ASME NM.3.2-2022
(Revision of ASME NM.3.2-2020)

Nonmetallic Materials
Part 2 — Reinforced Thermoset Plastic Material Specifications

ASME Standards for Nonmetallic Pressure Piping Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

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FOREWORD

In 2011, The American Society of Mechanical Engineers (ASME) established the Committee on Nonmetallic Pressure Piping Systems (NPPS) to develop standards for the construction of nonmetallic pressure piping systems. This Committee's goal was to specify construction* requirements for nonmetallic piping and piping products; such requirements were not adequately defined in existing standards.

Prior to the development of the ASME Standards for Nonmetallic Pressure Piping Systems, nonmetallic pressure piping requirements were contained within several existing standards. The nonmetallic piping requirements of the ASME B31 Code for Pressure Piping varied across Sections, with some Sections having no requirements for nonmetallic components at all. Other standards and codes, such as ASME RTP-1 and the ASME Boiler and Pressure Vessel Code (BPVC), Section X, included requirements for reinforced thermoset plastic (RTP) corrosion-resistant equipment but not for piping and piping components. ASME BPVC, Section III did have a few Code Cases that addressed requirements for some nonmetallic piping and piping components, including those made from glass-fiber-reinforced thermosetting resin and a few thermoplastics, e.g., high density polyethylene (HDPE) and poly(vinyl chloride) (PVC). However, the scope of these Code Cases was very limited, and in some cases the methodology was nearly 30 years old. The ASME NPPS Standards now serve as a centralized location for NPPS requirements and are developed by committees whose members are experts in this field. The NPPS Committee's functions are to establish requirements related to pressure integrity for the construction of nonmetallic pressure piping systems, and to interpret these requirements when questions arise regarding their intent.

ASME and the American Society for Testing and Materials (ASTM International) have cooperated for more than 50 years in the preparation of material specifications adequate for safety in the field of pressure equipment. This cooperative effort originated with metallic materials in ASME BPVC, Section II.

The evolution of this cooperative effort is described in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953. The following quotations, which are based on the minutes of the ASME Boiler and Pressure Vessel Committee, are taken from Professor Greene's history and illustrate the cooperative nature of the specifications found in ASME BPVC, Section II, Material Specifications:

> "General discussion of material specifications comprising [Paragraphs] 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications." (1914)
>
> "An ASME Subcommittee . . . was appointed to confer with the American Society for Testing Materials." (1916)
>
> "Because of this co-operation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. . . . In the 1924 Edition of the Code, ten specifications were in complete agreement with ASTM specifications, four in substantial agreement, and two covered materials for which the American Society for Testing Materials had no corresponding specifications. . . .
> "In Section II, Material Specifications, the paragraphs were given new numbers, beginning with S-1 and extending to S-213." (1925)
>
> "Section II was brought into agreement with changes made in the latest ASTM specifications since 1921." (1932)
>
> "The Subcommittee on Material Specifications . . . arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM Specifications." (1935)

* *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, erection, examination, inspection, testing, and overpressure protection.

This cooperation has continued with the ASME NPPS Standards. ASME NM.3.1 and ASME NM.3.2 contain many material specifications that are similar to the corresponding ASTM specifications but that have been modified for use in accordance with an ASME construction standard.[**] Many of these specifications are published in dual format, i.e., they include both U.S. Customary units and SI units. The metrication protocols followed in the specifications are those adopted by ASTM, and they usually conform to the requirements of IEEE/ASTM SI 10-1997, Standard for the Use of the International System of Units (SI): The Modern Metric System.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of non-ASTM material for ASME BPVC applications with the intent that ASME's procedures and practices for the adoption of ASTM material be used for the adoption of non-ASTM materials. ASME committees continue to consider materials for use in ASME applications; see Mandatory Appendix IV for guidance on the approval of new materials.

ASME material specifications identical to those of the originating organization are identified by both the ASME symbol and the originating organization's symbol. The specifications prepared and copyrighted by ASTM and other originating organizations are reproduced in this Standard with the permission of the respective organization. The NPPS Committee has carefully considered each new and revised specification, and has made such changes as deemed necessary to adapt the specification for use in accordance with an ASME construction standard. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM and ASME specifications identical.

ASME NM.3.2-2020 was approved by the American National Standards Institute (ANSI) on October 29, 2020.

ASME NM.3.2-2022 was approved by the ANSI on September 15, 2022.

[**] ASME construction standards include the ASME B16 series of standards, the ASME B31 Code for Pressure Piping, ASME BPVC, ASME NM.1, ASME NM.2, and ASME RTP-1.

ASME NPPS COMMITTEE
Nonmetallic Pressure Piping Systems

(The following is the roster of the Committee at the time of approval of this Standard.)

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Revisions and Errata. The committee processes revisions to this Standard on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published in the next edition of the Standard.

In addition, the committee may post errata on the committee web page. Errata become effective on the date posted. Users can register on the committee web page to receive e-mail notifications of posted errata.

This Standard is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Standard.

(c) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number(s)

(4) the edition(s) of the Standard to which the proposed case applies

(d) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Approved cases are posted on the committee web page.

Interpretations. Upon request, the committee will issue an interpretation of any requirement of this Standard. An interpretation can be issued only in response to a request submitted through the online Interpretation Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic e-mail confirming receipt.

ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers can track the status of their requests at http://go.asme.org/Interpretations.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings. The NPPS Standards Committee regularly holds meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the committee. Information on future committee meetings can be found on the committee web page at https://go.asme.org/NPPScommittee.

SPECIFICATIONS LISTED BY MATERIALS

INTRODUCTION

The ASME Standards for Nonmetallic Pressure Piping Systems (NPPS) are as follows:

NM.1 Thermoplastic Piping Systems: This Standard contains requirements for piping and piping components that are produced using thermoplastic resins or compounds. Thermoplastics are a specific group of nonmetallic materials that, for processing purposes, are capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

NM.2 Fiber-Reinforced Thermosetting-Resin Piping Systems: This Standard contains requirements for piping and piping components that are produced using fiber reinforcement embedded in or surrounded by cured thermosetting resin.

NM.3 Nonmetallic Materials: This Standard includes specifications for nonmetallic materials (except wood, nonfibrous glass, and concrete) and, in conformance with the requirements of the individual construction standards, methodologies, design values, limits, and cautions on the use of materials. This Standard is divided into three Parts:

– NM.3.1, Nonmetallic Materials, Part 1 — Thermoplastic Material Specifications: This Part contains thermoplastic material specifications identical to or similar to those published by the American Society for Testing and Materials (ASTM International) and other recognized national or international organizations.

– NM.3.2, Nonmetallic Materials, Part 2 — Reinforced Thermoset Plastic Material Specifications: This Part contains reinforced thermoset plastic material specifications identical to or similar to those published by ASTM and other recognized national or international organizations.

– NM.3.3, Nonmetallic Materials, Part 3 — Properties: This Part provides tables and data sheets for allowable stresses, mechanical properties (e.g., tensile and yield strength), and physical properties (e.g., coefficient of thermal expansion and modulus of elasticity) for nonmetallic materials.

It is the owner's responsibility to select the piping standard that best applies to the proposed piping installation. Factors to be considered by the owner include limitations of the standard, jurisdictional requirements, and the applicability of other standards. All applicable requirements of the selected standard shall be met. For some installations, more than one standard may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the standard if such requirements are necessary to ensure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to the following:

ASME B31.1, Power Piping: This code contains requirements for piping typically found in electric power generating stations, industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems.

ASME B31.3, Process Piping: This code contains requirements for piping typically found in petroleum refineries; onshore and offshore petroleum and natural gas production facilities; chemical, pharmaceutical, textile, paper, ore-processing, semiconductor, and cryogenic plants; food- and beverage-processing facilities; and related processing plants and terminals.

ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries: This code contains requirements for piping transporting products that are predominately liquid between plants and terminals, and within terminals and pumping, regulating, and metering stations.

ASME B31.5, Refrigeration Piping and Heat Transfer Components: This code contains requirements for piping for refrigerants and secondary coolants.

ASME B31.8, Gas Transmission and Distribution Piping Systems: This code contains requirements for piping transporting products that are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines.

ASME B31.9, Building Services Piping: This code contains requirements for piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in ASME B31.1.

ASME B31.12, Hydrogen Piping and Pipelines: This code contains requirements for piping in gaseous and liquid hydrogen service, and pipelines in gaseous hydrogen service.

National Fuel Gas Code: This code contains requirements for piping for fuel gas from the point of delivery to the connection of each fuel utilization device.

NFPA 99, Health Care Facilities: This standard contains requirements for medical and laboratory gas systems.

NFPA Fire Protection Standards: These standards contain requirements for fire protection systems using water, carbon dioxide, halon, foam, dry chemicals, and wet chemicals.

The ASME NPPS Standards specify engineering requirements deemed necessary for safe design and construction of nonmetallic pressure piping. These Standards contain mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities. These Standards do not address all aspects of these activities, and those aspects that are not specifically addressed should not be considered prohibited. While safety is the overriding consideration, this factor alone will not necessarily govern the final specifications for any piping installation. With few exceptions, the requirements do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. These Standards are not design handbooks. Many decisions that must be made to produce a safe piping installation are not specified in detail within these Standards. These Standards do not serve as substitutes for sound engineering judgment by the owner and the designer. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of these Standards. Engineering judgments must be consistent with the philosophy of these Standards, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of these Standards.

To the greatest possible extent, Standard requirements for design are stated in terms of basic design principles and formulas. These are supplemented as necessary with specific requirements to ensure uniform application of principles and to guide selection and application of piping elements. These Standards prohibit designs and practices known to be unsafe and contain warnings where caution, but not prohibition, is warranted.

These Standards generally specify a simplified approach for many of their requirements. A designer may choose to use a more rigorous analysis to develop design and construction requirements. When the designer decides to take this approach, he or she shall provide to the owner details and calculations demonstrating that design, fabrication, examination, inspection, testing, and overpressure protection are consistent with the criteria of these Standards. These details shall be adequate for the owner to verify the validity of the approach and shall be approved by the owner. The details shall be documented in the engineering design.

The designer is responsible for complying with requirements of these Standards and demonstrating compliance with the equations of these Standards when such equations are mandatory. These Standards neither require nor prohibit the use of computers for the design or analysis of components constructed to the requirements of these Standards. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and for the application of these programs to their design.

These Standards do not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal, and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

Suggested requirements of good practice are provided for the care and inspection of in-service nonmetallic pressure piping systems only as an aid to owners and their inspectors.

The requirements of these Standards are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the requirements of these Standards.

It is intended that editions of the ASME NPPS Standards not be retroactive. Unless agreement is specifically made between contracting parties to use another edition, or the regulatory body having jurisdiction imposes the use of another edition, the latest edition issued at least 6 months prior to the original contract date for the first phase of activity covering a piping installation shall be the governing document for all design, materials, fabrication, erection, examination, inspection, testing, and overpressure protection for the piping until the completion of the work and initial operation. Revisions to material specifications included in ASME NM.3.1 and ASME NM.3.2 are originated by ASTM and other recognized national or international organizations, and are usually adopted by ASME. However, those revisions do not necessarily indicate that materials produced to earlier editions of specifications are no longer suitable for ASME construction. Both ASME NM.3.1 and ASME NM.3.2 include a Mandatory Appendix, "Guideline on Acceptable ASTM Editions," that lists the latest edition of material specifications adopted by ASME as well as other editions considered by ASME to be identical for ASME construction.

Users of these Standards are cautioned against making use of revisions to these Standards without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

The specifications for materials published in ASME NM.3.1 and ASME NM.3.2 are identical or similar to those published by ASTM and other recognized national or international organizations. When reference is made in an ASME material specification to a non-ASME specification for which a companion ASME specification exists, the reference shall be interpreted as applying to the ASME specification.

Not all materials included in the specifications in ASME NM.3.1 and ASME NM.3.2 have been approved for use in ASME construction. Use is limited to those materials and grades approved by at least one of the ASME construction standards* for application under its requirements. Material produced to an acceptable material specification is not limited as to country of origin.

* ASME construction standards include the ASME B16 series of standards, the ASME B31 Code for Pressure Piping, ASME BPVC, ASME NM.1, ASME NM.2, and ASME RTP-1.

ASME NM.3.2-2022
SUMMARY OF CHANGES

Following approval by the ASME NPPS Committee and ASME, and after public review, ASME NM.3.2-2022 was approved by the American National Standards Institute on September 15, 2022.

ASME NM.3.2-2022 includes no technical changes. The front matter has been updated.

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SPECIFCATION FOR CONTACT-MOLDED REINFORCED THERMOSETTING PLASTIC (RTP) LAMINATES FOR CORROSION-RESISTANT EQUIPMENT

SC-582

(Identical with ASTM C582-09(R16) except for revisions in paras. 2.1 and 8.1; addition of section 10 and Annex A1 through Annex A3.)

Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment

1. Scope

1.1 This specification covers composition, thickness, fabricating procedures, and physical property requirements for glass fiber reinforced thermoset polyester, vinyl ester, or other qualified thermosetting resin laminates comprising the materials of construction for RTP corrosion-resistant tanks, piping, and equipment. This specification is limited to fabrication by contact molding.

NOTE 1—The laminates covered by this specification are manufactured during fabrication of contact-molded RTP tanks, piping, and other equipment.

NOTE 2—There is no known ISO equivalent to this standard.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, 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.*

1.4 *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:*

C581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service

D638 Test Method for Tensile Properties of Plastics

D695 Test Method for Compressive Properties of Rigid Plastics

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D883 Terminology Relating to Plastics

D2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

D2584 Test Method for Ignition Loss of Cured Reinforced Resins

D3039 Test Methods for Tensile Properties of Polymer Matrix Composite Materials

D3681 Test Method for Chemical Resistance of “Fiberglass” (Glass–Fiber–Reinforced Thermosetting-Resin) Pipe in a Deflected Condition

E84 Test Method for Surface Burning Characteristics of Building Materials

3. Definitions

3.1 Definitions used in this specification are in accordance with Terminology D883 unless otherwise indicated. The abbreviation for reinforced thermoset plastic is RTP.

3.2 *polyester*—resins produced by the polycondensation of dihydroxyderivatives and dibasic organic acids or anhydrides, wherein at least one component contributes ethylenic unsaturation yielding resins that can be compounded with styryl monomers and reacted to give highly crosslinked thermoset copolymers.

3.3 *vinyl ester*—resins characterized by reactive unsaturation located predominately in terminal positions that can be compounded with styryl monomers and reacted to give highly crosslinked thermoset copolymers.

NOTE 3—These resins are handled in the same way as polyesters in fabrication of RTP components.

3.4 *contact molding*—a method of fabrication wherein the glass-fiber reinforcement is applied to the mold, in the form of chopped strand mat or woven roving, by hand or from a reel, or in the form of chopped strands of continuous-filament glass from a chopper-spray gun. The resin matrix is applied by various methods, including brush, roller, or spray gun. Consolidation of the composite laminate is by rolling.

4. Classification

4.1 Laminates shall be classified according to type, class, and grade.

4.1.1 *Type*—In Roman numerals, shall designate the reinforcement structure comprised of specific plies of glass fiber in specific sequences.

4.1.1.1 *Type I*—A standard all-mat or chopped-roving construction, or both, as shown in Table 1.

4.1.1.2 *Type II*—A standard mat or chopped-roving and woven-roving construction, or combination thereof, as shown in Table 2.

4.1.1.3 Other types, such as standard mat or chopped roving with alternating layers of nonwoven biaxial or unidirectional reinforcement in the structured plies. may be qualified in accordance with Appendix X2.

4.1.2 *Class*—In capital letters, shall designate the generic resin: "P" for polyester and "V" for vinyl ester. The letters "FS" followed by parenthesis, "FS( )," shall designate fire retardancy, if specified, with maximum flame spread in the parentheses in accordance with Test Method E84.

NOTE 4—Fire retardancy by Test Method E84 is determined for 0.125-in. (3.175-mm) thick, flat laminates with all-mat glass content of 25 to 30 %.

NOTE 5—Maximum flame spread designation by Test Method E84 relates to measurement and description of the properties of materials, products, or systems in response to heat and flame under controlled laboratory conditions and should not be considered or used for the description or appraisal of the fire hazard of materials, products, or systems under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment that takes into account all the factors that are pertinent to an assessment of the fire hazard or a particular end use.

4.1.3 *Grade*—In Arabic numerals, shall designate the minimum physical property levels of a laminate at 73.4 ± 3.6°F (23 ± 2°C).

NOTE 6—The five Arabic grade numbers designate minimum physical property levels of a laminate obtained from tests of representative production process samples. They are not arbitrarily selected values.

4.1.4 *Thickness*—Nominal, shall be designated by Arabic number in decimal hundredths of an inch. (See Table 1 and Table 2 for standard thicknesses.)

NOTE 7—Table 1 and Table 2 are for reference purposes and do not preclude other laminate-type constructions, such as nonwoven biaxial or unidirectional fabric, which may be agreed upon between the buyer and the seller, or may be added to this specification if they have been fully identified and characterized, as shown in Appendix X2.

4.1.5 *Classification Requirements for Different Laminates*—Laminate designation from Table 3 shall consist of the abbreviation RTP followed by (*1*) type in Roman numerals; (*2*) class in capital letters followed by FS( ) if required; (*3*) grade consisting of five Arabic numbers to designate minimum levels of physical properties and (*4*) thickness designated by Arabic number in decimal inches (or ALL, if properties apply to all thicknesses).

4.1.5.1 *Examples:*

(*1*) RTP I 1 ALL, designates Type I polyester laminate, non-fire-retardant Grade 13211, having the following minimum physical property levels (see Table 3):

TABLE 1 Standard Laminate Composition Type I[A]

Calculated Thickness[BC] in.	Calculated Thickness[BC] (mm)	Corrosion Barrier[D] 1	2	3	Structural Plies[E] Number and Sequence of Plies 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Drafting Symbols
0.18	(4.6)	V	M	M	M	M														V, 4M
0.23	(5.8)	V	M	M	M	M	M													V, 5M
0.27	(6.9)	V	M	M	M	M	M	M												V, 6M
0.31	(7.9)	V	M	M	M	M	M	M	M											V, 7M
0.35	(8.9)	V	M	M	M	M	M	M	M	M										V, 8M
0.40	(10.2)	V	M	M	M	M	M	M	M	M	M									V, 9M
0.44	(11.2)	V	M	M	M	M	M	M	M	M	M	M								V, 10M
0.48	(12.2)	V	M	M	M	M	M	M	M	M	M	M	M							V, 11M
0.53	(13.5)	V	M	M	M	M	M	M	M	M	M	M	M	M						V, 12M
0.57	(14.5)	V	M	M	M	M	M	M	M	M	M	M	M	M	M					V, 13M
0.61	(15.5)	V	M	M	M	M	M	M	M	M	M	M	M	M	M	M				V, 14M
0.66	(16.8)	V	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M			V, 15M
0.70	(17.8)	V	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M		V, 16M
0.74	(18.8)	V	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	V, 17M

[A] Glass content, weight, % = 25 to 30, all thickness.
[B] Calculated thickness for design purposes is determined as follows:
V = Surfacing mat – 0.010 in./ply (0.25 mm/ply) when saturated with resin.
M = 1 ½ oz/ft^2 (459 g/m^2) mat – 0.043 in./ply (1.1 mm/ply) when saturated with resin.
[C] The thickness shall be not less than 90 % of the calculated thickness shown.
[D] Corrosion barrier (Plies 1, 2, and 3) shall gel before structural plies are added.
[E] Structural lay-up may be interrupted at intervals long enough to exotherm if required by the laminate manufacturing procedure and 6.3.1.

TABLE 2 Standard Laminate Composition Type II

Calculated Thickness[A,B]		Glass Content (weight, %)	Corrosion Barrier[C]			Structural Plies[D] Number and Sequence of Plies																		Drafting Symbols
in.	(mm)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
0.22	(5.6)	28 to 33	V	M	M	M	R	M																V, 2M, MRM
0.29	(7.4)	30 to 35	V	M	M	M	R	M	R	M														V, 2M, 2(MR)M
0.37	(9.4)	30 to 35	V	M	M	M	R	M	R	M	R	M												V, 2M, 3(MR)M
0.41	(10.4)	30 to 35	V	M	M	M	R	M	R	M	R	M	M											V, 2M, 3(MR)M, M
0.49	(12.5)	34 to 38	V	M	M	M	R	M	R	M	R	M	M	R	M									V, 2M, 3(MR)M, MRM
0.57	(14.5)	34 to 38	V	M	M	M	R	M	R	M	R	M	M	R	M	R	M							V, 2M, 3(MR)M, 2(MR)M
0.64	(16.3)	37 to 41	V	M	M	M	R	M	R	M	R	M	M	R	M	R	M	R	M					V, 2M, 3(MR)M, 3(MR)M
0.69	(17.5)	37 to 41	V	M	M	M	R	M	R	M	R	M	M	R	M	R	M	R	M	M				V, 2M, 3(MR)M, 3(MR)M,M
0.76	(19.3)	37 to 41	V	M	M	M	R	M	R	M	R	M	M	R	M	R	M	R	M	M	R	M		V, 2M, 3(MR)M, 3(MR)M, MRM

[A] Calculated thickness for design purposes is determined as follows:
V = Surfacing mat – 0.010 in./ply (0.25 mm/ply) when saturated with resin.
M = 1 ½ oz/ft^2 (459 g/m^2) mat = 0.043 in./ply (1.1 mm/ply) when saturated with resin.
R = 24½ oz/yd^2 (832 g/m^2) 5 × 4 woven roving = 0.033 in./ply (0.84 mm/ply) when saturated with resin.
[B] The thickness shall be not less than 90 % of the calculated thickness shown.
[C] Corrosion barrier (Plies 1, 2, and 3) shall gel before structural plies are added.
[D] Structural lay-up may be interrupted long enough to exotherm following an "M" ply, if required by the laminate manufacturing procedure. Location of exotherm plies may be shifted within the laminate body. No plies may be omitted. Refer to 6.3.1.

TABLE 3 Classification System for Hand Lay-up Laminates Using Minimum Property Values[A]

Classification Order RTP followed by:											
(1)	Type	I	II	III	IV	V					
(2)	Class	P Polyester	V Vinylester	. . .	. . .	. . .		followed by FS ( ), if specified with flame spread in parentheses in accordance with Test Method E84			
					Physical and Mechanical Properties						
(3)	Grade	1	2	3	4	5	6	7	8	9	0
1st Digit:	Tensile strength, ultimate psi × 10^3	9	11	13	15	17.5	20	. . .	. . .	. . .	. . .
	(MPa)	(62)	(76)	(90)	(104)	(121)	(138)	. . .	. . .	. . .	. . .
2nd Digit:	Tensile modulus, tangent psi × 10^3	0.85	0.95	1.05	1.15	1.3	1.5	1.75	2.0	. . .	. . .
	(MPa)	(5 863)	(6 552)	(7 242)	(7 932)	(8 966)	(10 346)	(12 070)	(13 794)	. . .	. . .
3rd Digit:	Flexural strength, ultimate psi × 10^3	16	18	20	22	24	. . .	. . .	. . .	. . .	. . .
	(MPa)	(110)	(124)	(138)	(152)	(166)	. . .	. . .	. . .	. . .	. . .
4th Digit:	Flexural modulus, psi × 10^6	0.7	0.85	1.0	1.15	1.3	1.5	. . .	. . .	. . .	. . .
	(MPa)	(4 828)	(5 863)	(6 897)	(7 932)	(8 966)	(10 346)	. . .	. . .	. . .	. . .
5th Digit:	Glass content, by weight, %	25	28	30	34	37	40	44	. . .	. . .	. . .

[A] Table will be completed as new resins and higher strength laminates become available.

Tensile strength, ultimate—9000 psi (62 MPa).
Tensile modulus—1 050 000 psi (7242 MPa).
Flexural strength, ultimate—18 000 psi (124 MPa).
Flexural modulus—700 000 psi (4828 MPa).
Glass content—25 %.
Thickness—"ALL" thicknesses.

(2) RTP II P FS(25) 55433.30, designates Type II, polyester fire-retardant resin laminate with a maximum flame spread of 25, Grade 55433 having the following minimum physical property levels (see Table 3):

Tensile strength, ultimate—17 500 psi (121 MPa).
Tensile modulus—1 300 000 psi (8966 MPa).

Flexural strength, ultimate—22 000 psi (152 MPa).
Flexural modulus—1 000 000 psi (6897 MPa).
Glass content—30 %.
Thickness—0.30 in. (7.62 mm).

5. Materials

5.1 *Resin Matrix System:*

5.1.1 The resin shall be determined to be acceptable for the service either by test, see 8.6, or by verified case history.

5.1.2 *Catalyst/Promoter System,* shall be as recommended or approved by the resin producer.

5.1.3 *Diluents,* such as added styrene, fillers, dyes, pigments, or flame retardants shall be used only when agreed upon between the fabricator and the buyer. When such items are required, limits for each shall be agreed upon between the fabricator and the buyer. A thixotropic agent may be added to the resin for viscosity control.

NOTE 8—The addition of fillers, dyes, pigments, flame retardants, and thixotropic agents may interfere with visual inspection of laminate quality.

NOTE 9—Chemical resistance can be significantly affected by the catalyst/promoter system, diluents, dyes, fillers, flame retardants, or thixotropic agent used in the resin.

5.1.4 *Resin Pastes,* used where necessary to fill crevices formed by joining subassemblies before overlay shall not be subject to the limitations of 5.1.3. Pastes shall be made with thixotropic agents.

5.1.5 *Ultraviolet Absorbers,* may be added to the exterior surface for improved weather resistance when agreed upon between the fabricator and the buyer.

5.2 *Fiber Reinforcement:*

5.2.1 *Surfacing Mat (veil)* is a thin mat of fine fibers used primarily to produce a smooth surface on a reinforced plastic.

5.2.1.1 Veil shall be determined to be acceptable for the service either by Test Methods C581 or D3681, or by a verified case history.

5.2.1.2 Requirements of acceptable surface veils are:

(a) Resin compatibility,

(b) Uniform fiber distribution,

(c) Single filaments (not bundled),

(d) The thickness shall be a minimum of 10 mils per ply when saturated with resin, and

(e) Minimum fiber length shall be 0.5 in.

NOTE 10—The chemical resistance of the RTP laminate is provided by the resin. In combination with the cured resin, the surfacing veil helps determine the thickness of the resin-rich layer, reduces microcracking, and provides a nonwicking chemically resistant layer.

Additional desirable considerations in choosing a veil for a specific application include:

(a) Drapability (surfacing veil should conform to mold shape),

(b) Dry and wet tensile strength,

(c) Binder solubility (if used),

(d) Wetability,

(e) Surfacing veil shall wet-out completely without trapping air during laminating, and

(f) Surfacing veil should not inhibit resin cure.

5.2.2 *Chopped-Strand Mat,* shall be "E" or "ECR" type glass fiber, 1½ oz/ft^2 (459 g/m^2), with sizing and binder compatible with the resin.

5.2.3 *Woven Roving,* shall be "E" or "ECR" type glass, 24½ oz/yd^2 (832 g/m^2), 5 by 4 square weave fabric having a sizing compatible with the resin.

5.2.4 *Roving,* used in chopper guns for spray-up application, shall be "E" or "ECR" type glass with sizing compatible with the resin.

5.2.5 *Other Reinforcements,* such as nonwoven biaxial or unidirectional fabric. These products shall be a commercial grade of "E" or "ECR" type glass fiber with a sizing that is compatible with the resin.

5.3 *Laminates:*

5.3.1 Laminate construction shall be in accordance with the tabulated lay-up sequence for the specified type.

5.3.2 *Type I,* laminate structure is detailed in Table 1.

5.3.3 *Type II,* laminate structure is detailed in Table 2.

6. Laminate Fabrication

6.1 Apply the catalyzed resin to a mold or mandrel properly prepared with a parting agent or film suitable for the lay-up resin. Next apply the specified surface mat, rolling so as to draw the resin through the mat for thorough wet-out and deaeration.

6.2 Apply resin and two plies of 1½-oz (42.6-g) mat. As an alternative, a minimum of two passes of chopped roving (minimum fiber length 1 in. (25.4 mm) and resin may be applied by the spray-up process equivalent in weight and thickness to 3 oz/ft^2 (918 g/m^2) of chopped mat. Each pass of chopped roving or ply of chopped-strand mat shall be thoroughly rolled out. This section of the laminate shall be allowed to exotherm prior to application of subsequent plies of reinforcement.

6.3 Continue lay-up in the sequence of plies, tabulated for the specified laminate type. Roll each ply for thorough wet-out and deaeration.

