B339-02
Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

Update No. 2
CAN/CSA-B339-02
February 2005

Note: *General Instructions for CSA Standards are now called Updates. Please contact CSA Information Products Sales or visit* ***www.ShopCSA.ca*** *for information about the* ***CSA Standards Update Service****.*

Title: *Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods* — originally published October 2002

Revisions issued: Update No. 1 — November 2003

If you are missing any General Instruction or Update, please contact CSA Information Products Sales or visit ***www.ShopCSA.ca****.*

The following revisions have been formally approved and are marked by the symbol delta (Δ) in the margin on the attached replacement pages:

Revised	Contents and Clauses 2, 5.9.3, 6.10.3, 8.5, 12.8.1, 15.8.1, 16.9.1, 20.3.1(b), 22.10.1, 23.9.1, 23.9.2(e), 24.2.2.3, 24.2.5, 24.6.1.1, 24.6.4.1, and 24.7.1
New	Clauses 5.9.4 and 6.10.4
Deleted	None

CAN/CSA-B339-02 originally consisted of **140 pages** (xv preliminary and 125 text), each dated **October 2002**. It now consists of the following pages:

October 2002	xiii–xv, 1, 2, 5–18, 21, 22, 25, 26, 29–42, 45–50, 55–60, 63–68, 71–74, 81–84, and 89–125
November 2003	Cover, title page, and copyright page
February 2005	iii–xii, 3–4A, 19–20A, 23–24A, 27, 28, 43, 44, 51–54, 61, 62, 69, 70, 75–80, and 85–88A

- Update your copy by inserting these revised pages.
- Keep the pages you remove for reference.

Δ Contents

Technical Committee on Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

M.F. Chell	Chell Engineering Services Inc., Fenelon Falls, Ontario	*Chair*
J. Wedding	Harsco Corporation: Gas & Fluid Control Group, Huntsville, Alabama, USA	*Vice-Chair*
M. Abdelli	Air Liquide Canada Inc., Montréal, Québec	
R. Awad	Régie du bâtiment du Québec, Montréal, Québec	
W.L. Birch	Luxfer Gas Cylinders, Riverside, California, USA	
D. Carter	Intertek Testing Services NA Ltd., Mississauga, Ontario	
G. Denison	DuPont Canada Inc., Streetsville, Ontario	
J. Dimmick	Pressed Steel Tank Company Inc., West Allis, Wisconsin, USA	
R.O. Dowling	CP Industries Incorporated, McKeesport, Pennsylvania, USA	*Associate*
S. Gentry	Worthington Cylinder Corporation, Columbus, Ohio, USA	
G. Giles	Giles Tool Agencies Limited, Scarborough, Ontario	*Associate*
C. Hall	Harsco Corporation: Gas & Fluid Control Group, Harrisburg, Pennsylvania, USA	*Associate*
B. Jeary	Dynetek Industries Ltd., Calgary, Alberta	*Associate*
M. Julien	Messer Canada, Mississauga, Ontario	
R. Lalonde	Praxair Canada Inc., St-Laurent, Québec	
K.T. Lau	Alberta Boilers Safety Association, Edmonton, Alberta	
C. Macey	Bruin Engineered Parts Incorporated, Midland, Ontario	

Minister — the Minister of Transport for Canada.

Noncorrosive — chemically and metallurgically compatible with the container such that the pressure-retaining integrity of the container is not adversely affected under the conditions of containment.

Nonrefillable container — a container that can be filled only once for the transportation of dangerous goods.

Plugged cylinder — a cylinder, the bottom end of which has been spun closed and permanently sealed by a threaded plug.

Pressure of contents — the sum of the partial pressures of all the commodities shipped in a single container, less one atmosphere (gauge pressure).

Pressure-relief device — a device intended to release the pressure in a container in the event of accidental overpressure or exposure to fire.

Product analysis — a chemical analysis of the semi-finished or finished material to determine conformance with the requirements of a specification.

Rebuilt container — a container subjected to a major repair, including any one or a combination of the following procedures:
(a) the repair of a welded pressure-retaining seam, where the repair welds exceed 75 mm in length or are spaced by less than 75 mm between the termination of one weld and the beginning of the next weld;
(b) the repair of a welded or brazed attachment joint to a pressure-retaining part involving welds or brazed joints that exceed 75 mm in length or are spaced by less than 75 mm between the termination of one joint and the beginning of the next joint;
(c) the replacement of a pressure-retaining component; and
(d) for series-8 cylinders, the replacement of the porous filler.

Δ **Reclaimed refrigerant gas** — used refrigerant gas processed to new product specifications.

Δ **Recovered refrigerant gas** — refrigerant gas, in any condition, removed from a system.

Δ **Recycled refrigerant gas** — used refrigerant gas processed to reduce contaminants by separating oil, removing noncondensables, and reducing moisture, acidity, and particulate matter to the levels specified in the Air-Conditioning and Refrigeration Institute publication IRG-2, *Handling and Reuse of Refrigerants in the United States* (1994).

Registered mark — the symbols or trademarks, or both, that have been registered with the Director and used in the marking of cylinders, spheres, and tubes as prescribed in this Standard.

Regulations — Regulations, pursuant to the *Transportation of Dangerous Goods Act,* Chapter 34, Statutes of Canada, 1992.

Rejected cylinder, sphere, or tube — a container not permitted for the transportation of dangerous goods unless reprocessed.

Repaired container — a container subjected to a repair involving welding or brazing but excluding any procedure listed under the definition of a rebuilt container.

Representative sample — a sample selected from a lot for testing that is expected to exhibit similar properties as the rest of the lot.

Seamless container (cylinder or **tube)** or **shell** — a one-piece container or shell that does not contain any line of juncture.

Series-3 container — a cylinder or a tube manufactured to a specification the designation of which starts with number 3.

Series-4 container — a cylinder or a sphere manufactured to a specification the designation of which starts with number 4.

Series-8 cylinder — a cylinder manufactured to a specification the designation of which starts with number 8.

Service pressure — the rated pressure marked on the container.
Note: *Containers designed and manufactured to this Standard have their service pressure marked in bar.*

Service temperature — the lowest content temperature for which an insulated cylinder is designed.

Specification — the complete description of the manufacturing requirements for a cylinder, sphere, or tube under a specific designation, eg, 4AAM33 or 4BWM.
Note: *The prefix of the specification designation (TC, CTC, etc.) identifies the regulatory authority responsible at the time of the manufacture of the container.*

Sphere — a container of spherical shape with a water capacity not greater than 45.4 L designed to withstand an internal pressure greater than 275 kPa (absolute).

Spun cylinder — a cylinder that has been welded closed at one end by the spinning process, without the addition of weld metal.

Tare of container — the mass of a container plus the mass of its valve(s).

Transportation — any mode of conveying dangerous goods on land (including rail and highway) or water or in air.

Tube — a seamless container of cylindrical shape with a water capacity greater than 450 L designed to withstand an internal pressure equal to or greater than 12.4 MPa.

Water capacity — the total mass or volume of water a container can hold at 15°C and at a pressure of 101.325 kPa (absolute).

3. Reference Publications

This Standard refers to the following publications and where such reference is made it shall be to the edition listed below, including all amendments published thereto. Where foreign standards are referenced, only the technical content applies. Except for the Canadian Regulations, where there is a variance with this Standard, the requirements of this Standard shall prevail. Users of this Standard are advised against attempting direct application of any of the following reference publications without carefully observing this Standard's reference to that Standard, Specification, or Code.
Note: *See Appendix A for information on the reference organizations.*

CSA Standards
B340-02,
Selection and Use of Cylinders, Spheres, Tubes, and Other Containers for the Transportation of Dangerous Goods, Class 2;

CAN/CSA-Z94.4-93 (R1997),
Selection, Use, and Care of Respirators.

The Aluminum Association
Aluminum Standards and Data, 2000 Edition.

defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test.

(f) The bottoms of bumped-back cylinders manufactured from tubing shall have a minimum thickness not less than 2 times the minimum design wall thickness. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.

(g) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of container) to minor axis not exceeding 2:1, or a dished shape falling within these two limits. Such ends shall have a minimum thickness not less than the minimum design wall thickness, except that

(i) the point of closure of cylinders closed by spinning shall not be less than 2 times the minimum design wall thickness; and

(ii) hemispherical ends drawn from sheet or plate shall have a thickness not less than 90% of the minimum design wall thickness.

(h) Other bottom designs shall be permitted, provided that

(i) each design has been qualified by the cycling test; and

(ii) detail information of the bottom design is available to the independent inspector.

5.6 Welding or Brazing

5.6.1 Cylinders

Fusion welding or brazing shall be permitted only for the attachment of neck rings and foot rings, which are nonpressure parts, and then only to the ends of cylinders having a service pressure of 3.5 MPa or less. Where welding is used, TC-3AM cylinders, neck rings, and foot rings shall be made of weldable steel with a carbon content not exceeding 0.25%. For TC-3ANM cylinders, welding rod shall be nickel. For TC-3ASM cylinders, welding rod shall be austenitic stainless steel.

5.6.2 Tubes

Welding or brazing shall be prohibited.

5.7 Heat Treatment

5.7.1 General

The completed containers shall be heat-treated.

5.7.2 Cylinders

5.7.2.1

Cylinders made from Grade A steel may be stress-relieved at a temperature not lower than 593°C. Cylinders made from Grades B and C steel shall be normalized at a metal temperature most suitable for the material grade. Liquid quenching of cylinders shall be prohibited.

5.7.2.2

Cylinders made from Grade H stainless steel shall be heat-treated to achieve the mechanical properties required in Clause 5.8.3 and at a temperature that prevents the formation of deleterious phases.

5.7.2.3

Cylinders made from Grade I nickel shall be heated to a metal temperature above 510°C for sufficient time to produce the specified mechanical properties. Prior to heat treatment, cylinders shall be clean and free from sulphur or lead-bearing materials. Furnace atmosphere during heat treatment shall be sulphur-free and neutral or reducing. Liquid quenching shall be permitted. After heat treatment the average grain size shall not exceed 64 µm.

5.7.3 Tubes

Tubes shall be normalized at a metal temperature most suitable for the material grade. Liquid quenching of tubes shall be prohibited.

5.8 Tensile Test

5.8.1 Cylinders

Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder, taken from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

5.8.2 Tubes

Two Type A specimens, located approximately 180° apart, shall be cut from 1 tube or test ring representing each heat and each batch, and shall be tested. Heats already represented in another group of heat-treated tubes that have passed the tests, need not be represented again, even if the number represented in each heat exceeds 200. Each test ring shall be of the same diameter, thickness, and material grade as the finished tubes it represents. The test ring shall be at least 60 cm long and have its ends covered during the heat-treatment process. Test rings shall be heat-treated with the tubes they represent. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the test tube or ring.

5.8.3 Requirements

The yield strength shall not exceed 73% of the tensile strength for steel containers and 50% of the tensile strength for nickel cylinders. The elongation shall be at least 40% in Type A specimens or at least 20% in other specimen types; if this elongation requirement is fulfilled, a flattening test is not required. Elongations less than the 40% and the 20% mentioned above shall be acceptable if they are, respectively, at least 20% or 10%, and if the containers meet the requirements of Clause 5.9.

5.9 Flattening Test

5.9.1 Cylinders

One representative cylinder, from each lot of 200 or less, shall be tested, if required (see Clause 5.8.3).

5.9.2 Tubes

Tubes or test rings taken and prepared in the same manner as the sample tubes or test rings for the tensile test shall be tested, if required (see Clause 5.8.3).

Δ 5.9.3 Alternative Bend Test

As an alternative to the flattening test specified in Clause 5.9.2, two bend test specimens, taken and prepared in the same manner and from the same tubes or test rings used for the tensile test specified in Clause 5.8.2, shall be subjected to the guided bend or semi-guided bend test specified in ASTM Standard E 290. The maximum allowable mandrel diameter shall be not more than 4 times the minimum design wall thickness of the tube.

Δ 5.9.4 Requirements

5.9.4.1

Steel samples shall be flattened to 6 times the wall thickness, and nickel samples shall be flattened to 4 times the wall thickness, without cracking.

5.9.4.2

When the alternative bend test is performed, the test specimens shall not crack when bent inward around the mandrel in the direction of curvature of the tube or test ring wall until the distance between the interior edges is less than or equal to the diameter of the mandrel.

5.10 Hydrostatic Test

5.10.1

Each container shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure;
(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of
    (i) 7.0 MPa; or

(c) Tubes shall be manufactured by any process that will produce seamless cylindrical shapes with integrally formed ends concave to pressure. Closure of tubes by the spinning process shall be prohibited.
(d) Imperfections such as mechanical marks, draw marks, pits, or other surface irregularities generally having a round bottom contour shall be acceptable, provided that the minimum design wall thickness is maintained.
(e) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the container may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall not be less than the minimum design wall thickness. Metal removal to eliminate isolated defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test. Surface conditioning, such as grit or shot blasting, or brushing, or interior polishing, may be done after the hydrostatic test, provided that the minimum design wall thickness is maintained.
(f) The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum design wall thickness. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.
(g) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of container) to minor axis not exceeding 2:1, or a dished shape falling within these two limits. Such ends shall have a minimum thickness not less than the minimum design wall thickness, except that

(i) the point of closure of cylinders closed by spinning shall not be less than 2 times the minimum design wall thickness; and

(ii) hemispherical ends drawn from sheet or plate shall have a thickness not less than 90% of the minimum design wall thickness.

(h) Other bottom designs shall be permitted, provided that
(i) each design has been qualified by the cycling test; and
(ii) detail information of the bottom design is available to the independent inspector.

6.6 Welding or Brazing

Welding or brazing shall be prohibited.

6.7 Heat Treatment

6.7.1

The completed containers shall be heat-treated.

6.7.2

All containers shall be quenched in oil or another suitable medium. The steel temperature on quenching shall be that recommended for the material grade, but in no case shall it exceed 955°C. Tubes shall be held at the heat-treating temperature for at least 2.4 min/mm of maximum sidewall thickness. Quenched containers shall be tempered at a temperature consistent with achieving the specified mechanical properties. The tempering temperature shall be not less than 540°C, except that containers made of intermediate manganese steel shall be tempered at a temperature not less than 620°C.

6.8 Magnetic Particle or Liquid Penetrant Inspection

6.8.1

Containers made of steels other than intermediate manganese, if quenched in a liquid producing a cooling rate in excess of 80% the cooling rate of water, shall be inspected after heat treatment by magnetic particle or liquid penetrant method to detect quenching cracks. Cylinders with quenching cracks shall be condemned. Tubes with quenching cracks shall be rejected. Imperfections that, in the opinion of the independent inspector, may weaken a container shall be cause for rejection.

6.8.2
Containers made of intermediate manganese steel shall be submitted, after heat treatment, to a magnetic particle or liquid penetrant inspection to detect quenching cracks. Containers with quenching cracks shall be condemned. Imperfections that, in the opinion of the independent inspector, may weaken a container shall be cause for rejection.

6.9 Tensile Test

6.9.1 Cylinders
Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder, taken from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

6.9.2 Tubes
Two Type A specimens, located approximately 180° apart, shall be cut from 1 tube or test ring representing each heat and each batch, and shall be tested. Heats already represented in another group of heat-treated tubes that have passed the tests need not be represented again, even if the number represented in each heat exceeds 200. Each test ring shall be of the same diameter, thickness, and material grade as the finished tubes it represents. The test ring shall be at least 60 cm long and have its ends covered during the heat-treatment process. Test rings shall be heat-treated with the tubes they represent. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the test tube or ring.

6.9.3 Requirements
The elongation shall be at least 20% in Type A specimens or at least 10% in other specimen types.

6.10 Flattening Test

6.10.1 Cylinders
One representative cylinder, taken from each lot of 200 or less, shall be tested.

6.10.2 Tubes
Tubes or test rings taken and prepared in the same manner as the sample tubes or test rings for the tensile test shall be tested.

Δ 6.10.3 Alternative Bend Test
As an alternative to the flattening test specified in Clause 6.10.2, two bend test specimens, taken and prepared in the same manner and from the same tubes or test rings used for the tensile test specified in Clause 6.9.2, shall be subjected to the guided bend or semi-guided bend test specified in ASTM Standard E 290. The maximum allowable mandrel diameter shall be not more than 4 times the minimum design wall thickness of the tube.

Δ 6.10.4 Requirements

6.10.4.1
Flattening to 6 times the wall thickness without cracking shall be required.

6.10.4.2
When the alternative bend test is performed, the test specimens shall not crack when bent inward around the mandrel in the direction of curvature of the tube or test ring wall until the distance between the interior edges is less than or equal to the diameter of the mandrel.

6.11 Hydrostatic Test

6.11.1

Each container shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure;
(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of
    (i) 7.0 MPa; or
    (ii) 1.5 times service pressure; and
(c) for tubes, 1.5 times service pressure.

(i) all radii of merging surfaces are equal to or greater than the knuckle radius;
(ii) each design has been qualified by the cycling test; and
(iii) detail information of the bottom design is available to the independent inspector.

7.6 Welding or Brazing

Welding or brazing shall be prohibited.

7.7 Heat Treatment

The completed cylinders shall be subjected to a solution heat treatment and an aging treatment that is appropriate for the material grade.

7.8 Tensile Test

7.8.1

Two Type A, C, or D specimens, located approximately 180° apart, shall be cut from 1 representative cylinder from each lot of 200 or less and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

7.8.2

The tensile test results shall meet the requirements of Table 7.2.

7.9 Flattening Test

7.9.1

One representative cylinder from each lot of 200 or less shall be tested.

7.9.2

Cylinders shall be flattened between two 60° angle wedge-shaped knife edges rounded in accordance with the radius specified in Table 7.3.

7.9.3

As an alternative to the test in Clause 7.9.2, a bend test in accordance with ASTM Standard E 290, using a mandrel diameter not more than 6 times the wall thickness, shall be permitted. If used, this test shall be performed on two samples from 1 representative cylinder from each lot of 200 or less.

7.9.4

Each test cylinder shall withstand flattening to 9 times the wall thickness without cracking. When the alternate bend test is used, the test specimens shall not crack when bent inward around a mandrel in the direction of curvature of the cylinder wall until the interior edges are at a distance apart not greater than the diameter of the mandrel.

7.10 Hydrostatic Test

7.10.1

Each cylinder shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The permanent volumetric expansion shall not exceed 6% of the total expansion at test pressure. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure; and

(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of
   (i) 7.0 MPa; or
   (ii) 1.5 times service pressure.

7.10.2
Alternative testing by the proof pressure method shall be permitted for cylinders having a water capacity not exceeding 1 L. Each cylinder shall be inspected under a pressure at least equal to the specified test pressure and show no defects.

7.11 Rejected Cylinders
Only one reheat treatment shall be permitted; cylinders shall then pass all specified tests. Repair by welding or spinning shall be prohibited.

7.12 Marking
Cylinders shall be marked on the shoulder, top end, or neck. The depth of markings shall be such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness.

Note: *Lot numbers in lieu of serial numbers are permitted for cylinders when the volumetric capacity does not exceed* 1.0 L.

8. Specification TC-3EM

8.1 General
TC-3EM containers are seamless steel cylinders with a maximum nominal outside diameter of 51 mm, a length less than 610 mm, and a service pressure of 12.4 MPa.

8.2 Materials

8.2.1
For carbon steel cylinders, steel shall be semi-killed or killed carbon steel of uniform quality conforming to the chemical composition specified in Table 8.1.

8.2.2
For stainless steel cylinders, steel shall be of uniform quality conforming to the chemical composition of Grade H, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.3.

8.3 Wall Thickness
The wall thickness shall be governed by other requirements in this Standard.

8.4 Openings
Openings shall be threaded. Straight threads shall have at least 4 engaging threads.

Δ 8.5 Manufacture
Cylinders shall be manufactured from seamless tubing, drawn plate, or solid billet. The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum wall thickness of the cylindrical shell. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.

12.8 Tensile Test

Δ **12.8.1**

From each lot of 200 or less, two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from one representative cylinder and tested.

12.8.2

For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

12.8.3

For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

12.9 Weld Tensile Test

A weld tensile test shall be required on a specimen cut across the major seam of 1 representative cylinder from each lot of 200 or less. As an alternative, the specimen may be cut from a welded test plate. The welded test plate shall be taken from one of the heats in the same lot, and it shall be in the same condition and of approximately the same thickness as the cylinder wall, except that in no case shall the thickness be less than 2.5 mm. The test plate shall be welded by the same procedure and subjected to the same heat treatment as the major seam on the cylinder.

12.10 Weld Guided-Bend Test

A root-bend test shall be required on a specimen cut from the cylinder seam or the welded test plate used for the weld tensile test. The alternate guided-bend test shall be permitted.

12.11 Rejected Cylinders

Repair of welds by welding shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, cylinders shall pass all specified tests.

12.12 Marking

12.12.1

Markings shall be placed

(a) on each cylinder shoulder or top end of 2.2 mm or more in thickness;

(b) on neck, valve boss, valve-protection collar, or similar part permanently attached to the top end of the cylinder; or

(c) on a plate at least 1.6 mm thick, attached by welding, or by brazing at a temperature of at least 595°C, along all edges of the plate to the top of the cylinder or one of its permanent attachments. Space shall be left on the plate to stamp at least 6 requalification dates.

Note: *The specification designation incorporates the service pressure.*

12.12.2

The manufacturer's mark, in front of the serial number, separated by a space, or the manufacturer's mark and serial number, may be stamped into the welded valve spud directly above the TC mark located on the top end of the cylinder.

13. Specification TC-4BM

13.1 General

TC-4BM containers are welded or brazed carbon steel cylinders with a service pressure range from 1.0 to 3.5 MPa. One longitudinal forge lap-welded or brazed seam shall be permitted.

13.2 Materials

Steel shall be semi-killed or killed carbon steel of uniform and, where applicable, weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

13.3 Wall Thickness

13.3.1

The minimum design wall thickness shall be as follows:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure or 3.1 MPa, whichever is the greater. The wall stress in Equation 1 shall not exceed the following:
   (i) 165 MPa for cylinders without a longitudinal seam;
   (ii) 157 MPa for cylinders having a brazed longitudinal seam;
   (iii) 124 MPa for cylinders having a forge lap-welded longitudinal seam; or

(b) 2.3 mm for cylinders with an outside diameter larger than 155 mm.

13.3.2

Ends convex to pressure shall have a minimum thickness equal to 200% of the minimum design wall thickness. Ends concave to pressure shall have a minimum thickness equal to 90% of the minimum design wall thickness. In both cases, the minimum design wall thickness shall be calculated as specified in Clause 13.3.1.

13.4 Openings

13.4.1

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by brazing, by welding, or by threads. Straight threads shall have at least 4 engaging threads.

13.4.2

For cylinders used as component parts of hand fire-extinguishers, a brass fitting may be brazed to the steel boss or flange.

13.5 Manufacture

13.5.1

Closure of cylinders by the spinning process shall be prohibited.

13.5.2

Circumferential seams shall be welded or brazed. Ends attached by brazing shall have a driving fit with the shell, unless the shell is crimped, swaged, or curled over the skirt or flange of the end, and shall be thoroughly brazed until there is complete penetration by the brazing material of the brazed joint. The depth of the brazing from the end of the shell shall be at least 4 times the thickness of the shell material at the joint.

15.7.2
The containers not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

15.8 Tensile Test

Δ **15.8.1**
From each lot of 200 cylinders or less, two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from one representative cylinder and shall be tested. Tensile tests shall be required on two Type A, C, or E specimens cut from a representative sample plate from the starting stock of each lot of 200 spheres or less. The sample plate shall have received the same heat treatment as the spheres.

15.8.2
For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

15.8.3
For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

15.9 Weld Tensile Test
A weld tensile test shall be required on a specimen cut across the major welded seam of 1 representative container from each lot of 200 or less. As an alternative, the specimen may be cut from a welded test plate. The welded test plate shall be taken from one of the heats in the same lot, and it shall be in the same condition and of approximately the same thickness as the container wall, except that in no case shall the thickness be less than 2.5 mm. The test plate shall be welded by the same procedure and subjected to the same heat treatment as the major seam on the container.

15.10 Weld Guided-Bend Test
A root-bend test shall be required on a specimen cut from the container seam or the welded test plate used for the weld tensile test. The alternate guided-bend test shall be permitted.

15.11 Leak Test of Final Assembly
If a valve or fitting is installed by a manufacturer, the completed assembly shall not leak when tested at a pressure of at least 600 kPa.

15.12 Rejected Containers
Repair of brazed seams by brazing, and welded seams by welding, shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, containers shall pass all specified tests.

15.13 Marking

15.13.1
Markings shall be placed
(a) on each cylinder shoulder or top half of a sphere of 2.2 mm or more in thickness;
(b) on neck, valve boss, valve-protection collar, or similar part permanently attached to the top of the container; or

(c) on a plate at least 1.6 mm thick, attached by welding, or by brazing at a temperature of at least 595°C, along all edges of the plate to the top of the container or one of its permanent attachments. Space shall be left on the plate to stamp at least 6 requalification dates.

15.13.2
Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

15.13.3
As alternatives, marks may be located as follows:
(a) on the sidewall adjacent to the top end of cylinders, for sidewalls not less than 2.3 mm thick; or
(b) on a cylindrical portion of the shell that extends beyond the recessed bottom of the cylinder, constituting an integral and non-pressure part of the cylinder.

Note: *The manufacturer's marks and serial number may, as an alternative, be stamped into the welded or brazed-on valve boss directly above the TC specification mark located on the top end of the cylinder.*

16. Specification TC-4BWM

16.1 General
TC-4BWM containers are welded carbon or high-strength low-alloy (HSLA) steel cylinders with a longitudinal electric-arc-welded seam and a service pressure range from 1.5 to 3.5 MPa.

16.2 Materials

16.2.1
Steel shall be semi-killed or killed carbon or HSLA steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

16.2.2
Steel shall have tensile properties that will allow the manufacturer to achieve in the cylinder a minimum tensile strength, in accordance with Clause 16.9, that satisfies the requirements of Clause 16.3.

16.3 Wall Thickness

16.3.1
The minimum design wall thickness shall be calculated as follows, using Equation 7:

$$t = \frac{D}{2}\left(1 - \sqrt{\frac{SE - 1.3P}{SE + 0.4P}}\right) \qquad (7)$$

where
t = minimum design wall thickness, mm
D = outside diameter, mm
S = maximum wall stress allowed, MPa
E = joint confidence factor of the longitudinal seam (see Clauses 16.5.5, 16.5.6, and 16.5.7)
P = the hydrostatic test pressure, MPa

The wall stress in Equation 7 shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 241 MPa, whichever is the lesser. The minimum design wall thickness shall not be less than 2.0 mm for cylinders with an outside diameter larger than 155 mm.

16.3.2
The minimum thickness of ends shall be not less than 90% of the minimum design wall thickness.

16.3.3
Where the design wall thickness is less than 2.5 mm, the ratio of tangential length to outside diameter shall not exceed 4:1.

16.4 Openings
Openings shall be provided with a fitting, boss, or pad integral with or securely attached to the cylinder by welding. Straight threads shall have at least 4 engaging threads.

16.5 Manufacture

16.5.1
Closure of cylinders by the spinning process shall be prohibited.

16.5.2
Ends shall be hemispherical or ellipsoidal in shape and concave to pressure. Ellipsoidal ends shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1.

16.5.3
Circumferential seams shall be welded by an electric-arc process. Joints shall be of the butt type with one member offset (joggle butt) or the lap type with a minimum overlap of 4 times the nominal sheet thickness.

16.5.4
Longitudinal seams shall be machine butt-welded by the electric-arc process. Longitudinal seams shall have complete joint penetration and be free from undercuts, overlaps, or abrupt ridges or valleys. Misalignment of mating butt edges shall not exceed 17% of the nominal sheet thickness or 0.8 mm, whichever is the lesser. Joints of nominal sheet thickness up to and including 3.2 mm shall be tightly butted. Where the nominal sheet thickness is greater than 3.2 mm, the joint may be gapped with a maximum distance equal to one-half the nominal sheet thickness or 0.8 mm, whichever is the lesser.

16.5.5
Where each longitudinal seam is radiographed completely, the joint confidence factor shall be 1.0.

16.5.6
Where the longitudinal seam of 1 cylinder from each lot of 50 consecutively welded cylinders is spot-radiographed, the joint confidence factor shall be 0.90. Following a shutdown of the welding operations exceeding 4 h, 1 of the first 5 cylinders welded shall be spot-radiographed. Spot radiographs shall be made on a completed welded cylinder and shall include the girth weld for 50 mm in both directions from the intersection of the longitudinal and girth welds, and shall include at least 150 mm of the longitudinal weld.

16.5.7
Where no radiographic inspection of the longitudinal seam is made, the joint confidence factor shall be 0.75.

16.5.8
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

16.5.9
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

16.6 Heat Treatment

16.6.1
The completed cylinders shall be heat-treated by any method that achieves a temperature in excess of 595°C throughout the cylinder. Liquid quenching of cylinders shall be prohibited.

16.6.2
Heat treatment shall not be required after welding or brazing weldable low-carbon parts to attachments of similar material that have been previously welded to the ends of the cylinders and heat-treated, provided that such subsequent welding or brazing does not produce a temperature in excess of 200°C in any part of the cylinder.

16.7 Radiographic Inspection
When 1 cylinder from each lot of 50 is radiographed and the sample fails to meet the requirements of the spot-radiographic inspection, 2 additional welds from the same lot shall be radiographed. If either of these fails to meet the requirements, then each cylinder may be radiographed. Only those passing the radiographic inspection shall be accepted.

16.8 Hydrostatic Test

16.8.1
One representative cylinder from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. If this first cylinder fails the volumetric expansion test, 2 additional representative cylinders shall be taken from the same lot and subjected to the same test. If either of these fails the test, then each cylinder in the lot shall be tested and have its volumetric expansion measured.

16.8.2
The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

16.8.3
In addition to the tests in Clause 16.8.1, one representative cylinder from each lot of 500 or less shall be tested hydrostatically to 4 times its service pressure without bursting. If this cylinder bursts at a pressure below 4 times its service pressure, the entire lot shall be rejected.

16.9 Tensile Test

Δ **16.9.1**

From each lot of 200 or less cylinders, 1 representative cylinder shall have tensile tests performed on Type A, B, C, or E specimens that have been cut from it, as follows:

(a) one specimen shall be cut longitudinally from the body section at least 90° away from the weld joint, and 1 specimen from either of the ends. If the ends are of different materials, a specimen shall be cut from each end; and

(b) if, due to welded attachments, there is insufficient space to obtain a specimen from the top end, the specimen may be cut from a representative end subjected to the same heat treatment as the cylinder.

19.8 Hydrostatic Test

19.8.1
Each container shall be tested hydrostatically to 2 times its service pressure, have its volumetric expansion measured, and then be inspected. Bulges, cracks, and weld defects shall be cause for rejection.

19.8.2
In addition to the tests in Clause 19.8.1, one representative container from each lot of 200 or less shall be tested hydrostatically to destruction. If this container bursts at a pressure below 3 times its service pressure, the entire lot shall be rejected.

19.9 Radiographic Inspection
Radiographic inspection shall be required, after the hydrostatic test, on all welded joints that are subjected to internal pressure. The independent inspector may decide that inspection of openings of less than 25% of the container diameter is unnecessary. Containers shall be rejected if there is evidence of defects.

19.10 Flattening Test

19.10.1
One representative container, taken from each lot of 200 or less, after the hydrostatic test, shall be tested.

19.10.2
Flattening to 50% of the original outside diameter without cracking shall be required.

19.11 Rejected Containers
Repair of welds by welding prior to process treatment shall be permitted. Following repair and heat treatment, containers shall pass all specified tests.

19.12 Test Conditions
All tests shall be performed at an ambient temperature between 16 and 32°C.

19.13 Marking
Markings shall be placed on each container on a permanent attachment or on a metal plate permanently secured to the container by means other than soft solder.

20. Specification TC-4EM

20.1 General
TC-4EM containers are welded aluminum cylinders made of 2 seamless drawn shells joined by a circumferential weld, with a service pressure range from 1.5 to 3.5 MPa.

20.2 Materials
Aluminum shall be aluminum alloy of uniform and weldable quality conforming to the chemical composition of alloy AA5154, specified in Table 20.1.

20.3 Wall Thickness

20.3.1

The wall stress for the minimum design wall thickness calculations shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 138 MPa, whichever is the lesser. The minimum design wall thickness shall be the greater value of the following:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure; or

Δ (b) 3.556 mm.

20.3.2

The minimum thickness of ends shall be not less than the minimum design wall thickness.

20.4 Openings

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by inert-gas-shielded arc welding or by threads. Straight threads shall have at least 4 engaging threads.

20.5 Manufacture

20.5.1

Closure of cylinders by the spinning process shall be prohibited.

20.5.2

The circumferential weld shall not be located closer to the point of tangency of the cylindrical portion with the shoulder than 20 times the cylindrical wall thickness.

20.5.3

Longitudinal seams shall be prohibited.

20.5.4

Neck rings, flanges, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable aluminum alloys.

20.5.5

All welding shall be by a gas-shielded arc process.

20.6 Tensile Test

20.6.1

Two Type A specimens, located approximately 180° apart, shall be cut from 1 representative cylinder from each lot of 200 or less, and shall be tested.

20.6.2

The elongation shall be at least 7%. The yield strength shall not exceed 80% of the tensile strength.

20.7 Weld Tensile Test

A weld tensile test shall be required on a specimen cut across the circumferential weld of the cylinder used for the tensile test. Edges of the reduced section shall be parallel for a distance of approximately 50 mm on either side of the weld. The calculated breaking stress determined from the breaking load and the minimum wall thickness in the lot shall be equal to at least 2 times the design wall stress at hydrostatic test pressure. The actual breaking stress shall be at least 207 MPa.

22.5 Manufacture

22.5.1
Closure of cylinders by the spinning process shall be prohibited. Welding of pressure-retaining parts shall be by the submerged or gas-shielded arc process.

22.5.2
Ends shall be hemispherical or ellipsoidal in shape. The ellipsoid shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1. Ends convex to pressure may have a torispherical shape.

22.5.3
Circumferential seams shall be machine-welded. Joints shall be butt, joggle butt, or lap-welded with a minimum overlap of 4 times the nominal sheet thickness. The minimum leg of any lap-welded fillet shall be at least 1.3 times the minimum design wall thickness, based on a joint confidence factor of 1.0. The fillet weld beads shall be flat or convex. The seams shall have complete joint penetration. Misalignment of mating butt edges shall not exceed 25% of the nominal sheet thickness or 1.2 mm, whichever is the smaller.

22.5.4
Longitudinal seams shall be machine butt-welded. Seams shall have complete joint penetration and be free from undercuts, overlaps, or abrupt ridges or valleys. Misalignment of mating butt edges shall not exceed 17% of the nominal sheet thickness or 0.8 mm, whichever is the smaller. Joints of nominal sheet thickness up to and including 3.2 mm shall be tightly butted. Where the nominal sheet thickness is greater than 3.2 mm, the joint may be gapped with a maximum distance equal to one-half the nominal sheet thickness or 0.8 mm, whichever is the smaller. Permanent backup strips are prohibited.

22.5.5
Where each longitudinal seam is radiographed completely, the joint confidence factor shall be 1.0.

22.5.6
Where the longitudinal seam of 1 cylinder from each lot of 50 consecutively welded cylinders is spot-radiographed, the joint confidence factor shall be 0.90. Following a shutdown of the welding operations exceeding 4 h, 1 of the first 5 cylinders welded shall be spot-radiographed. Spot radiographs shall be made on a completed cylinder shell and shall include the girth weld for 50 mm in both directions from the intersection of the longitudinal and girth welds, and shall include at least 150 mm of the longitudinal weld.

22.5.7
When no radiographic inspection of the longitudinal seam is made, the joint confidence factor shall be 0.75.

22.5.8
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

22.5.9
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

22.6 Heat Treatment

22.6.1

The completed cylinder shells shall be heat-treated by any method that achieves a temperature in excess of 595°C throughout the completed cylinder shell. Liquid quenching of shells shall be prohibited. TC-8WM cylinders may be heat-treated before all welding operations are completed.

22.6.2

Heat treatment shall not be required after welding weldable low-carbon parts to attachments of similar material that have been previously welded to the ends of the shells and heat-treated, provided such subsequent welding does not produce a temperature in excess of 200°C in any part of the cylinder shell.

22.7 Radiographic Inspection

Where 1 completed cylinder shell from each lot of 50 is radiographed and the sample fails to meet the requirements of the spot radiographic inspection, 2 additional welds from the same lot shall be radiographed. If either of these fails to meet the requirements, then each shell may be radiographed. Only those passing the radiographic inspection shall be accepted.

22.8 Macro-Etch Test

The macro-etch test applies to cylinder designs having one or two circumferential pressure-retaining lap-welded joints. A sample of the fillet lap weld shall be cut from 1 representative completed cylinder shell taken from each lot of 200 or less. This sample shall be cut across the fillet weld, macro-etched, and visually examined for full penetration at the root and into both members, for the length of the leg and the contour of the weld bead.

22.9 Hydrostatic Test

One representative completed cylinder shell from each lot of 200 or less shall be tested hydrostatically to 5.2 MPa and have its volumetric expansion measured. If this first cylinder shell fails the volumetric expansion test, then each shell in the lot shall be tested hydrostatically to 5.2 MPa and have its volumetric expansion measured. The completed cylinder shells not tested by the volumetric expansion method shall be inspected under a pressure within the range of 3.5 to 4.1 MPa and show no defects.

