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National Measurement Institute

NITP 10.2
National Instrument Test Procedures for Bulk LPG Flowmetering Systems

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PREFACE

On 30 June 2010 the uniform test procedures (i.e. relevant NMI V documents) were deemed to be national instrument test procedures (NITPs) for the purposes of section 18GG of the *National Measurement Act 1960* (Cth).

In 2011 the NITPs were renumbered to better align the numbers with the classes of pattern approval and servicing licensee. As a result this document (NMI V 9-2) became NITP 10.2.

The only changes that have been made to the latest edition of this document are it has been rebranded, renumbered, renamed and its cross-references have been updated. In all other respects it is identical with NMI V 9.2.

NMI's Chief Metrologist has determined that NITP 10.2 contains the test procedures for the verification of bulk LPG flowmetering systems.

ABBREVIATIONS

C_{pl}	pressure conversion factor
C_{plMM}	pressure conversion factor for the master meter
C_{tl}	temperature conversion factor
C_{tlFS}	temperature conversion factor for the flowmetering system
C_{tlMM}	temperature conversion factor for the master meter
D_{15}	density at 15°C
D_p	pressure difference
E_{AV}	average error
$E_{AV,C}$	average relative error for 3 compensated deliveries
E_C	conversion device error
E_{FS}	relative error
E_{FS15}	relative error in temperature **compensated** delivery
E_{rep}	repeatability error
F_{MM}	the flow rate indicated by the master meter
F_p	compressibility factor
MF_{MM}	master meter correction factor
MPD	maximum permissible difference
MPE	maximum permissible error
P_e	equilibrium vapour pressure
P_{MM}	pressure of the product passing through the master meter
Q_{max}	maximum flow rate
Q_{min}	minimum flow rate
T_{FS}	temperature of the product passing through the flowmetering system
T_{MM}	temperature of the product passing through the master meter
V_{FS}	volume indicated by flowmetering system in temperature **uncompensated** mode
$V_{FS,c}$	volume indicated by flowmetering system in temperature **converted** to base conditions
V_{FS15}	volume indicated by flowmetering system in temperature **compensated** mode
V_{MM}	volume indicated by the master meter
V_{REF15}	reference volume at 15°C

CONTENTS

EXPLANATION OF TERMS

For explanations of other terms see *General Information for Test Procedures*.

Adjustment

Alteration of the measurement parameters to bring the instrument within the allowable MPEs for an instrument in use.

Calibration

The set of operations that (under specified conditions) establishes the relationship between the indicated or nominal value of an instrument and the corresponding known value of the measured quantity.

Certification

The examination of an instrument by a **certifier** (the holder, or an employee of the holder, of a servicing licence) in order to mark the instrument indicating that it conforms with the relevant test procedures.

- **Initial certification** is the certification of a new instrument by a certifier which does not bear a verification or certification mark and has never been verified or certified before.
- **Subsequent certification** is any certification of an instrument by a certifier because the mark is no longer valid due to such reasons as:
  - repairs or adjustments have been made that affect metrological performance; or
  - the mark has been defaced or removed.

In-service Inspection

The examination of an instrument by an **inspector or certifier** to check that:
- the verification or certification mark is valid; and
- the errors do not exceed the MPEs permitted for in-service inspection.

In-service inspection does not permit the instrument to be marked with a verification or certification mark.

Verification

The examination of an instrument by an **inspector** in order to mark the instrument indicating that it conforms with the relevant test procedures.

- **Initial verification** is the verification of a new instrument by an inspector which does not bear a verification or certification mark and has never been verified or certified before.
- **Subsequent verification** is any verification of an instrument by an inspector because the mark is no longer valid due to such reasons as:
  - repairs or adjustments have been made that affect metrological performance; or
  - the mark has been defaced or removed.
- **Re-verification** is the examination of an instrument by an inspector to check that:
  - the verification or certification mark is valid; and
  - the instrument has not been modified in any way since verification or certification;

  in order to mark the instrument indicating that it conforms with the relevant test procedures.

1. SCOPE

NITP 10.2 describes the test procedures for the verification, certification and in-service inspection of bulk LPG flowmetering systems to ensure that they measure to within the maximum permissible errors (MPEs) specified in the National Measurement Regulations and that they comply with their certificate of approval.

These test procedures supersede *Test Procedure No 13. Non-driveway Flowmeters*, second edition, May 1990, found in Inspectors Handbook Number 6.

Certificates of approval are based on *NMI R 117-1. Measuring Systems for Liquids other than Water*. Refer to NMI R 117-1 for all metrological and technical requirements. The constituents of each flowmetering system are contained in the relevant certificate/s of approval. All flowmetering systems must also comply with the relevant Trade Measurement Act and Regulations.

Two test methods are described to test accuracy: the volumetric and the gravimetric method.

The test procedures for all other bulk flowmetering systems are described in NITP 5.2, and for fuel dispensers in NITP 5.1 and NITP 10.1.

2. EQUIPMENT FOR TESTING

1. Certificate/s of approval for the flowmetering system and any ancillary components or additional devices.
2. Appropriate reference standards of measure and equipment as follows:

   (a) For the **volumetric** method:

   - A master meter (±0.2% uncertainty) with reference standard thermometer (±0.2°C uncertainty) and 2 500 kPa reference standard pressure gauge (±25 kPa uncertainty) fitted to the inlet of the master meter.
   - A hydrometer pressure vessel with a reference standard hydrometer (±1 kg/m^3 uncertainty), a reference standard thermometer (±0.2°C uncertainty) and a 2 500 kPa reference standard pressure gauge (±25 kPa uncertainty).
   - A reference standard thermometer (±0.2°C uncertainty) suitable for inserting into the thermowell of the flowmetering system.