6.3.1 Interruption of laminate construction for exotherm shall follow instructions noted on Table 1 and Table 2 for the particular laminate type. The final ply of reinforcement before interruption for exotherm shall be 1½-oz/ft^2 (459-g/m^2) mat or chopped roving equivalent. The initial ply of the following lamination shall be 1½-oz/ft^2 mat or chopped roving equivalent.

6.4 The outer surface of the fabricated laminate shall be smooth and free of exposed glass fibers. The final ply shall be mat or chopped roving equivalent. A surfacing mat is not required unless specified. Surface resin may require the addition of paraffin or may be sealed with overlaid film, as required or approved by the resin producer, to ensure proper surface cure.

6.4.1 When pigmentation is specified, the pigment shall be incorporated only in the resin used to lay-up the final laminate ply.

6.5 All edges of reinforcement material except surfacing mat shall be lapped 1-in. (25.4-mm) minimum. Lapped edges of adjacent layers shall be staggered. Surfacing mat shall be butted together or have overlaps no more than ½ in. (12.7 mm). Gaps are not permitted.

7. Physical and Mechanical Properties

7.1 The composition and sequence requirements for Type I and II laminates are shown in Table 1 and Table 2.

7.2 The mechanical property requirements for Type I and II laminates are shown in Table 4.

7.3 Physical properties of each type and grade of laminate shall be established on flat laminates prepared under shop conditions. In Type II laminates the woven roving is to be laid square, and test specimens are to be cut parallel to the warp rovings.

7.3.1 Test specimens cut from fabricated equipment usually are not parallel to warp rovings. Interpretation of mechanical property data obtained from such specimens is discussed in Appendix X1.

8. Test Methods

8.1 *Tensile Strength and Tangent Modulus of Elasticity*—Test Method D638 or D3039.

8.1.1 Specimens shall be in accordance with Type III, Fig. 1 of Test Method D638 for all laminate thicknesses.

8.2 *Flexural Strength and Tangent Modulus of Elasticity*—Test Methods D790, Method I, Procedure A, and Table 1, 1/*d* = 16 to 1.

8.2.1 Specimens shall be the full thickness of the laminate as fabricated.

8.2.2 The loading nose shall be applied to the inner face of the laminate specimen.

8.3 *Glass Content*—Test Method D2584.

8.3.1 The residual, undisturbed glass-fiber plies from the ignition shall be separated carefully and counted to confirm standard lay-up sequence.

8.4 *Thickness* shall be measured with a ball-foot micrometer.

8.5 *Hardness*—Test Method D2583.

8.6 *Chemical Resistance*—Test Method C581.

8.6.1 Exposure tests under plant operating conditions shall employ Test Method C581 standard test laminate samples.

NOTE 11—Thicker laminates shall not be used for such tests, as results will vary significantly compared to exposure of standard samples in Test Method C581.

8.7 *Surface Flame-Spread Classification*—Test Method E84.

9. Workmanship and Finish

9.1 The finished laminate shall conform to visual acceptance criteria of Table 5.

9.2 The surface exposed to the chemical environment (process side) shall be smooth, resin-rich, and fully cured. The exterior surface shall also be fully cured.

9.2.1 The degree of cure shall be measured by a Barcol hardness test in accordance with Test Method D2583. At least 80 % of the random readings shall exceed at least 90 % of the resin manufacturer's recommended hardness for the cured resin.

9.2.2 Potential air-inhibited, undercured surfaces (both interior secondary lamination and exterior non-mold surfaces) shall be tested using an acetone sensitivity test. Four to five drops of acetone rubbed with a finger on the laminate surface, free of mold release, wax, dust, or dirt, until it evaporates, will not result in surface softness or tackiness.

10. Certification

10.1 See Annex A1 for certification requirements.

11. Keywords

11.1 contact molded; corrosion-resistant equipment; glass-fiber-reinforced; laminate; reinforced thermosetting plastic (RTP); thermoset polyester resin; thermoset vinyl ester resin

TABLE 4 Standard Laminate Properties

Calculated Thickness,[A] in. (mm)	Type	Mechanical Properties, min, psi (MPa)[C]				
		Tensile[B]		Flexural[D]		Edge Compression[E]
		Ultimate Stress × 10^{-3} (MPa)	Modulus × 10^{-6} (MPa)	Ultimate Stress × 10^{-3} (MPa)	Modulus × 10^{-6} (MPa)	Ultimate Stress × 10^{-3} (MPa)
ALL	I	9.0 (62)	0.85 (5862)	16.0 (110)	0.7 (4828)	16 (110)
0.22 (5.6)	II	12.0 (83)	0.9 (6207)	19.0 (131)	0.8 (5518)	16 (110)
0.30 (7.6)	II	13.5 (93)	1.1 (7587)	20.0 (138)	0.9 (6207)	18 (124)
0.37 (9.4) and up	II	15.0 (104)	1.2 (8276)	22.0 (152)	1.0 (6897)	20 (138)

[A] The thickness shall be not less than 90 % of the calculated thickness shown.
[B] Test Method D638.
[C] Barcol hardness should be 90 % (minimum) of cast resin hardness.
[D] Test Method D790.
[E] Test Method D695.

TABLE 5 Visual Acceptance Criteria

Visual Observation	Surface Inspected	
	Process Side	Nonprocess Side
Cracks	None	None
Crazing (fine resin-rich surface cracks)	None	Maximum dimension 1 in. (25.4 mm). Maximum density 5/ft^2 (0.1 m^2).[A]
Blisters (rounded elevations of the laminate surface over bubbles)	None	Maximum ¼ -in. (6.4-mm) diameter by ⅛ in. (3.2 mm) high. Maximum 2/ft^2 (2/0.1 m^2).[A]
Wrinkles and solid blisters	Maximum deviation, 20 % of wall thickness, but not exceeding ⅛ in. (3.2 mm).[A]	Maximum deviation, 20 % of wall thickness, but not exceeding 3⁄16 in. (4.8 mm).[A]
Pits (craters in the laminate surface)	Maximum dimensions, ⅛ -in. (3.2-mm) diameter by 1⁄32 in. (0.8 mm) deep. Maximum number 10/ft^2 (10/0.1 mm^2).[A]	Maximum dimension ⅛ -in. (3.2-mm) diameter by 1⁄16 in. (1.6 mm) deep. Maximum density 10/ft^2 (10/0.1 m^2).[A]
Surface porosity, pin holes, or pores in the laminate	Maximum dimensions, 1⁄16 -in. (1.6-mm) diameter by 1⁄32 in. (0.8 mm) deep. Maximum number 20/ft^2 (20 ⁄0.1 m^2) by 1⁄16 in. (1.6 mm). Must be resin-rich.[A]	Maximum dimension 1⁄16 -in. (1.6-mm) diameter by 1⁄16 in. deep. Maximum number 20/ft^2 (20/0.1 m^2). Must be resin-rich.[A]
Chips (small piece broken from edge or surface)	Maximum dimensions, ⅛ -in. (3.2-mm) diameter by 1⁄32 in. (0.8 mm) deep. Maximum number 1/ft^2 (1/0.1 m^2).[A]	Maximum dimension ¼ -in. (6.4-mm) diameter by 1⁄16 in. (1.6 mm) deep. Maximum number 5/ft^2 (5/0.1 m^2).[A]
Dry spot (non-wetted reinforcing)	None	Maximum dimensions 2 in.^{2} (13 cm^2) per ft^2 (0.1 m^2).[A]
Entrapped air (bubbles or voids or delaminations in the laminate)	Maximum diameter 1⁄16 in. (1.6 mm), 10/in.^{2} (10 ⁄6.5 cm^2) maximum density. Maximum diameter ⅛ in. (3.2 mm), 2/in.^{2} (2/6.5 cm^2) maximum density. Maximum depth of 1⁄32 in. (0.8 mm).[AB]	Maximum diameter 1⁄16 in. (1.6 mm). 10/in.^{2} (10 ⁄6.5 cm^2) maximum density. Maximum diameter ⅛ in. (3.2 mm), 2/in.^{2} (2/6.5 cm^2) maximum density. Maximum diameter 3⁄16 in. (4.8 mm), 2/ft^2 (2/0.1 m^2). Maximum density.[AB]
Exposed glass	None	None
Burned areas	None	None
Exposure of cut edges	None[C]	None[C]
Scratches	None over 0.005 in. deep and 4 in. long	Maximum length 12 in. (3.5 mm). Maximum depth 0.010 in. (0.25 mm) 2/ft^2 (2/0.1 m^2), maximum density.[A]
Foreign matter	None	⅛-in. (3.2-mm) diameter, maximum density 1/ft^2 (1 ⁄0.1 m^2). 3⁄16 -in. (4.8-mm) diameter, maximum density 1/ft^2 (1/0.1 m^2).[AD]

[A] Maximum 5 % of total surface area affected.
[B] Entrapped air or bubbles described are allowed, provided the surface cannot easily be broken with a pointed object, such as a knife blade.
[C] Cut edges must be covered with resin.
[D] Foreign matter must not penetrate the surface and must not contribute to entrapped air or other defects not allowed.

ANNEXES

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

A2. ALTERNATIVE TO TABLE 1

TABLE A2.1 Alternative to TABLE 1 Standard Laminate Composition Type [A]

Calculated Thickness		Corrosion Barrier [C]			Minimum Number of Mat Layers in the Structural Wall [E]		
Laminate [B,C] Thickness					Mat Designation		
in.	(mm)				1.5 oz	1.0 oz	0.75 oz
0.18	(4.6)	V	M	M	2	3	4
0.23	(5.8)	V	M	M	3	5	6
0.27	(6.9)	V	M	M	4	6	8
0.31	(7.9)	V	M	M	5	8	10
0.35	(8.9)	V	M	M	6	9	12
0.40	(10.2)	V	M	M	7	11	14
0.44	(11.2)	V	M	M	8	12	16
0.48	(12.2)	V	M	M	9	14	18
0.53	(13.5)	V	M	M	10	15	20
0.57	(14.5)	V	M	M	11	17	22
0.61	(15.5)	V	M	M	12	18	24
0.66	(16.8)	V	M	M	13	20	26
0.70	(17.8)	V	M	M	14	21	28
0.74	(18.8)	V	M	M	15	23	30

[A] Glass content, weight, % = 25 to 30, all thickness.
[B] Calculated thickness for design purposes is determined as follows:

Symbol	Description	Layer Thickness
V	Veil	0.010
M	1.5 oz CSM	0.043
M	1.0 oz CSM	0.028
M	0.75 oz CSM	0.022

[C] The thickness shall be not less than 90 % of the calculated thickness shown.
[D] Corrosion barrier (Plies 1, 2, and 3) shall gel before structural plies are added.
[E] Structural lay-up may be interrupted at intervals long enough to exotherm if required by the laminate manufacturing procedure and 6.3.1 with the caveat that the last layer before exotherm is mat and the first ply is also mat. Exotherm plies are not shown.

A3. ALTERNATIVE TO TABLE 2

TABLE A3.1 Alternative to TABLE 2 Standard Laminate Composition Type II

Calculated Thickness [A]		Corrosion Barrier [A,B,C]			Minimum Number of Repeating Layers in the Structural Wall [D]					
Laminate Thickness					Laminate Style					
in.	(mm)				1	2	3	4	5	6
0.22	(5.6)	V	M	M	2	2	2	2	1	1
0.29	(7.4)	V	M	M	4	3	3	3	2	2
0.37	(9.4)	V	M	M	6	5	5	4	3	3
0.41	(10.4)	V	M	M	6	5	5	5	4	4
0.49	(12.5)	V	M	M	8	7	7	6	5	5
0.57	(14.5)	V	M	M	10	8	8	7	6	6
0.64	(16.3)	V	M	M	11	10	10	8	7	7
0.69	(17.5)	V	M	M	13	11	11	9	8	7
0.76	(19.3)	V	M	M	14	12	12	10	9	8

[A] Calculated thickness for design purposes is determined as follows:

Description	Layer Thickness	Minimum Number of Layers required in the Corrosion Barrier
Veil thickness	0.010	1
1.5 oz CSM	0.043	2
1.0 oz CSM	0.028	3
0.75 oz CSM	0.022	4
24 oz Woven Roving	0.033	N/A
18 oz Woven Roving	0.024	N/A

[B] The thickness shall be not less than 90 % of the calculated thickness shown.

[C] Corrosion barrier (Plies 1, 2, and 3) shall gel before structural plies are added.

[D] Structural lay-up may be interrupted long enough to exotherm following an "M" ply, if required by the laminate manufacturing procedure. Location of exotherm plies may be shifted within the laminate body. No plies may be omitted. Refer to 6.3.1. The last layer before exotherm is mat and the first ply is also mat. Exotherm plies are not shown.

Style	Repeating Laminate Layers		
1	0.75 oz CSM	&	18 oz Woven Roving
2	0.75 oz CSM	&	24 oz Woven Roving
3	1.0 oz CSM	&	18 oz Woven Roving
4	1.0 oz CSM	&	24 oz Woven Roving
5	1.5 oz CSM	&	18 oz Woven Roving
6	1.5 oz CSM	&	24 oz Woven Roving

APPENDIXES

(Nonmandatory Information)

X1. INTERPRETATION OF DATA FROM ANISOTROPIC LAMINATES

X1.1 *General*—Mechanical properties of laminates containing alternative plies of woven roving and chopped strand mat are dependent upon relationship between the direction of the applied load and the direction of the roving strands. For 5 by 4 square weave roving, the approximate relationship is shown in Fig. X1.1.

X2. QUALIFICATION OF LAMINATE STRUCTURE FOR TYPE, CLASS, AND GRADE DESIGNATION

X2.1 *General*—The RTP laminate structures other than those covered by this specification may be characterized for designation as standard type, class, and grade by means of the following procedure.

X2.2 *Laminate Preparation:*

X2.2.1 Under shop fabrication conditions, lay up 12 by 25-in. (305 by 635-mm) flat laminates of the proposed laminate structure in nominal thicknesses of 3⁄16, 5⁄16, 1⁄2, and 3⁄4 in. (4.8, 8, 12.8, and 19.2 mm).

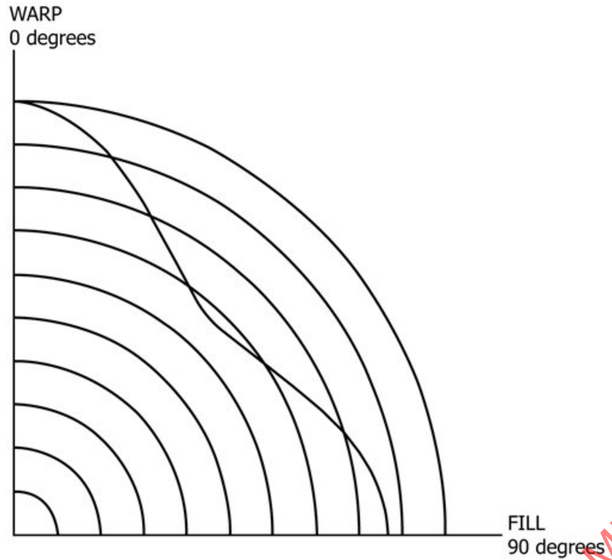
X2.2.1.1 Orientation of reinforcing fibers of fabrics shall be such as to produce maximum properties in the 25-in. (635-mm) direction of the laminate.

X2.2.1.2 Laminates having essentially unidirectional fiber reinforcement shall be 25 by 25-in. (635 by 635-mm) size to provide sufficient laminate for testing in two directions.

X2.2.1.3 The degree of cure of the surface exposed to the chemical environment (process side) shall be measured by a Barcol hardness test in accordance with Test Method D2583. At least 80 % of the random readings shall exceed at least 90 % of the resin manufacturer's recommended hardness for the cured resin.

X2.2.1.4 Cured laminates shall be flat within the limits of 1⁄8-in./ft (3.2-mm/0.1 m^2) deviation from a plane surface.

X2.3 *Testing:*



			Standard Deviation
Note:	At 45°,	Tensile strength is 69 % of 0°.	11 %
		Tensile modulus is 86 % of 0°.	2 %
	At 45°,	Flexural strength is 62 % of 0°.	14 %
		Flexural modulus is 72 % of 0°.	14 %
	At 45°,	Composition strength is 100 % of 0°.	11 %
		Composition modulus is 73 % of 0°.	20 %

FIG. X1.1 Directional Properties of RTP Alternating Mat/Woven Roving

X2.3.1 Tests shall be performed, and results certified, by a recognized independent testing laboratory experienced in the testing of RTP laminates.

X2.3.2 Determine mechanical and physical properties as required by Sections 7 and 8 of this specification.

X2.3.2.1 Unidirectional laminates, as described in X2.2.1.2, shall have properties determined both parallel to, and at 90° to, the direction of reinforcement.

X2.4 *Report:*

X2.4.1 The report shall describe laminate manufacture, date of manufacture, resin used with batch number noted, identification of reinforcements used, cure components, additives, and all pertinent cure information.

X2.4.2 The report shall contain the data obtained on all specimens, the laboratory that performed the tests, and the date performed.

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SPECIFICATION FOR GLASS FIBER STRANDS

SD-578/SD-578M

(Identical with ASTM D578/D578M-18 except for revisions to paras. 1.3, 2.3, Note 1, paras. 26.5, 26.6.4; addition of section 31 and Annex A1.)

Specification for Glass Fiber Strands

1. Scope

1.1 This specification covers the requirements for continuous fiber and staple fiber glass strands, including single, plied and multiple wound. It also covers textured glass fiber yarns. This specification is intended to assist ultimate users by designating the general nomenclature for the strand products that age generally manufactured in the glass fiber industry.

1.2 Glass fibers are produced having various compositions. General applications are identified by means of a letter designation. The letter designation represents a family of glasses that have provided acceptable performance to the end-user in the intended application. For example, the composition limits stated for E-Glass in this specification representing the glass fiber family for general and most electrical applications is designated by the letter *E*. Military specifications, such as, MIL-R-60346, recognize the composition limits described in this specification as meeting the respective requirements for E-Glass strands used in reinforced plastic structure applications.

1.3 Glass fiber strands have a variety of general uses under specific conditions, such as high physical or chemical stress, high moisture, high temperature, or electrical environments. Property requirements under specific conditions are agreed upon between the purchaser and the supplier. Electrical property requirements vary with specific end-use applications. For printed circuit board applications, other requirements may be needed such as the use of IPC Specification EG 4412 A for finished fabric woven from E-Glass for printed circuit boards, or Specification MIL-P-13949 for printed wiring boards applicable to glass fabric base.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 This specification is one of a series to provide a substitute for Military Specifications: MIL-Y-1140 Yarn, Cord, Sleeving, Cloth and Tape-Glass; and MIL-C-9084 Cloth, Glass Finished for Resin Laminates.

1.6 Additional ASTM specifications in this series have been drafted and appear in current editions of the *Annual Book of ASTM Standards*. These include finished glass fabrics, unfinished glass fabrics, glass tapes, glass sleevings, glass cords, glass sewing threads, and finished laminates made from finished glass fabrics.

1.7 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D123 Terminology Relating to Textiles

D1423/D1423M Test Method for Twist in Yarns by Direct-Counting

D1907/D1907M Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

D2256/D2256M Test Method for Tensile Properties of Yarns by the Single-Strand Method

D2258/D2258M Practice for Sampling Yarn for Testing

D2904 Practice for Interlaboratory Testing of a Textile Test

Method that Produces Normally Distributed Data (Withdrawn 2008)
D2906 Practice for Statements on Precision and Bias for Textiles (Withdrawn 2008)
D4963/D4963M Test Method for Ignition Loss of Glass Fiber Strands and Fabrics
D7018/D7018M Terminology Relating to Glass Fiber and Its Products

2.2 *ASTM Adjunct:*
TEX-PAC

2.3 *ASQC Standard:*
ANSI/ASQC Z1.4 Sampling Procedures for Inspection by Attributes

2.4 *Military Standards and Specifications:*
MIL-P-13949 Specification for Plastic Sheet, Laminated, Metal-Clad For Printed Wiring Board
MIL-R-60346 Roving, Glass Fibrous (for Prepreg Tape, Rovings, Filament Winding, and Pultrusion Applications)
MIL-G-55636B Glass Cloth, Resin Preimpregnated (B-STAGE) (For Multilayer Printed Wiring Boards) (Superseded by MIL-P-13949 1981)
MIL-Y-1140 Specification for Yarn, Cord, Sleeving, Cloth, and Tape-Glass
MIL-C-9084 Specification for Cloth Finished for Resin Laminates (Cancelled 1999)

2.5 *Institute for Interconnecting and Packaging Circuits Standard:*
IPC EG 4412 A Specification for Finished Fabric Woven from E-Glass for Printed Circuit Boards

3. Terminology

3.1 For all terminology related to D13.18, Glass Fiber and Its Products, see Terminology D7018/D7018M.

3.1.1 The following terms are relevant to this standard: atmosphere for testing textiles, chopped strand, continuous filament yarn, roving, staple glass yarn, strand, textured glass yarn.

3.2 For allother terminology related to textiles, refer to Terminology D123.

4. Classification of Glass Fiber

4.1 *"C" Glass*—A family of glasses composed primarily of the oxides of sodium, calcium, boron, aluminum, and silicon with a certified chemical composition which conforms to an applicable material specification and which produces good acid resistance (excluding HF).

4.2 *"E" Glass*—A family of glasses composed primarily of the oxides of calcium, aluminum, and silicon, which has the following certified chemical compositions.

4.2.1 The following certified chemical composition applies to glass fiber yarn products for printed circuit boards and aerospace.

Chemical	% by Weight
B_2O_3	5 to 10
CaO	16 to 25
Al_2O_3	12 to 16
SiO_2	52 to 56
MgO	0 to 5
Na_2O and K_2O	0 to 2
TiO_2	0 to 0.8
Fe_2O_3	0.05 to 0.4
Fluoride	0 to 1.0

4.2.2 The following certified chemical composition applies to glass fiber products used in general applications.

Chemical	% by Weight
B_2O_3	0 to 10
CaO and MgO	16 to 30
Al_2O_3	12 to 16
SiO_2	52 to 62
Total alkali metal oxides	0 to 2
TiO_2	0 to 1.5
Fe_2O_3	0.05 to 0.8
Fluoride	0 to 1.0

4.2.3 Electrical applications include a wide variety of uses. The composition in 4.2.1 is identical to IPC EG 4412 A for printed circuit boards and to MIL-G-55636B. Additionally, such fiber glass products often are specified for aerospace applications. Products covered by the composition range in 4.2.2 are used in general applications, such as power company equipment, high voltage devices, residential electric boxes, third rail covers, high voltage standoff rods, electrical pultrusion products, light poles, electrical tool covers, and electrical tape. Other applications include roofing, flooring, filtration, panel rovings, gun rovings, smc rovings, chopped strand reinforcements, paper yarns, and industrial yarns.

4.2.4 The nomenclature "E-CR-Glass" is used for boron-free modified E-Glass compositions for improved resistance to corrosion by most acids.

4.3 *"S" Glass*—A family of glasses composed primarily of the oxides of magnesium, aluminum, and silicon with a certified chemical composition which conforms to an applicable material specification and which produces high mechanical strength.

4.4 *"R"Glass*—A family of boron-free glasses composed primarily of the oxides of silicon, aluminum, calcium and magnesium, such glasses possessing excellent acid and water durability as well as specific strength and specific modulus levels significantly greater than E glass.

DESCRIPTION OF GLASS STRANDS

5. General

5.1 The construction of glass strands is described in a series of two to four segments of alphabetical or numerical characters.

NOTE 1—In glass fiber strand designations, and in the conversion of yards per pound to tex units, the following requirements are used:

(1) less than 2.50 tex—round to nearest 0.01 tex
(2) 2.50 tex to less than 5.00 tex—round to nearest 0.05 tex
(3) 5.00 tex to less than 10.0 tex—round to nearest 0.1 tex
(4) 10.0 tex to less than 250 tex—round to nearest 1.0 tex
(5) 250 tex to less than 2000 tex—round to nearest 5.0 tex
(6) 2000 tex to less than 100 000 tex—round to nearest 100 tex

5.1.1 For strands described in inch-pound units, the approximate yards per pound of the final strand can be computed by multiplying the yarn number designation of the single yarn or strand by 100 to obtain yards per pound for the single yarn or strand and then dividing by the total number of single yarns or strands in the final yarn. Actual yardage is less because of organic content and twist take-up during plying.

NOTE 2—Letter designations for filament diameter averages are shown in Table 1. The yards per pound stated in Table 2 is an approximate yarn number. The "As Received" yards per pound will be less than the bare glass values stated. This may be contributed by twist take-up, sizing percent, or purchaser agreement to produce to a lower yarn number to meet other requirements for a further manufactured product, or both. For example, EC9 66 1×0 (ECG 75 1/0) stated at approximately 66 tex [7500 yd/lb] will actually be about 68 tex [7300 yd/lb] in the delivered state for use in the electrical laminate industry."

6. Continuous Filament Yarns

6.1 *Descriptions of Continuous Filament Yarns*—The description of continuous filament yarns consists of the following four segments:

Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Glass family Fiber form Fiber diameter	Yarn number	Construction	Twist level Twist direction

6.1.1 *Segment One*—The parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, "C" for Continuous, and a symbol for average filament diameter range as directed in Table 1.

6.1.2 *Segment Two*—The second segment of the description of continuous filament yarns specifies the yarn number of the single yarn. For yarns described in SI units, the yarn number is specified in tex. For yarns described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is yards per pound divided by 100.

6.1.2.1 Some manufacturing processes are designed specifically to produce yarns consisting of hollow filaments. For these yarns, the suffix HF is attached to the second segment of the yarn description. For example, 40 HF (125HF) represents a 40 tex [125 × 100 yd/lb] single yarn consisting of hollow filaments.

6.1.3 *Segment Three*—The third segment of the description of continuous filament yarns specifies the number of single yarns in the complete yarn. For yarn described in SI units, the description consists of a count of the single yarns twisted together, a lower case multiplication sign or *x*, and a count of the twisted yarns plied together to form the final yarn. For yarns described in inch-pound units, the description consists of a count of the singles yarns twisted together, a division sign or "/", and a count of the twisted yarns plied together to form the final yarn.

NOTE 3—If additional stages of plying are involved, a lower case multiplication sign for SI units or a diagonal for inch-pound units, followed by the count of plied yarns being cabled is added for each additional cabling step. The total single yarns in the final yarn will always be the product of all the counts in this segment. When 0 (zero) appears as a count it is considered as 1 (one) for multiplication purposes.

6.1.4 *Segment Four*—The fourth segment of the description of continuous filament yarns specifies the twist level and direction. For yarns described in SI units, the description consists of an *S* or *Z* to show direction of twist immediately followed by the twist level in turns per metre (tpm) to the nearest 1 tpm. For yarns described in inch-pound units, the description consists of the twist level in turns per inch (tpi) to the nearest 0.1 tpi immediately followed by an *S* or *Z* to show direction of twist.

NOTE 4—Twist in turns per metre (tpm) equals twist in turns per inch (tpi) times 40. The exact factor 39.37 is rounded to 40 to obtain the twist in turns per metre to the nearest 1 tpm when starting from turns per inch to the nearest 0.1 tpi.

6.2 *Examples of Descriptions of Continuous Filament Yarns:*

6.2.1 *Example 1a, Singles Yarn Using SI Units*—The description of a singles continuous filament yarn using SI units might be:

EC6 33 1 × 0 Z40

where:

E = symbol for glass family used in general and most electrical applications,
C = symbol for continuous filament yarn,
6 = symbol for filament diameter average range 5.50 to 6.49 µm,
33 = nominal yarn number of single yarn, tex,
1×0 = one single yarn twisted without plying or cabling, and
Z40 = a twist level of 40 tpm in the "Z" direction.

The nominal yarn number in tex of the final yarn will be approximately 33 since there is only one strand in the final yarn.

6.2.2 *Example 1b, Singles Yarn Using Inch-Pound Units*—The description of a singles continuous filament yarn using inch-pound units might be:

ECDE 150 1/0 1.0Z

where:

E = symbol for glass family used in general and most electrical applications,
C = symbol for continuous filament yarn,
DE = symbol for filament diameter average range 0.00023 to 0.000269 in.,
150 = nominal yarn number of single yarns in hundreds of yards per pound [yd/lb],
1/0 = one single yarn twisted without plying or cabling, and
1.0Z = a twist level of 1.0 tpi in the "Z" direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 15 000 since there is only one strand in the final yarn.

