

Project Title

Pilot Study: Bilateral comparison for Volume inside a pipe prover - 120 and 60 L

Coordinator, Institute, Country

Erik Smits, VSL (Netherlands)

EURAMET Registration No.

1717

Subject Field

Flow

KCDB Identifier

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2025-11-12

Comparison report

Bilateral comparison for
Volume inside a pipe prover - 120 and 60 L

EURAMET project 1717 - Final report

Pilot: Erik Smits – VSL National Metrology Institute

VSL

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Revision history:

Draft A 06-11-2025	1) Report for participants VSL and Kalibra
Draft B 10-11-2025	1) Report for review by TC Flow (Subcommittee Volume)
Final 12-11-2025	1) For publication on EURAMET website page for project 1717
Final 19-11-2025	2) In the table in chapter 7 the volume for Kalibra was given in m ³ . Changed to L.

Note: Only main revision items listed

This comparison report was written based on the template for comparison reports by EURAMET TC-Flow subcommittee Volume (2025).

1 Introduction and objective

The CIPM Mutual Recognition Arrangement (CIPM MRA) provides the framework through which National Metrology Institutes (NMIs) and Designated Institutes (DIs) demonstrate the international equivalence of their measurement standards. As part of this arrangement, the BIPM publishes a list of Calibration and Measurement Capabilities (CMCs) on the KCDB website for all institutes that are signatories to the CIPM MRA.

Calibration services are only eligible for inclusion if the institute has implemented a quality management system in accordance with ISO/IEC 17025, the international standard for competent laboratories. In addition, quality assurance and confidence in a laboratory’s capabilities are strengthened through successful participation in international comparisons, which establish the degree of equivalence between the participating NMIs and/or DIs.

This comparison was performed to support the existing liquid volume CMC claims of VSL National Metrology institute (hereafter VSL) in the KCDB for pipe prover calibration with KCDB institute service code VSL/NE27. Next to the CMCs in the KCDB VSL has an accreditation according ISO/IEC 17025 (RvA K999) for these services. For years, VSL has sought to establish a comparison with another NMI or DI, but has been unsuccessful. Pipe provers are large instruments that cannot be transported between participants. Therefore, the pipe prover used for comparison must remain at a fixed location, requiring participants to travel to this site to perform measurements. Kalibra OGC Services (Pty) Ltd. (hereafter Kalibra), an ISO/IEC 17025 accredited company (SANAS CAL 161-14-00) can perform these calibrations globally. Kalibra faced the same challenge of finding a partner for comparison.

The comparison was piloted by Erik Smits, Chief Metrologist Flow from VSL. Warrick Riley, Technical Director is the contact person for Kalibra.

Both VSL and Kalibra have determine the volumes of the pipe prover located in the water flow facility of VSL in the European Center for Flow Measurement (ECFM) at a reference temperature of 20 °C and a reference pressure of 0 Pa(g) using their own calibration method to confirm the claimed CMCs from VSL and Kalibra. VSL was responsible for the evaluation of the comparison results.

2 Participants

NMI, DI or other	Country	Contact	Adres
VSL	The Netherlands	Erik Smits fsmits@vsl.nl	VSL ECFM (location of prover) Walrusweg 5 3199 ME Maasvlakte Rotterdam The Netherlands
Kalibra	South Africa	Warrick Riley warrick_riley@kalibraogcservices.com	Kalibra OGC Services (Pty) Ltd Acacia Business Park, Unit 34 Nguni Way, Waterfall, Hillcrest KwaZulu-Natal 3610 South-Africa

3 Transfer standard

The used standard is the pipe prover of the water flow calibration facilities that is part of the National Standards of the Netherlands located at the ECFM in Rotterdam the Netherlands. This is standard can't be transported and the measurements took place at this location.

