I. Field Evaluation and Permanence Tests for Mass Flow Meters

The following tests are considered to be appropriate for mass flow meters:

Type Evaluation

The gravimetric test method shall be used for type evaluation for meters indicating only in units of mass and may be used for meters indicating in units of volume. Meters indicating in only units of volume may be tested using a volumetric standard. Alternatively, transfer standard meters (master meters) may be used for type evaluation for meters indicating in either mass or volume units, provided that the master meter indicates in the appropriate units and is a traceable reference standard in compliance with all the requirements of this policy.

Test Data

Meters tested in a laboratory environment will be tested four times at each of five different flow rates. Use the product available in the laboratory for both the initial and the follow-up evaluation to establish "baseline" data for the meter's performance. A Certificate of Conformance (CC) may be issued for the product(s) tested in the laboratory; however, additional products will not be included until testing is completed with these products. After a "baseline" is obtained, products can be included on the CC by performing three tests at each of four different flow rates in the field for both the initial and follow-up evaluation. If a meter is tested in the field without first determining a "baseline," the meter must undergo four tests at each of five different flow rates; these criteria apply for both the initial and follow-up test.

Following the initial test, the meters will be placed into service for the permanence test. The minimum throughput criterion recommended for these meters are 60 days, or 2000 x maximum rated flow in units per minute. Following the period of use, the tests listed above are to be repeated. All results within the range of flow rates to be included on the certificate of conformance must be within the applicable tolerances. Extended flow range testing performed at the manufacturer's discretion may be included on the certificate of conformance provided the results are within the acceptable tolerances.

Gravimetric Standard

As a general guideline for the gravimetric standard, the value of the scale division should not be larger than one-tenth of the tolerance times the smallest test draft. The combined error of the standard used for testing measuring instruments shall not exceed 20% of the maximum permissible error to be applied. Using known weight (field standard), determine the error present in the weighing instrument over the weighing range that will be used in the test. The inherent error, if present, is to be factored out of the measurement. The scale will then be used as a transfer standard.

The reference scale used in the gravimetric test must be tested immediately prior to testing the mass flow meter. The test should be conducted no earlier than one day prior to the test of the mass flow meter. For example, the laboratory may arrive at the site and conduct the test of the reference scale on the first day and then return the second day to begin testing of the mass flow meter. If at all possible, the reference scale should not be used for other purposes during the testing of the mass flow meter. However, it is recognized that this is not always practical since the scale will often be used at the site for other purposes. If the evaluating laboratory has reason to believe that scale performance has changed (e.g., erratic readings, observed abuse of the scale, etc.) during the conduct of the mass flow meter test, testing of the reference scale should be repeated. If scale performance has changed, any meter tests that have already been performed must be repeated.

If necessary, the reference scale should also be tested after the test of the mass flow meter is completed; this includes testing after completing the series of initial tests in the permanence test and also after completing the series of subsequent tests in a permanence test.

Under no circumstances is the laboratory to accept test results from a prior scale inspection or test. The evaluating laboratory must witness the test of the reference scale, and the test must be conducted at the same time as the testing of the mass flow meter. Accuracy tests of the scale must be conducted with certified, traceable test weights. On the subsequent test of a meter after the permanence period, the reference scale must be retested; scale test results obtained during the initial test of the meter are not sufficient.

Remember that the reference scale serves as your test standard for the mass flow meter test, and you are to make error corrections to your mass flow meter test results based upon the test you perform on the reference scale. Therefore, it is essential to ensure that the standard is correct at all times during the test and to determine the exact errors in the scale in the range of weights where the mass flow meter will be tested.

The Sequence of Testing is To Occur as Follows:

1. Test the reference scale and note the errors in the weight ranges where the meter test will be conducted.
2. Perform initial tests of the mass flow meter.
3. If necessary, test the reference scale to determine that scale performance has not significantly changed.
4. Subject the meter to throughput during the permanence test.
5. Test the reference scale and note errors in the weight ranges where the meter test will be conducted.
6. Perform the subsequent tests of the mass flow meter.
7. If necessary, test the reference scale to determine that scale performance has not significantly changed. It is preferable to have a scale that is dedicated to only NTEP weighing during the evaluation of the meter. The scale shall be reverified if it is used for purposes other than evaluation weighing, or if the maximum time between the initial test and the permanence test exceeds five days.

