SOP 19

Standard Operating Procedure for Calibration of Graduated Neck-Type Metal Provers (Volume Transfer Method)[1]

1 Introduction

1.1 Purpose of Test

This procedure is used to calibrate graduated neck type metal test measures and provers (20 L (5 gal) and larger) that are used in verification of petroleum, biodiesel, ethanol, milk, and/or water meters. The test measure or prover being calibrated should be evaluated for conformance to appropriate specifications and tolerances (using the checklist provided in NIST Handbook 105-3, Specifications and Tolerances for Graduated Neck Type Volumetric Field Standards, 2010) if being used for legal weights and measures applications. (Alternatively, if requested by the customer, evaluation against OIML R 120 (2010), Standard capacity measures for testing measuring systems for liquids other than water, may be referenced.)

1.2 Prerequisites

1.2.1 Verify that the unknown prover has been properly cleaned and vented, with all petroleum products removed prior to submission for calibration to ensure laboratory safety and compliance with environmental disposal requirements. The prover may be visually inspected to determine that residual liquid petroleum products are not present. Smell is not necessarily an adequate indicator of cleanliness.

NOTE: Many laboratories have a policy regarding cleanliness of submitted volumetric standards to minimize water contamination with flammable petroleum products.

1.2.2 Verify that valid current calibration certificates with measurement values and uncertainties are available for all of the standards used in the test. All calibration values must have demonstrated metrological traceability to the international system of units (SI). Metrological traceability may be to the SI through a National Metrology Institute such as NIST.

1.2.3 Verify that the standards to be used have sufficiently small standard uncertainties for the intended level of calibration.

[1] Non-SI units are predominately in common use in State legal metrology laboratories, and/or the petroleum industry for many volumetric measurements, therefore non-SI units have been used to reflect the practical needs of the laboratories performing these measurements as appropriate. .

1.2.4 Verify the availability of an adequate supply of clean, preferably soft water (filtered and thermally equilibrated as appropriate) water (GLP 10). Water does not need to be distilled or deionized for use in this procedure. The equations used in GLP 10 for the calculation of water density (air saturated) may be used without a significant impact on the measurement results.

1.2.5 Verify that the operator has had specific training and is proficient in SOP 17, SOP 19, SOP 20, GMP 3, and is familiar with the operating characteristics and conditioning of the standards used.

1.2.6 Verify that the laboratory facilities meet the following minimum conditions to make possible the expected uncertainty achievable with this procedure:

Table 1. Laboratory environmental conditions.

Procedure	Temperature	Relative Humidity
Volume Transfer	18 °C to 27 °C Stable to ± 2.0 °C / 1 h	35 % to 65 % Stable to ± 20 % / 4 h

1.3 Field tests

1.3.1 A “field” calibration is considered one in which a calibration is conducted in uncontrolled environments, such as out-of-doors. Calibrations conducted under field and laboratory conditions are *not* considered equivalent.

1.3.2 The care required for field calibrations includes proper safety, a clean and bubble-free water supply, measurement control programs, and a stable temperature environment shaded from direct sunshine to allow the prover, field standard, and clean test liquid (water) to reach an equilibrium temperature with minimal evaporation. Environmental conditions must be selected to be within stated laboratory conditions during the measurements. All data and appropriate environmental conditions must be documented regardless of test location.

1.3.3 An increased number of check standard verifications are required to ensure continued suitability of calibration values generated in field conditions as well as to verify the validity of any standards taken out of a secure laboratory environment once the standard(s) are returned to the laboratory.

2 Methodology

2.1 Scope, Precision, Accuracy

This procedure is applicable for the calibration of any size metal prover within the limitations of the standards available. The repeatability attainable depends on strict adherence to the procedure, the care in volumetric adjustments, and the number of transfers, in the case of multiple transfers. The accuracy depends on the standards used.

2.2 Summary

Water is delivered from calibrated volumetric standard(s) into the unknown test measure or prover being calibrated. Depending on the respective volumes, multiple transfers may be required. While these should be minimized, a maximum number of 15 transfers are permitted to ensure that final uncertainties and systematic errors are sufficiently small for the intended applications. The temperature of the calibration medium (water) cannot be considered to be constant during transfers; hence, the temperature of the water for each transfer must be measured. Because of the large volumes, the difference in thermal expansion of the respective vessels must be considered.