22.10 Tensile Test

Δ 22.10.1

From each lot of 200 or less, 1 representative completed cylinder shell shall have tensile tests performed on Type A, B, C, or E specimens that have been cut from it, as follows:

(a) for designs having 2 deep drawn shells joined by a circumferential weld seam, 1 specimen shall be cut longitudinally from each part;

(b) for designs having a single deep drawn shell joined by a circumferential weld to a shallow bottom end assembled convex to pressure, 2 specimens shall be cut from the shell longitudinally, 180° from one another; and

(c) for designs having a longitudinal seam, 1 specimen shall be cut longitudinally from the body section, at least 90° away from the weld joint, and 1 specimen from either of the ends. If the ends are of different materials, a specimen shall be cut from each end.

22.10.2

For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

23.5.1.2
Maximum service pressure for longitudinally or helically welded cylinders shall be 3.5 MPa.

23.5.1.3
Maximum service pressure for aluminum containers shall be 3.5 MPa.

23.5.2 Welded Seams
Welded seams shall be properly aligned and welded by a method that provides clean, uniform joints with adequate penetration. Welded seams shall have a strength equal to or greater than the minimum strength of the shell material in the completed container.

23.5.3 Brazed Seams

23.5.3.1
Brazed seams shall be assembled with proper fit to ensure complete penetration of the brazing material throughout the brazed joint. The minimum width of the brazed joint shall be at least 4 times the thickness of the shell wall. Brazed seams shall have a design strength equal to or greater than 1.5 times the minimum strength of the shell wall.

23.5.3.2
Brazing on aluminum containers shall be prohibited.

23.5.3.3
The brazing material shall have a melting point not lower than 540°C.

23.6 Flattening Test

23.6.1 Sample Selection
One representative sample from the beginning of the production of each lot shall be tested. All containers produced per shift (not exceeding 10 h) shall be counted as 1 lot. This test shall be performed on a container that has been tested at test pressure.

23.6.2 Cylinders
Either a completed cylinder or a ring taken from the cylinder shall be tested. The ring shall not include the heat-affected zone or any weld.

23.6.3 Spheres
A ring from the sphere shall be tested. The test ring may include the circumferential weld if it is located at a 45 ± 5° angle to the ring.

23.6.4 Steel Samples
Flattening to 6 times the wall thickness without cracking shall be required.

23.6.5 Aluminum Samples
Flattening to 10 times the wall thickness without cracking shall be required.

23.6.6 Rejection Criteria
If any sample fails the test, the entire lot represented shall be rejected.

23.7 Pressure Tests

23.7.1 Pneumatic Pressure Test

23.7.1.1

Each container shall be:
(a) proof tested pneumatically to its test pressure for at least 30 s. Containers that give evidence of distortion or other defects shall be condemned; and
(b) leak tested, at not less than service pressure, by submerging it in water or by another suitable method. Containers that leak shall be rejected.

23.7.1.2

The test pressure shall be the pressure of the contents at 55°C or 1.2 MPa, whichever is the greater.

23.7.2 Burst Test

23.7.2.1

One representative container taken from the first containers produced in each lot, plus 1 container from each 1000 successively produced containers within the lot, shall be tested hydrostatically to destruction. All containers produced per shift (not exceeding 10 h) shall be counted as 1 lot.

23.7.2.2

The entire lot shall be rejected if a failure occurs at a pressure less than 2 times the test pressure.

23.7.2.3

The entire lot shall be rejected if a failure initiates in a braze or a weld or in a heat-affected zone.

23.7.2.4

The entire lot shall be rejected if a failure occurs in any opening or reinforcement or at a point of attachment in a sphere.

23.7.2.5

A cylinder lot shall be acceptable only if the failure occurs in the cylindrical portion of the cylinder and is longitudinally oriented.

23.8 Rejected Containers

23.8.1

Where defective containers with determinable causes for failure can be removed from a lot by testing or inspection, the remaining containers may be considered as a new lot. Repairs by rewelding or rebrazing shall be permitted; however, such repaired containers shall pass the pressure test.

23.8.2

Where a cylinder made from seamless steel tubing fails the flattening test, each cylinder in the lot shall undergo a suitable uniform heat treatment. Cylinders shall then pass all specified tests.

23.9 Marking

Δ **23.9.1**

Each container shall be marked. Marks shall be durable and waterproof. Stamping shall not be required.

23.9.2

The marks may be limited to the following:

(a) TC39M;
(b) the letters "NRC" for nonrefillable containers;
(c) the service pressure, in bar;
(d) the test pressure, in bar;
Δ (e) the manufacturer's registered mark;
(f) the lot or serial number; and
(g) the date of manufacture, unless it is indicated by the lot or serial number.

23.9.3

The markings shall be at least 3 mm high, and the markings specified in Items (a) through (e) of Clause 23.9.2 shall be displayed sequentially.

24. Requalification, Reheat Treatment, Repair, and Rebuilding

24.1 General

24.1.1 Scope

Clause 24 covers the requalification by retesting and reinspection, the reheat treatment, the repair, and the rebuilding of used containers.

Notes:

(1) *The prefix of a specification designation on a container identifies the regulatory authority responsible at the time the container was manufactured. In Clause 24, an obsolete specification is referenced by a prefix identifying the last regulatory authority under which containers of that specification are believed to have been manufactured. The prefix represents also the previous Canadian regulatory authorities or the US regulatory authorities under which containers of the same specification may have been manufactured.*

(2) *The prefixes other than "TC" are as follows:*

(a) CRC: Canadian Railway Commission;
(b) BTC: Board of Transport Commissioners for Canada;
(c) CTC: Canadian Transport Commission;
(d) ICC: US Interstate Commerce Commission; and
(e) DOT: US Department of Transportation.

(3) *Containers bearing the prefix "ICC" or "DOT" are containers that were manufactured to a US specification. Many such containers have been in use in Canada for years. In Clause 24, a specification designation preceded by the letters "ICC" or "DOT" identifies a specification that has never been adopted in Canada.*

(4) *All "TC" specifications include the letter "M". The addition of the letter "M" to a specification indicates a metric specification. Containers to specifications not including the letter "M" were built using yard-pound units of measurement, with service pressure in pounds per square inch.*

24.1.2 Requirements

The requalification, the repair, and the rebuilding of containers shall be conducted in accordance with CGA Publications C-1, C-3, C-5, C-6, C-6.1, C-6.2, C-6.3, C-8, and C-13. Rejected containers shall be reinspected, retested, reheat-treated, repaired, or rebuilt before being returned to service.

Note: *Where air or other gases are allowed in testing, proper precautions should be taken to protect personnel.*

24.2 Requalification

24.2.1 General Requirements

24.2.1.1

Each cylinder, sphere, or tube shall be requalified periodically in accordance with the requirements of Clause 24.2 and Table 24.1, except as provided in Clauses 24.2.1.6 and 24.2.1.7. Table 24.1 specifies the basic requalification procedures and periods. It also specifies alternative requalification procedures and periods that may be used, depending on service conditions. Alternative requalification methods and periods are referenced to specific clauses for complete descriptions of conditions under which the alternative procedures may be used.

24.2.1.2

Hydrostatic retests with volumetric expansion measurements and proof pressure retests, as required by Table 24.1, shall be performed in accordance with Clause 4.12.1.

24.2.1.3

Containers subject to a hydrostatic retest with volumetric expansion measurement shall also be visually inspected both internally, inasmuch as the size of the orifice(s) permit(s), and externally, in accordance with CGA Publication C-6, C-6.1, C-6.2, or C-6.3. The permanent expansion shall not exceed 10% of the total expansion, except for

(a) TC-3ALM cylinders, where it shall not exceed 6%;
(b) TC-3FCM, TC-3HWM, and TC-3HTM cylinders, where it shall not exceed 5%; and
(c) TC-4EM and CTC-4E cylinders, where it shall not exceed 12%.

24.2.1.4

Containers subject to a proof pressure retest shall also be visually inspected externally, in accordance with CGA Publication C-6.

24.2.1.5

Containers exempt from a pressure retest under Clause 24.2.9 shall be subjected to an external visual inspection.

24.2.1.6

Containers with a capacity of 1.0 L water or less shall be exempt from periodic requalification.

24.2.1.7

Containers with a service pressure of 2.1 MPa or less and a capacity of 4.5 L of water or less, and built to a specification that requires periodic hydrostatic retest with a volumetric expansion measurement (see Table 24.1), shall be exempt from the volumetric expansion measurement when retested hydrostatically, but shall be examined while under the specified retest pressure and show no leakage or other defects.

24.2.1.8

In addition to the periodic retests, whenever there is a reason to believe that the pressure-retention integrity of a container has been adversely affected by severe dents, corrosion, excessive heat, or other damage, the container shall be emptied and requalified before refilling.

24.2.1.9

Reheat-treated and rebuilt containers shall be processed and requalified in accordance with the container specification before being returned to service; compliance shall be verified by an independent inspector. Containers repaired by welding or brazing shall be requalified before being returned to service.

24.2.1.10
A container that does not meet the requalification requirements shall be rejected or condemned. Rejected containers may be reheat-treated, repaired, or rebuilt only in accordance with Clause 24.

24.2.1.11
Containers, except those manufactured to TC-3ALM, CTC-3AL, TC-3FCM, TC-3HTM, CTC-3HT, TC-3HWM, TC-4EM, CTC-4E, TC-4LM, and CTC-4L specifications, may be heat-treated if they have been rejected for excessive permanent expansion or for exposure to excessive heat. TC-4LM and CTC-4L cylinders exposed to excessive heat may be returned to service without retesting if the jacket and the vacuum remain intact. Aluminum and composite cylinders exposed to a temperature exceeding 175°C shall be condemned.

24.2.1.12
Containers that previously contained a corrosive liquid that, through its corrosive action, could affect the structural integrity of the container shall not be used for the transportation of any compressed gas, unless the container is retested in accordance with the requirements of the applicable specification. A container that contained a corrosive liquid for which decontamination methods cannot remove all significant residue or impregnation from the container shall not be used for the transportation of any compressed gas.

24.2.1.13
A cylinder in chlorine or sulphur dioxide service manufactured before April 20, 1915, shall be retested at 3.5 MPa.

24.2.2 Ten-Year Requalification Requirements

24.2.2.1
A TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, or TC-3ASM cylinder not exceeding 57 L of water capacity may be retested every 10 years only, provided that the cylinder complies with the following:
(a) if the cylinder is in a cluster, bank, group, or rack, it is removed from the cluster, bank, group, or rack each time it is filled;
(b) the cylinder is used exclusively for air, argon, ethylene, helium, hydrogen, krypton, neon, nitrogen, nitrous oxide, oxygen, xenon, and mixtures of these gases, without, or with up to 30% by volume of, carbon dioxide. These gases or mixtures shall have a dewpoint not exceeding –54°C at 101.325 kPa (absolute);
(c) prior to each refill, the cylinder is subjected to and passes the hammer test specified in CGA Publication C-6;
(d) the new hydrostatic test data of the cylinder meet one of the following requirements:
(i) the elastic expansion does not exceed the REE stamped on the cylinder at the time of manufacture;
(ii) the elastic expansion does not exceed the applicable rejection limit specified in Table 2 of CGA Publication C-5; or
(iii) either the average wall stress or the maximum wall stress does not exceed the corresponding wall stress limitation shown in Appendix B of CGA Publication C-5;
(e) the cylinder is stamped with a 5-pointed star following the last test or retest date;
(f) the cylinder is dried immediately following the hydrostatic retest to remove all traces of free water; and
(g) the cylinder is not used in a self-contained respirator or in a portable resuscitator.
Note: *Cylinders used in a self-contained respirator or in a portable resuscitator are to be retested, maintained, and inspected by a registered retester in accordance with the requirements of CSA Standard CAN/CSA-Z94.4.*

24.2.2.2
The retest period of a cylinder previously in compliance with Items (c), (d), (f), and (g) of Clause 24.2.2.1, but not in compliance with Item (b) of Clause 24.2.2.1, may be changed to a 10-year retest period only after the cylinder has been retested and confined to a gas service in compliance with Item (b) of Clause 24.2.2.1.

Δ

24.2.2.3
If, at any time, a cylinder marked with the star is used in a manner other than that specified in Clause 24.2.2.1, the star following the most recent test or retest date shall be obliterated by peening.

24.2.3 Cylinders with a Service Pressure of 2.1 MPa or Less in Nonflammable Liquid or Mixtures of Nonflammable Liquids and Nonflammable, Nonliquefied Compressed Gases in Noncorrosive Service
A TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, TC-3ANM, TC-3ASM, CTC-3B, or CTC-3BN cylinder used exclusively for nonflammable liquids or mixtures of nonflammable liquids and nonflammable, nonliquefied compressed gases in noncorrosive service may be retested every 10 years. The cylinder shall have a service pressure of 2.1 MPa or less and, except for TC-3ASM cylinders, be protected externally by a suitable corrosion-resistant coating, such as, but not limited to, paint, and internally by an equally corrosion-resistant lining. Each test shall be supplemented by a visual internal and external inspection, in accordance with CGA Publication C-6, at least once every 5 years.

24.2.4 Containers Used for Fire Extinguishers
A TC-4BM, CTC-4B, TC-4BAM, CTC-4BA, TC-4BWM, CTC-4BW, TC-4BM17ET, CTC-4B240ET, CTC-4B240FLW, TC-4EM, or CTC-4E container used for noncorrosive liquefied or nonliquefied compressed gases or mixtures of same and any noncorrosive fire-extinguishing agent may be hydrostatically retested with volumetric expansion measurement every 12 years. The container shall be protected externally by a suitable corrosion-resistant coating, such as, but not limited to, paint. Alternatively, the same containers may be proof pressure retested every 7 years.

Δ

24.2.5 Containers Used for Reclaimed, Recycled, or Recovered Refrigerant Gases
Containers used for reclaimed refrigerant gases shall be requalified in accordance with the applicable basic or alternative requalification procedures and periods specified in Clause 24.2.1. Containers used for recycled or recovered refrigerant gases shall be requalified in accordance with the basic requalification procedures and periods specified in Clause 24.2.1. Recycled and recovered refrigerant gases are considered to be corrosive due to contamination.

24.2.6 TC-3HTM and CTC-3HT Cylinders

24.2.6.1
In addition to the visual inspection requirements, TC-3HTM and CTC-3HT cylinders shall be requalified in accordance with CGA Publication C-8 and shall conform with the requirements of Clauses 24.2.6.2 to 24.2.6.5.

24.2.6.2
A cylinder shall not be returned to service if the elastic expansion at retest exceeds the original elastic expansion by more than 5% or the rejection elastic expansion limit (REE) marked on the cylinder.

24.2.6.3
A cylinder shall not be requalified at the termination of a 24-year period following the date of the

24.5.4 Series-8 Cylinders

24.5.4.1

The rebuilding shall be limited to
(a) the removal and replacement of the porous mass;
(b) the removal and replacement of one or more pressure-retaining parts attached by welding and not marked with the original specification markings;
(c) the removal and replacement of any non-pressure-retaining attachment by welding or brazing; and
(d) the removal and repair of any defect in a pressure-retaining welded seam.

24.5.4.2

Where cylinder rebuilding is limited to porous mass replacement without any welding, all the cylinders in the lot shall be proof pressure-tested to the range of 3.5 to 4.1 MPa, after the shells have been emptied. Reheat treatment shall not be required.

24.5.4.3

Where the cylinder rebuilding involves welding operations, the welding operations shall be performed only after the porous mass has been removed. All the shells in the lot after heat treatment shall be hydrostatically tested as follows:
(a) where complete material identification of the rebuilt shells is unknown, each shell in the lot shall be hydrostatically tested individually, with volumetric expansion measurement, at 5.2 MPa; and
(b) where complete material identification of the rebuilt shells is known, the lot shall be tested in accordance with the requirements of the specification.

24.6 Marking

24.6.1 General

Δ 24.6.1.1

Following requalification, each container shall be plainly and permanently marked as follows in accordance with Clauses 24.6.3 and 24.6.4:
(a) on the container, as permitted by the applicable specification;
(b) on the existing attached plate; or
(c) on a new metal plate in accordance with Clause 24.6.2, as permitted by the applicable specification.
The size of the marks shall be in accordance with Clause 4.17.5.

24.6.1.2

Subject to Clause 24.6.4, obliteration of the dates of previous tests or retests shall be prohibited.

24.6.2 Metal Plate

The marking on a new metal plate shall use any one or any combination of the following methods:
(a) embossing, including raised or indented characters;
(b) metal stamping;
(c) engraving; or
(d) any other method producing a permanent, legible marking and involving removal or addition of metal, except by heating of any kind.

24.6.3 Marking Information

24.6.3.1

The marking arrangement shall be as follows:

A B C D E
where
A = month of requalification (two digits), followed by a space
B = requalifier's or, where applicable, independent inspector's registered mark (indicated by XY in Clause 24.6.3.2), followed by a space
C = year of requalification (last two digits only)
D = procedure symbol (Δ, ★, □, **E, R, RB, RH, S,** or **FS**), followed by a space
E = repairer's (if different from requalifier), rebuilder's, or reheat treater's registered mark (indicated by WZ — see Clause 24.6.3.2).

24.6.3.2

The marking information after requalification shall be as follows:

		A	B	C	D	E
(a)	for a 3- or 5-year hydrostatic retest with volumetric expansion measurement	08	XY	94		
(b)	for a 7-year proof pressure retest	08	XY	94	Δ	
(c)	for a 10-year hydrostatic retest with volumetric expansion measurement	08	XY	94	★	
(d)	for a 10-year proof pressure retest	08	XY	94	♦	
(e)	for a 12-year hydrostatic retest with volumetric expansion measurement	08	XY	94	□	
(f)	for a visual reinspection	08	XY	94	E	
(g)	for requalification after a repair procedure	08	XY	94	R	WZ
(h)	for requalification after a rebuilding procedure	08	XY	94	RB	WZ
(i)	for requalification after reheat treatment only	08	XY	94	RH	WZ
(j)	for series-8 cylinder shell reinspection only	08	XY	94	S	
(k)	for series-8 cylinder shell and porous filler reinspection	08	XY	94	FS	

24.6.3.3

In addition to the marks required under Item (a) or (c) of Clause 24.6.3.2, a CTC-3A, CTC-3AA, CTC-3AX, CTC-3AAX, or DOT-3T container that meets the elastic expansion requirements of CGA Publication C-5 shall be marked with a + sign, immediately following the requalification date.

24.6.3.4

In addition to the marks required under Item (a) or (c) of Clause 24.6.3.2, a TC-3AM, TC-3AAM, TC-3AXM, TC-3AAXM, TC-3ASM, or TC-3TM container for which the elastic expansion exceeds the REE stamped on the cylinder at the time of manufacture or the applicable rejection limit specified in Table 2 of CGA Publication C-5, or for which the average or maximum wall stress exceeds the corresponding limitation in Appendix B of CGA Publication C-5, shall be marked with the letter "K", immediately following the service pressure marking.

24.6.3.5

In addition to the marks required in Item (k) of Clause 24.6.3.2, series-8 cylinders with nonmonolithic filler material shall be marked with the letter "N" after the original manufacturing date, eg, 04 ABC 72 N, the first time they are requalified after January 1993.

24.6.3.6
A container manufactured under a permit (or exemption) and for which a new specification has been adopted shall have its original marking maintained. The new specification marking shall be placed in proximity to the original marking before, or the first time the container is requalified after, the new specification becomes effective.

24.6.3.7
After requalification, if it is found that the tare of the container has changed by more than 1% from that marked on the container, the original tare shall be peened out, and the actual tare shall be stamped in accordance with the requirements of Clause 4.17 and the applicable specification.

24.6.3.8
When a cylinder is required to be condemned, the specification designation and service pressure markings shall be removed (eg, by peening out or stamping over with a series of Xs), or the word "CONDEMNED" shall be permanently and legibly stamped on the shoulder, top end, or neck.

24.6.4 Marking Maintenance

Δ **24.6.4.1**
Except as provided in Clause 24.6.4.4, any marking becoming illegible shall be remarked on the container or reproduced on a metal plate permanently secured to the cylinder or any permanent part of the container, excluding the sidewall.

24.6.4.2
Where attached to a nonpressure part of the container, the metal plate shall be attached by a permanent method such as, but not limited to, riveting, welding, spot welding, or brazing.

24.6.4.3
Where the metal plate is attached to a pressure-retaining part of a container, it shall be welded or brazed, as permitted in the applicable specification. The container shall be considered as a repaired or rebuilt container and further processed accordingly.

24.6.4.4
Where the space originally provided for marking requalification dates becomes filled, the expired requalification dates, except the last one, may be removed by peening, provided that
(a) permission to do so has been obtained from the owner of the container;
(b) the design minimum wall thickness is maintained; and
(c) the original manufacturing test date is not removed.

24.7 Reporting

Δ **24.7.1 Requalification**
Each requalification shall be recorded on a report form by the person performing the requalification. Typical report forms are shown in
(a) Appendix E of CGA Publication C-1, for a requalification hydrostatic test;
(b) Appendix A of CGA Publication C-6, for a requalification by visual inspection only; and
(c) Appendix B of CGA Publication C-13, for requalification of series-8 cylinders.

The format of the requalification report forms may be modified, but as a minimum all information shown on the form for the applicable test method shall be incorporated or attached. The reports shall include a record of the required test system accuracy verification.

24.7.2 Repair

Each repair by welding or brazing shall be recorded as an addition to the reports prepared in accordance with Clause 24.7.1. The repair procedure shall be reported in writing and, if necessary, by a sketch or sketches.

24.7.3 Reheat Treatment and Rebuilding

Reheat treatment, rebuilding, and related inspection shall be reported in writing and, if necessary, by a sketch or sketches. The report shall be in accordance with the applicable requirements of the container specification and Clause 24.

25. Registration

25.1 General

25.1.1

Clause 25 covers the registration requirements to manufacture, requalify, repair, reheat treat, rebuild, and inspect cylinders, spheres, and tubes (containers).

25.1.2

Applications for registration shall be submitted by registered mail to the Director.

25.2 Registration of Manufacturers of Containers

25.2.1 Initial Registration

25.2.1.1

A certificate of registration to manufacture containers of a new design shall be obtained from the Director prior to the release of such containers for the transportation of dangerous goods.

25.2.1.2

The following information shall be submitted in the application for registration:

(a) the name, address, and telephone number of the applicant;
(b) container drawings, the specification designations, and the design calculations;
(c) a manual detailing quality control, testing, and inspection procedures;
(d) the description of the manufacturing and testing facilities;
(e) the description of the manufacturing processes; and
(f) the name and address of the independent inspector to be employed.

25.2.1.3

Qualification tests for each new design (see Clause 4.13) shall be performed on 6 representative containers selected by the independent inspector from an initial production lot. The qualification tests shall be performed at a test facility approved by the Director.

Notes:

(1) *Additional qualification tests may be required by the Director.*

(2) *Upon verification by the Director of compliance of the application documentation with the requirements of this Standard, arrangements may be made for facility inspections by an officer of the Transport Dangerous Goods Directorate, Transport Canada.*

(3) *Upon satisfactory results of the inspection(s) of facilities and of the new design qualification tests, the Director may issue the certificate of registration.*

25.2.2 Renewal of Certificate of Registration

25.2.2.1

A certificate of registration is valid for 5 years, unless it is revoked by the Director.

Note: *A certificate of registration may be revoked by the Director, if the Director determines that the holder of the certificate of registration has not complied with or is not capable of consistently complying with the applicable requirements of this Standard.*

Update No. 1
B339-02
November 2003

Note: *General Instructions for CSA Standards are now called Updates. Please contact CSA Information Products Sales or visit* ***www.csa.ca*** *for information about the* ***CSA Standards Update Service****.*

Title: *Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods —* originally published October 2002

The following revisions have been formally approved:

Revised	Outside front cover, inside front cover, and title page
New	None
Deleted	None

CSA B339-02 originally consisted of **140 pages** (xv preliminary and 125 text), each dated **October 2002**. It now consists of the following pages:

October 2002	iii–xv and 1–125
November 2003	Cover, title page, and copyright page

- Update your copy by inserting these revised pages.
- Keep the pages you remove for reference.

CAN/CSA-B339-02
A National Standard of Canada
(approved November 2003)

Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

Standards Council of Canada
Conseil canadien des normes

The Canadian Standards Association (CSA), under whose auspices this National Standard has been produced, was chartered in 1919 and accredited by the Standards Council of Canada to the National Standards system in 1973. It is a not-for-profit, nonstatutory, voluntary membership association engaged in standards development and certification activities.

CSA standards reflect a national consensus of producers and users — including manufacturers, consumers, retailers, unions and professional organizations, and governmental agencies. The standards are used widely by industry and commerce and often adopted by municipal, provincial, and federal governments in their regulations, particularly in the fields of health, safety, building and construction, and the environment.

Individuals, companies, and associations across Canada indicate their support for CSA's standards development by volunteering their time and skills to CSA Committee work and supporting the Association's objectives through sustaining memberships. The more than 7000 committee volunteers and the 2000 sustaining memberships together form CSA's total membership from which its Directors are chosen. Sustaining memberships represent a major source of income for CSA's standards development activities.

The Association offers certification and testing services in support of and as an extension to its standards development activities. To ensure the integrity of its certification process, the Association regularly and continually audits and inspects products that bear the CSA Mark.

In addition to its head office and laboratory complex in Toronto, CSA has regional branch offices in major centres across Canada and inspection and testing agencies in eight countries. Since 1919, the Association has developed the necessary expertise to meet its corporate mission: CSA is an independent service organization whose mission is to provide an open and effective forum for activities facilitating the exchange of goods and services through the use of standards, certification and related services to meet national and international needs.

For further information on CSA services, write to
Canadian Standards Association
5060 Spectrum Way, Suite 100
Mississauga, Ontario, L4W 5N6
Canada

CANADIAN STANDARDS ASSOCIATION

The Standards Council of Canada is the coordinating body of the National Standards system, a federation of independent, autonomous organizations working towards the further development and improvement of voluntary standardization in the national interest.

The principal objects of the Council are to foster and promote voluntary standardization as a means of advancing the national economy, benefiting the health, safety, and welfare of the public, assisting and protecting the consumer, facilitating domestic and international trade, and furthering international cooperation in the field of standards.

A National Standard of Canada is a standard which has been approved by the Standards Council of Canada and one which reflects a reasonable agreement among the views of a number of capable individuals whose collective interests provide to the greatest practicable extent a balance of representation of producers, users, consumers, and others with relevant interests, as may be appropriate to the subject in hand. It normally is a standard which is capable of making a significant and timely contribution to the national interest.

Approval of a standard as a National Standard of Canada indicates that a standard conforms to the criteria and procedures established by the Standards Council of Canada. Approval does not refer to the technical content of the standard; this remains the continuing responsibility of the accredited standards-development organization.

Those who have a need to apply standards are encouraged to use National Standards of Canada whenever practicable. These standards are subject to periodic review; therefore, users are cautioned to obtain the latest edition from the organization preparing the standard.

The responsibility for approving National Standards of Canada rests with the
Standards Council of Canada
270 Albert Street, Suite 200
Ottawa, Ontario, K1P 6N7
Canada

Cette Norme nationale du Canada est offerte en anglais et en français.

Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users to judge its suitability for their particular purpose.

National Standard of Canada
(approved November 2003)

CAN/CSA-B339-02
Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

Prepared by

CANADIAN STANDARDS ASSOCIATION

Approved by
Standards Council of Canada

Published in October 2002 by Canadian Standards Association
A not-for-profit private sector organization
5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6
1-800-463-6727 • 416-747-4044

Visit our Online Store at www.csa.ca

ISBN 1-55324-813-9
Technical Editor: *Paul Levine*

(Copyright page replaced November 2003)

CSA Standards Update Service

B339-02
October 2002

Title: *Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods*
Pagination: 140 pages (xv preliminary and 125 text), each dated **October 2002**

Automatic notifications about any updates to this publication are available.

- To register for email notifications, and/or to download any existing updates in PDF, enter the Online Store at **www.csa.ca** and click on **My Account** on the navigation bar.

  The **List ID** for this document is **2012951**.

- To receive printed updates, please complete and return the attached card.

Name _____

Organization _____

Address _____

City _____

Province/State _____

Country _____ Postal/Zip Code _____

Email _____

B339-02

Affranchir
suffisamment
Place
Stamp Here

ASSOCIATION CANADIENNE DE NORMALISATION
BUREAU CENTRAL DE L'INFORMATION
5060 SPECTRUM WAY, BUREAU 100
MISSISSAUGA ON L4W 5N6
CANADA

CANADIAN STANDARDS ASSOCIATION
CONSOLIDATED MAILING LIST
5060 SPECTRUM WAY, SUITE 100
MISSISSAUGA ON L4W 5N6
CANADA

CSA Standard

B339-02
Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

Published in October 2002 by Canadian Standards Association
A not-for-profit private sector organization
5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6
1-800-463-6727 • 416-747-4044

ISBN 1-55324-813-9
Technical Editor: *Paul Levine*

Contents

Technical Committee on Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

M.F. Chell	Chell Engineering Services Inc., Fenelon Falls, Ontario	*Chair*
J. Wedding	Harsco Corporation: Gas & Fluid Control Group, Huntsville, Alabama, USA	*Vice-Chair*
M. Abdelli	Air Liquide Canada Inc., Montréal, Québec	
R. Awad	Régie du bâtiment du Québec, Montréal, Québec	
W.L. Birch	Luxfer Gas Cylinders, Riverside, California, USA	
D. Carter	Intertek Testing Services NA Ltd., Mississauga, Ontario	
G. Denison	DuPont Canada Inc., Streetsville, Ontario	
J. Dimmick	Pressed Steel Tank Company Inc., West Allis, Wisconsin, USA	
R.O. Dowling	CP Industries Incorporated, McKeesport, Pennsylvania, USA	*Associate*
S. Gentry	Worthington Cylinder Corporation, Columbus, Ohio, USA	
G. Giles	Giles Tool Agencies Limited, Scarborough, Ontario	*Associate*
C. Hall	Harsco Corporation: Gas & Fluid Control Group, Harrisburg, Pennsylvania, USA	*Associate*
B. Jeary	Dynetek Industries Ltd., Calgary, Alberta	*Associate*
M. Julien	Messer Canada, Mississauga, Ontario	
R. Lalonde	Praxair Canada Inc., St-Laurent, Québec	
K.T. Lau	Alberta Boilers Safety Association, Edmonton, Alberta	
C. Macey	Bruin Engineered Parts Incorporated, Midland, Ontario	

S. Minshall	Wolfedale Engineering Limited, Brampton, Ontario	
A.J. Nathanielsz	Regulatory Compliance Resources Inc., Toronto, Ontario	
J.K. O'Steen	U.S. Department of Transportation, Washington, District of Columbia, USA	*Associate*
A. Park	Transport Canada, Ottawa, Ontario	
T. Scott	The Scott Safety Associates, Guelph, Ontario	
J. Sharma	Technical Standards & Safety Authority, Toronto, Ontario	
G.E. Shepperdley	Vipond Systems Group, Mississauga, Ontario	
T. Siimes	Gas Cylinder Technologies, Tecumseh, Ontario	
D.J. Stainrod	D.J. Stainrod & Associates Ltd., Bowmanville, Ontario	
M. Trudgeon	Structural Composites Industries, Pomona, California, USA	*Associate*
J.P. Vassallo	Arrowhead Industrial Services, Incorporated, Graham, North Carolina, USA	*Associate*
R. Wahl	Manchester Tank & Equipment Company, Brentwood, Tennessee, USA	
R. Wark	Matheson Gas Products Canada Inc., Whitby, Ontario	
C. Webster	Powertech Labs Inc., Surrey, British Columbia	
N. White	Charonic Canada Incorporated, Belleville, Ontario	
G. Wilson	Arrowhead Industrial Services, Incorporated, Graham, North Carolina, USA	
P. Levine	CSA, Mississauga, Ontario	*Project Manager*

Preface

This is the fourth edition of CSA Standard B339, *Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods.* It supersedes the previous editions published in 1996, 1988, and 1983.

This Standard is one of a series of Standards prepared for use in conjunction with the Transportation of Dangerous Goods Regulations, which adopt this Standard by reference. Since the regulations may adopt this Standard with certain exceptions or additional requirements, they should be consulted to determine where they differ from the requirements of this Standard.

It should be noted that the amended, clear-language version of the Transportation of Dangerous Goods Regulations that reference CAN/CSA-B339-96 came into effect on 15 August 2002. The CSA Technical Committee on Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods, which is responsible for this Standard, has maintained close links with Transport Canada to ensure compatibility of the new edition of this Standard with the amended Transportation of Dangerous Goods Regulations. The Committee has also reviewed and made extensive use of Compressed Gas Association Publications and the US Code of Federal Regulations. This edition of CSA Standard B339 incorporates numerous amendments and refinements to the previous edition, while retaining the same basic format used in the previous edition.

The CSA Technical Committee on Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods is made up of members having responsibility and expertise as manufacturers or users or in related areas that include testing and inspection of containers and materials, material production, and regulatory interests. The Committee is confident that this Standard, developed by consensus, is practical, current with respect to technology and industry practices, useful, and acceptable to all interested parties.

This Standard is written in SI (metric) units, except for the cylinder marking requirements, where the service pressure and, where applicable (eg, Specification TC-39M), the test pressure are expressed in bar. However, for consistency in the design and test requirements of all containers, MPa and kPa have been retained as units to express service pressure. Considering the use of the "bar" unit by ISO (International Organization for Standardization) to mark service and test pressures, the Technical Committee decided to use the same unit for marking service pressure. The capital letter "M" is added to each specification designation to identify formally that the container specification is metricated.

This Standard was prepared by the Technical Committee on Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods, under the jurisdiction of the Strategic Steering Committee on Public Safety, and has been formally approved by the Technical Committee. It will be submitted to the Standards Council of Canada for approval as a National Standard of Canada.

October 2002

Notes:

(1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

(2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*

(3) *This publication was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this publication.*

(4) *CSA Standards are subject to periodic review, and suggestions for their improvement will be referred to the appropriate committee.*

(5) *All enquiries regarding this Standard, including requests for interpretation, should be addressed to Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6.*

Requests for interpretation should

(a) define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;

(b) provide an explanation of circumstances surrounding the actual field condition; and

(c) be phrased where possible to permit a specific "yes" or "no" answer.

Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are published in CSA's periodical* Info Update, *which is available on the CSA Web site at www.csa.ca.*

B339-02
Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods

1. Scope

1.1 General

This Standard covers requirements for the manufacturing, inspection, testing, marking, requalification, reheat treatment, repair, and rebuilding of cylinders, spheres, and tubes (containers) for the transportation of dangerous goods. In addition, it includes the requirements for the qualification of new designs and registration requirements.

1.2 Designations and Descriptions of Containers

1.2.1

This Standard covers the general requirements for containers (see Clause 4) and specific requirements, as specifications (see Clauses 5 to 23 inclusive), for the manufacture of each type of container. The general requirements are applicable to all containers, unless otherwise stated, or are not relevant in the individual specifications.

1.2.2

The specification designations and descriptions of containers covered in this Standard are listed in Tables 1.1, 1.2, 1.3, 1.4, 1.5, and 1.6.

Note: *It should be noted that compliance with the provisions of the* Transportation of Dangerous Goods Act *and the Regulations thereto may call for additional requirements due to particular characteristics or properties of individual dangerous goods.*

2. Definitions

The following definitions apply in this Standard:

Approved design — a design of a container the manufacturing of which has been approved by Transport Canada.

Autofrettage — a pressure application procedure used in manufacturing composite cylinders, which strains the metal liner past its yield point, sufficient to cause permanent plastic deformation, and which results in the liner having compressive stresses and the fibres having tensile stresses at zero internal pressure.

Bar — for the purpose of this Standard, a metric (non-SI) measurement unit for marking the service pressure on cylinders, spheres, and tubes for the transportation of dangerous goods. 1 bar = 100 kPa (0.1 MPa).

Batch — as it refers to heat treatment of tubes, 4 h or less of production when heat treating is performed in a continuous furnace, or each furnace load when heat treatment is performed in a batch furnace.

Cast or heat analysis — a chemical analysis of a cast or heat of metal as reported by the metal manufacturer.

Certificate of compliance — the independent inspector's report that certifies that the cylinders, spheres, or tubes conform to the requirements of this Standard at the time of manufacture.

Composite cylinder — a cylinder, the wall of which is made of more than one material.

Condemned cylinder, sphere, or tube — a container not permitted for the transportation of dangerous goods and not to be reconditioned.

Cylinder — a container of cylindrical shape with a water capacity not greater than 450 L designed to withstand an internal pressure greater than 275 kPa (absolute).

Dangerous goods — any product, substance, material, or organism listed in the schedules of the *Transportation of Dangerous Goods Act* or Regulations, or meeting the classification requirements laid out in those Regulations.

Defect — an imperfection of sufficient magnitude to warrant rejection in accordance with this Standard.

Director — the Director, Regulatory Affairs Branch, Transport Dangerous Goods Directorate, Transport Canada.

Imperfection — a material discontinuity or irregularity that is detectable by inspection in accordance with this Standard.

Independent inspector — a person registered by the Director, pursuant to Clause 25.4 of this Standard, to verify the compliance of cylinders, spheres, and tubes with the requirements of the applicable specifications.

Independent inspector's report — a report on any test, retest, or inspection required by this Standard.

Lot —
(a) In the context of container manufacture, a quantity of cylinders, spheres, tubes, or liners of the same size, design, manufacturing procedure, and material grade(s) successively manufactured on the same equipment. A lot requiring heat treatment or furnace brazing is processed through the same equipment under the same conditions of time, temperature, and furnace atmosphere.
Note: *In the context of container manufacture, the sample container(s) used for destructive testing need not be counted as part of the lot total.*
(b) In the context of used container reheat treatment and rebuilding, 100 or less containers of the same specification having the same general size and chemical composition.

