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Section 3.34. Cryogenic Liquid-Measuring Devices

A. Application

A.1. General. – This code applies to devices used for the measurement of cryogenic liquids such as, but not limited to oxygen, nitrogen, hydrogen, and argon.

(Amended 1986 and 1995)

A.2. Exceptions. – This code does not apply to the following:

- (a) Devices used for dispensing liquefied petroleum gases (for which see Section 3.32. Code for Liquefied Petroleum Gas and Anhydrous Ammonia Liquid-Measuring Devices).
- (b) Devices used solely for dispensing a product in connection with operations in which the amount dispensed does not affect customer charges.
- (c) Devices used solely for dispensing liquefied natural gas.
- (d) Mass flow meters. (Also see Section 3.37. Code for Mass Flow Meters.)

(Added 1994)

A.3. Additional Code Requirements. – In addition to the requirements of this code, Cryogenic Liquid-Measuring Devices shall meet the requirements of Section 1.10. General Code.

S. Specifications

S.1. Design of Indicating and Recording Elements and of Recorded Representations.

S.1.1. Primary Elements.

S.1.1.1. General. – A device shall be equipped with a primary indicating element and may also be equipped with a primary recording element.

S.1.1.2. Units. – A device shall indicate and record, if equipped to record, its deliveries in terms of: kilograms or pounds; liters or gallons of liquid at the normal boiling point of the specific cryogenic product; cubic meters (cubic feet) of gas at a normal temperature of 21 °C (70 °F) and an absolute pressure of 101.325 kPa (14.696 psia); or decimal subdivisions or multiples of the measured units cited above.

(Amended 2002)

S.1.1.3. Value of Smallest Unit. – The value of the smallest unit of indicated delivery, and recorded delivery, if the device is equipped to record, shall not exceed the equivalent of:

(a) for small delivery devices:

- (1) 1 L;
- (2) 0.1 gal;
- (3) 1 kg;
- (4) 1 lb;

- (5) 0.1 m³ of gas; or
 - (6) 10 ft³ of gas.
- (b) for large delivery devices:
- (1) 10 L;
 - (2) 1 gal;
 - (3) 10 kg;
 - (4) 10 lb;
 - (5) 1 m³ of gas; or
 - (6) 100 ft³ of gas.

(Amended 2002)

S.1.1.4. Advancement of Indicating and Recording Elements. – Primary indicating and recording elements shall be susceptible to advancement only by the normal operation of the device. However, a device may be cleared by advancing its elements to zero, but only if:

- (a) the advancing movement, once started, cannot be stopped until zero is reached; or
- (b) in the case of indicating elements only, such elements are automatically obscured until the elements reach the correct zero position.

S.1.1.5. Return to Zero. – Primary indicating and recording elements shall be readily returnable to a definite zero indication. Means shall be provided to prevent the return of primary indicating elements and of primary recording elements beyond their correct zero position.

S.1.2. Graduations.

S.1.2.1. Length. – Graduations shall be so varied in length that they may be conveniently read.

S.1.2.2. Width. – In any series of graduations, the width of a graduation shall in no case be greater than the width of the minimum clear interval between graduations, and the width of main graduations shall be not more than 50 % greater than the width of subordinate graduations. Graduations shall in no case be less than 0.2 mm (0.008 in) in width.

S.1.2.3. Clear Interval Between Graduations. – The clear interval shall be no less than 1.0 mm (0.04 in). If the graduations are not parallel, the measurement shall be made:

- (a) along the line of relative movement between the graduations at the end of the indicator; or
 - (b) if the indicator is continuous, at the point of widest separation of the graduations.
- (Also see S.1.3.6. Travel of Indicator.)

S.1.3. Indicators.

S.1.3.1. Symmetry. – The index of an indicator shall be symmetrical with respect to the graduations, at least throughout that portion of its length associated with the graduations.

S.1.3.2. Length. – The index of an indicator shall reach to the finest graduations with which it is used, unless the indicator and the graduations are in the same plane, in which case the distance between the end

of the indicator and the ends of the graduations, measured along the line of the graduations, shall be not more than 1.0 mm (0.04 in).

