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Dutch Metrology Institute

CMC Certificate

Certificate number : 39332268
Project number : 13302583

Applicant

Cameron Measurement Systems
Caldon® Ultrasonics Technology Center
1000 McClaren Woods Drive
Coraopolis, PA 15108
United States of America

Submitted

A test installation for the calibration of liquid flow meters.

Installation name	: large liquid flow meter calibration loop
Test liquids	: Exxsol D80, Drakeol 5 and Drakeol 32
Flow-rate range	: 10 to 3900 m^3/h
Viscosity range	: 1.5 to 200 mm^2/s (at 20°C)
Temperature range	: 5 to 40°C
Pressure range	: 1 to 10 $Pa\times10^5$

The test installation is in use for the calibration of flow meters using a unidirectional pipe prover, a small volume prover, ultrasonic and turbine flow meters as a reference at controlled temperatures. To operate the test installation and to process the calibration data two computers with specially designed software and PLC's are is in use.

A full description of the test installation can be found in the addendum to this certificate, called "Calibration and Measurement Capability (CMC) of Cameron's large liquid flow meter calibration loop", version 4; 12 December 2014. This addendum was verified and hallmarked by VSL.

CMC Calculation

The CMC uncertainty calculation method is described on page 2 of this certificate.

Period of Investigation

January 14th through December 11th 2014.

Results

The results of the CMC uncertainty calculation are shown on page 2 of this certificate.

Dordrecht, December 12th 2014
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F.M. Smits
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CMC Calculations

The Calibration and Measurement Capabilities (CMC's) were determined in accordance with the JCGM 100:2008 Evaluation of measurement data - Guide to the expression of uncertainty in measurement. The method is reported in the addendum to this certificate, called "Calibration and Measurement Capability (CMC) of Cameron's large liquid flow meter calibration loop", version 4; 12 December 2014.

Results

The Calibration and Measurement Capability are:

Prover calibration method

Used reference	CMC
Small volume prover 0.12 m^3	0.03%
Unidirectional pipe prover 10 m^3 (between switches 1-4)	0.04%
Unidirectional pipe prover 3.3 m^3 (between switches 2-3 and 3-4)	0.07%

Master meter calibration method

Used reference	CMC
1 reference flow meter	0.04%*
1 Ultrasonic reference flow meter	0.09%**
2 Ultrasonic reference flow meters used in parallel configuration	0.08%**

* Traceable to the small volume prover
** Traceable to the Unidirectional pipe prover

The reported Calibration and Measurement Capabilities are based on the standard uncertainty of measurement multiplied by a coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with the JCGM 100:2008 Evaluation of measurement data - Guide to the expression of uncertainty in measurement.

Usages of CMC

The Calibration and Measurement Capability is only valid if the following criteria are fulfilled:

1. Using the small volume prover
- minimum flow rate 10 m^3/h and maximum flow rate 750 m^3/h,
- the minimum amount of generated pulses by the meter under test is 10000 or pulse interpolation is used if less pulse are generated.

2. Using the unidirectional pipe prover
- minimum flow rate 40 m^3/h and maximum flow rate 2000 m^3/h,
- the minimum amount of generated pulses by the meter under test is 10000.

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3. Using the reference flow meters traceable to the small volume prover
- minimum flow rate 10 m^3/h and maximum flow rate 750 m^3/h,
- the minimum amount of generated pulses by the reference meters is 10000,
- the minimum amount of generated pulses by the meter under test is 10000.

4. Using the ultrasonic reference flow meters traceable to the unidirectional pipe prover
- minimum flow rate 500 m^3/h and maximum flow rate 3900 m^3/h,
- the minimum amount of generated pulses by the reference meters is 10000,
- the minimum amount of generated pulses by the meter under test is 10000.

Traceability

All instrument used in the test installation were verified to be traceable to primary and/or (inter)nationally accepted measurement standards.

Remarks

- The Calibration and Measurement Capability for mass and density are defined according CIPM MRA-D-04 version 4 (October 2013) "Calibration and Measurement capabilities in the context of the CIPM MRA" and ILAC-P14:01/2013 "ILAC Policy for Uncertainty in Calibration" as "A CMC is a Calibration and Measurement Capability available to customers under normal conditions". To identify all the sources contributing to the CMC uncertainty the guideline "WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty" from the Working Group for Fluid Flow of BIPM CCM is used.
- Instruments may be replaced as long as the uncertainties as mentioned in the addendum are granted.