Mass of a container — the mass of a completed container with all its affixed appurtenances, but excluding its valve(s) and excluding any devices that have to be removed for filling the container. For cylinders with porous filler, the mass of the filler, solvent, and saturation gas is included.

Material grade — a type and chemical composition of material from a given supplier, in which variations within the specified limits of the chemical composition have no significant effects on the mechanical properties achieved by the same heat-treatment or resin-curing schedule.

Minister — the Minister of Transport for Canada.

Noncorrosive — chemically and metallurgically compatible with the container such that the pressure-retaining integrity of the container is not adversely affected under the conditions of containment.

Nonrefillable container — a container that can be filled only once for the transportation of dangerous goods.

Plugged cylinder — a cylinder, the bottom end of which has been spun closed and permanently sealed by a threaded plug.

Pressure of contents — the sum of the partial pressures of all the commodities shipped in a single container, less one atmosphere (gauge pressure).

Pressure-relief device — a device intended to release the pressure in a container in the event of accidental overpressure or exposure to fire.

Product analysis — a chemical analysis of the semi-finished or finished material to determine conformance with the requirements of a specification.

Rebuilt container — a container subjected to a major repair, including any one or a combination of the following procedures:
(a) the repair of a welded pressure-retaining seam, where the repair welds exceed 75 mm in length or are spaced by less than 75 mm between the termination of one weld and the beginning of the next weld;
(b) the repair of a welded or brazed attachment joint to a pressure-retaining part involving welds or brazed joints that exceed 75 mm in length or are spaced by less than 75 mm between the termination of one joint and the beginning of the next joint;
(c) the replacement of a pressure-retaining component; and
(d) for series-8 cylinders, the replacement of the porous filler.

Registered mark — the symbols or trademarks, or both, that have been registered with the Director and used in the marking of cylinders, spheres, and tubes as prescribed in this Standard.

Regulations — Regulations, pursuant to the *Transportation of Dangerous Goods Act,* Chapter 34, Statutes of Canada, 1992.

Rejected cylinder, sphere, or tube — a container not permitted for the transportation of dangerous goods unless reprocessed.

Repaired container — a container subjected to a repair involving welding or brazing but excluding any procedure listed under the definition of a rebuilt container.

Representative sample — a sample selected from a lot for testing that is expected to exhibit similar properties as the rest of the lot.

Seamless container (cylinder or **tube)** or **shell** — a one-piece container or shell that does not contain any line of juncture.

Series-3 container — a cylinder or a tube manufactured to a specification the designation of which starts with number 3.

Series-4 container — a cylinder or a sphere manufactured to a specification the designation of which starts with number 4.

Series-8 cylinder — a cylinder manufactured to a specification the designation of which starts with number 8.

Service pressure — the rated pressure marked on the container.
Note: *Containers designed and manufactured to this Standard have their service pressure marked in bar.*

Service temperature — the lowest content temperature for which an insulated cylinder is designed.

Specification — the complete description of the manufacturing requirements for a cylinder, sphere, or tube under a specific designation, eg, 4AAM33 or 4BWM.
Note: *The prefix of the specification designation (TC, CTC, etc) identifies the regulatory authority responsible at the time of the manufacture of the container.*

Sphere — a container of spherical shape with a water capacity not greater than 45.4 L designed to withstand an internal pressure greater than 275 kPa (absolute).

Spun cylindera cylinder that has been welded closed at one end by the spinning process, without the addition of weld metal.

Tare of container — the mass of a container plus the mass of its valve(s).

Transportation — any mode of conveying dangerous goods on land (including rail and highway) or water or in air.

Tube — a seamless container of cylindrical shape with a water capacity greater than 450 L designed to withstand an internal pressure equal to or greater than 12.4 MPa.

Water capacity — the total mass or volume of water a container can hold at 15°C and at a pressure of 101.325 kPa (absolute).

3. Reference Publications

This Standard refers to the following publications and where such reference is made it shall be to the edition listed below, including all amendments published thereto. Where foreign standards are referenced, only the technical content applies. Except for the Canadian Regulations, where there is a variance with this Standard, the requirements of this Standard shall prevail. Users of this Standard are advised against attempting direct application of any of the following reference publications without carefully observing this Standard's reference to that Standard, Specification, or Code.
Note: *See Appendix A for information on the reference organizations.*

CSA Standards
B340-02,
Selection and Use of Cylinders, Spheres, Tubes, and Other Containers for the Transportation of Dangerous Goods, Class 2;

CAN/CSA-Z94.4-93 (R1997),
Selection, Use, and Care of Respirators.

The Aluminum Association
Aluminum Standards and Data, 2000 Edition.

ANSI/ASNT* Standard
ANSI/ASNT CP-189-1995,
Standard for Qualification and Certification of Nondestructive Testing Personnel.

ASTM† Standards
A 240/A 240M-02,
Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels;

A 370-02,
Standard Test Methods and Definitions for Mechanical Testing of Steel Products;

A 372/A 372M-99,
Standard Specification for Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels;

A 480/A 480M-02,
Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip;

A 505-00,
Standard Specification for General Requirements for Steel, Sheet and Strip, Alloy, Hot-Rolled and Cold-Rolled;

A 568/A 568M-02,
Standard Specification for General Requirements for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled;

B 221-00,
Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wires, Profiles, and Tubes;

B 557-94,
Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products;

D 638-02,
Standard Test Method for Tensile Properties of Plastics;

D 2343-95,
Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns and Rovings Used in Reinforced Plastics;

D 2344/D 2344M-00 e1,
Standard Test Method for Strength of Polymer Matrix Composite Materials and Their Laminates;

E 8-01,
Standard Test Methods for Tension Testing of Metallic Materials;

E 23-01,
Standard Test Methods for Notched Bar Impact Testing of Metallic Materials;

E 112-96 e1,
Standard Test Methods for Determining Average Grain Size;

E 114-95 (2001),
Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method;

E 165-02,
Standard Test Method for Liquid Penetrant Examination;

E 213-98,
Standard Practice for Ultrasonic Examination of Metal Pipe and Tubing;

E 290-97a,
Standard Test Method for Bend Testing of Materials for Ductility;

E 709-01,
Standard Guide for Magnetic Particle Examination.

CGA‡ Publications
C-1-1996,
Methods for Hydrostatic Testing of Compressed Gas Cylinders — Seventh Edition;

C-3-2000,
Standards for Welding on Thin-Walled Steel Cylinders — Fifth Edition;

C-5-1991,
Cylinder Service Life — Seamless, Steel, High-Pressure Cylinders — Fifth Edition;

C-6-2001,
Standards for Visual Inspection of Steel Compressed Gas Cylinders —Eighth Edition;

C-6.1-1995,
Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders — Third Edition;

C-6.2-1996,
Guidelines for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders — Third Edition;

C-6.3-1999,
Guidelines for Visual Inspection and Requalification of Low Pressure Aluminum Compressed Gas Cylinders — Second Edition;

C-8-1997,
Standard for Requalification of DOT-3HT, CTC-3HT, and TC-3HTM Seamless Steel Cylinders — Sixth Edition;

C-11-2001,
Recommended Practices for Inspection of Compressed Gas Cylinders at Time of Manufacture — Third Edition;

C-12-2002,
Qualification Procedure for Acetylene Cylinder Design — Fourth Edition;

C-13-2000,
Guidelines for Periodic Visual Inspection and Requalification of Acetylene Cylinders — Fourth Edition.

V-1-2001,
Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections — Ninth Edition.

CGSB§ Standard
CAN/CGSB-48.9712-2000,
Non-Destructive Testing — Qualification and Certification of Personnel.

Government of Canada Legislation
Transportation of Dangerous Goods Act, S.C. 1992, c. 34, and the Regulations thereto, including amendments.

ISO Standard**
9712:1999,
Non-destructive testing — Qualification and certification of personnel.

NASA††
Computer Code LEW-10352 (NASA CR-72124),
Computer Program for the Analysis of Filament-Reinforced Metal-Shell Pressure Vessels, May, 1966. Available through Cosmic of Athens, Georgia.

US Federal Standard
FED-STD-H28-1978,
Screw-Thread Standards for Federal Services-78.

**American National Standards Institute/American Society for Nondestructive Testing, Inc.*
†*American Society for Testing and Materials*
‡*Compressed Gas Association, Inc.*
§*Canadian General Standards Board*
***International Organization for Standardization*
††*National Aeronautics and Space Administration (USA)*

4. General Requirements and Specifications for Cylinders, Spheres, and Tubes

Notes:
(1) *See Clause 1.2.1.*
(2) *See Appendix B for tolerances not covered by this Standard.*

4.1 Materials and Parts

4.1.1
Metallic materials and parts shall be free from defects such as, but not limited to, seams, cracks, laminations, pits, etc. Imperfections may be permitted, removed, or repaired, provided that the minimum wall thickness and other requirements, where applicable, are in accordance with this Standard.

4.1.2
Materials of shells and ends of finished containers shall be identified by a suitable method during manufacture to provide traceability, as follows:
(a) for metal shells and ends, the metal shall be traceable to its heat or cast number; and
(b) for composite shells and ends, the filament and resin shall be traceable to their pertinent lot or batch number.

4.1.3
Parts in process shall have a smooth, uniform surface finish and shall be free from dirt and scale, to permit inspection.

4.2 Wall Thickness

4.2.1 General Requirements

Unless otherwise specified, the actual minimum wall thickness of a container shall not be less than the design wall thickness and shall not include galvanized or any other protective coating. Also, unless otherwise specified, the minimum design wall thickness shall be calculated as follows, using Equation 1 or Equation 2:

(a) for cylinders and tubes

$$t = \frac{D}{2}(1 - \beta) = \frac{d}{2}\left(\frac{1 - \beta}{\beta}\right) \quad \textbf{(1)}$$

where
t = minimum design wall thickness, mm
D = outside diameter, mm

$$\beta = \sqrt{\frac{S - 1.3P}{S + 0.4P}}$$

where
S = maximum design wall stress in accordance with each specification, MPa
P = pressure value in accordance with each specification, MPa
d = inside diameter, mm

(b) for spheres

$$t = \frac{PD}{4SE} = \frac{Pd}{4SE - 2P} \quad \textbf{(2)}$$

where
t = minimum design wall thickness, mm
P = pressure value in accordance with each specification, MPa
D = outside diameter, mm
S = maximum design wall stress in accordance with each specification, MPa
E = joint confidence factor (see Clauses 17.3, 18.3, 19.3, and 23.3.)
d = inside diameter, mm

4.2.2 Additional Requirements for Tubes

4.2.2.1

Tubes shall be designed to meet additional conditions that assume that a tube is horizontally supported at its two ends only and that it is uniformly loaded over its entire length. This load shall consist of the weight per unit of length of the straight cylindrical portion filled with water, compressed to the specified test pressure. The sum of twice the maximum tensile stress in the bottom fibres due to bending plus that in the same fibres (longitudinal stress) due to hydrostatic test pressure shall not exceed 80% of the minimum yield strength of the steel.

4.2.2.2

The maximum tensile stress due to bending shall be calculated using Equations 3, 4, and 5, as follows:

$$S = \frac{MC}{I} \quad \textbf{(3)}$$

where
S = tensile stress, MPa
M = bending moment, N•mm

$$= \frac{wL^2}{8} \quad \textbf{(4)}$$

where
w = weight per millimetre of length of tube filled with water, N•mm
L = length of tube (including neck), mm

$C = \text{radius}\left(\frac{D}{2}\ \text{of tube}\right)$, mm

I = moment of inertia, mm^4

$$= 0.04909\,(D^4 - d^4) \quad \textbf{(5)}$$

where
D = outside diameter, mm
d = inside diameter, mm

4.2.2.3
The maximum longitudinal tensile stress due to the hydrostatic test pressure shall be calculated using Equation 6, as follows:

$$S = \frac{A_1 P}{A_2} = \frac{d^2}{D^2 - d^2} \times P \quad \textbf{(6)}$$

where
S = tensile stress, MPa
A_1 = internal area in cross-section of tube, mm^2
P = hydrostatic test pressure, MPa
A_2 = area of metal in cross-section of tube, mm^2
d = inside diameter, mm
D = outside diameter, mm

4.3 Openings in Cylinders, Spheres, and Tubes

4.3.1
All openings shall be in the ends of containers. All openings shall be circular.

4.3.2
Threads in openings shall be clean-cut, even, without checks, and to gauge.

4.3.3
Taper threads shall comply with one of the following:
(a) American Standard Pipe Threads (NPT) in accordance with the requirements of US Federal Standard H28, Section 7;
(b) National Gas Taper Threads (NGT) standards in accordance with the requirements of CGA Publication V-1 and US Federal Standard H28, Sections 7 and 9; or
(c) threads in accordance with other North American standards, provided the strength is not less than that specified for NPT threads.

4.3.4
Straight threads shall comply with one of the following:
(a) National Gas Straight Threads (NGS) in accordance with the requirements of US Federal Standard H28, Sections 7 and 9;
(b) Unified Threads (UN) in accordance with the requirements of US Federal Standard H28, Section 2;
(c) Controlled Radius Root Threads (UNJ) in accordance with the requirements of US Federal Standard H28, Section 4; or
(d) threads in accordance with other North American standards, provided that the requirements of Clause 4.3.5 are met.

4.3.5
Straight threads shall have a tight fit and a calculated shear strength of at least 10 times the shear stress at the test pressure of the container. Shear stress shall be calculated by using the appropriate thread shear area, in accordance with US Federal Standard H28, Appendix A5, Section 3.

4.3.6
Closure of the fitting, boss, or pad shall prevent leakage.

4.3.7
Gaskets shall be used with straight threads and shall be capable of preventing leakage. Gaskets and sealants shall be compatible with the contents of the container.

4.4 Welding or Brazing
Where welding or brazing is permitted, the procedures and the welders or operators shall be qualified in accordance with the applicable requirements of CGA Publication C-3.

4.5 Heat Treatment

4.5.1
Where required by the specification, the heat treatment shall be conducted prior to testing and, unless otherwise specified, after all metal forming and/or welding, in such a manner as
(a) to achieve the specified mechanical properties in all areas verifiable by removal of the specified standard-size test specimens; and
(b) to stress relieve welds.

4.5.2
The heat-treating temperature shall be controlled. It shall be monitored by instrumentation.

4.5.3
For containers subjected to reheat treatment, measurements shall be made to verify that the minimum wall thickness meets the specification requirements after the final heat treatment.

4.6 Nondestructive Inspection of Finished or Partly Finished Containers

4.6.1 Magnetic Particle Inspection
Magnetic particle inspection shall be in accordance with ASTM Standard E 709.

4.6.2 Liquid Penetrant Inspection
Liquid penetrant inspection shall be in accordance with ASTM Standard E 165.

4.6.3 Ultrasonic Inspection

Ultrasonic inspection shall be in accordance with ASTM Standard E 213 for the angle beam technique. Ultrasonic inspectors shall be qualified to CGSB Standard CAN/CGSB-48.9712, ANSI/ASNT CP-189, or ISO Standard 9712.

4.6.4 Radiographic Inspection

Radiographic inspection shall be in accordance with CGA Publication C-3.

4.7 Leakage Test

4.7.1

All spun and plugged cylinders shall be tested for leakage by dry gas or air pressure after the bottom end has been cleaned and is free from all moisture on the test pressure side. The inside area of the cylinder bottom surrounding the closure shall be subjected to a pressure equal to at least the service pressure for a minimum of 1 min. This area shall be not less than 20 mm in diameter around the closure and at least 6% of the total bottom area. The opposite side shall be covered with water or another suitable medium and closely examined for indication of leakage. Cylinders that leak shall be rejected.

Note: *As a safety precaution, if manufacturers elect to perform this test before the hydrostatic test, they should design their apparatus so that the pressure is applied to the smallest area practicable, around the point of closure, so as to use the smallest possible volume of air or gas.*

4.7.2

Spun cylinders rejected under the provisions of Clause 4.7.1 may be reworked, by drilling to remove the defective material, tapping, and plugging, and reclassified as plugged cylinders. Plugged cylinders rejected under the provisions of Clause 4.7.1 may be reworked to install a larger-diameter plug. Each reworked cylinder shall pass the leakage test described in Clause 4.7.1.

4.8 Tensile Test

4.8.1

Tensile tests shall be performed, unless otherwise specified, in accordance with the following requirements, to determine yield strength, tensile strength, and elongation of the material after heat treatment when a heat treatment is specified:

(a) The yield strength in tension shall be the stress corresponding to a permanent strain of 0.2% of the gauge length.

(b) For steel and nickel, the yield strength shall be determined by either the offset method or the extension-under-load method described in ASTM Standard E 8. For aluminum, the yield strength shall be determined by either the offset method or the extension-under-load method described in ASTM Standard B 557.

(c) In the extension-under-load method, the total strain (or extension under load) corresponding to the stress at which the 0.2% permanent strain occurs may be determined with sufficient accuracy by calculating the elastic extension of the gauge length under the appropriate load and adding thereto 0.2% of the gauge length. Elastic extension calculations shall be based on the elastic modulus of the material used. In the event of controversy, the entire stress-strain diagram shall be plotted and the yield strength determined from the 0.2% offset. For the purpose of strain measurement, the initial strain reference shall be set while the specimen is under a stress of 80 MPa, for steel and nickel, or 40 MPa, for aluminum, the strain indicator being set at the calculated corresponding strain.

Note: *Elastic modulus for steel and nickel is 207 GPa. For aluminum it is 69 GPa.*

(d) The cross-head speed of the testing machine shall not exceed 3 mm/min during the yield-strength determination.

(e) Heating of specimens shall be prohibited.

(f) The specimens shall not be flattened, except that grip ends may be flattened to within 25 mm of each end of the reduced section.

(g) Where the container size does not permit securing straight specimens, the specimens may be straightened or flattened cold, by pressure only, not by blows, and shall be so recorded in the independent inspector's report.
(h) If the size of the cylinder and the specimens permits, the specimens may be taken from cylinders used in the flattening test, from material undisturbed by this latter test.
(i) In cases where, in the opinion of the independent inspector, the location of the test specimens in accordance with the specification makes them not representative of the physical properties of a sample container, additional specimens shall be taken from other locations designated by the independent inspector.

4.8.2

The following specimen types shall be used in accordance with each applicable specification:

Specimen type	Gauge length	Width	Thickness
Type A	50 mm	37 mm max.	Full wall thickness
Type B	200 mm	37 mm max.	Full wall thickness
Type C*	Min. 24 times wall thickness	Max. 6 times wall thickness	Full wall thickness
Type D	Reduced-section cylindrical specimen having a gauge length 4 times the diameter of the reduced section		
Type E	$5.65\sqrt{\text{specimen cross-sectional area}}$	Width:thickness ratio shall be not greater than 20, to suit capacity of testing machine	Full wall thickness

**Applies to specimens having wall thickness not greater than* 4.8 mm.

4.8.3

Results of the tensile test shall be in accordance with the requirements of the applicable specification for the minimum wall thickness of the lot. Otherwise, the lot shall be rejected.

4.9 Weld Tests

Where required by a specification, and after heat treatment where heat treatment is specified, specimens for the tensile, guided-bend, or alternate guided-bend test shall be taken from the specified seam and shall be prepared and tested in accordance with, and meet the requirements of, CGA Publication C-3.

4.10 Flattening Test

Where a flattening test is specified, the following procedure shall apply, unless otherwise indicated:
(a) Cylinders, or rings from cylinders or tubes, shall be flattened between two 60° angle wedge-shaped knife edges rounded to a 13 mm radius maximum or another suitable fixture having the same radius. The longitudinal axis of the sample shall be at approximately a 90° angle to the knife edges. The knife edges shall cover the entire width of the flattened sample.
(b) Spheres, or rings from spheres, shall be flattened between two parallel steel plates, with the sphere's welded seam perpendicular to the plates. Projecting appurtenances may be removed, by mechanical means only, prior to flattening. The plates shall cover completely the flattened sample.
(c) Cylinders or spheres shall be flattened, without cracking, until the separation distance between the knife edges or plates, as applicable, is equal to or less than the dimension required in the container specification. Otherwise, the lot shall be rejected.

4.11 Lot Qualification Burst Test

The burst test, where required, shall be in accordance with the relevant specification. The rate of pressurization shall not exceed 1.4 MPa/s. Failure of the test container shall be cause for the rejection of the lot.

4.12 Hydrostatic Test

4.12.1

Hydrostatic tests (volumetric expansion and proof pressure tests) shall be performed in accordance with CGA Publication C-1, except that
(a) the pressure-measuring device shall permit reading pressure to an accuracy of 1% in the range of 80–120% of the test pressure;
(b) the expansion-measuring device shall permit reading to an accuracy of 1% or 0.1 mL, whichever is greater; and
(c) a calibration cylinder, capable of verifying the equipment accuracy to ±1% for the material, size, and test pressure of the containers to be tested, shall be used to verify the accuracy of the equipment at the beginning of each day.

4.12.2

The permanent expansion, where volumetric expansion measurement is required, shall not exceed 10% of the total expansion at test pressure, unless otherwise specified.

4.12.3

The hydrostatic test shall be conducted after any heat treatment.

4.12.4

All containers failing to pass the hydrostatic test shall be rejected. Where a sample container from a lot fails to pass the hydrostatic test, the lot shall be rejected, unless otherwise specified.

4.13 New Design

4.13.1 New Design Criteria

Unless otherwise specified, a container made to a specification included in this Standard shall be considered to be of a new design, compared to an existing approved design, when
(a) it is manufactured in a different factory;
(b) it is manufactured by a different process;
(c) it is manufactured from a different material;
(d) the mechanical properties and microstructure are substantially modified as a consequence of a change in heat treatment;
(e) the inside diameter of at least one opening in the finished container is increased by 100% or more;
(f) the number of openings in the finished container is increased;
(g) the profile of an end is changed;
(h) a joint design is changed;
(i) the service pressure is changed by 10% or more, or 2 bar or more, whichever is greater;
(j) the design wall thickness or diameter is changed by 10% or more;
(k) an end thickness is changed by 30% or more; or
(l) the water capacity is increased by 30% or more.

4.13.2 Qualification of a New Design

Unless otherwise specified, the qualification of a new design shall be in accordance with the requirements of Clauses 4.13.3 to 4.13.6; it shall be carried out by or under the supervision of an independent inspector. Prior to the shipment of a lot of containers of a new approved design, representative containers shall have passed the new-design qualification tests.

4.13.3 Containers Submitted for Approval of Design

Containers submitted for approval of design shall
(a) be made of the same materials and with the same procedures, quality control, tools, and machinery

that are to be used for their production;
(b) be selected prior to any pressure testing from a sample lot in which the other containers meet the requirements of all acceptance tests and inspections of the applicable specification; and
(c) not have been in service.

4.13.4 Pressure-Cycling Test

For containers designed for an indefinite life span, the following shall apply:
(a) three representative sample containers shall be pressure-cycling tested;
(b) pressurization shall be performed hydrostatically at a maximum rate of 10 cycles/min, without distortion or failure between approximately 0 kPa and the hydrostatic test pressure, as required by the container specification, for 10 000 cycles. Appropriate recording instruments shall be used where the cycling pressurization equipment is left operating unattended;
(c) structural damage or leakage shall be prohibited;
(d) the lower cycling pressure shall not exceed 10% of the upper cycling pressure;
(e) during each cycle the time spent when the pressure is over 90% of the upper cycling pressure shall be equal to at least 20% of the cycle period;
(f) reasons for failure shall be determined; and
(g) all containers used in the cycling test shall be condemned.

4.13.5 Burst Test

Three containers shall be tested hydrostatically to destruction. The rate of pressurization shall not exceed 1.4 MPa/s. When the container is made to a specification that requires a burst test, the burst pressure shall be that required by the specification. For other cases, the burst pressure shall be as follows:
(a) for welded or brazed containers, the burst pressure shall be at least 3 times the service pressure;
(b) for seamless containers,
(i) aluminum cylinder designs with a service pressure equal to or greater than 3.5 MPa shall have a burst pressure at least 2.5 times the service pressure;
(ii) steel container designs with a service pressure equal to or greater than 6.9 MPa shall have a burst pressure at least 2.25 times the service pressure;
(iii) steel cylinder designs with a service pressure equal to or greater than 3.5 MPa and less than 6.9 MPa shall have a burst pressure at least 3 times the service pressure; and
(iv) designs with a test pressure of at least 2 times the service pressure shall have a burst pressure at least 4 times the service pressure.

The burst tear shall initiate in the longitudinal direction in the cylindrical portion of the cylinder or the tube when the ratio of tangential length to diameter is greater than 2. The actual pressure at burst shall be recorded. The container shall not fragment. The reason for failure to meet the requirements of the burst test shall be determined.

4.13.6 Microstructure Examination

Heat-treatment procedures for Grade H stainless steel shall be verified by microstructural examination of samples taken from both ends and the sidewall of a container.

4.14 Additional Requirements for Cylinders in Liquid Propane Gas (LPG) Service

4.14.1 Fixed Liquid-Level Gauges

Containers filled with a liquefied petroleum gas with a specific gravity of 0.504–0.510 at 15°C or greater may have their contents determined by using a fixed-length dip-tube gauging device as follows:
(a) The length of the dip tube shall be such that when a liquefied petroleum gas with a specific volume of 1.9 L/kg at a temperature of 4.4°C is charged into the container, the gas just reaches the bottom of the tube. The mass of this liquid shall not exceed 42% of the water capacity of the container.

(b) The length of the dip tube in mm, prefixed by the letters "DT" and followed by the unit symbol "mm", shall be stamped on the container, in accordance with Clause 4.17. For the purpose of this requirement, the marked length shall be expressed as the distance measured along the axis of a straight tube from the top of the boss through which the tube is inserted to the proper level of the liquid in the container.
(c) The inside diameter of the outlet from the dip tube shall be not larger than 1.4 mm.
(d) The proper installation of the dip tube shall be verified by the manufacturer at the time of installation.
(e) Containers with fixed liquid-level gauges that are permanently attached shall not have the dip tube (DT) stamping.

4.14.2 Water Capacity

The water capacity of the container in litres shall be stamped on the container.

4.15 Pressure-Relief Devices

Pressure-relief devices shall be in accordance with CSA Standard B340.

4.16 Inspection

4.16.1

For manufacturing, rebuilding, and reheat treating, inspection shall be performed by the manufacturer, rebuilder, and reheat treater, as well as by an independent inspector, in accordance with the applicable requirements of CGA Publication C-11. In addition, the independent inspector shall
(a) verify that the applicable design qualification tests have been performed with satisfactory results; and
(b) perform the internal inspection of seamless containers with a water capacity greater than 2 L, before closing.

4.16.2

Unless otherwise specified, where sample containers or specimens fail to pass any of the following tests:
(a) tensile test;
(b) flattening test;
(c) weld tensile test;
(d) weld bend test;
(e) burst test;
(f) impact test; or
(g) lot pressure-cycling test
and where the reason for failure is attributable to faulty testing equipment, specimen preparation, or testing procedure, the applicable test shall be repeated for lot acceptance and, except for the burst test and the lot pressure-cycling test, shall be made upon the same container(s) or liner(s) if sufficient material is left.

4.16.3

Where the failure of a weld tensile test is not attributable to the testing equipment, specimen preparation, or testing procedure, additional sample containers or welded test plates representing 1% of the lot, but in no case fewer than 2 units, shall be selected from the same lot and tested. Where one of these fails, the entire lot shall be rejected.

4.16.4

Acceptance criteria for surface imperfections in containers at the time of manufacture shall be in accordance with the requirements of this Standard and, where requirements are not given in this Standard, with those of CGA Publications C-6, C-6.1, C-6.2, and C-6.3.

4.17 Marking

4.17.1

Unless otherwise required in a specification, each approved cylinder, sphere, or tube shall be permanently and legibly stamped with marks specified in Clause 4.17.2. The marks specified in Items (a) to (c) of Clause 4.17.2 shall be arranged as shown in Figure 4.1.

4.17.2

The specified marks shall be

(a) Transport Canada mark, "TC";
(b) specification designation;
(c) service pressure (in bar);
(d) manufacturer's registered mark;
(e) manufacturer's serial number (numbers, letters);
(f) test month and year, eg, "09-86";
(g) independent inspector's registered mark (between month and year of test date);
(h) the letters "ST" followed by service temperature in degrees Celsius, where applicable;
(i) the word "SPUN" where an end closure in the finished container has been welded by the spinning process, or the word "PLUG" where an end closure in the finished container has been effected by plugging;
(j) water capacity (in litres) and the unit symbol "L" where applicable;
(k) the letter "T" followed by the tare (in kilograms) and the unit symbol "kg", where applicable;
(l) the letter "M" followed by the mass (in kilograms) and the unit symbol "kg", where applicable;
(m) the letters "REE" followed by the rejection elastic expansion, in millilitres, where applicable; and
(n) the letters "DT" followed by the length of the dip tube in millimetres, followed by the unit symbol "mm", where applicable.

4.17.3

Additional marks such as, but not limited to, the owner's registered mark shall be permitted provided that they are

(a) clear;
(b) legible;
(c) made in low-stress areas other than the sidewall; and
(d) not of a size or depth that will create harmful stress concentrations.

Such marks shall not conflict with any required markings.

4.17.4

A serial number shall not be duplicated by a manufacturer.

4.17.5

The size of marks shall be not less than 6 mm in height for cylinders and spheres and 12 mm in height for tubes, except that marks may be not less than 3 mm in height for cylinders less than 125 mm in outside diameter, provided the smaller marks are clear and legible.

4.17.6

For containers subject to periodic requalification, sufficient space for marking the requalification dates shall be provided.

4.17.7

Marking of mass or tare shall be to an accuracy of 1%.

4.18 Certificate of Compliance and Test Report

Certificates of compliance with chemical composition and test reports shall be prepared by the independent inspector. Typical formats are shown in Appendices A–G of CGA Publication C-11. The independent inspector shall furnish complete test reports for each lot as required by each specification.

5. Specifications TC-3AM, TC-3ANM, TC-3ASM, and TC-3AXM

5.1 General

5.1.1

TC-3AM containers are seamless carbon steel, carbon manganese steel, or intermediate manganese steel cylinders with a minimum service pressure of 1.0 MPa.

5.1.2

TC-3ANM containers are seamless nickel cylinders with a maximum capacity of 68 L of water and a service pressure range from 1.0 to 3.5 MPa.

5.1.3

TC-3ASM containers are seamless austenitic stainless steel cylinders with a minimum service pressure of 1.0 MPa.

5.1.4

TC-3AXM containers are seamless carbon manganese or intermediate manganese steel tubes.

5.2 Materials

5.2.1 General

If the heat identification is permanently stamped on the container, it shall be stamped in an area other than the sidewall.

5.2.2 TC-3AM Cylinders

Steel shall be semi-killed or killed carbon steel of uniform quality conforming to the chemical composition of Grade A, specified in Table 5.1, or alloy steel of uniform quality conforming to the chemical composition of either Grade B or C, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2. The service pressure of cylinders made from Grade A shall be less than 6.9 MPa.

5.2.3 TC-3ANM Cylinders

Nickel shall be nickel of uniform quality conforming to the chemical composition of Grade I, specified in Table 5.1.

5.2.4 TC-3ASM Cylinders

Steel shall be stainless steel of uniform quality conforming to the chemical composition of Grade H, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.3.

5.2.5 TC-3AXM Tubes

Steel shall be alloy steel of uniform quality conforming to the chemical composition of either Grade B or C, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2.

5.3 Wall Thickness

5.3.1 Cylinders

The minimum design wall thickness for a cylinder shall be the greater of the applicable values that follow:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the lower specified hydrostatic test pressure:

(i) for cylinders made from steel Grades A through C, with a service pressure less than 6.9 MPa, the wall stress in Equation 1 shall not exceed 45% of the minimum tensile strength as determined by the tensile test or 165 MPa, whichever is the lesser;

(ii) for cylinders made from steel Grades B and C, with a service pressure of 6.9 MPa or more, the wall stress in Equation 1 shall not exceed 380 MPa;

(iii) for cylinders made from stainless steel Grade H, the wall stress in Equation 1 shall not exceed 235 MPa; and

(iv) for cylinders made from nickel, the wall stress in Equation 1 shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 103 MPa, whichever is the lesser; or

(b) 1.3 mm for cylinders with an outside diameter of 127 mm or less, or 2.5 mm for cylinders with an outside diameter larger than 127 mm.

5.3.2 Tubes

The minimum design wall thickness for a tube shall be the greater value of the following:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure, and on the requirements of Clause 4.2.2. The wall stress in Equation 1 shall not exceed 380 MPa; or

(b) 5.7 mm.

5.4 Openings

Openings shall be threaded. Centre openings not exceeding the smaller of one-half of the outside diameter of the container or 220 mm may be used in ends having integrally formed necks. Other openings shall not exceed 61 mm in diameter. Openings in one end shall have ligaments between them of at least 3 times the average of their hole diameters, where the hole diameter is considered to be the maximum major thread diameter. Straight threads shall have at least 6 engaging threads.

5.5 Manufacture

Manufacturing considerations shall be as follows:

(a) The manufacturing process shall be capable of producing containers free from defects.

(b) Cylinders shall be manufactured by any of the following processes, or by a combination of the following processes, to produce seamless cylindrical shapes with integrally formed ends:

(i) backward extrusion;

(ii) hot or cold drawing;

(iii) ironing;

(iv) spinning of seamless cylindrical tubing. Closure of nickel cylinders by the spinning process shall be prohibited;

(v) billet piercing; and

(vi) hot swaging of seamless cylindrical pipe.

(c) Tubes shall be manufactured by any process that will produce seamless cylindrical shapes with integrally formed ends concave to pressure. Closure of tubes by the spinning process shall be prohibited.

(d) Imperfections such as mechanical marks, draw marks, pits, or other surface irregularities generally having a round bottom contour shall be acceptable, provided that the minimum design wall thickness is maintained.

(e) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the container may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall not be less than the minimum design wall thickness. Metal removal to eliminate isolated

defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test.

(f) The bottoms of bumped-back cylinders manufactured from tubing shall have a minimum thickness not less than 2 times the minimum design wall thickness. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.

(g) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of container) to minor axis not exceeding 2:1, or a dished shape falling within these two limits. Such ends shall have a minimum thickness not less than the minimum design wall thickness, except that

(i) the point of closure of cylinders closed by spinning shall not be less than 2 times the minimum design wall thickness; and

(ii) hemispherical ends drawn from sheet or plate shall have a thickness not less than 90% of the minimum design wall thickness.

(h) Other bottom designs shall be permitted, provided that

(i) each design has been qualified by the cycling test; and

(ii) detail information of the bottom design is available to the independent inspector.

5.6 Welding or Brazing

5.6.1 Cylinders

Fusion welding or brazing shall be permitted only for the attachment of neck rings and foot rings, which are nonpressure parts, and then only to the ends of cylinders having a service pressure of 3.5 MPa or less. Where welding is used, TC-3AM cylinders, neck rings, and foot rings shall be made of weldable steel with a carbon content not exceeding 0.25%. For TC-3ANM cylinders, welding rod shall be nickel. For TC-3ASM cylinders, welding rod shall be austenitic stainless steel.

5.6.2 Tubes

Welding or brazing shall be prohibited.

5.7 Heat Treatment

5.7.1 General

The completed containers shall be heat-treated.

5.7.2 Cylinders

5.7.2.1

Cylinders made from Grade A steel may be stress-relieved at a temperature not lower than 593°C. Cylinders made from Grades B and C steel shall be normalized at a metal temperature most suitable for the material grade. Liquid quenching of cylinders shall be prohibited.

5.7.2.2

Cylinders made from Grade H stainless steel shall be heat-treated to achieve the mechanical properties required in Clause 5.8.3 and at a temperature that prevents the formation of deleterious phases.

5.7.2.3

Cylinders made from Grade I nickel shall be heated to a metal temperature above 510°C for sufficient time to produce the specified mechanical properties. Prior to heat treatment, cylinders shall be clean and free from sulphur or lead-bearing materials. Furnace atmosphere during heat treatment shall be sulphur-free and neutral or reducing. Liquid quenching shall be permitted. After heat treatment the average grain size shall not exceed 64 µm.

5.7.3 Tubes

Tubes shall be normalized at a metal temperature most suitable for the material grade. Liquid quenching of tubes shall be prohibited.

5.8 Tensile Test

5.8.1 Cylinders

Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder, taken from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

5.8.2 Tubes

Two Type A specimens, located approximately 180° apart, shall be cut from 1 tube or test ring representing each heat and each batch, and shall be tested. Heats already represented in another group of heat-treated tubes that have passed the tests, need not be represented again, even if the number represented in each heat exceeds 200. Each test ring shall be of the same diameter, thickness, and material grade as the finished tubes it represents. The test ring shall be at least 60 cm long and have its ends covered during the heat-treatment process. Test rings shall be heat-treated with the tubes they represent. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the test tube or ring.

5.8.3 Requirements

The yield strength shall not exceed 73% of the tensile strength for steel containers and 50% of the tensile strength for nickel cylinders. The elongation shall be at least 40% in Type A specimens or at least 20% in other specimen types; if this elongation requirement is fulfilled, a flattening test is not required. Elongations less than the 40% and the 20% mentioned above shall be acceptable if they are, respectively, at least 20% or 10%, and if the containers meet the requirements of Clause 5.9.

5.9 Flattening Test

5.9.1 Cylinders

One representative cylinder, from each lot of 200 or less, shall be tested, if required (see Clause 5.8.3).

5.9.2 Tubes

Tubes or test rings taken and prepared in the same manner as the sample tubes or test rings for the tensile test shall be tested, if required (see Clause 5.8.3).

5.9.3 Requirements

Steel samples shall be flattened to 6 times the wall thickness, and nickel samples shall be flattened to 4 times the wall thickness, without cracking.

