Designation: D4551 – 22

An American National Standard

Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Flexible Concealed Water-Containment Membrane[1]

This standard is issued under the fixed designation D4551; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers poly(vinyl chloride) (PVC) flexible sheeting which is used without mastic, bedding, or coating for construction of concealed water-containment-membranes in applications where there is potential for costly secondary damage from water leakage and very long-term reliable performance is essential. Examples are fountains, pools, planters, shower and safe pans, tile tubs, or similar wet installations where the membrane is inaccessible once the construction is complete. Included are requirements for materials and sheeting, test methods, workmanship criteria, and methods of marking.

1.2 Recycled materials may be used in this product in accordance with the requirements in Section 5.

1.3 The tests are intended to ensure quality and performance and are not intended for design purposes. Tests have been selected to be conducted primarily with liquids that simulate the environment to which the membrane will be subjected during actual use.

1.4 This specification does not cover water-containment membranes exposed to ultraviolet light.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 There is no known ISO equivalent to this standard.

1.7 The following precautionary caveat pertains only to the test method 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *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]

D374/D374M Test Methods for Thickness of Solid Electrical Insulation

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D1004 Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting

D1203 Test Methods for Volatile Loss from Plastics Using Activated Carbon Methods

D1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature

D1243 Test Method for Dilute Solution Viscosity of Vinyl Chloride Polymers

D1600 Terminology for Abbreviated Terms Relating to Plastics

D3892 Practice for Packaging/Packing of Plastics

E96/E96M Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials

2.2 *ANSI Standard:*

Z 26.1 Safety Code for Safety Glazing Materials for Glazing Motor Vehicles Operating on Land Highways[3]

2.3 *Military Standard:*

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes[4]

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.24 on Plastic Building Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—For definitions of terms that appear in this specification relating to plastics, refer to Terminology D883. For abbreviations that appear in this specification, refer to Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *water-containment membrane, n*—a non-porous membrane impervious to water and resistant to permeation by water vapor to an extent that it provides a high degree of certainty that secondary damage from leakage shall not occur.

3.2.2 *homogeneous sheeting, n*—sheeting that is of uniform composition throughout its thickness.

4. Classification

4.1 The sheeting will be subdivided by grades based on thickness:

4.1.1 *Grade 30*—0.03 in. (0.77 mm).

4.1.2 *Grade 40*—0.04 in. (1.02 mm).

5. Materials and Manufacture

5.1 This specification covers poly(vinyl chloride) (PVC) water-containment membrane formulated from PVC materials meeting the following requirements:

5.1.1 A PVC resin with an inherent viscosity (logarithmic viscosity number) of not less than 0.92 as determined by Test Method D1243.

5.1.2 A PVC compound density of 1.26/1.29 g/cm^3 .

5.2 Recycle materials, used in this product shall meet all the requirements in Sections 3, 5, 6, and 9.

5.3 The use of water-soluble compounding ingredients shall be prohibited.

5.4 Plasticizers that are resistant to migration, mildew, and bacterial degradation shall be used.

6. Physical Properties

6.1 The sheeting shall conform to the physical requirements prescribed in Section 9 (Table 1) and Section 15 (Table 2).

TABLE 2 Quality Assurance Requirements

Property	Unit	Specification Grade 30	Specification Grade 40
Thickness	in. (mm)	0.030 (0.765), min	0.040 (1.02), min
Pinholes	number	none	none
Shrinkage at 158°F	% of original	5 %, max	5 %, max
Width	in. (cm)	+0.5 (1.27), –0.0	+0.5 (1.27), –0.0

6.2 Sheeting shall be compounded so that bonds between sheets used in fabrication of large water-containment membranes can be accomplished in the field without reducing the overall resistance of the membrane to permeation or leakage or significantly reducing the sheeting's physical strength. The manufacturer shall specify recommended bonding procedures in its product literature.