   (b) For the gravimetric method:

   - Weighing instrument with a suitable scale interval such that the uncertainty of the quantity delivered is one-third or better than the MPE.
   - Reference standard masses equivalent to the weight of the:
     - LPG for the intended delivery volume plus an additional 10% where the receiving vessel is tared; or
     - receiving vessel plus the weight of the LPG for the intended delivery volume plus an additional 10% where the receiving vessel is not tared.
   - A hydrometer pressure vessel with a reference standard hydrometer (±0.5 kg/m^3 uncertainty), and a reference standard thermometer (±0.2°C uncertainty).
   - A reference standard thermometer (±0.2°C uncertainty) suitable for inserting into the thermowell of the flowmetering system.
   - A receiving vessel of suitable capacity.
3. Current Regulation 13 certificates for all reference standards of measurement. Uncertainties must be in accordance with the National Measurement Regulations and not greater than one-third of the MPE of the flowmetering system under test for the volume delivered.

Note: Pressure gauges and thermometers may also be traceable by a NATA certificate. Check with the licensing authority to ascertain their requirements.

4. Safety equipment (see clause 3.1).
5. Relevant material safety data sheets.
6. Test report (see Appendix A).
7. Watch.
8. Australian Institute of Petroleum (AIP) work clearance forms, where applicable.
9. The following publications:
   - ASTM–IP–API Petroleum Measurement Tables for Light Hydrocarbon Liquids — Density Range 0.500 to 0.653 kg/L at 15°C.
   - API Manual of Petroleum Measurement Standards, Chapter 11.2.2M — Compressibility Factors for Hydrocarbons: 350–637 kg/m^3 Density (15°C) and –46°C to 60°C Metering Temperature.

   These documents are available on-line from www.techstreet.com.

3. VISUAL INSPECTION

Visually inspect the flowmetering system and record details of the required data and characteristics of the flowmetering system on the test report.

3.1 Safety Requirements

Testing flowmetering systems is potentially dangerous due to the highly flammable nature of LPG. To reduce risk:

1. Consult the relevant material safety data sheets.
2. Where applicable, follow the AIP work clearance procedure and complete associated work clearance forms.
3. At all times minimise exposure to LPG, move away from the flowmetering system whenever possible, work up-wind to reduce inhalation, wear gloves and wash hands after testing.
4. Wear anti-static clothing (e.g. 100% cotton), long pants, a long-sleeved shirt, safety shoes, a safety vest, gauntlet gloves and a face shield.
5. Use equipment approved for use in hazardous areas, e.g. torch and equipment requiring a power supply.
6. Ensure that a suitable fire extinguisher is available and within easy reach at all times.
7. Ensure that there are no potential ignition sources (e.g. lit cigarettes and battery-operated equipment) within the hazardous zones of the testing area.
8. Place a suitable warning sign in a position so that it is clearly visible to the public.
9. Where applicable, position safety cones or bollards to prevent vehicle access into the testing area. Ensure that the safety cones are visible to all pedestrian and traffic.
10. Use a static lead to dissipate any potential static electricity, e.g. between the flowmetering system, reference equipment and the receiving vessel.
11. When checking for leaks:
    - stop testing immediately if there is any sign of a leak; and
    - check the meter and pipe work carefully.

    To locate a leak, use appropriate gas detection equipment or your sense of smell and a soapy solution.

3.2 Required Data

1. Test report reference number.
2. Date of test.
3. Type of test: verification, certification or in-service inspection (for in-service inspection, ensure that the verification/ certification mark is in place).
4. Trading name.

5. Address of test site.
6. Name of contact at test site, if available.
7. Manufacturer.
8. Model.
9. Serial number/s.
10. Certificate/s of approval number/s.
11. Vehicle registration (if applicable).
12. LPG density range that the flowmetering system is approved to deliver.
13. Minimum flow rate marked on the data plate.
14. Maximum flow rate marked on the data plate.
15. Nominal flow rate (if applicable) marked on the data plate.
16. Minimum measured quantity.
17. Reading of the non-resettable totaliser (if applicable).
18. Software version and indicator model in use (if applicable). Refer to the certificate of approval for access instructions.

3.3 Characteristics of the Flowmetering System

1. Does the flowmetering system comply with its certificate/s of approval?
2. Are all mandatory descriptive markings clearly and permanently marked on a data plate which is fixed to the flowmetering system?
3. Are all permanently attached components fixed rigidly, e.g. meter, indicator, air separator, differential valve?
4. Are all indications legible and clearly visible under all conditions?
5. Are the hoses, if any, in a serviceable condition, e.g. they are not badly chafed, split, or worn through to the fabric?
6. Are there any leaks?

4. TEST PROCEDURES

The following series of test procedures, together with any test procedures specified in the certificate/s of approval, determine if the performance of the flowmetering system meets requirements and whether the system requires adjustment or service.

Each test procedure is explained as a discrete test. However tests can be combined to expedite the testing procedure. A suggested sequence for testing is shown in clause 5.

Remember to follow the safety requirements in clause 3.1.

4.1 Indicating Devices

4.1.1 Mechanical Indicator

Reading of the indications shall be precise, easy to read and non-ambiguous at whatever position the indicating device comes to rest.

If the device comprises several elements, it shall be arranged in such a way that the reading of the measured volume can be made by simple juxtaposition of the indications of the different elements. The decimal sign shall be distinct.

1. Start a delivery.
2. Circulate or dispense LPG for at least 1 minute at maximum attainable flow rate.
3. Stop the delivery.
4. Check that the volume indicating device is operating and provides an easy, unambiguous indication.
5. Determine whether the indicator has passed or failed.
6. Record the result on the test report.

4.1.2 Electronic Indicator

The checking facility for an electronic indicating device shall provide visual checking of the entire display, which shall meet the requirements of NMI R 117-1, clause 4.3.4.2 or as described in the certificate of approval.

1. Check that the display segments are not faulty. This may be achieved by powering down and then powering up the indicator.
2. Determine whether the indicator has passed or failed.
3. Record the result on the test report.