5.10 Hydrostatic Test

5.10.1

Each container shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure;
(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of
    (i) 7.0 MPa; or

(ii) 1.5 times service pressure; and
(c) for tubes, 1.5 times service pressure.

5.10.2
Alternative testing shall be permitted for TC-3AM and TC-3ASM cylinders having a service pressure less than 3.5 MPa. One representative cylinder, from each lot of 200 or less, shall be tested hydrostatically to 3 times its service pressure and have its volumetric expansion measured. All other cylinders in the same lot shall be inspected under a pressure of 2 times the service pressure and show no defects.

5.10.3
Alternative testing by the proof pressure method shall be permitted for cylinders having a water capacity not exceeding 1 L. Each cylinder shall be inspected under a pressure at least equal to the specified test pressure and show no defects.

5.11 Rejected Containers
Reheat treatment shall be permitted; containers shall then pass all specified tests. Repair by welding or spinning shall be prohibited.

5.12 Marking

5.12.1
Cylinders shall be marked on the shoulder, top end, or neck. Tubes shall be marked on one shoulder or neck. The depth of markings shall be such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness.

5.12.2
Containers with a water capacity greater than 1 L and service pressure equal to or greater than 3.5 MPa shall be marked with the rejection elastic expansion (REE) in millilitres. The REE shall be calculated in accordance with CGA Publication C-5.
Note: *Lot numbers in lieu of serial numbers are permitted for cylinders when the volumetric capacity does not exceed* 1.0 L.

6. Specifications TC-3AAM and TC-3AAXM

6.1 General

6.1.1
TC-3AAM containers are seamless alloy steel cylinders with a minimum service pressure of 1.0 MPa.

6.1.2
TC-3AAXM containers are seamless alloy steel tubes.

6.2 Materials

6.2.1 General
If the heat identification is permanently stamped on the container, it shall be stamped in an area other than the sidewall. Steel shall have tensile properties that will allow the manufacturer to achieve in the container a minimum tensile strength, in accordance with Clause 6.9, that satisfies the requirements of Clause 6.3.

6.2.2 Cylinders

Steel shall be alloy steel of uniform quality conforming to the chemical composition of Grade C, D, E, or F, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2. Where a Grade E carbon-boron steel is used, a hardenability test shall be performed on material from the first and last ingot of each heat of steel. The results of this test shall be recorded on the Record of Chemical Analysis of Material Form for the cylinders. This hardness test shall be made 8 mm from the quenched end of the Jominy quench bar. The hardness shall be at least HRC 33 and no more than HRC 53.

6.2.3 Tubes

Steel shall be alloy steel of uniform quality conforming to the chemical composition of Grade D or F, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2.

6.3 Wall Thickness

6.3.1 Cylinders

The minimum design wall thickness for a cylinder shall be the greater of the applicable values that follow:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure:

(i) for cylinders with a service pressure of 6.9 MPa or more, the wall stress in Equation 1 shall not exceed 67% of the minimum tensile strength as determined by the tensile test or 483 MPa, whichever is the lesser; and

(ii) for cylinders with a service pressure less than 6.9 MPa, the wall stress in Equation 1 shall not exceed 45% of the minimum tensile strength as determined by the tensile test or 165 MPa, whichever is the lesser; or

(b) 1.3 mm for cylinders with an outside diameter of 127 mm or less, or 2.5 mm for cylinders with an outside diameter larger than 127 mm.

6.3.2 Tubes

The minimum design wall thickness for a tube shall be the greater value of the following:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure, and on the requirements of Clause 4.2.2. The wall stress in Equation 1 shall not exceed 67% of the minimum tensile strength as determined by the tensile test or 483 MPa, whichever is the lesser; or

(b) 5.7 mm.

6.4 Openings

Openings shall be threaded. Centre openings not exceeding the smaller of one-half of the outside diameter of the container or 220 mm may be used in ends having integrally formed necks. Other openings shall not exceed 61 mm in diameter. Openings in one end shall have ligaments between them of at least 3 times the average of their hole diameters, where the hole diameter is considered to be the maximum major thread diameter. Straight threads shall have at least 6 engaging threads.

6.5 Manufacture

Manufacturing considerations shall be as follows:

(a) The manufacturing process shall be capable of producing containers free from defects.

(b) Cylinders shall be manufactured by any of the following processes, or by a combination of the following processes, to produce seamless cylindrical shapes with integrally formed ends:

(i) backward extrusion;
(ii) hot or cold drawing;
(iii) ironing;
(iv) spinning of seamless cylindrical tubing;
(v) hot swaging of seamless cylindrical pipe; and
(vi) billet piercing.

(c) Tubes shall be manufactured by any process that will produce seamless cylindrical shapes with integrally formed ends concave to pressure. Closure of tubes by the spinning process shall be prohibited.
(d) Imperfections such as mechanical marks, draw marks, pits, or other surface irregularities generally having a round bottom contour shall be acceptable, provided that the minimum design wall thickness is maintained.
(e) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the container may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall not be less than the minimum design wall thickness. Metal removal to eliminate isolated defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test. Surface conditioning, such as grit or shot blasting, or brushing, or interior polishing, may be done after the hydrostatic test, provided that the minimum design wall thickness is maintained.
(f) The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum design wall thickness. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.
(g) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of container) to minor axis not exceeding 2:1, or a dished shape falling within these two limits. Such ends shall have a minimum thickness not less than the minimum design wall thickness, except that

(i) the point of closure of cylinders closed by spinning shall not be less than 2 times the minimum design wall thickness; and

(ii) hemispherical ends drawn from sheet or plate shall have a thickness not less than 90% of the minimum design wall thickness.

(h) Other bottom designs shall be permitted, provided that
(i) each design has been qualified by the cycling test; and
(ii) detail information of the bottom design is available to the independent inspector.

6.6 Welding or Brazing

Welding or brazing shall be prohibited.

6.7 Heat Treatment

6.7.1

The completed containers shall be heat-treated.

6.7.2

All containers shall be quenched in oil or another suitable medium. The steel temperature on quenching shall be that recommended for the material grade, but in no case shall it exceed 955°C. Tubes shall be held at the heat-treating temperature for at least 2.4 min/mm of maximum sidewall thickness. Quenched containers shall be tempered at a temperature consistent with achieving the specified mechanical properties. The tempering temperature shall be not less than 540°C, except that containers made of intermediate manganese steel shall be tempered at a temperature not less than 620°C.

6.8 Magnetic Particle or Liquid Penetrant Inspection

6.8.1

Containers made of steels other than intermediate manganese, if quenched in a liquid producing a cooling rate in excess of 80% the cooling rate of water, shall be inspected after heat treatment by magnetic particle or liquid penetrant method to detect quenching cracks. Cylinders with quenching cracks shall be condemned. Tubes with quenching cracks shall be rejected. Imperfections that, in the opinion of the independent inspector, may weaken a container shall be cause for rejection.

6.8.2
Containers made of intermediate manganese steel shall be submitted, after heat treatment, to a magnetic particle or liquid penetrant inspection to detect quenching cracks. Containers with quenching cracks shall be condemned. Imperfections that, in the opinion of the independent inspector, may weaken a container shall be cause for rejection.

6.9 Tensile Test

6.9.1 Cylinders
Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder, taken from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

6.9.2 Tubes
Two Type A specimens, located approximately 180° apart, shall be cut from 1 tube or test ring representing each heat and each batch, and shall be tested. Heats already represented in another group of heat-treated tubes that have passed the tests need not be represented again, even if the number represented in each heat exceeds 200. Each test ring shall be of the same diameter, thickness, and material grade as the finished tubes it represents. The test ring shall be at least 60 cm long and have its ends covered during the heat-treatment process. Test rings shall be heat-treated with the tubes they represent. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the test tube or ring.

6.9.3 Requirements
The elongation shall be at least 20% in Type A specimens or at least 10% in other specimen types.

6.10 Flattening Test

6.10.1 Cylinders
One representative cylinder, taken from each lot of 200 or less, shall be tested.

6.10.2 Tubes
Tubes or test rings taken and prepared in the same manner as the sample tubes or test rings for the tensile test shall be tested.

6.10.3 Requirements
Flattening to 6 times the wall thickness without cracking shall be required.

6.11 Hydrostatic Test

6.11.1
Each container shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure;
(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of
    (i) 7.0 MPa; or
    (ii) 1.5 times service pressure; and
(c) for tubes, 1.5 times service pressure.

6.11.2
Alternative testing by the proof pressure method shall be permitted for cylinders having a water capacity not exceeding 1 L. Each cylinder shall be inspected under a pressure at least equal to the specified test pressure and show no defects.

6.12 Ultrasonic Inspection
The cylindrical section of each tube shall be inspected ultrasonically. If the inspection is performed prior to heat treatment, suitable controls for the prevention of quench cracks shall be in place. Any imperfection giving a response greater than that produced by a notch equal to 5% of the minimum design wall thickness shall be cause for rejection.

6.13 Rejected Containers
Reheat treatment shall be permitted; containers shall then pass all specified tests. Repair by welding or spinning shall be prohibited.

6.14 Hardness Test
After the final heat treatment, each tube shall be hardness-tested on the cylindrical section. A minimum of 4 readings shall be taken, 2 at each end of the tube, located 180° apart. The hardness shall not exceed HB 269. When the result of the initial hardness test exceeds the maximum permitted, 2 or more retests may be made; however, the hardness number obtained in each retest shall not exceed the maximum permitted. Tubes failing to pass the test shall be rejected.

6.15 Marking

6.15.1
Cylinders shall be marked on the shoulder, top end, or neck. Tubes shall be marked on one shoulder or neck. The depth of markings shall be such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness.

6.15.2
Containers with a water capacity greater than 1 L and service pressure equal to or greater than 3.5 MPa shall be marked with the rejection elastic expansion (REE) in millilitres. The REE shall be calculated in accordance with CGA Publication C-5.

Note: *Lot numbers in lieu of serial numbers are permitted for cylinders when the volumetric capacity does not exceed* 1.0 L.

7. Specification TC-3ALM

7.1 General
TC-3ALM containers are seamless aluminum alloy cylinders with a minimum service pressure of 1.0 MPa.

7.2 Materials

7.2.1
Aluminum shall be aluminum alloy of uniform quality conforming to the chemical composition of alloys AA6010 or AA6061, specified in Table 7.1.

7.2.2
Material identification shall provide traceability for the alloy, the aluminum producer's cast number, the solution heat-treatment batch number, and the lot number. If the identification is permanently stamped on the cylinder, it shall be stamped in an area other than the sidewall.

7.2.3
All starting stock shall be 100% ultrasonically inspected along the length from two planes 90° apart, in accordance with ASTM Standard E 114, using the straight-beam technique. The equipment and continuous scanning procedure shall be capable of detecting internal defects, such as cracks, that have an ultrasonic response greater than that of a calibration block with a 2 mm diameter flat-bottomed hole. The independent inspector shall perform or witness the ultrasonic inspection of all starting stock or obtain the material producer's certificate of ultrasonic inspection.

7.2.4
Cast stock shall have a uniform equiaxial grain structure, not to exceed 500 μm.

7.3 Wall Thickness
The minimum design wall thickness shall be the greater of the applicable values that follow:
(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure. The wall stress in Equation 1 shall not exceed 72% of the minimum yield strength or exceed 60% of the minimum tensile strength as determined by the tensile test, whichever is the lesser; or
(b) 2.1 mm for cylinders with an outside diameter of 127 mm or less, or 3.2 mm for cylinders with an outside diameter larger than 127 mm.

7.4 Openings
Openings shall be threaded. There shall not be more than one opening per cylinder end. The diameter of the opening shall not exceed the smaller of one-half of the outside diameter of the cylinder or 61 mm. Straight threads shall have at least 6 engaging threads.

7.5 Manufacture
Manufacturing considerations shall be as follows:
(a) The manufacturing process shall be capable of producing seamless cylinders free from defects, with integrally formed ends.
(b) Cylinder shells shall be manufactured by the backward extrusion process.
(c) Closure of cylinders by the spinning process shall be prohibited.
(d) Imperfections such as mechanical marks, draw marks, pits, or other surface irregularities generally having a round bottom contour shall be acceptable, provided the minimum design wall thickness is maintained.
(e) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the cylinder may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall not be less than the minimum design wall thickness. Metal removal to eliminate isolated defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test.
(f) The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum design wall thickness along the line of contact between the cylinder base and the floor.
(g) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal, or torispherical. Ellipsoidal ends shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1. Torispherical ends shall have a dish radius not greater than 1.2 times the inside diameter of the cylinder, and the knuckle radius shall be not less than 12% of the inside diameter. Ends shall have a minimum thickness not less than the minimum design wall thickness.
(h) The interior bottom contour may deviate from the true torispherical, hemispherical, or ellipsoidal configuration in any location provided that

(i) all radii of merging surfaces are equal to or greater than the knuckle radius;
(ii) each design has been qualified by the cycling test; and
(iii) detail information of the bottom design is available to the independent inspector.

7.6 Welding or Brazing

Welding or brazing shall be prohibited.

7.7 Heat Treatment

The completed cylinders shall be subjected to a solution heat treatment and an aging treatment that is appropriate for the material grade.

7.8 Tensile Test

7.8.1

Two Type A, C, or D specimens, located approximately 180° apart, shall be cut from 1 representative cylinder from each lot of 200 or less and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

7.8.2

The tensile test results shall meet the requirements of Table 7.2.

7.9 Flattening Test

7.9.1

One representative cylinder from each lot of 200 or less shall be tested.

7.9.2

Cylinders shall be flattened between two 60° angle wedge-shaped knife edges rounded in accordance with the radius specified in Table 7.3.

7.9.3

As an alternative to the test in Clause 7.9.2, a bend test in accordance with ASTM Standard E 290, using a mandrel diameter not more than 6 times the wall thickness, shall be permitted. If used, this test shall be performed on two samples from 1 representative cylinder from each lot of 200 or less.

7.9.4

Each test cylinder shall withstand flattening to 9 times the wall thickness without cracking. When the alternate bend test is used, the test specimens shall not crack when bent inward around a mandrel in the direction of curvature of the cylinder wall until the interior edges are at a distance apart not greater than the diameter of the mandrel.

7.10 Hydrostatic Test

7.10.1

Each cylinder shall be tested hydrostatically to its test pressure and have its volumetric expansion measured. The permanent volumetric expansion shall not exceed 6% of the total expansion at test pressure. The test pressure shall be as follows:

(a) for cylinders with service pressure less than 3.5 MPa, the greater of
    (i) 3.1 MPa; or
    (ii) 2 times service pressure; and
(b) for cylinders with service pressure equal to or greater than 3.5 MPa, the greater of

(i) 7.0 MPa; or
(ii) 1.5 times service pressure.

7.10.2
Alternative testing by the proof pressure method shall be permitted for cylinders having a water capacity not exceeding 1 L. Each cylinder shall be inspected under a pressure at least equal to the specified test pressure and show no defects.

7.11 Rejected Cylinders
Only one reheat treatment shall be permitted; cylinders shall then pass all specified tests. Repair by welding or spinning shall be prohibited.

7.12 Marking
Cylinders shall be marked on the shoulder, top end, or neck. The depth of markings shall be such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness.
Note: *Lot numbers in lieu of serial numbers are permitted for cylinders when the volumetric capacity does not exceed* 1.0 L.

8. Specification TC-3EM

8.1 General
TC-3EM containers are seamless steel cylinders with a maximum nominal outside diameter of 51 mm, a length less than 610 mm, and a service pressure of 12.4 MPa.

8.2 Materials

8.2.1
For carbon steel cylinders, steel shall be semi-killed or killed carbon steel of uniform quality conforming to the chemical composition specified in Table 8.1.

8.2.2
For stainless steel cylinders, steel shall be of uniform quality conforming to the chemical composition of Grade H, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.3.

8.3 Wall Thickness
The wall thickness shall be governed by other requirements in this Standard.

8.4 Openings
Openings shall be threaded. Straight threads shall have at least 4 engaging threads.

8.5 Manufacture
Cylinders shall be manufactured from seamless tubing. The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum wall thickness of the cylindrical shell. Such bottom thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.

8.6 Hydrostatic Test

8.6.1

One cylinder from each lot of 500 or less shall be tested hydrostatically. The cylinder shall burst at a pressure greater than 41 MPa without fragmenting or otherwise showing a lack of ductility, or shall hold a pressure of 83 MPa for 30 s without bursting. In the latter case, the cylinder shall be subjected, after the proof test, to a flattening test to 6 times its wall thickness without cracking.

8.6.2

The other cylinders shall be inspected under a pressure of at least 21 MPa and not exceeding 31 MPa and shall show no defect. The proof test pressure shall be within the range of 21–25 MPa when the burst test cylinder has failed at a pressure of 52 MPa or less.

8.7 Rejected Cylinders

Repair by welding or spinning shall be prohibited.

8.8 Marking

The specified marks shall be as follows:
(a) TC 3EM124;
(b) the manufacturer's mark;
(c) the original test date; and
(d) independent inspector's registered mark (between month and year of test date).

9. Specifications TC-3FCM and TC-3HWM

9.1 General

9.1.1

TC-3FCM containers are full-composite cylinders made of resin-impregnated continuous filament windings in both longitudinal and circumferential directions over a seamless aluminum liner, with a maximum capacity of 91 L of water and a service pressure range of 6.2–34.5 MPa.

9.1.2

TC-3HWM containers are partial-composite cylinders made of resin-impregnated continuous filament windings in the circumferential direction only over a seamless aluminum liner, with a maximum capacity of 91 L of water and a service pressure range of 6.2–34.5 MPa.

9.2 Materials

9.2.1 Aluminum Liners

Aluminum shall be aluminum alloy of uniform quality conforming to the chemical composition of alloys AA6010 or AA6061, specified in Table 7.1. Starting stock shall be cast stock, die- and mandrel-extruded tubing, sheet, or plate. Liners shall be traceable to heat-treatment batch number and inspection lot number. Cast stock shall have a uniform equiaxial grain structure not to exceed 500 µm. In addition
(a) all solid cast starting stock shall be 100% ultrasonically inspected along the length from two planes 90° apart; and
(b) all hollow cast starting stock shall be 100% ultrasonically inspected along the length over the entire transverse face.

The equipment and continuous scanning procedure for ultrasonic testing shall be in accordance with ASTM Standard E 114, using the straight-beam technique, and shall be capable of detecting internal

defects, such as cracks, that have an ultrasonic response greater than that of a calibration block with a 2 mm diameter flat-bottomed hole.

9.2.2 Filament Material

Filament material shall be commercial Type-S or commercial Type-E fibreglass. Filaments shall be tested in accordance with ASTM Standard D 2343 and have a minimum strand strength as follows:
(a) Type-S glass — 2760 MPa; and
(b) Type-E glass — 1380 MPa.

9.2.3 Resin System

9.2.3.1 TC-3FCM

The resin system shall be epoxy or modified epoxy type. The resin system shall be tested on sample coupons representative of the composite overwrap, in accordance with ASTM Standard D 2344 for the water-boil shear test, and shall have a minimum shear strength of 34.5 MPa.

9.2.3.2 TC-3HWM

The resin system shall be as follows:
(a) in accordance with Clause 9.2.3.1; or
(b) flexible isophthalic polyester type with at least 15% elongation.
The resin system shall be tested on sample coupons representative of the composite overwrap, in accordance with ASTM Standard D 638 for the water-boil tensile test and in accordance with ASTM Standard D 2344 for the water-boil shear test. A minimum value of 13.7 MPa shall be obtained in both cases.

9.3 Wall Thickness

9.3.1 General Requirements

The actual minimum liner thickness shall be not less than the design liner thickness and shall be such that after autofrettage, the compressive stress in the sidewall of the liner at zero pressure does not exceed 95% of the minimum yield strength, as determined in Clause 9.9, or 95% of the minimum design yield strength, as shown in the Basic Cylinder Design Information, Form J, (see Clause 9.13.7), whichever is the lesser. The maximum tensile stress in the liner at service pressure shall not exceed 60% of the minimum yield strength. Stresses shall be computed using Computer Code NASA CR-72124 or another suitable analysis technique.

9.3.2 TC-3FCM

9.3.2.1

The maximum filament stress at service pressure shall not exceed 30% of the filament stress at the burst pressure of the lot test cylinder.

9.3.2.2

The end designs shall incorporate added materials to ensure that the stresses in these areas are less than the stresses found in the cylindrical portion.

9.3.3 TC-3HWM

9.3.3.1

The maximum filament stress at service pressure shall not exceed 40% of the filament stress at the burst pressure of the lot test cylinder.

9.3.3.2
The end designs shall incorporate added materials to ensure that the stresses in these areas, not supported by the hoop wrap, are less than the stresses found in the cylindrical portion. The burst test may be used to demonstrate compliance.

9.3.3.3
The liner without overwrap shall be designed for a rated pressure of at least 50% of the marked service pressure of the composite cylinder.

9.3.3.4
The minimum design liner-wall thickness shall be the thickness based on Equation 1, Clause 4.2.1, where P is 1.5 times the liner's rated pressure. The wall stress in Equation 1 shall not exceed 72% of the minimum yield strength or exceed 60% of the minimum tensile strength as determined by the tensile test, whichever is the lesser.

9.4 Openings
Openings shall be threaded. The centreline of openings shall coincide with the longitudinal axis of the cylinder. Only straight threads with at least 6 engaging threads shall be used.

9.5 Manufacture

9.5.1 TC-3FCM

9.5.1.1
Interior folding in the neck area shall be prohibited, but a smooth gathering of the material in the neck in which there are no sharp, rooted folds shall be acceptable. The surface of the liner may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall be not less than the minimum design liner-wall thickness. Liner end contour shall be concave to pressure.

9.5.1.2
The composite cylinder shall be fabricated from an aluminum liner fully overwrapped with resin-impregnated continuous filament windings. Winding pattern shall be "helical or in plane" and "hoop wrap" applied under controlled tension to develop the design composite thickness. After winding is complete, the composite shall be cured according to a controlled temperature schedule and autofrettaged by pressurizing to not less than 117% and not greater than 128% of the specified test pressure.

9.5.2 TC-3HWM

9.5.2.1
The aluminum liner shall comply with the following:
(a) The liner shall be extruded from cast stock, or drawn from plate or sheet, or formed from die- and mandrel-extruded tubing or pipe.
(b) For ends concave to pressure, the inside shape shall be hemispherical, ellipsoidal, or torispherical. Ellipsoidal ends shall have a ratio of major axis (diameter of liner) to minor axis not exceeding 2:1. Torispherical ends shall have a dish radius not greater than 1.2 times the inside diameter of the liner, and the knuckle radius shall be not less than 12% of the inside diameter. The interior bottom contour may deviate from the true torispherical, hemispherical, or ellipsoidal configuration in any location, provided that
- (i) all radii of merging surfaces are equal to or greater than the knuckle radius; and
- (ii) detail information of the bottom design is available to the independent inspector.

(c) The bottoms of bumped-back cylinders shall have a minimum thickness not less than 2 times the minimum liner thickness along the line of contact between the cylinder base and the floor.

9.5.2.2

The composite cylinder shall be fabricated from an aluminum liner circumferentially wrapped, over the cylindrical portion, with resin-impregnated continuous filament windings. Winding pattern shall be "hoop wrap", applied under controlled tension to develop the design composite thickness. After winding is complete, the composite shall be cured according to a controlled temperature schedule and autofrettaged by pressurizing to not less than 117% and not greater than 128% of the specified test pressure.

9.6 Welding or Brazing

Welding or brazing shall be prohibited.

9.7 Heat Treatment

The aluminum liner shall be subjected to a solution heat treatment and an aging treatment to the T6 temper, prior to overwrapping and subjecting to pressure.

9.8 Resin Curing

The resin shall be cured at the temperature and by the process set forth in the cylinder manufacturer's specifications. Curing temperature and process shall correspond with that applied to the cylinders subjected to qualification tests. The curing temperature shall not exceed 175°C.

9.9 Tensile Test

9.9.1

Two Type A, C, or D specimens, located approximately 180° apart, shall be cut from 1 representative liner from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the liner.

9.9.2

The tensile test results shall meet the requirements of Table 7.2.

9.10 Lot Acceptance Cycling Test

9.10.1

One completed representative cylinder, from each lot of 200 or less, shall be subjected to a hydrostatic pressure-cycling test at a rate not exceeding 4 cycles/min. Appropriate recording instruments shall be used where the cycling pressurization equipment is left operating unattended. All cylinders used in the cycling test shall be destroyed.

9.10.2

Each test cylinder shall withstand at least 10 000 pressurizations between approximately zero and service pressure, followed by at least 30 pressurizations between zero and 1.11 times test pressure, without evidence of failure. When the test cylinder fails to withstand the cycling test, the lot represented shall be rejected.

9.11 Burst Test

9.11.1 General Requirements

One completed representative cylinder, from each lot of 200 or less, shall be tested hydrostatically to

destruction by pressurizing at a uniform rate up to the failure pressure. The cylinder subjected to the pressure-cycling test for lot acceptance may be used for the burst test.

9.11.2 TC-3FCM

Burst pressure shall be at least 3.33 times the service pressure, and in no case less than the value necessary to meet the stress criteria of Clause 9.3.2.1. Failure shall initiate in the cylinder sidewall. Cylinders with a service pressure not exceeding 150 bar shall remain in one piece. Actual burst pressure shall be recorded.

9.11.3 TC-3HWM

Burst pressure shall be at least 2.5 times the service pressure, and in no case less than the value necessary to meet the stress criteria of Clause 9.3.3.1. Failure shall initiate in the cylinder sidewall. Cylinders with a service pressure not exceeding 150 bar shall remain in one piece. Actual burst pressure shall be recorded.

9.12 Hydrostatic Test

9.12.1

Each cylinder shall be tested hydrostatically to 1.5 times its service pressure and have its volumetric expansion measured. In no case shall the test pressure exceed the autofrettage pressure.

9.12.2

Any internal pressure applied after autofrettage and before the official test shall not exceed 90% of the test pressure. The hydrostatic test shall not be repeated more than once.

9.12.3

The permanent volumetric expansion shall not exceed 5% of the total expansion at test pressure.

9.13 Design Qualification Tests

9.13.1 General

Qualification tests for filament-wrapped cylinders shall be in accordance with Clause 4.13 and Clause 9.13. Clause 9.13 shall have precedence over Clause 4.13.

9.13.2 Cylinder Qualification Tests

Cylinders representative of each new design shall be subjected to
(a) an ambient temperature cycling test, in accordance with Clause 9.13.3;
(b) an environmental cycling test, in accordance with Clause 9.13.3, except in cases where the new design is a modification of an approved design that has passed an environmental cycling test, and if the modification concerns one significant change only, limited to a change in diameter or service pressure of 20% or less, or a change in water capacity of 50% or less;
(c) a burst test, in accordance with Clause 9.13.4;
(d) a gunfire test, in accordance with Clause 9.13.5; and
(e) bonfire tests, in accordance with Clause 9.13.6.

9.13.3 Cycling Tests

Cycling testing shall be performed hydrostatically at a rate not exceeding 4 cycles/min from approximately 0 kPa to the specified pressure. Testing shall be as follows:
(a) Ambient temperature cycling test. One cylinder shall be cycling-tested at ambient temperature without failure
    (i) to service pressure for 10 000 cycles; and

(ii) to 1.11 times test pressure for 30 cycles.

(b) Environmental cycling test. One cylinder, free of any protective coating, shall be tested in accordance with the following sequence without distortion, deterioration, or failure:

(i) conditioning for 48 h, without pressure, at 60°C or higher and 95% or greater relative humidity;

(ii) cycling testing to service pressure for 5 000 cycles under the same conditions;

(iii) stabilization without pressure at ambient conditions;

(iv) cycling testing to service pressure for 5 000 cycles at –50°C or lower;

(v) stabilization without pressure at ambient conditions; and

(vi) cycling testing to 1.11 times test pressure for 30 cycles at ambient temperature.

The cylinders used in (a) and (b) above shall then be tested hydrostatically to destruction and the burst pressure recorded.

9.13.4 Burst Test

A representative cylinder shall be tested hydrostatically to destruction and meet the requirements of Clause 9.11. Burst pressure shall be recorded.

9.13.5 Gunfire Test

One representative cylinder, filled with air or nitrogen to service pressure, shall be impacted by a 7.5 mm calibre armour-piercing projectile having a velocity of approximately 850 m/s. The cylinder shall be so positioned that the projectile impact point is in the cylinder sidewall wrapping at approximately a 45° angle and aimed to exit at the cylinder sidewall. The distance from the firing location to the test cylinder shall not exceed 45 m. The tested cylinder shall reveal no evidence of a fragmentation failure. The approximate size of entrance and exit openings shall be recorded.

9.13.6 Bonfire Tests

Test cylinders shall be fitted with pressure-relief devices and charged with the intended lading to the prescribed filling pressure or density. Charging with air or nitrogen to service pressure shall be permitted if cylinders are to be charged only with nonliquefied gases. Fire for tests shall be generated by kerosene-soaked wood, gasoline, or JP-4 fuel. The lowest part of the cylinder shall be approximately 10 cm above the top of the wood when the wood fire is used and shall be approximately 10 cm above the liquid surface in the case of gasoline or JP-4 fuel. The test cylinder shall be exposed to the fire until completely vented. Time-pressure readings shall be recorded at 30 s intervals from the start of the fire until venting is completed. Test results shall be unacceptable if the contents vent from any location other than through a pressure-relief device. After satisfactorily passing the fire test, each cylinder shall be tested hydrostatically to destruction and the burst pressure recorded. Tests are to be performed as follows:

(a) Vertical test. The test cylinder shall be placed in the upright position and subjected to total fire engulfment, but in no case shall the flame be allowed to impinge directly on any relief device. Shielding of pressure-relief devices with a metal plate is permitted. For cylinders equipped with relief devices on both ends, the bottom relief devices shall be shielded from any flame impingement.

(b) Horizontal test. The test cylinder shall be placed in the horizontal position and the entire length subjected to flame impingement, except that the flames shall not be allowed to impinge directly on any relief device. Shielding of pressure-relief devices with a metal plate shall be permitted.

(c) Cylinders for liquefied gas service. At least 1 representative cylinder shall be subjected to the horizontal test and 2 to the vertical test.

(d) Cylinders for nonliquefied gas service only. At least 2 cylinders shall be subjected to the vertical test. The horizontal test is not required.

9.13.7 Qualification Test Report

A report of all tests for each new design, describing test setup, procedure, and results, shall be prepared. This report shall include at least the basic information on each cylinder tested, as identified on Form J.

9.14 Rejected Liners and Cylinders

Only 1 reheat treatment shall be permitted; liners shall then pass all specified tests. Composite cylinders manufactured from reheat-treated liners shall be processed as a separate inspection lot.

9.15 Inspection

9.15.1

The independent inspector shall determine that all materials comply with the requirements of this Standard. The independent inspector shall verify the chemical composition of each cast of liner material by analysis or by obtaining the producer's certified analysis. A certification from the manufacturer indicating compliance with this requirement shall be acceptable when verified by product analysis on 1 sample taken from 1 cylinder liner from each lot of 200 or less. The independent inspector shall verify compliance with the provisions of Clause 9.2.

9.15.2

The independent inspector shall verify the winding process to ensure that the composite material is uniform, of required thickness and pattern, and in accordance with the composite structure present in cylinders subjected to the design qualification tests.

9.15.3

The independent inspector shall verify compliance of the cylinders with all the requirements, including markings, condition of inside, heat treatment, and threads. The independent inspector shall report the minimum thickness of the liner wall noted.

9.15.4

The independent inspector shall witness all tests and pressurizations; obtain copies of all test results and certification; and report volumetric capacity, permanent expansion, and completed composite-cylinder mass.

9.15.5

The independent inspector shall prepare a report, in the format of Forms A to G for all inspected and approved TC-3FCM cylinders, or in the format of Forms H, B, C, I, E, F, and G for all inspected and approved TC-3HWM cylinders.

9.16 Marking

9.16.1 General

Cylinders shall be marked in the epoxy coating on the side near the valve outlet end. Stamping on the wrapping shall be prohibited.

9.16.2 TC-3HWM

Additional markings shall be permitted in the composite, or may be stamped in low-stress areas of the aluminum liner, other than the sidewall, provided the markings are not of a size and depth to become harmful stress risers.

10. Specification TC-3HTM

10.1 General

TC-3HTM containers are seamless alloy steel cylinders for aircraft use, with a maximum capacity of 68 L of water, and a minimum service pressure of 6.2 MPa.

10.2 Materials

10.2.1

Steel shall be alloy steel of uniform quality conforming to the chemical composition of Grade F, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2.

10.2.2

Steel shall have tensile properties that will allow the manufacturer to achieve in the cylinder a minimum tensile strength, in accordance with Clause 10.9, that satisfies the requirements of Clause 10.3.

10.2.3

If the heat identification is permanently stamped on the cylinder, it shall be stamped in an area other than the side wall.

10.3 Wall Thickness

The minimum design wall thickness shall be the greater of the applicable values that follow:
(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure. The wall stress in Equation 1 shall not exceed 67.5% of the minimum tensile strength as determined by the tensile test or 652 MPa, whichever is the lesser; or
(b) 1.3 mm for cylinders with an outside diameter of 127 mm or less, or 2.5 mm for cylinders with an outside diameter larger than 127 mm.

10.4 Openings

Openings shall be threaded. There shall be only 1 opening per cylinder, not exceeding the smaller of one-half of the outside diameter of the cylinder or 61 mm. Straight threads shall have at least 6 engaging threads.

10.5 Manufacture

Manufacturing considerations shall be as follows:
(a) The manufacturing process shall be capable of producing cylinders free from defects.
(b) Cylinders shall be manufactured by any of the following processes, or by a combination of the following processes, to produce seamless cylindrical shapes with integrally formed ends concave to pressure:
- (i) backward extrusion;
- (ii) hot or cold drawing;
- (iii) ironing; and
- (iv) spinning of seamless cylindrical tubing.

(c) The general surface finish shall not exceed a roughness of 5.8 μm. Individual irregularities such as draw marks, scratches, pits, etc, should be held to a minimum.
(d) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the cylinder may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall not be less than the minimum design wall thickness. Metal removal to eliminate isolated defects and to cut threads may be done after the hydrostatic test; metal removal for any other purpose shall be done prior to the hydrostatic test.
(e) The inside shape of ends shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1, or a dished shape falling within these two limits.
(f) Ends shall have a minimum thickness not less than the minimum design wall thickness, except that on cylinders formed from sheet or plate the thickness of hemispherical bottom ends shall not be less than 90% of the minimum design wall thickness.
(g) The point of closure of cylinders closed by spinning shall be not less than 2 times the minimum design wall thickness.

10.6 Welding or Brazing

Welding or brazing shall be prohibited.

10.7 Heat Treatment

10.7.1

The completed cylinders shall be heat-treated.

10.7.2

All cylinders shall be quenched in oil or another suitable medium. The steel temperature on quenching shall be that recommended for the material grade, but in no case shall it exceed 955°C. Quenched cylinders shall be tempered at a temperature consistent with achieving the specified mechanical properties. The tempering temperature shall be not less than 455°C.

10.8 Nondestructive Inspection

Cylinders shall be inspected by a magnetic particle or liquid penetrant method to detect quenching cracks. The inspection shall be performed on the inside of the cylinders before closing and externally on the finished cylinders after heat treatment. Cylinders with quenching cracks shall be condemned. Imperfections that, in the opinion of the independent inspector, may weaken a cylinder or decrease its durability shall be cause for rejection.

10.9 Tensile Test

10.9.1

Two Type C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder from each lot of 200 or less, and shall be tested. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the cylinder.

10.9.2

The tensile strength shall not exceed 1138 MPa. The elongation shall be at least 6%.

10.10 Flattening Test

10.10.1

One representative cylinder from each lot of 200 or less shall be tested.

10.10.2

Flattening to 10 times the wall thickness without cracking shall be required.

10.11 Pressure-Cycling and Burst Tests for Lot Acceptance

The pressure-cycling test described in Clause 10.13 shall be repeated on 1 representative cylinder from each lot of 200 or less made from the same heat of steel. Failure of the test cylinder shall be cause for rejection of the lot. The cycling-tested cylinder or another cylinder shall be subjected to a burst test and meet the requirements of the burst test described in Clause 4.13.5.

10.12 Hydrostatic Test

10.12.1

Each cylinder shall be tested hydrostatically to 1.5 times its service pressure and have its volumetric expansion measured. The permanent volumetric expansion shall not exceed 5% of the total expansion at test pressure.

10.12.2
Alternative testing by the proof pressure method shall be permitted for cylinders having a water capacity not exceeding 1 L. Each cylinder shall be inspected under a pressure at least equal to the specified test pressure and show no defects.

10.13 Design Qualification
New designs shall meet the requirements of Clause 4.13, except that each cycling-tested cylinder shall withstand at least 10 000 pressurizations to the service pressure without failure.

10.14 Rejected Cylinders
Spun cylinders rejected in the leakage test shall be condemned. Reheat treatment is permitted; cylinders shall then pass all specified tests. Repair by welding or spinning shall be prohibited.

10.15 Marking

10.15.1
Cylinders shall be marked on the shoulder, top end, or neck by
(a) low-stress-type steel stamping in an area and to a depth such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness; or
(b) a permanently attached metal plate.
Marking on the sidewall shall be prohibited.

10.15.2
Cylinders with a water capacity greater than 1 L shall be marked with the rejection elastic expansion (REE) in millilitres. The REE of a cylinder is 1.05 times its original elastic expansion.
Note: *Lot numbers in lieu of serial numbers are permitted for cylinders when the volumetric capacity does not exceed* 1.0 L.