6.3 The sheeting shall be monolithic and homogeneous.

7. Dimensions

7.1 Minimum thickness of Grade 30 sheeting shall be 0.03 in. (0.765 mm) and minimum thickness of Grade 40 sheeting shall be 0.04 in. (1.02 mm).

8. Workmanship

8.1 The sheet shall be inspected for appearance, thickness, width, and workmanship. The material shall be free of pin holes, foreign inclusions, undispersed materials, or other defects that could affect serviceability.

9. Qualification Tests

9.1 The PVC sheeting shall pass all the qualification tests prescribed in Section 11 and Table 1.

10. Sampling

10.1 Test specimens shall be selected at random from production stock. In each roll selected, units comprising the required number of specimens shall be taken from a portion not including the first or last foot of the roll or portions within 6 in. of the edge of the roll.

TABLE 1 Qualification Tests

Property	Unit	Specification	
		Grade 30	Grade 40
Thickness	in. (mm)	0.030 (0.765), min	0.040 (1.02), min
Tensile strength	lbf/in. (kN/m) of width	60 (10.45), min	80 (14.05), min
Tensile stress at 100 % elongation	lbf/in. (kN/m) of width	30 (5.23), min	40 (7.03), min
Elongation at break	%	300, min	300, min
Tear resistance	lbf/in. (kN/m) of width	185 (32.5), min	250 (43.7), min
Pinholes	number	none	none
Micro-organism resistance	specimen, pass/fail	12 of 12 pass	12 of 12 pass
Puncture resistance	specimen, pass/fail	6 of 6 pass	6 of 6 pass
Indentation resistance	specimen, pass/fail	3 of 3 pass	3 of 3 pass
Folding resistance	specimen, pass/fail	3 of 3 pass	3 of 3 pass
Chemical resistance			
Distilled H_2O	% weight change	+1 %, max	+1 %, max
Soapy H_2O	% weight change	+2 %, max	+2 %, max
Alkali	specimen, pass/fail	3 of 3 pass	3 of 3 pass
Hydrostatic pressure test	specimen, pass/fail	3 of 3 pass	3 of 3 pass
Shrinkage	% original	5 %, max	5 %, max
Volatile loss at 158°F	% loss	1.5 max	1.5 max

11. Test Methods

11.1 *Thickness*—Test five specimens obtained from locations equidistant across the width of the sheet in accordance with Method C of Test Methods D374/D374M. Report thickness of each specimen and location in sheet.

11.2 *Stress-Strain Properties*—Determine tensile stress at 100 % elongation (modulus), tensile strength, and ultimate elongation in accordance with Method A of Test Methods D412, using a dumbbell specimen (Die C). Report physical properties as the average value from testing of 6 specimens.

11.3 *Pinholes*—Examine sheeting for pinholes by viewing the surface of the sheeting while held under slight-hand tension. Position a bright light source behind the film so as to clearly illuminate the surface without producing glare in the observer's eyes. A pinhole is defined as any opening observed in the sheet under the conditions specified. Examine a 12-in. (305-mm) strip from the entire width of the sheet and report the presence or absence of pinholes.

11.4 *Resistance to Chemical Reagents*—Conduct this test in accordance with Test Method D543, Procedure 1.

11.4.1 Weigh loss after immersion in distilled water at 120°F (49°C) for 24 h.

11.4.2 Weigh loss after immersion in a 1 % soapy water solution at 120°F (49°C) for 24 h.

11.4.3 *Alkali Resistance Test*—This test indicates the effect of hot alkali solutions on the plastic membrane materials.

11.4.3.1 *Specimens*—Each test unit shall consist of three specimens of flat material 3 by 3 in. (76 by 76 mm) selected in accordance with 12.1.

11.4.3.2 *Procedure*—Make a solution by dissolving 5.0 g of reagent-grade sodium hydroxide and 5.0 g of reagent-grade potassium hydroxide in 1 L of distilled water in a beaker. The solution shall be maintained at a temperature of 150°F (66°C).