2.3 Standards and Equipment

2.3.1 Calibrated volumetric standards of suitable sizes.

2.3.2 Calibrated flask(s) of suitable sizes to calibrate neck of prover.

2.3.3 A funnel for transferring water from the flask into the prover or test measure.

2.3.4 Meniscus reading device (See GMP 3).

2.3.5 Calibrated thermometer, with resolution and uncertainty less than 0.1 °C.

2.3.6 Timing device (calibration is not required; uncertainty of the measurement only needs to be less than 5 s for a 30 s pour time.)

2.3.7 Sturdy platform, with appropriate safety conditions, with sufficient height to hold standard and to permit transfer of water from it to the prover by gravity flow.

2.3.8 Clean pipe or tubing (hoses) to facilitate transfer of water from the laboratory standard to prover. Pipe and hose lengths must be minimized to reduce water retention errors. Care must be taken during wet-downs and runs to ensure complete drainage and consistent retention in all hoses or pipes.

2.4 Procedure

2.4.1 Cleanliness verification

Fill and drain both the standard and unknown test measure or prover to be calibrated and check for visual evidence of soiling and of improper drainage. If necessary, clean with non-foaming detergent and water and rinse thoroughly (see GMP 6).

2.4.2 Neck scale plate verification. (This is generally only conducted for new or damaged measures or those that have not been calibrated by the laboratory in the past.)

2.4.2.1 Fill the unknown prover with water from the standard. Adjust and check the prover level by placing a precision spirit or electronic digital level vertically on the neck on at least two locations, 90 degrees apart around the circumference of the neck and adjust the orientation of the standard until the neck is as close to vertical (plumb or perpendicular to the horizontal plane) as possible. Verify and adjust any mounted levels that are on the prover to agree (when present and when possible). Check the prover system for leaks. This neck scale plate verification may be used as a wetted-down run.

2.4.2.2 Bleed the liquid level down to a graduation near the bottom of the upper neck. "rock" the prover to "bounce" the liquid level, momentarily, to ensure that it has reached an equilibrium level. Read and record this setting to be used as the initial scale reading sr_i for verification of the neck scale plate.

2.4.2.3 Recheck the scale reading, and then add water from calibrated standards equal to approximately $^1/_4$ or $^1/_5$ of the graduated neck volume and record the scale reading.

2.4.2.4 Repeat 2.4.2.3 by successive additions until water is near the top of the scale. Record scale readings after each addition. The last reading will be the final scale reading, sr_f. The closer the water is to the top of the neck, the harder it may be to "bounce" the liquid in the gauge.

2.4.2.5 A plot of scale readings with respect to the total volume of water that is added V_w should be linear and will be a gross check of the validity of this calibration.

2.4.2.6 Calculate and assess the accuracy of the neck scale for each interval. The error should be less than 0.5 % of the graduated neck

volume or $^1/_4$ of a graduation (whichever is smaller) per NIST Handbook 105-3. If the error is greater than this, the scale should be replaced. Uncertainties associated with the neck scale calibration are primarily related to the setting of the meniscus on the flask used (with each drop), the reading of the meniscus on the unknown prover (at each volume reading), and the calibration uncertainty of the flask. These uncertainties must be considered when evaluating the acceptability of the neck scale. Alternatively, a Neck Scale Correction Value (NSCV) may be issued with instructions to the user if it is anticipated that this correction value will be used.

2.4.2.7 Neck scale errors less than 0.5 % of the graduated neck volume should be included in the uncertainty estimate associated with the prover calibration.

2.4.2.8 The neck scale correction value is calculated as follows:

$$NSCV = \frac{V_w}{\left(sr_f - sr_i\right)} \qquad \text{Eqn. 1}$$

Table 2. Variables for neck scale correction value equation.

NSCV	Neck scale correction value
Vw	Total volume of water added to neck
sr_f	Scale reading, final
sr_i	Scale reading, initial

2.4.3 Body Calibration

2.4.3.1 Fill the standard with water and then transfer the water into the unknown prover establishing a wet down of the standard. Wait 30 s after the cessation of the main flow before closing the drain valve on the standard. Level the unknown prover, and drain the water, again waiting 30 s after cessation of the main flow, before closing the drain valve. This establishes a "wetted-down" condition for provers with no bottom zero. If the unknown test vessel is a 5 gal (20 L) hand-held test measure, fill the unknown vessel with water to its nominal mark and empty it using a 30 s (± 5 s) pour followed by a 10 s drain after cessation of the main flow to establish the wetted-down condition.

