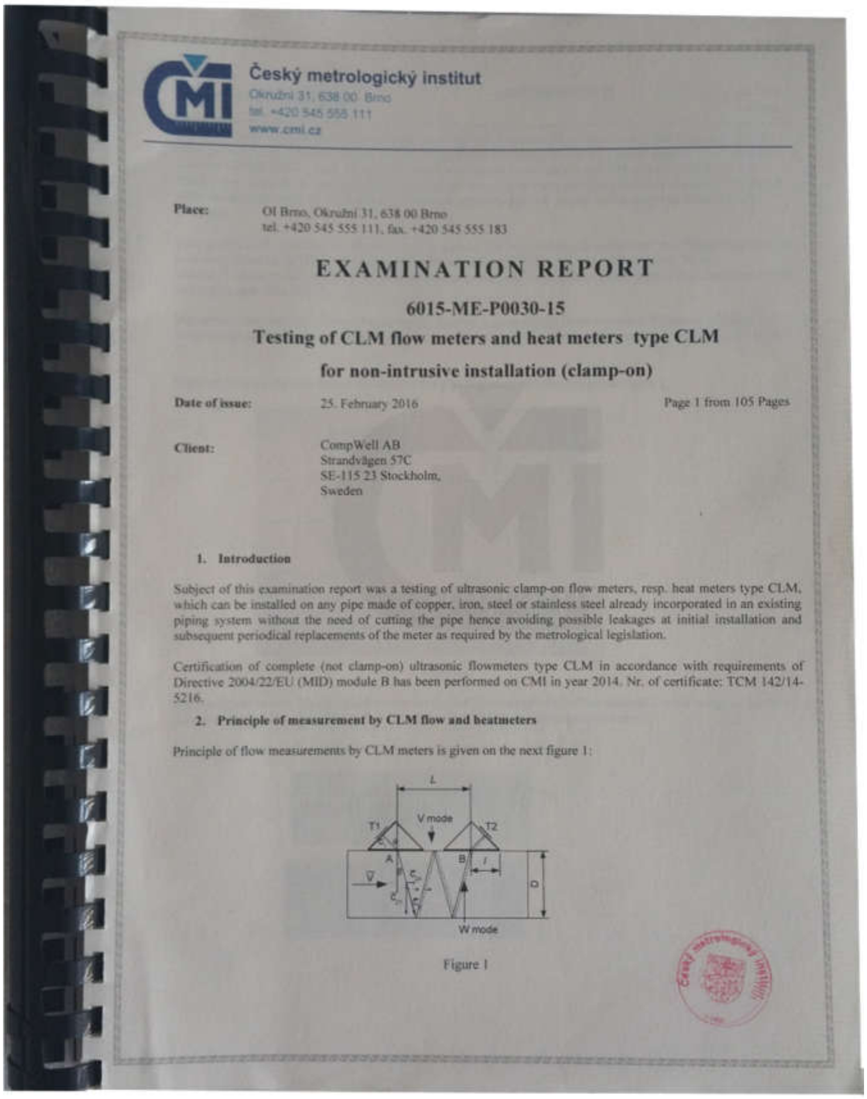
(c) EC and EMC (the meter must pass electrical safety and electromagnetic tests).
As in (a) above. Electronic circuitry, sensor and the installation process are identical in both cases and pass the required test exactly the same way.
Statement: CLM glued to a preinstalled pipe in a building meets EC and EMC requirements.

(d) Software (the software powering the meter must fulfill the WELMEC standard)
As in (a) above. Electronic circuitry, sensor and the software are identical in both cases and pass the required test exactly the same way.
Statement: CLM glued to a preinstalled pipe in a building meets Software requirements.

5.2 Accuracy

(a) Accuracy (the accuracy must be within the limits in the presence of disturbers as defined by the MID norm). Results of the accuracy tests for CLM installed with the flow corrector are not applicable to the CLM installed on an existing pipe. Se the following sections:

The methods used to prove that CLM installed on an existing pipe meets the MID accuracy requirement are described in the Examination Report 6015-ME-P0030-15 below



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tel. +420 545 555 111
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Place: OI Brno, Okružní 31, 638 00 Brno
tel. +420 545 555 111, fax. +420 545 555 183

EXAMINATION REPORT

6015-ME-P0030-15

Testing of CLM flow meters and heat meters type CLM

for non-intrusive installation (clamp-on)

Date of issue: 25. February 2016 — Page 1 from 105 Pages

Client: CompWell AB
Strandvägen 57C
SE-115 23 Stockholm,
Sweden

1. Introduction

Subject of this examination report was a testing of ultrasonic clamp-on flow meters, resp. heat meters type CLM, which can be installed on any pipe made of copper, iron, steel or stainless steel already incorporated in an existing piping system without the need of cutting the pipe hence avoiding possible leakages at initial installation and subsequent periodical replacements of the meter as required by the metrological legislation.

