Designation: ~~D1998 – 15~~ D1998 – 21

Standard Specification for
Polyethylene Upright Storage Tanks[1]

1. Scope*

1.1 This specification covers flat-bottom, upright, cylindrical tanks molded in one-piece seamless construction by rotational molding. The tanks are molded from polyethylene for above ground, vertical installation and are capable of containing aggressive chemicals at atmospheric pressure. Included are requirements for materials, properties, design, construction, dimensions, tolerances, workmanship and appearance. Tank capacities are from 1900 L (500 gal) up.

1.2 This specification covers the design of stationery vessels for use at atmospheric pressure intended for use with liquids heated below their flash points and continuous service temperatures below 66°C (150°F) for Type I tanks and below 60°C (140°F) for Type II tanks.

1.2.1 NFPA Standards 30 and NFPA 31 shall be consulted for installations that are subject to the requirements of these standards.

1.3 For service requirements beyond the scope of this specification (1.2), such as externally imposed mechanical forces, internal pressure or vacuum, higher temperature service, etc., other relevant sources of standards, for example, local and state building codes, NFPA, ASME, ARM, etc., shall be consulted.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—ISO 13341:2005+A1:2011 and ISO 13575:2012 are similar, but not equivalent to this standard.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate* ~~safety~~ *safety, health,* *and* ~~health~~environmental *practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
D618 Practice for Conditioning Plastics for Testing

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*A Summary of Changes section appears at the end of this standard.

D883 Terminology Relating to Plastics
D1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3892 Practice for Packaging/Packing of Plastics
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
F412 Terminology Relating to Plastic Piping Systems

2.2 *OSHA Standard:*
29 CFR 1910.106 Occupational Safety and Health Administration, Flammable and Combustible Liquids[3]

2.3 *ANSI Standard:*
B-16.5 Pipe Flanges and Flanged Fittings[4]

2.4 *NFPA Standards:*
30 Flammable and Combustible Liquid Code[5]
31 Installation of Oil Burning Equipment[5]

2.5 *ISO Standards:*[6]
ISO 13341:2005+A1:2011 Static Thermoplastic Tanks for the Above Ground Storage of Chemicals – Blow Moulded or Rotationally Moulded Polyethylene Tanks – Requirements and Test Methods
ISO 13575:2012 Static Thermoplastic Tanks for Above Ground Storage of Domestic Heating Oils, Kerosene and Diesel Fuels – Blow Moulded and Rotationally Moulded Polyethylene Tanks and Rotationally Moulded Tanks Made of Anionically Polymerized Polyamide 6 – Requirements and Test Methods

3. Terminology

3.1 *Definitions*—Definitions are in accordance with For definitions of terms used in this specification and associated with plastics issues, refer to the terminology contained in Terminologies D883 and F412 and the Association of Rotational Molders (ARM) Glossary of Terms,[7] unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bottom knuckle radius, n*—the outside corner radius.

3.2.2 *impact failure, n*—any crack in the test specimen resulting from the impact and visible in normal room lighting to a person with normal eyesight.

3.2.3 *rotational molding, n*—a three-stage commercial process consisting of loading the mold with powdered resin, fusing the resin by heating while rotating the mold about more than one axis, and cooling and removing the molded article.

3.2.4 *service factor, n*—a number less than 1.0 (that takes into consideration all the variables and degrees of safety involved in a polyethylene storage tank installation) that is multiplied by the hydrostatic design basis to give the design hoop stress.

4. Classification

4.1 Tanks meeting this specification are classified according to type as follows, and it is the responsibility of the purchaser to specify Type I or Type II:

4.1.1 Type I—Tanks molded from cross-linkable polyethylene.

4.1.2 Type II—Tanks molded from non-cross-linkable polyethylene.

5. Materials

5.1 This specification is based upon the use of 100 % virgin polyethylene intended for the rotational molding process. Any use

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[3] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210.
[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.10036, http://www.ansi.org.
[5] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101.02169-7471, http://www.nfpa.org.
[6] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[7] Available from Association of Rotational Molders, 800 Roosevelt Road, C-312, Glen Ellyn, IL 60137, tel: 630-942-6589.

of regrind, recycled or reprocessed materials, or combinations of such materials, shall not rely upon the performance data of their original constituents, but must meet the requirements of this specification in its own right.

