Technical Training Document

ASTM D 1998 - 21

Standard Specification
for
Polyethylene Upright Storage Tanks

I. PURPOSE

The purpose of this document is to familiarize the reader with ASTM D 1998 - 21 and to emphasize its significance. This document is intended to serve as a supplement to the ASTM Standard and is not intended to preempt the requirements of that standard. ASTM D 1998 - 21 should be read in its entirety before applying this supplemental information.

II. REFERENCES

Standard Specification for Polyethylene Upright Storage Tanks, ASTM Designation D 1998 - 21, current edition Sept. 1, 2006, American Society for Testing and Materials, ASTM Committee D - 20 on Plastics, Subcommittee D20.15 on Thermoplastic Materials (Section D20.15.01).

Glossary of Terms, Association of Rotational Molders, 1986.

2014 Annual Book of ASTM Standards, Section 8 - Plastics

Tank Installation and Use Instructions, Poly Processing Co., page 3.

III. TEXT

Background Information on ASTM:

The American Society for Testing and Materials (ASTM) is a scientific and technical organization dedicated to "the development of standards on characteristics and performance of materials, products, systems, and services; and the promotion of related knowledge." The organization was founded in 1898 and is the world's largest source of voluntary consensus standards. The ASTM is an operational network of 157 primary technical committees and 1925 subcommittees. This structure exists to allow for a balanced representation among producers, users, and general interestparties.

The ASTM Designation:

The designation for the ASTM Standard Specification for Polyethylene Upright Storage Tanks is "D 1998 -21." The "D 1998" is a fixed designation and the "21" signifies either the year of original adoption or the year of latest revision. The year of latest reapproval is indicated by a number in parentheses while a superscript epsilon (ε) shows that an editorial change has occurred since the last revision or reapproval.

Breakdown of ASTM D 1998 - 21:

The ASTM D 1998 - 21 Standard is divided into 15 sections as follows:

1. Scope
2. Referenced Documents
3. Terminology
4. Classification
5. Materials
6. Design Requirements
7. Fittings
8. Performance Requirements
9. Dimensions and Tolerances
10. Workmanship
11. Test Methods
12. Marking
13. Packing, Packaging, Marking
14. Shipping
15. Keywords

These fifteen sections are further subdivided and in this training document the resulting subdivisions will be referred to as "sections" as well. For example, section 3.1 indicates the first subdivision of section 3 which is **Terminology**; section 10.2 indicates the second subdivision of section 10 which is **Workmanship**, etc.

Discussion of the 15 Subgroups:

1. Scope

This section of the ASTM Standard sets up the range of products covered by the standard with regard to the material of construction, manufacturing process, product application, and product size. The following chart groups products according to whether or not they fall into the scope of the ASTM Standard:

Products which are covered by the <u>ASTM Standard must be</u>:	Examples of products not covered by the <u>ASTM Standard</u>:
One-piece seamless tanks molded from polyethylene through the rotational molding process, <u>and</u>	Slope bottom tanks Rectangular tanks Horizontal tanks Underground tanks Agricultural tanks
flat bottom, cylindrical tanks for vertical above ground installation, <u>and</u>	General purpose tanks Tanks subject to vacuum conditions Tanks subject to higher than atmospheric pressure Tanks containing liquids above their flash points
tanks with capacities of 500 gallons and up	Type I tanks containing liquids above 150° Type II tanks containing liquids above 140° Tanks with capacities of less than 500 gallons

The **Scope** section covers several other points involving design, safety, and interpretation:

Design - The ASTM Standard states that the exposure of tanks to forces such as windload, seismic, agitation; service temperatures above 73.4º F; or pressure greater than 10 inches of water column (.36 psi) constitutes the need for special design considerations. Section 1.3 states that such considerations are not covered in the ASTM Standard and should be given to products subject to these conditions.

Safety - The ASTM Standard by purpose does not attempt to address the safety issues associated with the test methods mentioned in the **Test Methods** section. Furthermore, it is declared in the **Scope** section of the ASTM Standard that "it is the responsibility of the user of this standard" to set up proper safety and health guidelines for test practices.