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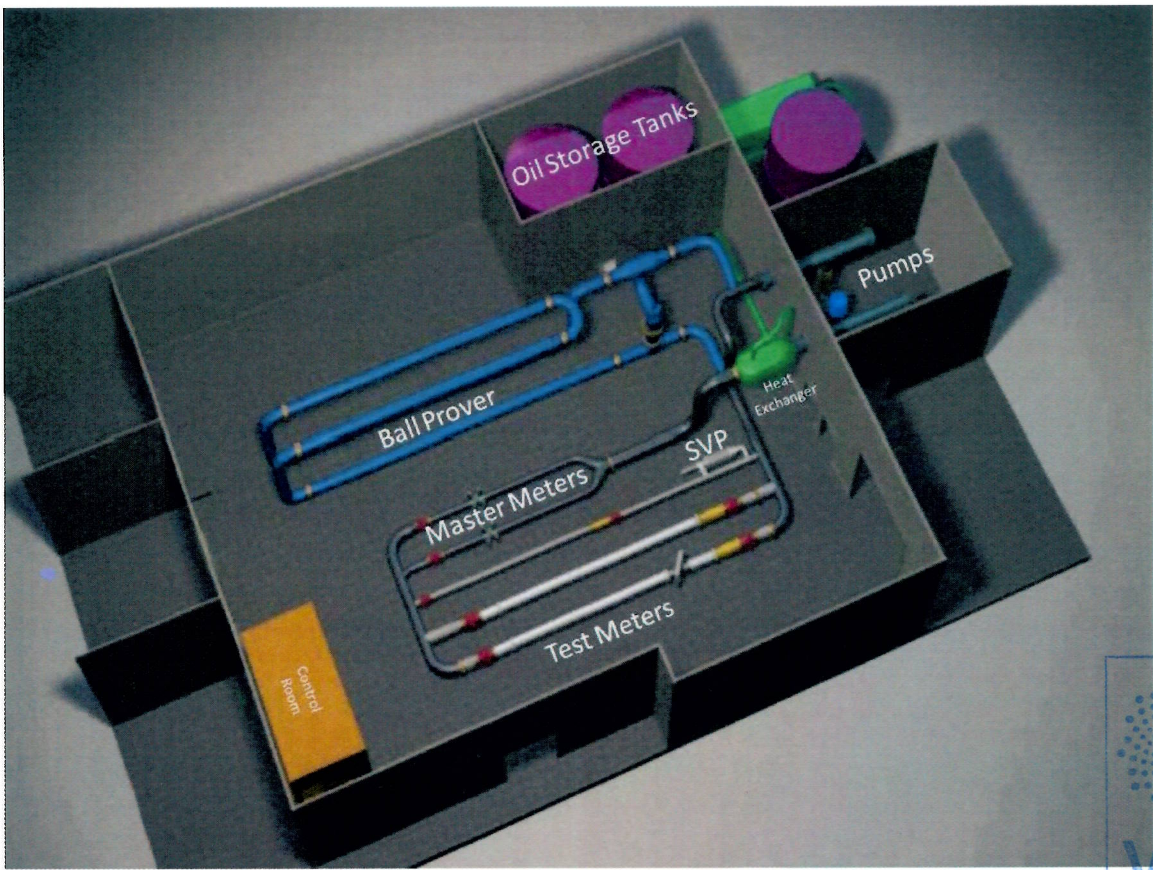
Calibration and Measurement Capability (CMC) of the liquid flow meter calibration loop of Cameron

Version 4: December 12th 2014



Lay-out of the liquid flow meter calibration loop

Owner

Cameron Measurement Systems
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Description of the liquid flow meter calibration loop