S.1.3.3. Width. – The width of the index of an indicator in relation to the series of graduations with which it is used shall be not greater than the:

- (a) *width of the narrowest graduation;* and*
*[*Nonretroactive as of January 1, 2002]*
 (Amended 2001)
- (b) width of the minimum clear interval between graduations.

When the index of an indicator extends along the entire length of a graduation, that portion of the index of the indicator that may be brought into coincidence with the graduation shall be of the same width throughout the length of the index that coincides with the graduation.

S.1.3.4. Clearance. – The clearance between the index of an indicator and the graduations shall in no case be more than 1.5 mm (0.06 in).

S.1.3.5. Parallax. – Parallax effect shall be reduced to the practicable minimum.

S.1.3.6. Travel of Indicator. – If the most sensitive element of the primary indicating element uses an indicator and graduations, the relative movement of these parts corresponding to the smallest indicated value shall be not less than 0.5 mm (0.20 in).

S.1.4. Computing-Type Device.

S.1.4.1. Printed Ticket. – Any printed ticket issued by a device of the computing type on which there is printed the total computed price shall have printed clearly thereon also the total quantity of the delivery and the price per unit.

S.1.4.2. Money-Value Computations. – Money-value computations shall be of the full-computing type in which the money-value at a single unit price, or at each of a series of unit prices, shall be computed for every delivery within either the range of measurement of the device or the range of the computing elements, whichever is less. Value graduations shall be supplied and shall be accurately positioned. The total price shall be computed on the basis of the quantity indicated when the value of the smallest division indicated is equal to or less than the values specified in S.1.1.3. Value of Smallest Unit.

S.1.4.3. Money-Values, Mathematical Agreement. – Any digital money-value indication and any recorded money-value on a computing type device shall be in mathematical agreement with its associated quantity indication or representation to within 1 cent of money-value.

S.2. Design of Measuring Elements.

S.2.1. Vapor Elimination. – A measuring system shall be equipped with an effective vapor eliminator or other effective means to prevent the measurement of vapor that will cause errors in excess of the applicable tolerances. (Also see Section T. Tolerances.)

S.2.2. Directional Flow Valves. – A valve or valves or other effective means, automatic in operation, to prevent the reversal of flow shall be installed in or adjacent to the measuring device.
 (Amended 1978)

S.2.3. Maintenance of Liquid State. – A device shall be so designed that the product being measured will remain in a liquid state during passage through the device.

S.2.4. Automatic Temperature or Density Compensation. – A device shall be equipped with automatic means for adjusting the indication and/or recorded representation of the measured quantity of the product, to indicate and/or record in terms of: kilograms or pounds; or liters or gallons of liquid at the normal boiling point of the specific cryogenic product; or the equivalent cubic meters (cubic feet) of gas at a normal temperature of 21 EC (70 EF) and an absolute pressure of 101.325 kPa (14.696 lb/in² absolute). *When a compensator system malfunctions, the indicating and recording elements may indicate and record in uncompensated volume if the mode of operation is clearly indicated, e.g., by a marked annunciator, recorded statement, or other obvious means.**

*[*Nonretroactive as of January 1, 1992]*

(Amended 1991 and 2002)

S.2.5. Provision for Sealing. – Adequate provision shall be made for an approved means of security (e.g., data change audit trail) or for physically applying a security seal in such a manner that requires the security seal to be broken before an adjustment or interchange may be made of:

- (a) any measuring or indicating element;
- (b) any adjustable element for controlling delivery rate when such rate tends to affect the accuracy of deliveries;
- (c) any automatic temperature or density compensating system; and
- (d) any metrological parameter that will affect the metrological integrity of the device or system.

When applicable, any adjusting mechanism shall be readily accessible for purposes of affixing a security seal.