5.1.1 The polyethylene shall have a stress-cracking resistance of 500 h minimum F50 in accordance with Test Method D1693, Condition A, full-strength stress-cracking agent. The test specimens shall be compression molded or rotational molded. If compression molded, Procedure C of Annex A1 of Practice D4703 shall be followed for both types of polyethylene with a minimum platen temperature of 177°C (350°F) for Type II materials. The temperature for Type I (cross-linkable) polyethylene shall be 197°C (390°F) and the platen shall be kept closed under full pressure for five minutes at the specified temperature in order to bring about the crosslinking reaction. If the test specimens are rotational molded, the conditions for rotational molding shall be similar to the conditions used for molding a tank from this polyethylene.

NOTE 2—The stress-cracking test is not used as an indicator of general chemical resistance of a polyethylene. Refer to the polyethylene supplier's or molder's chemical-resistance chart for information on the resistance of the polyethylene to specific chemicals or products, or test specific products or chemicals prior to use.

5.2 All tanks used for outdoor installation shall contain an ultraviolet stabilizer at a level adequate to give protection for the intended service life of the tanks. This stabilizer shall be compounded into the polyethylene.

5.3 Any pigments added must be compatible with the polyethylene and shall not exceed 0.5 % dry blended, and 2 % compounded in, of the total weight.

NOTE 3—The use of dry-blended pigments ~~may~~can have an effect on physical properties, that is, impact strength.

5.4 Each resin used in designing tanks covered by this specification shall have hydrostatic-hoop-stress data available.

6. Design Requirements for Both Type I and Type II Tanks

6.1 *Cylinder Shell (Unsupported Portion of Tanks)*—The minimum required wall thickness of the cylindrical shell at any fluid level (F) shall be determined by the following equations, but shall not be less than 4.7 mm (0.187 in.) thick. The tolerance indicated in 9.1.2 applies to these dimensions.

$$HL = HM - F \tag{1}$$

where:
HL = head at level F, m (ft),
HM = maximum fluid head, m (ft), and
F = any fluid level, m (ft).

For illustration, see Fig. 1.

$$T = P \times OD/2 \; SD \tag{2}$$

where:
T = wall thickness, mm (in.),
P = pressure, MPa (0.0098 MPa/m-H_2O × SG × HL (m)), or psi (0.433 psi/ft-H_2O × SG × HL (ft)),
SG = specific gravity of fluid,
HL = head at level F, m (ft),
OD = outside diameter of tank, mm (in.), and
SD = hydrostatic design stress, MPa (psi).

6.1.1 The hydrostatic design stress that is used to determine the minimum wall thickness at any fluid level must be based on hoop stress data for the resin. The hoop stress data, obtained in accordance with the procedures of Test Method D2837, provide a hydrostatic-design-basis for the resin. The hydrostatic-design-basis must be reduced by a service factor to determine the actual hydrostatic design stress. The maximum service factor shall be 0.5 for wall thicknesses less than 9.5 mm (0.375 in.). For thicknesses equal to or greater than 9.5 mm (0.375 in.), the maximum service factor shall be 0.475. For example, if the hydrostatic-design-basis for the resin is 8.7 MPa (1260 psi), the hydrostatic design stress for a tank with wall thickness greater than 9.5 mm (0.375 in.) is 0.475 × 8.7 = 4.1 MPa (or 0.475 × 1260 = 600 psi).
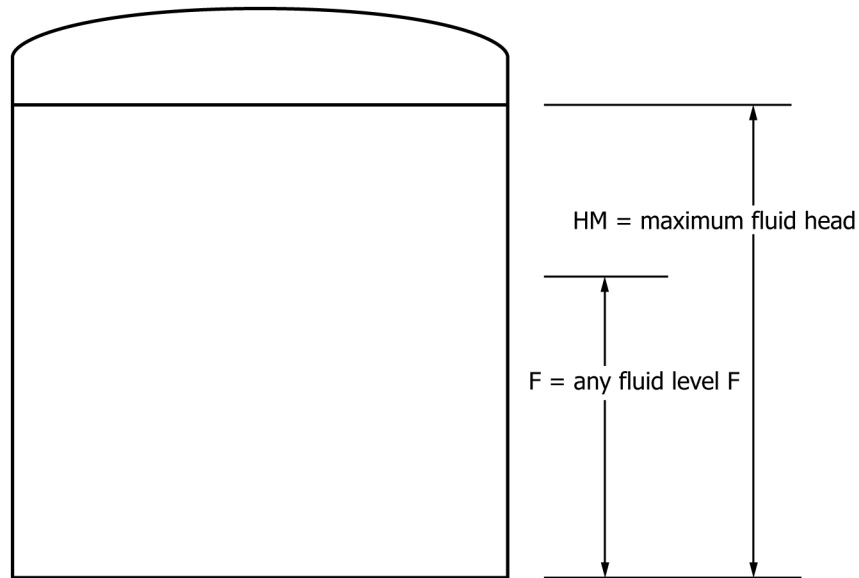
FIG. 1 Illustration of Cylinder Shell