6.2.3 *Example 2a, Plied Yarn Using SI Units*—The description of a plied continuous filament yarn using SI units might be:

EC9 33 2 × 2 S152

where:

E = symbol for glass family used in general and most electrical applications,
C = symbol for continuous filament yarn,
9 = symbol for filament diameter average range 8.50 to 9.49 µm,
33 = nominal yarn number of single yarns, tex,
2×2 = two single yarns twisted together and two such yarns plied together, and
S152 = a twist level of 152 tpm in the "S" direction.

The nominal yarn number in tex of the final yarn will be approximately 132 or four times 33 tex.

6.2.4 *Example 2b, Plied Yarn Using Inch-Pound Units*—The description of a plied continuous filament yarn using inch-pound units might be:

ECG 150 2/2 3.8S

where:

E = symbol for glass family used in general and most electrical applications,
C = symbol for continuous filament yarn,
G = symbol for filament diameter average range 0.00035 to 0.000399 in.,
150 = nominal yarn number of single yarns in hundreds of yards per pound,
2/2 = two single yarns twisted together and two such yarns plied together, and
3.8S = a twist level of 3.8 tpi in the "S" direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 3750 or 150 hundreds of yards per pound divided by four.

7. Discontinuous or Staple Filament Yarns

7.1 *Descriptions of Discontinuous or Staple Filament Yarns*—If SI units are used, the description of yarns made from staple fibers contains four segments and the fiber form is designated "D" for discontinuous. If inch-pound units are used, the description of yarns made from staple fibers contains three segments and the fiber form is designated" S" for staple.

7.1.1 The four segments in a description of yarns made from discontinuous fibers when using SI units are:

Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Glass family Fiber form Fiber diameter	Yarn number	Construction	Twist level Twist direction

7.1.1.1 *Segment One*—For yarns made from discontinuous filaments and described in SI units, the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, "D" for discontinuous; and a numeric symbol for filament diameter as directed in Table 1.

7.1.1.2 *Segment Two*—For yarns made from discontinuous filaments and described in SI units, the second segment of the description of discontinuous filament yarns specifies the yarn number of the single yarn in tex.

7.1.1.3 *Segment Three*—For yarns made from discontinuous filaments and described in SI units, the third segment of the description of discontinuous filament yarns specifies the number of single yarns in the complete yarn. The description consists of the following with no intervening spaces: (1) a count of the singles yarns twisted together, (2) a lower case multiplication sign or *x*, (3) a count of the twisted yarns plied together to form the final yarn, and (4) a symbol *R* when yarn is reinforced by a single continuous filament yarn (Note 3).

7.1.1.4 *Segment Four*—For yarns made from discontinuous filaments and described in SI units, the fourth segment of the description of discontinuous filament yarns specifies the twist level and direction. The description consists of an *S* or *Z* to show direction of twist immediately followed by the twist level in turns per metre (tpm) to the nearest 1 tpm (Note 4).

7.1.2 The three segments in a description of yarns made from staple fibers when using inch-pound units are:

Segment 1	*Segment 2*	*Segment 4*
Glass family Fiber form Fiber diameter	Yarn number ply count	Twist level Twist direction

7.1.2.1 *Segment One*—For yarns made from staple filaments and described in inch-pound units, the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, *S* for staple; and a letter symbol for filament diameter average range as directed in Table 1.

7.1.2.2 *Segment Two*—For yarns made from staple filaments and described in inch-pound units, the second segment of the description of staple filament yarns specifies the number of singles yarn in the complete yarn. The description consists of the following with no intervening spaces: (1) the nominal yarn number of the single yarns in hundreds of yards per pound; that is, yards per pound divided by 100, (2) the divisor sign or "/" , (3) a count of the twisted yarns plied together in the final yarn, and (4) a symbol *R* when yarn is reinforced by a single continuous filament yarn. (Note 3)

7.1.2.3 *Segment Three*—For yarns made from staple filaments and described in inch-pound units, the third segment of the description of staple filament yarns specifies the twist level and direction. The description consists of the twist level in turns per inch (tpi) to the nearest 0.1 tpi immediately followed by an *S* or *Z* to show direction of twist.

7.2 *Examples of Descriptions of Staple or Discontinuous Filament Yarns Using SI Units:*

7.2.1 *Example 3a, Yarn from Discontinuous Filaments Using SI Units*—The description of a yarn made from discontinuous filament might be:

CD10 198 1 × 2 S260

where:

C = symbol for glass family used in acid resistant applications,
D = symbol for discontinuous filament yarn,
10 = symbol for filament diameter average range 6.50 to 7.49 µm,
198 = nominal yarn number of single yarns, tex,
1×2 = two single yarns plied, and
S260 = a twist level of 260 tpm in the "S" direction.

The nominal yarn number in tex of the final yarn will be approximately 396 since two strands of 198 tex are combined in the final yarn.

7.2.1.1 If the above yarn were reinforced by a single strand of continuous filament yarn, *R* would be added to the second segment of the description to give: CD10 198R 1×2 S260 (Note 4).

7.2.2 *Example 3b, Yarn from Staple Filaments Using Inch-Pound Units*—The description of a staple filament yarn using inch-pound units might be:

CSH 25/2 6.5S

where:

C = symbol for glass family used in acid resistant applications,
S = symbol for staple filament yarn,
H = symbol for filament diameter average range 0.00040 to 0.000449 in.,
25/2 = nominal yarn number of single yarns in hundreds of yards per pound and two such yarns plied together, and
6.5S = a twist level of 6.5 tpi in the “S” direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 1250 or 25 hundreds of yards per pound divided by two.

7.2.2.1 If the above yarn were reinforced by a single strand of continuous filament yarn, *R* would be added to the second segment of the description to give: CSH 25/2R 6.5S (Note 4).

8. Textured Yarns

8.1 The description of textured yarns consist of either three or four segments.

8.1.1 *Three Segment Description of Textured Yarns*—The segments in a three segment description of textured yarns are:

Segment 1	*Segment 2*	*Segment 3*
Glass family Yarn type Fiber diameter	Yarn number	Manufacturer's code

8.1.1.1 *Segment One*—For textured yarns the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for yarn type, *T* for textured; and a symbol for filament diameter as directed in Table 1.

8.1.1.2 *Segment Two*—The second segment of the description of textured yarns specifies the yarn number of the final yarn, not necessarily of the single yarns. For yarns described in SI units, the yarn number is specified in tex (Note 1). For yarns described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is, yards per pound divided by 100.

8.1.1.3 *Segment Three*—The third segment of the description of textured yarns specifies the manufacturer's product code.

8.1.2 *Four Segment Description of Textured Yarns*—The segments in a four segment description of textured yarns are:

Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Glass family Yarn type Fiber diameter	Yarn number	Construction	Manufacturer's code

8.1.2.1 *Segment One*—For textured yarns the parts of segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for yarn type, *T* for textured; and a symbol for filament diameter as directed in Table 2.

8.1.2.2 *Segment Two*—The second segment of the description of textured yarns specifies the yarn number of the final yarn, not necessarily of the single yarns. For yarns described in SI units, the yarn number is specified in tex (Note 2). For yarns described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is, yards per pound divided by 100.

8.1.2.3 *Segment Three*—The third segment of the description of textured yarns specifies the number of single yarns in the complete yarn. For yarn described in SI units, the description consists of a count of the singles yarns, a lower case multiplication sign or *x*, and a count of the single yarns fabricated together to form the final yarn. For yarns described in inch-pound units, the description consists of a count of the single yarns, a division sign or “/”, and a count of the single yarns fabricated together to form the final yarn.

8.1.2.4 *Segment Four*—The fourth segment of the description of textured yarns specifies the manufacturer's product code.

8.2 *Examples of Descriptions of Textured Yarns:*

8.2.1 *Examples 5a and 5b, Textured Yarns Using SI Units*—The description of a textured yarn using SI units might be:

Three − segment description − (ET 9 134 (Manufacturer's Code))
Four − segment description − (ET 9 134 1 × 2 (Manufacturer's Code))

where:

E = symbol for glass family used in general and most electrical applications,
T = symbol for textured yarn,
9 = symbol for filament diameter average range 0.00035 to 0.000399 in.,
134 = nominal yarn number, tex,
1×2 = one singles yarn and two such yarns fabricated together, and
manufacturer's code = further identification as necessary by manufacturer to define process, sizing, etc.

The actual tex of the final yarn may vary and result in a higher value. This is dependent upon the yarn number of the input yarn and the degree of texture.

8.2.2 *Examples 5c and 5d, Textured Yarns Using Inch-Pound Units*—The description of a textured yarn using inch-pound units might be:

Three − segment description − (ETG 37 (Manufacturer's Code))
Four − segment description − (ETG 37 1 / 2 (Manufacturer's Code))

where:

E = symbol for glass family used in general and most electrical applications,

T = symbol for textured yarn,
G = symbol for filament diameter average range 0.00035 to 0.000399 in.,
37 = nominal yarn number in hundreds of yards per pound,
1/2 = one singles yarn and two such yarns fabricated together, and
manufacturer's code = further identification as necessary by manufacturer to define process, sizing, etc.

The actual yards per pound of the final yarn may vary and result in a lower value. This is dependent upon the yarn number of the input yarn and the degree of texture.

9. Rovings

9.1 *Descriptions of Rovings*—The description of rovings consists of either two or three segments.

9.1.1 *Two Segment Description for Rovings*—The segments in a two segment description of rovings are:

Segment 1	*Segment 2*
Product type	Yarn number

9.1.1.1 *Segment One*—For rovings, the first segment of the description of glass rovings represents the manufacturer's product type, which includes binder (sizing) and sliver (strand). It consists of number or letter designations, or both letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code may directly follow the product type, or may be separated by a space.

9.1.1.2 *Segment Two*—For rovings, the second segment of the description specifies the yarn number of the total roving. For rovings described in SI units, the yarn number is specified in tex. For such rovings described in inch-pound units, the yarn number is specified in yards per pound.

NOTE 5—Roving yield is synonymously used for yarn number of roving products in the glass fiber industry. The term yarn number is used throughout Specification D578 to represent the more universal term.

9.1.2 *Three Segment Description for Rovings*—The segments in a three segment description of rovings are:

Segment 1	*Segment 2*	*Segment 3*
Product type	Yarn number	Manufacturer's product code

9.1.2.1 For rovings, the first and second segments of the three segment description are as described in 9.1.1.1 and 9.1.1.2. The third segment references a manufacturer's product code and may be represented by letters or numbers, or both.

9.2 *Examples of Descriptions of Rovings:*

9.2.1 *Examples 6a, 6b, 6c, and 6d, Rovings Using SI Units*—The description of rovings using SI units might be:

$$\text{Two} - \text{segment description} - (a)\ 988AB\ 4400/(b)\ 998\ BA\ 4400$$
$$\text{Three} - \text{segment description} - (c)\ 526HT\ 3100\ 1325864355/(d)\ 995AA\ 2350\ 71B68820$$

where:
988AB = manufacturer's product type and manufacturer's code,
988BA = manufacturer's product type and manufacturer's code,
526HT = manufacturer's product type,
4400 = nominal yarn number for total roving, tex,
3100 = nominal yarn number for total roving in tex,
2350 = nominal yarn number for total roving in tex, and
1325864355 = manufacturer's product code.
71B68820 = manufacturer's product code

9.2.2 *Examples 6e, 6f, 6g and 6h, Rovings Using Inch-Pound Units*—The description of rovings using inch-pound units might be:

$$\text{Two} - \text{segment description} - (e)\ 988AB\ 113/(f)\ 998BA\ 113$$
$$\text{Three} - \text{segment description} - (g)\ 526HT\ 161\ 1325864355/(h)\ 995AA\ 211\ 71B68820$$

where:
988AB = manufacturer's product type and manufacturer's product code,
988BA = manufacturer's product type and manufacturer's product code,
526HT = manufacturer's product type,
113 = nominal yarn number for total roving, yd/lb,
161 = nominal yarn number for total roving, yd/lb,
1325864355 = manufacturer's product code, and
71B68820 = manufacturer's product code.

9.3 It is customary for producers of glass fiber rovings to indicate the compatibility of the binder (sizing) applied to the rovings to the matrix resins in which they can be used.

9.3.1 The designation shall follow the form "[matrix resin] compatible."

9.3.2 Examples of this designation would be "epoxy compatible" or "polyester compatible."

9.3.3 The resin compatibility is not part of the three segment description outlined in 9.1.2, but is available upon request from the manufacturer of the roving.

NOTE 6—Discontinued MIL-R-60346 referred to the resin compatibility by the term "Class 1" for epoxy compatible rovings and "Class 2" for polyester compatible rovings.

10. Chopped Strand from Continuous Filament Strands

10.1 *Descriptions of Chopped Strand from Continuous Filament Strands*—The description of chopped strand from continuous filament strands consists of either two, three, or four segments. For chopped strand used to reinforce thermoplastic and thermosetting plastic compounds, the description consists of two segments. For dry sized glass chopped strand, the description consists of three segments. For wet sized glass chopped strand, the description consists of four segments.

10.1.1 *Two Segment Description for Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds*—The segments in a description for chopped strand used to reinforce thermoplastic and thermosetting compounds are:

Segment 1	*Segment 2*
Product type	Strand length

10.1.1.1 *Segment One*—The first segment of the description of chopped strand used to reinforce thermoplastic and thermosetting compounds represents the manufacturer's product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the product type.

10.1.1.2 *Segment Two*—The second segment of the description of chopped strand used to reinforce thermoplastic and thermosetting compounds specifies the length of the chopped strand. For chopped strands described in SI units, the nominal chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.1.2 *Three Segment Description for Dry Sized Chopped Strand*—The segments in a description of dry chopped strand are:

Segment 1	*Segment 2*	*Segment 3*
Filament diameter	Sizing or product type	Strand length

10.1.2.1 *Segment One*—The first segment of the description of dry sized chopped strand represents the nominal filament diameter range. When using SI units, this segment consists of a number specifying the nominal filament diameter range in micrometers as directed in Table 1. When using inch pound units, this segment consists of one or two letters as directed in Table 1.

10.1.2.2 *Segment Two*—The second segment of the description of dry sized chopped strand represents the manufacturer's sizing or product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the sizing or product type.

10.1.2.3 *Segment Three*—The third segment of the description of dry sized chopped strand specifies the length of the chopped strand. For chopped strands described in SI units, the nominal chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.1.3 *Four Segment Description for Wet Sized Chopped Strand*—The segments in a description of wet chopped strand are:

Segment 1	*Segment 2*	*Segment 3*	*Segment 4*
Filament diameter	Sizing or product type	Moisture content	Strand length

10.1.3.1 *Segment One*—The first segment of the description of wet sized chopped strand represents the nominal filament diameter range. When using SI units, this segment consists of a number specifying the nominal filament diameter range in micrometres as directed in Table 1. When using inch-pound units, this segment consists of one or two letters as directed in Table 1.

10.1.3.2 *Segment Two*—The second segment of the description of wet sized chopped strand represents the manufacturer's sizing or product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the product type.

10.1.3.3 *Segment Three*—The third segment of the description of wet sized chopped strand specifies the nominal percent moisture content. This segment consists of a number representing the percent moisture content in both SI units and inch pound units.

NOTE 7—Some manufacturers omit this segment when describing wet sized chopped strand.

10.1.3.4 *Segment Four*—The fourth segment of the description of wet sized chopped strand specifies the length of the chopped strand. For chopped strands described in SI units, the nominal chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.2 *Examples of Descriptions of Chopped Strands:*

10.2.1 *Example 7a, Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds Using SI Units*—The description of chopped strand used to reinforce thermoplastic and thermosetting compounds using SI units might be:

405AB 13 mm

where:

405AB = manufacturer's product type and process code, and
13 = length, mm.

10.2.2 *Example 7b, Dry Sized Chopped Strand Using SI Units*—The description of dry sized chopped strand using SI units might be:

9 µm 685 13 mm

where:

9 = symbol for filament diameter average range 8.50 to 9.49 µm,
685 = manufacturer's sizing code or process code, or both, and
13 = length, mm.

10.2.3 *Example 7c, Wet Sized Chopped Strand Using SI Units*—The description of wet sized chopped strand using SI units might be:

16 µm 775 14.5 32 mm

where:

16 = symbol for filament diameter average range 15.5 to 16.49 µm,
775 = manufacturer's sizing code or process code, or both,
14.5 = moisture content, % (Note 7), and
32 = length, mm.

10.2.4 *Example 7d, Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds Using Inch-Pound Units*—The description of chopped strand used to reinforce thermoplastic and thermosetting compounds using inch-pound units might be:

405AB ½ in.

where:

405AB = manufacturer's product type and process code, and
½ = length, in.

10.2.5 *Example 7e, Dry Sized Chopped Strand Using Inch-Pound Units*—The description of dry chopped strand using inch-pound units might be:

G685 ½ in.

where:

G = symbol for filament diameter average range 0.00035 to 0.000399 in.,
685 = manufacturer's sizing code or process code, or both, and
½ = length, in.

10.2.6 *Example 7f, Wet Sized Chopped Strand Using Inch-Pound Units*—The description of wet sized chopped strand using inch-pound units might be:

M 775 14.5 1¼ in.

where:

M = symbol for filament diameter average range 0.00060 to 0.000649 in.
775 = manufacturer's sizing code or process code, or both,
14.5 = moisture content, %, and
1¼ = length, in.

11. Ordering Information

11.1 The purchase order or other agreement shall specify: specification conformance number, title, and year of issue; designation of strand construction; product quantity; and any special provisions.

REQUIREMENTS

12. Material

12.1 The fibers shall be free of any free alkali metal oxides, such as soda or potash, and from foreign particles, dirt, and other impurities. The glass classification shall be agreed upon between the purchaser and the supplier in an applicable material specification or other agreement. The composition of the E-Glass classification of glass fiber shall be within the limits specified in 4.2.1 or 4.2.2 as agreed upon between the purchaser and supplier.

13. Workmanship

13.1 As agreed upon between the purchaser and the supplier, the defects listed in Table 3 shall be considered cause for rejection of the package in which they occur. The allowable quality level (AQL) shall be agreed upon between the purchaser and the supplier.

14. Physical Properties

14.1 The nominal and physical properties of glass fiber strands shall conform to the requirements of Tables 1, 2, 4, and 5, as applicable. The tolerances shall be subject to the tolerances as agreed upon between the purchaser and the supplier. However, the following maximum tolerances apply:

14.1.1 *Yarn Number, Tex [Yards per Pound), Individual Value*—Plus or minus 10 % for continuous filament yarns. Plus or minus 20 % for discontinuous or staple yarns. Plus or minus 15 % for textured yarns. Plus or minus 8.5 % for roving produced by either conventional or nonconventional roving winding processes, except certain rovings produced by other than conventional winding processes shall have a ±13 % tolerance when agreed upon between the purchaser and the supplier.

NOTE 8—Historically, it has been conventional practice to attenuate glass through bushings having 204 or 408 holes to produce strands containing those numbers of filaments. Then, rovings were made from those strands having 1, 12, 15, 20, 30, and 60 ends. Although this practice is still used by some suppliers, others are attenuating fiber glass through bushings consisting of up to several thousand holes to make heavy rovings containing only a single strand. Since the strands are not twisted, rovings made with the larger single strands are equivalent, for most purposes, to those made with the smaller conventional made multiple strands. Since many older material specifications specify in accordance with the older multiple strand designation, a purchasing activity should review and agree upon with the supplier activity, the acceptability of the single strand roving having an equivalent yarn number.

14.1.1.1 The tex [yards per pound] as determined in Section 23 and specified in Tables 2, 4, and 5 are the bare glass nominal. A commercial yarn normally has a size (binder) treatment which will increase tex [decrease yards per pound] in proportion to the amount of size.

14.1.2 *Breaking Strength*—No individual break shall be less than the specified minimum requirement in Tables 2, 4, and 5.

14.2 When required for roving and chopped strand, the nominal and physical properties shall be agreed upon between the purchaser and the supplier in an applicable material specification or other agreement, subject to the requirements of Table 2 and 14.1.1.

15. Ignition Loss (Organic Content)

15.1 The ignition loss (organic content) shall be within the tolerances as agreed upon between the purchaser and the supplier, or as specified in an applicable material specification or other agreement.

16. Packaging

16.1 The glass fiber strand shall be put up on packages, and in containers whose dimensions shall be agreed to between the purchaser and supplier.

16.2 Each package of strand, put up as specified, shall be further packaged to afford adequate protection against physical damage during shipment from the supply source to the receiving activity. The supplier may use his standard practice when it meets this requirement.

16.3 For government procurement, the contracting instrument shall specify the put up (see 11.1) and AQL (see 13.1).

17. Marking

17.1 Each package of strand shall be marked to show the construction designation of the glass fiber strand as specified in Sections 5 – 10. Each container of packages shall be marked as agreed upon between the purchaser and supplier.

18. Sampling, Inspection, and Number of Specimens

18.1 *Lot Size*—A lot shall consist of each shipment, date code, or consignment of a single strand designation. This may constitute all or part of any one customer order. The lot size is the total number of packages of strand in the incoming shipment date code, or consignment.

NOTE 9—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between packages of strand and between test specimens from a package of strand to produce a sampling plan with meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

18.2 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping units specified in Practice D2258/D2258M. Consider shipping cases or other shipping units to be the primary sampling units.

18.3 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping unit in the lot sample the number of packages or ends directed in 18.3.1 and 18.3.2. Preferably, the same number of packages should be taken from each shipping unit in the lot sample. If differing numbers of packages are to be taken from shipping units in the lot sample, determine at random which shipping units are to have each number of packages drawn.

18.3.1 *Workmanship*—Take at random the number of packages or ends of strand as directed in ANSI/ASQC Z1.4. Select an acceptable quality level (AQL) that is agreeable to both the purchaser and the supplier.

18.3.2 *Other Properties*—Take at random the number of bobbins or packages of strand specified in Table 6.

18.4 *Test Specimens*—Proceed as follows:

18.4.1 *Workmanship*—Use the packages of strand in the laboratory sample as the specimens. Evaluate the results of inspecting the specimens using ANSI/ASQC Z1.4, normal inspection, and an acceptable quality level agreed upon between the purchaser and the supplier.

18.4.2 *Other Properties*—Take the number of specimens per laboratory sampling unit specified in the applicable test method.

TEST METHODS

19. Conditioning

19.1 Condition the laboratory samples without preconditioning for a period of at least 5 h in the atmosphere for testing glass textiles, unless otherwise specified.

20. Material

20.1 Upon prior agreement, accept the supplier's certification that the material is of the correct family of glass fiber as specified in Section 4. Verify that the fiber is the specified filament type during testing for strand construction as directed in Section 22. Determine the freedom from undesirable impurities during inspection for workmanship as directed in Section 21.

21. Workmanship

21.1 Examine the outer surface of each package of strand in the laboratory sample by counting the defects listed in Table 3 regardless of their proximity to one another, except where two or more defects represent a single local condition. In such cases, count only the most serious defect.

22. Strand Construction

22.1 Verify the number of single strands and the number of plied or cabled strands on each package of strand in the laboratory sample while determining the twist direction or twist level as directed in Section 24 or 25.

23. Yarn Number

23.1 Determine the yarn number of bare glass yards per pound as directed in Test Method D1907/D1907M, Option 1, excluding preconditioning.

23.1.1 Prior to conditioning, place the skein in a muffle furnace and heat to 625 ± 25°C [1157 ± 45°F] for 15 min.

23.2 *Calculations:*

23.2.1 Calculate the yards per pound from the length and average mass of the specimens using Eq 1 or Eq 2:

$$Y = (453.6 \times L)/A \quad (1)$$

$$Y = (7000 \times L)/B \quad (2)$$

where:

Y = yarn number, yd/lb,
L = specimen length, yd,
A = average mass of specimens, g, and
B = average mass of specimens, grains.

23.2.2 Calculate the tex equivalents using Eq 3 and 4:

$$\text{Tex} = A/(0.0009144L) \quad (3)$$

$$\text{Tex} = 496055/Y \quad (4)$$

where:

A = average mass of specimens, g,
L = specimen length, yd, and
Y = yarn number, yd/lb.

23.2.3 Calculate the yarn construction designation using Eq 5:

$$YC = \frac{Y}{100} \quad (5)$$

where:

YC = yarn number, hundreds of yd/lb, and
Y = yarn number, yd/lb.

24. Direction of Twist

24.1 Verify the direction of twist in each laboratory sampling unit as directed in Test Method D1423/D1423M.

25. Twist Level

25.1 Determine the twist level in each laboratory sampling unit as directed in Test Method D1423/D1423M.

26. Filament Diameter

26.1 *Scope*—This test method covers the determination of the average diameter of textile glass fibers by the microprojector method.

26.2 *Significance and Use:*

26.2.1 The microprojection procedure for testing glass fibers is considered satisfactory for acceptance testing of commercial shipments. In cases of disagreement arising from differences in values reported by the purchaser and supplier when using this method for acceptance testing, the statistical bias, if any, between the laboratories of the purchaser and the supplier shall be determined with each comparison being based on testing specimens randomly drawn from one sample of material of the type being evaluated.

26.3 *Apparatus:*

26.3.1 *Microprojector,* equipped with mechanical stage, controls, screen, and optics to provide a magnification of 1000×.

26.3.2 *Scale,* with divisions that can be read to fiber diameter values of 0.254 µm [10^{-5} in.].

26.3.3 *Magnifier.*

26.3.4 *Scissors.*

26.3.5 *Pick Needles.*

26.3.6 *Glass Slides,* 25 by 76 mm [1 by 3 in.].

26.3.7 *Square Cover Glasses,* 22 mm [⅞ in.].

26.3.8 *Mounting Mediums,* that at 25°C [77°F], one has a refractive index of 1.600 to 1.6008 for E-Glass Fiber and a second has a refractive index of 1.470 ± 0.0002 for S-2 Glass.

26.4 *Procedure:*

26.4.1 *Mounting and Measuring Fibers*—Place one drop of mounting medium in the middle of a 25 by 76-mm [1 by 3-in.] slide. Select a test specimen of about 75 fibers. Immerse the tips of the fibers in the mounting medium and separate the fibers with pick needles or similar tool. Arrange them approximately parallel to each other on the glass slide. A binocular microscope or a magnifier may facilitate this separation. Place one edge of the cover glass in contact with the slide and allow it to settle slowly to facilitate the removal of air bubbles.

26.4.1.1 For E-Glass Fiber, use a mounting medium having a refractive index on 1.600 to 1.6008 and for S-2 Glass, use a mounting medium having a refractive index on 1.470 ± 0.0002 at 25°C [77°F].

NOTE 10—If the filaments will not separate due to excessive binder, or type binder, or organic compounds are affecting the measurement of the diameter of the filaments, the test specimen should be burned off as directed in Section 23.

26.4.2 *Manipulation of the Microprojector*—Insert the prepared slide in the mechanical stage of the microprojector. Slowly and carefully focus the fibers by adjusting the position of the light source, moving the condenser, regulating the aperture and field diaphragms, and manipulating the adjustment to provide optimum illumination, freedom of aberrations, and maximum resolution of the projected image of the fiber (edges should be black lines of minimum width—failure to do this will definitely impact preciseness).

26.4.3 *Measurement of Filament Diameter*—Begin at the left edge of the mount and measure the diameter of each fiber, which is clearly defined, as it is brought into the field of view by traversing the stage. Restrict the area of measurement to that part of the fiber which appears within the middle of the field. Place the zero line of the scale so that it just touches the left edge of the fiber image, and observe where the extreme right edge of the image crosses the scale ruling. Read the diameter to the nearest 0.25 µm [10^{-5} in.] and average for the laboratory sampling unit and for the lot.

26.4.4 *Number of Measurements*—Measure a total of 50 fibers per specimen.

26.5 *Report*—Report that the test for fiber diameter was made as directed in Section 26. Describe the material or product sampled and the method of sampling. Report the average filament diameter for each laboratory sampling unit and for the lot.

26.6 *Precision and Bias:*

26.6.1 *Summary*—Based upon limited information from one laboratory, the single-operator and within-laboratory components of variation and critical differences shown in Tables 7 and 8 are approximate. These tables are constructed to illustrate what one laboratory found when all the observations were taken by the same well-trained operator using the same piece of equipment and specimens randomly drawn from the sample of material. For this laboratory, in comparing two averages, the differences should not exceed the single-operator precision values shown in Table 8 for the respective number of tests in 95 out of 100 cases. Differences for other laboratories may be larger or smaller. The number of laboratories available to perform the procedures in this test method has diminished over the last few years. If additional laboratories are identified to perform these tests, between-laboratory precision can be established.