4.2 Zero Setting

This test does not apply to systems that do not have a re-settable indicator.

The zero setting device shall not permit any alteration of the measurement result shown by the indicating device other than by making the result disappear and displaying zeros (NMI R 117-1, clause 3.2.4.2).

Once the zeroing operation has begun it shall be impossible for the indicating device to show a result different from that of the measurement which has just been made, until the zeroing operation has been completed. The indicating device shall not be capable of being reset to zero during measurement (NMI R 117-1, clause 3.2.4.3).

The residual volume indication after return to zero for:

- **mechanical** indicating devices shall not be more than 0.2 of a scale interval; or
- **electronic** indicating devices shall be zero without any ambiguity (NMI R 117-1, clauses 3.2.4.5).

1. Start a delivery.
2. Circulate or dispense LPG for at least 1 minute at maximum attainable flow rate.
3. Stop the delivery.
4. Reset the volume indicating device to zero by operating the zero setting function once.
5. Check that the volume indicating device is indicating zero.
6. Determine if the zero setting function has passed or failed.
7. Record the result on the test report.

4.3 Non-return Valve

A flowmetering system in which the liquid could flow in the opposite direction to that of normal flow when the pump is stopped shall be provided with a non-return valve.

1. Prime the flowmetering system.
2. Stop the delivery by closing the delivery nozzle or a valve downstream of the meter.
3. Stop the pump.
4. After 2 minutes reset the indicator to zero.
5. Start the pump and check the volume indication remains on zero.
6. Determine whether the non-return valve has passed or failed.
7. Record the result on the test report.

4.4 Interlock

When a common indicator (or pumping unit) is used for two or more flowmetering systems it shall not be possible for LPG to be delivered unless the LPG is measured and shown on the indicating device.

1. Start a delivery from any other flowmetering system that shares the indicator and/or the common pumping unit with the flowmetering system under test.
2. If the system shares a common pumping unit then while the pumping unit it operating, attempt to make a delivery from the flowmetering system under test by opening the transfer device without a delivery being authorised from the system.
3. Ensure that it is not possible to make a delivery from the flowmetering system under test.
4. Determine whether the flowmetering system has passed or failed.
5. Record results on the test report.

4.5 Maximum Flow Rate

The maximum achievable flow rate shall be within the approved range (Q_{min} to Q_{max}) marked on the data plate.

4.5.1 Systems with an Independent Pumping Unit

1. Start a delivery and allow the flow rate to stabilise at the maximum achievable flow rate.
2. Time a 30 second delivery noting the initial and final volume indications.
3. Use these volume indications to calculate the maximum achievable flow rate.
4. Determine whether the flow rates are within the approved range.
5. Record the result on the test report.

4.5.2 Systems Sharing a Common Pumping Unit

Steps 5 to 7 are only required:

- at initial verification/certification;
- when changes affecting flow rate occur; or
- at the discretion of the trade measurement authority.

1. Ensure no other flowmetering system sharing the common pumping unit is operating.
2. Start a delivery from the flowmetering system under test and allow the flow rate to stabilise at the maximum achievable flow rate.
3. Time a 30 second delivery noting the initial and final volume indications.
4. Use these volume indications to calculate the maximum achievable flow rate.
5. Commence deliveries from all flowmetering systems which share the common pumping unit.
6. Once all the flowmetering systems have stabilised at their maximum attainable flow rate, time a 30 second delivery noting the initial and final volume indications.
7. Use these volume indications to calculate the maximum achievable flow rate.
8. Determine whether the flow rates are within the approved range.
9. Record the result on the test report.

4.6 Density and Temperature Settings

In addition to the volume at metering conditions and the volume at 15°C, the values of other measured quantities (e.g. density, pressure, temperature) shall be accessible for each test measurement (NMI R 117-1, clause 3.7.7).

The following requirements must be met:

- the density displayed or set by the flowmetering system must be within ±10 kg/m^3 of the value measured by the certified hydrometer; and
- the temperature displayed by the flowmetering system must be within ±0.5°C of the value measured by the certified thermometer.

To accurately compare the reference volume and indicated volume these volumes must be corrected to a base temperature of 15°C.

In addition to temperature corrections, pressure corrections are also required for volumetric testing to determine the volume at base conditions. To make these pressure calculations it is necessary to determine the equilibrium vapour pressure of the LPG.

To complete these corrections the LPG density, temperature and equilibrium vapour pressure must be measured.

This procedure is generally completed after the first accuracy test to ensure that the LPG is representative of the LPG in the supply tank.

1. Obtain the necessary information from the certificate of approval and/or the manual to access the display of LPG density and temperature.

2. Place oil or glycol in the thermowell of the flowmetering system and insert the thermometer.
3. Circulate LPG through the flowmetering system until the temperature has stabilised and record the temperature (T_{FS}).
4. Check that the temperature displayed by the flowmetering system is within ±0.5°C of the temperature determined in step 3.
5. Introduce a sample of LPG from the flowmetering system into the hydrometer pressure vessel until the certified hydrometer is floating.
6. Disconnect the hydrometer pressure vessel from the flowmetering system.
7. Slowly reduce the vapour pressure in the pressure vessel until the LPG just starts to boil.
8. Place the hydrometer pressure vessel in a safe place out of direct sunlight until the LPG temperature has stabilised.
9. Record the density and temperature. For the volumetric method also record the equilibrium vapour pressure (P_e).

   Note: Remember to include the calibration correction factor for the hydrometer, thermometer and pressure gauge.
10. Use the corrected density and temperature readings in conjunction with ASTM–IP–API Table 53 to calculate the density at 15°C (D_{15}) and record $D_{15.}$
11. Check that the density displayed or set by the flowmetering system is within ±10 kg/m^3 of D_{15} (determined in step 10).
12. Record results on the test report.
13. Release the LPG from the pressure vessel in a safe manner.