11.4.3.3 Immerse each specimen in its own individual beaker of solution in accordance with 11.4.3.2. Immerse the specimen for 72 h, and completely change the solution every 24 h. Before immersion of a specimen in the new solution, the solution shall be at a temperature of 150°F (66°C).

11.4.3.4 Test each specimen for waterproofness in accordance with 11.8 for hydrostatic pressure test.

11.5 *Microorganism Resistance Test*—Determine the resistance of PVC membrane to mold growth in accordance with Annex A1.

11.6 *Strength and Toughness Tests:*

11.6.1 *Puncture Resistance Test*—Determine the resistance of the material to mechanical damage which might occur during the installation of the water-containment membrane in accordance with the procedure described in Annex A2.

11.6.2 *Indentational Resistance Test*—Determine the ability of the material to withstand nail-head indentation without impairing waterproofness. Conduct the test in accordance with the procedure detailed in Annex A3.

11.6.3 *Folding Resistance Test*—Determine the ability of the material to withstand corner folding without impairing waterproofness in accordance with the procedure outlined in Annex A4.

11.7 *Shrinkage*—Test for 1 h at 158°F (70°C) in accordance with Test Method D1204.

11.8 *Hydrostatic Pressure Test*—Determine the ability of plastic membrane material to withstand water pressure without leaking in accordance with the test procedure in Annex A5.

11.9 *Tear Resistance*—Determine the average value for six specimens in accordance with Test Method D1004.

11.10 *Volatile Loss*—Determine volatile loss in accordance with Test Methods D1203, Method A. Test specimens shall be nominal thickness sheeting.

12. Conditioning

12.1 Condition all qualification test specimens at 73 ± 4°F (23 ± 2°C) and 50 ± 10 % relative humidity for not less than 40 h prior to testing, in accordance with Method A of Methods D618.

12.2 In-plant quality control specimens shall be conditioned at 73 ± 4°F (23 ± 2°C) for 2 h in air.

13. Product Marking

13.1 Material complying with this specification shall be continuously marked and shall include the following spaced out at intervals of not more than 2 ft (610 mm).

13.1.1 Manufacturer's name (or brand name or trademark).

13.1.2 Material designation.

13.1.3 Designation, Grade 30 or Grade 40, with which the sheet complies.

13.1.4 Designation, "ASTM D4551", with which the sheet complies.

13.1.5 The production code shall be included inside the core of all shipping units.

14. Packaging and Package Marking

14.1 The material shall be rolled on a substantial core and packaged in standard commercial containers, so constructed as to ensure acceptance by common or other carriers for safe transportation to the point of delivery.

14.2 All packing, packaging, and marking provisions of Practice D3892 shall apply to this specification.

15. Quality Assurance

15.1 Sheeting manufactured from compound qualified by Section 9 shall pass the quality assurance and control requirements prescribed in Table 2.

15.2 If the results of any tests do not conform to the requirements of this specification, retesting to determine conformity shall be performed.

16. Keywords

16.1 flexible sheeting; fountains; planters; pools; poly(vinyl chloride); PVC; recycle usage; shower and safe pans; tile tubs; water containment membrane; water leakage resistance; water permeation

SUPPLEMENTARY REQUIREMENTS

QUALITY ASSURANCE PROVISIONS FOR GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* Federal/Military procurement, not domestic sales or transfers.

S1. Selection of Acceptable Quality Level (AQL) and of Inspection Level (IL) shall be made with consideration of the specific use requirements. This is discussed in Sections 7 and 8 of the above document, with reference to MIL-STD-105.

S3. In the absence of contrary requirements the following values shall apply:

	IL	AQL
Defects in material and workmanship	II	2.5
Defects of preparation for delivery	S-2	2.5
Testing (products)	S-1	1.5
Testing (polymer, unfabricated)	S-1	...