26.6.2 *Single-laboratory Test Data*—A single-laboratory test was run in 1991 in which a randomly drawn sample of 600 denier glass fiber strand was selected and four slides prepared, two by each of two different operators. Two operators in the laboratory each measured 60 specimens from each of the four prepared slides using the fiber diameter test method in Specification D578. Thirty of the sixty fibers from each slide were measured on one day and thirty specimens from each slide were measured on a second day for a total of 240 measurements. Analysis of the data was conducted using Practice D2904, Practice D2906, and Adjunct TEX-PAC. The components of variance for fiber diameter of glass fiber strands expressed as standard deviations were calculated to be the values listed in Table 7.

26.6.3 *Precision*—Since tests were conducted in only one laboratory, estimates of between laboratory precision may be either underestimated or overestimated to a considerable extent and should be used with special caution. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as nearly homogeneous as possible and then randomly assigned in equal numbers to each of the laboratories. However, when agreed upon between the contractual parties, for the approximate components of variance reported in Table 7, two averages of observed values may be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 8, for fiber diameter of glass fiber strands.

26.6.4 *Bias*—The procedure in para. 26.6 for measuring the filament diameter of glass filaments has no bias because the value of that property can be defined only in terms of a test method.

27. Breaking Strength

27.1 *Procedure*—Determine the breaking strength of strand as directed in Test Method D2256/D2256M, Option 1A, excluding preconditioning. Set the distance between clamps (gage length) to 250 ± 2 mm [10 ± 0.05 in.] from nip to nip. Test five specimens per laboratory sampling unit. Use the preferred constant rate of extension (CRE) type tensile testing machine operated at a speed of 250 ± 6 mm/min [10 ± 0.25 in./min]. When agreed upon between the purchaser and the supplier, a constant rate of load (CRL) type testing machine operated at a rate of speed of loading greater than 28 mN/tex [28 gf/den.]/min or a constant rate of traverse (CRT) type testing machine operated at 300 ± 10 mm/min [12 ± 0.5 in./min] may be used. When using flat clamp faces they should be rubber faced to minimize crushing in the clamps. When test specimens continue to slip or break in the clamps, other clamp facings or protection of the test specimen within contact of the clamp faces should be employed. The test specimen preparation option described in 27.2 has been used successfully.

27.2 *Test Specimen Preparation Option*—When slippage or breakage occurs in the clamps, optionally prepare test specimens as follows:

27.2.1 *Materials:*

27.2.1.1 *White Cardboard,* sub 65 grade.

27.2.1.2 *Paint Brush,* 16 to 25 mm [0.625 to 1.0 in.] wide with bristles 25 mm [1.0 in.] long.

27.2.1.3 *Masking Tape,* 12 mm [0.5 in.] wide.

27.2.2 *Preparation:*

27.2.2.1 Lay a 250 by 330-mm [10 by 13-in.] piece of white cardboard on a flat surface. Draw two legible lines 250 ± 1 mm [10 ± 0.05 in.] from each other across the center section of the cardboard in the 75-mm [10-in.] direction. Draw an additional parallel line 25 mm [1.0 in.] outward from each previously drawn line.

27.2.2.2 Lay six test specimens on the cardboard parallel to the 330-mm [13-in.] direction approximately 25 mm [1.0 in.] apart. Secure the ends of the test specimen to the cardboard outside the previously drawn lines using pieces of 12 mm [0.5 in.] masking tape.

27.2.2.3 Uniformly apply a resin or equivalent bonding mixture to ends of the test specimen between the 25-mm [1-in.] spaced lines. Do not include the center 250 mm [10 in.] between drawn lines.

27.2.2.4 Place a 25 ± 1-mm [1.0 ± 0.05-in.] strip of cardboard over the resin impregnated area of the test specimen. Allow to dry a minimum of 16 h.

NOTE 11—When a substitute mixture is used, drying time may vary.

27.2.2.5 Cut the cardboard and specimen assembly into strips without touching the test specimens.

27.2.2.6 Load the cut test specimen assembly strip in the clamps of the tensile tester having the 250-mm [10-in.] exposed portion between both clamps. Cut the cardboard backing across, midway between the ends, taking care not to damage the test specimen.

27.3 *Precision and Bias*—The precision and bias of the procedure in Specification D578 for breaking strength are as specified in Test Method D2256/D2256M.

28. Ignition Loss

28.1 Determine the ignition loss of each laboratory sampling unit as directed in Test Method D4963/D4963M.

29. Packaging and Marking

29.1 During the sampling and testing of the shipment, verify the correctness of packaging and marking.

CONFORMANCE AND KEYWORDS

30. Conformance

30.1 The purchaser and the supplier shall agree on a procedure to establish conformance, including control charts furnished by the supplier, a sequential sampling plan, or double-sampling plan outlined in 30.2.

30.2 In the absence of a control chart or sequential sampling plan, proceed as directed in 30.2.1 – 30.2.3.

30.2.1 If the test results for a lot conform to the requirements for all characteristics listed in Sections 12 – 17, and Tables 1–6, the lot shall be considered acceptable.

30.2.2 If the test results for one or more characteristics do not conform to the requirements, take a new laboratory sample from either the original lot sample or a new lot sample. Test the new sample for the characteristic(s) that did not conform to the requirements in the first test and average the results of the first and second samples as if they were oner test of double the original number of specimens. If the new average(s) conform(s) to the specified requirements, the lot shall be considered acceptable.

30.2.3 If the test results obtained as directed in 30.2.2 do not conform to the specified requirements, the lot shall be considered unacceptable.

31. Certification

31.1 See Annex A1 for certification requirements.

32. Keywords

32.1 breaking strength; certification; chopped glass strand; construction designation; diameter; glass fiber; glass roving; glass strands; glass yarns; ignition loss (organic content); workmanship; yarn number

TABLE 1 Letter Designations for Glass Strand Filament Diameters

Filament Size Designation		Nominal Range for Filament Diameter Average	
Inch-Pound System, Letter	SI System, Number	in.	μm[A]
B	3.5	0.00013 to 0.000159	3.30 to 4.05
C	4.5	0.00016 to 0.000189	4.06 to 4.82
D	5	0.00019 to 0.000229	4.83 to 5.83
DE	6	0.00023 to 0.000269	5.84 to 6.85
E	7	0.00025 to 0.000299	6.35 to 7.61
F	8	0.00030 to 0.000345	7.62 to 8.88
G	9	0.00035 to 0.000399	8.89 to 10.15
H	11	0.00040 to 0.000449	10.16 to 11.42
J	12	0.00045 to 0.000499	11.43 to 12.69
K	13	0.00050 to 0.000549	12.70 to 13.96
L	14	0.00055 to 0.000599	13.97 to 15.23
M	16	0.00060 to 0.000649	15.24 to 16.50
N	17	0.00065 to 0.000699	16.51 to 17.77
P	18	0.00070 to 0.000749	17.78 to 19.04
Q	20	0.00075 to 0.000799	19.05 to 20.31
R	21	0.00080 to 0.000849	20.32 to 21.58
S	22	0.00085 to 0.000899	21.59 to 22.85
T	23	0.00090 to 0.000949	22.86 to 24.12
U	24	0.00095 to 0.000999	24.13 to 25.40

[A] The low values stated for each micrometre range are exact equivalents to inches, rounded to the nearest hundredth micrometre. The high values stated for each micrometre range are slightly higher than exact equivalents to inches to provide continuation between ranges. They are consistent for inch-pound and SI filament size descriptions commonly used in the industry. In some publications, the SI designation for H filament size has been shown as 10.

TABLE 2 Physical Properties of Continuous Filament Yarns

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC5 2.75 1×0	ECD 1800 1/0	20 to 40	0.5 to 1.0	...	...	2.75	180 000	1.1	0.25
EC5 2.75 1×2	ECD 1800 1/2	...	...	152 to 176	3.8 to 4.4	5.5	90 000	...	...
EC5 5.5 1×0	ECD 900 1/0	20 to 40	0.5 to 1.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	160 to 200	4.0 to 5.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	120 to 160	3.0 to 4.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	400	10.0	...	...	5.5	90 000	2.2	0.5
EC6 8.25	ECDE 600 1/0	20 to 40	0.5 to 1.0	...	...	8.25	60 000	3.3	0.75
EC5 5.5 1×2	ECD 900 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	11	45 000	4.9	1.1
EC5 5.5 1×2	ECD 900 1/2	...	...	340	8.5	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	20 to 40	0.5 to 1.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	40 to 80	1.0 to 2.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	80 to 120	2.0 to 3.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	160 to 200	4.0 to 5.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	400	10	...	...	11	45 000	...	...
EC6 16 1×0	ECDE 300 1/0	20 to 40	0.5 to 1.0	...	...	16	30 000	8.0	1.9
EC5 5.5 1×3	ECD 900 1/3	...	...	152 to 176	3.8 to 4.4	16.5	30 000	8.0	1.8
EC5 5.5 1×3	ECD 900 1/3	...	...	340	8.5	16.5	30 000	8.0	1.8
EC5 11 2×0	ECD 450 2/0	160 to 200	4.0 to 5.0	...	...	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	...	...	60	1.5	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	...	...	340	8.5	22	22 500	9.8	2.2
EC5 22 1×0	ECD 225 1/0	40 to 80	1.0 to 2.0	...	...	22	22 500	10.7	2.4
EC5 22 1×0	ECD 225 1/0	20 to 40	0.5 to 1.0	...	...	22	22 500	10.7	2.4
EC5 22 1×0	ECD 225 1/0	160 to 200	4.0 to 5.0	...	...	22	22 500	10.7	2.4
EC7 22 1×0	ECE 225 1/0	20 to 40	0.5 to 1.0	...	...	22	22 500	9.8	2.2
EC7 22 1×0	ECE 225 1/0	160 to 200	4.0 to 5.0	...	...	22	22 500	9.8	2.2
EC7 22 1×0	ECE 225 1/0	400	10.0	...	...	22	22 500	9.8	2.2
EC5 11 3×0	ECD 450 3/0	160 to 200	4.0 to 5.0	...	...	33	15 000	17.3	3.9
EC5 11 1×3	ECD 450 1/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	33	15 000	17.3	3.9
EC5 11 1×3	ECD 450 1/3	...	...	340	8.5	33	15 000	17.3	3.9
EC3.5 33 1×0	ECB 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	17.8	4.0
EC3.5 33 1×0	ECB 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	17.8	4.0
EC4.5 33 1×0	ECC 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	15.6	3.5
EC4.5 33 1×0	ECC 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	15.6	3.5
EC6 33 1×0	ECDE 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	15.6	3.5
EC6 33	ECDE 150	90	2.25	...	...	33	15 000	15.6	3.5

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
1×0	1/0								
EC6 33 1×0	ECDE 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	15.6	3.5
EC9 33 1×0	ECG 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	13.3	3.0
EC9 33 1×0	ECG 150 1/0	40 to 80	1.0 to 2.0	...	...	33	15 000	13.3	3.0
EC9 33 1×0	ECG 150 1/0	52	1.3	...	...	33	15 000	13.3	3.0
EC9 33 1×0	ECG 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	13.3	3.0
EC9 33 1×0	ECG 150 1/0	224	5.6	...	...	33	15 000	13.3	3.0
EC9 33 1×0	ECG 150 1/0	280	7.0	...	...	33	15 000	13.3	3.0
EC13 40HF 1×0	ECK 125 HF 1/0	20 to 40	0.5 to 1.0	...	...	40	12 500	14.2	3.2
EC5 11 4×0	ECD 450 4/0	160 to 200	4.0 to 5.0	...	...	44	11 250	19.6	4.4
EC5 11 2×2	ECD 450 2/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	19.6	4.4
EC5 22 2×0	ECD 225 2/0	160 to 200	4.0 to 5.0	...	...	44	11 250	21.4	4.8
EC5 22 1×2	ECD 225 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	21.4	4.8
EC5 22 1×2	ECD 225 1/2	...	...	340	8.5	44	11 250	21.4	4.8
EC7 22 2×0	ECE 225 2/0	160 to 200	4.0 to 5.0	...	...	44	11 250	19.6	4.4
EC7 22 1×2	ECE 225 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	19.6	4.4
EC7 22 1×2	ECE 225 1/2	...	...	340	8.5	44	11 250	19.6	4.4
EC11 45 1×0	ECH 110 1/0	20 to 40	0.5 to 1.0	...	...	45	11 000	18.2	3.9
EC6 50 1×0	ECDE 100 1/0	20 to 40	0.5 to 1.0	...	...	50	10 000	17.8	4.0
EC6 50 1×0	ECDE 100 1/0	28	0.7	...	...	50	10 000	17.8	4.0
EC6 50 1×0	ECDE 100 1/0	80	2.0	...	...	50	10 000	17.8	4.0
EC9 50 1×0	ECG 100 1/0	20 to 40	0.5 to 1.0	...	...	50	10 000	...	...
EC8 55 1×0	ECF 90 1/0	40	1.0	...	...	55	9 000	27	6.0
EC5 11 3×2	ECD 450 3/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	29.4	6.6
EC5 22 3×0	ECD 225 3/0	160 to 200	4.0 to 5.0	...	...	66	7 500	32.0	7.2
EC5 22 1×3	ECD 225 1/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	32.0	7.2
EC7 22 3×0	ECE 225 3/0	120 to 160	3.0 to 4.0	...	...	66	7 500	29.4	6.6
EC7 22 3×0	ECE 225 3/0	160 to 200	4.0 to 5.0	...	...	66	7 500	29.4	6.6
EC7 22 1×3	ECE 225 1/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	29.4	6.6
EC3.5 33 2×0	ECB 150 2/0	80 to 120	2.0 to 3.0	...	...	66	7 500	35.6	8.0
EC3.5 33 2×0	ECB 150 2/0	120 to 160	3.0 to 4.0	...	...	66	7 500	35.6	8.0
EC3.5 33 1×2	ECB 150 1/2	...	...	112 to 152	2.8 to 3.8	66	7 500	...	...
EC6 33 2×0	ECDE 150 2/0	120 to 160	3.0 to 4.0	...	...	66	7 500	31.1	7.0
EC6 33 1×2	ECDE 150 1/2	...	...	112 to 152	2.8 to 3.8	66	7 500	...	...
EC4.5 33 2×0	ECC 150 2/0	40 to 80	1.0 to 2.0	...	...	66	7 500	47.2	10.6
EC4.5 33 2×0	ECC 150 2/0	120 to 160	3.0 to 4.0	...	...	66	7 500	33.4	7.5

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC9 33 2×0	ECG 150 2/0	120 to 160	3.0 to 4.0	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	160 to 200	4.0 to 5.0	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	224	5.6	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	320	8.0	...	...	66	7 500	28.5	6.4
EC9 33 1×2	ECG 150 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	66	7 500	26.5	6.0
EC6 66 1×0	ECDE 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	28	0.7	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	80 to 120	2.0 to 3.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	78	0.7	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	280	7.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	320	8.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	80 to 120	2.0 to 3.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC5 22 4×0	ECD 225 4/0	120 to 160	3.0 to 4.0	...	...	88	5 625	46.3	10.4
EC7 22 2×2	ECD 225 2/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	88	5 625	42.7	9.6
EC7 22 2×2	ECE 225 2/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	88	5 625	39.1	8.8
EC11 90 1×0	ECH 55 1/0	20 to 40	0.5 to 1.0	...	...	90	5 500	42.3	9.5
EC13 90 1×0	ECK 55 1/0	20 to 40	0.5 to 1.0	...	...	90	5 500	42.3	9.5
EC9 100 1×0	ECG 50 1/0	20 to 40	0.5 to 1.0	...	...	99	5 000	44.0	10.0
EC5 11 3×3	ECD 450 3/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	99	5 000	44.0	9.9
EC6 33 3×0	ECDE 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	...	...
EC6 33 1×3	ECDE 150 1/3	...	...	112 to 152	2.8 to 3.8	99	5 000	46.7	10.5
EC4.5 33 3×0	ECC 150 3/0	40 to 80	1.0 to 2.0	...	...	99	5 000	48.9	11.0
EC4.5 33 3×0	ECC 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	48.9	11.0
EC9 33 3×0	ECG 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	42.7	9.6
EC9 33 3×0	ECG 150 3/0	160 to 200	4.0 to 5.0	...	...	99	5 000	42.7	9.6
EC9 33	ECG 150	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	99	5 000	40.0	9.0

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
1×3	1/3								
EC5 11 3×4	ECD 450 3/4	...	...	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC5 11 4×3	ECD 450 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC5 22 3×2	ECD 225 3/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	64.0	14.4
EC7 22 3×2	ECE 225 3/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC3.5 33 4×0	ECB 150 4/0	40 to 80	1.0 to 2.0	...	...	132	3 750	71.2	16.0
EC6 33 4×0	ECDE 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	...	TBD
EC6 33 2×2	ECDE 150 2/2	...	...	112 to 152	2.8 to 3.8	132	3 750	...	TBD
EC6 33 1×4	ECDE 150 1/4	...	...	112 to 152	2.8 to 3.8	132	3 750	...	TBD
EC4.5 33 4×0	ECC 150 4/0	40 to 80	1.0 to 2.0	...	...	132	3 750	62.3	14.0
EC4.5 33 1×0	ECC 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	62.3	14.0
EC9 33 4×0	ECG 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	56.9	12.8
EC9 33 4×0	ECG 150 4/0	160 to 200	4.0 to 5.0	...	...	132	3 750	56.9	12.8
EC9 33 2×2	ECG 150 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	132	3 750	53.4	12.0
EC4.5 66 2×0	ECC 75 2/0	80 to 120	2.0 to 3.0	...	...	132	3 750	50.7	11.4
EC4.5 66 2×0	ECC 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC6 66 2×0	ECDE 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	280	7.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	320	8.0	...	...	132	3 750	50.7	11.4
EC9 66 1×2	ECG 75 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	132	3 750	50.7	11.4
EC13 66 2×0	ECK 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC6 134 1×0	ECDE 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC6 134 1×0	ECDE 37 1/0	80 to 120	2.0 to 3.0	...	...	134	3 700	49.8	11.2
EC6 134 1×0	ECDE 37 1/0	120 to 160	3.0 to 4.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	40 to 80	1.0 to 2.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	120 to 160	3.0 to 4.0	...	...	134	3 700	49.8	11.2
EC13 134 1×0	ECK 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC5 11 3×5	ECD 450 3/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	165	3 000	70.3	15.8
EC5 11 4×4	ECD 450 4/4	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	176	2 813	78.3	17.6
EC9 33 2×3	ECG 150 2/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	80.1	18.0
EC9 33 3×2	ECG 150 3/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	80.1	18.0
EC9 66 3×0	ECG 75 3/0	120 to 160	3.0 to 4.0	...	...	198	2 500	76.1	17.1
EC9 66 1×3	ECG 75 1/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	76.1	17.1
EC9 100 1×2	ECG 50 1/2	120 to 160	3.0 to 4.0	...	...	198	2 500	...	...

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC11 198 1×0	ECH 25 1/1	20 to 40	0.5 to 1.0	...	...	198	2 500	75.6	17.0
EC5 11 4×5	ECD 450 4/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	220	2 250	100	22.6
EC5 22 2×5	ECD 225 2/5	...	...	152 to 176	3.8 to 4.4	220	2 250	107	24
EC7 22 2×5	ECE 225 2/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	220	2 250	107	24
EC13 40HF 2/3	ECK 125 HF 2/3	80 to 140	2.0 to 3.5	7.6 to 136	1.9 to 3.4	238	2080	85.4	19.2
EC13 40HF 1×6	ECK 125 HF 1/6	80 to 140	2.0 to 3.5	7.6 to 136	1.9 to 3.4	238	2080	85.4	19.2
EC5 22 4×3	ECD 225 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	265	1 875	128	28.8
EC7 22 4×3	ECE 225 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	265	1 875	117	26.4
EC9 33 1×2	ECG 150 1/2	...	...	112 to 152	2.8 to 3.8	265	1 875	...	...
EC9 33 4×2	ECG 150 4/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	107	24.0
EC9 66 4×0	ECG 75 4/0	120 to 160	3.0 to 4.0	...	...	265	1 875	101	22.8
EC9 66 2×2	ECG 75 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	101	22.8
EC9 134 2×0	ECG 37 2/0	120 to 160	3.0 to 4.0	...	...	265	1 875	101	22.8
EC13 66 2×2	ECK 75 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	101	22.8
EC9 134 1×2	ECG 37 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	270	1 850	101	22.8
EC13 275 1×0	ECK 18 1/0	20 to 40	0.5 to 1.0	...	...	275	1 800	102	23.0
EC9 33 3×3	ECG 150 3/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	300	1 665	120	27.0
EC9 33 3×4	ECG 150 3/4	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	160	36.0
EC9 33 4×3	ECG 150 4/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	160	36.0
EC9 66 2×3	ECG 75 2/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	152	34.2
EC9 134 1×3	ECG 37 1/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	405	1 230	152	34.2
EC9 33 4×4	ECG 150 4/4	120 to 160	3.0 to 4.0	100 to 140	2.5 to 3.5	530	938	213	48.0
EC9 66 2×4	ECG 75 2/4	...	...	112 to 152	2.8 to 3.8	530	938	203	45.6
EC9 33 4×5	ECG 150 4/5	...	...	100 to 140	2.5 to 3.5	660	750	285	64
EC9 33 4×6	ECG 150 4/6	...	...	100 to 140	2.5 to 3.5	795	625	342	76.8
EC9 33 4×7	ECG 150 4/7	...	...	100 to 140	2.5 to 3.5	925	536	399	89.6
EC4 2.2 1×0	ECBC 2250 1×0	20 to 40	0.5 to 1.0	...	...	2.20	225.000	0.9	0.20
EC4 3.31 1×0	ECBC 1500 1×0	20 to 40	0.5 to 1.0	...	...	3.31	150.000	1.3	0.30
EC4.5 4.13 1×0	ECC 1200 1×0	20 to 40	0.5 to 1.0	...	...	4.13	120.000	1.65	0.375

[A] For engineering information only, and may be made by substituting other yarn equivalents, providing fiber diameter and other properties are not affected. For example, when EC9 66 2 × 2 (ECG 75 2/2) is substituted with EC9 112 1 × 2 (ECG 37 1/2), the final yarn number remains the same.

[B] The yards per pound stated in Table 1 is an approximate yarn number. The "As Received" yards per pound will be less than the bare glass values stated. This may be contributed by twist take-up, sizing percent, or purchaser agreement to produce to a lower yarn number to meet other requirements for a further manufactured product, or combination thereof. For example, EC9 66 1 × 0 (ECG 75 1/0) stated at approximately 66 tex [7500 yd/lb] will actually be about 68 tex [7300 yd/lb] in the delivered state for use in the electrical laminate industry.

TABLE 3 Visual Examination of Yarn

Visual Characteristic	Defect
Appearance and Workmanship	Any cut, chaf, damage, or excessive filamentation, affecting serviceability[A] Finish other than specified Spot or stain[A] Embedded foreign matter[A]
Put-up (Package/Bobbin Build)	Any defect or package abnormality affecting the free unhampered unwinding of yarn or affecting the secure holding of yarn winds on the bobbin or package Not put up on bobbin or package as specified

[A] Clearly visible at normal inspection distance of approximately 1 m [3 ft].

TABLE 4 Physical Properties of Typical (Discontinuous) Staple Filament Glass Yarns

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[13]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
ED7 71R 1×0	ESE 70/1R	340	8.5	...	...	71	7000	7.6	1.7
ED7 99R 1×0	ESE 50/1R	340	8.5	...	...	99	5000	12.5	2.8
CD9 198R 1×0	CSG 25/1R	340	8.5	...	...	198	2500	20.9	4.7
CD9 198 1×0	CSG 25/1	340	8.5	...	...	198	2500	20.9	4.7
ED7 198 1×0	ESE 25/1	340	8.5	...	...	198	2500	20.9	4.7
CD9 260R 1×0	CSG 19/1R	280	7.0	...	...	260	1900	...	...
CD9 260 1×0	CSG 19/1	160	4.0	...	...	260	1900	...	...
CD9 395R 1×0	CSG 12.5/1R	160	4.0	...	...	385	1285	40.0	9.0
ED7 395 1×0	ESE 12.5/1	160	4.0	...	...	385	1285	40.0	9.0
CD9 395 1×0	CSG 12.5/1	160	4.0	...	...	385	1285	40.0	9.0
CD9 415 1×0	CSG 12/1	160	4.0	...	...	415	1200	...	...
CD9 495 1×0	CSG 10/1	160	4.0	...	...	510	975	46.7	10.5
CD9 550 1×0	CSG 9/1	160	4.0	...	...	570	870	...	...
CD9 590 1×0	CSG 8.4/1	160	4.0	...	...	590	840	...	...
CD9 620 1×0	CSG 8/1	160	4.0	...	...	636	780	...	...
CD9 800 1×0	CSG 6.2/1	160	4.0	...	...	795	624	...	...
CD9 825 1×0	CSG 6/1	160	4.0	...	...	855	580	...	...
CD9 990 1×0	CSG 5/1	80	2.0	...	...	980	505	...	...
CD9 1240 1×0	CSG 4/1	80	2.0	...	...	1235	402	...	...
CD9 1415 1×0	CSG 3.5/1	80	2.0	...	...	1480	335	...	...
CD10 1415 1×0	CSH 3.5/1	80	2.0	...	...	1480	335	93.4	21.0
CD9 1770 1×0	CSG 2.8/1	80	2.0	...	...	1850	268	122	27.5
CD9 1985 1×0	CSG 2.5/1	168	4.2	...	...	2000	247	...	...
CD9 2900 1×0	CSG 1.7/1	80	2.0	...	...	3000	167	...	...
CD10 2900 1×0	CSH 1.7/1	80	2.0	...	...	3000	167	187	42.0
CD9 3300 1×0	CSG 1.5/1	80	2.0	...	...	3500	140	...	...
CD9 3500 1×0	CSG 1.4/1	80	2.0	...	...	3900	128	227	51.0
ED7 71R 1×2	ESE 70/2R	340	8.5	260	6.5	142	3500	19.0	4.3
ED7 99R 1×2	ESE 50/2R	340	8.5	260	6.5	198	2500	24.9	5.6
ED7 124R 1×2	ESE 40/2R	340	8.5	260	6.5	248	2000	32.0	7.2
ED7 160R 1×2	ESE 31/2	340	8.5	260	6.5	320	1550	38.2	8.6
ED7 198R 1×2	ESE 25/2	340	8.5	260	6.5	385	1285	40.9	9.2
CD9 198R 1×2	CSG 25/2R	340	8.5	260	6.5	385	1285	...	...
CD9 198 1×2	CSG 25/2	340	8.5	260	6.5	385	1285	...	...
CD9 198R 1×4	CSG 25/4R	...	...	140	3.5	770	644	...	...
CD9 198 1×4	CSG 25/4	...	...	140	3.5	770	644	...	...
CD9 260R 1×2	CSG 19/2R	...	...	220	5.5	505	978	...	...
CD9 260 1×2	CSG 19/2	...	...	220	5.5	505	978	...	...
CD9 395R 1×2	CSG 12.5/2R	...	...	140	3.5	775	642	...	...
ED7 395 1×2	ESE 12.5/2	160	4.0	140	3.5	775	642	80.0	18.0
CD9 395 1×2	CSG 12.5/2	160	4.0	140	3.5	775	642	...	...
CD9 395 2×4	CSG 12.5/2/4	...	...	120	3.0	3100	160	...	...
CD9 395 2×4×6	CSG 12.5/2/4/6	...	...	80	2.0	9200	54	...	...
CD9 415 1×2	CSG 12/2	...	...	140	3.5	805	618	...	...
ED7 472 1×2	ESE 10.5/2	160	4.0	140	3.5	945	525	93.4	21.0
CD9 495 1×2	CSG 10/2	...	...	140	3.5	965	515	...	...
CD9 550 1×2	CSG 9/2	...	...	140	3.5	1070	463	...	...
ED7 590 1×2	ESE 8.4/2	160	4.0	140	3.5	1180	420	109	24.6
CD9 590 1×2	CSG 8.4/2	160	4.0	140	3.5	1180	420	...	...
CD9 620 1×2	CSG 8/2	...	...	140	3.5	1205	412	116	26.0
CD9 620 1×5	CSG 8/5	...	...	80	2.0	3000	165	...	...
ED7 800 1×2	ESE 6.2/2	160	4.0	140	3.5	1555	319	164	37.0
CD9 800 1×2	CSG 6.2/2	160	4.0	140	3.5	1555	319	...	...
CD9 825 1×2	CSG 6/2	160	4.0	140	3.5	1605	309	...	...
CD9 990 1×2	CSG 5/2	...	...	80	2.0	1930	257	...	...
CD9 1770 1×2	CSG 2.8/2	...	...	80	2.0	3800	130	...	...
CD9 1985 1×2	CSG 2.5/2	...	...	80	2.0	4100	120	...	...
CD9 2100 1×4	CSG 2.4/4	40	1.0	...	...	8300	60	511	115
CD10 2100 1×4	CSH 2.4/4	40	1.0	...	...	8300	60	...	...
CD9 2100 1×8	CSG 2.4/8	40	1.0	...	...	16000	31	...	...
CD9 2900 1×3	CSG 1.7/3	...	...	48	1.2	8900	56	560	126
CD9 3300 1×2	CSG 1.5/2	...	...	48	1.2	6500	76	...	...
CD9 3300 1×4	CSG 1.5/4	...	...	48	1.2	13100	38	...	...
CD9 3500 1×2	CSG 1.4/2	...	...	80	2.0	6900	72	...	...
CD9 3500 1×3	CSG 1.4/3	...	...	48	1.2	10300	48	...	...