If a bottom zero is present, follow the guidance provided in SOP 21 for LPG provers as follows: When the liquid reaches the top of the lower gauge glass, close the valve and allow the water to drain

from the interior of the prover into the lower neck for 30 s. Then bleed slowly with the bleed valve (4) until the bottom of the liquid meniscus reaches the zero graduation. (This step should be started during the 30 s drain period but should not be completed before the end of the drain period.)

Alternatively, the prover may be completely drained with a 30 s drain time after the cessation of the main flow, and then refilled with a funnel and small volume of water to set the zero mark (which will add to the prover calibration uncertainty due to variable retention characteristics).

2.4.3.2 Run 1. Fill the standard and measure and record the temperature.

2.4.3.2.1 Measure and record the temperature of the water in the standard, t_1, then adjust the standard prover to its reference mark or record the neck reading, and then discharge into the unknown prover. Wait 30 s after cessation of the main flow to attain specified drainage, and then close the delivery valve. Remove any hoses or pipes to prevent additional water transfer.

2.4.3.2.2 Repeat step 2.4.3.2.1 as many times as necessary (note the 15-drop limit) to fill the unknown prover to its nominal volume. Verify the level condition and record the temperature of water in the standard for each drop, t_1 to t_N.

2.4.3.2.3 Level the filled unknown prover. Check the prover level by placing a precision spirit or electronic digital level vertically on the neck on at least two locations, 90 degrees apart around the circumference of the neck and adjust the orientation of the unknown measure until the neck is as close to vertical (plumb or perpendicular to the horizontal plane) as possible. Verify and adjust any mounted levels that are on the prover to agree (when present and when possible). Read and record the scale plate (gauge) reading.

2.4.3.2.4 Measure the temperature of the water in the unknown prover, t_x, and record. For test measures without thermometer wells, the temperature should be taken as close as possible to the center (vertically and horizontally) of the cylinder of the test measure main body (and not in the neck). For larger provers, and when thermometer wells are present, the average temperature, calculated from temperatures taken at

multiple locations from within the unknown prover should be used. (Alternatively, if a prover has mounted thermometers, the internal temperature from multiple locations within the prover may be used).

2.4.3.2.5 Perform the calculations described in section 3 to determine the prover volume at the appropriate reference temperature.

2.4.3.4 Adjust the scale as needed. If adjusted, record the adjusted prover gauge reading for determining the "as left" value for Run 1. Run 2 will validate the setting. Alternatively, the average of Run 1 and Run 2 may be used with the adjustment made after Run 2. In that case, a validation run is required to ensure correct setting of the scale plate.

2.4.3.5 Run 2 - Repeat the process described in 2.4.3.2. Replicate runs of the test measure or prover must agree within ± 0.02 % of the test volume during calibration. (Agreement value is calculated as the difference between Run 1 and Run 2, divided by the nominal volume, and then multiplied by 100.)

NOTE: If excess disagreement between replicated measurements is observed, check all vessels for cleanliness, leaks, drain lines, additional valve, or damage, identifying and correcting any problems. Lack of measurement agreement may be due to contamination, lack of cleanliness, excessive temperature changes, poor laboratory conditions, or poor field conditions, such as when calibration is conducted in an unstable environment. Repeatability problems must be corrected before calibration can be completed.

2.4.3.7 Seal the equipment as specified in the laboratory policy.

3 Calculations

The following calculations assume that the standard was calibrated using a reference temperature of 60 °F *(15.56* °C*) and that you are calibrating a field standard to a reference temperature of 60* °F *(15.56* °C*). Equations for situations where different reference temperatures are involved follows in Sections 3.4 to 3.6.*

3.1 Single Delivery

3.1.1 Calculate V_{X60}, the volume of the unknown prover at 60 °F, using the following equation:

$$V_{X60} = \frac{\rho_1 \left\{ \left(V_{S60} + \Delta_1 \right) \left[1 + \alpha \left(t_1 - 60\ ^\circ\mathrm{F} \right) \right] \right\}}{\rho_x \left[1 + \beta \left(t_x - 60\ ^\circ\mathrm{F} \right) \right]} \qquad \text{Eqn. 2}$$