4.7 Accuracy

LPG must be sold at converted volume measured at 15°C. Unconverted volume is a delivery made at ambient temperature. When testing the accuracy of a flowmetering system, both converted volume and unconverted volume are required.

Minimum measured quantity is the value below which the result may be subject to an excessive relative error. If this value is not stated in the certificate of approval then it is 200 times the scale interval of the indicating device.

When a flowmetering system delivers converted volume it is said to be in temperature compensated mode, and when it delivers unconverted volume it is said to be in temperature uncompensated mode.

In this section, two test methods are described to test accuracy:

- the **volumetric** method (see clause 4.7.1) which uses a master meter as the traceable reference standard; and
- the **gravimetric** method (see clause 4.7.2) which uses masses in conjunction with a weighing instrument as the traceable reference standard.

Testing is carried out as follows:
- three deliveries at the maximum achievable flow rate; and
- one delivery at the minimum flow rate.

The results are then analysed to determine if the results are within the MPEs given in Table 1 and whether the flowmetering system needs adjustment.

Table 1. MPEs for LPG flowmetering systems

Verification/certification	±0.6%
In-service inspection	±1%

4.7.1 Volumetric Method

1. Ensure the flowmetering system is in temperature uncompensated mode.
2. Place oil or glycol in the thermowell of the flowmetering system, insert the thermometer.
3. Connect the master meter outlet hose to the liquid transfer line of the supply tank.
4. Connect the flowmetering system nozzle to the inlet of the master meter.
5. Slowly open the flowmetering system nozzle and then fully open the flow control valve on the master meter to allow testing at maximum flow rate.
6. Open the master meter nozzle and circulate at least 200 L of LPG through the system and back to the supply tank until the temperature and master meter pressure readings have stabilised.
7. Reset the master meter and flowmetering system to zero.
8. Make a delivery at the maximum achievable flow rate for a volume which is at least equal to the greatest of:
   - 1 minute delivery;
   - 2 × minimum measured quantity;
   - 1500 scale intervals for a system with a digital indicator; or
   - the minimum quantity for the master meter as specified in the certificate of verification.
9. Record the maximum achievable flow rate.
10. Approximately half way through the delivery, record the temperature of the LPG in the flowmetering system and the master meter (T_{FS} and T_{MM}), the flow rate indicated by the master meter (F_{MM}) and the pressure at the master meter (P_{MM}).
11. Complete the delivery using the master meter nozzle and record the indicated volume from the master meter (V_{MM}) and the uncompensated volume from the flowmetering system (V_{FS}).
12. Use D_{15}, T_{FS} and T_{MM} in conjunction with ASTM–IP–API Table 54 to determine the conversion factors C_{tlFS} and C_{tlMM} for the effect of temperature on LPG at the flowmetering system and at the master meter respectively.
13. Calculate the pressure conversion factor (C_{plMM}) for the effect of pressure on LPG at the master meter by using D_{15}, P_e, P_{MM}, T_{MM} and the compressibility factor from the API Manual of Petroleum Measurement Standards, Chapter 11.2.2M. Alternatively, use the simplified abridged tables given in Appendix B.
14. Determine the meter factor for the master meter (MF_{MM}) using the indicated flowrate (F_{MM}) and the Regulation 13 certificate of verification.
15. Calculate the converted and corrected master meter volume as follows:
    $V_{REF15} = V_{MM} \times C_{tlMM} \times C_{plMM} \times MF_{MM}$
16. Calculate the converted flowmetering system volume as follows:
    $V_{FS,c} = V_{FS} \times C_{tlFS}$
17. Calculate the relative error (E_{FS}) by comparing the calculated converted volume for the flowmetering system with the converted test volume, i.e.
    $E_{FS} = (V_{FS,c} - V_{REF15}) / V_{REF15} \times 100$

    Note: A positive error indicates that the flowmetering system is over-reading and under-delivering.
18. Repeat steps 7 to 17 **twice more**.
19. Repeat steps 7 to 17 at Q_{min} **once**.
20. Where the flowmetering system has a linearisation correction facility, repeat steps 7 to 17 at each flow rate where the linearisation correction is not set to unity.
21. Determine if all the results in steps 16 are within the allowable MPE (see Table 1).

22. If meter adjustments are made repeat steps 7 to 21.
23. Record results on the test report.

4.7.2 Gravimetric Method

1. Ensure the flowmetering system is in temperature uncompensated mode.
2. Place oil or glycol in the thermowell of the flowmetering system, insert the thermometer.
3. Ensure the weighing instrument is level.
4. Test the weighing instrument for accuracy (see clause 2, point 2(b)). Record any errors and apply as applicable.
5. Place the pressurised LPG cylinder on the weighing instrument, tare off the cylinder by using the taring device or by recording the tare value.
6. Reset the flowmetering system to zero.
7. Make a delivery at the maximum achievable flow rate for a volume which is at least equal to the greatest of:
   - 1 minute delivery;
   - 2 × minimum measured quantity; or
   - 1500 scale intervals for a system with a digital indicator.

   Note: To maintain the delivery at maximum flow rate, it may be necessary to only half fill the LPG cylinder.
8. Record the maximum achievable flow rate.
9. Approximately half way through the delivery, record the temperature of the LPG in the flowmetering system (T_{FS}).
10. Complete the delivery and record the uncompensated volume indication (V_{FS}) on the flowmetering system and the mass of the LPG delivered.
11. Convert the mass to volume at base conditions (V_{REF15}) by dividing the mass by D_{15} (see clause 4.6).
12. Use D_{15} and T_{FS} in conjunction with ASTM–IP–API Table 54 to determine the temperature conversion factor (C_{tlFS}).
13. Calculate the converted flowmetering system volume as follows:
    $V_{FS,c} = V_{FS} \times C_{tlFS}$
14. Calculate the relative error (E_{FS}) by comparing the calculated converted volume for the flowmetering system with the converted test volume, i.e.
    $E_{FS} = (V_{FS,c} - V_{REF15}) / V_{REF15} \times 100$

    Note: A positive error means that the flowmetering system is over-reading and under-delivering.
15. Repeat steps 5 to 14 **twice more.**
16. Repeat steps 5 to 14 at Q_{min} **once.**
17. Where the flowmetering system has a linearisation correction facility, repeat steps 5 to 14 at each flow rate where the linearisation correction is not set to unity.
18. Determine if all the results in step 14 are within the allowable MPE (see Table 1).
19. If meter adjustments are made repeat steps 5 to 18.
20. Record results on the test report.