*[Audit trails shall use the format set forth in Table S.2.5. Categories of Device and Methods of Sealing]**

*[*Nonretroactive as of January 1, 1995]*

(Amended 2006)

Table S.2.5. Categories of Device and Methods of Sealing	
Categories of Device	Methods of Sealing
Category 1: <i>No remote configuration capability.</i>	<i>Seal by physical seal or two event counters: one for calibration parameters and one for configuration parameters.</i>
Category 2: <i>Remote configuration capability, but access is controlled by physical hardware.</i> <i>The device shall clearly indicate that it is in the remote configuration mode and record such message if capable of printing in this mode or shall not operate while in this mode.</i>	<i>The hardware enabling access for remote communication must be on-site. The hardware must be sealed using a physical seal or an event counter for calibration parameters and an event counter for configuration parameters. The event counters may be located either at the individual measuring device or at the system controller; however, an adequate number of counters must be provided to monitor the calibration and configuration parameters of the individual devices at a location. If the counters are located in the system controller rather than at the individual device, means must be provided to generate a hard copy of the information through an on-site device.</i>
Category 3: <i>Remote configuration capability access may be unlimited or controlled through a software switch (e.g., password).</i> <i>The device shall clearly indicate that it is in the remote configuration mode and record such message if capable of printing in this mode or shall not operate while in this mode.</i>	<i>An event logger is required in the device; it must include an event counter (000 to 999), the parameter ID, the date and time of the change, and the new value of the parameter. A printed copy of the information must be available through the device or through another on-site device. The event logger shall have a capacity to retain records equal to 10 times the number of sealable parameters in the device, but not more than 1000 records are required. (Note: Does not require 1000 changes to be stored for each parameter.)</i>

[Nonretroactive as of January 1, 1995]

(Table Added 2006)

S.3. Design of Discharge Lines and Discharge Line Valves.

S.3.1. Diversion of Measured Liquid. – No means shall be provided by which any measured liquid can be diverted from the measuring chamber of the device or the discharge line therefrom, except that a manually controlled outlet that may be opened for purging or draining the measuring system shall be permitted. Effective means shall be provided to prevent the passage of liquid through any such outlet during normal operation of the device and to indicate clearly and unmistakably when the valve controls are so set as to permit passage of liquid through such outlet.

S.3.2. Discharge Hose. – The discharge hose of a measuring system shall be of the completely draining dry-hose type.

S.4. Marking Requirements.

S.4.1. Limitation of Use. – If a measuring system is intended to measure accurately only liquids having particular properties, or to measure accurately only under specific installation or operating conditions, or to

measure accurately only when used in conjunction with specific accessory equipment, these limitations shall be clearly and permanently marked on the device.

S.4.2. Discharge Rates. – A meter shall be marked to show its designed maximum and minimum discharge rates.

S.4.3. Temperature or Density Compensation. – Devices equipped with an automatic temperature or density compensator, shall be clearly and conspicuously marked on the primary indicating elements, recording elements, and recorded representations to show that the quantity delivered has been adjusted to the conditions specified in S.2.4. Automatic Temperature or Density Compensation.

N. Notes

N.1. Test Liquid. – A meter shall be tested with the liquid to be commercially measured except that, in a type evaluation examination, nitrogen may be used.

N.2. Vaporization and Volume Change. – Care shall be exercised to reduce to a minimum vaporization and volume changes. When testing by weight, the weigh tank and transfer systems shall be pre-cooled to liquid temperature prior to the start of the test to avoid the venting of vapor from the vessel being weighed.

N.3. Test Drafts.

N.3.1. Gravimetric Test. – Weight test drafts shall be equal to at least the amount delivered by the device in 2 minutes at its maximum discharge rate, and shall in no case be less than 907 kg (2000 lb).

N.3.2. Transfer Standard Test. – When comparing a meter with a calibrated transfer standard, the test draft shall be equal to at least the amount delivered by the device in two minutes at its maximum discharge rate, and shall in no case be less than 180 L (50 gal) or equivalent thereof. When testing uncompensated volumetric meters in a continuous recycle mode, appropriate corrections shall be applied if product conditions are abnormally affected by this test mode.

(Amended 1976)

N.4. Density. – Temperature and pressure of the metered test liquid shall be measured during the test for the determination of density or volume correction factors when applicable. For Liquid Density and Volume Correction Factors (with respect to temperature and pressure) the publications shown in Table N.4. Density or Volume Correction Factors shall apply.