11. Specification TC-3TM

11.1 General
TC-3TM containers are seamless alloy steel tubes.

11.2 Materials

11.2.1
Steel shall be open-hearth, basic oxygen-, or electric-furnace process steel of uniform quality conforming to the chemical composition of Grade G, specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2.

11.2.2
Steel shall have tensile properties that will allow the manufacturer to achieve in the tube a minimum tensile strength, in accordance with Clause 11.9, that satisfies the requirements of Clause 11.3.

11.2.3
If the heat identification is permanently stamped on the tube, it shall be stamped in an area other than the sidewall.

11.3 Wall Thickness

The minimum design wall thickness shall be the greater value of the following:
(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure, and on the requirements of Clause 4.2.2. The wall stress in Equation 1 shall not exceed 67% of the minimum tensile strength as determined by the tensile test or 624 MPa, whichever is the lesser; or
(b) 5.7 mm.

11.4 Openings

Openings shall be threaded. Centre openings not exceeding the smaller of one-half of the outside diameter of the tube or 220 mm may be used in ends having integrally formed necks. Other openings shall not exceed 61 mm in diameter. Openings in one end shall have ligaments between them of at least 3 times the average of their hole diameters, where the hole diameter is considered to be the maximum major thread diameter. Straight threads shall have at least 6 engaging threads.

11.5 Manufacture

Manufacturing considerations shall be as follows:
(a) The manufacturing process shall be capable of producing tubes free from defects. Tubes shall be manufactured by any process that will produce seamless cylindrical shapes with integrally formed ends concave to pressure. Closure of tubes by the spinning process shall be prohibited.
(b) Imperfections such as mechanical marks, draw marks, pits, or other surface irregularities generally having a round bottom contour shall be acceptable, provided the minimum design wall thickness is maintained.
(c) Fissures, laps, tears, or other imperfections that are stress risers shall not be acceptable. The surface of the tube may be machined or otherwise treated to eliminate defects. The thickness of the treated areas shall be not less than the minimum design wall thickness. Metal removal to eliminate isolated defects and to cut threads may be done after the hydrostatic test. Metal removal for any other purpose shall be done prior to the hydrostatic test.
(d) The inside shape of ends shall be hemispherical, ellipsoidal with a ratio of major axis (diameter of tube) to minor axis not exceeding 2:1, or a dished shape falling within these two limits. Ends shall have a minimum thickness not less than the minimum design wall thickness.

11.6 Welding or Brazing

Welding or brazing shall be prohibited.

11.7 Heat Treatment

11.7.1

The completed tubes shall be heat-treated.

11.7.2

The following shall apply:
(a) Tubes shall be heated and held at the heat-treating temperature for at least 2.4 min/mm of maximum sidewall thickness.
(b) Tubes shall be quenched in a suitable liquid medium having a cooling rate not in excess of 80% that of water.
(c) The steel temperature on quenching shall be that recommended for the material grade, but in no case shall it exceed 955°C.
(d) Quenched tubes shall be tempered at a temperature not lower than 565°C. They shall be held at this temperature for at least 2.4 min/mm of maximum sidewall thickness and then air-cooled under conditions recommended for the material grade.

11.8 Hardness Test

After the final heat treatment, each tube shall be hardness-tested on the cylindrical section. A minimum of 4 readings shall be taken, two at each end of the tube, located 180° apart. The hardness shall not exceed HRC 36. When the result of the initial hardness test exceeds the maximum permitted, 2 or more retests may be made; however, the hardness number obtained in each retest shall not exceed the maximum permitted. Tubes failing to pass the test shall be rejected.

11.9 Tensile Test

11.9.1

Two Type A specimens, located approximately 180° apart, shall be cut from 1 tube or test ring representing each heat and each batch, and shall be tested. Heats already represented in another group of heat-treated tubes, which have passed the tests, need not be represented again, even if the number represented in each heat exceeds 200. Each test ring shall be of the same diameter, thickness, and material grade as the finished tubes it represents. The test ring shall be at least 60 cm long and have its ends covered during the heat-treatment process. Test rings shall be heat-treated with the tubes they represent. The longitudinal axis of each specimen shall be parallel to the longitudinal axis of the test tube or ring.

11.9.2

The tensile strength shall not exceed 1070 MPa. The elongation shall be at least 16%.

11.10 Impact Test

11.10.1

Each impact specimen shall be a Charpy V-notch type, size 10 × 10 mm, taken in accordance with ASTM Standard A 370. Where only a reduced-size specimen can be obtained, it shall be the largest standard subsize obtainable, but not smaller than 10 × 5 mm.

11.10.2

Three Charpy impact specimens from the sidewall shall be tested from each sample. The samples shall be tubes or test rings taken and prepared in the same manner as the sample tubes or test rings for the tensile test, except that each 3 specimen group shall not represent more than 200 tubes of one heat. The axis of the specimen shall be parallel to the longitudinal axis of the tube or the test ring, and the axis of the notch shall be perpendicular to the surface of the tube.

11.10.3

The Charpy V-notch impact properties for the 3 impact specimens tested at –50°C shall not be less than the values shown in Table 11.1. Where the results of the test fail to meet the impact test requirements, the lot shall be rejected.

11.11 Hydrostatic Test

Each tube shall be tested hydrostatically to 1.5 times its service pressure and have its volumetric expansion measured.

11.12 Ultrasonic Inspection

After the hydrostatic test, the cylindrical section of each tube shall be inspected ultrasonically. Any imperfection giving a response greater than that produced by a notch equal to 5% of the minimum design wall thickness shall be cause for rejection.

11.13 Rejected Tubes

Reheat treatment shall be permitted; tubes shall then pass all specified tests. Repairs by welding shall be prohibited. Tubes rejected by ultrasonic testing may be repaired and requalified in accordance with Clause 11.5.

11.14 Marking

11.14.1

Tubes shall be marked on one shoulder or neck. The depth of markings shall be such that the metal thickness measured from the root of the stamping to the interior surface is at least equal to the minimum design wall thickness.

11.14.2

Each tube shall be marked with its mass.

11.14.3

Each tube shall be marked with the rejection elastic expansion (REE) in millilitres. The REE shall be calculated in accordance with CGA Publication C-5.

12. Specification TC-4AAM33

12.1 General

TC-4AAM33 containers are welded carbon steel or high-strength low-alloy (HSLA) steel cylinders without a longitudinal seam and with a service pressure of 3.3 MPa.

12.2 Materials

12.2.1

Steel shall be semi-killed or killed carbon or HSLA steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

12.2.2

Steel shall have tensile properties that will allow the manufacturer to achieve in the cylinder a minimum tensile strength, in accordance with Clause 12.8, that satisfies the requirements of Clause 12.3.

12.3 Wall Thickness

12.3.1

The minimum design wall thickness shall be as follows:
(a) the thickness based on Equation 1, Clause 4.2.1, where P is 6.6 MPa. The wall stress in Equation 1 shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 241 MPa, whichever is the lesser; or
(b) 2.0 mm for cylinders with an outside diameter larger than 127 mm.

12.3.2

The minimum thickness of ends shall be not less than 90% of the minimum design wall thickness and in no case less than 2.0 mm for cylinders with an outside diameter larger than 127 mm.

12.3.3
Where the design wall thickness is less than 2.5 mm, the ratio of tangential length to outside diameter shall not exceed 4:1.

12.4 Openings
Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by welding or by threads. Straight threads shall have at least 6 engaging threads.

12.5 Manufacture

12.5.1
Closure of cylinders by the spinning process shall be prohibited.

12.5.2
Circumferential seams shall be welded only. Longitudinal seams shall be prohibited.

12.5.3
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

12.5.4
Neck rings, foot rings, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

12.6 Heat Treatment

12.6.1
The completed cylinders shall be heat-treated by any method that achieves a temperature in excess of 595°C throughout the cylinder. Liquid quenching of cylinders shall be prohibited.

12.6.2
Heat treatment shall not be required after welding low-carbon parts to attachments of similar material that have been previously welded to the ends of cylinders and heat-treated, provided such subsequent welding does not produce a temperature in excess of 200°C in any part of the cylinder.

12.7 Hydrostatic Test

12.7.1
One representative cylinder from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. If this first cylinder fails the volumetric expansion test, 2 additional representative cylinders shall be taken from the same lot and subjected to the same test. If either of these fails the test, then each cylinder in the lot shall be tested and have its volumetric expansion measured.

12.7.2
The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

12.8 Tensile Test

12.8.1

From each lot of 200 or less, two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from 1 representative cylinder that has passed the hydrostatic test, and shall be tested.

12.8.2

For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

12.8.3

For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

12.9 Weld Tensile Test

A weld tensile test shall be required on a specimen cut across the major seam of 1 representative cylinder from each lot of 200 or less. As an alternative, the specimen may be cut from a welded test plate. The welded test plate shall be taken from one of the heats in the same lot, and it shall be in the same condition and of approximately the same thickness as the cylinder wall, except that in no case shall the thickness be less than 2.5 mm. The test plate shall be welded by the same procedure and subjected to the same heat treatment as the major seam on the cylinder.

12.10 Weld Guided-Bend Test

A root-bend test shall be required on a specimen cut from the cylinder seam or the welded test plate used for the weld tensile test. The alternate guided-bend test shall be permitted.

12.11 Rejected Cylinders

Repair of welds by welding shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, cylinders shall pass all specified tests.

12.12 Marking

12.12.1

Markings shall be placed
(a) on each cylinder shoulder or top end of 2.2 mm or more in thickness;
(b) on neck, valve boss, valve-protection collar, or similar part permanently attached to the top end of the cylinder; or
(c) on a plate at least 1.6 mm thick, attached by welding, or by brazing at a temperature of at least 595°C, along all edges of the plate to the top of the cylinder or one of its permanent attachments. Space shall be left on the plate to stamp at least 6 requalification dates.
Note: *The specification designation incorporates the service pressure.*

12.12.2

The manufacturer's mark, in front of the serial number, separated by a space, or the manufacturer's mark and serial number, may be stamped into the welded valve spud directly above the TC mark located on the top end of the cylinder.

13. Specification TC-4BM

13.1 General

TC-4BM containers are welded or brazed carbon steel cylinders with a service pressure range from 1.0 to 3.5 MPa. One longitudinal forge lap-welded or brazed seam shall be permitted.

13.2 Materials

Steel shall be semi-killed or killed carbon steel of uniform and, where applicable, weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

13.3 Wall Thickness

13.3.1

The minimum design wall thickness shall be as follows:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure or 3.1 MPa, whichever is the greater. The wall stress in Equation 1 shall not exceed the following:
   (i) 165 MPa for cylinders without a longitudinal seam;
   (ii) 157 MPa for cylinders having a brazed longitudinal seam;
   (iii) 124 MPa for cylinders having a forge lap-welded longitudinal seam; or

(b) 2.3 mm for cylinders with an outside diameter larger than 155 mm.

13.3.2

Ends convex to pressure shall have a minimum thickness equal to 200% of the minimum design wall thickness. Ends concave to pressure shall have a minimum thickness equal to 90% of the minimum design wall thickness. In both cases, the minimum design wall thickness shall be calculated as specified in Clause 13.3.1.

13.4 Openings

13.4.1

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by brazing, by welding, or by threads. Straight threads shall have at least 4 engaging threads.

13.4.2

For cylinders used as component parts of hand fire-extinguishers, a brass fitting may be brazed to the steel boss or flange.

13.5 Manufacture

13.5.1

Closure of cylinders by the spinning process shall be prohibited.

13.5.2

Circumferential seams shall be welded or brazed. Ends attached by brazing shall have a driving fit with the shell, unless the shell is crimped, swaged, or curled over the skirt or flange of the end, and shall be thoroughly brazed until there is complete penetration by the brazing material of the brazed joint. The depth of the brazing from the end of the shell shall be at least 4 times the thickness of the shell material at the joint.

13.5.3
Where a longitudinal seam in shells is used it shall be forge lap-welded, copper-brazed, copper-alloy-brazed, or silver-alloy-brazed. When brazed, the plate edge shall be lapped at least 8 times its thickness, laps being held in position, substantially metal to metal, by electric spot welding. Brazing shall be done by using a process that ensures complete penetration. The copper-alloy composition shall be copper, minimum 95%; silicon, from 1.5 to 3.85%; and manganese, from 0.25 to 1.10%. The silver alloy shall have a melting point above 540°C.

13.5.4
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

13.5.5
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding or brazing to the ends of cylinders only. Where welding is used, attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

13.6 Heat Treatment
Parts formed by drawing or pressing shall be heat-treated.

13.7 Tensile Test

13.7.1
From each lot of 200 or less, two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from 1 representative cylinder and shall be tested.

13.7.2
The yield strength shall not exceed 73% of the tensile strength. For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen.

13.8 Flattening Test
Flattening tests shall be required only for cylinders made of lap-welded tubing. Rings (crop ends) cut from each end of tubing shall be tested with the weld 45° or less from the point of greatest stress. If a ring fails, another ring from the same end of the tubing may be tested. Flattening to 6 times the wall thickness without cracking shall be required.

13.9 Hydrostatic Test

13.9.1
One representative cylinder from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. If this first cylinder fails the volumetric expansion test, 2 additional representative cylinders shall be taken from the same lot and subjected to the same test. If either of these fails the test, then each cylinder in the lot shall be tested and have its volumetric expansion measured.

13.9.2
The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and shall show no defects.

13.10 Leak Test of Final Assembly

If a valve or fitting is installed by a manufacturer, the completed assembly shall not leak when tested at a pressure of at least 600 kPa.

13.11 Rejected Cylinders

Repair of brazed seams by brazing, and welded seams by welding, shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, cylinders shall pass all specified tests.

13.12 Marking

13.12.1

Markings shall be placed

(a) on each cylinder shoulder, top end, neck, or valve-protection collar that is permanently attached to the cylinder and forms an integral part thereof; or

(b) on the sidewall adjacent to the top end, if the wall is not less than 2.3 mm thick.

13.12.2

Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

Notes:

(1) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are not more than* 51 mm *in outside diameter.*

(2) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are more than* 51 mm *in outside diameter when the volumetric capacity does not exceed* 2.8 L.

(3) *The manufacturer's marks and serial number may, as an alternative, be stamped into the welded or brazed-on valve boss directly above the TC specification mark located on the top end of the cylinder.*

14. Specification TC-4BM17ET

14.1 General

TC-4BM17ET containers are brazed or spun carbon steel cylinders made from electric-resistance-welded tubing, with a maximum capacity of 5.5 L of water, a maximum length of 535 mm, and a service pressure of 1.7 MPa.

14.2 Materials

14.2.1

Steel shall be semi-killed or killed carbon steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

14.2.2

The addition of alloying elements permitted in Table 12.1 shall be prohibited.

14.3 Wall Thickness

The minimum design wall thickness shall be the greater value of the following:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is 3.4 MPa. The wall stress in Equation 1 shall not exceed 124 MPa; or

(b) 1.1 mm.

14.4 Openings

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by brazing, welding, or by threads. Straight threads shall have at least 4 engaging threads.

14.5 Manufacture

14.5.1

Closure of cylinders by the spinning process shall be permitted. The bottom ends of cylinders formed by spinning shall have a minimum thickness not less than 2 times the minimum design wall thickness. Such bottom-end thickness shall be measured within an area bounded by a line representing the points of contact between the cylinder and the floor when the cylinder is in a vertical position.

14.5.2

Ends may be attached to shells by lap brazing or may be formed integrally. Bottom ends attached to cylindrical shells by welding shall have a minimum thickness not less than twice the minimum design wall thickness. Such bottom-end thickness shall be within an area bounded by a line representing the points of contact between the cylinder and floor when the cylinder is in a vertical position. Circumferential seams shall be brazed only. Ends attached by brazing shall have a driving fit with the shell, unless the shell is crimped, swaged, or curled over the skirt or flange of the end, and shall be thoroughly brazed until there is complete penetration by the brazing material of the brazed joint. The depth of the brazing from the end of the shell shall be at least 4 times the thickness of the shell material at the joint. The brazing material shall have a melting point above 540°C.

14.5.3

Longitudinal seams in shells shall be electric-resistance-welded only. Repairs shall not be made to longitudinal joints.

14.5.4

Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding or brazing to the ends of cylinders only. Where welding is used, attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

14.6 Heat Treatment

14.6.1

Ends formed by drawing or pressing shall be heat-treated.

14.6.2

Cylinders with integrally formed ends shall be normalized. Normalizing and brazing operations may be combined, provided the operation is performed at a temperature in excess of the upper critical temperature of the steel.

14.7 Tensile Test

14.7.1

Two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from 1 representative cylinder and shall be tested. In the case of cylinders of capacity greater than 1.4 L, the specimens shall be taken from each lot of 200 or less, and for cylinders having a capacity of 1.4 L or less, specimens shall be taken from each lot of 500 or less.

14.7.2
The yield strength shall not exceed 73% of the tensile strength. For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen.

14.8 Hydrostatic Test

14.8.1
One representative cylinder from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

14.8.2
In addition to the tests in Clause 14.8.1, one representative cylinder from each lot of 1000 or less produced each day shall be tested hydrostatically to destruction. If this first cylinder bursts at a pressure below 5 times its service pressure, 2 additional representative cylinders shall be taken from the same lot and tested to destruction. If either of these bursts at a pressure below 5 times its service pressure, the entire lot shall be rejected.

14.9 Flattening Test

14.9.1
One representative cylinder from each lot of 200 or less after the hydrostatic test shall be tested. The weld shall be located at the point of greatest stress. Flattening to 6 times the wall thickness without cracking shall be required.

14.9.2
As an alternative to the requirements of Clause 14.9.1, two rings cut from an end of a length of tubing used in the production of a lot may be used for the flattening test, provided that the rings accompany the lot that they represent in all thermal processing operations. At least 1 of the rings shall pass the flattening test.

14.10 Rejected Cylinders
Repair of brazed seams by brazing shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, cylinders shall pass all specified tests.

14.11 Marking

14.11.1
Markings shall be placed
(a) on each cylinder shoulder, top end, neck, or valve-protection collar that is permanently attached to the cylinder and forms an integral part thereof; or
(b) on the sidewall adjacent to the top end, if the wall is not less than 2.3 mm thick.
Note: *The specification designation incorporates the service pressure.*

14.11.2
Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

Notes:
(1) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders not over* 51 mm *in outside diameter.*
(2) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are more than* 51 mm *in outside diameter when the volumetric capacity does not exceed* 2.8 L.
(3) *The manufacturer's marks and serial number may, as an alternative, be stamped into the welded or brazed-on valve boss directly above the TC specification mark located on the top end of the cylinder.*

15. Specification TC-4BAM

15.1 General

TC-4BAM containers are welded or brazed carbon or high-strength low-alloy (HSLA) steel cylinders and spheres with a service pressure range from 1.5 to 3.5 MPa. One longitudinal brazed seam shall be permitted in cylinders.

15.2 Materials

15.2.1

Steel shall be semi-killed or killed carbon or HSLA steel of uniform and, where applicable, weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

15.2.2

Steel shall have tensile properties that will allow the manufacturer to achieve in the container a minimum tensile strength, in accordance with Clause 15.8, that satisfies the requirements of Clause 15.3.

15.3 Wall Thickness

15.3.1

The wall stress for the minimum design wall thickness calculations shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 241 MPa, whichever is the lesser. The wall stress of cylinders having a copper-brazed longitudinal seam shall not exceed 95% of either of the above values. The minimum design wall thickness shall be as follows:
(a) the thickness based on Equation 1 or 2, Clause 4.2.1, where P is the specified hydrostatic test pressure and E is
(i) 0.85 for the girth weld area and the heat-affected zones, which are considered to extend a distance of 6 times the actual wall thickness from the centreline of each weld; and
(ii) 1.0 for all other areas; or
(b) 2.0 mm minimum for containers with an outside diameter larger than 155 mm.

15.3.2

The minimum thickness of cylinder ends shall be not less than 90% of the minimum design wall thickness.

15.3.3

Where the design wall thickness of a cylinder is less than 2.5 mm, the ratio of tangential length to outside diameter shall not exceed 4:1.

15.4 Openings

Openings shall be provided with a fitting, boss, or pad securely attached by brazing or welding to cylinders, and by welding only to spheres. Straight threads shall have at least 4 engaging threads.

15.5 Manufacture

15.5.1
Closure of cylinders by the spinning process shall be prohibited.

15.5.2
Cylinder circumferential seams shall be welded or brazed. Cylinder halves attached by brazing shall have a driving fit with the shell, unless the shell is crimped, swaged, or curled over the skirt or flange of the end, and shall be thoroughly brazed until there is complete penetration by the brazing material of the brazed joint. The depth of the brazing from the end of the shell shall be at least 4 times the thickness of the shell material at the joint. Spheres shall be made of 2 circumferentially welded seamless drawn hemispheres.

15.5.3
Where a longitudinal seam in shells is used, it shall be copper-brazed, copper-alloy-brazed, or silver-alloy-brazed. When brazed, the plate edge shall be lapped at least 8 times its thickness, laps being held in position, substantially metal to metal, by electric spot welding. Brazing shall be done by using a process that ensures complete penetration. The copper-alloy composition shall be copper, minimum 95%; silicon, from 1.5 to 3.85%; manganese, from 0.25 to 1.10%. The silver alloy shall have a melting point above 540°C. Copper-brazed longitudinal seams shall have a strength at least 1.5 times the strength of the steel wall.

15.5.4
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

15.5.5
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding or brazing to spheres and to the ends of cylinders. Where welding is used, attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

15.6 Heat Treatment

15.6.1
The completed containers shall be heat-treated by any method that achieves a temperature in excess of 595°C. When brazed joints are used, heat treatment may be done before, during, or after brazing operations. Liquid quenching of containers shall be prohibited.

15.6.2
Heat treatment shall not be required after welding or brazing weldable low-carbon parts to attachments of similar material that have been previously welded or brazed to spheres or to the ends of cylinders and heat-treated, provided such subsequent welding or brazing does not produce a temperature in excess of 200°C in any part of the container.

15.7 Hydrostatic Test

15.7.1
One representative container from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. If this first container fails the volumetric expansion test, 2 additional representative containers shall be taken from the same lot and subjected to the same test. If either of these fails the test, then each container in the lot shall be tested and have its volumetric expansion measured.

15.7.2
The containers not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

15.8 Tensile Test

15.8.1
From each lot of 200 cylinders or less, two Type A, B, C, or E specimens, located approximately 180° apart, shall be cut from 1 representative cylinder that has passed the hydrostatic test and shall be tested. Tensile tests shall be required on two Type A, C, or E specimens cut from a representative sample plate from the starting stock of each lot of 200 spheres or less. The sample plate shall have received the same heat treatment as the spheres.

15.8.2
For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

15.8.3
For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

15.9 Weld Tensile Test
A weld tensile test shall be required on a specimen cut across the major welded seam of 1 representative container from each lot of 200 or less. As an alternative, the specimen may be cut from a welded test plate. The welded test plate shall be taken from one of the heats in the same lot, and it shall be in the same condition and of approximately the same thickness as the container wall, except that in no case shall the thickness be less than 2.5 mm. The test plate shall be welded by the same procedure and subjected to the same heat treatment as the major seam on the container.

15.10 Weld Guided-Bend Test
A root-bend test shall be required on a specimen cut from the container seam or the welded test plate used for the weld tensile test. The alternate guided-bend test shall be permitted.

15.11 Leak Test of Final Assembly
If a valve or fitting is installed by a manufacturer, the completed assembly shall not leak when tested at a pressure of at least 600 kPa.

15.12 Rejected Containers
Repair of brazed seams by brazing, and welded seams by welding, shall be permitted. Reheat treatment shall be permitted. Following repair and reheat treatment, containers shall pass all specified tests.

15.13 Marking

15.13.1
Markings shall be placed
(a) on each cylinder shoulder or top half of a sphere of 2.2 mm or more in thickness;
(b) on neck, valve boss, valve-protection collar, or similar part permanently attached to the top of the container; or

(c) on a plate at least 1.6 mm thick, attached by welding, or by brazing at a temperature of at least 595°C, along all edges of the plate to the top of the container or one of its permanent attachments. Space shall be left on the plate to stamp at least 6 requalification dates.

15.13.2
Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

15.13.3
As alternatives, marks may be located as follows:
(a) on the sidewall adjacent to the top end of cylinders, for sidewalls not less than 2.3 mm thick; or
(b) on a cylindrical portion of the shell that extends beyond the recessed bottom of the cylinder, constituting an integral and non-pressure part of the cylinder.
Note: *The manufacturer's marks and serial number may, as an alternative, be stamped into the welded or brazed-on valve boss directly above the TC specification mark located on the top end of the cylinder.*

16. Specification TC-4BWM

16.1 General
TC-4BWM containers are welded carbon or high-strength low-alloy (HSLA) steel cylinders with a longitudinal electric-arc-welded seam and a service pressure range from 1.5 to 3.5 MPa.

16.2 Materials

16.2.1
Steel shall be semi-killed or killed carbon or HSLA steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

16.2.2
Steel shall have tensile properties that will allow the manufacturer to achieve in the cylinder a minimum tensile strength, in accordance with Clause 16.9, that satisfies the requirements of Clause 16.3.

16.3 Wall Thickness

16.3.1
The minimum design wall thickness shall be calculated as follows, using Equation 7:

$$t = \frac{D}{2}\left(1 - \sqrt{\frac{SE - 1.3P}{SE + 0.4P}}\right) \qquad \textbf{(7)}$$

where
t = minimum design wall thickness, mm
D = outside diameter, mm
S = maximum wall stress allowed, MPa
E = joint confidence factor of the longitudinal seam (see Clauses 16.5.5, 16.5.6, and 16.5.7)
P = the hydrostatic test pressure, MPa

The wall stress in Equation 7 shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 241 MPa, whichever is the lesser. The minimum design wall thickness shall not be less than 2.0 mm for cylinders with an outside diameter larger than 155 mm.

16.3.2
The minimum thickness of ends shall be not less than 90% of the minimum design wall thickness.

16.3.3
Where the design wall thickness is less than 2.5 mm, the ratio of tangential length to outside diameter shall not exceed 4:1.

16.4 Openings
Openings shall be provided with a fitting, boss, or pad integral with or securely attached to the cylinder by welding. Straight threads shall have at least 4 engaging threads.

16.5 Manufacture

16.5.1
Closure of cylinders by the spinning process shall be prohibited.

16.5.2
Ends shall be hemispherical or ellipsoidal in shape and concave to pressure. Ellipsoidal ends shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1.

16.5.3
Circumferential seams shall be welded by an electric-arc process. Joints shall be of the butt type with one member offset (joggle butt) or the lap type with a minimum overlap of 4 times the nominal sheet thickness.

16.5.4
Longitudinal seams shall be machine butt-welded by the electric-arc process. Longitudinal seams shall have complete joint penetration and be free from undercuts, overlaps, or abrupt ridges or valleys. Misalignment of mating butt edges shall not exceed 17% of the nominal sheet thickness or 0.8 mm, whichever is the lesser. Joints of nominal sheet thickness up to and including 3.2 mm shall be tightly butted. Where the nominal sheet thickness is greater than 3.2 mm, the joint may be gapped with a maximum distance equal to one-half the nominal sheet thickness or 0.8 mm, whichever is the lesser.

16.5.5
Where each longitudinal seam is radiographed completely, the joint confidence factor shall be 1.0.

16.5.6
Where the longitudinal seam of 1 cylinder from each lot of 50 consecutively welded cylinders is spot-radiographed, the joint confidence factor shall be 0.90. Following a shutdown of the welding operations exceeding 4 h, 1 of the first 5 cylinders welded shall be spot-radiographed. Spot radiographs shall be made on a completed welded cylinder and shall include the girth weld for 50 mm in both directions from the intersection of the longitudinal and girth welds, and shall include at least 150 mm of the longitudinal weld.

16.5.7
Where no radiographic inspection of the longitudinal seam is made, the joint confidence factor shall be 0.75.

16.5.8
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

16.5.9
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

16.6 Heat Treatment

16.6.1
The completed cylinders shall be heat-treated by any method that achieves a temperature in excess of 595°C throughout the cylinder. Liquid quenching of cylinders shall be prohibited.

16.6.2
Heat treatment shall not be required after welding or brazing weldable low-carbon parts to attachments of similar material that have been previously welded to the ends of the cylinders and heat-treated, provided that such subsequent welding or brazing does not produce a temperature in excess of 200°C in any part of the cylinder.

16.7 Radiographic Inspection
When 1 cylinder from each lot of 50 is radiographed and the sample fails to meet the requirements of the spot-radiographic inspection, 2 additional welds from the same lot shall be radiographed. If either of these fails to meet the requirements, then each cylinder may be radiographed. Only those passing the radiographic inspection shall be accepted.

16.8 Hydrostatic Test

16.8.1
One representative cylinder from each lot of 200 or less shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured. If this first cylinder fails the volumetric expansion test, 2 additional representative cylinders shall be taken from the same lot and subjected to the same test. If either of these fails the test, then each cylinder in the lot shall be tested and have its volumetric expansion measured.

16.8.2
The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

16.8.3
In addition to the tests in Clause 16.8.1, one representative cylinder from each lot of 500 or less shall be tested hydrostatically to 4 times its service pressure without bursting. If this cylinder bursts at a pressure below 4 times its service pressure, the entire lot shall be rejected.

16.9 Tensile Test

16.9.1
From each lot of 200 or less cylinders, 1 representative cylinder that has passed the hydrostatic test shall have tensile tests performed on Type A, B, C, or E specimens that have been cut from it, as follows:
(a) one specimen shall be cut longitudinally from the body section at least 90° away from the weld joint, and 1 specimen from either of the ends. If the ends are of different materials, a specimen shall be cut from each end; and
(b) if, due to welded attachments, there is insufficient space to obtain a specimen from the top end, the specimen may be cut from a representative end subjected to the same heat treatment as the cylinder.

16.9.2
For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

16.9.3
For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

16.10 Weld Tensile Test
A weld tensile test shall be required on a specimen cut across the longitudinal seam of 1 representative cylinder from each lot of 200 or less.

16.11 Weld Guided-Bend Test
A root-bend test shall be required on a specimen cut from the cylinder seam used for the weld tensile test. The alternate guided-bend test shall be permitted.

16.12 Leak Test of Final Assembly
If a valve or fitting is installed by a manufacturer, the completed assembly shall not leak when tested at a pressure of at least 600 kPa.

16.13 Rejected Cylinders
Seams may be repaired by an electric-arc process, provided that all defective weld metal is removed. Reheat treatment shall be permitted. Following repair and reheat treatment, cylinders shall pass all specified tests.

16.14 Marking

16.14.1
Markings shall be placed
(a) on each cylinder shoulder or top end of 2.2 mm or more in thickness;
(b) on neck, valve boss, valve-protection collar, or similar part permanently attached to the top end of the cylinder; or
(c) on a plate at least 1.6 mm thick, attached by welding, or by brazing at a temperature of at least 595°C, along all edges of the plate to the top end of the cylinder or one of its permanent attachments. Space shall be left on the plate to stamp at least 6 requalification dates.

16.14.2
Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

17. Specification TC-4DM

17.1 General
TC-4DM containers are welded carbon, alloy, or stainless steel spheres or cylinders for aircraft use, with a maximum capacity of 45.4 L of water and a service pressure range from 2.1 to 3.5 MPa.

17.2 Materials

Steel shall be
(a) semi-killed or killed carbon or high-strength low-alloy (HSLA) steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2;
(b) nonstandard Grade 4130 alloy steel of uniform and weldable quality conforming to Table 17.1. The tolerances for product analysis shall be as given in Table 17.2; or
(c) stainless steel of uniform and weldable quality conforming to one of the types specified in Table 17.3. The tolerances for product analysis shall be as given in Table 17.4.

17.3 Wall Thickness

The wall stress for the minimum design wall thickness calculations shall not exceed 165 MPa except that where nonstandard Grade 4130 steel or Type 304, 316, 321, or 347 stainless steel is used, the wall stress shall not exceed 255 MPa. The minimum design wall thickness shall be the greater of the applicable values that follow:
(a) the thickness based on Equation 1 or 2, Clause 4.2.1, where P is 2 times the service pressure and E is
(i) 0.85 for the circumferential weld area and the heat-affected zones, which are considered to extend a distance of 6 times the actual wall thickness from the centreline of the weld; and
(ii) 1.0 for all other areas; or
(b) 1.0 mm for containers with a capacity of 18.0 L or less, or 2.4 mm for containers with a capacity greater than 18.0 L.

17.4 Openings

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the container by brazing, by welding, or by threads. The fitting, boss, or pad shall be of steel suitable for the method of attachment. Straight threads shall have at least 4 engaging threads.

17.5 Manufacture

17.5.1

Abrupt changes in wall thickness shall be prohibited.

17.5.2

Spheres shall be made of 2 circumferentially welded seamless drawn hemispheres. Cylinders shall be made of 2 circumferentially welded seamless drawn shells.

17.6 Heat Treatment

The completed containers shall be heat-treated.

17.7 Tensile Test

17.7.1 Spheres

Tensile tests shall be required on 2 Type A or C specimens cut from a representative sample plate taken from the starting stock of each lot of 200 spheres or less. The sample plate shall have received the same heat treatment as the spheres.

17.7.2 Cylinders

Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder taken from each lot of 200 or less and shall be tested.

17.8 Hydrostatic Test

17.8.1
Each container shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured.

17.8.2
Alternatively, 1 representative container, from each lot of 200 or less, shall be tested hydrostatically to 3 times its service pressure and have its volumetric expansion measured. All other containers in the same lot shall be inspected under a pressure of 2 times the service pressure and show no defects.

17.9 Flattening Test
From each lot of 200 or less, one representative container shall be tested, if required (see Clause 17.10) after the hydrostatic test.

17.10 Requirements for the Tensile and the Flattening Tests
The tensile and the flattening test results shall meet either of the following:
(a) no flattening test shall be required when the elongation is at least 20% in Type B and C specimens, or 40% in Type A specimens, and when the yield strength is not over 73% of the tensile strength; or
(b) if conditions in Item (a) are not met, a flattening test shall be required without cracking to 50% of the original outside diameter. The elongation shall be at least 10% in Type B and C specimens or at least 20% in Type A specimens.

17.11 Rejected Containers
Reheat treatment shall be permitted. Repair of welds by welding prior to heat treatment shall be permitted. Following repair and heat treatment, containers shall pass all specified tests.

17.12 Marking
Markings shall be placed on each container where the metal is at least 2.3 mm thick or on a metal plate permanently secured to the container by means other than soft solder.

Notes:

(1) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are not more than* 51 mm *in outside diameter.*

(2) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are more than* 51 mm *in outside diameter when the volumetric capacity does not exceed* 1 L.

18. Specification TC-4DAM

18.1 General
TC-4DAM containers are welded alloy steel spheres or cylinders for aircraft use, with a maximum capacity of 45.4 L of water, and a service pressure range from 3.5 to 6.2 MPa.

18.2 Materials

18.2.1
Steel shall be Grade 4130 alloy steel of uniform and weldable quality conforming to the chemical composition of Grade F specified in Table 5.1. The tolerances for product analysis shall be as given in Table 5.2.

18.2.2
Steel shall have tensile properties that will allow the manufacturer to achieve in the container a minimum tensile strength, in accordance with Clause 18.10, that satisfies the requirements of Clause 18.3.

18.3 Wall Thickness
The wall stress for the minimum design wall thickness calculations shall not exceed 67% of the minimum tensile strength as determined by the tensile and burst tests or 483 MPa, whichever is the lesser. The minimum design wall thickness shall be the greater value of the following:

(a) the thickness based on Equation 1 or 2, Clause 4.2.1, where P is 2 times the service pressure and E is
    (i) 0.85 for the circumferential weld area and the heat-affected zones, which are considered to extend a distance of 6 times the actual wall thickness from the centreline of the weld; and
    (ii) 1.0 for all other areas; or
(b) 1.0 mm.

18.4 Openings
Openings shall be provided with a fitting, boss, or pad of weldable steel securely attached to the container by electric-arc welding. Straight threads shall have at least 4 engaging threads.

18.5 Manufacture

18.5.1
Abrupt changes in wall thickness shall be prohibited.

18.5.2
Spheres shall be made of 2 circumferentially welded seamless drawn hemispheres. Cylinders shall be made of 2 circumferentially welded seamless drawn shells.

18.5.3
Seams shall be welded by an electric-arc process. Seams shall be of the butt type and means shall be provided to ensure complete penetration of the joint. Seams may also be of the joggle butt type.

18.5.4
Attachments shall be welded to spheres and to the ends of cylinders only. Attachments made of weldable steel, other than Grade 4130, shall have a carbon content not exceeding 0.25%.

18.6 Heat Treatment

18.6.1
The completed containers shall be heat-treated.

18.6.2
Containers shall be quenched or normalized. The steel temperature on quenching shall be that recommended for the material grade, but in no case shall it exceed 955°C. Quenched containers shall be tempered at a temperature consistent with achieving the specified mechanical properties. The tempering temperature shall be not less than 540°C. Normalizing shall be performed at a temperature of 900°C.

18.7 Nondestructive Inspection after Heat Treatment
Containers quenched in water or in a liquid producing a cooling rate in excess of 80% of the cooling rate of water shall be inspected by a nondestructive inspection method to detect quenching cracks. Containers with quenching cracks shall be condemned.

18.8 Hydrostatic Test

18.8.1
Each container shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured.

18.8.2
In addition to the tests in Clause 18.8.1, one representative container, from each lot of 200 or less, shall be tested hydrostatically to destruction. If this container bursts at a pressure below 3 times its service pressure, the entire lot shall be rejected.

18.9 Radiographic Inspection of Welds
Radiographic inspection shall be required, after the hydrostatic test, on all welded joints that are subjected to internal pressure. The independent inspector may decide that inspection of openings less than 25% of the container diameter is unnecessary. Containers shall be rejected if there is evidence of defects.