4.8 Conversion Device

The maximum permissible difference (MPD) between the percentage error for the unconverted volume and the volume converted to 15°C shall not exceed **0.4%** (NMI R 117-1, clause 2.7.1).

This test would normally be carried out after the accuracy test.

1. Calculate and record the average relative error (E_{AV}) of three deliveries made in uncompensated mode which were completed at the maximum achievable flowrate during accuracy testing (clause 4.7).
2. Circulate LPG through the flowmetering system until the temperature has stabilised and the flowmetering system is conditioned.

3. Complete three deliveries in temperature compensated mode at maximum achievable flow rate in accordance with either:
   - clause 4.7.1 steps 7 to 15; or
   - clause 4.7.2 steps 5 to 11.
4. Calculate the relative error in temperature compensated mode for each delivery (E_{FS15}) as follows: $E_{FS15} = (V_{FS15} - V_{REF15}) / V_{REF15} \times 100$
5. Calculate the average relative error $E_{AV,C}$ of the three deliveries.
6. Calculate the conversion device error as follows: $E_C = E_{AV,C} - E_{AV}$.
7. Ensure that E_C is no greater than 0.4%.
8. Record results on the test report.
9. Ensure the flowmetering system is left in temperature compensated mode.

4.9 Repeatability

This test is not required for vehicle-mounted flowmetering systems.

Flowmetering systems approved to operate at a nominal flow rate (which shall be marked on the data plate) shall meet the following requirement.

For any quantity equal to or greater than **five times** the minimum measured quantity, the repeatability error of the flowmetering system shall not be greater than **0.4%**.

1. Calculate the repeatability error (E_{rep}) by subtracting the minimum E_{FS} from the maximum E_{FS} determined in the accuracy tests at the maximum achievable flow rate (see clause 4.6).
2. Determine whether the flowmetering system has passed or failed.
3. Record results on the test report.

4.10 Meter Creep

This test is only required when the transfer device is a nozzle.

Where the pump continues to operate after a delivery without any flow of LPG, the MPE of the delivery shall not exceed the values given in Table 1 for accuracy.

1. Conduct an additional accuracy delivery at maximum flow rate in accordance with either:
   - clause 4.7.1 steps 7 to 15; or
   - clause 4.7.2 steps 5 to 11.

   However DO NOT record V_{FS}, record it in accordance with step 2 below.
2. With the pump operating allow the flowmetering system to bypass for 2 minutes and record the volume indication (V_{FS}).
3. Use D_{15} and T_{FS} in conjunction with the appropriate volume correction tables to determine the temperature conversion factor C_{tlFS}. See Appendix B.1 for details on how to work this out.
4. Calculate the converted volume as follows: $V_{FS,c} = V_{FS} \times C_{tlFS}$, where V_{FS} was determined in step 2.
5. Calculate and record the relative error as follows:
   $E_{FS} = (V_{FS,c} - V_{REF15}) / V_{REF15} \times 100$, where $V_{FS,c}$ was determined in step 4 and V_{REF15} in step 1.
6. Determine whether the results are within the allowable MPE (see Table 1).
7. Record the results on the test report.

4.11 Pre-set Indications

A pre-set accuracy test is not required if the pre-set facility is marked 'Pre-set value not for trade use'.

Flowmetering systems with a volume indicating device may also be fitted with a volume pre-setting device, which stops the flow of the liquid when the quantity corresponds to the pre-set value (NMI R 117-1, clause 3.6.10).

4.11.1 Pre-set Indications

1. Check that all pre-set buttons are operational.
2. Reset the flowmetering system to zero.

3. Enter a suitable pre-set value using the pre-set facility. Make sure the pre-set amount appears on the display.
4. Start a delivery into the receiving vessel at the maximum attainable flow rate allowing the pre-set facility to slow down and complete the delivery automatically.
5. Check that the volume indication on the display corresponds exactly to the pre-set amount.
6. Determine whether the flowmetering system has passed or failed.
7. Record results on the test report.

4.11.2 Accuracy of Pre-set

1. Enter and record a suitable pre-set amount.
2. Conduct an additional accuracy delivery at maximum flow rate in accordance with either:
   - clause 4.7.1 steps 7 to 17; or
   - clause 4.7.2 steps 5 to 14.

   Allow the flow control valve to stop the delivery.
3. Determine whether the results are within the allowable MPE (see Table 1).
4. Record results on the test report.

4.12 Printing Devices

4.12.1 Discrete Ticket Printing

1. Insert a ticket.
2. Reset the indicator on the flowmetering system to zero.
3. Start a delivery and ensure that the ticket cannot be removed.
4. Stop the delivery and print a ticket.
5. Remove the ticket and ensure printing will not occur if no ticket is present.
6. Examine the ticket to ensure that:
   - the digits in the printing are correctly aligned;
   - all printings are clear, indelible and unambiguous and include the units of measurement;
   - the scale interval of the printer is the same as the scale interval of the indicator;
   - the volume indicated on the ticket agrees exactly with the meter reading; and
   - the ticket complies with the certificate of approval or *General Supplementary Certificate of Approval S1/0/A Electronic Indicating and Printing Devices for Measuring Instruments*.
7. Repeat steps 1 to 6 to ensure transaction serial numbers are sequential.
8. Determine whether the ticket printing device has passed or failed.
9. Record the result on the test report and attach the tickets to the test report.