Interpretation - Section 1.5 refers to the interpretation of impact values in the **Performance Requirements** section (section 8). Values are stated in foot-pounds with Joules (newton-meters) to the right in parentheses. Section 1.5 points out that the metric units of Joules are to observed as information only and that the U.S. units of foot-pounds are to be Interpreted as the actual standard. (NOTE: ASTM D 1998 - 21 uses the phrase "inch-pounds" in section 1.5. It should be noted that foot-pounds are given in section 8 as the standard for low-temperature impact.)

2. Referenced Documents

Section 2 lists the documents used as resources for the ASTM Standard D 1998 - 21. There are four subdivisions in section 2 and they exist to stratify the resources into the four organizations whose documents were used as reference material. The four organizations are as follows:

ASTM	American Society for Testing and Materials
OSHA	Occupational Safety and Health Administration
ANSI	American National Standards Institute
NFPA	National Fire Protection Association
ISO	International Organization for Standardization

3. Terminology

Section 3 defines terms used in the standard in accordance with reference documents ASTM D 883 and F 412, and the Association of Rotational Molders Glossary of Terms. The three terms defined in section 3 are *rotational molding*, *impact failure*, and *service factor* and the definitions given are as follows:

- Rotational Molding — 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.

- Impact Failure — any crack in the test specimen resulting from the impact and visible in normal room lighting to a person with normal eyesight.

- Service Factor — a number less than 1.0 (which takes into consideration all the variables and degrees of safety involved in a polyethylene storage tank installation) which is multiplied by the hydrostatic design basis to give the design hoop stress.

These definitions are specific to ASTM D 1998 - 21 and are established as operational definitions in order to allow readers of the ASTM Standard to be unified in their understanding of these terms. This attempts to eliminate interpretation errors caused by differences in perceptions that may occur between different readers.

4. Classification

Section 4 discusses the breakdown of tanks by the type of polyethylene used in their construction. The two classifications of tanks are Type I and Type II and are defined as follows:

- Type I — the classification name given to tanks molded from cross-linkable polyethylene.
- Type II — the classification name given to tanks molded from noncross-linkable polyethylene.

5. Materials

Section 5 describes the standards for the input material (resin). This section states that the polyethylene used in the production process is to be free from previous processing other than that required for the initial manufacturing of the resin. This standard prohibits the use of regrind or recycled material as an input material. Structural requirements for the polyethylene are also mentioned in this section in terms of stress- cracking resistance, test conditions, and guidelines for obtaining the test specimen. At the end of subdivision 5.1.1, the standard states that stress-cracking test specimens which are rotationally molded must be done so under conditions similar to that of the tanks which will be molded from this material. It is also pointed out in this section that stress-cracking resistance of the polyethylene is not an indicator of the material's general chemical resistance and that chemical resistance charts should be referred to for chemical resistance properties.

Subdivision 5.2 requires that tanks intended for outdoor applications have an ultraviolet stabilizer compounded in the polyethylene. Section 5.3 gives the maximum weight of pigment in terms of percentage of total weight. The maximum weight for dry blended pigment is given as .5% while 2% is the maximum given for pigment compounded into the polyethylene. A note in section 5.3 states that impact strength can be affected by using dry blended pigments.

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

This section addresses the design requirements for the cylinder shell, top head, top edge of open top tanks, and bottom head. In this section, the most emphasized aspect of the tank is its structural integrity as a function of necessary wall thickness. Wall thickness for the cylinder shell is determined by applying the following formula given in section 6.1:

$$T = \frac{P \times O.D.}{2\,SD} = \frac{0.433 \times S.G. \times H \times O.D.}{2\,SD}$$

where T = wall thickness, in. (mm)
SD = hydrostatic design stress, psi (MPa)
P = pressure (0.433 x S.G. x H), psi (MPa)
H = fluid head, ft. (m)
S.G. = specific gravity of fluid (g/cm^3)
O.D. = outside diameter, in. (mm)

The wall thickness (T) required for various portions on the tank shell is dependent upon the amount of ***application stress*** imposed to these portions and the ***design allowable hoop stress*** of the resin. Both of these design stresses are tensile stresses.