Additional Considerations:

1. The reference scale should be adjusted to have errors as close to zero as practicable.
2. When weighing individual test drafts, the beginning weight (tare) and ending weight (gross) must both be corrected for scale error at that load range in order to determine the correct net weight for the run.
3. All scale readings should be made using error weights to 0.1 d or using expanded resolution if available. The scale should repeat successive readings of the same load within 0.5 scale divisions. An NTEP approved scale is not required.
4. If reasonably stable readings using error weights cannot be achieved due to wind or other environmental factors, testing should be suspended until such time that stable readings can be achieved.
5. The NTEP Laboratory and the applicant may consider setting the scale up and calibrating with a smaller division or using an expanded resolution mode if available. If the scale is set up and calibrated with a smaller division and the resulting total number of divisions for the scale exceeds the n_{max} allowed for the device, the use of the scale will be restricted to the type evaluation weighings only.
6. To conduct the mass flow meter tests, position the test vessel completely on the scale and in the same position for all weighments.
7. When "semi" tractor/trailer tankers are used, the maximum gross load can be reduced by uncoupling the tractor and weighing only the trailer.
8. The driver should be out of the truck and the engine off whenever weighments are made.
9. The scale shall be within 5 miles of the meter evaluation site unless it is possible to determine fuel consumption and make appropriate corrections for the fuel consumed.

Notes: Measurement Canada requires that the minimum scale division not exceed one fifth of the limit of error for the test draft. Test criteria are being developed for an abbreviated follow-up test.

Test Drafts with a Gravimetric Standard

All test drafts shall meet the following criteria:

The minimum quantity for any test draft shall be equal to or greater than the amount delivered in one minute at the flow rate being tested, and any test draft shall be equal to or greater than ten times the division size of the available reference scale(s) divided by the applicable draft tolerance in percent for the device under test. As a formula:

Minimum draft size ≥10 (scale "d") /Applicable Draft Tolerance for one minutes flow

For example: With a scale division of 0.1 lb (or 1 lb with 10:1 expanded resolution or by using error weights) and an applicable tolerance of 0.2%, the minimum draft must be equal to or greater than 500 lb.

With a scale division of 0.5 lb (or 5 lb with 10:1 expanded resolution / error weights) and an applicable tolerance of 0.3%, the minimum draft must be equal to or greater than 1667 lb.

Transfer Standard Meter (Master Meter) Qualification

Prior to using the master meter for field evaluation testing, traceability of the master meter (master meter) measurements shall be established and documented in one of the two ways described here:

- Calibration in the units (mass or volume) by an independent laboratory that is accredited to ISO17025 standards by a recognized notified body (e.g., NVLAP, A2LA). The documentation of the scope of accreditation of the lab must indicate that the uncertainty of the calibrated master meter measurements, in the units to be tested, is less than or equal to 1/3 of the tolerance allowed for the device in service that is to be tested. The lab used to calibrate the master meter shall maintain and provide on demand the following documentation that will include the following:
    - The date and time of the most recent calibration,
    - the metrological traceability chain linking the master meter calibration to NIST standards,
    - the uncertainty of the calibrated master meter stated in the Scope of Accreditation,
    - the measurement procedures used to calibrate the master meter,
    - the Certificate of Accreditation to ISO 17025 as proof of the technical competence of the lab and its personnel,
    - the master meter calibration test results realized in SI units,
    - the periodic calibration verification schedule and the calibration history of the master meter,
    - the measurement assurance program data for the lab,
    - A statement of compliance with NCWM Publication 14 on the master meter test reports.
- Calibration of a master meter by a lab that is not accredited to ISO17025 may be performed, so long as the calibration is witnessed by the official inspector or evaluator. In cases where the inspector or evaluator witnesses the calibration of the master meter in a lab that is not ISO17025 accredited, the inspector or evaluator must also witness the verification of the gravimetric scales with mass standards traceable to NIST prior to the use of that scale(s) to calibrate the master meter. The uncertainty of the calibration should be documented and approved by the inspector or evaluator as being less than or

equal to 1/3 of the tolerance that is to be tested. The following documentation of the master meter traceability should be included in the report filed by the inspector and or evaluator:

- The date and time of the witnessed calibration,
- the metrological traceability chain linking the master meter to NIST standards,
- the uncertainty of the calibrated master meter,
- the measurement procedures used to calibrate the master meter,
- the observed technical competence of the lab and its personnel,
- the master meter calibration test results realized in SI units.

When the master meter has been shown through testing against traceable standards to have the same calibration configuration values between liquid and gas, the calibration may be done on either liquid or gas, regardless of whether the master meter will be used as a liquid or a gas transfer standard during field evaluation testing.

At the discretion of the inspector or evaluator, calibration verification of the master meter may be required immediately following field evaluation testing. The decision whether to require post-testing calibration verification of the master meter should be based on:

- The time that has passed since the most recent calibration of the master meter
- The past history performance and stability documented for the master meter
- The data collected during the field evaluation (e.g., irregular or unusually close to allowed tolerance)

Test Drafts with a Transfer Standard Meter (Master Meter)

All test drafts shall meet the following criteria:

The minimum quantity for any test draft shall be equal to or greater than the amount delivered in one minute at the flow rate being tested, and any test draft shall be equal to or greater than ten times the MMQ of the master meter.

MMQ testing may be performed with master meters with smaller quantities than required above, provided that MMQ of the master meter is equal to or less than the MMQ of the device being evaluated.

Testing for Volume Units Only or to Add Volume Units to Existing Certificates

In order to add volumetric indications to an existing NTEP Certificate of Conformance (CC) for a meter which already covers mass indications for a meter, the following criteria relative to meter sizes to be covered on the CC must be met:

- At least one meter size must be tested in the volumetric mode.
- If the meter size(s) selected for testing is not already covered on the existing CC, then the request is treated as a submission to add a new meter size (e.g., a permanence test is required and testing must be performed in both the mass and the volume modes of operation.)

Note: During an evaluation of a meter to add volume unit to an existing certificate the tolerance specified in the mass flow meters code is to be applied to both the initial and the final tests. No adjustments may be made

to the meter during this period. This tolerance is to be applied even if different liquid temperatures and pressures exist between the initial and final tests. During the evaluation of a meter for volume units only for a product specific application where a separate product specific NIST Handbook 44 code exists; e.g., LPG, cryogenic liquids, CO2, etc., the appropriate NIST Handbook 44 section for the intended application will be applied.

Determination of performance relative to repeatability, accuracy, and linearity should be performed using accepted statistical methodology. Reference documents include: 1) SAMA Standard PMC 20.1-1973, Process Measurement and Control Terminology; 2) ANSI/ASME MFC-2M-1983, Measurement Uncertainty for Fluid Flow in Closed Conduits; and 3) ANSI/ASME MFC-1M-1979, Glossary of Terms Used in the Measurement of Fluid Flow in Pipes.

Repeatability for Mass Flow Meters (Mass Flow Meters Code Reference T.3.)

When multiples tests are conducted at approximately the same flow rate, the range of the test results for the flow rate shall not exceed:

1. 0.2% for retail liquid motor fuel devices. AND
2. 40% of the applicable tolerance for all other devices listed in Table T.2. of the Mass Flow Meters Code.

Note: The normal test of a mass flow metering system shall be made at the maximum discharge rate developed under the conditions of the installation. Any additional tests conducted at flow rates down to and including the rated minimum discharge flow rate shall be considered normal tests. (Code reference N.6.) Special test tolerances shall apply to tests such as a split compartment test conducted to develop operating characteristic of the measuring systems.