ANNEXES

(Mandatory Information)

A1. MICROORGANISM RESISTANCE TEST

A1.1 *Specimens*—Each unit of specimens shall consist of twelve samples of material each 1½ by 1½ in. (38 by 38 mm) square, selected in accordance with 11.1.

A1.2 *Apparatus*, medium and test fungi.

A1.2.1 Apparatus shall consist of:

A1.2.1.1 *Autoclave,* capable of maintaining an interior temperature of 251 ± 4°F (122 ± 2°C) at a pressure of 15.5 ± 0.5 lb psig (107 ± 3.5 kPa) for the purpose of sterilizing glassware and the medium.

A1.2.1.2 *Erlenmeyer Flask,* 100-cm^2 capacity.

A1.2.1.3 *Glass Beads,* ¼ in. (6 mm) in diameter, 5 pieces.

A1.2.1.4 *Glass Pipettes,* two required.

A1.2.1.5 *Wire Loop,* of nichrome wire.

A1.2.1.6 *Petri Dishes* (4 in.) 10 cm in diameter with covers capable of being sealed with cellophane tape. One petri dish is required for each of the twelve samples comprising a test unit.

A1.2.1.7 *Incubation Chamber,* capable of maintaining a temperature of 84.5 ± 1.8°F (29± 1°C) and a relative humidity of at least 50 %.

A1.2.1.8 *Sterile Room,* dust-free, using sterilamps, antiseptic spray, or air filtration under pressure to maintain sterile conditions.

A1.2.2 *Test Fungi:*

A1.2.2.1 *Chaetomium globosum,* ATCC 6205.

A1.2.2.2 *Aspergillus niger,* ATCC 6275.

A1.2.3 *Medium*—A culture medium of the following composition:

NH_4NO_3	3.0 g
KH_2PO_4	2.5 g
$MgSO_47H_2O$	2.0 g
K_2HPO_4	2.0 g
Agar	20.0 g

Distilled water to make 1000 mL

Adjust the pH to a range from 6.4 to 6.8 with HCl or NaOH, as required. This is the base medium for both fungus cultures. However, the medium to be used for the Aspergillus niger shall be enriched by adding 30 g of brown sugar.

A1.3 *Procedure:*

A1.3.1 Prepare medium as specified in A1.2.3 and pour in the required number of petri dishes to a depth of ⅜ in. (9.5 mm).

A1.3.2 Sterilize in the autoclave, all of the apparatus in A1.2.1 including the medium contained in the petri dishes by retention in the autoclave at the temperature and pressure prescribed in A1.2.1.1 for 60 min. After sterilization, remove to sterile room of A1.2.1.8, taking care not to contaminate the sterilized equipment and medium. Use the sterile room for all preparation procedures.

A1.3.3 *Cultures, Stock and Substocks, and Inoculum:*

A1.3.3.1 Carefully maintain *Chaetomium globosum fungus stock cultures* on strips or squares of sterile porous filter paper, or blotting paper, on a sterilized culture medium as specified in A1.2.3 and A1.3.2. If there is evidence of contamination, promptly renew the culture. The culture may be kept for not more than four months in a refrigerator at approximately 37.5 to 50°F (3 to 10°C).

(1) Prepare subcultures from a stock culture by transferring spores from the stock culture to a sterilized covered petri dish containing sterilized medium. Incubate the subculture for a period of 7 to 21 days at 84.5 ± 1.8°F (29 ± 1°C) in the incubation chamber until in a ripe fruiting condition.

(2) Prepare inoculum by transferring the spores with the sterilized wire loop to a sterilized Erlenmeyer flask containing five sterilized glass beads and 10 mL of distilled water. Shake this mixture sufficiently to break up the spores, after which the solution shall be diluted to 200 mL.

A1.3.3.2 Carefully maintain *Aspergillus niger fungus stock cultures* as specified in A1.3.3.1 (*1*) on a medium as specified in A1.3.3.1.

(1) Prepare subcultures and incubate as in A1.3.3.1 (*1*) using a medium as specified in A1.3.3.1.