4.12.2 Continuous Ticket Printing

1. Reset the indicator on the flowmetering system to zero.
2. Commence and complete a delivery.
3. Print transaction details.
4. Examine the printed details to ensure that:
   - the digits in the printing are correctly aligned;
   - all printings are clear, indelible and unambiguous and include the units of measurement;
   - the scale interval of the printer is the same as the scale interval of the indicator;
   - the volume indicated on the transaction detail agrees exactly with the meter reading; and
   - the printed detail complies with the certificate of approval or *General Supplementary Certificate of Approval S1/0/A Electronic Indicating and Printing Devices for Measuring Instruments*.

5. Repeat steps 1 to 4 to ensure transaction serial numbers are sequential.
6. Remove the continuous feed paper and ensure printing will not occur if no paper is present.
7. Determine whether the printing device has passed or failed.
8. Record the result on the test report and attach the transaction details to the test report.

5. SUGGESTED SEQUENCE FOR TESTING

1. Consult the relevant materials safety data sheets.
2. Where applicable, raise an AIP work clearance permit and a fuel withdrawal advice form.
3. Ensure all safety, environmental and site authorisations/permits have been issued.
4. Check the certificate of approval for any additional tests required. Make provision for including these tests in the testing sequence.
5. Visually inspect the flowmetering system and record the required data and characteristics of the system on the test report.
6. Conduct the indicating device test (clause 4.1).
7. Conduct an accuracy test (clause 4.7) and during the first delivery conduct a density and temperature setting test (clause 4.6).
8. Whilst conducting the accuracy test, check:
   - zero setting (clause 4.2);
   - maximum flow rate (clause 4.5);
   - printing device (clause 4.12); and
   - repeatability (clause 4.9) if applicable.
8. Conduct a conversion device test (clause 4.8).
9. Conduct a pre-set indication test and a pre-set volume accuracy test (clause 4.11).
10. If required, conduct a non-return (reverse flow) test (clause 4.3).
11. If required, conduct a meter creep test (clause 4.10).
12. Conduct an interlock test (clause 4.4).
13. Carry out anything else necessary to complete the procedure. This may include:
    - obliterating verification, certification and control marks from the flowmetering system; and
    - stamping the flowmetering system (for more information on stamping see *General Information for Test Procedures*).

APPENDIX A. TEST REPORT

Test reports consist of a common front page accompanied by **one** of the following test reports:

(a) volumetric testing; or
(b) gravimetric testing.

Although the format of the test reports may vary according to the individual needs and requirements of trade measurement authorities and licensees, the following test reports contains the minimum amount of information that must be recorded.

If the certificate of approval requires additional tests, attach pages that record the results of these tests.

Number each page of the test report in the style shown at the top of each page.

Test Report for LPG Flowmetering Systems

Test report reference number .... Date of test......................................

Type of test (tick one) ☐ Verification ☐ Certification ☐ In-service inspection

For in-service inspection record the verification/certification mark...

Trading name ....

Address of test site ....

Name of contact at test site (if applicable)..

Manufacturer .... Model ....

Serial number/s .... Certificate/s of approval number/s..............................

Vehicle registration (if applicable) .... LPG density range ....

Minimum flow rate (Q_{min})........................... L/min Maximum flow rate (Q_{max}) ....L/min

Nominal flow rate (if applicable)................. L/min Minimum measured quantity ....

Reading of the non-resettable totaliser (if applicable) ....

Software version and indicator model in use (if applicable) ....

Does the flowmetering system comply with its certificate/s of approval?	yes/no
Are all mandatory descriptive markings clearly and permanently marked on a data plate which is fixed to the flowmetering system?	yes/no
Are all permanently attached components fixed rigidly?	yes/no
Are the indications legible and clearly visible under all conditions?	yes/no
Are the hoses, if any, in a serviceable condition?	yes/no/na
Are there any leaks?	yes/no

Indicating devices (clause 4.1)	☐ Pass ☐ Fail
Zero setting (clause 4.2)	☐ Pass ☐ Fail ☐ na
Non-return valve (clause 4.3)	☐ Pass ☐ Fail ☐ na
Interlock (clause 4.4)	☐ Pass ☐ Fail ☐ na
Maximum flow rate (clause 4.5)	☐ Pass ☐ Fail
Accuracy volumetric method (clause 4.7.1) on Test Report (a)	☐ Pass ☐ Fail ☐ na
Accuracy gravimetric method (clause 4.7.2) on Test Report (b)	☐ Pass ☐ Fail ☐ na
Conversion device (clause 4.8)	☐ Pass ☐ Fail ☐ na
Repeatability (clause 4.9)	☐ Pass ☐ Fail ☐ na
Meter creep (clause 4.10) and Test Report (a) OR (b)	☐ Pass ☐ Fail ☐ na
Pre-set indications (clause 4.11.1)	☐ Pass ☐ Fail ☐ na
Accuracy of pre-set (clause 4.11.2)	☐ Pass ☐ Fail ☐ na
Printing device (clause 4.12)	☐ Pass ☐ Fail
Overall result	**☐ Pass ☐ Fail**

(a) Volumetric Testing

Master meter serial number =	Density displayed by flowmetering system = kg/L	Temperature displayed by flowmetering system = °C

Hydrometer readings (clause 4.6)	Pressure		Temperature		Density		Density at 15°C
	Observed	Corrected	Observed	Corrected	Observed	Corrected	D_{15} =
	kPa	kPa	°C	°C	kg/L	kg/L	