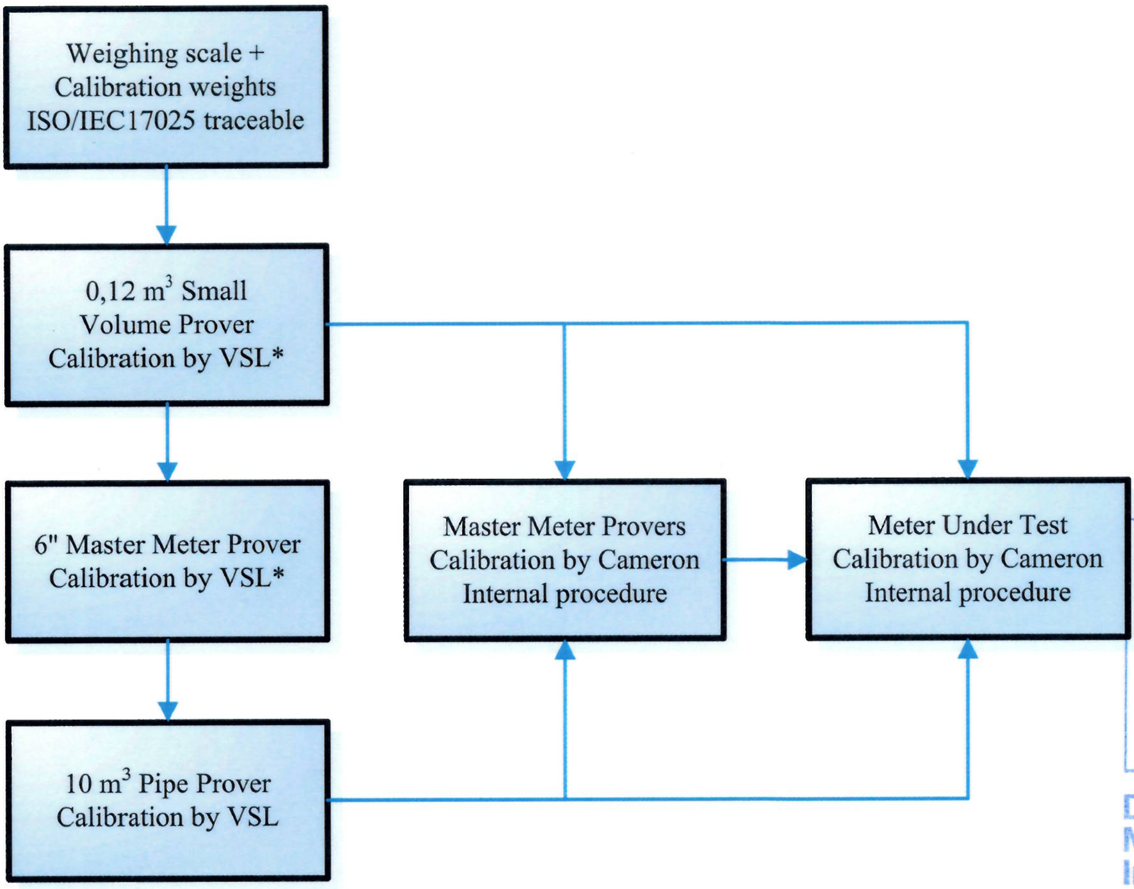
The main purpose of the liquid flow meter calibration loop is to calibrate liquid flow meters with internal diameters from 4 to 24 inch (100 to 600 mm). Two different calibration methods are in use, the pipe prover method and the master meter prover method. The liquid flow meter calibration loop can be filled with different type of liquids (oils) to change the viscosity. Changing the viscosity simulates field conditions for different types of liquid flow meters and Reynolds number calculations. In this document all the aspects necessary to perform the calculation of the CMC values for each of the methods are laid down.

The main components of the liquid flow meter calibration loop are:

- Three storage tanks for different liquids (oils) with different viscosities ranging from 1.5 to 200 mm^2/s (cSt),
- Two pumps 250HP generating a total maximum flow rate of 3900 m^3/h and a minimum flow rate of 10 m^3/h,
- A heat exchanger to keep the liquids at a constant temperature (to ensure stable viscosity and density during calibration),
- Two 10" (250 mm) 8 path ultrasonic master meters (make: Cameron Caldon Ultrasonics),
- A 6" and a 4" (150 and 100 mm) master meter,
- Three test sections for a meter under test nominal 8, 16 and 24 inch (200, 600 and 600 mm). All can be reduced down to smaller diameters (minimum 4 inch.),
- A unidirectional pipe prover with a nominal volume of 10 m^3, with three nominal 3.3 m^3 sections (make: F.H. Malony),
- A small volume prover with a nominal volume of 0.12 m^3 (make: Brooks Instruments),
- Temperature and pressure sensors to register fluid property variations,
- Computers and electronics to control the liquid flow meter calibration loop and to calculate results.