(Amended 1986 and 2004)

Table N.4. Density or Volume Correction Factors	
Cryogenic Liquid	Publication
Argon	Tegeler, Ch., Span, R., Wagner, W. “A New Equation of State for Argon Covering the Fluid Region for Temperatures from the Melting Line to 700 K at Pressures up to 1000 Mpa.” <i>J. Phys. Chem. Ref. Data</i> , 28(3):779-850, 1999.
Ethylene	Smukala, J., Span, R., Wagner, W. “New Equation of State for Ethylene Covering the Fluid Region for Temperatures from the Melting Line to 450 k at Pressures up to 300 Mpa.” <i>J. Phys. Chem. Ref. Data</i> , 29(5):1053-1122, 2000.
Nitrogen	Span, R., Lemmon, E.W., Jacobsen, R.T, Wagner, W., and Yokozeki, A. “A Reference Thermodynamic Property Formulation for Nitrogen.” <i>J. Phys. Chem. Ref. Data</i> , Volume 29, Number 6, pp. 1361-1433, 2000.
Oxygen	Schmidt, R., Wagner, W. “A New Form of the Equation of State for Pure Substances and its Application to Oxygen.” <i>Fluid Phase Equilib.</i> , 19:175-200, 1985
Hydrogen	Leachman, J. W., Jacobsen, R. T., Lemmon, E.W., and Penoncello, S.G. “Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen” <i>J. Phys. Chem. Ref. Data</i> , Volume 38, Number 3, pp. 565, 2009.
<p>Note: A complete database program containing all of the most recent equations for calculating density for various cryogenic liquids is available at www.nist.gov/srd/nist23.cfm. There is a fee for download of this database.</p>	

(Added 2004)

N.5. Testing Procedures.

N.5.1. Normal Tests. – The “normal” tests of a device shall be made over a range of discharge rates that may be anticipated under the conditions of installation.

N.5.1.1. Repeatability Tests. – Tests for repeatability should 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.

(Added 2001)

N.5.2. Special Tests. – Any test except as set forth in N.5.1. Normal Tests shall be considered a “special” test. Tests shall be conducted, if possible, to evaluate any special elements or accessories attached to or associated with the device. A device shall be tested at a minimum discharge rate of:

- (a) 50 % of the maximum discharge rate developed under the conditions of installation, or the minimum discharge rate marked on the device, whichever is less; or
- (b) the lowest discharge rate practicable under conditions of installation.

Special tests may be conducted to develop any characteristics of the device that are not normally anticipated under the conditions of installation.

N.6. Temperature Correction. – Corrections shall be made for any changes in volume resulting from the differences in liquid temperature between time of passage through the meter and time of volumetric determination of test draft.

N.7. Automatic Temperature or Density Compensation. – When a device is equipped with an automatic temperature or density compensator, the compensator shall be tested by comparing the quantity indicated or recorded by the device (with the compensator connected and operating) with the actual delivered quantity corrected to the normal boiling point of the cryogenic product being measured or to the normal temperature and pressure as applicable.

T. Tolerances

T.1. Application.

T.1.1. To Underregistration and to Overregistration. – The tolerances hereinafter prescribed shall be applied to errors of underregistration and errors of overregistration.

T.2. Tolerance Values. – The maintenance and acceptance tolerances for normal and special tests shall be as shown in Table T.2. Accuracy Classes and Tolerances for Cryogenic Liquid-Measuring Devices.

(Amended 2003)

Accuracy Class	Application	Acceptance Tolerance	Maintenance Tolerance	Special Test Tolerance
2.5	Cryogenic products; liquefied compressed gases other than liquid carbon dioxide	1.5 %	2.5 %	2.5 %

(Added 2003)

T.3. On Tests Using Transfer Standards. – To the basic tolerance values that would otherwise be applied, there shall be added an amount equal to two times the standard deviation of the applicable transfer standard when compared to a basic reference standard.