(2) Prepare inoculum as specified in A1.3.3.1 (*2*).

A1.3.4 Inoculate six specimens of each test unit as defined in A1.1 with each of the two varieties of fungi. Inoculate three with the face side up and three with the back side up.

A1.3.4.1 *Preparation*—Handle each specimen under aseptic conditions and sterilize by dipping in 70 % ethanol for a few seconds followed by a thorough rinse in distilled water after which place each firmly in the center of the solidified agar medium in its respective petri dish. Test six of the specimens with one fungi and six with the other. Of each subunit of six, test three with one surface in contact with the medium and three in contact with the opposite surface as stated under A1.3.4.

A1.3.4.2 Place controls in each petri dish along with the specimen. Each control shall be a strip of sterile blotting paper or filter paper placed on the agar separated from the specimen. The purpose of the control is to provide a medium for the fungi, thus proving that the fungi is active.

A1.3.4.3 Make inoculation with a particular fungus by using a sterile pipette individual to the fungus. With the pipette, distribute approximately 1.5 mL of inoculum over the specimen, the control, and the surrounding medium.

A1.3.5 Incubate the inoculated specimens for a period of 28 days at a temperature of 84.5 ± 1.8°F (29 ± 1°C) and a relative humidity of 90 %. An appropriate incubation condition is obtained by placing the covered and sealed petri dishes in a room or chamber maintained at 85°F (29.5°C) and 50 % relative humidity.

A1.3.6 *Results*—Reject test dishes with controls that do not exhibit a substantial growth of fungi after 7 days of incubation and start anew. Examine a unit test, the controls of which indicate a substantial fungus growth, after the required 28-day incubation period. If after this period any one of the specimens show evidence of evenly distributed or intense localized fungus growth under 16X magnification of either side of the sample (excluding growth overlapping the edges), the test sample shall be considered to have failed the test.

A1.3.6.1 Photographs of the specimen taken at the end of the 28 day incubation period are required as a part of the test on fungus resistance. Take each photograph with a scale laid beside the specimen to indicate its size, allowing the light conditions of the photographs to reveal the nature and height of the fungus growth on the surface of the material. Enlarge the photographs so the specimen will be a 6 by 6 in. (152 by 152 mm) size.

A2. PUNCTURE-RESISTANCE TEST

A2.1 *Specimens*—Six 10 by 10 in. (254 by 254 mm) pieces of material shall make up each test unit.

A2.2 *Apparatus:*[5]

A2.2.1 *Specimen Holder* (Fig. A2.1), shall consist of two 10 by 10 in. (254 by 254-mm) square pieces of ¾ in. (19 mm) smooth surface hard maple. One of these pieces shall contain a symmetrically located 6 by 6-in. (152 by 152-mm) opening in the center. Sandwich the specimen between two specimen holders, placing the holder with the opening on top. Three thumb screws or bolts located in the center of each side are used to securely clamp the specimen within the holder.

A2.2.2 *Impact Dart*—A7 ± 1-oz (196 to 201-g) steel dart as described in Fig. A2.2.

A2.3 *Procedure:*

A2.3.1 Test three specimens with one side up and three with the opposite side up.

A2.3.2 Place a single specimen between the holding frame halves and clamp securely by tightening the thumb screws. Suspend the impact dart vertically above the center of the specimen with a vertical distance of 3 ft (0.91 m) between the nose of the dart and the surface of the specimen.

A2.3.3 Release the dart for one free fall on each specimen.

A2.4 *Results:*

A2.4.1 Visible rupture of any specimens shall require rejection of the materials in accordance with 17.2.

A2.4.2 All specimens passing this test for rupture shall be further hydrostatically tested in accordance with 11.8 with the point of impact in the center of the test apparatus.

[5] Photographs of apparatus described are published in Federal Housing Administration Document 4900.1, Appendix D, available from the U.S. Department of Housing and Urban Development, 451 7th St., SW, Washington, DC 20410.