Specification of the pipe prover:

Type pipe prover	: Small volume Prover (SVP) this type is also known as a Compat Prover
Manufacturer	: Daniel (Emerson Process Management)
Type / model	: P18ZB6AZA2F1HCK
Serial number	: 0409-159986-10-1
Year build	: 2004
Q_{max}	: 794 m ³ /h
Nominal volume	: 60 and 120 L
Reference temperature	: 20 °C
Reference pressure	: 0 Pa(g)
Steel pipe wall	: 17-4 PH Stainless
Steel detector rods	: Invar
Area expansion coefficient pipe	: 21.6 E ⁻⁶ °C ⁻¹ (U 5 %)
Linear expansion coefficient rods	: 1.44 E ⁻⁶ °C ⁻¹ (U 5 %)
Internal pipe diameter	: 0.4445 m (U 0.001 m)
Wall thickness pipe	: 0.03175 m (U 0.0005 m)
Modules of elasticity	: 19.65 E ⁻¹⁰ Pa (U 5 %)
Displacer type	: Piston with poppet valve
Detector	: Optical

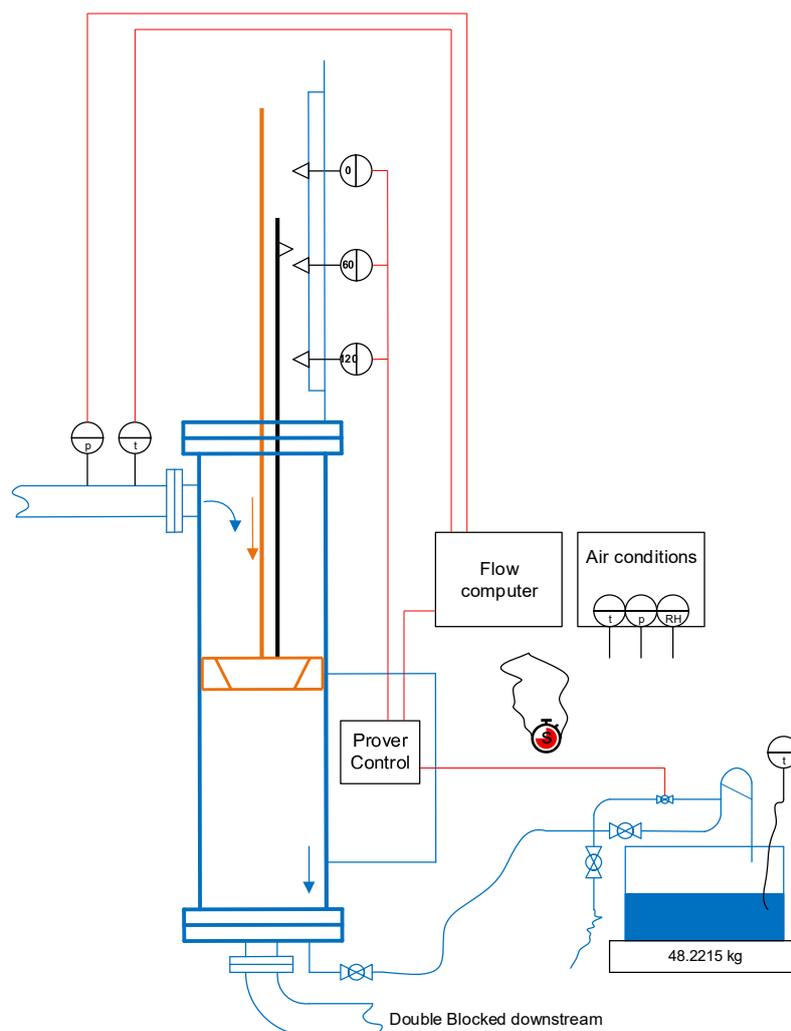
Picture of pipe prover:



4 Measurement procedure

Both VSL and Kalibra used their own calibration procedure for the calibration of the pipe prover. This includes the calculation of the reference volumes and the measurement uncertainties. The VSL laboratory has a climate control so the conditions during the measurement were very stable. The results are calculated at the reference temperature and pressure as stated in paragraph 3. The volumes calibrated are the so-called downstream volumes for detector pairs at 60 and 120 L. The 30 L volume was not calibrated.