For a full description of the liquid flow meter calibration loop see Cameron quality manual document CLP 1 "Flow loop calibration and operation procedure", Revision 8.

Main traceability chain set up for the liquid flow meter calibration loop



* VSLis the National Metrology Institute [NMI] of the Netherlands

During all steps in the traceability chain temperature and pressures are measured. All instruments for measuring temperature and/or pressure are traceable to a National Metrology Institute or an ISO/IEC 17025 accredited company. For a full description of the traceability chain see Cameron quality manual document CLM 5.6 "Measurement Traceability", Revision 6 and document CLP 6 "Uncertainty and traceability - flow loop calibration", Revision 6 and CLP 6.1 "Uncertainty and traceability – small volume prover flow loop", Revision 4.

CMC using the Pipe Provers as a reference

For a full description of the CMC claims see Cameron quality manual document CLP 6 "Uncertainty and traceability - flow loop calibration", Revision 6 and CLP 6.1 "Uncertainty and traceability – small volume prover flow loop", Revision 4.

CMC using the Master Meter Provers as a reference

For a full description of the CMC claims see Cameron quality manual document CLP 6 "Uncertainty and traceability - flow loop calibration", Revision 6 and CLP 6.1 "Uncertainty and traceability – small volume prover flow loop", Revision 4.

Round Robin results

Round robin between Cameron and TUV NEL:

A comparison between the calibrations performed by the Cameron laboratory and by The National Engineering Laboratory, an ISO/IEC17025 accredited laboratory, using a specially designed calibration package showed: "It can be concluded from the results in Section 4 that the Cameron Measurement Systems oil flow calibration laboratory and the corresponding UK National standards operated by TUV NEL are equivalent in terms of their reference measurements of volume passed through the meter under test. This result validates the traceability of the Cameron laboratory and its associated statement of uncertainty. It is underpinned by the ISO/IEC17025 accreditation of the TUV NEL facility. This is reinforced by the position of TUV NEL as custodian of the UK National Standard for flow measurement and hence the inclusion of the facilities in regular internationally recognized intercomparison exercises."

The results are shown in document entitled "BI-LATERAL INTERCOMPARISON OF OIL FLOW FACILITIES BETWEEN TUV NEL AND CAMERON MEASUREMENT SYSTEMS" TUV NEL Report No. 2008/316.

Round robin between Cameron and Alden Research Laboratories:

A comparison between the calibrations performed by the Cameron laboratory and by Alden Research Laboratories, an ISO/IEC17025 accredited laboratory, using a 16 inch 280C—RN flow meter showed: "It can be concluded from the results in Section 4 that the Cameron Measurement Systems oil flow calibration laboratory and the corresponding test facility at Alden Research Laboratories are equivalent in terms of their reference measurements of volume passed through the meter under test. This result validates the traceability of the Cameron laboratory and its associated statement of uncertainty. It is underpinned by the ISO/IEC17025 accreditation of the Alden Research Laboratories facility.

The results are shown in document entitled "Inter-Comparison of Flow Facilities – Cameron Measurement Systems and Alden Research Laboratories" Cameron Engineering report: ER-920 Revision 1.

Repairs and replacement of instruments

The CMC values can be subjected to change when instruments are repaired or replaced. In Cameron quality manual document CLP 14 "Flow facility maintenance procedures", Revision 4 the conditions for the repair and replacement are described. To maintain the correct CMC values the new calibration uncertainty of an instrument that is repaired or replaced should be equal or lower than the evaluated uncertainty during the CMC calculation.

Revisions of quality manual documents

It is allowed to update the quality manual documents but a check must be made whether a new revision does not affect the outcome of the calculated CMC's. Therefore it is possible that newer revisions of quality manual documents replace the revisions mentioned in this document.

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