	Q_{max} (clause 4.7)			Q_{min} (clause 4.7)	Meter creep (clause 4.10)	Compensated Q_{max} (clause 4.8)			Linearisation correction (clause 4.7)		
Totaliser at the end = L											
Totaliser at the start = L											
Total volume used = L	Test 1	Test 2	Test 3			Test 1	Test 2	Test 3	L 1	L 2	L 3
Maximum achievable flow rate (L/min)											
T_{FS} (°C)											
T_{MM} (°C)											
P_{MM} (kPa)											
V_{MM} (L)											
V_{FS} (L)											
V_{FS15} (L)											
C_{tlFS}♣ (using D_{15}, T_{FS}, Table 54)						1.000*	1.000*	1.000*			
C_{tlMM} ♣ (using D_{15}, $T_{MM,}$ Table 54)											
C_{plMM} (using P_e, D_{15}, T_{MM}, P_{MM})											
MF_{MM}											
V_{REF15}♦=[V_{MM}×C_{tlMM}×C_{plMM}×MF_{MM}] (L)											
$V_{FS,c}$ = [V_{FS} × C_{tlFS}]											
E_{FS} = [($V_{FS,c}$ – V_{REF15}) / V_{REF15} × 100]											
E_{FS15} = [($V_{FS,c}$ – V_{REF15}) / V_{REF15} × 100]											
	E_{AV} =					$E_{AV,C}$ =					
E_C = ($E_{AV,c}$ – E_{AV})											

♣ If the difference between T_{FS} and T_{MM} is <0.5°C, the conversion factors can be set to unity (see Appendix B).
♦ The correction factor MF_{MM} is the meter factor obtained from a traceable measurement report.
* For compensated delivery the conversion factor C_{tlFS} must be set to unity.

Inspector's/certifier's name..Identification number ....

Signature ....

Comments ....

....

(b) Gravimetric Testing

Density displayed by flowmetering system = kg/L	Temperature displayed by flowmetering system = °C

Hydrometer readings (clause 4.6)	Temperature		Density		Density at 15°C
	Observed	Corrected	Observed	Corrected	D_{15} =
	°C	°C	kg/L	kg/L	

Totaliser at the end = L Totaliser at the start = L	Q_{max} (clause 4.7)			Q_{min} (clause 4.7)	Meter creep (clause 4.10)	Compensated (clause 4.8)			Linearisation correction (clause 4.7)		
Total volume used = L	Test 1	Test 2	Test 3			Test 1	Test 2	Test 3	L 1	L 2	L 3
Maximum achievable flow rate (L/min)											
Mass of LPG (kg)											
T_{FS} (°C)											
V_{FS} (L)											
V_{FS15} (L)											
V_{REF15} (L)											
C_{tlFS} (using D_{15}, T_{FS} Table 54)						1.000*	1.000*	1.000*			
$V_{FS,c} = (V_{FS} \times C_{tlFS})$											
$E_{FS} = [(V_{FS,c} - V_{REF15}) / V_{REF15} \times 100]$											
$E_{FS15} = [(V_{FS,c} - V_{REF15}) / V_{REF15} \times 100]$											
	E_{AV} =					$E_{AV,c}$ =					
$E_C = (E_{AV,c} - E_{AV})$											

* For compensated delivery the conversion factor C_{tlFS} must be set to unity.

Inspector's/certifier's name...Identification number ....

Signature ....

Comments ....

....

APPENDIX B. CONVERSION FACTORS FOR DENSITY, TEMPERATURE AND PRESSURE

Due to the nature of LPG with its significant expansion and contraction due to temperature and corresponding pressure, it is necessary to consider the temperature and pressure of LPG whenever comparing volume measurements.

This section gives procedures and examples showing how to obtain the conversion factors for the effect of temperature and pressure on LPG in order to convert the measured volume at operating conditions to a volume at base conditions.

Theoretically, all conversions should be applied to all measurements but in practice some may be ignored depending on the conditions. For example, if the temperature of the liquid is the same in both the proving device and in the flowmeter-under-test, the conversion factor for the change in volume due to temperature need not be applied.

B.1 Density

In order to perform various other conversions and calculations associated with the measurement of LPG quantities, the density of LPG at 15°C is required. For this purpose an LPG hydrometer pressure vessel is used in accordance with international standard ISO 3993.

In practice the measurement of LPG density is seldom carried out at 15°C and as such, ASTM–IP–API Table 53 is used for converting the measured density at observed temperature to density at 15°C. It is used as follows.

Consider that the certified hydrometer gives an observed density of 0.505 kg/L, after applying any correction specified in the measurement report for the traceable hydrometer. Suppose that the observed density of LPG using the hydrometer pressure vessel was determined at a temperature of 25°C, then using the table, the density of LPG at 15°C is 0.520 kg/L; obtained at the intersection of the column for observed density 0.505 and the row for temperature 25°C.

Note: There is a negligible difference between hydrometers marked in specific gravity 60/60°F and those marked with density at 15°C, for which ASTM–IP–API Table 21 can be used.

B.2 Temperature

Volumes at different temperatures must either be converted to a common temperature, or as recommended by standards, converted to base temperature before comparing the volumes measured. The conversion factor, C_{tl}, is used for converting the volume at operating temperature to a volume at 15°C, and is obtained using ASTM–IP–API Table 54. It is used as follows.

Consider that the temperature of LPG is 25°C, and using the hydrometer pressure vessel the density of LPG at 15°C was calculated to be 0.520 kg/L, then using the table the volume conversion factor $C_{tl} = 0.972$; obtained at the intersection of the column for density 0.520 and the row for the observed temperature 25°C.