VSL prepared the pipe prover to make sure it was free of air during the calibration and that the water temperature was stable during the measurement. The smallest pump of the water flow was used to generate the flow of water. Connection for the so-called water draw unit was made according to the drawing below. Launching and returning the piston to the start position was done with a switch on the electronics panel on the pipe prover. The pipe prover was set to measure 60 or 120 L depending on the measurement using a switch on the same panel. The pre-run volume is about 40 L before the start detector is activated. A standardised connector is on the pipe prover to connect the water draw unit using an almost inflexible hose at the used pressure (± 250 Kpa). The process water of VSL's water flow facility is used. A static leak check was performed before the measurements took place by VSL showing no leak. The method was based on the described method in the manual of the pipe prover [18]. A dynamic leak check was up to the participants procedure and was performed by both Kalibra and VSL and the results are very small and were added to the measurement uncertainty.



5 Short term-stability for the Pipe Prover

Measurements by both VSL and Kalibra were conducted on the same extended workday on 28 October 2025. This approach eliminated the need to assess the pipe prover’s stability, as no variation can be expected within this small timeframe.

6 Reporting the results and measurement uncertainty

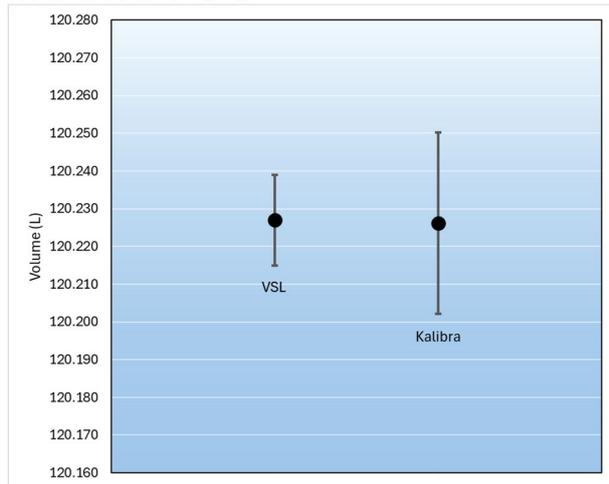
In the protocol, it was initially assumed that an MS Excel workbook would be provided for entering results, as is customary in other EURAMET volume comparisons. However, since this is a pilot study, both parties agreed during the project to report only two volumes 60 L and 120 L along with the associated CMCs or, if larger, the measurement uncertainties. Both VSL and Kalibra determined that their uncertainties remained within their respective CMCs, and these values are therefore reported. The results and associated uncertainties are documented in the official calibration certificates, which are included in Annex A and Annex B.

7 Measurement results

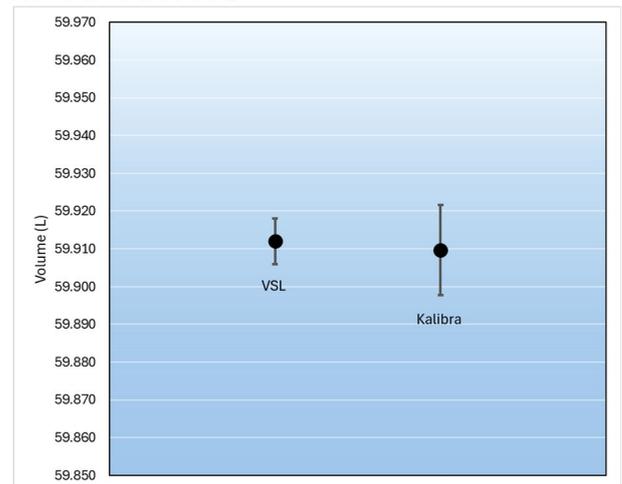
The measurement results are reported in the calibration certificates that can be found in Annex A and Annex B. Both are calculated to the reference conditions. Reference condition for temperature 20 °C and for pressure 0 Pa(g):

Nominal volume (L)	VSL			Kalibra		
	Volume (L)	CMC (%)	CMC (L)	Volume (L)	CMC (%)	CMC (L)
120	120.227	0.01	0.0120227	120.2261	0.02	0.024045
60	59.912	0.01	0.0059912	59.9097	0.02	0.011982

Nominal volume 120 L



Nominal volume 60 L



8 Result analysis

The results are considered equivalent if the so called E_n score is equal or less than 1.