18.10 Tensile Test

18.10.1 Spheres
Tensile tests shall be required on 2 Type A or C specimens cut from a representative sample plate from the starting stock of each lot of 200 spheres or less. The sample plate shall have received the same heat treatment as the spheres.

18.10.2 Cylinders
Two Type A, B, or C specimens, located approximately 180° apart, shall be cut from 1 representative cylinder taken from each lot of 200 or less, and shall be tested.

18.10.3 Requirements
The elongation shall be at least 10% for Type B and C specimens, or 20% for Type A specimens.

18.11 Flattening Test

18.11.1
From each lot of 200 or less, one representative container shall be tested, after the hydrostatic test.

18.11.2
Flattening to 50% of the original outside diameter without cracking shall be required.

18.12 Rejected Containers
Reheat treatment shall be permitted. Repair of welds by welding prior to heat treatment shall be permitted. Following repair and heat treatment, containers shall pass all specified tests.

18.13 Marking
Markings shall be placed on each container on a permanent attachment or on a metal plate permanently secured to the container by means other than soft solder.

Notes:

(1) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are not more than* 51 mm *in outside diameter.*

(2) *Lot numbers in lieu of serial numbers for lots of 500 cylinders or less are permitted for cylinders that are more than* 51 mm *in outside diameter when the volumetric capacity does not exceed* 1 L.

19. Specification TC-4DSM

19.1 General

TC-4DSM containers are welded stainless steel spheres or cylinders for aircraft use, with a maximum capacity of 45.4 L of water and a service pressure range from 3.5 to 6.2 MPa.

19.2 Materials

Steel shall be stainless steel of uniform and weldable quality conforming to the chemical composition of Type 304, 321, or 347 specified in Table 17.3. The tolerances for product analysis shall be as given in Table 17.4.

19.3 Wall Thickness

The wall stress for the minimum design wall thickness calculations shall not exceed 414 MPa. The minimum design wall thickness shall be the greater value of the following:

(a) the thickness based on Equation 1 or 2, Clause 4.2.1, where P is 2 times the service pressure and E is
    (i) 0.85 for the circumferential weld area and the heat-affected zones, which are considered to extend a distance of 6 times the actual wall thickness from the centreline of the weld; and
    (ii) 1.0 for all other areas; or
(b) 1.0 mm.

19.4 Openings

Openings shall be provided with a fitting, boss, or pad of weldable stainless steel securely attached to the container by inert-gas-shielded arc welding. Straight threads shall have at least 4 engaging threads.

19.5 Manufacture

19.5.1

Abrupt changes in wall thickness shall be prohibited.

19.5.2

Spheres shall be made of 2 circumferentially welded seamless drawn hemispheres. Cylinders shall be made of 2 circumferentially welded seamless drawn shells.

19.5.3

Seams shall be welded by the inert-gas-shielded arc process. Seams shall be of the butt type, and means shall be provided to ensure complete penetration of the joint.

19.5.4

Attachments shall be welded to spheres and to the ends of cylinders only. Attachments shall be of weldable stainless steels that comply with Clause 19.2.

19.6 Heat Treatment

The seamless shell components may be stress-relieved or annealed for forming. Welded containers shall be stress-relieved at a temperature of 413 ± 14°C after process treatment.

19.7 Process Treatment

Each cylinder and sphere shall be pressurized hydraulically in a water jacket to at least 100%, but not more than 110%, of the test pressure and maintained at this pressure for a minimum of 3 min. Total and permanent expansion shall be recorded and included in the independent inspector's report.

19.8 Hydrostatic Test

19.8.1
Each container shall be tested hydrostatically to 2 times its service pressure, have its volumetric expansion measured, and then be inspected. Bulges, cracks, and weld defects shall be cause for rejection.

19.8.2
In addition to the tests in Clause 19.8.1, one representative container from each lot of 200 or less shall be tested hydrostatically to destruction. If this container bursts at a pressure below 3 times its service pressure, the entire lot shall be rejected.

19.9 Radiographic Inspection
Radiographic inspection shall be required, after the hydrostatic test, on all welded joints that are subjected to internal pressure. The independent inspector may decide that inspection of openings of less than 25% of the container diameter is unnecessary. Containers shall be rejected if there is evidence of defects.

19.10 Flattening Test

19.10.1
One representative container, taken from each lot of 200 or less, after the hydrostatic test, shall be tested.

19.10.2
Flattening to 50% of the original outside diameter without cracking shall be required.

19.11 Rejected Containers
Repair of welds by welding prior to process treatment shall be permitted. Following repair and heat treatment, containers shall pass all specified tests.

19.12 Test Conditions
All tests shall be performed at an ambient temperature between 16 and 32°C.

19.13 Marking
Markings shall be placed on each container on a permanent attachment or on a metal plate permanently secured to the container by means other than soft solder.

20. Specification TC-4EM

20.1 General
TC-4EM containers are welded aluminum cylinders made of 2 seamless drawn shells joined by a circumferential weld, with a service pressure range from 1.5 to 3.5 MPa.

20.2 Materials
Aluminum shall be aluminum alloy of uniform and weldable quality conforming to the chemical composition of alloy AA5154, specified in Table 20.1.

20.3 Wall Thickness

20.3.1

The wall stress for the minimum design wall thickness calculations shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 138 MPa, whichever is the lesser. The minimum design wall thickness shall be the greater value of the following:

(a) the thickness based on Equation 1, Clause 4.2.1, where P is the specified hydrostatic test pressure; or

(b) 3.6 mm.

20.3.2

The minimum thickness of ends shall be not less than the minimum design wall thickness.

20.4 Openings

Openings, except those for pressure-relief devices, shall be provided with a fitting, boss, or pad securely attached to the cylinder by inert-gas-shielded arc welding or by threads. Straight threads shall have at least 4 engaging threads.

20.5 Manufacture

20.5.1

Closure of cylinders by the spinning process shall be prohibited.

20.5.2

The circumferential weld shall not be located closer to the point of tangency of the cylindrical portion with the shoulder than 20 times the cylindrical wall thickness.

20.5.3

Longitudinal seams shall be prohibited.

20.5.4

Neck rings, flanges, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable aluminum alloys.

20.5.5

All welding shall be by a gas-shielded arc process.

20.6 Tensile Test

20.6.1

Two Type A specimens, located approximately 180° apart, shall be cut from 1 representative cylinder from each lot of 200 or less, and shall be tested.

20.6.2

The elongation shall be at least 7%. The yield strength shall not exceed 80% of the tensile strength.

20.7 Weld Tensile Test

A weld tensile test shall be required on a specimen cut across the circumferential weld of the cylinder used for the tensile test. Edges of the reduced section shall be parallel for a distance of approximately 50 mm on either side of the weld. The calculated breaking stress determined from the breaking load and the minimum wall thickness in the lot shall be equal to at least 2 times the design wall stress at hydrostatic test pressure. The actual breaking stress shall be at least 207 MPa.

20.8 Weld Guided-Bend Test

A root-bend test shall be required on a specimen cut from the cylinder used for the weld tensile test.

20.9 Hydrostatic Test

20.9.1

Each cylinder shall be tested hydrostatically to 2 times its service pressure and have its volumetric expansion measured; however, when the design wall stress is 124 MPa or less at test pressure, at least 1 representative cylinder from each lot of 200 or less shall be tested and have its volumetric expansion measured. The permanent volumetric expansion shall not exceed 12% of the total expansion at test pressure.

20.9.2

The cylinders not tested by the volumetric expansion method shall be inspected under a pressure of 2 times the service pressure and show no defects.

20.9.3

In addition to the tests in Clauses 20.9.1 and 20.9.2, one representative cylinder from each lot of 1000 or less shall be tested hydrostatically to 4 times its service pressure without bursting. If this cylinder bursts below 4 times its service pressure, the entire lot shall be rejected.

20.10 Flattening Test

20.10.1

From each lot of 200 or less, a representative cylinder that has passed the hydrostatic test shall have a ring containing the circumferential weld cut from it. The weld reinforcement shall be removed by machining or grinding so that the weld is flush with the surface of the parent metal. The ring width shall be not less than 30 times the cylinder wall thickness. The welded seam shall be in the centre of the ring. The ring shall be flattened to 6 times the wall thickness without cracking .

20.10.2

Where the weld is not at mid-length of the cylinder, the ring shall be flattened between plates with the weld at a right angle to the plates.

20.10.3

Where the weld is at mid-length of the cylinder, the test may be as outlined in Item (a) of Clause 4.10, with the welded seam in line with the plane of the applied load, or as outlined in Clause 20.10.2.

20.11 Leak Test of Final Assembly

If a valve or fitting is installed by a manufacturer, the completed assembly shall not leak when tested at a pressure of at least 600 kPa.

20.12 Rejected Cylinders

Repair of welds by welding shall be permitted. Following repair, cylinders shall pass all specified tests.

20.13 Marking

20.13.1

Markings shall be placed on each cylinder shoulder, top end, neck, valve-protection collar, or similar part permanently attached to the top end of the cylinder.

20.13.2
Each valved cylinder shall be marked with its tare. Where the cylinder is not equipped with a valve(s), its mass shall be marked in lieu of the tare.

21. Specification TC-4LM

21.1 General
TC-4LM containers are fusion-welded stainless steel cylinders, insulated and contained within an outer protective metal jacket, with a service pressure range from 0.3 to 3.5 MPa and a service temperature of –196°C or lower. Table 21.1 specifies the service temperature required for each product.

21.2 Materials
Steel shall be stainless steel of uniform and weldable quality conforming to the chemical composition of Type 304, specified in ASTM Standard A 240. The chemical composition and mechanical property requirements shall be as given in Tables 21.2 and 21.3. The tolerances for product analysis shall be as given in Table 21.4. The notch-toughness requirements of the sheet metal shall be in accordance with Clause 21.11.

21.3 Wall Thickness

21.3.1
The minimum design wall thickness shall be the thickness based on Equation 1, Clause 4.2.1, where P is the specified test pressure. The wall stress in Equation 1 shall not exceed 50% of the minimum tensile strength across the welded seam as determined by the weld tensile test, or 50% of the minimum tensile strength of the base metal as determined by the tensile test, or the yield strength of the base metal as determined by the tensile test, or 310 MPa, whichever is the least. The wall stress in Equation 1 for cylinders having a longitudinal seam shall not exceed 85% of the above applicable value.

21.3.2
The minimum thickness of ends shall be not less than 90% of the minimum design wall thickness.

21.4 Openings
Openings in cylinders shall be provided with a fitting, boss, or pad either integral with or securely attached to the cylinder by fusion welding. Openings in cylinders shall not exceed 76 mm in diameter or 33% of the cylinder diameter, whichever is the smaller. Attachments to a fitting, boss, or pad may be made by welding, brazing, threads, or by other mechanical means. Straight threads shall have at least 4 engaging threads.

21.5 Manufacture

21.5.1 Cylinder

21.5.1.1
Ends shall be seamless, concave to pressure, and hemispherical or ellipsoidal. Ellipsoidal ends shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1.

21.5.1.2
Ends and cylindrical section shall conform to the design shape and have no abrupt shape changes.

21.5.1.3
For liquefied hydrogen service, the cylinders shall be designed to stand on end with the axis of the cylindrical body vertical.

21.5.2 Outer Jacket and Insulation
The surface of the cylinder shall be insulated with fire-resistant material. The insulation on a nonevacuated jacket shall be covered with a steel jacket not less than 1.5 mm thick or an aluminum jacket not less than 1.75 mm thick, so constructed that moisture cannot come in contact with the insulating material. If a vacuum is maintained in the insulation space, the evacuated jacket shall be designed for a minimum collapsing pressure of 200 kPa differential, whether made of steel or aluminum. The construction shall be such that the total heat transfer from the atmosphere at ambient temperature to the contents of the cylinder will not exceed 0.000581 W/°C (0.000581 watts per degree Celsius) differential in temperature per litre of water capacity of the cylinder. For liquefied hydrogen service, the total heat transfer, with a temperature difference of 289°C, shall not exceed that required to vent 0.83 m^3/h of hydrogen gas.

21.6 Welding and Joining

21.6.1
All seams in the cylinder shall be fusion-welded with complete joint penetration. Seams shall be butt or joggle-butt joints. Cylinder joints shall be in reasonably true alignment. Attachments shall be fusion-welded to the walls and ends of the cylinder, and shall be of a weldable material that complies with the impact requirements.

21.6.2
Impact tests on the welds shall be performed in accordance with Clause 21.11 as required and as part of the qualification of each welding procedure and operator.

21.6.3
Brazing, soldering, and threading shall be permitted only for joints not made directly to the cylinder body.

21.7 Radiographic Inspection
One representative finished longitudinal seam shall be taken from each lot of 100 or less and radiographed throughout its entire length and pass the radiographic inspection for lot acceptance. Should this sample fail to meet the requirements, 2 additional seams from the same lot shall be radiographed and pass the radiographic inspection for lot acceptance. If either of these fails to meet the requirements, then each cylinder may be radiographed as outlined above and pass the radiographic inspection for acceptance. Only those passing the radiographic inspection shall be accepted.

21.8 Tensile Test

21.8.1
Two Type A specimens, cut from each heat of starting stock, shall be tested.

21.8.2
The tensile test results shall meet the requirements of Table 21.3. The required elongation may be reduced numerically by 2 for each 52 MPa increment of tensile strength above 690 MPa, to a maximum of 5 such increments. In no case shall the elongation be less than 20%.

21.9 Weld Tensile Test

A weld tensile test shall be required on a specimen cut across the major seam of 1 representative cylinder from each lot of 200 or less. As an alternative, the specimen may be cut from a welded test plate. The welded test plate shall be taken from one of the heats in the same lot, and it shall be in the same condition and of approximately the same thickness as the cylinder wall. The test plate shall be welded by the same procedure as the major seam.

21.10 Weld Guided-Bend Test

A root-bend test shall be required on a specimen cut from the cylinder seam or the welded test plate used for the weld tensile test, and from any other seam or equivalent welded test plate, if the seam is welded by a procedure different from that used for the major seam. The alternate guided-bend test shall be permitted.

21.11 Impact Test

21.11.1

One set of 3 impact test specimens shall be tested to determine the impact properties of the deposited weld metal

(a) as part of the qualification of the welding procedure;
(b) as part of the qualification of the operators;
(c) for each heat of welding rod or wire used; and
(d) for each 300 m of weld made with the same heat of welding rod or wire.

21.11.2

All impact test specimens shall be of the Charpy type, keyhole or milled U-notch, and shall conform in all respects to Figure 4 of ASTM Standard E 23. Each set of impact specimens shall be taken across the weld and have the notch located in the weld metal.

21.11.3

Where the cylinder material thickness is 2.5 mm or thicker, impact specimens shall be cut from a cylinder or welded test plate used for the tensile or bend test. The dimension along the axis of the notch shall be reduced to the largest possible of 10 mm, 7.5 mm, 5 mm, or 2.5 mm, depending upon cylinder thickness.

21.11.4

Where the material in the cylinder or welded test plate is not of sufficient thickness to prepare 2.5 mm impact test specimens, 2.5 mm specimens shall be prepared from a welded test plate made from 3.2 mm thick material meeting the specified material requirements and having a carbon analysis of 0.05% minimum, but not necessarily from one of the heats used in the lot of cylinders. The test piece shall be welded by the same welding procedure as used on the particular cylinder seam being qualified.

21.11.5

Impact test specimens shall be cooled to the design service temperature. The testing apparatus shall conform to the requirements of ASTM Standard E 23. The test piece, as well as the handling tongs, shall be cooled for a length of time sufficient to reach the service temperature. The temperature of the cooling device shall be maintained within a range of ±1.7°C. The specimen shall be quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than 6 s.

21.11.6

The impact properties of each set of impact specimens shall be not less than the values shown in Table 21.5.

21.11.7
Where the average value of the 3 specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than 1 specimen is below the required average value, or where the value for 1 specimen is below the minimum value permitted for a single specimen, a retest of 3 additional specimens shall be made. The value of each of these retest specimens shall equal or exceed the required average values in Table 21.5.

21.12 Hydrostatic Proof Pressure Test
Before insulating and jacketing, each cylinder shall be inspected under a pressure of 2 times its service pressure without evidence of leakage, distortion, or other defects.

21.13 Rejected Cylinders
Repair of welds by fusion welding shall be permitted. Following repair, cylinders shall pass all specified tests.

21.14 Marking

21.14.1
Cylinder markings shall be placed on each cylinder jacket shoulder or top end, or on a permanently attached plate, or on the end protective ring.

21.14.2
The service pressure may be marked to the nearest tenth of a bar.

21.14.3
The markings shall also include
(a) the service temperature when below –196°C;
(b) the tare;
(c) near the manufacturer's mark, the maximum mass of contents for cylinders having a service temperature below –196°C;
(d) the letters "AL" following the service pressure, when the outer jacket is made of aluminum; and
(e) special orientation instructions (eg, "this side up") if the cylinder is designed to be used in an orientation other than vertical with openings at the top.

21.14.4
Except for serial numbers, jacket material designation, and orientation instructions, the markings shall be duplicated on the cylinders.

22. Specifications TC-8WM and TC-8WAM

22.1 General

22.1.1
TC-8WM containers are welded carbon steel cylinders containing a porous filler impregnated with a solvent to carry acetylene, with a service pressure of 1.7 MPa.

22.1.2
TC-8WAM containers are welded high-strength low-alloy (HSLA) steel cylinders or welded carbon and HSLA steel cylinders containing a porous filler impregnated with a solvent to carry acetylene, with a service pressure of 1.7 MPa.

22.2 Materials

22.2.1 TC-8WM

Steel shall be semi-killed or killed carbon steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

22.2.2 TC-8WAM

Steel shall be semi-killed or killed carbon steel or HSLA steel of uniform and weldable quality conforming to Table 12.1. The tolerances for product analysis shall be as given in Table 12.2.

22.3 Wall Thickness

22.3.1

The minimum design wall thickness shall be calculated as follows using Equation 8:

$$t = \frac{D}{2}\left(1 - \sqrt{\frac{SE - 1.3P}{SE + 0.4P}}\right) \quad \textbf{(8)}$$

where
t = minimum design wall thickness, mm
D = outside diameter, mm
S = maximum wall stress allowed, MPa
E = joint confidence factor of the longitudinal seam (see Clauses 22.3.4, 22.5.3, 22.5.5, 22.5.6, and 22.5.7)
P = 5.2 MPa

The wall stress in Equation 8 for HSLA steel shall not exceed 50% of the minimum tensile strength as determined by the tensile test or 241 MPa, whichever is the lesser. The wall stress in Equation 8 for cylinder bodies and for the cylindrical portion of the cylinder ends made of carbon steel shall not exceed 179 MPa.

22.3.2

The minimum design wall thickness shall be not less than 2.2 mm for cylinders with an outside diameter larger than 127 mm.

22.3.3

Where the design wall thickness is less than 2.5 mm, the ratio of tangential length to outside diameter shall not exceed 3.5.

22.3.4

Ends convex to pressure shall have a minimum thickness equal to 200% of the minimum design wall thickness. Ends concave to pressure shall have a minimum thickness equal to 90% of the minimum design wall thickness. In both cases, the minimum design wall thickness shall be calculated using Equation 8, with a joint confidence factor equal to 1.0.

22.4 Openings

Openings shall be provided with a fitting, boss, or pad integral with or securely attached to the cylinder by welding. Straight threads shall have at least 4 engaging threads.

22.5 Manufacture

22.5.1
Closure of cylinders by the spinning process shall be prohibited. Welding of pressure-retaining parts shall be by the submerged or gas-shielded arc process.

22.5.2
Ends shall be hemispherical or ellipsoidal in shape. The ellipsoid shall have a ratio of major axis (diameter of cylinder) to minor axis not exceeding 2:1. Ends convex to pressure may have a torispherical shape.

22.5.3
Circumferential seams shall be machine-welded. Joints shall be butt, joggle butt, or lap-welded with a minimum overlap of 4 times the nominal sheet thickness. The minimum leg of any lap-welded fillet shall be at least 1.3 times the minimum design wall thickness, based on a joint confidence factor of 1.0. The fillet weld beads shall be flat or convex. The seams shall have complete joint penetration. Misalignment of mating butt edges shall not exceed 25% of the nominal sheet thickness or 1.2 mm, whichever is the smaller.

22.5.4
Longitudinal seams shall be machine butt-welded. Seams shall have complete joint penetration and be free from undercuts, overlaps, or abrupt ridges or valleys. Misalignment of mating butt edges shall not exceed 17% of the nominal sheet thickness or 0.8 mm, whichever is the smaller. Joints of nominal sheet thickness up to and including 3.2 mm shall be tightly butted. Where the nominal sheet thickness is greater than 3.2 mm, the joint may be gapped with a maximum distance equal to one-half the nominal sheet thickness or 0.8 mm, whichever is the smaller. Permanent backup strips are prohibited.

22.5.5
Where each longitudinal seam is radiographed completely, the joint confidence factor shall be 1.0.

22.5.6
Where the longitudinal seam of 1 cylinder from each lot of 50 consecutively welded cylinders is spot-radiographed, the joint confidence factor shall be 0.90. Following a shutdown of the welding operations exceeding 4 h, 1 of the first 5 cylinders welded shall be spot-radiographed. Spot radiographs shall be made on a completed cylinder shell and shall include the girth weld for 50 mm in both directions from the intersection of the longitudinal and girth welds, and shall include at least 150 mm of the longitudinal weld.

22.5.7
When no radiographic inspection of the longitudinal seam is made, the joint confidence factor shall be 0.75.

22.5.8
Exposed bottom welds on cylinders that are more than 460 mm long shall be protected by foot rings.

22.5.9
Neck rings, foot rings, handles, bosses, pads, and valve-protection rings may be attached by welding to the ends of cylinders only. Attachments shall be of weldable steel with a carbon content not exceeding 0.25%.

22.6 Heat Treatment

22.6.1

The completed cylinder shells shall be heat-treated by any method that achieves a temperature in excess of 595°C throughout the completed cylinder shell. Liquid quenching of shells shall be prohibited. TC-8WM cylinders may be heat-treated before all welding operations are completed.

22.6.2

Heat treatment shall not be required after welding weldable low-carbon parts to attachments of similar material that have been previously welded to the ends of the shells and heat-treated, provided such subsequent welding does not produce a temperature in excess of 200°C in any part of the cylinder shell.

22.7 Radiographic Inspection

Where 1 completed cylinder shell from each lot of 50 is radiographed and the sample fails to meet the requirements of the spot radiographic inspection, 2 additional welds from the same lot shall be radiographed. If either of these fails to meet the requirements, then each shell may be radiographed. Only those passing the radiographic inspection shall be accepted.

22.8 Macro-Etch Test

The macro-etch test applies to cylinder designs having one or two circumferential pressure-retaining lap-welded joints. A sample of the fillet lap weld shall be cut from 1 representative completed cylinder shell taken from each lot of 200 or less. This sample shall be cut across the fillet weld, macro-etched, and visually examined for full penetration at the root and into both members, for the length of the leg and the contour of the weld bead.

22.9 Hydrostatic Test

One representative completed cylinder shell from each lot of 200 or less shall be tested hydrostatically to 5.2 MPa and have its volumetric expansion measured. If this first cylinder shell fails the volumetric expansion test, then each shell in the lot shall be tested hydrostatically to 5.2 MPa and have its volumetric expansion measured. The completed cylinder shells not tested by the volumetric expansion method shall be inspected under a pressure within the range of 3.5 to 4.1 MPa and show no defects.

22.10 Tensile Test

22.10.1

From each lot of 200 or less, 1 representative completed cylinder shell that has passed the hydrostatic test shall have tensile tests performed on Type A, B, C, or E specimens that have been cut from it, as follows:

(a) for designs having 2 deep drawn shells joined by a circumferential weld seam, 1 specimen shall be cut longitudinally from each part;

(b) for designs having a single deep drawn shell joined by a circumferential weld to a shallow bottom end assembled convex to pressure, 2 specimens shall be cut from the shell longitudinally, 180° from one another; and

(c) for designs having a longitudinal seam, 1 specimen shall be cut longitudinally from the body section, at least 90° away from the weld joint, and 1 specimen from either of the ends. If the ends are of different materials, a specimen shall be cut from each end.

22.10.2

For Type A specimens, the elongation shall be at least 40%. For Type B and C specimens, the elongation shall be at least 20%. The required elongation may be reduced numerically by 2 for Type A specimens, and by 1 for Type B and C specimens, for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

22.10.3
For Type E specimens, the elongation shall be at least that specified in Table 12.3 for the cross-sectional area of the specimen. The required elongation may be reduced numerically by 1 for each 52 MPa increment of tensile strength above 345 MPa, to a maximum of 4 such increments.

22.10.4
For carbon steel material, the yield strength shall not exceed 73% of the tensile strength.

22.11 Weld Tensile Test
A weld tensile test shall be required on a specimen cut from the completed cylinder shell used for the tensile test. On a cylinder shell with a longitudinal seam, the specimen shall be cut across the longitudinal seam. On a cylinder shell without a longitudinal seam, the specimen shall be cut across the circumferential seam.

22.12 Weld Guided-Bend Test
A root-bend test shall be required on a specimen cut from the completed cylinder-shell seam used for the weld tensile test.

22.13 Proof Test
This test shall apply to cylinder designs having a longitudinal seam. One completed representative cylinder shell from each day's production or lot of 500, whichever is the greater, shall be tested to 8.3 MPa without bursting or leaking. All cylinders subjected to this test shall be destroyed.

22.14 Dissolved Acetylene System

22.14.1 Porous Filler

22.14.1.1
Cylinders shall contain a porous filler approved and tested in accordance with CGA Publication C-12. A well drilled into the porous filler beneath the valve shall be permitted, provided that the well is stuffed with a material that will not impair the function of the porous filler.

22.14.1.2
Overall shrinkage of the porous filler shall be permitted, provided that the total clearance between the cylinder shell and the porous filler, after adding the solvent, does not exceed 0.5% of the diameter when measured diametrically and 0.5% of the length when measured longitudinally, or 3.2 mm, whichever is the lesser.

22.14.1.3
The clearance between the shell and the porous filler shall be checked on every cylinder. This verification may be conducted before introduction of the solvent. Cylinders meeting the shrinkage requirements under these conditions shall be considered as meeting the requirements after solvent addition.

22.14.1.4
The pores shall be uniform and shall not be visible at a magnification of 500 times. The porosity of the filler shall not exceed 92%. If the porosity of each cylinder is not known, then 1 representative cylinder taken each lot of 200 or less shall be tested by filling with a fluid or by another method approved by the independent inspector. A porosity greater than 92% shall be cause for the rejection of the lot.

22.14.2 Solvents

22.14.2.1 General

The solvent shall be either acetone or dimethylformamide (DMF) of commercial purity.

22.14.2.2 Acetone

The maximum quantity of acetone permitted in a cylinder shall be calculated using Equation 9, as follows:

$$MQ_a = 0.381\ pVF \quad \textbf{(9)}$$

where
MQ_a = maximum quantity of acetone in a cylinder, kg
p = minimum filler porosity expressed as a fractional ratio or 0.90, whichever is the smaller
V = minimum internal shell volume, L
F = F_1 or F_2 (see Table 22.1) = the acetone correction factor

22.14.2.3 DMF

The maximum quantity of DMF permitted in a cylinder shall be calculated using Equation 10, as follows:

$$MQ_d = 0.5105\ pVG \quad \textbf{(10)}$$

where
MQ_d = maximum quantity of DMF in a cylinder, kg
p = minimum filler porosity expressed as a fractional ratio or 0.90, whichever is the smaller
V = minimum internal shell volume, L
G = G_1 or G_2 (see Table 22.2) = the DMF correction factor

22.14.3 Saturation Acetylene

Saturation acetylene in a cylinder shall be calculated using Equation 11 or 12 where applicable, as follows:
(a) when solvent is acetone,

$$S_a = 0.025\ Q_a \quad \textbf{(11)}$$

or
(b) when solvent is DMF,

$$S_d = 0.043\ Q_d \quad \textbf{(12)}$$

where
S_a = saturation acetylene in acetone, kg
Q_a = quantity of acetone in accordance with cylinder design, kg
S_d = saturation acetylene in DMF, kg
Q_d = quantity of DMF in accordance with cylinder design, kg

22.14.4 Acetylene Capacity

22.14.4.1

The maximum rated acetylene capacity of a cylinder shall be determined using Equation 13 or 14 where applicable, as follows:
(a) when solvent is acetone,

$$MRAC = 0.899\ R(Q_a - 0.9\Delta) - S_a \quad \textbf{(13)}$$

or
(b) when solvent is DMF,

$$MRAC = 0.899\ W(Q_d - 0.9\Delta) - S_d \quad \textbf{(14)}$$

where
MRAC = maximum rated acetylene capacity, m^3
R and W are defined in Tables 22.1 and 22.2, respectively
Δ = difference, if any, between the actual tare and the tare stamped on the cylinder, kg
Q_a, Q_d, S_a, and S_d are as defined in Clause 22.14.3

22.14.4.2
The cylinder manufacturer's published maximum rated acetylene capacity shall not exceed the maximum rated acetylene capacity.

22.15 New Design
Cycling testing for design qualification of cylinders with a longitudinal seam shall be conducted on completed cylinder shells at 2.8 MPa for at least 10 000 cycles without distortion or failure. Following the cycling test the shells shall be pressurized to a minimum of 8.3 MPa without bursting or leaking.

22.16 Rejected Completed Cylinder Shells
Seams may be repaired by submerged or gas-shielded arc welding, provided that all defective weld metal is removed. Reheat treatment shall be permitted. Following repair and reheat treatment, completed cylinder shells shall pass all specified tests.

22.17 Inspection
The independent inspector of the completed cylinder shells shall verify that the shell design has successfully passed a cycling pressurization test.

22.18 Marking

22.18.1
Markings shall be placed
(a) on each cylinder shoulder, top end, neck, valve boss, valve-protection collar, or similar part permanently attached to the top end of the cylinder; or
(b) on a plate at least 1.6 mm thick, attached by welding along all edges of the plate to the top of the cylinder or to one of its permanent attachments.

Space shall be left on the plate to stamp at least 6 requalification dates.

22.18.2
Each cylinder shall be marked with its tare and solvent identification if other than acetone. Cylinders containing dimethylformamide shall be identified by the letters "DMF".

22.18.3
Each cylinder shall be marked with the manufacturer's maximum rated capacity in cubic metres (see Figure 4.1).

22.18.4
Completed cylinder shells (without porous filler), when delivered, shall each be marked for identification per each lot of 200 or less.
Note: *The service pressure is not marked on acetylene cylinders.*

23. Specification TC-39M

23.1 General

TC-39M containers are nonrefillable, seamless or welded carbon steel or aluminum, or brazed carbon steel, spheres or cylinders. For service pressures up to 3.5 MPa, the maximum capacity shall be 25 L of water. For service pressures greater than 3.5 MPa, the maximum capacity shall be 4.54 L of water. The service pressure shall not exceed 80% of the test pressure.

23.2 Materials

23.2.1 Steel

23.2.1.1

Steel, except as specified in Clause 23.2.1.2, shall be carbon steel of uniform and, where applicable, weldable quality conforming to the chemical composition specified in Table 23.1. Product analysis limits shall be as given in Table 23.2. Killed steel, deep-drawing quality, shall be used for welded containers not subjected to a heat treatment.

23.2.1.2

Steel used for cylinders with integrally formed ends and made of hot-drawn and finished seamless tubing shall be carbon steel with a chemical composition not exceeding carbon, 0.55%; phosphorus, 0.045%; and sulphur, 0.05%.

23.2.2 Aluminum

Aluminum shall be aluminum alloy of uniform and weldable quality conforming to the chemical composition of alloys AA1100, AA1170, AA3003, AA5052, AA5086, AA5154, AA6010, AA6061, AA6063, or AA6351. (See the Aluminum Association, *Aluminum Standards and Data*.)

23.3 Wall Thickness

The minimum design wall thickness shall be the thickness based on Equation 1 or 2, Clause 4.2.1, where P is the specified test pressure and E is 1.0. The wall stress in Equation 1 or 2 shall not exceed the yield strength of the completed cylinder wall.

23.4 Openings

23.4.1

Openings and their reinforcements shall be within a circle, concentric and normal to the longitudinal axis of the container. The diameter of the circle shall not exceed 80% of the outside diameter of the container. Unless an end has adequate thickness, each opening shall be reinforced by a securely attached fitting, boss, pad, or collar, or by other suitable means.

23.4.2

Material used for welded openings and attachments shall be of weldable quality and compatible with the material of the container.

23.5 Manufacture

23.5.1 General

23.5.1.1

Attachments to the containers shall not be detrimental to the integrity of the containers. Welding or brazing of attachments to the containers shall be completed prior to all pressure tests.

23.5.1.2
Maximum service pressure for longitudinally or helically welded cylinders shall be 3.5 MPa.

23.5.1.3
Maximum service pressure for aluminum containers shall be 3.5 MPa.

23.5.2 Welded Seams
Welded seams shall be properly aligned and welded by a method that provides clean, uniform joints with adequate penetration. Welded seams shall have a strength equal to or greater than the minimum strength of the shell material in the completed container.

23.5.3 Brazed Seams

23.5.3.1
Brazed seams shall be assembled with proper fit to ensure complete penetration of the brazing material throughout the brazed joint. The minimum width of the brazed joint shall be at least 4 times the thickness of the shell wall. Brazed seams shall have a design strength equal to or greater than 1.5 times the minimum strength of the shell wall.

23.5.3.2
Brazing on aluminum containers shall be prohibited.

23.5.3.3
The brazing material shall have a melting point not lower than 540°C.

23.6 Flattening Test

23.6.1 Sample Selection
One representative sample from the beginning of the production of each lot shall be tested. All containers produced per shift (not exceeding 10 h) shall be counted as 1 lot. This test shall be performed on a container that has been tested at test pressure.

23.6.2 Cylinders
Either a completed cylinder or a ring taken from the cylinder shall be tested. The ring shall not include the heat-affected zone or any weld.

23.6.3 Spheres
A ring from the sphere shall be tested. The test ring may include the circumferential weld if it is located at a 45 ± 5° angle to the ring.

23.6.4 Steel Samples
Flattening to 6 times the wall thickness without cracking shall be required.

23.6.5 Aluminum Samples
Flattening to 10 times the wall thickness without cracking shall be required.

23.6.6 Rejection Criteria
If any sample fails the test, the entire lot represented shall be rejected.

23.7 Pressure Tests

23.7.1 Pneumatic Pressure Test

23.7.1.1

Each container shall be:
(a) proof tested pneumatically to its test pressure for at least 30 s. Containers that give evidence of distortion or other defects shall be condemned; and
(b) leak tested, at not less than service pressure, by submerging it in water or by another suitable method. Containers that leak shall be rejected.

23.7.1.2

The test pressure shall be the pressure of the contents at 55°C or 1.2 MPa, whichever is the greater.

23.7.2 Burst Test

23.7.2.1

One representative container taken from the first containers produced in each lot, plus 1 container from each 1000 successively produced containers within the lot, shall be tested hydrostatically to destruction. All containers produced per shift (not exceeding 10 h) shall be counted as 1 lot.

23.7.2.2

The entire lot shall be rejected if a failure occurs at a pressure less than 2 times the test pressure.

23.7.2.3

The entire lot shall be rejected if a failure initiates in a braze or a weld or in a heat-affected zone.

23.7.2.4

The entire lot shall be rejected if a failure occurs in any opening or reinforcement or at a point of attachment in a sphere.

23.7.2.5

A cylinder lot shall be acceptable only if the failure occurs in the cylindrical portion of the cylinder and is longitudinally oriented.

23.8 Rejected Containers

23.8.1

Where defective containers with determinable causes for failure can be removed from a lot by testing or inspection, the remaining containers may be considered as a new lot. Repairs by rewelding or rebrazing shall be permitted; however, such repaired containers shall pass the pressure test.

23.8.2

Where a cylinder made from seamless steel tubing fails the flattening test, each cylinder in the lot shall undergo a suitable uniform heat treatment. Cylinders shall then pass all specified tests.

23.9 Marking

23.9.1

Each cylinder shall be marked. Marks shall be durable and waterproof. Stamping shall not be required.

23.9.2

The marks may be limited to the following:
(a) TC39M;
(b) the letters "NRC" for nonrefillable containers;
(c) the service pressure, in bar;
(d) the test pressure, in bar;
(e) the manufacturer's registration number;
(f) the lot or serial number; and
(g) the date of manufacture, unless it is indicated by the lot or serial number.

23.9.3

The markings shall be at least 3 mm high, and the markings specified in Items (a) through (e) of Clause 23.9.2 shall be displayed sequentially.

24. Requalification, Reheat Treatment, Repair, and Rebuilding

24.1 General

24.1.1 Scope

Clause 24 covers the requalification by retesting and reinspection, the reheat treatment, the repair, and the rebuilding of used containers.

Notes:

(1) *The prefix of a specification designation on a container identifies the regulatory authority responsible at the time the container was manufactured. In Clause 24, an obsolete specification is referenced by a prefix identifying the last regulatory authority under which containers of that specification are believed to have been manufactured. The prefix represents also the previous Canadian regulatory authorities or the US regulatory authorities under which containers of the same specification may have been manufactured.*

(2) *The prefixes other than "TC" are as follows:*
(a) CRC: Canadian Railway Commission;
(b) BTC: Board of Transport Commissioners for Canada;
(c) CTC: Canadian Transport Commission;
(d) ICC: US Interstate Commerce Commission; and
(e) DOT: US Department of Transportation.