Certification of complete (not clamp-on) ultrasonic flowmeters type CLM in accordance with requirements of Directive 2004/22/EU (MID) module B has been performed on CMI in year 2014. Nr. of certificate: TCM 142/14-5216.

2. Principle of measurement by CLM flow and heatmeters

Principle of flow measurements by CLM meters is given on the next figure 1:

Figure 1

5.2.1. Factory calibration of CLM for a given geometry of the piping system.

Examination Report 605-ME-P0030-15 confirms that the CLM pre-calibrated for a given geometry passes MID defined accuracy tests.

Statement: If the geometry of the piping system is known the meter can be pre-calibrated to meet the required accuracy.

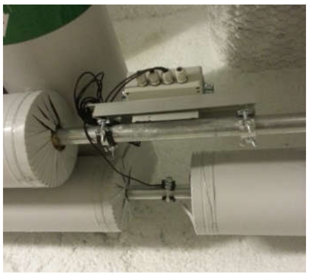
CLM-sensor attached to a 15 mm pipe

Applications: Factory built bathroom, water mixer with built in meters. .
Advantage: Size, no parts required

5.2.2. Factory calibration for mounting on pipes from various manufacturers.

Examination Report 605-ME-P0030-15 confirms that the CLM pre-calibrated for installation on pipes with the known parameters meets MID accuracy requirement when installed on pipes from different manufacturers.

Statement: If the diameter of the pipe is known the meter can be pre-calibrated to meet the required accuracy.



CLM-sensor attached to a 40 mm pipe

Application for pipe of up to 108 mm in diameter.
Closed piping system with known geometry (no disturbance on x cm) and known pipe dimensions
Advantage: Installation costs (flanges, valves, labor). No risk for leakage.

5.2.3. On-site calibration

Examination Report 605-ME-P0030-15 confirms that the CLM installed in the system of unknown geometry on a pipe with unknown dimensions will meet MID accuracy requirement after it has been calibrated on-site by Mobile Calibration Station MCS designed and manufactured by CompWell and certified by the Test Institute.

Statement: CLM installed in a system of unknown geometry on a pipe with unknown dimensions will meet MID accuracy requirement after it has been calibrated on-site by Mobile Calibration Station MCS.

Application: Open system with unknown geometry (metering in an apartment), leakage sensor
Advantage: Size, installation cost, no risk for leakage.

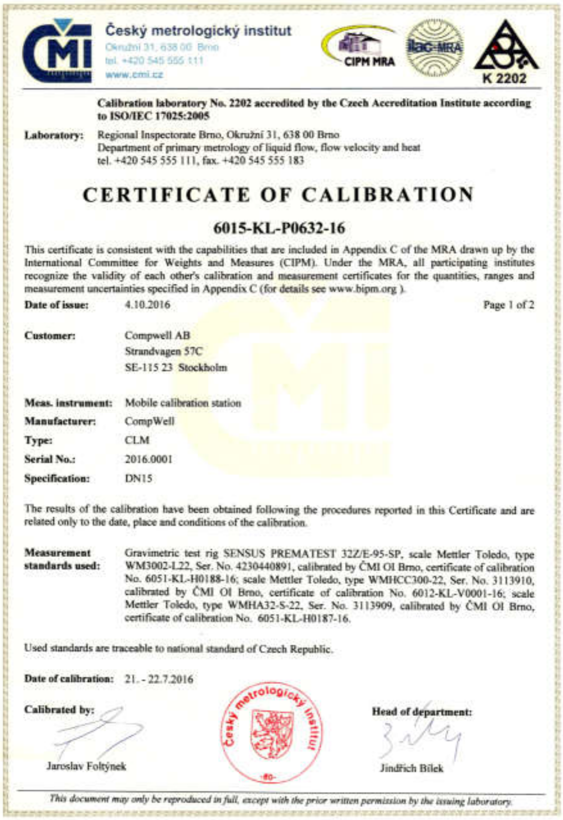
6. Steg 3. Mobile Calibration Station

CompWell developed and manufactures the Mobile Calibration Station, MCS.

MCS consists of a set of Reference Meters and an electronic module, The Calibrator. The Calibrator connects to the calibrated CLM (by wire or radio) and to a PC (Tablet) for storing the test results and generating test protocols.

Volume of the water flowing through the CLM under calibration and through the MCS is measured by both devices simultaneously. The flow values are set automatically by the Calibrator. The results are compared continuously. CLM corrects it’s parameters if required. To prove that CLM calibrated in a such a way measures with the same accuracy as the MCS the verification process can be performed.

MCS is a certified metering instrument with Certificate nr 6105-KL-P0632-16.