The E_n value calculation is:

$$E_n = \frac{(V_{VSL} - V_{Kalibra})}{\sqrt{U_{VSL}^2 + U_{Kalibra}^2}}$$

Where:

E_n = E_n Score

V_{VSL} = Volume reported by VSL (L)

$V_{Kalibra}$ = Volume reported by Kalibra (L)

U_{VSL} = Expanded uncertainty of the reported volume by VSL (L)

$U_{Kalibra}$ = Expanded uncertainty of the reported volume by Kalibra (L)

A positive E_n suggest that VSL's results are higher than Kalibra's results and a negative E_n the opposite.

However, when assessing equivalence, the absolute value of the E_n score is used.

Interpretation:

$E_n \leq 1$: The results are considered equivalent within the stated uncertainties.

$E_n > 1$: The results are not equivalent, indicating a potential discrepancy in measurement or uncertainty estimation.

The E_n value is at a nominal volume of 120 L:

$$E_n = \frac{(120.227 - 120.2261)}{\sqrt{0.0120227^2 + 0.0240452^2}} = \mathbf{0.034}$$

The E_n value is at a nominal volume of 60 L:

$$E_n = \frac{(59.912 - 59.9097)}{\sqrt{0.0059912^2 + 0.0119819^2}} = \mathbf{0.172}$$

Both volumes show good consistency between VSL and Kalibra and passed the E_n evaluation.

9 Conclusion

In conclusion, the comparison demonstrates that all calculated E_n values based on the calibrated volumes and CMCs are well within the normalized threshold of 1, confirming strong agreement between the results of VSL and Kalibra. This outcome provides clear evidence that the measurement processes and uncertainty estimations of both organizations are robust and reliable. The results support the validity of the claimed Calibration and Measurement Capabilities (CMCs), reinforcing the credibility of both laboratories in their respective accreditation processes.

10 Reference documents

- [1] ISO/IEC17025 (2017): General requirements for the competence of testing and calibration laboratories
- [2] ISO7278-2 (2022): Petroleum measurement systems, Part 2: Pipe prover design, calibration and operation
- [3] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML and ILAC (2008): Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM), GUM 1995 with minor corrections, JCGM 100:2008
- [4] BIPM CCM-WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty, October 21, 2013
- [5] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML and ILAC (2012): International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM) 3rd edition, JCGM 200:2012
- [6] BIPM (2019, 9th edition): The International System of Units brochure
- [7] BIPM CIPM MRA-G-13 (November 2024, version 1.3): Calibration and Measurement Capabilities in the context of the CIPM MRA
- [8] BIPM CCM WGFF Guidelines for CMC Uncertainty and Calibration Report Uncertainty, 21 October 2013
- [9] BIPM Metrologia 39 (2002 page 589 to 595): M.G. Cox, The evaluation of key comparison data
- [10] BIPM Metrologia 38 (2001 page 301 to 309): Recommend table for the density of water between 0 °C and 40 °C based on recent experimental reports
- [11] OIML R111-1 (2004) Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3, OIML, Paris, 2004,
- [12] OIML D036 (2020) Pipe provers for verification and calibration of measuring systems for liquids, OIML, Paris, 2020
- [13] ILAC P10:07/2020 ILAC Policy on Metrological Traceability of Measurements Results
- [14] ILAC P14:09/2020 ILAC Policy for Uncertainty in Calibration
- [15] RvA T018-NL/UK Acceptabele herleidbaarheid / Acceptable traceability, Versie/Version 4.1, 17-02-2021
- [16] API Manual of Petroleum Measurement Standards all standards but specifically:
 - API MPMS 4.9.1 “Introduction to the Determination of the Volume of Displacement Tank Provers”, Second edition (April 2022)
 - API MPMS 4.9.2 “Determination of the volume of Displacement and Tank Provers by the Waterdraw Method of Calibration”, First edition (December 2005) and reaffirmed July 2015
 - API MPMS 4.9.4 “Determination of the volume of Displacement and Tank Provers by the Gravimetric Method of Calibration”, First edition (October 2010) and reaffirmed September 2021
 - API MPMS 11.4.1 “Density of Water and Water Volume Correction Factors for Calibration of Volumetric Provers” Second edition (July 2018) and reaffirmed August 2023
 - API MPMS 12.2.4 “Calculation of Base Prover Volumes by the Waterdraw Method” First edition (December 1997) and reaffirmed January 2022
- [17] EURAMET Calibration Guide No. 18, Version 4.0 (11/2015) – Guidelines on the Calibration of Non-Automatic Weighing Instruments
- [18] Daniel/Emerson Compact Prover Manual-rev.jan.2012 (3-9008-701 Revision F)