TABLE 5 Physical Properties of Typical Textured Glass Yarns

Yarn Designation		Approximate Yarn Number		Breaking Strength Minimum, avg	
SI Unit (tex)	Inch-Pound Unit	tex	yd/lb	N	lbf
ET6 33	ETDE 150	35	14 300	5.6	1.2
ET6 50	ETDE 100	53	9400	6.7	1.5
ET4.5 66	ETC 75	70	7100	11.1	2.5
ET6 66	ETDE 75	70	7100	6.7	1.5
ET6 99	ETDE 50	106	4700	13.3	3.0
ET9 134	ETG 37	139	3500	17.8	4.0
ET4.5 134	ETC 37	141	3500	22.2	5.0
ET6 134	ETDE 37	143	3500	22.2	5.0
ET4.5 198	ETC 25.0	198	2500	...	...
ET6 198	ETDE 25.0	198	2500	27	6.0
ET4.5 275	ETC 18.0	275	1800	...	...
ET6 275	ETDE 18	282	1800	35.6	8.0
ET9 275	ETG 18.0	282	1800	35.6	8.0
ET4.5 420	ETC 11.8	420	1180	...	...
ET6 425	ETDE 11.6	430	1160	52	15.0
ET9 430	ETG 11.6	430	1160	89	20.0
ET6 550	ETDE 9.0	550	900	66.7	15.0
ET9 550	ETG 9.0	550	900	133	30.0
ET6 825	ETDE 6.0	825	600	89	20.0
ET9 825	ETG 6.0	825	600	89	20.0
ET9 990	ETG 5.0	990	505	89	20.0
ET6 1100	ETDE 4.5	1100	450	178	40.0
ET9 1100	ETG 4.5	1100	450	111	25.0
ET6 1415	ETDE 3.5	1415	350	267	60.0
ET9 1415	ETG 3.5	1415	350	133	30.0
ET6 1804	ETDE 2.75	1804	275	...	...
ET9 1804	ETG 2.75	1804	275	...	...
ET9 1835	ETG 2.70	1835	271	160	36.0
ET6 2205	ETDE 2.25	2205	225	...	...
ET9 2205	ETG 2.25	2205	225	...	...
ET9 2610	ETG 1.9	2610	190	267	60.0
ET6 2800	ETDE 1.75	2800	175	267	60.0
ET9 2800	ETG 1.75	2800	175	267	60.0
ET9 3545	ETG 1.4	3545	140	267	60.0
ET9 4510	ETG 1.1	4510	110	267	60.0
ET96614	ETG 0.75	6614	75	289	65.0

TABLE 6 Sample Size Determination

Lot Size, Packages per Lot	Sample Size, Number of Packages
15 or less	2
16 to 40	3
41 to 110	5
111 to 300	7
301 to 500	10
501 or more	15

TABLE 7 Fiber Diameter inches × 10^{-5}

Components of Variance Expressed as Standard Deviations[A]			
Material	Grand Average	Single-Operator Precision	Within-Laboratory Precision
600 Denier Glass Fiber Strand	43.0	2.80	0

[A] The square roots of the components of variance are being reported to express the variability in the appropriate units of measure rather than as the squares of those units of measure.

TABLE 8 Fiber Diameter inches × 10^{-5}

Critical Differences for the Conditions Noted[A]			
Material	Number of Observations in each Average	Single-Operator Precision	Within-Laboratory Precision
600 Denier Glass Fiber Strand	30	1.42	1.42
	50	1.10	1.10
	100	0.78	0.78
	200	0.55	0.55

[A] The critical differences were calculated using $t = 1.960$, which is based on infinite degrees of freedom.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

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SPECIFCATION FOR EPOXY RESINS

SD-1763

(Identical with ASTM D1763-00(R13) except for revisions to Note 1, para. 2.2, editorial changes, and addition of section 9 and Annex A1.)

Specification for Epoxy Resins

1. Scope

1.1 This specification covers totally reactive epoxy resins supplied as liquids or solids which can be used for castings, coatings, tooling, potting, adhesives, or reinforced applications. The addition of hardeners in the proper proportions causes these resins to polymerize into infusible products. The properties of these products can be modified by the addition of various fillers, reinforcements, extenders, plasticizers, thixotropic agents, etc. The epoxy resins described also can be used as stabilizers and cross-linking agents; and they can be combined with other reactive products.

1.2 It is not the function of this specification to provide engineering data or to guide the purchaser in the selection of a material for a specific end use. Ordinarily the properties listed in Table 1 and Table 2 are sufficient to characterize a material under this specification, and it is recommended that routine inspection be limited to testing for such properties.

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in SI units are to be regarded as standard.

NOTE 1—ISO 3673–1 is similar but not equivalent to this specification. Product classification and characterization are not the same.

2. Referenced Documents

2.1 *ASTM Standards:*

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D883 Terminology Relating to Plastics

D1209 Test Method for Color of Clear Liquids (Platinum-Cobalt Scale)

D1544 Test Method for Color of Transparent Liquids (Gardner Color Scale)

D1652 Test Method for Epoxy Content of Epoxy Resins

D3104 Test Method for Softening Point of Pitches (Mettler Softening Point Method)

D3892 Practice for Packaging/Packing of Plastics

2.2 *ISO Standard:*

ISO 3673–1 Plastics—Epoxy Resins—Part 1: Designation

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions of terms used in this specification are in accordance with Terminology D883.

4. Classification

4.1 The resins covered contain no hardeners. Resin types covered are divided into specific groups by their chemical nature:

4.1.1 *Type I*—Bisphenol A and epichlorohydrin.

4.1.2 *Type II*—Reaction product of phenol and formaldehyde (novolac resin) and epichlorohydrin.

4.1.3 *Type III*—Cycloaliphatic and peracid epoxies.

4.1.4 *Type IV*—Glycidyl esters.

4.1.5 *Type V*—Reaction product of epichlorohydrin and *p*-aminophenol.

4.1.6 *Type VI*—Reaction product of epichlorohydrin and glyoxal tetraphenol.

4.2 These types may be further subdivided by grades:

4.2.1 *Grade* 1—Resins containing no diluent.

4.2.2 *Grade* 2—Resins modified with a reactive diluent. Each class of Grade 2 resin can be made from any class of Grade 1 resin.

4.2.3 Each grade may include as many classes as are shown in the tables.

TABLE 1 Requirements for Type I, Grade 1, Epoxy Resin

Class	Epoxy Content		Viscosity, cP at 25°C	Mettler Softening Point, °C	Color[A] Gardner-Holdt, max
	Equivalents/100 g	WPE[B]			
A[C]	0.500 to 0.588	170 to 200	3000 to 20 000		3
B	0.443 to 0.527	190 to 226	15 000 to 40 000		5
C	0.357 to 0.443	226 to 280	←—— semi-solid	——→	5
D	0.125 to 0.357	280 to 800		40 to 90	5
E	0.067 to 0.125	800 to 1500		90 to 110	5
F	0.040 to 0.067	1500 to 2500		110 to 140	5
G	0.017 to 0.040	2500 to 6000		134 to 180	6
H	0.010 to 0.020	5000 to 10 000		160 to 200	7

[A] Test Method D1209 with a maximum color of 100 defines low color Type I resins.
[B] WPE = weight per epoxy equivalent.
[C] Can exist as a supercooled liquid.

TABLE 2 Requirements for Type I, Grade 2, Epoxy Resin

Class	Epoxy Content	Viscosity, cP at 25°C
A	[A]	100 to 500
B	[A]	500 to 900
C	[A]	900 to 4000
D	[A]	4000 to 10 000

[A] The WPE of these diluted resins shall be agreed upon between the purchaser and the seller.

5. Requirements

5.1 The resin shall be of uniform quality and as free of contamination as can be achieved by good manufacturing practice.

5.2 The resin shall conform to the requirements prescribed in Tables 1-7 for the type, grade, and class of material specified.

6. Sampling

6.1 Take a representative sample sufficient for the test specified either from a well-blended bulk lot prior to packaging or by withdrawing samples with a thief from no less than 5 % of the containers comprising the lot or shipment.

6.2 Unless the samples taken from the containers show evidence of variability, blend them into a single composite sample on which to conduct the specified tests. Instead of the foregoing, adequate statistical sampling acceptable to the purchaser and the seller may be substituted.

7. Test Methods

7.1 Determine compliance with the requirements specified in Table 1 in accordance with the following methods:

7.1.1 *Viscosity*—Test Method D445.

7.1.2 *Weight per Epoxy Equivalent—(WPE)*—Test Method D1652.

7.1.3 *Color*—Test Method D1544, except for Classes IV through VII, where a 40 % solids solution in butyl carbitol shall be used.

7.1.4 *Color*—Test Method D1209 is used to characterize the low color Type I and Type III resins.

7.1.5 *Softening Point*—Test Method D3104.

8. Packaging and Package Marking

8.1 *Packaging*—The material shall be packaged in a standard commercial container so constructed as to protect the product from contamination and ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery, unless otherwise specified in the contract or order.

8.2 *Package Marking*—Shipping containers shall be marked with the name of the product and its manufacturer, its type and grade, lot or control number, and the quantity contained as defined by the contract or order under which shipment is made.

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

9. Certification

9.1 See Annex A1 for certification requirements.

10. Keywords

10.1 epoxy; resins

TABLE 3 Requirements for Type II, Grade 1, Epoxy Novolac Resins

Class	Epoxy Content		Viscosity, cP at 25°C	Mettler Softening Point, °C	Color[A], Gardner-Holdt, max
	Equivalents/100 g	WPE[B]			
A	0.500 to 0.588	170 to 200	35 000 to 100 000		3
B	0.537 to 0.575	174 to 186	12 000 to 19 000		7
C	0.476 to 0.555	180 to 210	16 to 30[C]		...
D	0.455 to 0.525	190 to 220	4000 to 10 000 at 55°C	48 to 60	4
E	0.333 to 0.370	270 to 300		70 to 80	9
F	0.294 to 0.345	290 to 340	B–D[A]	90 to 100	10[A]

[A] Test Method D1209 with a maximum color of 300 defines low color Type III resins.
[B] Fifty percent solution in acetone.
[C] Forty percent in diethylene glycol mono *n*-butyl ether.

TABLE 4 Requirements for Type III, Grade 1, Cycloaliphatic Resins

Class	Epoxy Content		Viscosity, cP at 25°C	Color, Gardner-Holdt, max
	Equivalents/100 g	WPE		
A	1.35 to 1.43	70 to 74	13 max	1
B	1.250 to 1.350	74 to 80	7	1
C	0.98 to 1.09	91 to 102	<100 at 45°C	2
D	0.625 to 1.000	100 to 160	80 to 500	3
E	0.833 to 0.909	110 to 120	80 to 150	...
F	0.699 to 0.763	131 to 143	350 to 450	1
G	0.649 to 0.751	133 to 154	7000 to 17 000 at 38°C	2
H	0.465 to 0.488	205 to 216	500 to 1500	2
I	0.462 to 0.487	210 to 221	500 to 1000	1
J	0.238 to 0.270	370 to 420	50[A]	...
K	0.233 to 0.256	309 to 430	300 to 600 at 40°C	2[B]
L	0.232 to 0.256	390 to 430	450 at 40°C	2

[A] Forty percent solution in acetone.
[B] At 40°C.

TABLE 5 Requirements for Type IV, Grade 1, Glycidyl Esters

Class	Epoxy Content		Viscosity, cP at 25°C	Color, Gardner-Holdt, max
	Equivalents/100 g	WPE		
A[A]	0.790 to 0.835	120 to 130	300 to 500	6
B[A]	0.625 to 0.668	150 to 160	200 to 400	3
C[B]	0.625 to 0.668	150 to 160	1000 to 1300	5
D[C]	0.391 to 0.438	244 to 256	5 to 10	1

[A] Cycloaliphatic.
[B] Aromatic.
[C] Saturated monocarboxylic acid.

TABLE 6 Requirements for Type V, Grade 1, Reaction Product of Epichlorohydrin and of *p*-Aminophenol

Class	Epoxy Content		Viscosity, cP at 25°C	Color, Gardner-Holdt, max
	Equivalents/100 g	WPE		
A	0.990 to 1.03	95 to 107	550 to 850	...
B	0.869 to 0.952	105 to 115	1500 to 5000	...

TABLE 7 Requirements for Type VI, Grade 1, Reaction Product of Epichlorohydrin and Glyoxal Tetraphenol

Class	Epoxy Content		Viscosity, cP at 25°C	Color, Gardner-Holdt, max
	Equivalents/100 g	WPE		
A	0.416 to 0.526	190 to 240	10[A]	...

[A] Fifty percent solution in acetone.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

SPECIFICATION FOR REINFORCED EPOXY RESIN GAS PRESSURE PIPE AND FITTINGS

SD-2517

(Identical with ASTM D2517-18 except for revisions to paras. 2.1, 4.2; addition of paras. 2.2, 2.3, section 10, and Annex A1; deletion of Notes 4 and 5; revisions to paras. X1.1.1, X1.2.1, and X2.1.1.)

Specification for
Reinforced Epoxy Resin Gas Pressure Pipe and Fittings

1. Scope

1.1 This specification covers requirements and methods of test for materials, dimensions and tolerances, hydrostatic-burst strength, chemical resistance, and longitudinal tensile properties, for reinforced epoxy resin pipe and fittings for use in gas mains and services for direct burial and insertion applications. The pipe and fittings covered by this specification are intended for use in the distribution of natural gas, petroleum fuels (propane–air and propane–butane vapor mixtures), manufactured and mixed gases where resistance to gas permeation, toughness, resistance to corrosion, aging, and deterioration from water, gas, and gas additives are required. Methods of marking are also given. Design considerations are discussed in Appendix X1.

1.2 The values in SI units are to be regarded as the standard.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, 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.*

NOTE 1—There is no known ISO equivalent to this standard.

1.4 A recommended inplant quality control program is given in Appendix X2.

2. Referenced Documents

2.1 *ASTM Standards:*

D396 Specification for Fuel Oils
D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1898 Practice for Sampling of Plastics (Withdrawn 1998)
D2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D2924 Test Method for External Pressure Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D3039 Test Method for Tensile Properties of Polymer Matrix Composite Materials
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D3839 Guide for Underground Installation of "Fiberglass" (Glass-Fiber Reinforced Thermosetting-Resin) Pipe
D3892 Practice for Packaging/Packing of Plastics
D5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings
F412 Terminology Relating to Plastic Piping Systems

2.2 *ASME Codes and Standards:*

ASME B31.8 Code, Gas Transmission and Distribution Piping System

ASME NM.3.2, SD-2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

ASME NM.3.2, SD-5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings

2.3 U.S. Department of Transportation (DOT) Office of Pipleline Safety (OPS):

49 CFR 192—Title 49 of The Code of Federal Regulations Part 192 — Transportation of Natural Gas and Other Gas by Pipeline: Minimum Federal Safety Standards

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 or F412. Abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for fiberglass pipe is RTRP and the abbreviation for fiberglass fittings is RTRF.

3.1.2 The gas industry technology used in this specification is in accordance with definitions given in The Department of Transportation of Natural and Other Gas by Pipeline Minimum Safety Standards.

3.1.3 *Standards Reinforced Thermosetting Resin Pipe Materials Designation Code*—The pipe material designation code shall consist of the abbreviation RTRP followed by type and grade in arabic numerals, class by a capital letter and the long term steady pressure strength by a second capital letter. The fittings material designation shall consist of the abbreviation RTRF followed by type (method of manufacture), grade (general type of resin), class (configuration of joining system), and pressure rating.

4. Classification

4.1 *Pipe*—The pipe covered in this specification is made by the filament winding process and is described in Specification D2996. Requirements of this pipe are based on short-term tests defined in this specification.

4.2 *Fittings*—This specification covers *a)* reinforced epoxy resin fittings described in specification D5685 and made of the type of materials covered in Section 5, and *b)* metal fittings which have been designed and tested in accordance with the provisions of 49 CFR 192, which are capable of being joined to the pipe and will provide a suitable gas distribution system.

5. Materials

5.1 The resins and reinforcements used to make pipe shall be as specified in 5.1.1.

5.1.1 This specification covers glass fiber reinforced epoxy resin pipe and fittings as defined in Specification D2996 as RTRP Type 1; Grade 1; Classes A, C, F, and H; and Hydrostatic Design Basis U, W, X, Y, and Z —Example: RTRP 11 HZ and fittings as defined in specification D5685-RTRF Types 1, 2, 3, 4, and 5; Grade 1; Class A, C, F, and H; Category 1, 2, 3, 4, and 5; and Pressure Rating Category D, E, F, G, H, I, and J—Example: RTRF 21A2D.

NOTE 2—The particular reinforced thermosetting resin included initially in this specification for gas pressure piping was selected on the basis of engineering test studies made by Battelle Memorial Institute, experimental use in field installations, and technical data supplied by the manufacturers of the plastics materials used to make the pipe and fittings. It is the intent of ASTM Committee D-20 on Plastics to consider for inclusion other resins and reinforcements in this specification when evidence is presented to show that they are suitable for gas service. Minimum requirements are an ASTM pipe specification and long-term strength determined in accordance with Test Method D2992, Procedure B, in addition to the requirements of this specification.

6. Requirements

6.1 *Workmanship*—The pipe and fittings shall be free of visible cracks, holes, foreign inclusions, blisters, and other injurious defects. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 *Pipe Dimensions and Tolerances:*

6.2.1 *Diameters*—The outside diameter of the pipe shall be in accordance with Table 1 when measured in accordance with 8.4.1.

6.2.2 *Wall Thickness*—The wall thickness of the pipe shall meet the requirements given in Table 1 when measured in accordance with 8.4.1.

6.2.3 *Lengths*—The pipe shall be in lengths as specified on the purchase order when measured in accordance with 8.4.1.

NOTE 3—Either threaded adaptors or bonded joints are acceptable. Jointers of up to 5 % of the shipment are acceptable to meet the length requirements. No section less than 1.5 m (5 ft) long can be used to make a joint and only one jointer can be used in a length.

6.3 *Fittings Dimensions and Tolerances*— The fittings dimensions shall enable the pipe and fittings to be joined and shall be measured in accordance with 8.4.2.

NOTE 4—DELETED

6.4 *Short-Term Rupture Strength* (*Burst Pressure*)—The minimum hoop stress at burst for pipe covered by this specification shall be as listed in Table 2 when tested in accordance with 8.5. The minimum burst requirements for fittings covered by this specification shall be 4.82 MPa (700

TABLE 1 Pipe Dimensions, mm (in.)

Nominal	Outside Diameter	Tolerance	Minimum Wall Thickness
2	60.325 (2.375)	+1.524, −0.457 (+0.060, −0.018)	1.524 (0.060)
3	88.900 (3.500)	+1.524, −0.457 (+0.060, −0.018)	1.524 (0.060)
4	114.300 (4.500)	+1.524, −0.457 (+0.060, −0.018)	1.780 (0.070)
6	168.275 (6.625)	+1.678, −0.711 (+0.066, −0.028)	2.540 (0.100)
8	219.075 (8.625)	+2.184, −1.016 (+0.086, −0.040)	3.227 (0.125)
10	273.050 (10.750)	+2.743, −1.219 (+0.108, −0.048)	3.830 (0.150)
12	323.850 (12.750)	+3.251, −1.422 (+0.128, −0.056)	4.215 (0.175)

TABLE 2 Minimum Physical Property Requirements for Pipe

Physical Property	Test Method	23°C (73.4°F)	65.6°C (150°F)
Short-term rupture strength (burst) min, hoop stress, psi	D1599	40 000	35 000
Static hydrostatic hoop stress 10^5 h (estimated), min, psi	D2992	15 000	14 000
Hydrostatic collapse min, psig	D2924	14.7	11.0
Longitudinal tensile strength, min, psi	D2105	8 900	8 300
Parallel plate crush strength, min Pipe stiffness at 5% deflection, psi	D2412	45	41

psi) internal pressure or 27.5 MPa (4000 psi) hoop tensile stress, whichever is greater, when tested in accordance with 8.5 at temperatures of 23°C (73.4°F) and 65.6°C (150°F), and calculated using the equation listed in Test Method D1599 for hoop stress. The calculations shall use the fittings wall thickness and diameter at a point where the wall thickness is at a minimum and which is also in the section of the fittings which is not reinforced by the pipe.

6.5 *Crush Strength*—The minimum stiffness at 5 % deflection of the pipe shall be as shown in Table 2 when tested in accordance with Test Method D2412.

6.6 *Chemical Resistance*—The pipe shall not change more than ±12 % in apparent tensile strength when measured in accordance with 8.7.

NOTE 5—DELETED

6.7 *Longitudinal* (*Tensile Strength*)—The minimum longitudinal tensile strength for pipe covered by this specification shall be as listed in Table 2 when tested in accordance with Test Method D2105.

6.8 *Hydrostatic Collapse*—The minimum factor for pipe covered by this specification shall be as listed in Table 2 when tested in accordance with Test Method D2924.

7. Adhesive Requirements

7.1 Adhesives used to join reinforced epoxy resin pipe shall be suitable for use with the pipe and fittings and meet the requirements listed in 7.2 and 7.3.

NOTE 6—It is recommended that the working (pot) life of the adhesive be agreed upon between the purchaser and the manufacturer.

7.2 *Adhesive Test*—All adhesives covered by this specification shall have a minimum ultimate shear strength of 10.3 MPa (1500 psi) when tested in accordance with 8.8.

7.3 *Packaging*—Each adhesive kit shall contain the necessary components and instruction sheets, which shall include cure times and pot life.

8. Test Methods

8.1 *Sampling*—Take a sample of the pipe and fittings sufficient to determine conformance with this specification. About 15 m (50 ft) of pipe or tubing are required to make the tests prescribed. The number of fittings required varies, depending upon the size and type of fitting. It is suggested that a sampling plan be agreed upon by the purchaser and the manufacturer (see Practice D1898).

8.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 48 h, in accordance with Procedure A of Practice D618 for those tests where conditioning is required and in all cases of disagreement.

8.3 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F), unless otherwise specified.

8.4 *Dimensions and Tolerances:*

8.4.1 *Wall Thickness and Diameter*—Determine in accordance with Practice D3567.

8.4.2 *Liner Thickness*—When the test specimens contain a liner, determine the average liner thickness in accordance with Practice D3567.

8.5 *Short-Term Hydrostatic Failure Strength (Minimum Hoop Stress)*—Determine in accordance with Test Method D1599. Fittings shall be tested with pipe nipples bonded in the sockets.

8.6 *Apparent Tensile Properties*—The apparent tensile strength shall be determined in accordance with Procedure B of Test Method D2290.

8.7 *Chemical Resistance*—Determine the resistance to the following chemicals in accordance with Procedure II of Test Method D543, except use ring specimens cut from pipe for this purpose:

Chemical	Concentration, %
Fuel Oil No. 1 (Specification D396)	100
t-butyl mercaptan	5 in fuel oil
Antifreeze agents (at least one shall be used):	
Methanol	100
Isopropanol	100
Ethylene glycol	100

Cut specimens from the pipe in accordance with 8.6; test five specimens with each reagent. Coat specimen edges with adhesive prior to immersion. Completely immerse the specimens in the chemicals for 72 h. Upon removal from the chemicals, wipe the specimens with a clean dry cloth, condition in the testing room for a period not to exceed 2 h, and then test in tension in accordance with 8.6.

8.8 *Adhesive Test*—The ultimate shear strength for adhesives used to bond pipe and fittings together shall be determined in accordance with the following procedure; it is applicable to all adhesives covered by this specification.

8.8.1 *Principle*—Laboratory shear specimens are made by bonding together two 3 by 13 by 75-mm (⅛ by ½ by 3-in.), reinforced thermosetting plastic laminates using the supplied adhesive kits. This specimen is then cured in accordance with instructions supplied with the adhesive. After curing, the specimen is pulled apart in a universal testing machine.

8.8.2 *Test Specimen*—The test specimen shall be made using longitudinally reinforced epoxy resin laminates that are made of the same materials as the pipe with dimensions of 5 by 13 by 75 mm (⅛ by ½ by 3 in.). Each specimen shall have a bonding surface on one end made by milling off 5 mils of the surface for a length of 2 mm (¾ in.). Test a minimum of five test specimens.

8.8.3 *Procedure:*

8.8.3.1 Clean the milled surfaces of two 75-mm (3-in.) long laminates using solvent supplied with adhesive.

8.8.3.2 Mix the adhesive components in accordance with instructions supplied with the adhesives.

8.8.3.3 Wet the cleaned surface of the laminates with the mixed adhesive.

8.8.3.4 Press the adhesive-coated areas of the laminates together, maintaining alignment of edges and clamp so that the specimen is held together using uniform pressure. Pressure used shall be sufficient to yield specimens with adhesive line thicknesses that do not exceed 0.9 mm (1⁄32 in.).

8.8.3.5 Note the time when assembly is completed.

8.8.3.6 Check the temperature in the room and determine the cure time from instructions supplied with the adhesive.

8.8.3.7 When the required amount of time has elapsed, remove the specimen from the clamping fixture, and place it in grips of the universal testing machine. Good alignment in the grips is essential. Set speed control at 5.1 to 6.4 mm (0.20 to 0.25 in.)/min and start the testing machine. Record the breaking load.

8.8.4 *Calculation*—Calculate the ultimate shear strength of the adhesive using the following equation and report to three significant figures:

$$\sigma = P/A \quad (1)$$

where:

σ = ultimate shear stress, MPa (or psi),
P = ultimate load, N (or lbf), and
A = bond area, mm^2 (or $in.^2$).

For each series of tests, calculate the arithmetic mean of all values obtained to three significant figures and report as the "average value." Calculate the standard deviation as follows and report to two significant figures:

$$s = \left[\left(\sum X2 - n\bar{X}^2\right)/(n = 1)\right]^{\frac{1}{2}} \quad (2)$$

where:

s = estimated standard deviation,
X = value of a single observation,
n = number of observations, and
$\bar{X}$ = arithmetical average of the set of observations.

9. Packaging and Marking

9.1 *Pipe*—All required marking shall be legible and so applied without indentation as to remain legible under normal handling and installation practices. These markings shall consist of the manufacturer's name or trademark, the nominal pipe size, and the standard reinforced plastic pipe identification at each end of the pipe. In addition to the above, the pipe shall bear an appropriate code number which will ensure identification of the pipe as to the month and year of production and raw materials used in the production of said pipe. The manufacturer shall maintain such additional records as are necessary to confirm identification of all coded pipe. Marking shall include the designation ASTM D2517.

9.2 *Fittings*—All fittings shall be marked on the body or hub. The marking shall consist at least of the manufacturer's name or trademark, or both, and the symbol for the type of material and size. Marking shall include the designation ASTM D2517.

9.3 *Adhesives*—All adhesive containers shall be marked on the container. The marking shall consist of the manufacturer's name or trademark, or both, manufacturing date, shelf life, and storage requirements.

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

10. Certification

10.1 See Annex A1 for certification requirements.

11. Keywords

11.1 filament wound; compression molded; configuration of joining system; rupture strength; crush strength; chemical resistance; apparent tensile properties; adhesive

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIXES

(Nonmandatory Information)

X1. DESIGN

X1.1 General

X1.1.1 The design of a plastic piping system for gas must include consideration of the effect of the environment while under stress, as well as internal and external loads. The combined effects of time, stress, and environment must be investigated as an overall basis for selecting a specific kind and size of plastic pipe. The selection of design stresses for RTRP is the prerogative of the DOT/OPS. The AGA Plastic Pipe Committee and members of Committee D-20 are cooperating with DOT to provide assistance in selecting safe design stress levels for the various kinds of plastic pipe.