(3) *Containers bearing the prefix "ICC" or "DOT" are containers that were manufactured to a US specification. Many such containers have been in use in Canada for years. In Clause 24, a specification designation preceded by the letters "ICC" or "DOT" identifies a specification that has never been adopted in Canada.*

(4) *All "TC" specifications include the letter "M". The addition of the letter "M" to a specification indicates a metric specification. Containers to specifications not including the letter "M" were built using yard-pound units of measurement, with service pressure in pounds per square inch.*

24.1.2 Requirements

The requalification, the repair, and the rebuilding of containers shall be conducted in accordance with CGA Publications C-1, C-3, C-5, C-6, C-6.1, C-6.2, C-6.3, C-8, and C-13. Rejected containers shall be reinspected, retested, reheat-treated, repaired, or rebuilt before being returned to service.

Note: *Where air or other gases are allowed in testing, proper precautions should be taken to protect personnel.*

24.2 Requalification

24.2.1 General Requirements

24.2.1.1

Each cylinder, sphere, or tube shall be requalified periodically in accordance with the requirements of Clause 24.2 and Table 24.1, except as provided in Clauses 24.2.1.6 and 24.2.1.7. Table 24.1 specifies the basic requalification procedures and periods. It also specifies alternative requalification procedures and periods that may be used, depending on service conditions. Alternative requalification methods and periods are referenced to specific clauses for complete descriptions of conditions under which the alternative procedures may be used.

24.2.1.2

Hydrostatic retests with volumetric expansion measurements and proof pressure retests, as required by Table 24.1, shall be performed in accordance with Clause 4.12.1.

24.2.1.3

Containers subject to a hydrostatic retest with volumetric expansion measurement shall also be visually inspected both internally, inasmuch as the size of the orifice(s) permit(s), and externally, in accordance with CGA Publication C-6, C-6.1, C-6.2, or C-6.3. The permanent expansion shall not exceed 10% of the total expansion, except for

(a) TC-3ALM cylinders, where it shall not exceed 6%;
(b) TC-3FCM, TC-3HWM, and TC-3HTM cylinders, where it shall not exceed 5%; and
(c) TC-4EM and CTC-4E cylinders, where it shall not exceed 12%.

24.2.1.4

Containers subject to a proof pressure retest shall also be visually inspected externally, in accordance with CGA Publication C-6.

24.2.1.5

Containers exempt from a pressure retest under Clause 24.2.9 shall be subjected to an external visual inspection.

24.2.1.6

Containers with a capacity of 1.0 L water or less shall be exempt from periodic requalification.

24.2.1.7

Containers with a service pressure of 2.1 MPa or less and a capacity of 4.5 L of water or less, and built to a specification that requires periodic hydrostatic retest with a volumetric expansion measurement (see Table 24.1), shall be exempt from the volumetric expansion measurement when retested hydrostatically, but shall be examined while under the specified retest pressure and show no leakage or other defects.

24.2.1.8

In addition to the periodic retests, whenever there is a reason to believe that the pressure-retention integrity of a container has been adversely affected by severe dents, corrosion, excessive heat, or other damage, the container shall be emptied and requalified before refilling.

24.2.1.9

Reheat-treated and rebuilt containers shall be processed and requalified in accordance with the container specification before being returned to service; compliance shall be verified by an independent inspector. Containers repaired by welding or brazing shall be requalified before being returned to service.

24.2.1.10
A container that does not meet the requalification requirements shall be rejected or condemned. Rejected containers may be reheat-treated, repaired, or rebuilt only in accordance with Clause 24.

24.2.1.11
Containers, except those manufactured to TC-3ALM, CTC-3AL, TC-3FCM, TC-3HTM, CTC-3HT, TC-3HWM, TC-4EM, CTC-4E, TC-4LM, and CTC-4L specifications, may be heat-treated if they have been rejected for excessive permanent expansion or for exposure to excessive heat. TC- 4LM and CTC-4L cylinders exposed to excessive heat may be returned to service without retesting if the jacket and the vacuum remain intact. Aluminum and composite cylinders exposed to a temperature exceeding 175°C shall be condemned.

24.2.1.12
Containers that previously contained a corrosive liquid that, through its corrosive action, could affect the structural integrity of the container shall not be used for the transportation of any compressed gas, unless the container is retested in accordance with the requirements of the applicable specification. A container that contained a corrosive liquid for which decontamination methods cannot remove all significant residue or impregnation from the container shall not be used for the transportation of any compressed gas.

24.2.1.13
A cylinder in chlorine or sulphur dioxide service manufactured before April 20, 1915, shall be retested at 3.5 MPa.

24.2.2 Ten-Year Requalification Requirements

24.2.2.1
A TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, or TC-3ASM cylinder not exceeding 57 L of water capacity may be retested every 10 years only, provided that the cylinder complies with the following:
(a) if the cylinder is in a cluster, bank, group, or rack, it is removed from the cluster, bank, group, or rack each time it is filled;
(b) the cylinder is used exclusively for air, argon, ethylene, helium, hydrogen, krypton, neon, nitrogen, nitrous oxide, oxygen, xenon, and mixtures of these gases, without, or with up to 30% by volume of, carbon dioxide. These gases or mixtures shall have a dewpoint not exceeding –54°C at 101.325 kPa (absolute);
(c) prior to each refill, the cylinder is subjected to and passes the hammer test specified in CGA Publication C-6;
(d) the new hydrostatic test data of the cylinder meet one of the following requirements:
(i) the elastic expansion does not exceed the REE stamped on the cylinder at the time of manufacture;
(ii) the elastic expansion does not exceed the applicable rejection limit specified in Table 2 of CGA Publication C-5; or
(iii) either the average wall stress or the maximum wall stress does not exceed the corresponding wall stress limitation shown in Appendix B of CGA Publication C-5;
(e) the cylinder is stamped with a 5-pointed star following the last test or retest date;
(f) the cylinder is dried immediately following the hydrostatic retest to remove all traces of free water; and
(g) the cylinder is not used in a self-contained respirator or in a portable resuscitator.
Note: *Cylinders used in a self-contained respirator or in a portable resuscitator are to be retested, maintained, and inspected by a registered retester in accordance with the requirements of CSA Standard CAN/CSA-Z94.4.*

24.2.2.2
The retest period of a cylinder previously in compliance with Items (c), (d), (f), and (g) of Clause 24.2.2.1, but not in compliance with Item (b) of Clause 24.2.2.1, may be changed to a 10-year retest period only after the cylinder has been retested and confined to a gas service in compliance with Item (b) of Clause 24.2.2.1.

24.2.2.3
If, at any time, a cylinder marked with the star is used in a manner other than that specified in Clause 24.2.2.1, the star following the most recent test or retest date shall be obliterated by peening. Subsequent retests shall be conducted every 5 years.

24.2.3 Cylinders with a Service Pressure of 2.1 MPa or Less in Nonflammable Liquid or Mixtures of Nonflammable Liquids and Nonflammable, Nonliquefied Compressed Gases in Noncorrosive Service
A TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, TC-3ANM, TC-3ASM, CTC-3B, or CTC-3BN cylinder used exclusively for nonflammable liquids or mixtures of nonflammable liquids and nonflammable, nonliquefied compressed gases in noncorrosive service may be retested every 10 years. The cylinder shall have a service pressure of 2.1 MPa or less and, except for TC-3ASM cylinders, be protected externally by a suitable corrosion-resistant coating, such as, but not limited to, paint, and internally by an equally corrosion-resistant lining. Each test shall be supplemented by a visual internal and external inspection, in accordance with CGA Publication C-6, at least once every 5 years.

24.2.4 Containers Used for Fire Extinguishers
A TC-4BM, CTC-4B, TC-4BAM, CTC-4BA, TC-4BWM, CTC-4BW, TC-4BM17ET, CTC-4B240ET, CTC-4B24OFLW, TC-4EM, or CTC-4E container used for noncorrosive liquefied or nonliquefied compressed gases or mixtures of same and any noncorrosive fire-extinguishing agent may be hydrostatically retested with volumetric expansion measurement every 12 years. The container shall be protected externally by a suitable corrosion-resistant coating, such as, but not limited to, paint. Alternatively, the same containers may be proof pressure retested every 7 years.

24.2.5 Containers Used for Reclaiming, Recycling, or Recovering Refrigerant Gases
Containers used for reclaiming, recycling, or recovering refrigerant gases shall be requalified in accordance with the basic requirements of Clause 24.2.1. Reclaimed, recycled, or recovered refrigerant gases are considered to be corrosive due to contamination.

24.2.6 TC-3HTM and CTC-3HT Cylinders

24.2.6.1
In addition to the visual inspection requirements, TC-3HTM and CTC-3HT cylinders shall be requalified in accordance with CGA Publication C-8 and shall conform with the requirements of Clauses 24.2.6.2 to 24.2.6.5.

24.2.6.2
A cylinder shall not be returned to service if the elastic expansion at retest exceeds the original elastic expansion by more than 5% or the rejection elastic expansion limit (REE) marked on the cylinder.

24.2.6.3
A cylinder shall not be requalified at the termination of a 24-year period following the date of the

original test or after 4380 pressurizations, whichever occurs first. If a cylinder is refilled more than an average of once every other day, an accurate record of the number of refillings shall be maintained.

24.2.6.4

Retest markings shall be applied by low-stress-type steel stamping to a depth no greater than that of the original marking at the time of manufacture. Stamping on the sidewall shall be prohibited.

24.2.6.5

When a cylinder not marked with a rejection elastic expansion (REE) is retested, it shall be stamped with the REE in millilitres near the existing marked original elastic expansion. The REE for a cylinder shall be 1.05 times its original elastic expansion.

24.2.7 TC-3FCM and TC-3HWM Cylinders

TC-3FCM and TC-3HWM cylinders shall be condemned at the termination of a 15-year period following the date of the original test.

24.2.8 Series-8 Cylinders

Series-8 cylinders shall be retested and reinspected in accordance with CGA Publication C-13.

24.2.9 Requalification by Visual Reinspection Only

24.2.9.1

The containers identified in Clause 24.2.9.3 and used exclusively for the corresponding services indicated therein may be periodically requalified by external visual reinspection without pressure retesting.

Visual reinspections shall be performed in accordance with CGA Publication C-6, C-6.1, or C-6.3, as applicable.

24.2.9.2

The requalification period for containers requalified by external visual reinspection as specified in Clause 24.2.9.1 shall be 5 years. An extension to 10 years shall be acceptable, provided the container is confined to a service in compliance with the following:

(a) the lading is a liquefied gas;

(b) the LC_{50} of the lading, by reason of toxicity, is not less than 5000 mL/m^3;

(c) the LC_{50} of the lading, by reason of a corrosion effect on tissues of the respiratory tract, is not less than 5000 mL/m^3; and

(d) contamination of the lading by water does not make the lading corrosive to the metals of containment.

Note: *LC_{50} is defined in the Transportation of Dangerous Goods Regulations.*

24.2.9.3

The visual inspection in lieu of the hydrostatic retest may be used on the following containers:

(a) TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, CTC-3B, TC-3ANM, CTC-3A480X, CTC-3BN, TC-4AAM33, CTC-4AA480, TC-4BM, CTC-4B, TC-4BAM, CTC-4BA, TC-4BWM, CTC-4BW, CTC-4B240FLW, TC-4BM17ET, CTC-4B240ET, TC-4EM, and CTC-4E containers used to transport a liquefied or nonliquefied noncorrosive gas that requires a marked service pressure not exceeding 3.5 MPa;

(b) ICC-3, TC-3AM, CTC-3A, TC-3AAM, CTC-3AA, CTC-3B, TC-4BM, CTC-4B, TC-4BAM, CTC-4BA, TC-4BWM, and CTC-4BW containers used exclusively to transport hydrogen fluoride, anhydrous. TC-4BM, CTC-4B, TC-4BAM, and CTC-4BA cylinders shall be of welded construction only. All cylinders shall be cleaned to bare metal before reinspection;

(c) TC-4BM, CTC-4B, TC-4BAM, CTC-4BA containers of welded construction only, and TC-4BWM and CTC-4BW cylinders used to transport ethyleneimine, inhibited;

(d) steel or nickel cylinders used to transport nickel carbonyl; and
(e) cylinders used to transport flammable or corrosive liquids without addition of compressed gas.

24.3 Reheat Treatment

24.3.1
Prior to reheat treatment, each container shall be inspected internally and externally in accordance with CGA Publication C-6.

24.3.2
Containers shall be segregated in lots (see Clause 2) for reheat treatment. Data from the original Certificate of Compliance of the manufacture of the containers shall be available.

24.3.3
The reheat treatment and inspection shall be performed in accordance with the specification of the containers, except as provided in Clause 24.3.4.

24.3.4
A hydrostatic retest shall be performed on each container in the lot after reheat treatment, in accordance with the requirements for the hydrostatic test of the container specification. Where a specification requires a volumetric expansion measurement for each container in the lot, any container with a permanent expansion greater than 10% shall be rejected. The lot size shall be reduced accordingly. The remaining containers in the lot shall be acceptable only if one of the following requirements is met:
(a) Where the permanent expansion of the containers in the lot ranges from 0 to 10% of the total expansion, the container with the lowest permanent expansion shall be subjected to and meet the requirements of the tensile and flattening tests in accordance with the specification. The results of the tensile and flattening tests shall be reported.
(b) Where the permanent expansion of all the containers in the lot ranges from 3 to 10% of the total expansion, no further tests are required. To achieve this result, the hydrostatic retest pressure may be increased to 115% of the specified retest pressure. A retest pressure higher than 115% of the specified retest pressure may be used with the specific approval of an independent inspector.

24.4 Repair

24.4.1 General Requirements

24.4.1.1
Any repair shall be made in accordance with the following:
(a) The repair and the inspection of the repair shall be made in accordance with the requirements of the container specification.
(b) The repairer shall have all pertinent information regarding the procedure, equipment, and filler metal or brazing material used during manufacture and shall use a similar method for repair.
(c) Welding shall be limited to fusion welding.
(d) Welding or brazing shall be performed on an area free from contaminants.
(e) A defect, such as porosity in a pressure-retaining seam, shall be completely removed before rewelding. Puddling may be used to remove such a defect.

24.4.1.2
After removal of a nonpressure attachment and before its replacement, the container shall be inspected in accordance with CGA Publication C-6.

24.4.1.3
Reheat treatment of a container after repair shall not be required.

24.4.2 Additional Requirements for TC-4LM and CTC-4L Cylinders

24.4.2.1
Repairs to a TC-4LM and CTC-4L cylinder shall be limited to the following:
(a) the removal of either end of the insulation jacket to permit access to the cylinder, piping system, or neck tube;
(b) the replacement of the neck tube only when
(i) a 13 mm piece of the original neck tube protruding above the top end and the original weld attaching the neck tube to the cylinder are sound; and
(ii) the replacement neck tube is welded to the remaining 13 mm piece of the original neck tube;
(c) the replacement of material such as, but not limited to, the insulating material and the piping system within the insulation space. Any material used as replacement material shall be identical to that used in the original manufacture; and
(d) other welding or brazing procedures not excluded by the definition of a rebuilt container, except weld repair on the cylinder.

24.4.2.2
After repair the cylinder shall be
(a) tested to its service pressure;
(b) leak-tested before and after reassembly of the insulation jacket, using a helium mass spectrometer; and
(c) tested for heat conductivity requirements.

24.4.3 Additional Requirements for Series-8 Cylinders

24.4.3.1
Repairs to a series-8 cylinder shall be made only on a cylinder that has been drained of acetylene to atmospheric pressure.

24.4.3.2
After repair the cylinder shall be proof pressure-tested at service pressure with dry nitrogen. As an alternative, this test may be performed on the initial refill at the terminal pressure of the refill.

24.5 Rebuilding

24.5.1 General Requirements

24.5.1.1
Welding or brazing shall be made in accordance with the following:
(a) The rebuilding and the inspection of the rebuilt container shall be in accordance with the requirements of the container specification.
(b) The rebuilder shall have all pertinent information regarding the procedure, equipment, and filler metal or brazing material used during manufacture and shall use a similar method for rebuilding.
(c) Welding shall be limited to fusion welding.
(d) Welding or brazing shall be performed on an area free from contaminants.
(e) A defect, such as porosity in a pressure-retaining seam, shall be completely removed before rewelding. Puddling may be used to remove such a defect.

24.5.1.2
After removal of a nonpressure attachment and before its replacement, the containers shall be inspected in accordance with CGA Publication C-6.

24.5.1.3
Containers with a pressure-retaining brazed seam other than for the attachment of a head or a part on a head shall not be rebuilt.

24.5.1.4
New material used for rebuilding shall be in conformance to the material requirements of the applicable specification, including chemical composition, verification of analysis, inspection, and tensile test.

24.5.1.5
Except as otherwise provided, reheat treatment of containers after rebuilding shall be performed in accordance with the applicable specification.

24.5.2 Series-4 Containers, except TC-4LM and CTC-4L Cylinders

24.5.2.1
Replacement of an end marked with the original container specification shall be prohibited.

24.5.2.2
After reheat treatment, requalification shall be conducted by hydrostatic testing as follows:
(a) when complete material identification of the rebuilt containers is unknown, each container in the lot shall be hydrostatically tested individually, with volumetric expansion measurement, at the test pressure specified in the applicable specification; and
(b) when complete material identification of the rebuilt containers is known, the lot shall be tested in accordance with the requirements of the applicable specification.

24.5.3 TC-4LM and CTC-4L Cylinders

24.5.3.1
The rebuilding shall be limited to, in addition to the operations permitted under repair (see Clause 24.4.2.1),
(a) substituting or adding any material in the insulation space not identical to that used in the original manufacture of that cylinder;
(b) making a weld repair not exceeding 150 mm in length on the longitudinal seam of the cylinder or 300 mm in length on a circumferential weld joint of the cylinder; and
(c) replacing the outer jacket.

24.5.3.2
Heat treatment of cylinders shall be prohibited.

24.5.3.3
After rebuilding, each cylinder shall be proof-tested at 2 times its service pressure. Each cylinder and its vacuum insulation jacket shall be leak-tested on the inner container and leak-tested again after complete assembly, using a helium mass spectrometer.

24.5.4 Series-8 Cylinders

24.5.4.1

The rebuilding shall be limited to
(a) the removal and replacement of the porous mass;
(b) the removal and replacement of one or more pressure-retaining parts attached by welding and not marked with the original specification markings;
(c) the removal and replacement of any non-pressure-retaining attachment by welding or brazing; and
(d) the removal and repair of any defect in a pressure-retaining welded seam.

24.5.4.2

Where cylinder rebuilding is limited to porous mass replacement without any welding, all the cylinders in the lot shall be proof pressure-tested to the range of 3.5 to 4.1 MPa, after the shells have been emptied. Reheat treatment shall not be required.

24.5.4.3

Where the cylinder rebuilding involves welding operations, the welding operations shall be performed only after the porous mass has been removed. All the shells in the lot after heat treatment shall be hydrostatically tested as follows:
(a) where complete material identification of the rebuilt shells is unknown, each shell in the lot shall be hydrostatically tested individually, with volumetric expansion measurement, at 5.2 MPa; and
(b) where complete material identification of the rebuilt shells is known, the lot shall be tested in accordance with the requirements of the specification.

24.6 Marking

24.6.1 General

24.6.1.1

Following requalification, each container shall be plainly and permanently marked by stamping, in accordance with Clauses 24.6.2, 24.6.3, and 24.6.4,
(a) into the metal of the container, as permitted by the applicable specification;
(b) into the existing attached plate; or
(c) into a new metal plate, as permitted by the applicable specification.
The size of the marks shall be in accordance with Clause 4.17.5.

24.6.1.2

Subject to Clause 24.6.4, obliteration of the dates of previous tests or retests shall be prohibited.

24.6.2 Metal Plate

The marking on a new metal plate shall use any one or any combination of the following methods:
(a) embossing, including raised or indented characters;
(b) metal stamping;
(c) engraving; or
(d) any other method producing a permanent, legible marking and involving removal or addition of metal, except by heating of any kind.

24.6.3 Marking Information

24.6.3.1

The marking arrangement shall be as follows:

A B C D E
where
A = month of requalification (two digits), followed by a space
B = requalifier's or, where applicable, independent inspector's registered mark (indicated by XY in Clause 24.6.3.2), followed by a space
C = year of requalification (last two digits only)
D = procedure symbol (Δ, ★, □, **E, R, RB, RH, S,** or **FS**), followed by a space
E = repairer's (if different from requalifier), rebuilder's, or reheat treater's registered mark (indicated by WZ — see Clause 24.6.3.2).

24.6.3.2

The marking information after requalification shall be as follows:

		A	B	C	D	E
(a)	for a 3- or 5-year hydrostatic retest with volumetric expansion measurement	08	XY	94		
(b)	for a 7-year proof pressure retest	08	XY	94	Δ	
(c)	for a 10-year hydrostatic retest with volumetric expansion measurement	08	XY	94	★	
(d)	for a 10-year proof pressure retest	08	XY	94	♦	
(e)	for a 12-year hydrostatic retest with volumetric expansion measurement	08	XY	94	□	
(f)	for a visual reinspection	08	XY	94	E	
(g)	for requalification after a repair procedure	08	XY	94	R	WZ
(h)	for requalification after a rebuilding procedure	08	XY	94	RB	WZ
(i)	for requalification after reheat treatment only	08	XY	94	RH	WZ
(j)	for series-8 cylinder shell reinspection only	08	XY	94	S	
(k)	for series-8 cylinder shell and porous filler reinspection	08	XY	94	FS	

24.6.3.3

In addition to the marks required under Item (a) or (c) of Clause 24.6.3.2, a CTC-3A, CTC-3AA, CTC-3AX, CTC-3AAX, or DOT-3T container that meets the elastic expansion requirements of CGA Publication C-5 shall be marked with a + sign, immediately following the requalification date.

24.6.3.4

In addition to the marks required under Item (a) or (c) of Clause 24.6.3.2, a TC-3AM, TC-3AAM, TC-3AXM, TC-3AAXM, TC-3ASM, or TC-3TM container for which the elastic expansion exceeds the REE stamped on the cylinder at the time of manufacture or the applicable rejection limit specified in Table 2 of CGA Publication C-5, or for which the average or maximum wall stress exceeds the corresponding limitation in Appendix B of CGA Publication C-5, shall be marked with the letter "K", immediately following the service pressure marking.

24.6.3.5

In addition to the marks required in Item (k) of Clause 24.6.3.2, series-8 cylinders with nonmonolithic filler material shall be marked with the letter "N" after the original manufacturing date, eg, 04 ABC 72 N, the first time they are requalified after January 1993.

24.6.3.6
A container manufactured under a permit (or exemption) and for which a new specification has been adopted shall have its original marking maintained. The new specification marking shall be placed in proximity to the original marking before, or the first time the container is requalified after, the new specification becomes effective.

24.6.3.7
After requalification, if it is found that the tare of the container has changed by more than 1% from that marked on the container, the original tare shall be peened out, and the actual tare shall be stamped in accordance with the requirements of Clause 4.17 and the applicable specification.

24.6.3.8
When a cylinder is required to be condemned, the specification designation and service pressure markings shall be removed (eg, by peening out or stamping over with a series of Xs), or the word "CONDEMNED" shall be permanently and legibly stamped on the shoulder, top end, or neck.

24.6.4 Marking Maintenance

24.6.4.1
Except as provided in Clause 24.6.4.4, any marking becoming illegible shall be remarked on the container or reproduced on a metal plate permanently secured to the cylinder or any permanent part of the upper end of the container, excluding the sidewall.

24.6.4.2
Where attached to a nonpressure part of the container, the metal plate shall be attached by a permanent method such as, but not limited to, riveting, welding, spot welding, or brazing.

24.6.4.3
Where the metal plate is attached to a pressure-retaining part of a container, it shall be welded or brazed, as permitted in the applicable specification. The container shall be considered as a repaired or rebuilt container and further processed accordingly.

24.6.4.4
Where the space originally provided for marking requalification dates becomes filled, the expired requalification dates, except the last one, may be removed by peening, provided that
(a) permission to do so has been obtained from the owner of the container;
(b) the design minimum wall thickness is maintained; and
(c) the original manufacturing test date is not removed.

24.7 Reporting

24.7.1 Requalification
Each requalification shall be recorded on a report form by the person performing the requalification. Typical report forms are shown in
(a) Appendix E of CGA Publication C-1, for a requalification hydrostatic test;
(b) Appendix A of CGA Publication C-6, for a requalification by visual inspection only; and
(c) Appendix B of CGA Publication C-13, for requalification of series-8 cylinders.

24.7.2 Repair
Each repair by welding or brazing shall be recorded as an addition to the reports prepared in accordance with Clause 24.7.1. The repair procedure shall be reported in writing and, if necessary, by a sketch or sketches.

24.7.3 Reheat Treatment and Rebuilding

Reheat treatment, rebuilding, and related inspection shall be reported in writing and, if necessary, by a sketch or sketches. The report shall be in accordance with the applicable requirements of the container specification and Clause 24.

25. Registration

25.1 General

25.1.1

Clause 25 covers the registration requirements to manufacture, requalify, repair, reheat treat, rebuild, and inspect cylinders, spheres, and tubes (containers).

25.1.2

Applications for registration shall be submitted by registered mail to the Director.

25.2 Registration of Manufacturers of Containers

25.2.1 Initial Registration

25.2.1.1

A certificate of registration to manufacture containers of a new design shall be obtained from the Director prior to the release of such containers for the transportation of dangerous goods.

25.2.1.2

The following information shall be submitted in the application for registration:
(a) the name, address, and telephone number of the applicant;
(b) container drawings, the specification designations, and the design calculations;
(c) a manual detailing quality control, testing, and inspection procedures;
(d) the description of the manufacturing and testing facilities;
(e) the description of the manufacturing processes; and
(f) the name and address of the independent inspector to be employed.

25.2.1.3

Qualification tests for each new design (see Clause 4.13) shall be performed on 6 representative containers selected by the independent inspector from an initial production lot. The qualification tests shall be performed at a test facility approved by the Director.

Notes:

(1) *Additional qualification tests may be required by the Director.*

(2) *Upon verification by the Director of compliance of the application documentation with the requirements of this Standard, arrangements may be made for facility inspections by an officer of the Transport Dangerous Goods Directorate, Transport Canada.*

(3) *Upon satisfactory results of the inspection(s) of facilities and of the new design qualification tests, the Director may issue the certificate of registration.*

25.2.2 Renewal of Certificate of Registration

25.2.2.1

A certificate of registration is valid for 5 years, unless it is revoked by the Director.

Note: *A certificate of registration may be revoked by the Director, if the Director determines that the holder of the certificate of registration has not complied with or is not capable of consistently complying with the applicable requirements of this Standard.*

25.2.2.2

Application for the renewal of a certificate of registration is required no later than 5 years from the date of issue of the previous certificate. An application for renewal of a certificate of registration shall include information required in Clause 25.2.1.2. Container qualification tests are not required if the application does not include new designs.

Note: *Only changes to the information provided in the original application pursuant to Clause 25.2.1.2 are required. If no changes have occurred, a statement to that effect should be made in the application for renewal.*

25.2.2.3

A certificate of registration shall remain valid beyond 5 years if, following a bona fide application for renewal of registration by registered mail, made prior to the expiry date, a new certificate is not issued and the certificate due to expire is not revoked by the Director.

Notes:

(1) *Upon verification by the Director of compliance of the application documentation with the requirements of this Standard, arrangements may be made for facility inspections by an officer of the Transport Dangerous Goods Directorate, Transport Canada.*

(2) *Upon satisfactory inspection of facilities, the Director may issue the new certificate of registration.*

25.3 Registration for Requalification, Repair, Reheat Treatment, and Rebuilding of Used Containers

25.3.1 Manufacturers

Manufacturers holding a certificate of registration are authorized to requalify, repair, reheat treat, and rebuild containers of the specification designations listed on their certificate of registration.

25.3.2 Nonmanufacturers: Initial Registration

A certificate of registration shall be obtained from the Director prior to requalifying, repairing, reheat treating, or rebuilding used containers. The following information shall be submitted in the application for registration:

(a) the name, address, and telephone number of the applicant;
(b) the listing of the container specifications and the scope of work covered by the application;
(c) the applicable quality control procedures;
(d) the description of processes and testing facilities;
(e) training, qualifications, and experience that would enable the applicant to perform inspections and tests required by this Standard; and
(f) the name and address of the independent inspector to be employed, where applicable.

Notes:

(1) *Upon verification by the Director of compliance of the application documentation with the requirements of this Standard, arrangements may be made for facility inspections by an officer of the Transport Dangerous Goods Directorate, Transport Canada.*

(2) *Upon satisfactory inspection of facilities, the Director may issue the Certificate of Registration.*

(3) *Provincial jurisdiction may require additional certifications.*

25.3.3 Nonmanufacturers: Renewal of Certificate of Registration

25.3.3.1

A certificate of registration is valid for 5 years unless it is revoked by the Director.

Note: *A certificate of registration may be revoked by the Director, if the Director determines that the holder of the certificate of registration has not complied with or is not capable of consistently complying with the applicable requirements of this Standard.*

25.3.3.2

Application for the renewal of a certificate of registration is required no later than 5 years from the date of issue of the previous certificate. An application for renewal of a certificate of registration shall include information required in Clause 25.3.2.

Note: *Only changes to the information provided in the original application pursuant to Clause 25.3.2 are required. If no changes have occurred, a statement to that effect should be made in the application for renewal.*

25.3.3.3

A certificate of registration shall remain valid beyond 5 years if, following a bona fide application for renewal of registration by registered mail, made prior to the expiry date, a new certificate is not issued and the certificate due to expire is not revoked by the Director.

Notes:

(1) *Upon verification by the Director of compliance of the application documentation with the requirements of this Standard, arrangements may be made for facility inspections by an officer of the Transport Dangerous Goods Directorate, Transport Canada.*

(2) *Upon satisfactory inspection of facilities, the Director may issue the new certificate of registration.*

(3) *Provincial jurisdiction may require additional certifications.*

25.4 Registration of Independent Inspectors

25.4.1 Initial Registration

25.4.1.1

A certificate of registration shall be obtained from the Director prior to inspecting, testing, and certifying new, reheat-treated, or rebuilt used containers.

The following information shall be submitted in the application for registration:

(a) name, address, telephone number, and principal business activity of the applicant;
(b) name and address of each facility where tests and inspections are to be performed;
(c) listing of container specifications applied for;
(d) detailed description of the inspection and testing facilities;
(e) qualifications and experience of the applicant that would enable the applicant to perform inspections and tests required by this Standard; and
(f) experience and qualification of independent inspector's staff.

25.4.1.2

The applicant for the certificate of registration shall not be directly or indirectly controlled by any person or firm that manufactures, reheat treats, or rebuilds containers.

Note: *Upon acceptance of suitability of personal qualifications and experience of the applicant and the inspection personnel and verification of suitability of testing facilities, the Director may issue a certificate of registration.*

25.4.2 Renewal of Certificate of Registration

25.4.2.1

A certificate of registration is valid for 5 years unless it is revoked by the Director.

Note: *A certificate of registration may be revoked by the Director, if the Director determines that the holder of the certificate of registration has not complied with or is not capable of consistently complying with the applicable requirements of this Standard.*

25.4.2.2

Application for the renewal of a certificate of registration is required no later than 5 years from the date of issue of the previous certificate. An application for renewal of a certificate of registration shall include information required in Clause 25.4.1.1.

Notes:

(1) *Only changes to the information provided in the original application pursuant to Clause 25.4.1.1 are required. If no changes have occurred, a statement to that effect should be made in the application for renewal.*

(2) *Upon verification and acceptance of application documentation, the Director may issue the new certificate of registration.*

25.4.2.3

A certificate of registration shall remain valid beyond 5 years, if following a bona fide application for renewal of registration by registered mail, made prior to the expiry date, a new certificate is not issued and the certificate due to expire is not revoked by the Director.

25.5 Addenda to Certificates of Registration

25.5.1

Application for an addendum to a certificate of registration to amend the scope of the certificate shall be submitted to the Director by a certificate holder.

25.5.2

A change in scope is any change that requires updating the information previously submitted to the Director for the purpose of obtaining a certificate. In the case of the independent inspector, this includes changes in the independent inspector's staff and qualifications.

25.5.3

The application shall include the following information:
(a) the name and address of the applicant (new and former name and addresses, where applicable);
(b) the certificate of registration number and expiry date; and
(c) the reason for the request, such as new container design, change in process, replacement of equipment, etc.

Note: *Subject to satisfactory review of submitted information, the Director may issue an addendum to a certificate of registration.*

Table 1.1
Designation and Description of Seamless Cylinders and Tubes

(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity or size	Service pressure MPa
TC-3AAM	Seamless alloy steel cylinders	450 L max.	1.0 min
TC-3AAXM	Seamless alloy steel tubes	> 450 L	12.4 min
TC-3ALM	Seamless aluminum alloy cylinders	450 L max	1.0 min
TC-3AM	Seamless carbon steel or manganese steel cylinders	450 L max	1.0 min
TC-3ANM	Seamless nickel cylinders	68 L max	1.0 min 3.5 max
TC-3ASM	Seamless austenitic stainless steel cylinders	450 L max	1.0 min
TC-3AXM	Seamless manganese steel tubes	> 450 L	12.4 min
TC-3EM	Seamless steel cylinders	51 mm OD nom. max < 610 mm in length	12.4
TC-3HTM	Seamless alloy steel cylinders for aircraft use	68 L max	6.2 min
TC-3TM	Seamless alloy steel tubes	> 450 L	12.4 min

Table 1.2
Designation and Description of Welded Cylinders and Spheres*

(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity	Service pressure, MPa
TC-4AAM33	Welded carbon or HSLA† steel cylinders without longitudinal seam	450 L max	3.3
TC-4BM	Welded or brazed carbon steel cylinders; longitudinal forge lap-welded or brazed seam permitted	450 L max	1.0 min 3.5 max
TC-4BM17ET	Brazed or spun carbon steel cylinders made from electric-resistance-welded tubing	5.5 L max	1.7
TC-4BAM	Welded or brazed carbon or HSLA† steel cylinders or spheres; longitudinal brazed seam permitted in cylinders	450 L max	1.5 min 3.5 max
TC-4BWM	Welded carbon or HSLA† steel cylinders with a longitudinal electric-arc-welded seam	450 L max	1.5 min 3.5 max
TC-4DM	Welded carbon, alloy, or stainless steel spheres or cylinders	45.4 L max	2.1 min 3.5 max
TC-4DAM	Welded alloy steel spheres or cylinders	45.4 L max	3.5 min 6.2 max
TC-4DSM	Welded stainless steel spheres or cylinders	45.4 L max	3.5 min 6.2 max
TC-4EM	Welded aluminum cylinders with one circumferential seam	450 L max	1.5 min 3.5 max

**This listing excludes nonrefillable containers and containers with porous fillers.*
†*High-strength low-alloy.*

Table 1.3
Designation and Description of Nonrefillable Containers

(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity	Service pressure, MPa
TC-39M	Nonrefillable, seamless or welded carbon steel or aluminum, or brazed carbon steel, spheres or cylinders	4.54 L max	None specified
		Over 4.54 L to 25 L max	3.5 max

Table 1.4
Designation and Description of Composite Cylinders
(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity	Service pressure, MPa
TC-3FCM	Fully wrapped composite cylinders	91 L max	6.2 min 34.5 max
TC-3HWM	Hoop-wrapped composite cylinders	91 L max	6.2 min 34.5 max

Table 1.5
Designation and Description of Insulated Cylinders
(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity	Service pressure, MPa
TC-4LM	Stainless steel fusion-welded cylinders insulated and contained within an outer protective metal jacket	450 L max	0.3 min 3.5 max

Table 1.6
Designation and Description of Cylinders for Acetylene Service
(See Clause 1.2.2.)

Specification designation No.	General description	Water capacity	Service pressure, MPa
TC-8WM	Welded carbon steel cylinders with porous filler; welded longitudinal body seam permitted	None specified	1.7
TC-8WAM	Welded HSLA* steel cylinders with porous filler; welded longitudinal body seam permitted	None specified	1.7

**High-strength low-alloy.*

Table 5.1
Chemical Composition Requirements for Steel and Nickel

(See Clauses 5.2.2, 5.2.3, 5.2.4, 5.2.5, 6.2.2, 6.2.3, 8.2.2, 10.2.1, 11.2.1, and 18.2.1.)

Mass %

Grade	Type of material	Carbon		Manganese		Phosphorus	Sulphur	Silicon		Chromium		Molybdenum		Nickel		Boron		Iron	Other requirements*
		Min	Max	Min	Max	Max	Max	Min	Max	Min	Max.	Min	Max	Min	Max	Min	Max		
A	Carbon steel	0.10	0.35	—	0.90	0.035	0.025	—	—	—	—	—	—	—	—			Bal.	1, 4
B	Carbon manganese steel	0.25	0.50	—	1.75	0.035	0.025	—	—	—	—	—	—	—	—	—	—	Bal.	2
C	Intermediate manganese steel	0.25	0.40	1.35	1.65	0.035	0.025	0.10	0.30	—	—	—	—	—	—	—	—	Bal.	2
D	Chrom-Moly steel, Non standard 4130	0.25	0.35	0.40	0.90	0.035	0.025	0.15	0.35	0.80	1.10	0.15	0.25	—	—	—	—	Bal.	2, 5
E	Carbon Boron steel	0.27	0.37	0.80	1.40	0.035	0.025	—	0.30	—	—	—	—	—	—	0.0005	0.003	Bal.	2
F	Chrom-Moly steel (4130)‡	0.28	0.33	0.40	0.60	0.035	0.025	0.15	0.35	0.80	1.10	0.15	0.25	—	—	—	—	Bal.	2, 5
G	Chrom-Moly steel (ASTM A 372 Type VIII)‡	0.35	0.50	0.75	1.05	0.035	0.025	0.15	0.35	0.80	1.15	0.15	0.25	—	—	—	—	Bal.	2, 5
H	Stainless steel	—	0.08	—	2.00	0.035	0.030	—	1.00	16.0	20.0	2.0†	3.0	8.0	15.0	—	—	Bal.	—
I	Nickel	—	—	—	—	—	—		—	—	—	—	—	99.0	—	—	—	—	3

**Other requirements:*

(1) *Forging or drawing quality steel required; rimmed steel not allowed.*

(2) *Forging or drawing quality steel required, produced to predominantly fine-grain practice.*

(3) *Product analysis.*

(4) *Allowed only for cylinders with service pressure less than* 6.9 MPa.