11 Abbreviations

API	American Petroleum Institute
BIPM	Bureau International des Poids et Mesures (The International Bureau of Weights and Measures)
CIPM	Comité International des Poids et Mesures (Committee International for Weights and Measures)
CIPM MRA	Mutual Recognition Arrangement
CMC	Calibration and Measurement Capabilities
DI	Designated Institute
GUM	Guide to the expression of Uncertainty in Measurement
ID	Internal Diameter
IEC	International Electrotechnical Commission
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
KCDB	Key Comparison Data Base (CIPM at BIPM)
NMI	National Metrology Institute
MPMS	Manual of Petroleum Measurement Standards
OIML	International Organization of Legal Metrology
PP	Pipe Prover
RvA	Raad voor Accreditatie (Council for Accreditation in the Netherlands)
SANAS	South African National Accreditation System (Council for Accreditation in South Africa)
SI	The International System of Units
SVP	Small Volume Prover
VIM	International Vocabulary of Metrology
VSL	Van Swinden Laboratory (National Metrology Institute of the Netherlands)
WGFF	Working Group for Fluid Flow of BIPM

Annex A: Calibration certificate VSL(no. 3930077)



CERTIFICATE OF CALIBRATION

3930077
Page 1 of 3

Applicant VSL B.V.
Walrusweg 5
3199 ME Maasvlakte Rotterdam
The Netherlands

Submitted A Pipe Prover

Manufacturer : Daniel (Emerson Process Management)
Serial number : 0409-159986-10-1
Nominal volumes : 0.120 m³, 0.060 m³ and 0.030 m³
Q_{max} : 794 m³/h
Q_{min} : 0.794 m³/h
Type pipe prover : Small Volume Prover (SVP)

Calibration method The prover volume between two detectors in the measurement section of the pipe prover at reference conditions for temperature and pressure has been determined by comparison with a weighing scale using the so called gravimetric water draw method. The test liquid during the calibration was water.

The measurements are performed at an ambient air temperature of (19.6 ± 0.3) °C, an air pressure of (1004 ± 5) hPa and a relative air humidity of (52 ± 5) %.

Date of calibration 28 October 2025

Calibration location VSL B.V.
Walrusweg 5
3199 ME Maasvlakte Rotterdam
The Netherlands

Result The results of the calibration are presented on page 2.
The reported uncertainty of measurement is based on the standard uncertainty multiplied by a coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approximately 95 %. The standard uncertainty has been determined in accordance with the GUM 'Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement'.

Traceability The results of the calibration services are traceable to primary and/or (inter)nationally accepted measurement standards.

Maasvlakte Rotterdam, 31 October 2025
On behalf of VSL,
The Certificate Committee



VSL B.V.
Thijssseweg 11, 2629 JA Delft (NL)
T +31 15 269 15 00
I www.vsl.nl

This certificate is electronically signed and sealed. This can be verified on www.vsl.nl/en/digital-certificates. This certificate is issued under the provision that no liability is accepted, and that the applicant gives warranty for each responsibility against third parties.

The measurement results presented in this certificate only relate to the standard(s) as described in this certificate.

This document may be freely distributed, but always in its entirety.