X1.2 Internal Pressure

X1.2.1 The design stresses for natural gas are based on the 100 000-h hydrostatic strength of the pipe of 75°F obtained in accordance with Procedure B of Practice D2992. The 100 000-h strengths of the plastics included in the applicable ASTM specifications are as follows:

Plastic Pipe Material Designation	Long-Term (100 000-h) Strength at 23°C (73°F)
RTRP (glass fiber reinforced epoxy resin pipe)	15 000 psi

Strengths for other RTRP materials will be added when these materials are included in the applicable ASTM specifications. The design stresses are obtained by multiplying the 100 000-h strength by design factors or service factors in accordance with the class of location as described in Chapter IV of the ASME B31.8 Code and 49 CFR 192.

X1.3 External Loads

X1.3.1 It is recognized that certain minimum requirements exist for the support of earth loads from backfill and other external forces. Proper installation techniques can be used with flexible conduit (as defined by Marston and Spangler) to support relatively large earth loads without excessive deflection by mobilizing lateral passive soil forces. Proper installation technique ensures that the necessary passive soil pressure at the sides of the pipe will be developed and maintained. It is also recognized that the internal pressures may be valuable in minimizing the deflection caused by earth loads. However, the magnitude of this latter effect is somewhat subjective, and therefore installation procedures defined in Test Method D3839 are recommended instead of more specific information.

X2. RECOMMENDED IN-PLANT QUALITY CONTROL PROGRAM FOR REINFORCED EPOXY RESIN PIPE INTENDED FOR USE IN NATURAL GAS SERVICE

X2.1 Introduction

X2.1.1 The following in-plant quality control program covering material, performance requirements, and marking shall be used in manufacture to provide reasonable assurance that the RTRP pipe and fittings for use with the type of RTRP supplied under this specification meets the requirements of the applicable standard. The pipe and fittings producers shall maintain records on all aspects of this program and supply these to the purchaser, if requested.

X2.2 Material

X2.2.1 The pipe and fittings manufacturer shall use only those raw materials that are allowed by the applicable standard and shall so certify.

X2.3 Pipe Tests

X2.3.1 *Product Quality Control (See Note X2.1)*—The tests in Table X2.1 shall be made per size per processing unit at the denoted frequencies and the test results recorded and filed for inspection, upon request.

NOTE X2.1—When the pipe fails to meet the specification (or standard) requirement in any test, additional tests shall be made on the pipe produced back to the previous acceptable results to select the pipe produced in the interim that does pass the requirement. Pipe that does not meet the requirement shall be rejected.

X2.4 Test Methods

X2.4.1 The test methods may be those generally used by the manufacturer, but in case of question, those given in the applicable ASTM standard shall be used.

TABLE X2.1 Pipe Tests

Property	Test Method	Test Frequency
Visual	...	all
Dimensions:		
Diameter	D3567	900 m (3000 ft) or once/3h
Wall thickness	D3567	1500 m (5000 ft) or once/lot[A]
Mechanical properties:		
Burst pressure	D1599	5000 ft
Short-term static (20 h) or cyclic[B]	D1598 (D2143)	24 h

[A] Whichever is most frequent.
[B] A cyclic pressure test made in accordance with the procedure in Test Method D2143 may be substituted for the static test requirements if it has been demonstrated that the results of the two methods are equivalent.

X2.5 Records

X2.5.1 A code number shall be included in the marking on the pipe. If required, on the directional fittings, the code number may be used to identify in the records the following:

X2.5.2 The compound,

X2.5.3 The date of manufacture,

X2.5.4 The shift,

X2.5.5 The test results required in this in-plant quality control program, and

X2.5.6 The manufacturer.

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SPECIFICATION FOR FILAMENT-WOUND "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PIPE

SD-2996

(Identical with ASTM D2996-17 except for revisions to paras. 2.1, 8.7, section 9, para. X1.1.1; addition of Annex A1; and editorial corrections.)

Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

1. Scope

1.1 This specification covers machine-made reinforced thermosetting resin pressure pipe (RTRP) manufactured by the filament winding process up to 60 in. nominal size. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, methods of test, and marking.

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

1.3 The following safety hazards caveat pertains only to the test method portion, Section 8, 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.*

NOTE 1—The term "fiberglass pipe" as described in Section 3 of this specification applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP). This specification covers only reinforced thermosetting resin pipe (RTRP).

NOTE 2—This specification is applicable to RTRP where the ratio of outside diameter to wall thickness is 10:1 or more.

NOTE 3—There is no known ISO equivalent to this standard.

NOTE 4—For the purposes of this standard, polymer does not include natural polymers.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

D638 Test Method for Tensile Properties of Plastics

D883 Terminology Relating to Plastics

D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure

D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2105 Test Method for Longitudinal Tensile Properties of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube

D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe

D2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe (Withdrawn 2017)

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings

D3039 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials

D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings

F412 Terminology Relating to Plastic Piping Systems

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminologies D883 and F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for reinforced thermosetting resin pipe is RTRP.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coating*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

3.2.2 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.3 *filament winding*—a process used to manufacture tubular goods by winding continuous fibrous glass strand roving, or roving tape, saturated with liquid resin or preimpregnated with partially cured resin (subsequent heating may be required to polymerize the resin system) onto the outside of a mandrel in a predetermined pattern under controlled tension; the inside diameter (ID) of the pipe is fixed by the mandrel outside diameter and the outside diameter (OD) of the pipe is determined by the amount of material that is wound on the mandrel.

3.2.4 *liner*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 8.3.2, which does not contribute to the strength in the determination of the hydrostatic design basis.

3.2.5 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.2.7 *reinforced wall thickness*—the total wall thickness minus the liner or exterior coating thickness, or both.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by type, grade, class, and hydrostatic design basis in accordance with Classification D2310 and by a secondary cell classification system that defines the basic mechanical properties of the pipe. These types, grades, classes, hydrostatic design basis categories, and cell classification designations are as follows:

4.1.1 *Types:—Type 1*

Filament wound.

4.1.2 *Grades:—Grade 1*

Glass fiber reinforced epoxy resin pipe.

Grade 2—Glass fiber reinforced polyester resin pipe.

Grade 7—Glass fiber reinforced furan resin pipe.

4.1.3 *Classes:—Class A*

No liner.

Class B—Polyester resin liner (nonreinforced).

Class C—Epoxy resin liner (nonreinforced).

Class E—Polyester resin liner (reinforced).

Class F—Epoxy resin liner (reinforced).

Class H—Thermoplastic resin liner (specify).

Class I—Furan resin liner (reinforced).

4.1.4 *Hydrostatic Design Basis*—Two methods of classifying the hydrostatic design basis of the pipe are provided. Pipe meeting this specification shall be classified using either the cyclic test method or the static test method, or both, and the designations as shown in Table 1. Appendix X1 explains how these design basis categories are to be used.

4.1.4.1 For pipe subjected to axial or end loads, the effect of these loads shall be represented in the HDB testing. In the designation code, the numeral 1 shall immediately follow the HDB letter class if free-end type closures were used and the numeral 2 shall immediately follow the HDB letter class if restrained-end type closures were used to establish the HDB.

4.1.5 *Mechanical Properties*—Table 2 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE 5—For the purposes of this classification, polyester resins shall include vinylester resins, but the purchaser should consult with the manufacturer to determine which resin is applicable for the specific conditions in which the pipe will be used.

NOTE 6—All possible combinations covered by the above classification system may not be commercially available.

4.1.6 *Designation Code*—The pipe designation code shall consist of the abbreviation RTRP, followed by the type and grade in Arabic numerals, the class and static or cyclic HDB level in capital letters, the type of end closure used, and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and pipe stiffness.

Example: RTRP-11FA1-1334. Such a designation would describe a filament-wound, glass-fiber reinforced, epoxy pipe having a reinforced epoxy liner; a cyclic pressure strength exceeding 2500 psi (17.2 MPa) using free-end closures; a short-term rupture strength exceeding 10 000 psi (68.9 MPa); a longitudinal tensile strength exceeding 25 000 psi (172 MPa); a longitudinal tensile modulus exceeding 3×10^6 psi (20.7×10^3 MPa); and a pipe stiffness exceeding 36 psi (248 kPa).

5. Materials and Manufacture

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall meet the performance requirements of this specification.

6. Physical Requirements

6.1 *Workmanship*—The pipe shall be free of all defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas which, due to their

TABLE 1 Hydrostatic Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Hoop Stress, psi (MPa)	Designation	Hoop Stress, psi (MPa)
A	2 500 (17.2)	Q	5 000 (34.5)
B	3 150 (21.7)	R	6 300 (43.4)
C	4 000 (27.6)	S	8 000 (55.2)
D	5 000 (34.5)	T	10 000 (68.9)
E	6 300 (43.4)	U	12 500 (86.2)
F	8 000 (55.2)	W	16 000 (110)
G	10 000 (68.9)	X	20 000 (138)
H	12 500 (86.2)	Y	25 000 (172)
		Z	31 500 (217)

TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	Cell Limits 0	1	2	3	4	5	6
1	Short-term rupture strength hoop tensile stress, min, psi	. . .	10 000	30 000	40 000	50 000	60 000	70 000
	(MPa)	. . .	(68.9)	(207)	(276)	(345)	(414)	(483)
2	Longitudinal tensile strength min, psi	. . .	8000	15 000	25 000	35 000	45 000	55 000
	(MPa)	. . .	(55.2)	(103)	(172)	(241)	(310)	(379)
3	Longitudinal tensile modulus, min, psi × 10^6	. . .	1	2	3	4	5	6
	(MPa)	. . .	(6900)	(13 000)	(20 700)	(27 600)	(34 500)	(41 400)
4	Pipe stiffness at 5 % deflection, min, psi	. . .	5	9	18	36	72	144
	(kPa)	. . .	(34)	(62)	(124)	(248)	(496)	(993)

nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, and other physical properties. The pipe shall be round and straight and the bore of the pipe shall be smooth and uniform. All pipe ends shall be cut at right angles to the axis of the pipe and any sharp edges removed.

6.2 *Dimensions and Tolerances:*

6.2.1 *Inside and Outside Diameter*—The inside and outside diameter and tolerances of pipe meeting these specifications shall conform to the requirements in one of the Tables 3-6, when determined in accordance with 8.3.1.

6.2.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not at any point be less than 87.5 % of the nominal wall thickness published in the manufacturer's literature current at the time of purchase when measured in accordance with 8.3.1.

TABLE 3 Dimensions and Tolerances for Outside Diameter (OD) Series Pipe with Steel-Pipe-Equivalent (Iron Pipe Size)

Nominal Pipe Size, in.	in.	(mm)
1	1.315 + 0.060 −0.016	33.40 + 1.52 −0.41
1½	1.900 + 0.060 −0.018	48.26 + 1.52 −0.46
2	2.375 + 0.060 −0.018	60.32 + 1.52 −0.46
2½	2.875 + 0.060 −0.018	73.02 + 1.52 −0.46
3	3.500 + 0.060 −0.018	88.90 + 1.52 −0.46
4	4.500 + 0.060 −0.018	114.30 + 1.52 −0.46
6	6.625 + 0.066 −0.028	168.28 + 1.68 −0.64
8	8.625 + 0.086 −0.040	219.08 + 2.18 −1.02
10	10.750 + 0.108 −0.048	273.05 + 2.74 −1.22
12	12.750 + 0.128 −0.056	323.85 + 3.25 −1.42
14	14.000 + 0.145 −0.064	355.60 + 3.68 −1.63
16	16.000 + 0.165 −0.074	406.40 + 4.19 −1.88

[A] Outside diameters other than listed in Tables 3 to 6 shall be permitted by agreement between the manufacturer and the purchaser.

TABLE 4 Dimensions and Tolerances for Inside Diameter (ID) Series Pipe

Nominal Pipe Size, in.	in.	mm
1	1.00 ± 0.06	25.4 ± 1.52
1½	1.500 ± 0.06	38.1 ± 1.52
2	2.000 ± 0.06	50.8 ± 1.52
2½	2.500 ± 0.06	63.5 ± 1.52
3	3.000 ± 0.12	76.2 ± 3.05
4	4.000 ± 0.12	101.6 ± 3.05
6	6.000 ± 0.25	152.4 ± 6.35
8	8.000 ± 0.25	203.2 ± 6.35
10	10.000 ± 0.25	254.0 ± 6.35
12	12.000 ± 0.25	304.8 ± 6.35
14	14.000 ± 0.25	355.6 ± 6.35
15	15.000 ± 0.25	381.0 ± 6.35
16	16.000 ± 0.25	406.4 ± 6.35
18	18.000 ± 0.25	457.2 ± 6.35
20	20.000 ± 0.25	508.0 ± 6.35
24	24.000 ± 0.25	609.6 ± 6.35
30	30.000 ± 0.30	762.0 ± 7.62
36	36.000 ± 0.36	914.4 ± 9.14
42	42.000 ± 0.42	1066.8 ± 10.68
48	48.000 ± 0.48	1219.2 ± 12.19
54	54.000 ± 0.54	1371.6 ± 13.72
60	60.000 ± 0.60	1524.0 ± 15.24

6.3 *Performance*—Pipe meeting this specification shall be categorized by a long-term static or cyclic hydrostatic design basis as shown in Table 1 when tested in accordance with 8.4 or 8.5. Additionally, the pipe shall meet the applicable cell limit requirements for short-term rupture strength, longitudinal tensile strength, longitudinal tensile modulus, and apparent stiffness factor as described in Table 2 when tested in accordance with 8.6 through 8.8.

6.3.1 Any significant changes in the original pipe categorized in 6.3, with respect to materials or manufacturing process, will require recategorizing according to 6.3. These changes include, but are not limited to: a change in reinforcement type, composition, or binder; a change in resin type, composition, or cure; or change in linear composition, thickness, or cure.

NOTE 7—The purchaser should consult the manufacturer for the proper class, type, and grade of pipe to be used under the installation and operating conditions, with respect to temperature, conveyed fluid, pressure, etc., that will exist for the project in which the pipe is to be used.

TABLE 5 Dimensions for Outside Diameter (OD) Series Pipe with Cast-Iron-Pipe-Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.50 ± 0.05	63.50 ± 1.3
3	3.96 ± 0.06	100.58 ± 1.5
4	4.80 ± 0.06	121.92 ± 1.5
6	6.90 ± 0.06	175.26 ± 1.5
8	9.05 ± 0.06	229.87 ± 1.5
10	11.10 ± 0.06	281.94 ± 1.5
12	13.20 ± 0.06	335.28 ± 1.5
14	15.30 + 0.05 −0.08	388.62 + 1.3 −2.0
16	17.40 + 0.05 −0.08	441.96 + 1.3 −2.0
18	19.50 + 0.05 −0.08	495.3 + 1.3 −2.0
20	21.60 + 0.05 −0.08	548.6 + 1.3 −2.0
24	25.80 + 0.05 −0.08	655.3 + 1.3 −2.0
30	32.00 + 0.08 −0.06	655.3 + 2.0 −1.5
36	38.30 + 0.08 −0.06	972.8 + 1.3 −1.5
42	44.50 + 0.08 −0.06	1130.3 + 2.0 −1.5
48	50.80 + 0.08 −0.06	1290.3 + 2.0 −1.5
54	57.56 + 0.08 −0.06	1462.0 + 2.0 −1.5
60	61.61 + 0.08 −0.06	1564.9 + 2.0 −1.5

TABLE 6 Dimensions for Inside Diameter (ID) Series Pipe with Iron Pipe Size Equivalent

Nominal Pipe Size, in.	in.	mm
2	2.25 + 0.05 −0.05	57.15 + 1.27 −1.27
3	3.34 + 0.06 −0.06	84.84 + 1.52 −1.52
4	4.37 + 0.06 −0.06	111.00 + 1.52 −1.52
6	6.43 + 0.06 −0.06	163.32 + 1.52 −1.52
8	8.39 + 0.06 −0.06	213.11 + 1.52 −1.52
10	10.43 + 0.06 −0.06	264.92 + 1.52 −1.52
12	12.38 + 0.06 −0.06	314.45 + 1.52 −1.52
14	13.60 + 0.05 −0.08	345.44 + 1.27 −2.03
16	15.40 + 0.05 −0.08	391.16 + 1.27 −2.03

7. Sampling

7.1 At least one sample of pipe, to determine conformance of the material to the short-term hoop tensile rupture requirements as shown in Table 2, shall be taken at random on a weekly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with accepted statistical practice or as agreed upon between the purchaser and the seller.

7.2 For individual orders, only those additional tests and number of tests specifically agreed upon between the purchaser and the seller need to be conducted.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 48 h prior to test, in accordance with Procedure A of Methods D618, for those tests where conditioning is required, and in all cases of disagreement.

8.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity, unless otherwise specified in the test method or in this specification.

8.3 *Dimensions and Tolerances:*

8.3.1 *Wall Thickness and Diameter*—Determine in accordance with Practice D3567.

8.3.2 *Liner Thickness*—If the test specimens contain a liner, determine the average liner thickness in accordance with Practice D3567.

8.4 *Long-Term Cyclic Hydrostatic Strength*—Determine in accordance with Procedure A of Method D2992, following Test Method D2143.

8.5 *Long-Term Static Hydrostatic Strength*—Determine in accordance with Procedure B of Method D2992, following Test Method D1598.

8.6 *Short-Term Hydrostatic Failure Strength*—Determine in accordance with Test Method D1599.

8.7 *Longitudinal Tensile Properties*—Determine in accordance with Test Methods D2105, D638, or D3039.

8.8 *Pipe Stiffness*—Determine in accordance with Test Method D2412. The reported stiffness shall be based on 5 % deflection.

9. Certification

9.1 See Annex A1 for certification requirements.

10. Product Marking

10.1 Each piece of pipe shall be marked at least once per section. Each piece of pipe shall be marked with the following information in such a manner that it remains legible under normal handling and installation practices:

10.1.1 Nominal pipe size (for example, 2 in.).

10.1.2 Identification of reinforced thermosetting resin pipe in accordance with the designation code given in Section 4.

10.1.3 ASTM D2996 with which the pipe complies.

10.1.4 Manufacturer's name (or trademark).

11. Keywords

11.1 filament-wound FRP pipe; mechanical properties; physical properties; pressure rating; tolerances; wall thickness

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIX

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN BASIS, CATEGORIES, SERVICE FACTORS, AND PRESSURE RATINGS

X1.1 Hydrostatic Design Basis

X1.1.1 The hydrostatic design basis for reinforced thermosetting resin pipe is the estimated long-term hydrostatic strength obtained in accordance with Test Method D2992. In Test Method D2992 either Procedure A, using data obtained in accordance with Test Method D2143, or Procedure B, using data obtained in accordance with Test Method D1598, is used to determine the estimated long-term hydrostatic strength. This strength in the wall of the pipe is equal to the circumferential stress due to internal hydrostatic pressure that will fail the pipe when extrapolated to 150×10^6 pressure cycles (Procedure A) or to 100 000 h under continuously applied pressure (Procedure B).

X1.2 Hydrostatic Design Basis Categories

X1.2.1 The hydrostatic design basis category is obtained from Table X1.1 or Table X1.2 using the estimated long-term hydrostatic strength as the calculated value.

X1.3 Service (Design) Factor

X1.3.1 The service (design) factor is a number equal to 1.00 or less which takes into consideration all the variables and degree of safety involved in a reinforced thermosetting resin pressure piping installation and is selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables (specifically, normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures of this method). The second group considers the application or use (specifically, installation, environment, temperature hazard involved, life expectancy desired, and the degree of reliability selected).

TABLE X1.1 Hydrostatic Design Basis Categories by Procedure A

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
2 500 (17.2)	2 400 to 3 010 (16.5 to 20.8)
3 150 (21.7)	3 020 to 3 020 (20.8 to 26.3)
4 000 (27.6)	3 830 to 4 790 (26.4 to 33.0)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)

TABLE X1.2 Hydrostatic Design Basis Categories by Procedure B

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
5 000 (34.5)	4 800 to 5 900 (33.1 to 40.7)
6 300 (43.4)	6 000 to 7 500 (41.4 to 51.7)
8 000 (55.2)	7 600 to 9 500 (52.4 to 65.5)
10 000 (68.9)	9 600 to 11 900 (66.2 to 82.1)
12 500 (86.2)	12 000 to 15 200 (82.9 to 105)
16 000 (112)	15 300 to 18 900 (105 to 130)
20 000 (138)	19 000 to 23 000 (131 to 159)
25 000 (173)	24 000 to 29 000 (165 to 200)
31 500 (217)	30 000 to 38 000 (207 to 262)

NOTE X1.1—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after fully evaluating the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

X1.4 Hydrostatic Design Stress

X1.4.1 The hydrostatic design stress is the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure will not occur. It is obtained by multiplying the hydrostatic design basis as determined by Procedure A or Procedure B by the service (design) factor.

X1.5 Pressure Rating

X1.5.1 The pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

X1.5.2 The pressure rating for each diameter and wall thickness of pipe and fitting is calculated from hydrostatic design stress for the specific pipe by means of the following formula:

$$S = P\,(D - t)/2t$$

where:

S = hydrostatic design stress, psi (MPa),
P = pressure rating, psi (MPa),
D = average outside diameter, in. (mm), and
t = minimum reinforced wall thickness, in. (mm).

SPECIFICATION FOR CENTRIFUGALLY CAST "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PIPE

SD-2997

(Identical with ASTM D2997-15 except for revisions to paras. 2.1, 4.1.4, Table 1, section 8; addition of Annex A1; and editorial changes.)

Specification for Centrifugally Cast “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

1. Scope

1.1 This specification covers machine-made glass-fiber-reinforced thermosetting-resin pressure pipe manufactured by the centrifugal casting process. Included are a classification system and requirements for materials, mechanical properties, dimensions, performance, test methods, and marking.

NOTE 1—The term “fiberglass pipe” as described in Section 3 applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP).

NOTE 2—Pipe covered by this specification has been found suitable for conveying gases, petroleum products, or corrosive fluids.

NOTE 3—For the purposes of this standard, polymer does not include natural polymers.

1.2 The values given in parentheses are for information only.

NOTE 4—There is no known ISO equivalent to this standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 7, 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C33 Specification for Concrete Aggregates
D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2105 Test Method for Longitudinal Tensile Properties of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube
D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D3039 Test Method for Tensile Properties of Polymer Matrix Composite Materials
D3567 Practice for Determining Dimensions of “Fiberglass” (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
F412 Terminology Relating to Plastic Piping Systems

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D883 and F412 and abbreviations with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aggregate, n*—a siliceous sand conforming to the requirements of Specification C33, except that the requirements for gradation shall not apply.

3.2.2 *centrifugal casting, n*—a manufacturing process used to produce tubular goods by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system. The outside diameter (OD) of the finished pipe is fixed by the inside diameter (ID) of the mold tube. The inside diameter of the pipe is determined by the amount of material introduced into the mold.

3.2.3 *fiberglass pipe, n*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.2.4 *liner, n*—the inner portion of the wall at least 0.005 in. (0.13 mm) in thickness, as determined in 7.4 which does not contribute to the strength in the determination of the hydrostatic design basis.

3.2.5 *reinforced polymer mortar pipe (RPMP), n*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP), n*—a fiberglass pipe without aggregate.

3.2.7 *reinforced wall thickness, n*—the total wall thickness minus the liner or exterior surface resin layer thickness, or both.

4. Classification

4.1 *General*—Pipe meeting this specification is classified by type, grade, class, and hydrostatic design basis, and by a secondary cell classification system that defines the basic mechanical properties of the pipe. These types, grades, classes, hydrostatic design basis categories, and cell classification designations are as follows:

4.1.1 *Types:—Type II*

Centrifugally cast pipe.

4.1.2 *Grades:—Grade 1*

Glass-fiber-reinforced epoxy-resin pipe.

Grade 2—Glass-fiber-reinforced polyester-resin pipe.

Grade 3—Glass-fiber reinforced polydicyclopentadiene-resin pipe.

Grade 8—Glass-fiber-reinforced polyester-resin mortar pipe.

Grade 9—Glass fiber reinforced epoxy resin mortar pipe.

4.1.3 *Classes:—Class A*

No liner.

Class B—Polyester-resin liner, nonreinforced.

Class C—Epoxy-resin liner, nonreinforced.

Class D—Polydicyclopentadiene-resin liner, nonreinforced.

NOTE 5—For the purposes of this classification, polyester resin includes vinylester resins, but the purchaser should consult with the manufacturer to determine which resin is applicable for the specific conditions in which the pipe will be used.

4.1.4 *Hydrostatic Design Basis*—Two methods of classifying the hydrostatic design basis of the pipe are provided. Pipe meeting this specification shall be classified using either the cyclic test method or the static test method, or both, and the designations are shown in Table 1. Appendix X1 explains how to use the design basis categories shown in Table 1.

4.1.5 *Mechanical Properties*—Table 2 presents a cell classification system for identifying the mechanical properties of pipe covered by this specification.

NOTE 6—All possible combinations covered by the preceding classification system may not be commercially available.

4.1.6 *Designation Code*—The pipe designation code shall consist of the abbreviation RTRP or RPMP, followed by the type and grade in Arabic numerals, the class and static or cyclic hydrostatic design basis level in capital letters, and four Arabic numbers identifying, respectively, the cell classification designations of the short-term rupture strength, longitudinal tensile strength, tensile modulus, and pipe stiffness. Thus, a complete pipe designation code shall consist of four letters, two numerals, two letters, and four numerals.

4.1.6.1 *Example*—RTRP-21CA-1334. Such a designation would describe a centrifugally cast, glass-fiber-reinforced, epoxy pipe having a nonreinforced epoxy liner; a long-term cyclic pressure strength level exceeding 2500 psi (17.2 MPa); a short-term rupture strength exceeding 4000 psi (27.6 MPa); a longitudinal tensile strength exceeding 16 000 psi (110 MPa); a longitudinal tensile modulus exceeding 1.5×10^6 psi (10 300 MPa); and a pipe stiffness of 72 psi (496 kPa).

NOTE 7—Although the *Form and Style for ASTM Standards* manual requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

TABLE 1 Hydrostatic Design Basis Categories

Cyclic Test Method		Static Test Method	
Designation	Hoop Stress, psi (MPa)	Designation	Hoop Stress, psi (MPa)
A	2500 (17.2)	Q	5000 (34.5)
B	3150 (21.7)	R	6300 (43.4)
C	4000 (27.6)	S	8000 (55.2)
D	5000 (34.5)	T	10 000 (68.9)
E	6300 (43.4)	U	12 500 (86.2)
F	8000 (55.2)	W	16 000 (110)
G	10 000 (68.9)	X	20 000 (138)
H	12 500 (86.2)	Y	25 000 (172)
		Z	31 500 (217)

5. Materials

5.1 *General*—The resins, reinforcements, colorants, fillers, and other materials, when combined as a composite structure, shall produce a pipe that shall be classified in accordance to this specification based on performance.

6. Requirements

6.1 *Workmanship*—The pipe shall be free from all defects, including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas which, as a result of their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. The pipe shall be round and straight, and the bore of the pipe shall be smooth and uniform. All pipe ends shall be cut at right angles to the axis of the pipe, and any sharp edges removed.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameter*—The outside diameter and tolerances of pipe meeting this specification shall conform to the requirements in Table 3, when determined in accordance with 7.4.

6.2.2 *Wall Thickness*—The minimum wall thickness of pipe furnished under this specification shall not at any point be less than 87.5 % of the nominal wall thickness published in the manufacturer's literature, current at the time of purchase, when measured in accordance with 7.4.

TABLE 2 Physical Property Requirements

Designation Order Number	Mechanical Property	Cell Limits 0[A]	1	2	3	4	5	6
1	Short time rupture strength hoop tensile stress, min, psi (MPa)	—	4000 (27.6)	12 000 (82.7)	22 000 (152)	30 000 (207)	40 000 (276)	50 000 (345)
2	Longitudinal tensile strength, min, psi (MPa)	—	2000 (13.8)	8000 (55.2)	16 000 (110)	22 000 (152)	30 000 (207)	40 000 (276)
3	Longitudinal tensile modulus, min, psi × 10^6 (MPa)	—	0.6 (4100)	1.3 (9000)	1.5 (10 300)	1.9 (13 100)	2.5 (17 200)	3.0 (20 700)
4	Pipe stiffness at 5 % deflection, psi (kPa)	—	9 (62)	18 (124)	36 (248)	72 (496)	144 (993)	288 (1986)

[A]0 = Unspecified.