Testing for Multi-Product Applications

Multi-product applications (that is, applications in which the meter will be used without a change to zero or calibration to dispense different products which vary in specific gravity by more than 0.1) must include a multi-product test. The multi-product initial test will be performed on the meter without a change to zero or calibration using multiple products having a difference in specific gravity of at least 0.2. For devices which will be used to dispense multiple products having a specific gravity range greater than 0.2, the multi-product testing must be performed over the anticipated range before multi-product applications will be included on the CC. For the multi-product testing, throughput testing will be performed on one or a combination of the products; testing for the subsequent test will be conducted on both products without a change to zero or calibration. The CC for a mass flow meter will cover multi-product applications where the specific gravity of a single product, or multiple products, varies by the amount tested throughout the entire approved specific gravity range of the meter.

Example: Where a meter has been tested and a certificate issued for multi-product with one liquid having a specific gravity of 0.7 and another liquid having a specific gravity of 1.0 and the meter is subsequently tested to expand the range with a liquid having a specific gravity of 1.6 the allowed variation of densities covered by the CC will be from 0.7 through 1.6. Multi-product testing requirements do not apply to meters used to dispense a product such as propane in which the density varies in normal operation.

Additional Considerations for Testing Mass Flow Meters Dispensing Compressed Natural Gas (CNG)

1. Ideally, the device should be tested over a temperature range. Because this is not possible to easily regulate in the field, to observe any effects of temperature changes test early in the day and then again later in the day.

   Note: The evaluating laboratory should attempt to test at as wide a temperature range as possible; however, it is recognized that this may not always be possible and, in some cases, little or no variation in temperature will be experienced.

2. The magnitude of the draft (and, therefore, the time required for delivery) may impact upon the test results. For very small drafts, the start and stop effects can become significant and may result in large variability. Because CNG stations are presently few and far between in some areas, it is anticipated that these devices will be heavily used to "top off" tanks. Consequently, the minimum measured quantity declared for the device can be significant. It is desirable to have at least some tests run at or near the minimum measured quantity.
3. In setting up the arrangements for testing, the resolution of the scale relative to the test draft must be considered and "rounding error" of the scale must be kept to an acceptably small level. As a general guideline, the value of the scale division should not exceed one-tenth of the tolerance applied to the device. Either a high-resolution scale is needed; error weights should be used; or a larger test draft selected. A combination of these approaches may be used. The total error of the transfer standard must be limited to less than one-third of the tolerance. Therefore, the scale must be thoroughly tested; the repeatability of the scale verified; and corrections made to the results of the meter test to correct for any errors determined during the scale test.
4. The repeatability of the test results must be within 40% of the absolute value of the maintenance tolerance and the results of each test shall be within the applicable tolerances.

   Tests for repeatability shall include a minimum of three consecutive test drafts of approximately the same size and be conducted under controlled conditions where variations in factors, such as temperature, pressure, and flow rate, are reduced to the extent that they will not affect the results obtained.
5. Repeat tests should be run over a range of flows or, because the device may operate at only one flow in the field installation, over a range of quantities.
6. The typical tank size being filled by the device will be 7-10 kg (16-20 lb.) A very large tank size may be 20 kg (40 lb) if a vehicle is equipped with two tanks. The average amount dispensed will probably be around 4 kg (8 lb).
7. Because the zero changes with temperature, the zero must be sealable as noted in the Mass Flow Meters Code in *NIST Handbook 44*. CNG meters must indicate on the basis of mass, with the computation of total sale based on mass units. Supplemental units may be used in addition to the mass units; however, these must be clearly identified as supplementary units. It is suggested that conversion charts be provided to explain to the consumer how the conversion factor for the supplemental units is derived.

The Following Tests are Considered Appropriate for CNG Dispensers:

1. Normal Test (Code References S.3.7., N.4., N.6.1., T.2. and T.3.)

Computer Jump:

- Remove nozzle from dispenser and connect to test cylinder. (Test cylinder pressure should not be greater than 200 psi to simulate an actual delivery.)
- Turn nozzle valve from "OFF" position to "FILL" position.
- Empty discharge hose.
- Turn nozzle valve to "OFF" position.

- Activate dispenser.
- Observe dispenser indications, if computer jump occurs, take appropriate action.