The ***application stress*** is dependent on the pressure (P) exerted on the tank wall by the design fluid. This pressure (P) is dependent on the density of the design fluid and the height of the fluid column (H) affecting the tank portion being considered. Design pressure (P) is determined by taking the pressure exerted by a one foot water column (0.433 psi) and multiplying it by the relative density of the design fluid (S.G.) and then by the height of the fluid column involved (H).

The ***design allowable hoop stress*** is dependent on the hydrostatic design basis and the service factor used. The hydrostatic design basis is dependent on the service temperature of the design fluid. Service temperatures above 73.4° F require downgrading of the maximum allowable hoop stress. The service factor is dependent on the wall thickness of the tank. For wall thicknesses greater than .375 inches, the maximum service factor is 0.475; for wall thicknesses less than .375 inches, the maximum service factor is 0.5. At Poly Processing, the design hoop stress for a 100° F service temperature is applied as a maximum hoop stress and is derated for service temperatures above 100° using a constant service factor of 0.475. The resulting design hoop stresses used in the wall thickness formula for various service temperatures are as follows:

Service Temperature	Design Hoop Stress
100° F	600 psi
110° F	550 psi
120° F	500 psi
150° F	450 psi
140° F	400 psi
150° F	300 psi

The following example illustrates the process of wall thickness determination through using the equation given in section 6.1:

Given: Service temperature of 100° F
Fluid specific gravity of 1.35
Maximum fluid height of 10 feet
Outside diameter of tank of 108 inches

$$T = \frac{P \times O.D.}{2\ SD} = \frac{0.433 \times S.G. \times H \times O.D.}{2\ SD}$$

therefore:

$$T = \frac{P \times 108}{2 \times 600} = \frac{0.433 \times 1.35 \times 10 \times 108}{2 \times 600}$$

$$T = \frac{P \times 108}{1200} = \frac{5.8455 \times 108}{1200} = \mathbf{.526\ in.}$$

The example calculation indicates that given a maximum service temperature of 100° F, the minimum required wall thickness for the unsupported tank shell exposed to a 10 ft. column of 1.35 S.G. fluid is .526 inches. In addition to supplying this wall thickness formula, section 6.1 states that wall thickness shall not be below .187 (3/16) inches at any point on the cylindrical shell of the tank (e.g. any fluid height). The remaining subdivisions of section 6 collectively state that neither the top head, bottom head, nor supported tank shell shall have a wall thickness less than .187 inches.

Section 6.4 calls for a minimum bottom head knuckle radius of 1 inch. Section 6.5 requires the top edge of open top tanks to be reinforced by design in order to maintain its shape after installation.

7. Fittings

This section addresses the requirement for chemical compatibility among fitting materials, the requirement for rounded corners on all holes cut in the tank, minimum sizes for venting, structural requirements for fittings, the need for hold down devices for outdoor tanks, and bolt circle compatibility requirements.

Venting is to be sized as no smaller than the larger of inlet and extraction sizes and no lower than 1" nominal inside diameter. Bolt circles are to comply with ANSI/ASME B-16.5 for 150 psi fittings.

8. Performance Requirements

Section 8 describes how the manufacturer tests for proper molding of both Type I and Type II tanks. Low-temperature impact tests are performed on Type I and Type II test samples to indicate the quality of the product. The minimum requirements for passing the low-temperature impact test are listed for various wall thicknesses in section 8.1.1.

Percent gel tests are performed on Type I samples to determine the amount of crosslinking present in the molded material. The ASTM D 1998 - 21 minimum requirement for percent gel is 60%.

These tests are discussed thoroughly in section 11.

9. Dimensions and Tolerances

Section 9 begins by stating that all dimensions are to be taken with the tank in the vertical position and unfilled. Tolerance for outside diameter and out of roundness is to be plus or minus 3%.