3.2 Multiple Deliveries

3.2.1 Calculate V_{X60}, the volume of the unknown prover at 60 °F, using the following equation:

$$V_{X60} = \frac{\rho_1 \left\{ \left(V_{S60} + \Delta_1 \right) \left[1 + \alpha \left(t_1 - 60^\circ\mathrm{F} \right) \right] \right\} + \rho_2 \left\{ \left(V_{S60} + \Delta_2 \right) \left[1 + \alpha \left(t_2 - 60^\circ\mathrm{F} \right) \right] \right\} + \ldots + \rho_N \left\{ \left(V_{S60} + \Delta_N \right) \left[1 + \alpha \left(t_N - 60^\circ\mathrm{F} \right) \right] \right\}}{\rho_x \left[1 + \beta \left(t_x - 60^\circ\mathrm{F} \right) \right]} \qquad \text{Eqn. 3}$$

Table 3. Variables for V_{X60} equations.

Symbols Used in Equations	
V_{X60}	volume of the unknown vessel at 60 °F
V_{S60}	volume of the standard vessel at 60 °F
$\rho_1, \rho_2, \ldots, \rho_N$	density of the water in the standard prover where ρ_1 is the density of the water for the first delivery, ρ_2 is the density of the water for the second delivery, and so on until all N deliveries are completed
$\Delta_1, \Delta_2, \ldots, \Delta_N$	volume difference between water level and the reference mark on the standard where the subscripts *1, 2,..., N,* represent each delivery as above. If the water level is below the reference line, Δ is negative. If the water level is above the reference line, Δ is positive. If the water level is at the reference line, Δ is zero NOTE: units must match volume units for the standard. The Δ is zero for slicker-plate type standards.
$t_1, t_2, \ldots, t_N$	temperature of water for each delivery with the subscripts as above
α	coefficient of cubical expansion for the standard in units / ºF
ß	coefficient of cubical expansion for the prover in units / ºF
t_x	temperature of the water in the filled unknown vessel in units ºF
ρ_x	density of the water in the unknown vessel in g/cm^3
Note: Values for the density of water may be calculated from the equations given in GLP 10.	

3.3 Prover Error/Correction or Deviation From Nominal

The total calculated volume of the prover at its reference temperature should be reported on the calibration report. The SI unit of volume is m^3, so a conversion factor is to be included on the report in the notes section when other volume units are used.

The prover volume for an open neck prover equals the V_{x60} value minus the gauge reading that is the difference from the nominal volume (with matched units).

$$Prover\ volume = V_{X\,60} - gauge\ reading \qquad \text{Eqn. 4}$$

$$Prover\ error = Prover\ volume - V_{Nom} \qquad \text{Eqn. 5}$$

$$Prover\ error = V_{X\,60} - gauge\ reading - V_{Nom} \qquad \text{Eqn. 6}$$

where:

V_{Nom} = Nominal Volume (taking care to match units)

V_{X60} is the calculated volume of water that should be observed in the prover. A positive prover error means that the prover is larger than nominal. A negative prover error means that the prover is smaller than nominal.

Example 1: If V_{X60} is 100.02 gal and gauge reading is 0.02 gal (above nominal);
then the prover volume at nominal is 100.00 gal;
and the prover error and correction are 0; and
no adjustment is needed.

Example 2: If V_{X60} is 100.02 gal and gauge reading is -0.02 gal (below nominal);
then the prover volume at nominal is 100.04 gal;
the prover error is + 0.04 gal; and
to adjust the prover, set the gauge to read 0.02 gal (the volume level will show a gauge reading of 0.02 gal, which is 4.62 in^3 or about 5 in^3, above nominal.)