6.1.2 Tank hoop stresses shall be derated for service above 23°C (73.4°F).

6.2 *Cylinder Shell (Externally Supported Tanks)*—The minimum required wall thickness for the cylinder straight shell must be sufficient to support its own weight in an upright position without any external support, but shall not be less than 4.7 mm (0.187 in.) thick. The tolerance indicated in 9.1.2 applies to these dimensions.

6.3 *Top Head*—Must be integrally molded with the cylinder shell. The minimum thickness of the top head shall be equal to the top of the straight wall.

6.4 *Bottom Head*—Must be integrally molded with the cylinder shell. The minimum thickness for a full-supported flat-bottom head shall be 4.7 mm (0.187 in.). The radius of the bottom knuckle of a flat-bottom tank shall not be less than 25.4 mm (1 in.) for tanks with a diameter less than 1.8 m (6 ft) and 38.1 mm (1.5 in.) for a diameter greater than 1.8 m (6 ft). The minimum thickness of the radius shall not be less than the maximum thickness of the cylinder wall.

6.5 *Bottom Knuckle Radius*—The minimum thickness of the outer radius shall not be less than the maximum thickness of the cylinder wall.

Note 4—Since it is difficult to control the absolute radius dimension and, in the absence of any FEA or scientific analysis, it is recommended that the outside radius of the bottom knuckle of a flat-bottom tank not be less than 25.4 mm (1 in.) for tanks with a diameter less than 1.8 m (6 ft) and 38.1 mm (1.5 in.) for a diameter greater than 1.8 (6 ft).

6.6 *Open-Top Tanks*—The top edge of open tanks shall be reinforced by design to maintain its shape after installation.

7. Fittings

7.1 Fabricated nozzles, gaskets, and other fitting accessories must be chemically compatible with the materials to be handled in the tanks.

7.2 Openings that are cut in tanks to install fittings must not have sharp corners. Holes shall have minimum clearance to insure best performance of fittings.

7.3 The size, location, and specification, and so forth, for manways and fittings shall be agreed upon between the purchaser and the manufacturer.

7.4 The vents must comply with OSHA 1910.106 (F) (iii) (2) (IV) (9) normal venting for atmospheric tanks, or other accepted standard, or shall be at least as large as the filling or withdrawal connection, whichever is larger but in no case less than 25.4 mm (1 in.) nominal inside diameter.

7.5 Fittings installed in tanks shall be of appropriate strength to meet manufacturer and purchaser specifications.

7.6 Bolts securing mechanical fittings must be manufactured of materials compatible with tank contents.

7.7 Provisions shall be made to attach hold-down devices to the tanks for outdoor service.

7.8 For all flanged connectors, the flange drilling and bolting shall be in accordance with ANSI/ASME B-16.5 for 150 psi (1 MPa) pressure class straddling the principal centerline of the vessel.

8. Performance Requirements

8.1 The following performance requirements shall be met by Type I and Type II tanks:

8.1.1 *Low-Temperature Impact*—Low-temperature impact shall be determined using the test method described in 11.3. The requirements for Type I and Type II tanks are as follows:

Wall thickness, mm (in.)	Impact energy, min. J (ft-lb)
4.7 mm (0.187 in.) to and including 6.4 mm (0.25 in.)	122.0 (90)
6.6 mm (0.26 in.) to and including 12.9 mm (0.50 in.)	135.5 (100)
12.9 mm (0.51 in.) to and including 19.3 mm (0.75 in.)	203.2 (150)
19.3 mm (0.76 in.) to and including 25.4 mm (1.00 in.)	271.0 (200)
Greater than 25.4 mm (1.00 in.)	271.0 (200)

8.1.2 *Percent Gel, for Type I Tanks Only*—The percent gel level shall be determined using the test method described in 11.4. The percent gel level for Type I tanks on the inside 3.2 mm (0.125 in.) of the wall shall be a minimum of 60 %.