Section 9.1.3 gives the tolerance for wall thickness at the head and shell portions of the tank to be plus or minus 20% of the design thickness. This section goes on to say that the amount of tank area that is measured to be less than the design thickness is not to exceed 10% of the total tank area. Also, any individual low wall thickness area shall not exceed 1 square foot.

The tolerance for the placement of fittings is addressed in section 9.1.4 in terms of radial dimensions (degrees) and elevation (inches). The tolerance for fitting location elevation is plus or minus .5 inches and the tolerance for radial location is plus or minus 2° at ambient temperature. The radial tolerance of 2° can be easily translated into circumferential inches by multiplying the fraction 2/360 by the outside circumference of the tank in inches as follows:

> Given a tank with an outside diameter of 72 inches, the circumference at the outside wall of the tank is found by multiplying pi (ν) by the outside diameter (72 inches in this case):
>
> $$\nu \text{ x } 72 = 226.19 \text{ inches}$$
>
> Since 226.19 inches is the outside circumference of this tank, radial degrees for this tank can be equated as 360° = 226.19 inches. Furthermore, this can be reduced to .63 inches per degree making 2° approximately 1.25 inches.
>
> Multiplying 2/360 (.0056) by the outside circumference (226.19 inches) also gives the approximate value of 1.25 inches. Both of these approaches utilize the same concept of proportionality.

According to the ASTM Standard, the radial tolerance for a fitting being placed on this example tank would be plus or minus 1.25 inches at ambient temperature (e.g. a 2.5 inch range of possible locations for the fitting in question). While this would be within the technical range of acceptance according to the ASTM Standard, this may not be acceptable to the customer.

10. Workmanship

So far, the ASTM Standard has addressed many aspects of the product such as the definition of what products are covered, the quality requirements of the input material, and the design of the product. Sections 8 and 9 focused on measuring quality quantitatively with numerical methods. Section 10 focuses on measuring quality qualitatively with visual methods.

Type I tanks are required to be practically free from visual defects, foreign particles, bubbles, pinholes, pimples, crazing, cracks, and delaminations. These visible flaws are not only unattractive from the cosmetic standpoint but may also weaken the tank structurally. Type II tanks, according to section 10.1, are allowed to have the presence of fine bubbles as long as the bubbles do not interfere with proper fusion of the resin melt. Section 10.2 explains that different resins and different molding conditions may yield various interior surface characteristics; therefore, the level of finish quality is to be determined by the manufacturer and the buyer.

11. Test Methods

Section 11 gives a thorough description of the low-temperature impact tests for Type I and Type II tanks, percent gel determination for Type I tanks, visual inspections, and the water test. The significance behind performing the low-temperature impact test is to measure the quality of the molding process. By subjecting a test specimen to a specified level of impact energy, a relative measurement basis can be established for impact resistance. In this case, the standard is regarded as a certain value of foot-pounds of impact energy applied to the conditioned test specimen by an impact dart.

Accuracy and precision statements for the impact test method were obtained by issuing a round robin, which consisted of the shared experimental testing of two materials among seven participating laboratories. The information resulting from this method is used to measure variability within the labs and variability among the labs. This allows for determining the characteristics of repeatability and reproducibility (respectively) which are measures used to establish the approximate precision of the test method. Statements of test variability and confidence are given in section 11.3.6.2. This round robin was administered in 1988 and involved low-temperature impact tests performed at -40° F. Currently, a round robin is being conducted to provide test results at the ASTM required test temperature of -20° F.

The ASTM Standard calls for an impact dart to be dropped through either a 3" pipe or a 2" x 2" angle. The Poly Processing lab uses a twenty pound impact dart with a 3" pipe. To impose an impact of 90 foot-pounds (the minimum required impact value for wall thicknesses less than or equal to .25 in.) the twenty pound dart is dropped from 4.5 ft. The impact value is obtained by multiplying the weight of the dart by the distance dropped. Wall thicknesses greater than 1.00 in. must withstand an impact of 200 foot-pounds; therefore, the dart is dropped from 10 feet.