3.4 Alternative Reference Temperatures

3.4.1 Reference temperatures other than 60 ºF (15.56 ºC) may occasionally be used. Common reference temperatures for other liquids follow, however not all of them may be suitable for use with standards calibrated using this procedure:

Commodity	Reference Temperature
Frozen food labeled by volume (e.g., fruit juice)	-18 ºC (0 ºF)
Beer	3.9 ºC (39.1 ºF)
Food that must be kept refrigerated (e.g., milk)	4.4 ºC (40 ºF)
Distilled spirits or petroleum	15.56 ºC (60 ºF)
Petroleum (International Reference)	15 ºC (59 ºF)
Compressed Natural Gas (CNG)	15 ºC (60 ºF)
Wine	20 ºC (68 ºF)
Unrefrigerated liquids (e.g., sold unchilled, like soft drinks)	20 ºC (68 ºF)
Hydrogen (H_2)	21 ºC (70 ºF)
Petroleum (Hawaii)	26.67 ºC (80 ºF)

Equations for calculations when using alternative reference temperatures follow:

3.5 Single Delivery

3.5.1 Calculate V_{Xtref}, the volume of the unknown prover at its designated reference temperature (°F), using the following equation:

$$V_{Xtref} = \frac{\rho_1 \left\{ \left(V_{S\,tref} + \Delta_1 \right) \left[1 + \alpha \left(t_1 - \mathrm{t}_{\mathrm{ref\ S}} \right) \right] \right\}}{\rho_x \left[1 + \beta \left(t_x - \mathrm{t}_{\mathrm{ref\ X}} \right) \right]} \qquad \text{Eqn. 6}$$

3.6 Multiple Deliveries

3.5.1 Calculate V_{Xtref}, the volume of the unknown prover at its designated reference temperature, using the following equation:

$$V_{X\mathrm{tref_X}} = \frac{\rho_1 \left\{ \left(V_{S\mathrm{tref_S}} + \Delta_1 \right) \left[1 + \alpha_1 \left(t_1 - t_{\mathrm{refS}} \right) \right] \right\} + \rho_2 \left\{ \left(V_{S\mathrm{tref_S}} + \Delta_2 \right) \left[1 + \alpha_2 \left(t_2 - t_{ref\,S} \right) \right] \right\} + \ldots + \rho_N \left\{ \left(V_{S\mathrm{tref_S}} + \Delta_N \right) \left[1 + \alpha_N \left(t_N - t_{ref\,S} \right) \right] \right\}}{\rho_x \left[1 + \beta \left(t_x - t_{\mathrm{ref\,X}} \right) \right]}$$

Eqn. 7

Table 3A. Variables for V_{XtrefX} equations.

Symbols Used in Equations	
V_{XtrefX}	volume of the unknown vessel, V_X at its designated reference temperature, $t_{ref\ X}$
V_{StrefS}	volume of the standard vessel, V_S at its designated reference temperature, $t_{ref\,S}$
$\rho_1, \rho_2, \ldots, \rho_N$	density of the water in the standard where ρ_1 is the density of the water for the first delivery, ρ_2 is the density of the water for the second delivery, and so on until all N deliveries are completed
$\Delta_1, \Delta_2, \ldots, \Delta_N$	volume difference between water level and the reference mark on the standard where the subscripts *1, 2,..., N*, represent each delivery as above. If the water level is below the reference line, Δ is negative. If the water level is above the reference line, Δ is positive. If the water level is at the reference line, Δ is zero. NOTE: units must match volume units for the standard. The Δ is zero for slicker-plate type standards.
$t_1, t_2, \ldots, t_N$	temperature of water for each delivery with the subscripts as above
α	coefficient of cubical expansion for the standard in its designated units
ß	coefficient of cubical expansion for the prover in its designated units
t_x	temperature of the water in the filled unknown vessel in designated units
ρ_x	density of the water in the prover in g/cm^3
Notes: Values for the density of water may be calculated from the equations given in GLP 10. The cubical coefficient of the materials must match the unit assigned to the temperature measurement.	

4 Measurement Assurance

4.1. Duplicate the process with a suitable check standard or have a suitable range of check standards for the laboratory. See SOP 17, SOP 20 and SOP 30. Plot the check standard volume and verify it is within established limits OR a *t*-test may be incorporated to check the observed value against an accepted value. The mean of the check standard observations is used to evaluate bias and drift over time. Check standard observations can be used to calculate the standard deviation of the measurement process which contributes to the Type A uncertainty components.

4.2. If a standard deviation chart is used for measurement assurance, the standard deviation of each combination of Run 1 and Run 2 is calculated and the pooled (or average) standard deviation is used as the estimate of variability in the measurement process. Note: the pooled or average standard deviation over time reflects varying conditions of test items that are submitted to the laboratory, but may not reflect potential meniscus reading errors (See GMP 3.)