Český metrologický institut
Okružní 31, 638 00 Brno
tel. +420 545 555 111
www.cmi.cz

CIPM MRA

ilac-MRA

K 2202

Calibration laboratory No. 2202 accredited by the Czech Accreditation Institute according to ISO/IEC 17025:2005

Laboratory: Regional Inspectorate Brno, Okružní 31, 638 00 Brno
Department of primary metrology of liquid flow, flow velocity and heat
tel. +420 545 555 111, fax. +420 545 555 183

CERTIFICATE OF CALIBRATION

6015-KL-P0632-16

This certificate is consistent with the capabilities that are included in Appendix C of the MRA drawn up by the International Committee for Weights and Measures (CIPM). Under the MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see www.bipm.org).

Date of issue: 4.10.2016 Page 1 of 2

Customer: Compwell AB
Strandvagen 57C
SE-115 23 Stockholm

Meas. instrument: Mobile calibration station
Manufacturer: CompWell
Type: CLM
Serial No.: 2016.0001
Specification: DN15

The results of the calibration have been obtained following the procedures reported in this Certificate and are related only to the date, place and conditions of the calibration.

Measurement standards used: Gravimetric test rig SENSUS PREMATEST 32Z/E-95-SP, scale Mettler Toledo, type WM3002-L22, Ser. No. 4230440891, calibrated by ČMI OI Brno, certificate of calibration No. 6051-KL-H0188-16; scale Mettler Toledo, type WMHCC300-22, Ser. No. 3113910, calibrated by ČMI OI Brno, certificate of calibration No. 6012-KL-V0001-16; scale Mettler Toledo, type WMHA32-S-22, Ser. No. 3113909, calibrated by ČMI OI Brno, certificate of calibration No. 6051-KL-H0187-16.

Used standards are traceable to national standard of Czech Republic.

Date of calibration: 21. - 22.7.2016

Calibrated by: Jaroslav Foltýnek

Český metrologický institut -80-

Head of department: Jindřich Bílek

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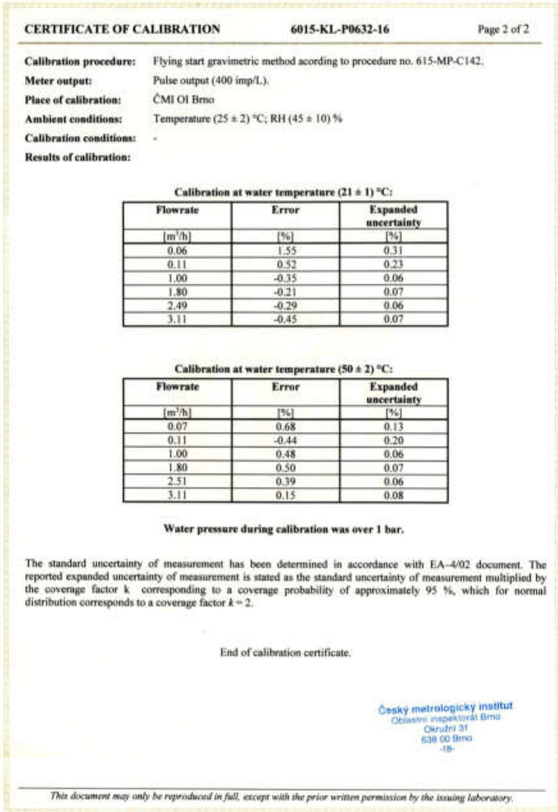

CERTIFICATE OF CALIBRATION **6015-KL-P0632-16** Page 2 of 2

Calibration procedure: Flying start gravimetric method acording to procedure no. 615-MP-C142.
Meter output: Pulse output (400 imp/L).
Place of calibration: ČMI OI Brno
Ambient conditions: Temperature (25 ± 2) °C; RH (45 ± 10) %
Calibration conditions: -
Results of calibration:

Calibration at water temperature (21 ± 1) °C:

Flowrate	Error	Expanded uncertainty
[m³/h]	[%]	[%]
0.06	1.55	0.31
0.11	0.52	0.23
1.00	-0.35	0.06
1.80	-0.21	0.07
2.49	-0.29	0.06
3.11	-0.45	0.07

Calibration at water temperature (50 ± 2) °C:

Flowrate	Error	Expanded uncertainty
[m³/h]	[%]	[%]
0.07	0.68	0.13
0.11	-0.44	0.20
1.00	0.48	0.06
1.80	0.50	0.07
2.51	0.39	0.06
3.11	0.15	0.08

Water pressure during calibration was over 1 bar.

The standard uncertainty of measurement has been determined in accordance with EA-4/02 document. The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k corresponding to a coverage probability of approximately 95 %, which for normal distribution corresponds to a coverage factor $k = 2$.

End of calibration certificate.

Český metrologický institut
Oblastní inspektorát Brno
Okružní 31
638 00 Brno
-18-

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7. Summary.

CLM mounted on a pipe which is part of an existing piping system meets all the MID requirements if installed as specified in section 5.