TABLE 3 Outside Dimensions and Tolerances

Nominal Pipe Size, in.	in.	(mm)
1	1.315 ± 0.009	(33.401 ± 0.229)
1½	1.900 ± 0.009	(48.260 ± 0.229)
2	2.375 ± 0.012	(60.325 ± 0.305)
2½	2.875 ± 0.012	(73.025 ± 0.305)
3	3.500 ± 0.012	(88.900 ± 0.305)
4	4.500 ± 0.015	(114.300 ± 0.381)
6	6.625 ± 0.025	(168.275 ± 0.635)
8	8.625 ± 0.025	(219.075 ± 0.635)
10	10.750 ± 0.025	(273.050 ± 0.635)
12	12.750 ± 0.025	(323.850 ± 0.635)
14	14.000 ± 0.035	(355.600 ± 0.889)

6.2.3 *Liner Thickness*—Except for Class A unlined products, all other classes shall have a minimum liner thickness of 0.005 in. (5 mil), when measured in accordance with 7.4.

6.3 *Performance*—Pipe meeting this specification shall be categorized by a long-term static or cyclic hydrostatic design basis shown in Table 1, when tested in accordance with 7.5 and 7.6. Additionally, the pipe shall meet the applicable cell limit requirements for short-term rupture strength, longitudinal tensile strength, tensile modulus, and pipe stiffness described in Table 2, when tested in accordance with 7.7, 7.8, and 7.9.

7. Test Methods

7.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 48 h prior to test, in accordance with Procedure A of Practice D618, for those tests where conditioning is required, and in all cases of disagreement.

7.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity, unless otherwise specified in the test specification.

7.3 *Sampling*—Samples of pipe to determine conformance of the material to be short-term rupture requirements shown in Table 2 shall be taken at random on a weekly basis or on each production run, whichever is the most frequent. The rate of sampling for the other tests listed shall be in accordance with the accepted statistical practice and as agreed upon between the purchaser and the seller.

NOTE 8—For individual orders, only those additional tests and number of tests specifically agreed upon between the purchaser and the seller need be conducted.

7.4 *Dimensions and Tolerances*—Determine in accordance with Practice D3567.

7.5 *Long-Term Cyclic Pressure Strength*—Determine in accordance with Procedure A of Practice D2992.

7.6 *Long-Term Static Pressure Strength*—Determine in accordance with Procedure B of Practice D2992.

7.7 *Short-Term Rupture Strength*—Determine in accordance with Test Method D1599.

7.8 *Longitudinal Tensile Properties*—Determine in accordance with Test Method D2105.

7.9 *Pipe Stiffness*—Determine in accordance with Test Method D2412. The reported stiffness shall be based on 5 % deflection.

8. Certification

8.1 See Annex A1 for certification requirements.

9. Marking

9.1 Each piece shall be marked at least once and at lengths of at least every 15 ft. Each piece of pipe shall be marked with the following information in such a manner that it remains legible under normal handling and installation practices:

9.1.1 Nominal pipe size (for example, 2 in.),

9.1.2 Identification of fiberglass pipes in accordance with the designation code given in Section 5,

9.1.3 This designation, D2997, with which the pipe complies, and

9.1.4 Manufacturer's name (or trademark).

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIX

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN BASIS, CATEGORIES, SERVICE FACTORS, AND PRESSURE RATINGS

X1.1 Hydrostatic Design Basis

X1.1.1 The hydrostatic design basis is the estimated long-term hydrostatic strength on which service factors (1.0 or less) are applied to obtain a hydrostatic design stress. The long-term hydrostatic strength is obtained by Practice D2992. In Practice D2992, either Procedure A using data obtained in accordance with Test Method D2143 or Procedure B using data obtained in accordance with Test Method D1598 is used to determine the long-term hydrostatic strength extrapolated at 50 years.

X1.1.2 The long-term hydrostatic strength is the estimated tensile stress in the wall of the pipe in the hoop orientation due to internal hydrostatic pressure that will cause failure after 50 years (657 × 10^6 pressure cycles by Procedure A or 438 000 h of static pressure by Procedure B).

X1.2 Hydrostatic Design Basis Categories

X1.2.1 The hydrostatic design basis is obtained by categorizing the long-term strength in accordance with Table X1.1 or Table X1.2.

X1.3 Service (Design) Factor

X1.3.1 The service (design) factor is a number equal to 1.00 or less that takes into consideration all the variables and degree of safety involved in a fiberglass pressure piping installation, and is selected for the application on the basis of two general groups of conditions.

X1.3.2 The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures of this method. The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectance desired, and the degree of reliability selected.

TABLE X1.1 Hydrostatic Design Basis Categories by Procedure A

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
2500 (17.2)	2400 to 3010 (16.5 to 20.8)
3150 (21.7)	3020 to 3820 (20.8 to 26.3)
4000 (27.6)	3830 to 4790 (26.4 to 33.0)
5000 (34.5)	4800 to 5900 (33.1 to 40.7)
6300 (43.4)	6000 to 7500 (41.4 to 51.7)
8000 (55.2)	7600 to 9500 (52.4 to 65.5)
10 000 (68.9)	9600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)

TABLE X1.2 Hydrostatic Design Basis Categories by Procedure B

Hydrostatic Design Basis Category, psi (MPa)	Range of Calculated Values, psi (MPa)
5000 (34.5)	4800 to 5900 (33.1 to 40.7)
6300 (43.4)	6000 to 7500 (41.4 to 51.7)
8000 (55.2)	7600 to 9500 (52.4 to 65.5)
10 000 (68.9)	9600 to 11 900 (66.2 to 82.0)
12 500 (86.2)	12 000 to 15 200 (82.7 to 105)
16 000 (110)	15 300 to 18 900 (106 to 130)
20 000 (138)	19 000 to 23 000 (131 to 159)
25 000 (172)	24 000 to 29 000 (166 to 200)
31 500 (217)	30 000 to 38 000 (207 to 262)

NOTE X1.1—It is not the intent of this specification to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

X1.4 Hydrostatic Design Stress

X1.4.1 The hydrostatic design stress is the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation as a result of internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure will not occur. It is obtained by multiplying the hydrostatic design basis as determined by Procedure A or Procedure B by the service (design) factor.

X1.5 Pressure Rating

X1.5.1 The pressure rating is the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

X1.5.2 The pressure rating for each diameter and wall thickness of pipe and fitting is calculated from the hydrostatic design stress for the specific pipe by means of the ISO formula:

$$S = P(D - t)/2t$$

where:

S = hoop stress,
P = internal pressure,
D = average outside diameter, and
t = minimum reinforced wall thickness.

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SPECIFICATION FOR JOINTS FOR PLASTIC PRESSURE PIPES USING FLEXIBLE ELASTOMERIC SEALS

SD-3139

(Identical with ASTM D3139-19 except for revisions to para. 4.1, addition of paras. 2.4, 10.2 and Annex A1, and editorial changes.)

Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

1. Scope

1.1 This specification covers the types of joints required for plastic pipe pressure systems with a wall thickness equal to or greater than that of SDR 64 and intended for use in supply and distribution lines for water, using flexible elastomeric seals. This specification covers the test requirements, test method, and materials. The test methods described are not intended to be routine quality control tests but are to evaluate the performance characteristics of the joint.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.3 The following safety hazards caveat pertains to the test method portion, Section 6, 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products

F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *AWWA Standard:*

AWWA C651 Standard for Disinfecting Water Mains

2.3 *NSF Standard:*

ANSI/NSF Standard No. 61 for Drinking Water System Components-Health Effects

2.4 *ASME Standard:*

ASME NM.3.2, SF-477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 This specification covers two types of mechanical joints based on effecting water tightness through compression of an elastomeric seal or ring:

3.1.2 *mechanical joint*—a joint in which a positive seal is achieved when a gasket is compressed by means of a mechanical device.

3.1.3 *push-on-joint*—a joint in which a continuous elastomeric ring gasket is compressed into an annular space formed by the pipe or fitting socket and the spigot end of the pipe and forms a positive seal after being assembled. Details of the joint design and assembly shall be in accordance with the manufacturer's instructions.

4. Materials and Manufacture

4.1 The materials used in elastomeric seals shall meet the requirements of Specification F477 (ASME SF-477).

4.2 *Lubricant*—The lubricant shall be nontoxic and shall have no deteriorating effects on the gasket and pipe materials. It shall not impart taste or odor to water in a pipe that has been flushed in accordance with AWWA C651. When used in a potable water system, the lubricant shall meet the requirements of ANSI/NSF Standard No. 61. The lubricant container shall be labeled with the manufacturer's trademark or the pipe manufacturer's name.

5. Performance Requirements

5.1 The joint shall be designed to provide a permanent seal and shall be qualified in accordance with Section 8.

5.1.1 All surfaces of the joint upon or against which the gasket may bear shall be free of imperfections that could adversely affect the performance of the joint.

5.2 *Pressure Rating*—Designs not meeting the requirements of 6.2 shall be tested to verify that the hydrostatic design basis category for joint assemblies shall not be lower than the hydrostatic design basis category for pipe when tested under the same procedure. The hydrostatic design basis for this joint design shall be established on a representative size at a minimuim test level of 10 points and 2000 h with data analysis in accordance with Test Method D2837, except that the ends shall be restrained. Test pressure levels (and calculated stresses) for establishing hydrostatic design basis shall be calculated on pipe minimum wall dimensions after dimensioning both the bell and spigot pipe ends.

5.2.1 Joint designs shall require retesting under this section only if the joint design is changed or if the pipe compound is altered in any manner that produces a lower hydrostatic design basis category when compared with the compound used in the previous validation testing of the joint design.

5.3 *Mechanical Joint*—The mechanical joint shall provide a pressure rating equal to or greater than that of the corresponding pipe.

5.3.1 *Internal Stiffener*—The pipe spigot shall have a wall thickness sufficient to withstand, without deformation or collapse, the compressive force exerted when the fitting is tightened. If the wall is not sufficient to withstand the compressive force, then a rigid tubular internal stiffener shall be used in conjunction with compressive-type mechanical joint fittings. A stiffener specified by the manufacturer for this purpose shall be used.

5.4 *Joint Deflection*—The joint shall provide a seal when the pipe spigot is deflected axially in the socket to the maximum unstressed limit permitted by dimensional clearance between the spigot and bell.

6. Dimensions, Mass, and Permissible Variations

6.1 *Joint Dimensions and Tolerances*—The dimensions of the bell, socket, and plain end shall be in accordance with the manufacturer's standard design dimensions of the joint.

6.2 *Push-On Joint*—The minimum wall thickness of the bell at any point between the ring groove (annular gasket space) and the pipe barrel, shall conform to the dimension ratio requirements for the pipe barrel. The minimum wall thickness in the sealing portion of the ring groove and bell entry sections shall equal or exceed the minimum wall thickness requirements of the pipe barrel (see Fig. 1 or Fig. 2).

6.3 *Gasket Dimensions*—Gasket dimensions shall be in accordance with the manufacturer's standard design dimensions and tolerances. The gasket shall be of such size and shape as to provide an adequate compressive force against the spigot and socket after assembly to effect a positive seal under all combinations of permitted joint and gasket tolerances. The gasket shall be the sole element depended upon to make the joint flexible and water tight. The gasket shall be a continuous elastomeric ring.

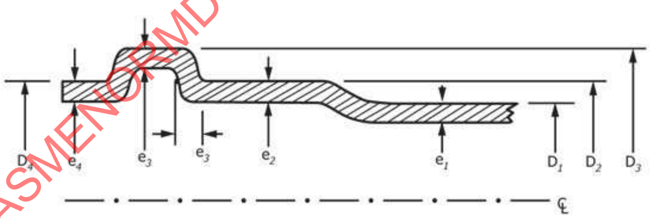
7. Workmanship, Finish, and Appearance

7.1 The manufacturer of these joints shall produce joints meeting the requirements of this specification. Components of the joints shall be homogenous throughout and free from visible cracks, holes, foreign inclusions, or injurious defects. The components of the joints shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 The assembled joints shall pass the following laboratory qualifying tests. (For referee testing, standard laboratory conditions of 23 °C and 50 % relative humidity in accordance with Practice D618, Procedure A will apply.)

8.1.1 *Internal Pressure Testing*—Laboratory hydrostatic pressure tests on joints shall be made on an assembly of two sections of pipe properly connected in accordance with the

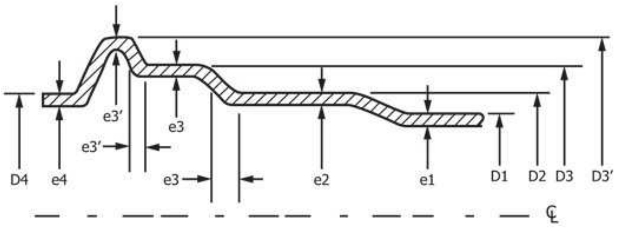


C_L = center line
D_1 = average outside diameter - pipe
D_2 = average outside diameter - socket
D_3 = average outside diameter - annular gasket space
D_4 = average outside diameter - entry lip
e_1 = minimum wall thickness - pipe
e_2 = minimum wall thickness - socket
e_3 = minimum wall thickness - sealing portion of the annular gasket space
e_4 = minimum wall thickness - entry lip
S_W = hydrostatic design stress

P_W = pressure rating shall be determined as follows:

$S_W = P_W(D - e)/2e$ (Method D 2837)
$e_1 = D_1[(2S_W/P_W) + 1]$
$e_2 = D_2/[(2S_W/P_W) + 1]$
$e_3 \geq e_1$
$e_4 \geq e_1$
$[(2S_W/P_W) + 1] = SDR$

FIG. 1 Relationship of Dimensions in 6.2



C_L = center line
D_1 = average outside diameter - pipe
D_2 = average outside diameter - socket
D_3 = average outside diameter - sealing portion of the annular gasket space
D_3' = average outside diameter - locking portion of the annular gasket space
D_4 = average outside diameter - entry lip
e_1 = minimum wall thickness - pipe
e_2 = minimum wall thickness - socket
e_3 = minimum wall thickness - sealing portion of the annular gasket space
e_3' = minimum wall thickness - locking portion of the annular gasket space
e_4 = minimum wall thickness - entry lip

S_W = hydrostatic design stress
P_W = pressure rating shall be determined as follows:
$S_W = P_W(D - e)/2e$ (Method D 2837)
$e_1 = D_1[(2S_W/P_W) + 1]$
$e_2 = D_2/[(2S_W/P_W) + 1]$
$e_3 \geq e_1$
$e_3' \geq 0.9e1$
$e_4 \geq e_1$

FIG. 2 Relationship of Dimensions in 6.2

joint design and deflected to the limit defined in 5.4. No coatings, fillings, or packings, other than lubricants recommended in 4.2, shall be placed prior to water tightness tests. After the pipe sections are fitted together with the gasket or gaskets in place, the assembly shall be subjected to separate internal pressure tests, first at 50 % of rated pressure for 60 min, then at 2½ times the rated pressure for 60 min without leakage at either pressure for the duration of either test. The pressure shall then be continuously increased to the minimum short-term rupture requirement of the applicable pipe without leakage. The pressure increase from 2½ times rated to minimum short-term rupture requirement shall occur over a 60 to 70-s period. Test times longer than 70 s are allowed because successful achievement of the minimum short-term rupture strength at times greater than 70 s represents a more severe test condition.

NOTE 1—Times greater than 70 s may be needed to bring larger-sized specimens to the short-term rupture (quickburst) pressure. The test is more difficult to pass using greater pressurizing times.

8.1.2 *Vacuum Test*—The assembled joint shall withstand a minimum vacuum of 75.0 kPa gauge (22.1 in. Hg) for 1 h while in the auxiliary deflected position in accordance with 8.1.1. A vacuum greater than 75.0 kPa gauge (22.1 in. Hg) up to a maximum of 77.0 kPa gauge (22.7 in. Hg) shall be applied to the sample and shall not decline below 75.0 kPa gauge (22.1 in. Hg) during the 1 h test period. The order of the Internal Pressure Testing and Vacuum Test is not critical or prescribed; the tests can be performed in any order.

9. Rejection and Rehearing

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) shall be conducted again only by agreement between the purchaser and the seller. Under such agreement, minimum requirements shall not be lowered, nor tests omitted, substituted, changed, or modified, nor shall specification limits be changed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Certification

10.1 When specified in the purchase order or contract, the purchaser shall be furnished certification by affidavit that samples representing each lot of production have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test or inspection results shall be furnished.

10.2 See Annex A1 for additional certification requirements.

11. Keywords

11.1 compression-type; elastometric; joints; push-on joint; rigid; seals

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

SPECIFICATION FOR "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PRESSURE PIPE

SD-3517

(Identical with ASTM D3517-19 except for revisions to Note 6, paras. 6.4.1, 8.4; addition of para. 2.4, section 10, Annex A2; and editorial changes.)

Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe

1. Scope

1.1 This specification covers machine-made fiberglass pipe, 8 in. (200 mm) through 156 in. (4000 mm), intended for use in water conveyance systems which operate at internal gage pressures of 450 psi (3103 kPa) or less. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. The standard is suited primarily for pipes to be installed in buried applications, although it may be used to the extent applicable for other installations such as, but not limited to, jacking, tunnel lining and slip-lining rehabilitation of existing pipelines.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

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

NOTE 2—There is no known ISO equivalent to this standard.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 8, 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.*

1.4 *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:*

C33/C33M Specification for Concrete Aggregates
D638 Test Method for Tensile Properties of Plastics
D695 Test Method for Compressive Properties of Rigid Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D3892 Practice for Packaging/Packing of Plastics
D4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *ISO Standard:*

ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition

2.3 *NSF Standard:*

Standard No. 61 Drinking Water System Components

2.4 *ASME Standards:*

ASME NM.2, Glass-Fiber-Reinforced Thermosetting Resin Piping Systems

ASME NM.3.2, SF-477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

ASME NM.3.2, SD-4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 and Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular, or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

3.2.2 *flexible joint* —a joint that is capable of axial displacement or angular rotation, or both.

3.2.3 *liner*—a resin layer, with or without filler, or reinforcement, or both, forming the interior surface of the pipe.

3.2.4 *qualification test*—one or more tests used to prove the design of a product. Not a routine quality control test.

3.2.5 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.2.6 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.2.7 *rigid joint* —a joint that is not capable of axial displacement or angular rotation.

3.2.8 *surface layer*—a resin layer, with or without filler, or reinforcements, or both, applied to the exterior surface of the pipe structural wall.

4. Classification

4.1 *General*—This specification covers fiberglass pressure pipe defined by raw materials in the structural wall (type) and liner, surface layer material (grade), operating pressure (class), and pipe stiffness. Table 1 lists the types, liners, grades, classes, and stiffnesses that are covered.

NOTE 3—All possible combinations of types, liners, grades, classes, and stiffnesses may not be commercially available. Additional types, liners, grades, and stiffnesses may be added as they become commercially available. The purchaser should determine for himself or consult with the manufacturer for the proper class, type, liner, grade and stiffness of pipe to be used under the installation and operating conditions that will exist for the project in which the pipe is to be used.

4.2 *Designation Requirements*—The pipe materials designation code shall consist of the standard designation, ASTM D3517, followed by type, liner, and grade in Arabic numerals, class by the letter C and two or three Arabic numerals, and pipe stiffness by a capital letter. Table 1 presents a summary of the designation requirements. Thus, a complete material code shall consist of ASTM D3517. . . three numerals, C . . . and two or three numerals, and a capital letter.

NOTE 4—Examples of the designation are as follows: *(1)* ASTM D3517-1-1-3-C50-A for glass-fiber reinforced aggregate and polyester resin mortar pipe with a reinforced thermoset liner and an unreinforced polyester resin and sand surface layer, for operation at 50 psi (345 kPa), and having a minimum pipe stiffness of 9 psi (62 kPa), *(2)* ASTM D3517-4-2-6-C200-C for glass-fiber reinforced epoxy resin pipe with a non-reinforced thermoset liner, no surface layer, for operation at 200 psi (1380 kPa), and having a minimum pipe stiffness of 36 psi (248 kPa).

NOTE 5—Although the "Form and Style for ASTM Standards" manual requires that the type classification be roman numerals, it is recognized that companies have stencil cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

5. Materials and Manufacture

5.1 *General*—The thermosetting resins, glass fiber reinforcements, fillers, and other materials, when combined as a composite structure, shall produce piping products that meet the performance requirements of this specification.

5.2 *Wall Composition*—The basic structural wall composition shall consist of thermosetting resin, glass fiber reinforcement, and, if used, an aggregate filler.

5.2.1 *Resin*—A thermosetting polyester or epoxy resin, with or without filler.

5.2.2 *Reinforcement*—A commercial grade of glass fibers compatible with the resin used.

5.2.3 *Aggregate*—A siliceous sand conforming to the requirements of Specification C33/C33M, except that the requirements for gradation shall not apply.

NOTE 6—Fiberglass pipe intended for use in the transport of potable water should be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in NSF/ANSI Standard No. 61. The seal or mark of the laboratory making the evaluation should be included on the fiberglass pipe.

5.3 *Liner and Surface Layers*—Liner or surface layer, or both, when incorporated into or onto the pipe, shall meet the structural requirements of this specification.

5.4 *Joints*—The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition. A particular type of joint may be restrained or unrestrained and flexible or rigid depending on the specific configuration and design conditions.

5.4.1 *Unrestrained*—Pipe joints capable of withstanding internal pressure but not longitudinal tensile loads.

5.4.1.1 *Coupling or Bell-and-Spigot Gasket Joints,* with a groove either on the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness. For typical joint details see Fig. 1.

5.4.1.2 *Mechanical Coupling Joint,* with elastomeric seals.

5.4.1.3 *Butt Joint*, with laminated overlay.

5.4.1.4 *Flanged Joint*, both integral and loose ring.

5.4.2 *Restrained*—Pipe joints capable of withstanding internal pressure and longitudinal tensile loads..

5.4.2.1 Joints similar to those in 5.4.1.1 with supplemental restraining elements.

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation Order	Property	Cell Limits (Note 1)								
1	Type	1 glass-fiber-reinforced thermosetting polyester (Note 2) resin mortar (RPMP polyester (Note 2))	2 glass-fiber-reinforced thermosetting polyester (Note 2) resin (RTRP polyester (Note 2))	3 glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)	4 glass-fiber-reinforced thermosetting epoxy resin (RTRP epoxy)					
2	Liner	1 reinforced thermoset liner	2 non-reinforced thermoset liner	3 thermoplastic liner	4 no liner					
3	Grade	1 polyester (Note 2) resin surface layer—reinforced	2 polyester (Note 2) resin surface layer—non-reinforced	3 polyester (Note 2) resin and sand surface layer nonreinforced	4 epoxy resin surface layer—reinforced	5 epoxy resin surface layer—non-reinforced	6 no surface layer			
4	Class (Note 3)	C50	C100	C150	C200	C250	C300	C350	C400	C450
5	Pipe Stiffness psi (kPa)	A 9 (62)	B 18 (124)	C 36 (248)	D 72 (496)					

NOTE 1—The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with non-commercially available products. The manufacturer should be consulted.

NOTE 2—For the purposes of this standard, polyester includes vinyl ester resins.

NOTE 3— Based on operating pressure in psig (numerals).

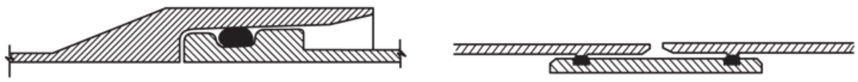


FIG. 1 Typical Joints

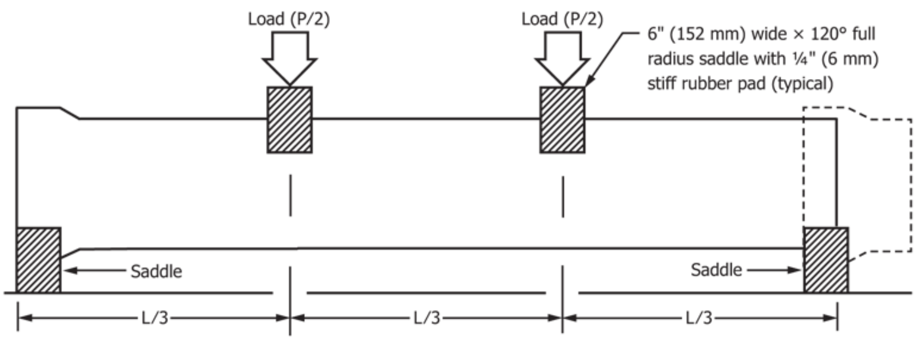


FIG. 2 Beam Strength—Test Setup

5.4.2.2 *Butt Joint,* with laminated overlay.

5.4.2.3 *Bell-and-Spigot,* with laminated overlay.

5.4.2.4 *Bell-and-Spigot,* adhesive-bonded joint: Three types of adhesive-bonded joints are permitted by this standard as follows:

(1) Tapered bell-and-spigot, an adhesive joint that is manufactured with a tapered socket for use in conjunction with a tapered spigot and a suitable adhesive.

(2) Straight bell-and-spigot, an adhesive joint that is manufactured with an untapered socket for use in conjunction with an untapered spigot and a suitable adhesive.

(3) Tapered bell and straight spigot, an adhesive joint that is manufactured with a tapered socket for use with an untapered spigot and a suitable adhesive.

5.4.2.5 *Flanged Joint,* both integral and loose ring

5.4.2.6 *Mechanical Coupling,* an elastomeric sealed coupling with a supplemental restraining elements.

5.4.2.7 *Threaded Joints.*

NOTE 7—Other types of joints may be added as they become commercially available.

NOTE 8—Restrained joints typically increase service loads on the pipe to greater than those experienced with unrestrained joints. The purchaser is cautioned to take into consideration all conditions that may be encountered in the anticipated service and to consult the manufacturer regarding the suitability of a particular type and class of pipe for service with restrained joint systems.

5.5 *Gaskets*—Elastomeric gaskets when used with this pipe shall conform to the requirements of Specification F477.

6. Requirements

6.1 *Workmanship:*

6.1.1 Each pipe shall be free from all defects including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.2 The inside surface of each pipe shall be free of bulges, dents, ridges, and other defects that result in a variation of inside diameter of more than ⅛ in. (3.2 mm) from that obtained on adjacent unaffected portions of the surface. No glass fiber reinforcement shall penetrate the interior surface of the pipe wall.

6.1.3 Joint sealing surfaces shall be free of dents, gouges, and other surface irregularities that will affect the integrity of the joints.

6.2 *Dimensions:*

6.2.1 *Pipe Diameters*—Pipe shall be supplied in the nominal diameters shown in Table 2 or Table 3. The pipe diameter tolerances shall be as shown in Table 2 or Table 3, when measured in accordance with 8.1.1.

6.2.2 *Lengths*—Pipe shall be supplied in nominal lengths of 10, 20, 30, 40, and 60 ft. (3.05, 6.10, 9.15, 12.19, and 18.29 m). The actual laying length shall be the nominal length ±2 in. (±51 mm), when measured in accordance with 8.1.2. At least 90 % of the total footage of any one size and class, excluding special order lengths, shall be furnished in the nominal lengths specified by the purchaser. Random lengths, if furnished, shall not vary from the nominal lengths by more than 5 ft (1.53 m) or 25 %, whichever is less.

6.2.3 *Wall Thickness*—The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less than 87.5 % of the nominal wall thickness when measured in accordance with 8.1.3.

6.2.4 *Squareness of Pipe Ends*—All points around each end of a pipe unit shall fall within ±¼ in. (±6.4 mm) or ±0.5 % of the nominal diameter of the pipe, whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe, when measured in accordance with 8.1.4.