5 Assignment of Uncertainties

5.1 The limits of expanded uncertainty, U, include estimates of the standard uncertainty of the laboratory volumetric standards used, u_s, plus the standard deviation of the process, s_p, at the 95 % level of confidence. See SOP 29 for the complete standard operating procedure for calculating the uncertainty.

5.1.1 The standard uncertainty for the standard, u_s, is obtained from the calibration report. The combined standard uncertainty, u_c, is used and not the expanded uncertainty, U, therefore the reported uncertainty for the standard will usually need to be divided by the coverage factor k. See SOP 29 for the complete standard operating procedure for calculating the uncertainty when multiple deliveries or multiple standards are used to ensure correct handling of correlated uncertainties. Fifteen is the maximum recommended number of deliveries from a laboratory standard to a prover under test to minimize calibration uncertainties to the levels identified previously.

5.2 The standard deviation of the measurement process, s_p, is taken from a control chart for a check standard or from standard deviation charts from provers of similar size (See SOP 17, SOP 20 and SOP 30). The larger of the value from the standard deviation over time for a check standard or from the standard deviation chart should be used in the uncertainty calculations. If a check standard is available, it is possible to evaluate the presence of bias in the measurement process.

5.3 Neck calibration uncertainty should be estimated based on the uncertainty of standards used, errors observed during calibration, ability to read the meniscus of all standards involved (see GMP 3) and the repeatability of the neck calibration.

5.4 Other standard uncertainties usually included at this calibration level primarily include 1) uncertainties associated with the ability to read the meniscus, only part of which is included in the process variability due to parallax and visual capabilities, and 2) uncertainties associated with temperature corrections that include values for the cubical coefficient of expansion for the prover under test, the accuracy and gradients associated with temperature measurements in test measures or provers. Additional factors that might be included are: round robin data showing reproducibility, environmental variations over time, and bias or drift of the standard as noted in control charts.

5.5 To properly evaluate uncertainties and user requirements (tolerances), assessment of additional user uncertainties may be required by laboratory staff. Through proper use of documented laboratory and field procedures, additional uncertainty factors may be minimized to a level that does not contribute significantly to the previously described factors. Additional standard uncertainties in the calibration of field standards and their use in meter verification may include: how the prover level is established, how delivery and drain times are determined, the use of a proper "wetted-down" prior to calibration or use, whether gravity drain is used during calibration or whether the volume of water is eliminated by pumping, the cleanliness of the prover and calibration medium, prover retention characteristics related to inside surface, contamination or corrosion, and total drain times, and possible air entrapment in the water, and connecting pipes. Systematic errors may be observed between laboratory calibration practices where a gravity drain is used and field use where the pumping system is used.

5.6 Example components to be considered for an uncertainty budget table are shown in Table 4. Multiple values of some items may need to be considered (e.g., multiple drops from the standard, multiple meniscus readings, and multiple temperature readings.)

Table 4. Example Uncertainty Budget Table.

Uncertainty Component Description	Symbol	Source	Typical Distribution
Uncertainty of the standard (5.1)	u_s	Calibration report; may be multiplied or added based on dependencies	Rectangular or Normal divided by coverage factor
Accepted standard deviation of the process (5.2)	s_p	Control chart, standard deviation chart	Normal
Uncertainty or uncorrected error associated with a neck calibration (5.3)	u_n	From experimental data	Rectangular
Ability to read the Meniscus in S (5.4)	u_m	None if using a slicker-plate type standard; GMP 3	Triangular
Ability to read the Meniscus in X (5.4)	u_m	GMP 3	Triangular

Water temperature (S) (5.4)	u_{ts}	Consider accuracy, resolution, and gradients	Rectangular
Water temperature (X) (5.4)	u_{tx}	Consider accuracy, resolution, and gradients	Rectangular
Cubical Coefficient of Expansion on S (5.4)	u_{CCE}	5 % to 10 % (EURAMET CG-21)	Rectangular
Cubical Coefficient of Expansion on X (5.4)	u_{CCE}	5 % to 10 % (EURAMET CG-21)	Rectangular
Uncertainty of bias or drift of standards (5.2)	u_b	From control chart	Rectangular
Uncertainty of drain time	u_d	From experimental data	Normal