B.3 Pressure

Volumes at different pressures must either be converted to a common pressure, or as recommended by standards, converted to base pressure before comparing the volumes measured. The conversion factor C_{pl} is used for converting the volume at operating pressure to a volume at base pressure, and is given by the following equation:

$$C_{pl} = 1 / [1 - (F_p \times D_p)]$$

where:

F_p is 1 / [A + (D_p × B)], namely the compressibility factor; calculated using constants A and B obtained from API Manual of Petroleum Measurement Standards, Chapter 11.2.2M

D_p is the difference between the operating pressure (e.g. P_{FS} or P_{MM}) and the equilibrium vapour pressure (P_e) of LPG at operating temperature (T_{FS} or T_{MM})

B.3.1 How to Use the API Manual of Petroleum Measurement Standards

To calculate C_{pl}, use the temperature of LPG metered (T_{MM}) and the density of LPG at 15°C, to obtain the constants A and B from Chapter 11.2.2M. Then obtain the pressure difference (D_p) by taking the difference between the pressure of LPG metered at operating conditions (P_{MM}), and the equilibrium vapour pressure (P_e).

The equilibrium vapour pressure (P_e) can be obtained either by using the LPG hydrometer pressure vessel fitted with a pressure gauge or by reading the vapour pressure of LPG in the supply tank. Now insert the values obtained into the above equations to calculate C_{pl}.

To assist users, approximate tables (Tables B.1 to B.4) have been generated with values of the conversion factor (C_{pl}) for various values of LPG density at different conditions.

Note: The shaded areas represent an effect less than 0.1% which is considered to be insignificant and the value of C_{pl} may be taken as equal to unity.

B.3.2 How to Use Tables B.1 to B.4

Consider that the temperature of LPG at the meter is 17°C, at a pressure of 1 150 kPa, and using the hydrometer pressure vessel the density of LPG at 15°C was calculated to be 520 kg/m^3, and the equilibrium vapour pressure (P_e) of LPG at approximately 17°C was 550 kPa.

From this data the pressure difference (D_p) is 600 kPa (namely 1 150 kPa – 550 kPa), and for LPG temperature in the range 10°C to 20°C, Table B.2 is used to obtain the value for C_{pl} = 1.002 8 (outlined in black).

Table B.1. Conversion factors, C_{pl}, for LPG at **5°C** (±5°C)

D_p (kPa)	LPG density (kg/m^3) at 15°C					
	510	520	530	540	550	560
100	1.000 4	1.000 4	1.000 4	1.000 3	1.000 3	1.000 3
200	1.000 8	1.000 8	1.000 7	1.000 7	1.000 6	1.000 6
300	1.001 3	1.001 2	1.001 1	1.001 0	1.000 9	1.000 8
400	1.001 7	1.001 5	1.001 5	1.001 3	1.001 2	1.001 1
500	1.002 1	1.002 0	1.001 8	1.001 6	1.001 5	1.001 4
600	1.002 5	1.002 3	1.002 1	1.002 0	1.001 8	1.001 7
700	1.002 9	1.002 7	1.002 5	1.002 3	1.002 1	1.001 9
800	1.003 3	1.003 1	1.002 8	1.002 6	1.002 4	1.002 2

Note: D_p is the pressure difference between the operating pressure at the meter (P_{MM}) and the equilibrium vapour pressure (P_e) of LPG at the operating temperature.

Table B.2. Conversion factors, C_{pl}, for LPG at **15°C** (±5°C)

D_p (kPa)	LPG density (kg/m³) at 15°C					
	510	520	530	540	550	560
100	1.000 5	1.000 5	1.000 4	1.000 4	1.000 4	1.000 3
200	1.001 0	1.000 9	1.000 8	1.000 8	1.000 7	1.000 7
300	1.001 5	1.001 4	1.001 3	1.001 2	1.001 1	1.001 0
400	1.002 0	1.001 8	1.001 7	1.001 5	1.001 4	1.001 3
500	1.002 5	1.002 3	1.002 1	1.001 9	1.001 7	1.001 6
600	1.003 0	1.002 8	1.002 5	1.002 3	1.002 1	1.001 9
700	1.003 5	1.003 2	1.002 9	1.002 7	1.002 5	1.002 3
800	1.004 0	1.003 7	1.003 3	1.003 1	1.002 8	1.002 6

Table B.3. Conversion factors, C_{pl}, for LPG at **25°C** (±5°C)

D_p (kPa)	LPG density (kg/m³) at 15°C					
	510	520	530	540	550	560
100	1.000 6	1.000 6	1.000 5	1.000 5	1.000 4	1.000 4
200	1.001 3	1.001 1	1.001 0	1.000 9	1.000 8	1.000 8
300	1.001 9	1.001 7	1.001 5	1.001 4	1.001 3	1.001 1
400	1.002 5	1.002 3	1.002 0	1.001 8	1.001 7	1.001 5
500	1.003 1	1.002 8	1.002 5	1.002 3	1.002 1	1.001 9
600	1.003 7	1.003 4	1.003 0	1.002 7	1.002 5	1.002 3
700	1.004 3	1.003 9	1.003 5	1.003 2	1.002 9	1.002 7
800	1.004 9	1.004 5	1.004 0	1.003 7	1.003 3	1.003 0

Table B.4. Conversion factors, C_{pl}, for LPG at **35°C** (±5°C)

D_p (kPa)	LPG density (kg/m³) at 15°C					
	510	520	530	540	550	560
100	1.000 8	1.000 7	1.000 6	1.000 6	1.000 5	1.000 5
200	1.001 6	1.001 4	1.001 3	1.001 1	1.001 0	1.000 9
300	1.002 4	1.002 1	1.001 9	1.001 7	1.001 5	1.001 4
400	1.003 2	1.002 8	1.002 5	1.002 3	1.002 0	1.001 8
500	1.003 9	1.003 5	1.003 1	1.002 8	1.002 5	1.002 3
600	1.004 7	1.004 2	1.003 7	1.003 4	1.003 0	1.002 7
700	1.005 5	1.004 9	1.004 4	1.003 9	1.003 5	1.003 2
800	1.006 2	1.005 5	1.005 0	1.004 5	1.004 0	1.003 6

Note: D_p is the pressure difference between the operating pressure at the meter (P_{MM}) and the equilibrium vapour pressure (P_e) of LPG at the operating temperature.