Note: A test cylinder is not necessary for the computer jump test on dispensers equipped with an autovent system. To test, turn dispenser on and observe the indication display for computer jump when the dispenser shuts off.

Minimum Test Drafts are as Follows:

- Place empty test cylinder on the scale.
- Access mass display of the dispenser.
- Tare weight of the test cylinder, chocks and stand.
- Connect the nozzle to the test cylinder.
- Fill the test cylinder to 1/3 capacity full at maximum flow rate.
- Disconnect the nozzle from the test cylinder.
- Compare mass display to scale indication.
- Determine dispenser error. (Code Reference T.2.)
- Leave product in test cylinder.
- Tare the weight of the test cylinder, chocks and stand.
- Connect the nozzle to the test cylinder.
- Begin the fill operation with product in the cylinder; fill cylinder to 2/3 capacity at maximum flow rate.
- Disconnect the nozzle from the test cylinder.
- Compare mass display to scale indication.
- Determine dispenser error. (Code Reference T.2.)
- Tare the weight of the test cylinder, chocks, and stand.
- Connect the nozzle to the test cylinder.
- Begin the fill operation with product in the cylinder; fill cylinder to capacity at maximum flow rate.
- Disconnect the nozzle from the test cylinder.
- Compare mass display to scale indication.
- Determine dispenser error. (Code Reference T.2.)
- Return product to owner/operator of dispenser. (Code Reference UR.3.8.)
- Place empty test cylinder on scale (scale may be supported by chocks and stand.)
- Tare the weight of the test cylinder, chocks, and stand.
- Connect the nozzle to the test cylinder.
- Fill test cylinder to capacity at maximum flow rate.
- Disconnect the nozzle from the test cylinder.
- Compare mass display to scale indication.
- Determine dispenser error. (Code Reference T.2.)
- Return product to owner/operator of dispenser.
- Repeating previous tests. (Code Reference T.3.(a))
- Applicable tolerance for multiple tests at the same flow rate.
- Return product to owner/operator of dispenser.
- If the meter minimum measured quantity (MMQ) is less than the smallest test draft, conduct a test at the MMQ value. (Code Reference N.4.)

Note: If 300 divisions (d) or 2.27 kilograms (5 pounds) is greater than 1/3 of the test cylinder capacity, then the test cylinder should be emptied to accommodate a delivery of at least 300 d or 2.27 kilograms (5 pounds) otherwise a larger tank is necessary.

2. Check effectiveness of zero-setback interlock. (Code References S.3.8., UR3.6. and UR.3.7.
    - No subsequent delivery until indicating and recording element returned to zero.
    - After delivery is complete the dispenser starting lever (mechanism) is shutoff, interlock engaged, and discharge nozzle is in the designed hanging position. Note: This does not apply to nozzle control.
    - Remove nozzle from hanging position.
    - Reset computer to zero and turn on dispenser.
    - Attempt to return the nozzle to its designed hanging position, carefully remove nozzle and connect it to the test tank and open valve. Move the dispenser starting lever (mechanism) to "ON" position and attempt to dispense product. Note: This does not apply to nozzle control.
    - Product should not flow without resetting the indications to zero.
3. Check operation of low-flow cut-off valve . (Code Reference UR.2.3.)
    - Valve shall not be set lower than the minimum flow rate.
    - Valve stops registration when flow is below the low-flow cut-off value.
    - Connect nozzle to empty test tank and dispense product. Slowly throttle down on the valve on the test tank to the minimum attainable flow rate. Product delivery should not occur below the mass flow meter minimum flow rate.
4. Power loss test. (Code References S.2.4.1. and S.2.4.2.)
    - Transaction in progress at power loss, information shall be retainable for 15 minutes.
    - Device memory shall retain quantity of product and sales price during power loss.
    - Security seal--apply wire security seal to secure adjusting mechanism (if applicable.)
    - (Code References G-UR.4.5. and S.3.5.)
    - Note on the official report the number of gasoline gallon equivalents of product dispensed during the test.
    - After all equipment at a location has been tested, review results to determine compliance with equipment maintenance and use of adjustments. (Code Reference G-UR.4.1. and G-UR.4.3.)