CERTIFICATE OF CALIBRATION

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Pipe prover data

Type pipe prover	: Small Volume Prover (Compact Prover)
Manufacturer	: Daniel (Emerson Process Management)
Type / model code	: P18ZB6AZA2F1HCK
Serial number	: 0409-159986-10-1
Year build	: 2004
Q _{max}	: 794 m ³ /h
Q _{min}	: 0.794 m ³ /h
Nominal volumes	: 0.120 m ³ , 0.060 m ³ and 0.030 m ³
Reference temperature	: 20 °C
Reference pressure	: 0 Pa(g)
Material of SVP wall	: Stainless Steel PH17-4
Internal pipe diameter	: 0.4445 m
Wall thickness	: 0.03175 m
Area thermal expansion coefficient	: 21.60 E-6 °C ⁻¹
Modules of elasticity	: 196,500,000 kPa
Material of rods between detectors	: Invar steel
Linear thermal expansion coefficient ^[1]	: 1.44 E-6 °C ⁻¹
Displacer type	: Piston with poppet valve

Results The reference volume at the reference conditions of 20 °C and 0 Pa(g) are:

Between detectors	V (m ³)	U (%)
0 and 0.120	0.120227	0.01
0 and 0.060	0.059912	0.01
0 and 0.030	-- ^[2]	--

Remarks ^[1] The linear thermal expansion coefficient for Invar steel is given in prover manual: "Daniel/Emerson Compact Prover Manual-rev.jan.2012 (3-9008-701 Revision F)";
^[2] The volume between detectors 0 and 0.030 was not calibrated.

Seals No seals are placed on the detectors or on any other location of the pipe prover.



CERTIFICATE OF CALIBRATION

3930077
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The reported results are consistent with the national designation of VSL, its international acceptance under the CIPM MRA and international accreditation (ILAC/RvA) as mentioned on this page. If identified, only the noted designation or accreditation is valid.

[1] The reported content in this certificate is traceable to the National (Primary) Standards of The Netherlands, which realize units of measurement according to the International System of Units (SI). Measurement traceability is realized according to ILAC policy on Metrological Traceability of Measurement results (ILAC-P10:07/2020) and Acceptable Traceability (RvA-T018-NL/UK, article 3.1).



Van Swinden Laboratorium (VSL) is designated by law as the National Metrology Institute (NMI) of the Netherlands. As such, it provides direct traceability of measurement results to internationally accepted measurement standards. VSL is a signatory member of the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM). The existence of mutual confidence in product specifications and product control is of fundamental importance in order to fulfill international, harmonized legislation on trade, quality, health, safety, and the environment. In this respect, standardized and equivalent measurement units and traceability to internationally accepted standards are essential. More information can be found at <https://www.vsl.nl/>.

[2] The reported content in this certificate is consistent with the Calibration and Measurement Capability represented in the Key Comparison Database (KCDB) as part of the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM).



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

[3] The reported content in this certificate is consistent with the RvA scope of accreditation of VSL with identification K999 for calibrations against the requirements as laid down in ISO/IEC 17025:2017.



The scope can be verified on <https://www.rva.nl/>. RvA is signatory of the EA MLA and ILAC MRA.

Annex B: Calibration certificate Kalibra(no. NLPJ25007-VSL/ILC)

		CALIBRATION CERTIFICATE FOR COMPACT PROVER	Doc No NLPJ25007-VSL/ILC
			Rev 0
			Date 28/10/2025

START OF CALIBRATION CERTIFICATE

Equipment Owner	VSL (Van Swinden Laboratories)	CALIBRATION DATE:	31/05/2024
Client /ILC Participant	Kalibra OGC Services (Pty) Ltd	Certificate No	NLPJ25007-VSL/ILC
Location	VSL B.V. Walrusweg 5 3199 ME Maasvlakte Rotterdam The Netherlands		

Compact Prover			
Manufacture	Daniel/SVP	Year re-furbish	2024
Serial Number	0409-159986-10-1	Max Flow rate	794 m3/h
Nominal volumes	0.120 m ³ , 0.060 m ³ and 0.030 m ³	Min Flow rate	0,795 m3/h
Material	Stainless Steel PH17-4	Area (Ga): SS 304	0,0000346
Internal Diameter	0,4445 m	Modulus (E) SS304	1931000
Pipe Thickness	0,03175 m	Detector (G) SS 304	0,00000173
Displacer Type	Piston/Poppet seal	Compressibility Water	0,0000464

Calibration Methodology

Calibration was performed using the gravimetric method, with volume derived from mass and corrected for density at measured temperature and pressure. All calculations and traceability conform to the following standards:

- API MPMS Chapter 4.9
- ISO 8316
- ISO 6578
- OIML D 36:2020
- ISO/IEC Guide 98-3 (GUM)