(5) *Small quantities of elements that are not specified or required may be found in alloy steels. These elements are to be considered incidental and are acceptable to the following maximum amounts: copper to 0.35%; nickel to 0.25%.*

†*This minimum applies only to Type 316 stainless steel.*

‡*Maximum permitted sulphur content is lower than that allowed by standard reference tables.*

Table 5.2
Product Analysis Tolerances for Steel Grades A to G in Table 5.1

(See Clauses 5.2.2, 5.2.5, 6.2.2, 6.2.3, 10.2.1, 11.2.1, and 18.2.1.)

Element	Limit or specified range, mass %	Tolerance, mass %	
		Under minimum limit	Over maximum limit
Carbon	To 0.15 incl.	0.02	0.03
	Over 0.15 to 0.50 incl.	0.03	0.04
Manganese	To 0.60 incl.	0.03	0.03
	Over 0.60 to 1.15 incl.	0.04	0.04
	Over 1.15 to 2.50 incl.	0.05	0.05
Phosphorus	All ranges, except product analysis not required for rephosphorized steels		0.01
Sulphur	All ranges		0.01
Silicon	To 0.35 incl.	0.02	0.03
Chromium	To 0.90 incl.	0.03	0.03
	Over 0.90 to 2.10 incl.	0.05	0.05
	For Grade G: 0.80 to 1.15	0.05	0.05
Molybdenum	To 0.20 incl.	0.01	0.01
	Over 0.20 to 0.40 incl.	0.02	0.02
	For Grade G: 0.15 to 0.25 incl.	0.02	0.02

Table 5.3
Product Analysis Tolerances for Stainless Steel Grade H in Table 5.1

(See Clauses 5.2.4 and 8.2.2.)

Element	Limit or specified range, mass %	Tolerance, mass %	
		Under minimum limit	Over maximum limit
Carbon	To 0.15 incl.	0.01	0.01
Manganese	To 0.60 incl	0.03	0.03
	Over 1.15 to 2.50 incl.	0.05	0.05
Phosphorus	All ranges		0.01
Sulphur	All ranges		0.01
Silicon	To 0.30 incl.	0.02	0.03
	Over 0.30 to 1.00 incl.	0.05	0.05
Nickel	Over 5.30 to 10.00 incl.	0.10	0.10
	Over 10.00 to 15.00 incl.	0.15	0.15
Chromium	To 0.90 incl.	0.03	0.03
	Over 0.90 to 2.10 incl.	0.05	0.05
	Over 15.00 to 20.00 incl.	0.20	0.20
Molybdenum	To 0.20 incl.	0.01	0.01
	Over 0.20 to 0.40 incl.	0.02	0.02
	Over 1.75 to 3.00 incl	0.10	0.10

Table 7.1
Chemical Composition Requirements* for Aluminum Alloys
(See Clauses 7.2.1 and 9.2.1.)

Aluminum alloy designation	Mass %										Other†		
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Each	Total	Al
6010	0.80–1.20	0.50 max	0.15–0.60	0.20–0.80	0.60–1.00	0.10 max	0.25 max	0.10 max	0.01 max	0.01 max	0.05 max	0.15 max	remainder
6061	0.40–0.80	0.70 max	0.15–0.40	0.15 max	0.80–1.20	0.04–0.35	0.25 max	0.15 max	0.01 max	0.01 max	0.05 max	0.15 max	remainder

**ASTM Standard B 221.*

†Analysis is regularly made only for the elements for which specific limits are shown. If, however, the presence of other elements is suspected, or in the course of routine analysis is indicated to be in excess of specified limits, further analysis shall be made to determine that these other elements are not in excess of the amount specified.

Table 7.2
Specified Mechanical Properties for Aluminum Alloys for Seamless and Composite Cylinders

(See Clauses 7.8.2 and 9.9.2.)

Alloy and temper	Tensile strength, MPa		Elongation, % min. for Type A or D specimen
	Ultimate, minimum	Yield, minimum	
6010-T6(2)	290	255	14(1)
6061-T6	262	241	14(1)

Notes:

(1) *10% elongation is permitted when using a Type C specimen.*

(2) *Sheet metal in a thickness range of* 0.5 *to* 6.4 mm.

Table 7.3
Flattening Knife-Edge Radius for Aluminum Alloys

(See Clause 7.9.2.)

Wall thickness, mm	Flattening knife-edge radius, maximum mm
Under 3.81	12.7
3.81 to 6.34	22.2
6.35 to 8.88	38.1
8.89 to 11.42	54.0
11.43 to 13.96	69.9
13.97 to 16.50	88.9
16.51 to 19.04	104.8

Table 8.1
Chemical Composition Requirements for Carbon Steel

(See Clause 8.2.1.)

Element	Maximum, mass %
Carbon	0.55
Phosphorus	0.045
Sulphur	0.025

Table 11.1
Charpy Impact Test Requirements
(See Clause 11.10.3.)

Size of specimen, mm	Average value for 3 specimens, minimum, J	Minimum value for 1 specimen, J
10.0 × 10.0	40	32
10.0 × 7.5	30	24
10.0 × 5.0	24	20

Table 12.1
Chemical Composition Requirements for Carbon and High-Strength Low-Alloy* Steel Sheet
(See Clauses 12.2.1, 13.2, 14.2, 15.2.1, 16.2.1, 17.2, and 22.2.)

Element	Maximum, mass %
Carbon	0.22
Manganese	1.25
Phosphorus	0.04
Sulphur	0.05

**For HSLA steel, ferritic grain size shall be 6 or finer, in accordance with ASTM Standard E 112.*

Notes:

(1) *High-strength low-alloy steel is defined as a weldable steel with increased allowable design stresses conforming to the requirements of this Table.*

(2) *Other alloying elements may be added singly or in combination as necessary to attain the required properties. The choice of, and limits for, additional elements other than those specified above shall be established with the purchaser and reported by the supplier.*

Table 12.2
Product Analysis Tolerances for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, Hot-Rolled Strip, and Cold-Rolled Sheet*

(See Clauses 12.2.1, 13.2, 14.2.1, 15.2.1, 16.2.1, 17.2, and 22.2.)

		Tolerance, mass %	
Element	Limit or specified range mass %	Under minimum limit	Over maximum limit
Carbon	To 0.15 incl.	0.02	0.03
	Over 0.15 to 0.40 incl.	0.03	0.04
	Over 0.40 to 0.80 incl.	0.03	0.05
	0ver 80	0.03	0.06
Manganese	To 0.60 incl.	0.03	0.03
	Over 0.60 to 1.15 incl.	0.04	0.04
	Over 1.15 to 1.65 incl.	0.05	0.05
Phosphorus	—	—	0.01
Sulphur	—	—	0.01
Silicon	To 0.30 incl.	0.02	0.03
	Over 0.030 to 0.60 incl.	0.05	0.05
	Over 0.60	0.05	—
Copper	—	0.02	—

**ASTM Standard A 568.*

Table 12.3
Elongation Requirements for Type E Specimens

(See Clauses 12.8.3, 13.7.2, 14.7.2, 15.8.3, 16.9.3, and 22.10.3.)

Cross-sectional area, A, of test specimen, mm^2	Required elongation, %
50	38
100	33
150	31
200	29
250	28
300	27
350	26
400	25
450	25
500	24
550	24
600	23
650	23

Note: *Values for cross-sectional areas between those stated may be calculated from the following equation:*

$$\% \text{ elongation} = \frac{83.8}{A^{0.2}}$$

Values so calculated shall be rounded to the nearest 1%.

Table 17.1
Chemical Composition Requirements for Nonstandard Grade 4130 Steel Sheet

(See Clause 17.2.)

Element	Ranges and limits, mass %
Carbon	0.25–0.35
Manganese	0.40–0.60
Phosphorus	0.04 max.
Sulphur	0.05 max.
Silicon	0.15–0.35
Chromium	0.80–1.10
Molybdenum	0.15–0.25

Table 17.2
Product Analysis Tolerances for Alloy Steel Sheet and Strip, Hot-Rolled and Cold-Rolled*

(See Clause 17.2.)

Element	Limit or specified range, mass %	Tolerance over maximum limit or under minimum limit, mass %
Carbon	To 0.30 incl.	0.01
	Over 0.30 to 0.75 incl.	0.02
	Over 0.75	0.03
Manganese	To 0.90 incl.	0.03
	Over 0.90 to 2.10 incl.	0.04
Phosphorus	Over max. only	0.005
Sulphur	Over max. only	0.005
Silicon	To 0.35 incl.	0.02
	Over 0.35 to 2.20 incl.	0.05
Copper	To 1.00 incl.	0.03
	Over 1.00 to 2.00 incl.	0.05
Nickel	To 1.00 incl.	0.03
	Over 1.00 to 2.00 incl.	0.05
	Over 2.00 to 5.30 incl.	0.07
	Over 5.30 to 10.00 incl.	0.10
Chromium	To 0.90 incl.	0.03
	Over 0.90 to 2.10 incl.	0.05
	Over 2.10 to 3.99 incl.	0.10
Molybdenum	To 0.20 incl.	0.01
	Over 0.20 to 0.40 incl.	0.02
	Over 0.40 to 1.15 incl.	0.03
Vanadium	To 0.10 incl.	0.01
	Over 0.10 to 0.25 incl.	0.02
	Over 0.25 to 0.50 incl.	0.03
	Minimum value specified; check under minimum limit	0.01
Tungsten	To 1.00 incl.	0.04
	Over 1.00 to 4.00 incl.	0.08
Aluminum	To 0.10 incl.	0.03
	Over 0.10 to 0.20 incl.	0.04
	Over 0.20 to 0.30 incl.	0.05
	Over 0.30 to 0.80 incl.	0.07
	Over 0.80 to 1.80 incl.	0.10

**ASTM Standard A 505.*

Table 17.3
Chemical Composition Requirements for Stainless Steel Sheet

(See Clauses 17.2 and 19.2.)

	Ranges and limits, mass %			
Element	**Type 304**	**Type 316**	**Type 321**	**Type 347**
Carbon (max)	0.08	0.08	0.08	0.08
Manganese (max)	2.00	2.00	2.00	2.00
Phosphorus (max)	0.030	0.045	0.030	0.030
Sulphur (max)	0.030	0.030	0.030	0.030
Silicon (max)	0.75	1.00	0.75	0.75
Nickel	8.0–11.0	10.0–14.0	9.0–13.0	9.0–13.0
Chromium	18.0–20.0	16.0–18.0	17.0–20.0	17.0–20.0
Molybdenum	—	2.0–3.0	—	—
Titanium	—	—	5 × C min 0.60 max	—
Niobium + Tantalum	—	—	—	10 × C min 1.00 max

Table 17.4
Product Analysis Tolerances for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*

(See Clauses 17.2 and 19.2.)

Element	Limit or specified range, mass %	Tolerance over maximum limit or under minimum limit, mass %
Carbon	To 0.010 incl.	0.002
	Over 0.010 to 0.030 incl.	0.005
	Over 0.030 to 0.20 incl.	0.01
	Over 0.20 to 0.60 inc.	0.02
Manganese	To 1.00 incl.	0.03
	Over 1.00 to 3.00 incl.	0.04
	Over 3.00 to 6.00 incl.	0.05
	Over 6.00 to 10.00 incl.	0.06
	Over 10.00 to 15.00 inc.	0.10
	Over 15.00 to 20.00 incl.	0.15
Phosphorus	To 0.040 incl.	0.005
	Over 0.040 to 0.20 incl.	0.010
Sulphur	To 0.040 incl.	0.005
	Over 0.040 to 0.20 incl.	0.010
	Over 0.20 to 0.50 incl.	0.020
Silicon	To 1.00 incl.	0.05
	Over 1.00 to 3.00 incl.	0.10
Chromium	Over 4.00 to 10.00 incl.	0.10
	Over 10.00 to 15.00 incl.	0.15
	Over 15.00 to 20.00 incl.	0.20
	Over 20.00 to 30.00 incl.	0.25

(Continued)

Table 17.4 (Concluded)

Element	Limit or specified range, mass %	Tolerance over maximum limit or under minimum limit, mass %
Nickel	To 1.00 incl.	0.03
	Over 1.00 to 5.00 incl.	0.07
	Over 5.00 to 10.00 incl.	0.10
	Over 10.00 to 20.00 incl.	0.15
	Over 20.00 to 30.00 incl.	0.20
Molybdenum	Over 0.20 to 0.60 incl.	0.03
	Over 0.60 to 2.00 incl.	0.05
	Over 2.00 to 7.00 incl.	0.10
Titanium	To 1.00 incl.	0.05
	Over 1.00 to 3.00 incl.	0.07
Cobalt	Over 0.05 to 0.50 incl.	0.01†
	Over 0.50 to 2.00 incl.	0.02
	Over 2.00 to 5.00 incl.	0.05
Niobium plus tantalum	To 1.50 incl.	0.05
Tantalum	To 0.10 incl.	0.02
Copper	To 0.50 incl.	0.03
	Over 0.50 to 1.00 incl.	0.05
	Over 1.00 to 3.00 incl.	0.10
	Over 3.00 to 5.00 incl.	0.15
	Over 5.00 to 10.00 incl.	0.20
Aluminum	To 0.15 incl.	–0.005, + 0.01
	Over 0.15 to 0.50 incl.	0.05
	Over 0.50 to 2.00	0.10
Nitrogen	To 0.02 incl.	0.005
	Over 0.02 to 0.19 incl.	0.01
	Over 0.19 to 0.25 incl.	0.02
	Over 0.25 to 0.35 incl.	0.03
Tungsten	To 1.00 incl.	0.03
	Over 1.00 to 2.00 incl.	0.05
Vanadium	To 0.50 incl.	0.03
	Over 0.50 to 2.00 incl.	0.05
Selenium	All	0.03

**ASTM Standard A 480*

†Product analysis limits for cobalt under 0.05% have not been established. The manufacturer should be consulted for them.

Table 20.1
Chemical Composition Requirements for Aluminum Alloy AA5154*

(See Clause 20.2.)

Element	Ranges and limits, mass %
Iron	0.40 max
Silicon	0.25 max
Copper	0.10 max
Manganese	0.10 max
Magnesium	3.1–3.9
Chromium	0.15–0.35
Zinc	0.20 max
Titanium	0.20 max
Others, each	0.05 max
Others, total	0.15 max
Aluminum	Remainder

**Analysis shall be made regularly only for the elements specifically mentioned above. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine conformance with the limits specified for other elements.*

Table 21.1
Service Temperature Requirements for TC-4LM Cylinders

(See Clause 21.1.)

Cryogenic product	Design service temperature, °C
Argon	–196°C or lower
Helium	–269°C or lower
Hydrogen	–253°C or lower
Neon	–246°C or lower
Nitrogen	–196°C or lower
Oxygen	–196°C or lower
Carbon Dioxide	–196°C or lower
Nitrous Oxide	–196°C or lower

Table 21.2
Chemical Composition Requirements for Stainless Steel, Type 304

(See Clause 21.2.)

Element	Ranges and limits, mass %
Carbon*	0.08 max
Manganese	2.00 max
Phosphorus	0.045 max
Sulphur	0.030 max
Silicon	1.00 max
Nickel	8.00 to 10.50
Chromium	18.00 to 20.00

**The carbon analysis shall be reported to the nearest hundredth of 1%.*

Table 21.3
Mechanical Properties (Annealed) of Stainless Steel, Type 304

(See Clauses 21.2 and 21.8.2.)

Tensile strength, minimum	517 MPa
Yield strength, minimum	207 MPa
Elongation in Type A specimen, minimum	30%

Table 21.4
Product Analysis Tolerances for Stainless Steel, Type 304

(See Clause 21.2.)

Element	Limits or specified range, mass %	Tolerance over the maximum limit or under the minimum limit, mass %
Carbon	To 0.030 incl. Over 0.030 to 0.20 incl.	0.005 0.010
Manganese	To 1.00 incl. Over 1.00 to 3.00 incl.	0.030 0.040
Phosphorus*	To 0.040 incl. Over 0.040 to 0.20 incl.	0.005 0.010
Sulphur	To 0.040 incl.	0.005
Silicon	To 1.00 incl.	0.050
Chromium	Over 15.00 to 20.00 incl.	0.200
Nickel	Over 5.00 to 10.00 incl. Over 10.00 to 20.00 incl.	0.100 0.150

**Rephosphorized steels are not subject to product analysis for phosphorus.*

Table 21.5
Impact Values for Stainless Steel, Type 304
(See Clauses 21.11.6 and 21.11.7.)

Size of specimen, mm	Average value for 3 specimens, minimum, J	Minimum value for 1 specimen, J
10.0 × 10.0	20.3	13.6
10.0 × 7.5	16.9	11.5
10.0 × 5.0	13.6	9.5
10.0 × 2.5	6.8	4.7

Table 22.1
Acetone Correction Factors
(See Clauses 22.14.2.2 and 22.14.4.1.)

R	F_1	F_2
0.58	0.963	1.000
0.57	0.971	1.009
0.56	0.980	1.018
0.55	0.989	1.027
0.54	0.998	1.036
0.53	1.007	1.045
0.52	1.016	1.055
0.51	1.025	1.064
0.50	1.034	1.074

Note:

R = *total acetylene-to-acetone mass ratio selected by the manufacturer*

F_1 = *acetone correction factor for cylinders with an internal shell volume of* 9 L *or less*

F_2 = *acetone correction factor for cylinders with an internal shell volume greater than* 9 L

Table 22.2
DMF Correction Factors
(See Clauses 22.14.2.3 and 22.14.4.1.)

W	G_1	G_2
0.475	0.985	1.000
0.470	0.990	1.005
0.460	0.999	1.014
0.450	1.009	1.024
0.440	1.018	1.034
0.430	1.028	1.044
0.420	1.038	1.054
0.410	1.048	1.064
0.400	1.059	1.075

Note:

W = total acetylene-to-DMF mass ratio selected by the manufacturer

G_1 = DMF correction factor for cylinders with an internal shell volume of 9 L *or less*

G_2 = DMF correction factor for cylinders with an internal shell volume greater than 9 L

Table 23.1
Chemical Composition Requirements for Weldable Carbon Steel Sheet
(See Clause 23.2.1.1.)

Element	Maximum, mass %
Carbon	0.12
Phosphorus	0.04
Sulphur	0.05

Table 23.2
Product Analysis for Carbon Steel Sheet
(See Clause 23.2.1.1.)

Element	Maximum, mass %
Carbon	0.15
Phosphorus	0.05
Sulphur	0.06

Table 24.1
Container Requalification Periods and Procedures

(See Clauses 24.2.1.1, 24.2.1.2, and 24.2.1.7.)

Container specification	Minimum retest pressure	Hydrostatic retest with volumetric expansion measurement		Proof pressure retest		Visual reinspection per Clause 24.2.9	
		Period	Procedure	Period	Procedure	Period	Procedure (per Clause 24.2.9.3)
ICC-3	20.7 MPa	5 years	Basic			5 years	Alternative (b), (d), or (e)
CTC-3A CTC-3AA	1.67 SP*	5 years	Basic			5 or 10 years	Alternative (a), (b), (d), or (e)
TC-3AM TC-3AAM TC-3ASM	†	10 years	Alternative 24.2.2 or 24.2.3				
TC-3ALM	†	5 years	Basic			5 years	Alternative (e)
CTC-3AL	1.67 SP	5 years	Basic			5 years	Alternative (e)
CTC-3AX CTC-3AAX DOT-3T	1.67 SP	5 years	Basic			5 years	Alternative (d) and (e)
TC-3AXM TC-3AAXM TC-3TM	1.5 SP						
TC-3ANM CTC-3BN	2 SP	5 years	Basic			5 or 10 years	Alternative (a), (d), or (e)
		10 years	Alternative 24.2.3				
CTC-3A480X	1.67 SP	5 years	Basic			5 or 10 years	Alternative (a), (d), or (e)

(Continued)

Table 24.1 (Continued)

Container specification	Minimum retest pressure	Hydrostatic retest with volumetric expansion measurement		Proof pressure retest		Visual reinspection per Clause 24.2.9	
		Period	Procedure	Period	Procedure	Period	Procedure (per Clause 24.2.9.3)
CTC-3B	2 SP	5 years 10 years	Basic 24.2.3			5 or 10 years	Alternative (a), (b), (d), or (e)
TC-3EM CTC-3E		Retest not required					
TC-3FCM TC-3HWM	1.5 SP	3 years	Basic				
TC-3HTM	1.5 SP	3 years	Basic and 24.2.6				
CTC-3HT	1.67 SP						
TC-4AAM33 CTC-4AA480	2 SP	5 years	Basic			5 or 10 years	Alternative (a), (d), or (e)
TC-4BM, CTC-4B, TC-4BAM, CTC-4BA, TC-4BWM, CTC-4BW, TC-4BM17ET, CTC-4B240ET, CTC-4B240FLW	2 SP	5 years 12 years	Basic Alternative 24.2.4	7 years	Alternative 24.2.4	5 or 10 years	Alternative (a), (b), (c), (d), or (e)
TC-4DM, CTC-4D, TC-4DAM, CTC-4DA, TC-4DSM, CTC-4DS	2 SP	5 years	Basic			5 years	Alternative (d) or (e)
TC-4EM CTC-4E	2 SP	5 years 12 years	Basic Alternative 24.2.4	7 years	Alternative 24.2.4	5 or 10 years	Alternative (a) or (e)

(Continued)

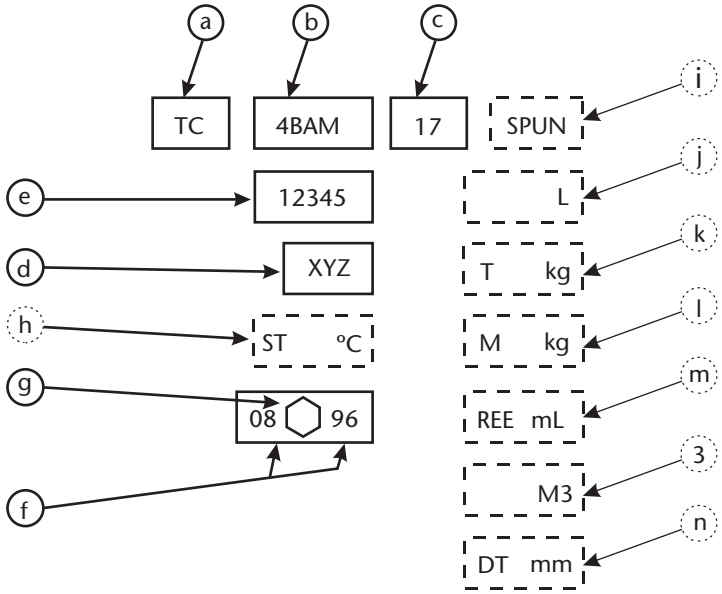
Table 24.1 (Concluded)

Container specification	Minimum retest pressure	Hydrostatic retest with volumetric expansion measurement		Proof pressure retest		Visual reinspection per Clause 24.2.9	
		Period	Procedure	Period	Procedure	Period	Procedure (per Clause 24.2.9.3)
TC-4LM CTC-4L	Retest not required						
TC-8WAM, TC-8WM, CTC-8, CTC-8AL, CTC-8WC	See Clause 24.2.8						
Any cylinder on permit or exemption	As required by permit or exemption						
Cylinders manufactured to a foreign specification, filled for export	As required by actual specification or as per the marked test pressure. If requirement unknown, as per equivalent Canadian specification						

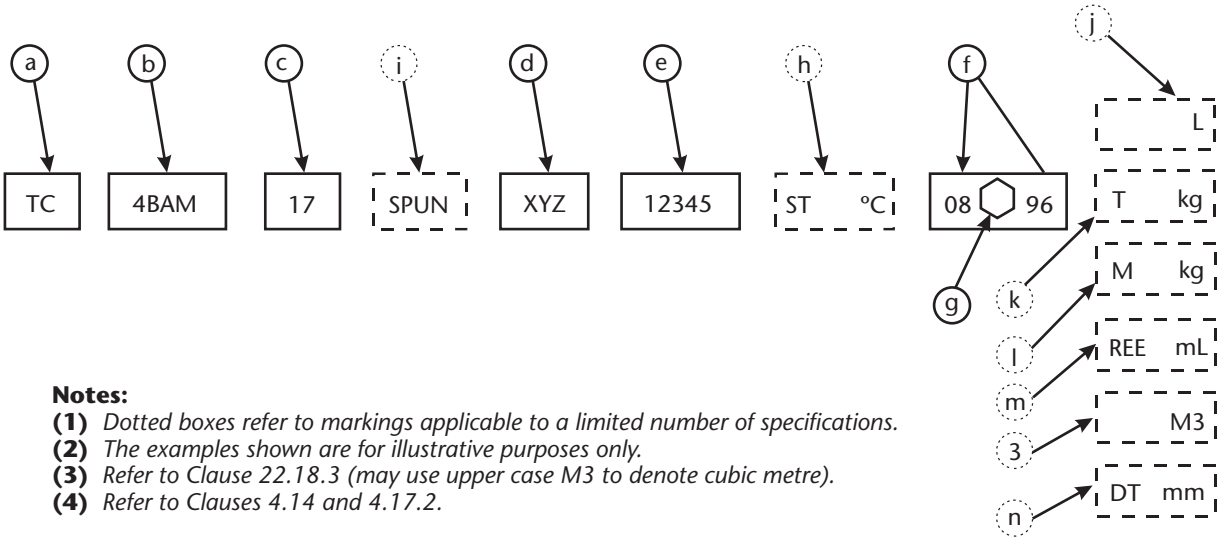
**SP means service pressure.*

†*For cylinders with a service pressure less than* 3.5 MPa*, the greater of* 3.1 MPa *or 2 SP; and for cylinders with a service pressure equal to or greater than* 3.5 MPa*, the greater of* 7.0 MPa *or 1.5 SP.*

(i) Vertical



(ii) Horizontal



Notes:
(1) *Dotted boxes refer to markings applicable to a limited number of specifications.*
(2) *The examples shown are for illustrative purposes only.*
(3) *Refer to Clause 22.18.3 (may use upper case M3 to denote cubic metre).*
(4) *Refer to Clauses 4.14 and 4.17.2.*

Figure 4.1
Typical Marking Arrangements
(See Clauses 4.17.1 and 22.18.3.)

Manufacture of TC-3FCM Cylinders

Independent Inspector's Report

Place _____

Date _____

Manufactured by _____

Location _____

Manufactured for _____

Location _____

Consigned to _____

Location _____

Quantity _____

Size: OD _____ mm Length: _____ mm

Marks placed on _____ of the cylinder are:

TC _____

Serial numbers _____ to _____ inclusive

Manufacturer's registered mark _____

Independent inspector's registered mark _____

Test date _____

Other marks (if any) _____

Each composite cylinder was made by completely overwrapping a seamless aluminum liner with resin-impregnated filament reinforcement. Composite overwrap was made by winding resin-impregnated _____ continuous filament over this liner in both longitudinal and circumferential directions; the resin was then cured at controlled temperature. Aluminum was identified by cast numbers and verified as to chemical composition; a record thereof is attached. Liners were solution-treated and artifically aged to T-6 temper. Tensile tests were made in the presence of the independent inspector, and a report of the results on specimens taken from these liners is attached. Each liner was inspected both before and after closing the ends. All that were inspected were found to be free from seams, cracks, laminations, and other defects. Liner walls were measured, and the minimum thickness noted was at least equal to the minimum design wall thickness. The outside diameter was found by a close approximation to be _____ mm.

Filament and resin were certified by the manufacturer and identified by package number. Filament was verified as to strand strength. Composite was verified as to shear strength. After wrapping, composite was cured to manufacturer's specification. Autofrettage and hydrostatic test, as specified, were made in the presence of the independent inspector. All cylinders accepted are in compliance with requirements. Results of autofrettage and test pressurizations are attached. Tensile stress on the aluminum liner is calculated to be _____ MPa at service pressure. Filament stresses are calculated to be _____ MPa in the hoop direction and _____ MPa in the longitudinal direction at service pressure.

I hereby certify that all of these cylinders proved satisfactory in every way and comply with the requirements of TC-3FCM, except as follows: Exceptions made to any reporting or testing requirement of this section are

_____

_____

(Signed) _____
Independent Inspector

Form A

Record of Chemical Analysis of Material for Cylinder Liner

Place _____

Date _____

Numbered _____ to _____ inclusive.

Size _____ mm outside diameter by _____ mm long.

Made by _____ Company.

For _____ Company.

Material description _____

Note: *Any omission of analyses by casts, if permitted, must be accounted for, by notation hereon, reading "the certificate of the manufacturer of material has been secured, found satisfactory, and placed on file", or by attaching a copy of the certificate.*

Alloy designation	Cast	Cylinders represented (serial nos.)	Chemical Analysis												
												Others			
			Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Pb	Bi	Each	Total	Al

Material was manufactured and mill analysis made by _____

Originals of the certified mill analysis reports are in files of the manufacturer.

(Signed) _____

Independent Inspector

Form B

Record of Tensile Tests of Material for Cylinder Liners

Place _____

Date _____

Numbered _____ to _____ inclusive.

Size _____ mm outside diameter by _____ mm long.

Made by _____ Company.

For _____ Company.

Test specimen description _____

Lot Code	Cylinders represented by test (serial numbers)	Yield strength, MPa	Tensile strength, MPa	Elongation in Type ___ specimen, %

(Signed) _____
Independent Inspector

Form C

Report of Composite Strength

Place _____

Date _____

Materials _____

Manufactured by _____

For _____

Numbered _____ to _____ inclusive.

Filament designation and specification _____

Manufactured by _____

Manufacturing package number	Interlaminar shear strength, MPa

(Signed) _____
Independent Inspector

Form D

Resin-System Components Manufacturing Batch Numbers

Resin		Curing agent		Accelerator	
Batch number	Type	Batch number	Type	Batch number	Type

(Signed) _____

Independent Inspector

Form E

Hydrostatic Test Data

Place _____

Date _____

Manufactured by _____

For _____

Numbered _____ to _____ inclusive.

Symbol _____

Minimum specified test pressure _____ MPa

						Hydrostatic test			
	Mass, kg								
Serial number	Liner	Composite	Total	Volume, mL	Auto-frettage pressure, MPa	Total expansion, mL	Permanent expansion, mL	Ratio of permanent to total expansion, %	Actual test pressure, MPa

(Signed) _____
Independent Inspector

Form F

Lot Cycling and Burst Test Data

Type of test	Serial number	Number of pressurizations: To service pressure	Number of pressurizations: To 1.11 times test pressure	Burst pressure, MPa
Cycling				
Burst				

(Signed) _____
Independent Inspector

Form G

Report on Manufacture of TC-3HWM Cylinders

Independent Inspector's Report

Place _____

Date _____

Manufactured by _____ Location _____

Manufactured for _____ Location _____

Consigned to _____ Location _____

Quantity _____ Size: OD _____ mm, Length _____ mm

Marks placed on _____ of the cylinder are

TC _____ Serial numbers _____ to _____ inclusive.

Manufacturer's registered mark _____

Independent inspector's registered mark _____

Test date _____

Other marks (if any) _____

Each composite cylinder was made by circumferentially overwrapping a seamless aluminum liner with resin-impregnated filament reinforcement. Composite overwrap was made by winding resin-impregnated continuous filament over this liner in the circumferential direction only; the resin was then cured at controlled temperature. The liners are in compliance with all liner requirements of this specification and have a liner rated pressure of _____ MPa. Compliance of the liners with these requirements was verified by performance of the specified tests or by obtaining the report of the independent inspector performing the tests. Filament and resin were certified by the manufacturers and identified by package number. Filament was verified as to strand strength. Composite was verified as to shear strength and tensile strength. After wrapping, composite was cured to the manufacturer's specification. Autofrettage and hydrostatic test, as specified, were made in the presence of the independent inspector. All cylinders accepted are in compliance with requirements. Tensile stress on the aluminum liner is calculated to be _____ MPa at service pressure. Filament stress is calculated to be _____ MPa at service pressure.

I hereby certify that all of these cylinders proved satisfactory in every way and comply with the requirements of TC-3HWM, except as follows: exceptions made to any reporting or testing requirements of this section are

_____

_____

_____

(Signed) _____
Independent Inspector

Form H

Report of Composite Strength

Place _____

Date _____

Materials _____

Manufactured by _____

For _____

Numbered _____ to _____ inclusive.

Filament designation and specification _____

Manufactured by _____

Manufacturing package number	Tensile strength, MPa	Interlaminar shear strength, MPa

(Signed) _____
Independent Inspector

Form I

Basic Cylinder Design Information

Dimensional, Material, and Pressure Data

Date _____

Manufacturer _____

Cylinder description _____

Design no. _____

(1)	Service pressure	_____ MPa
(2)	Autofrettage pressure*	_____ MPa
(3)	Test pressure	_____ MPa
(4)	Minimum specified burst pressure	_____ MPa
(5)	Calculated burst pressure	_____ MPa
(6)	Volume	_____ L
(7)	Inside diameter	_____ mm
(8)	Outside diameter	_____ mm
(9)	Liner material and temper	_____
(10)	Filament material	_____
(11)	Resin material	_____
(12)	Mass of cylinder	_____ kg
(13)	Mass of liner	_____ kg
(14)	Mass of composite material	_____ kg
(15)	Minimum sidewall thickness of liner (qualification test cylinder)	_____ mm
(16)	Minimum design wall thickness of liner	_____ mm
(17)	Yield strength of liner (qualification test cylinder)	_____ MPa
(18)	Minimum design yield strength of liner	_____ MPa
(19)	Nominal thickness of overwrap	_____ mm
(20)	Minimum strand strength of filament	_____ MPa
(21)	Minimum shear strength of resin	_____ MPa

** The total and permanent volumetric expansion readings obtained in the autofrettage pressurizations shall be recorded for each cylinder submitted to the qualification tests.*

Design Stresses and Load Distribution

	Direction		Distribution, MPa		Load distribution, %	
Pressure	Long.	Circ.	Liner	Overwrap	Liner	Overwrap
Zero	†			‡		‡
		†				
Service	†			‡		‡
		†				
1.11 times test	†			‡		‡
		†				
Minimum burst†	†			‡		‡
		†				

†*Based on Clause 9.3.*
‡*Does not apply to TC-3HWM cylinders.*

Form J

Appendix A
Reference Organizations

Note: *This Appendix is not a mandatory part of this Standard.*

Codes, Standards, and Publications of the following organizations are referenced in this Standard:

The Aluminum Association
818 Connecticut Avenue, N.W.
Washington, DC 20006
USA

ASNT
American Society for Nondestructive Testing
PO Box 28518
1711 Arlingate Lane
Columbus, Ohio 43228-0518
USA

ASTM
American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103
USA

CGA
Compressed Gas Association, Inc.
4221 Walney Road, 5th Floor
Chantilly, Virginia 20151
USA

CGSB
Canadian General Standards Board
Ottawa, Ontario
K1A 1G6

CSA
Canadian Standards Association
5060 Spectrum Way, Suite 100
Mississauga, Ontario
L4W 5N6

ISO
ISO Central Secretariat
1, rue de Varembé,
Case postale 56,
CH-1211 Geneva 20, Switzerland

NASA
National Aeronautics and Space Administration
Systems Engineering and Technology
Washington, DC 20546
USA

Transport Canada
Transport Dangerous Goods Directorate
330 Sparks Street, 9th Floor
Ottawa, Ontario
K1A 0N5

US Federal Standards
Superintendent of Documents
US Government Printing Office
Washington, DC 20402
USA

Appendix B
Suggested Practice for Tolerances Not Covered by This Standard

Note: *This Appendix is not a mandatory part of this Standard.*

Volume: container water capacity	+3% –1%
Perpendicularity: maximum deviation from vertical for free-standing cylinders	1°
Ovality: difference between maximum and minimum outside diameter in the same cross-section	2% of mean outside diameter
Straightness: deviation from a straight line	0.4% of cylindrical length
Tare: variation from minimum mass specified in cylinder design	+10% –0%

Proposition de modification

N'hésitez pas à nous faire part de vos suggestions et de vos commentaires. Au moment de soumettre des propositions de modification aux normes CSA et autres publications CSA prière de fournir les renseignements demandés ci-dessous et de formuler les propositions sur une feuille volante. Il est recommandé d'inclure

- le numéro de la norme/publication
- le numéro de l'article, du tableau ou de la figure visé
- la formulation proposée
- la raison de cette modification.

Proposal for change

CSA welcomes your suggestions and comments. To submit your proposals for changes to CSA Standards and other CSA publications, please supply the information requested below and attach your proposal for change on a separate page(s). Be sure to include the

- Standard/publication number
- relevant Clause, Table, and/or Figure number(s)
- wording of the proposed change
- rationale for the change.

Nom/Name: _____

Affiliation: _____

Adresse/Address: _____

_____

Ville/City: _____

État/Province/State: _____

Pays/Country: _____ **Code postal/Postal/Zip code:** _____

Téléphone/Telephone: _____ **Télécopieur/Fax:** _____

Date: _____

ISBN 1-55324-813-9