(Added 1976)

T.4. Repeatability. – When multiple tests are conducted at approximately the same flow rate and draft size, the range of the test results for the flow rate shall not exceed 40 % of the absolute value of the maintenance tolerance and the results of each test shall be within the applicable tolerance. Also see N.5.1.1. Repeatability Tests.

(Added 2001)

UR. User Requirements

UR.1. Installation Requirements.

UR.1.1. Discharge Rate. – A device shall be so installed that the actual maximum discharge rate will not exceed the rated maximum discharge rate. If necessary, means for flow regulation shall be incorporated in the installation.

UR.1.2. Length of Discharge Hose. – The discharge hose shall be of such a length and design as to keep vaporization of the liquid to a minimum.

UR.1.3. Maintenance of Liquid State. – A device shall be so installed and operated that the product being measured shall remain in the liquid state during passage through the meter.

UR.2. Use Requirements.

UR.2.1. Return of Indicating and Recording Elements to Zero. – The primary indicating elements (visual) and the primary recording elements shall be returned to zero immediately before each delivery.

UR.2.2. Condition of Discharge System. – The discharge system, up to the measuring element, shall be precooled to liquid temperatures before a “zero” condition is established prior to the start of a commercial delivery.

UR.2.3. Vapor Return Line. – A vapor return line shall not be used during a metered delivery.
(Amended 1976)

UR.2.4. Drainage of Discharge Line. – On a dry-hose system, upon completion of a delivery, the vendor shall leave the discharge line connected to the receiving container with the valve adjacent to the meter in the closed position and the valve at the discharge line outlet in the open position for a period of at least:

- (a) 1 minute for small delivery devices; and
- (b) 3 minutes for large delivery devices

to allow vaporization of some product in the discharge line to force the remainder of the product in the line to flow into the receiving container.

(Amended 1976)

UR.2.5. Conversion Factors. – Established conversion values (Also see references in Table N.4. Density or Volume Correction Factors.) shall be used whenever metered liquids are to be billed in terms of:

- (a) kilograms or pounds based on a meter indication of liters, gallons, cubic meters of gas, or cubic feet of gas;
- (b) cubic meters or cubic feet of gas based on a meter indication of liters or gallons, kilograms, or pounds; or
- (c) liters or gallons based on a meter indication of kilograms or pounds, cubic meters of gas or cubic feet of gas.

All sales of cryogenics shall be based on either kilograms or pounds, liters or gallons of liquid at NBP¹, cubic meters of gas or cubic feet of gas at NTP¹.

(Amended 1986)

UR.2.6. Temperature or Density Compensation.

UR.2.6.1. Use of Automatic Temperature or Density Compensators. – If a device is equipped with an automatic temperature or density compensator, this shall be connected, operable, and in use at all times. Such automatic temperature or density compensator may not be removed, nor may a compensated device be replaced with an uncompensated device, without the written approval of the weights and measures authority having jurisdiction over the device.

UR.2.6.2. Tickets or Invoices. – Any written invoice or printed ticket based on a reading of a device that is equipped with an automatic temperature or density compensator shall have shown thereon that the

¹ See Appendix D, Definitions.

quantity delivered has been adjusted to the quantity at the NBP of the specific cryogenic product or the equivalent volume of gas at NTP.

UR.2.6.3. Printed Ticket. – Any printed ticket issued by a device of the computing type on which there is printed the total computed price, the total quantity of the delivery, or the price per unit, shall also show the other two values (either printed or in clear hand script).

UR.2.6.4. Ticket in Printing Device. – A ticket shall not be inserted into a device equipped with a ticket printer until immediately before a delivery is begun, and in no case shall a ticket be in the device when the vehicle is in motion while on a public street, highway, or thoroughfare.

UR.2.7. Pressure of Tanks with Volumetric Metering Systems without Temperature Compensation. – When the saturation pressure of the product in the vendor's tank exceeds 240 kPa (35 psia), a correction shall be applied to the written invoice or printed ticket using the appropriate tables as listed in Table N.4. Density or Volume Correction Factors; or the saturation pressure shall be reduced to 207 kPa (30 psia) (if this can be safely accomplished) prior to making a delivery.

(Added 1976)