9. Dimensions and Tolerances

9.1 *General*—All dimensions will be taken with the tank in the vertical position, unfilled. Tank dimensions will represent the exterior measurements.

9.1.1 *Outside Diameter*—The tolerance for the outside diameter, including out of roundness, shall be ±3 %.

9.1.2 *Shell Wall and Head Thickness*—The tolerance for average thickness at each elevation shall be −10 % of the design thickness on the low side and shall be unlimited on the high side. The tolerance for individual audit readings shall be limited to −20 % of the design thickness. The total amount of surface area on the low side of the tolerance shall not exceed 10 % of the total surface area.

9.1.3 *Placement of Fittings*—The tolerance for fitting placements shall be 12.7 mm (0.5 in.) in elevation and 2° radial at ambient temperature.

10. Workmanship

10.1 Type I finished tank walls shall be free, as commercially practicable, of visual defects such as foreign inclusions, air bubbles, pinholes, pimples, crazing, cracking and delaminations that will impair the serviceability of the vessel. Fine bubbles are acceptable with Type II tanks to the degree to which they do not interfere with proper fusion of the resin melt.

10.2 The acceptable finish shall be predetermined by agreement between the molder and the buyer.

11. Test Methods

11.1 *Test Specimens*—Test specimens shall be taken from an area that is representative of the bottom side wall. If no representative sample cut-out area in the tank is available, test specimens shall be molded in a test mold. In either case, prior testing shall verify that the tank wall and the test specimen have equal impact resistance.

11.1.1 The test mold shall be constructed of the same type material and have the same wall thickness as the tank mold. The thickness of the specimen from a test mold shall be the same as the thickness of the bottom sidewall within the tolerances as defined in 9.1.2. The test mold shall be molded with each tank.

11.2 *Conditioning*—If requested, test specimens shall be conditioned at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 40 h prior to testing in accordance with Procedure A of Practice D618.

11.3 *Low-Temperature Impact Test:*

11.3.1 *Scope*—This test method is for the determination of the impact property of rotational-molded polyethylene tanks at low temperature. The test method is used on tanks molded from both crosslinked and non-crosslinked polyethylenes.

11.3.2 *Summary of Test Method*—Test specimens are cut from available areas on the tank and conditioned at ~~−29°C~~ −29°C (−20°F) for a specified time. A suitable type of test apparatus is shown in Fig. 2 and Fig. 3. The specimens are placed, inside-surface down, in the sample holder and immediately impacted from a prescribed height with a dart of specified weight and tip radius. The specimen is observed for failure on both surfaces. The test prescribes a minimum impact value that the specimen must pass.