Reference Standards

The calibration and uncertainty evaluation conform to the following standards and guides:

- ISO/IEC 17025:2017 — Laboratory competence and traceability
- API MPMS Chapter 4.9 — Small Volume Prover methodology
- ISO 8316 — Gravimetric volume determination
- ISO 6578 — Density interpolation from temperature and pressure
- OIML D 36:2020 — Application of ISO/IEC 17025 to volume calibration
- ISO/IEC Guide 98-3 (GUM) — Uncertainty evaluation framework

Calculation Chain

- m* mass measured by calibrated balance (resolution: 0.001 g)
- ρ* density interpolated per ISO 6578
- Correction factors applied per API MPMS 4.9
- Thermal expansion correction per ISO 8316
- Uncertainty evaluated per GUM, traceable to national standards

Instrumentation Summary table

Measurement Type	Instrument Make	Probe / Model	Serial No.	Calibration Source	UOM
Temperature	Testo 925 Digital	K-Type	34880592	Labfix (NMISA traceable)	±0.2 °C
Pressure	SA Gauge Pressure	—	SG0112891	WIKA CPC6000	±0.02 bar
Mass	Sartorius Balance	10K62/1234	3233419	VSL-accredited lab	±0.0001 kg
Density Reference	ISO 6578 Interpolation	—	—	Temperature & pressure	—

Traceability & Suitability Declaration All equipment listed above has been calibrated by-accredited laboratories, with valid certificates traceable to national or international standards.

		CALIBRATION CERTIFICATE FOR COMPACT PROVER	Doc No NLPJ25007-VSL/ILC
			Rev 0
			Date 28/10/2025

Calibration Results Summary

Volumes were calculated by converting measured mass to volume using interpolated density per ISO 6578. All corrections and uncertainty contributions are embedded per ISO 8316 and API MPMS 4.9. Final volumes in table below are normalized to reference conditions of 20 °C and 0 Pa(g).

Between Detectors	Reference Volume (m³)	Expanded Uncertainty (±%)
0 & 0,120	0,1202261	0,02
0 & 0.060	0,0599097	0,02
0 & 0.030	[Not assessed]	

Metrologist Remarks

The small volume between detectors 0 and 0.030 m3 was not calibrated.
Note - detectors of SVP has not been sealed

Uncertainty of Measurement

The expanded uncertainty of measurement is ±0.01926 L, corresponding to a relative expanded uncertainty of ±0.02%, calculated per GUM, ISO/IEC 17025, API MPMS Chapter 4.9, and OIML D 36:2020. This differs from VSL's declared ±0.01% due to instrumentation resolution and environmental control. All results remain within acceptable interlaboratory tolerance and are traceable to national standards. This certificate is provided for interlaboratory review and confirmation.

Traceability

Calibration was performed by Kalibra OGC Services (Pty) Ltd as part of an interlaboratory comparison with VSL. All measurements are traceable to national and international standards via SANAS-accredited instrumentation and ILAC-recognized procedures. This certificate is valid only in its entirety and may be reproduced with written permission.

Summary and Compliance

Resolution Measurement system resolution was refined to 0.001 kg, forming the basis for the updated uncertainty evaluation. This resolution supports traceable, repeatable readings in accordance with ISO/IEC 17025 Clause 6.4.3 on equipment suitability and is embedded in the mass-to-volume conversion logic per ISO 8316.

Control

Senior Metrologist: Warrick Riley







Signed by: Warrick Hilton Riley
Signed at: 2025-11-07 14:27:09 +02:00
Reason: Witnessing Warrick Hilton Riley

Issue Date _____





Legal Disclaimer

This certificate is issued under the condition that Kalibra OGC Services (Pty) Ltd accepts no liability. The applicant indemnifies Kalibra OGC Services against any liability to third parties. If this certificate is not fully signed, including control authorization, it constitutes a draft version only. This calibration report is confidential and proprietary information of Kalibra OGC Services. Reproduction, distribution, or disclosure to third parties, in whole or in part, without prior written consent from Kalibra OGC Services is strictly prohibited.

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END OF CALIBRATION CERTIFICATE