6 Report

6.1 Report results as described in SOP 1, Preparation of Calibration/Test Results, with the addition of the following:

"To Contain" or "To Deliver" prover volume, reference temperature, uncertainty, material, thermal coefficient of expansion (assumed or measured), construction, any identifying markings, tolerances (if appropriate), laboratory temperature, water temperature(s) at time of test, barometric pressure, relative humidity, and any out–of-tolerance conditions. Appendix B, Example Temperature Correction Chart may be provided as a supplement to the calibration report to encourage appropriate volumetric corrections of the provers during routine use.

Additional References:

Bean, V. E., Espina, P. I., Wright, J. D., Houser, J. F., Sheckels, S. D., and Johnson, A. N., NIST Calibration Services for Liquid Volume, NIST Special Publication 250-72, National Institute of Standards and Technology, Gaithersburg, MD, (2009).

EURAMET Calibration Guide 21, Guidelines on the Calibration of Standard Capacity Measures Using the Volumetric Method (Version 1.0, 04/2013).

Appendix A
Volume Transfer Data Sheet

Laboratory data and conditions:

Vessel Owner		Operator	
Vessel ID		Date	
Nominal Volume		Air Temperature	
Material		Relative Humidity	
Cubical Coefficient of Expansion		Standard deviation of the process, s_p from Control Chart	
Reference temperature of unknown prover		Standard deviation of the process, s_p from the Standard Deviation Chart	
Unknown prover graduations		Degrees of Freedom	
Applicable specifications and tolerances			

Volume standard(s) data:

ID (Note ID of Standards)	Nominal Volume	Volume/Correction	Expanded Unc: From cal. report	Unc: *k* factor	Cubical Coefficient of Expansion
S					
S					
S					
S					

Run 1: Data for volumes delivered from the standards:

DROP #	Reported Volume (gal)	Material (MS/SS/BS/SL)	Water Temp (°C) (Must be ≥ 0.5 °C and < 40 °C)	Gauge Delta (in^3)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Run 1: Data from the filled unknown field standard:

Material for the Unknown:		MS, SS, TP, AL, PVLC
Final Gauge Reading:		in^3
Final Water Temperature:		°C

Run 2: Data for volumes delivered from the standards:

DROP #	Reported Volume (gal)	Material (MS/SS/BS/SL)	Water Temp (°C) (Must be ≥ 0.5 °C and < 40 °C)	Gauge Delta (in^3)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Run 2: Data from the filled unknown field standard:

Material for the Unknown:		MS, SS, TP, AL, PVLC
Final Gauge Reading:		in^3
Final Water Temperature:		°C

Appendix B
Example Temperature Correction Table*

Example for a **100** gallon prover and 60 °F reference temperature.				
CCE	Mild Steel 1.86 x 10-5/°F		Stainless Steel 2.65 x 10-5/°F	
Temperature °F	in^3	gal	in^3	gal
-20	-34	-0.149	-49	-0.212
-15	-32	-0.139	-46	-0.199
-10	-30	-0.130	-43	-0.186
-5	-28	-0.121	-40	-0.172
0	-26	-0.112	-37	-0.159
5	-24	-0.102	-34	-0.146
10	-21	-0.093	-31	-0.133
15	-19	-0.084	-28	-0.119
20	-17	-0.074	-24	-0.106
25	-15	-0.065	-21	-0.093
30	-13	-0.056	-18	-0.079
35	-11	-0.047	-15	-0.066
40	-9	-0.037	-12	-0.053
45	-6	-0.028	-9	-0.040
50	-4	-0.019	-6	-0.026
55	-2	-0.009	-3	-0.013
60	0	0.000	0	0.000
65	2	0.009	3	0.013
70	4	0.019	6	0.026
75	6	0.028	9	0.040
80	9	0.037	12	0.053
85	11	0.046	15	0.066
90	13	0.056	18	0.080
95	15	0.065	21	0.093
100	17	0.074	24	0.106
105	19	0.084	28	0.119
110	21	0.093	31	0.133
115	24	0.102	34	0.146
120	26	0.112	37	0.159
CCE = coefficient of cubical expansion				

*Provide only the applicable coefficient of cubical expansion for the prover under test.