11.3.3 *Significance and Use:*

11.3.3.1 The dart impact test at −29°C (−20°F) produces a value that is used as an indication of the quality of the tank. If the molding conditions were inadequate and a homogenous melt was not obtained, the impact will likely be low. Higher impact values are obtained with ideal molding conditions indicating that a quality part with good impact resistance has been molded.
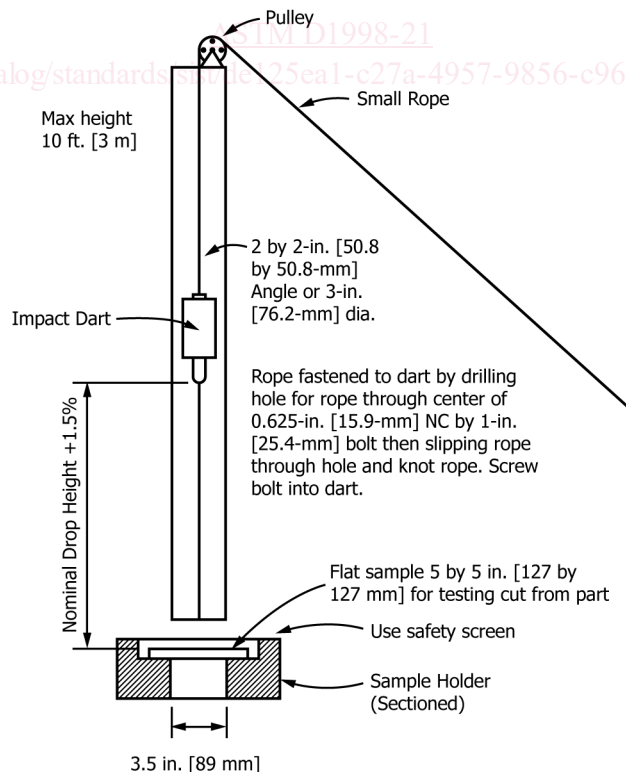
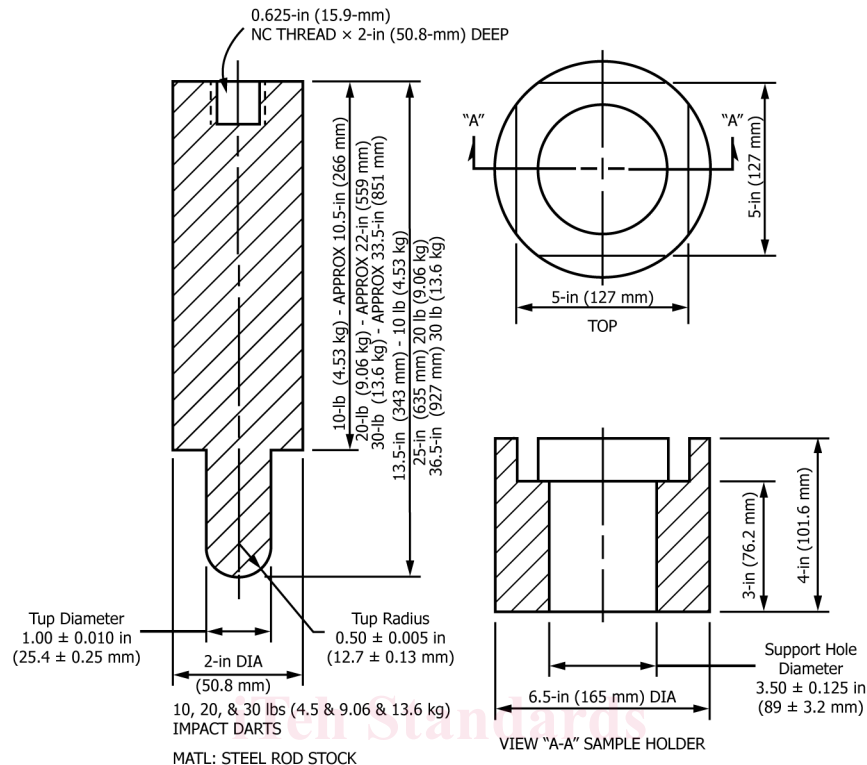

FIG. 2 Dart Drop Impact Test Apparatus

FIG. 3 Dart Drop Impact Test Apparatus

11.3.3.2 The impact test gives a true indication of how well the tank was molded.

11.3.4 *Procedure:*

11.3.4.1 Cut specimens to loosely fit the 127 mm by 127 mm (5 in. by 5 in.) sample holder (See Fig. 3). Specimens shall be approximately 127 mm by 127 mm (5 in. by 5 in.), or the maximum size available. In those tanks where specimens of the above size are not available, the supplier must show correlation data between the smaller size and the recommended size.

11.3.4.2 Cool bath ~~to −29°C~~to −29°C (−20°F) by immersing small quantities of dry ice in isopropyl alcohol used as the bath medium or chill the specimens in a freezer if available. (**Warning**—Care shall be exercised as the dry ice will agitate the solution violently.)

Note 5—An alternative temperature for impact ~~is −40°C~~is −40°C (−40°F) or, in some cases, the service temperature. In applications that have a service temperature ~~between −29°C~~between −29°C (−20°F) ~~and −40°C~~and −40°C (−40°F), either the service temperature ~~or −40°C~~or −40°C (−40°F) shall be used. For applications that have a service temperature ~~below −40°C~~below −40°C (−40°F), the impact temperature shall be at or below the service temperature.

11.3.4.3 Immerse the specimens in the bath for a minimum of 30 min while maintaining the bath temperature. More immersion time is required for specimens greater than 6.4 mm (0.25 in.) thick or for specimens chilled in air instead of alcohol. A minimum of two hours is required for air chilled specimens.

11.3.4.4 Remove specimens from the freezer or bath one at a time. Within five seconds, release the dart and impact each specimen on the outer surface. Use the impact energy specified in 8.1.1 as calculated by multiplying the nominal dart weight (known to ±1 %) by the drop height (Fig. 2). The specimen shall not fail at the specified impact energy (see 3.2.2 for the definition of failure). Whenever possible, choose a dart weight that permits the drop height to be between 0.8 and 2.3 m (2.5 and 7.5 ft) in order to minimize the effect of velocity on the result of the test.