For cross-linkable samples, the gel test is administered in order to determine the amount of crosslinking present in the sample. The test specimen is first placed in a special container and weighed. While in the container, the specimen is then submerged in boiling o-xylene and the uncrosslinked material is dissolved. The resulting weight is compared to the original weight to determine the percentage of uncrosslinked material present in the sample. The sample values from the test specimen are then assumed to be reasonably accurate estimates of the amount of crosslinking present in the entire product. The minimum allowable gel percentage at Poly Processing is 60% as per ASTM.

Accuracy and precision statements for the percent gel test (referred to as the O-Xylene insoluble fraction) are given in section 11.4.10.2 and are based on a round robin administered 1989.

The third and fourth test methods described in section 11 are the visual inspection and water test. The visual inspection simply refers back to the **Workmanship** section where visually notable defects are defined. The **Workmanship** section states that these defects are not acceptable and the **Test Methods** section emphasizes the fact that a visual inspection is required to detect them. The implication here is that samples passing the gel test and the low-temperature impact test may come from a tank having these visual defects. The water test demonstrates the ability of the tank and its fittings to perform under hydrostatic pressure. Section 11.6 states that this test should occur at the time of installation before service by filling the tank completely with water. The duration of the water test is not specified in the ASTM Standard. Poly Processing hydrostatically tests tanks by filling them with water to straight wall capacity and allowing them to stand for one hour minimum; however, more time may be required by the customer. In the manual entitled Tank Installation and Use Instructions by Poly Processing Company, it is recommended that tanks be water tested in the field for 24 hour minimum before use.

12. Marking

Section 12 declares that the tank marking shall be permanent and indicate the producer, month and year of manufacture, capacity, design specific gravity, serial number, and classification of the tank as Type I or Type II.

Section 12.2 brings in OSHA standard 29 CFR 1970.106 which requires proper warning or caution signs to be placed on the tank in a visible manner. Section 12.3 states that tank capacities are to be based on total tank volume.

13. Packing, Packaging, and Marking

Section 15 references ASTM Practice D 3892 as the guidelines for the standard. A copy of ASTM Practice D 3892 is included at the back of this training document. ASTM Practice D 3892 supports the measures required in the **Shipping** section regarding the protection of products from shipping mishaps and offers more detail concerning appropriate procedures for packing and packaging. The scope of ASTM D 3892 includes packaging and packing of thermoset and thermoplastic resins and fabricated shapes.

14. Shipping

Section 14 addresses the maintaining of quality in the delivering of the product to the customer. Protection of open top tanks, flange faces, pipe and tubing, and fittings are to be adequately protected from scratches and damage during the shipping process. This statement requires the use of fitting protectors such as thread protectors for bolts and suitable plywood, hard-board, or securely fastened plastic for flange faces. Most of the statements given in section 14 exist as recommendations since shipping methods differ somewhat among manufacturers. Poly Processing utilizes the ability to place fittings inside tanks as a means of protection during shipping.

Section 14.5 lays out the responsibilities for the parties involved in the product transactions in the case of damage that occurs during shipping. The manufacturer's shipping instructions are to be followed and it is the purchaser's responsibility to visually inspect products for damage that may have occurred during transit. If damage occurs in shipping, the purchaser is responsible for filing a claim with the carrier. The purchaser should inform the supplier if the manufacturer does not repair the damage before the product is put into service. The purchaser is also responsible for any future "effects of the tank failure" resulting from shipping damage.

15. Keywords

Three keywords are mentioned in section 15 which represent the scope of ASTM D 1998 - 21. The words are:

polyethylene tanks upright

IV. SUMMARY OF KEY POINTS

A. ASTM D 1998 - 21 serves as a printed referential standard of quality for the producers of polyethylene upright storage tanks.

B. ASTM D 1998 - 21 should be read and understood in its entirety by all employees of the manufacturer to provide a consistent understanding of the pertinent minimum standards and thus facilitate quality control.

C. Some of the products of Poly Processing Company do not fall into the intended scope of ASTM D 1998 - 21. Products not falling into the scope of D 1998 – 21 are to be given the same level of quality considerations and, where applicable, the same minimum requirements should be imposed.