6.3 *Soundness*—Unless otherwise agreed upon between purchaser and supplier, test each length of pipe up to 96 in. (2400 mm) diameter hydrostatically without leakage or cracking, at

TABLE 2 Nominal Inside Diameters (ID) and Tolerances Inside Diameter Control Pipe

Inch-Pound Units		SI Units			
Nominal Diameter[A], in.	Tolerance, in.	Nominal Metric Diameter[B], mm	ID Range[B], mm Minimum	ID Range[B], mm Maximum	Tolerance[B] on Declared ID, mm
8	±0.25	200	196	204	±1.5
10	±0.25	250	246	255	±1.5
12	±0.25	300	296	306	±1.8
14	±0.25	400	396	408	±2.4
15	±0.25	500	496	510	±3.0
16	±0.25	600	595	612	±3.6
18	±0.25	700	695	714	±4.2
20	±0.25	800	795	816	±4.2
21	±0.25	900	895	918	±4.2
24	±0.25	1000	995	1020	±5.0
27	±0.27	1200	1195	1220	±5.0
30	±0.30	1400	1395	1420	±5.0
33	±0.33	1600	1595	1620	±5.0
36	±0.36	1800	1795	1820	±5.0
39	±0.39	2000	1995	2020	±5.0
42	±0.42	(2200)	2195	2220	±6.0
45	±0.45	2400	2395	2420	±6.0
48	±0.48	(2600)	2595	2620	±6.0
51	±0.51	2800	2795	2820	±6.0
54	±0.54	(3000)	2995	3020	±6.0
60	±0.60	3200	3195	3220	±7.0
66	±0.66	(3400)	3395	3420	±7.0
72	±0.72	3600	3595	3620	±7.0
78	±0.78	(3800)	3795	3820	±7.0
84	±0.84	4000	3995	4020	±7.0
90	±0.90	...	...	...	...
96	±0.96	...	...	...	...
102	±1.00	...	...	...	...
108	±1.00	...	...	...	...
114	±1.00	...	...	...	...
120	±1.00	...	...	...	...
132	±1.00	...	...	...	...
144	±1.00	...	...	...	...
156	±1.00	...	...	...	...

[A]Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.
[B]Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

the internal hydrostatic proof pressures specified for the applicable class in Table 4, when tested in accordance with 8.2. For sizes over 96 in. (2400 mm), the frequency of hydrostatic leak tests shall be as agreed upon by purchaser and supplier.

6.4 *Hydrostatic Design Basis:*

6.4.1 *Long-Term Hydrostatic Pressure*—The pressure classes shall be based on long-term hydrostatic pressure data obtained in accordance with 8.3 and categorized in accordance with Table 5. Pressure classes are based on extrapolated strengths at 50 years. For pipe subjected to longitudinal loads or circumferential bending, the effect of these conditions on the hydrostatic design pressure, classification of the pipe shall be considered.

6.4.2 *Control Requirements*—Test pipe specimens periodically in accordance with Practice D2992.

NOTE 9—Hydrostatic design basis (HDB-extrapolated value at 50 years) determined in accordance with Procedure A of Practice D2992, may be substituted for the Procedure B evaluation required by 8.3. It is generally accepted that the Procedure A HDB value times 3 is equivalent to the Procedure B HDB value.

6.5 *Stiffness*—Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness ($F/\Delta y$) specified in Table 6, when tested in accordance with 8.4. At deflection level A per Table 7, there shall be no visible damage in the test specimen evidenced by surface cracks. At deflection level B per Table 7, there shall be no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass fiber reinforcement, and fracture or buckling of the pipe wall.

NOTE 10—This is a visual observation (made with the unaided eye) for quality control purposes only and should not be considered a simulated service test. Table 7 values are based on an in-use long-term deflection limit of 5 % and provide an appropriate uniform safety margin for all pipe stiffnesses. Since the pipe stiffness values ($F/\Delta y$) shown in Table 6 vary, the percent deflection of the pipe under a given set of installation conditions will not be constant for all pipes. To avoid possible misapplication, take care to analyze all conditions which might affect performance of the installed pipe.

6.5.1 For other pipe stiffness levels, appropriate values for Level A and Level B deflections (Table 7) may be computed as follows:

$$\text{Level A at new PS} = \left(\frac{72}{\text{new PS}}\right)^{0.33}(9) \quad (1)$$

$$\text{Level B at new PS} = \text{new Level A} \div 0.6$$

6.5.2 Since products may have use limits of other than 5 % long-term deflection, Level A and Level B deflections (Table 7) may be proportionally adjusted to maintain equivalent in-use

TABLE 3 Nominal Outside Diameters (OD) and Tolerances

NOTE 1—The external diameter of the pipe at the spigots shall be within the tolerances given in the table, and the manufacturer shall declare his allowable maximum and minimum spigot diameters. Some pipes are manufactured such that the entire pipe meets the OD tolerances while other pipes meet the tolerances at the spigots, in which case, if such pipes are cut (shortened) the ends may need to be calibrated to meet the tolerances.

Nominal Pipe Size, in.	Steel Pipe Equivalent (IPS) OD's, in.	Tolerance, in.	Cast Iron Pipe Equivalent OD's, in.	Tolerance, in.
8	8.625	+0.086 −0.040	9.05	
10	10.750	+0.108 −0.048	11.10	±0.06
12	12.750	+0.128 −0.056	13.20	
14	14.000	+0.140 −0.062	15.30	
16	16.000	+0.160 −0.070	17.40	
18	. . .	. . .	19.50	+0.05 −0.08
20	. . .	. . .	21.60	
24	. . .	. . .	25.80	
30	. . .	. . .	32.00	
36	. . .	. . .	38.30	
42	. . .	. . .	44.50	+0.08
48	. . .	. . .	50.80	−0.06
54	. . .	. . .	57.56	
60	. . .	. . .	61.61	

Metric Pipe Size, mm	Ductile Iron Pipe Equivalent, mm	Tolerance Upper, mm	Tolerance Lower, mm	International O.D., mm	Tolerance Upper, mm	Tolerance Lower, mm
200	220.0	+1.0	0.0	. . .	. . .	. . .
250	271.8	+1.0	-0.2	. . .	. . .	. . .
300	323.8	+1.0	-0.3	310	+1.0	-1.0
350	375.7	+1.0	-0.3	361	+1.0	-1.2
400	426.6	+1.0	-0.3	412	+1.0	-1.4
450	477.6	+1.0	-0.4	463	+1.0	-1.6
500	529.5	+1.0	-0.4	514	+1.0	-1.8
600	632.5	+1.0	-0.5	616	+1.0	-2.0
700				718	+1.0	-2.2
800				820	+1.0	-2.4
900				924	+1.0	-2.6
1000				1026	+2.0	-2.6
1200				1229	+2.0	-2.6
1400				1434	+2.0	-2.8
1600				1638	+2.0	-2.8
1800				1842	+2.0	-3.0
2000				2046	+2.0	-3.0
2200				2250	+2.0	-3.2
2400				2453	+2.0	-3.4
2600				2658	+2.0	-3.6
2800				2861	+2.0	-3.8
3000				3066	+2.0	-4.0
3200				3270	+2.0	-4.2
3400				3474	+2.0	-4.4
3600				3678	+2.0	-4.6
3800				3882	+2.0	-4.8
4000				4086	+2.0	-5.0

safety margins. For example, a 4 % long-term limiting deflection would result in a 20 % reduction of Level A and Level B deflections, while a 6 % limiting deflection would result in a 20 % increase in Level A and Level B deflection values. However, minimum values for Level A and Level B deflections shall be equivalent to strains of 0.6 and 1.0 % respectively (as computed by Eq X1.4 in Appendix X1 of Specification D3262).

6.5.3 For high stiffness pipes, 5 % deflection will likely be above the use limit and the adjusted level A test deflection. For very high stiffness pipes, 5 % deflection may also be greater than the adjusted level B test deflection. In such cases, the pipes may be damaged or fail prior to determining the pipe stiffness at 5 % deflection. Therefore, it is permitted to set the pipe stiffness test deflection equal to the adjusted level A

TABLE 4 Hydrostatic-Pressure Test

Pressure Class	Hydrostatic Proof Pressure	
	Pipe Diameters up to and Including 54 in.	Pipe Diameters >54 in. up to and Including 96 in.
(psi)	psi (kPa)	psi (kPa)
C50	100 (689)	75 (517)
C100	200 (1379)	150 (1034)
C150	300 (2068)	225 (1551)
C200	400 (2757)	300 (2068)
C250	500 (3447)	375 (2585)
C300	600 (4136)	450 (3102)
C350	700 (4826)	525 (3619)
C400	800 (5515)	600 (4136)
C450	900 (6205)	675 (4654)

TABLE 5 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

TABLE 6 Minimum Stiffness at 5 % Deflection

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	Designation			
	A	B	C	D
8	. . .	. . .	36 (248)	72 (496)
10	. . .	18 (124)	36 (248)	72 (496)
12 and greater	9 (62)	18 (124)	36 (248)	72 (496)

TABLE 7 Ring Deflection Without Damage or Structural Failure

	Nominal Pipe Stiffness, psi			
	9	18	36	72
Level A	18 %	15 %	12 %	9 %
Level B	30 %	25 %	20 %	15 %

deflection, but not greater than 5 %. See Note 11 for additional information and further clarification.

NOTE 11—Depending upon the product modulus and allowable ring bending strain, this will likely begin affecting pipes with stiffness between 200 and 400 psi. For example, a pipe with pipe stiffness of PS360 may have a use limit of 4.3 %, an adjusted level A deflection of 4.5 % and an adjusted level B deflection of 7.5 %. Therefore, the new pipe stiffness test deflection would be 4.5 %. Another possible product with a pipe stiffness of PS900 may have a use limit of 2.8 %, an adjusted level A deflection of 2.7 % and an adjusted level B deflection of 4.5%. Therefore, the new pipe stiffness test deflection would be 2.7 %.

6.6 *Hoop-Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the hoop-tensile strength shown for each size and class in Table 8, when tested in accordance with 8.5.

6.6.1 *Alternative Requirements*—When agreed upon between the purchaser and the supplier, the minimum hoop-tensile strength shall be as determined in accordance with 8.5.1.

6.7 *Joint Tightness*—All joints shall meet the laboratory performance requirements, of Specification D4161. Unrestrained joints shall be tested with a fixed end closure condition and restrained joints shall be tested with a free end closure condition. Rigid joints shall be exempt from angular deflection requirements of D4161. Rigid joints typically include butt joints with laminated overlay, bell-and-spigot joints with laminated overlay, flanged, bell-and-spigot adhesive bonded and threaded.

6.8 *Longitudinal Strength:*

6.8.1 *Beam Strength*—For pipe sizes up to 27 in. the pipe shall withstand, without failure, the beam loads specified in Table 9, when tested in accordance with 8.6.1. For pipe sizes larger than 27 in., and alternatively for smaller sizes, adequate beam strength is demonstrated by tension and compression tests conducted in accordance with 8.6.2 and 8.6.3, respectively, for pipe wall specimens oriented in the longitudinal direction, using the minimum tensile and compressive strength specified in Table 9.

6.8.2 *Longitudinal Tensile Strength*—All pipe manufactured under this specification shall have a minimum axial tensile elongation at failure of 0.25% and meet or exceed the longitudinal tensile strength shown for each size and class in Table 10, when tested in accordance with 8.6.2.

NOTE 12—The values listed in Table 10 are the minimum criteria for products made to this standard. The values may not be indicative of the axial strength of some products, or of the axial strength required by some installation conditions and joint configurations.

6.8.3 Conformance to the requirements of 6.8.1 shall satisfy the requirements of 6.8.2 for those pipe sizes and classes where the minimum longitudinal tensile strength values of Table 9 are equal to the values of Table 10. Conformance to the requirements of 6.8.2 shall satisfy the longitudinal tensile strength requirements of 6.8.1.

7. Sampling

7.1 *Lot*—Unless otherwise agreed upon between the purchaser and the supplier, one lot shall consist of 100 lengths of each type, grade, and size of pipe produced.

7.2 *Production Tests*—Select one pipe at random from each lot and take one specimen from the pipe barrel to determine conformance of the material to the workmanship, dimensional, and stiffness, and strength requirements of 6.1, 6.2, 6.5, and 6.6, respectively. Unless otherwise agreed upon between purchaser and supplier, all pipes (up to 96-in. (2400-mm) diameter) shall meet the soundness requirements of 6.3.

7.3 *Qualification Tests*—Sampling for qualification tests (see section 3.2.4) is not required unless otherwise agreed upon between the purchaser and the supplier. Qualification tests, for which a certification and test report shall be furnished when requested by the purchaser include the following:

7.3.1 *Long-Term Hydrostatic Pressure Test.*

7.3.2 *Joint-Tightness Test* (See 6.7).

TABLE 8 Minimum Hoop Tensile Strength of Pipe Wall

NOTE 1—The values in this table are equal to 2*PD*, where *P* is the pressure class in psi and *D* is the nominal diameter in inches.

Inch-Pound Units									
Nominal Diameter (in.)	Hoop Tensile Strength, lbf/in. Width								
	Pressure Class								
	C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	800	1600	2400	3200	4000	4800	5600	6400	7200
10	1000	2000	3000	4000	5000	6000	7000	8000	9000
12	1200	2400	3600	4800	6000	7200	8400	9600	10 800
14	1400	2800	4200	5600	7000	8400	9800	11 200	12 600
15	1500	3000	4500	6000	7500	9000	10 500	12 000	13 500
16	1600	3200	4800	6400	8000	9600	11 200	12 800	14 400
18	1800	3600	5400	7200	9000	10 800	12 600	14 400	16 200
20	2000	4000	6000	8000	10 000	12 000	14 000	16 000	18 000
21	2100	4200	6300	8400	10 500	12 600	14 700	16 800	18 900
24	2400	4800	7200	9600	12 000	14 400	16 800	19 200	21 600
27	2700	5400	8100	10 800	13 500	16 200	18 900	21 600	24 300
30	3000	6000	9000	12 000	15 000	18 000	21 000	24 000	27 000
33	3300	6600	9900	13 200	16 500	19 800	23 100	26 400	29 700
36	3600	7200	10 800	14 400	18 000	21 600	25 200	28 800	32 400
39	3900	7800	11 700	15 600	19 500	23 400	27 300	31 200	35 100
42	4200	8400	12 600	16 800	21 000	25 200	29 400	33 600	37 800
45	4500	9000	13 500	18 000	22 500	27 000	31 500	36 000	40 500
48	4800	9600	14 400	19 200	24 000	28 800	33 600	38 400	43 200
51	5100	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900
54	5400	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600
60	6000	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000
66	6600	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400
72	7200	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800
78	7800	15 600	23 400	31 200	39 000	46 800	54 600	62 400	70 200
84	8400	16 800	25 200	33 600	42 000	50 400	58 800	67 200	75 600
90	9000	18 000	27 000	36 000	45 000	54 000	63 000	72 000	81 000
96	9600	19 200	28 800	38 400	48 000	57 600	67 200	76 800	86 400
102	10 200	20 400	30 600	40 800	51 000	61 200	71 400	81 600	91 800
108	10 800	21 600	32 400	43 200	54 000	64 800	75 600	86 400	97 200
114	11 400	22 800	34 200	45 600	57 000	68 400	79 800	91 200	10 2600
120	12 000	24 000	36 000	48 000	60 000	72 000	84 000	96 000	108 000
132	13 200	26 400	39 600	52 800	66 000	79 200	92 400	105 600	118 800
144	14 400	28 800	43 200	57 600	72 000	86 400	100 800	115 200	129 600
156	15 600	31 200	46 800	62 400	78 000	93 600	109 200	124 800	140 400

SI Units									
	Hoop Tensile Strength N/mm Width								
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	138	276	414	552	690	828	966	1104	1241
250	173	345	517	690	862	1035	1207	1380	1552
300	207	413	620	827	1034	1241	1448	1655	1862
350	242	482	724	965	1207	1448	1690	1931	2172
375	259	517	776	1034	1293	1552	1811	2069	2327
400	276	551	827	1103	1379	1655	1931	2207	2482
450	311	620	931	1241	1552	1862	2173	2483	2793
500	345	689	1034	1379	1724	2069	2414	2759	3103
550	380	758	1137	1517	1896	2276	2655	3035	3413
600	414	827	1241	1655	2069	2483	2897	3311	3724
700	483	965	1448	1931	2414	2897	3380	3863	4344
750	518	1034	1551	2069	2586	3104	3621	4139	4655
850	587	1171	1758	2344	2931	3517	4104	4690	5275
900	621	1240	1861	2482	3103	3724	4345	4966	5585
1000	690	1378	2068	2758	3448	4138	4828	5518	6206
1100	759	1516	2275	3034	3793	4552	5311	6070	6827
1150	794	1585	2378	3172	3965	4759	5552	6346	7137
1200	828	1654	2482	3310	4138	4966	5794	6622	7447
1300	897	1791	2688	3585	4482	5379	6276	7173	8068
1400	966	1929	2895	3861	4827	5793	6759	7725	8688
1500	1035	2067	3102	4137	5172	6207	7242	8277	9309
1700	1173	2343	3516	4689	5862	7035	8208	9381	10 550
1800	1242	2480	3722	4964	6206	7448	8690	9932	11 171
2000	1380	2756	4136	5516	6896	8276	9656	11 036	12 412
2200	1518	3032	4550	6068	7586	9104	10 622	12 140	13 653
2300	1587	3169	4756	6343	7930	9517	11 104	12 691	14 274
2400	1656	3307	4963	6619	8275	9931	11 587	13 243	14 894
2600	1794	3583	5377	7171	8965	10 759	12 553	14 347	16 136

2800	1932	3858	5790	7722	9654	11 586	13 518	15 450	17 377
2900	2001	3996	5997	7998	9999	12 000	14 001	16 002	17 997
3000	2070	4134	6204	8274	10 344	12 414	14 484	16 554	18 618
3400	2346	4685	7031	9377	11 723	14 069	16 415	18 761	21 100
3600	2484	4961	7445	9929	12 413	14 897	17 381	19 865	22 342
4000	2760	5512	8272	11 032	13 792	16 552	19 312	22 072	24 824

TABLE 9 Beam-Strength Test Loads

Nominal Diameter, in.	Beam Load (*P*)		Minimum Longitudinal Tensile Strength, per Unit of Circumference		Minimum Longitudinal Compressive Strength, per Unit of Circumference	
	lbf	(kN)	lbf/in.	(kN/m)	lbf/in.	(kN/m)
8	800	(3.6)	580	(102)	580	(102)
10	1200	(5.3)	580	(102)	580	(102)
12	1600	(7.1)	580	(102)	580	(102)
14	2200	(9.8)	580	(102)	580	(102)
15	2600	(11.6)	580	(102)	580	(102)
16	3000	(13.3)	580	(102)	580	(102)
18	4000	(17.8)	580	(102)	580	(102)
20	4400	(19.6)	580	(102)	580	(102)
21	5000	(22.2)	580	(102)	580	(102)
24	6400	(28.5)	580	(102)	580	(102)
27	8000	(35.6)	580	(102)	580	(102)
30	. . .	. . .	580	(102)	580	(102)
33	. . .	. . .	640	(111)	640	(111)
36	. . .	. . .	700	(122)	700	(122)
39	. . .	. . .	780	(137)	780	(137)
42	. . .	. . .	800	(140)	800	(140)
45	. . .	. . .	860	(150)	860	(150)
48	. . .	. . .	920	(161)	920	(161)
51	. . .	. . .	980	(171)	980	(171)
54	. . .	. . .	1040	(182)	1040	(182)
60	. . .	. . .	1140	(200)	1140	(200)
66	. . .	. . .	1260	(220)	1260	(220)
72	. . .	. . .	1360	(238)	1360	(238)
78	. . .	. . .	1480	(260)	1480	(260)
84	. . .	. . .	1600	(280)	1600	(280)
90	. . .	. . .	1720	(301)	1720	(301)
96	. . .	. . .	1840	(322)	1840	(322)
102	. . .	. . .	1940	(340)	1940	(340)
108	. . .	. . .	2060	(360)	2060	(360)
114	. . .	. . .	2180	(382)	2180	(382)
120	. . .	. . .	2280	(400)	2280	(400)
132	. . .	. . .	2520	(440)	2520	(440)
144	. . .	. . .	2740	(480)	2740	(480)
156	. . .	. . .	2964	(519)	2964	(519)

7.3.3 *Longitudinal-Strength Test,* including:

7.3.3.1 Beam strength and

7.3.3.2 Longitudinal tensile strength.

7.4 *Control Tests*—The following test is considered a control requirement and shall be performed as agreed upon between the purchaser and the supplier:

7.4.1 *Soundness Test*—102-in. (2600-mm) diameter pipe and larger.

7.4.2 Perform the sampling and testing for the control requirements for hydrostatic design basis at least once every two years.

7.5 For individual orders conduct only those additional tests and numbers of tests specifically agreed upon between the purchaser and the supplier.

8. Test Methods

8.1 *Dimensions:*

8.1.1 *Diameters:*

8.1.1.1 *Inside Diameter*—Take inside diameter measurements at a point approximately 6 in. (152 mm) from the end of the pipe section using a steel tape or an inside micrometer with graduations of 1⁄16 in. (1 mm) or less. Make two 90° opposing measurements at each point of measurement and average the readings.

8.1.1.2 *Outside Diameter*—Determine in accordance with Test Method D3567.

8.1.2 *Length*—Measure with a steel tape or gage having graduations of 1⁄16 in. (1 mm) or less. Lay the tape or gage on or inside the pipe and measure the overall laying length of the pipe.

8.1.3 *Wall Thickness*—Determine in accordance with Test Method D3567.

8.1.4 *Squareness of Pipe Ends*—Rotate the pipe on a mandrel or trunnions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively, when squareness of pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at frequent enough intervals to ensure that the squareness of the pipe ends is maintained within tolerance.

8.2 *Soundness*—Determine soundness by a hydrostatic proof test procedure. Place the pipe in a hydrostatic pressure testing machine that seals the ends and exerts no end loads. Fill the pipe with water, expelling all air, and apply internal water pressure at a uniform rate not to exceed 50 psi (345 kPa)/s until the Table 4 test pressure specified in accordance with 6.3 is reached. Maintain this pressure for a minimum of 30 s. The pipe shall show no visual signs of weeping, leakage, or fracture of the structural wall.

8.3 *Long-Term Hydrostatic Pressure*—Determine the long-term hydrostatic pressure at 50 years in accordance with Procedure B of Practice D2992, with the following exceptions permitted:

8.3.1 Test at ambient temperatures between 50 and 110°F (10 and 43.5°C) and report the temperature range experienced during the tests.

NOTE 13—Tests indicate no significant effects on long-term hydrostatic pressure within the ambient temperature range specified.

8.3.2 Determine the hydrostatic design basis for the glass fiber reinforcement in accordance with the method in Annex A1.

8.3.3 Calculate the long-term hydrostatic pressure and categorize by class in accordance with Table 5. A1.6 explains how to calculate the long-term hydrostatic pressure.

TABLE 10 Longitudinal Tensile Strength of Pipe Wall

Inch-Pound Units									
Nominal Diameter (in.)	Longitudinal Tensile Strength lbf/in. of Circumference								
	Pressure Class								
	C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	580	580	580	580	580	624	700	800	900
10	580	580	580	580	650	780	875	1000	1125
12	580	580	580	624	780	936	1050	1200	1350
14	580	580	609	728	910	1092	1225	1400	1575
15	580	580	653	780	975	1170	1313	1500	1688
16	580	580	696	832	1040	1248	1400	1600	1800
18	580	580	783	936	1170	1404	1575	1800	2025
20	580	580	870	1040	1300	1560	1750	2000	2250
21	580	609	914	1092	1365	1638	1838	2100	2363
24	580	696	1044	1248	1560	1800	2100	2400	2700
27	580	783	1175	1404	1688	2025	2363	2700	3038
30	580	870	1305	1560	1875	2250	2625	3000	3375
33	627	957	1436	1716	2063	2475	2888	3300	3713
36	684	1044	1566	1800	2250	2700	3150	3600	4050
39	741	1131	1697	1872	2340	2808	3276	3744	4212
42	798	1218	1827	2016	2520	3024	3528	4032	4536
45	855	1305	1958	2160	2700	3240	3780	4320	4860
48	912	1392	2088	2304	2880	3456	4032	4608	5184
51	969	1479	2219	2448	3060	3672	4284	4896	5508
54	1026	1566	2349	2592	3240	3726	4347	4968	5589
60	1140	1740	2520	2880	3600	4140	4830	5520	6210
66	1254	1914	2673	3036	3795	4554	5313	5808	6534
72	1368	2088	2916	3312	4140	4968	5796	6336	7128
78	1482	2106	3159	3432	4290	5148	6006	6864	7722
84	1596	2268	3402	3696	4620	5292	6174	7056	7938
90	1710	2430	3645	3960	4950	5670	6615	7380	8303
96	1824	2592	3888	4224	5280	6048	7056	7680	8640
102	1938	2754	4131	4488	5610	6426	7497	8160	9180
108	2052	2916	4374	4752	5940	6804	7938	8640	9720
114	2166	3078	4617	5016	6270	7182	8379	9120	10 260
120	2280	3240	4860	5280	6600	7560	8820	9600	10 800
132	2508	3564	5346	5808	7260	8316	9702	10 560	11 880
144	2736	3888	5832	6336	7920	9072	10 584	11 520	12 960
156	2964	4212	6318	6864	8580	9828	11 466	12 480	14 040

SI Units									
	Longitudinal Tensile Strength N/mm of Circumference								
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	102	102	102	102	102	109	123	140	158
250	102	102	102	102	114	137	153	175	197
300	102	102	102	109	137	164	184	210	236
350	102	102	107	127	159	191	215	245	276
375	102	102	114	137	171	205	230	263	296
400	102	102	122	146	182	219	245	280	315
450	102	102	137	164	205	246	276	315	355
500	102	102	152	182	228	273	306	350	394
550	102	107	160	191	239	287	322	368	414
600	102	122	183	219	273	315	368	420	473
700	102	137	206	246	296	355	414	473	532
750	102	152	229	273	328	394	460	525	591
850	110	168	251	301	361	433	506	578	650
900	120	183	274	315	394	473	552	630	709
1000	130	198	297	328	410	492	574	656	738
1100	140	213	320	353	441	530	618	706	794
1150	150	229	343	378	473	567	662	757	851
1200	160	244	366	403	504	605	706	807	908
1300	170	259	388	429	536	643	750	857	965
1400	180	274	411	454	567	652	761	870	979
1500	200	305	441	504	630	725	846	967	1087
1700	220	335	468	532	665	797	930	1017	1144
1800	240	366	511	580	725	870	1015	1110	1248
2000	260	369	553	601	751	902	1052	1202	1352
2200	279	397	596	647	809	927	1081	1236	1390
2300	299	426	638	693	867	993	1158	1292	1454
2400	319	454	681	740	925	1059	1236	1345	1513
2600	339	482	723	786	982	1125	1313	1429	1608
2800	359	511	766	832	1040	1192	1390	1513	1702
2900	379	539	809	878	1098	1258	1467	1597	1797

3000	399	567	851	925	1156	1324	1545	1681	1891
3400	439	624	936	1017	1271	1456	1699	1849	2080
3600	479	681	1021	1110	1387	1589	1853	2017	2270
4000	519	738	1106	1202	1503	1721	2008	2185	2459

8.4 *Stiffness*—Determine the pipe stiffness

$$PS = F/\Delta y \quad (2)$$

where:

PS = pipe stiffness, psi (kPa)
F = load, lbs/lineal-in. (N/mm)
Δy = pipe deflection, in. (mm)

at 5% deflection or the adjusted level determined in accordance with 6.5.3 for the specimen, using the apparatus and procedure of Test Method D2412, with the following exceptions permitted:

8.4.1 Measure the wall thickness to the nearest 0.01 in. (0.25 mm).

8.4.2 Load the specimen to 5 % deflection or the adjusted level determined in accordance with 6.5.3 and record the load. Then load the specimen to deflection level A per Table 7 or to the adjusted level A deflection determined in accordance with 6.5.1 and 6.5.2 and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level B per Table 7 or to the adjusted level B deflection determined in accordance with 6.5.1 and 6.5.2 and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass fiber reinforcement, and fracture or buckling of the pipe wall. Calculate the pipe stiffness at 5 % deflection.

8.4.3 For production testing, test only one specimen to determine the pipe stiffness.

8.4.4 The maximum specimen length shall be 12 in. (305 mm), or the length necessary to include stiffening ribs, if they are used, whichever is greater.

NOTE 14—As an alternative to determining the pipe stiffness using the apparatus and procedure of Test Method D2412 the supplier may submit to the purchaser for approval a test method and test evaluation on Test Method D790, accounting for the substitution of curved test specimens and measurement of stiffness at 5 % deflection.

8.5 *Hoop-Tensile Strength*—Determine the hoop-tensile strength by Test Method D2290, except that the sections on Apparatus and Test Specimens may be modified to suit the size of specimens to be tested, and the maximum load rate may not exceed 0.10 in/min. Alternatively, Test Method D638 may be employed. Specimen width may be increased for pipe wall thicknesses greater than 0.55 in. (14 mm). Means may be provided to minimize the bending moment imposed during the test. Cut three specimens from the test sample. Record the load to fail each specimen and determine the specimen width as close to the break as possible. Use the measured width and failure load to calculate the hoop-tensile strength.

8.5.1 *Alternative Minimum Hoop-Tensile Strength Requirement*—As an alternative, the minimum hoop-tensile strength values may be determined as follows:

$$F = (S_i/S_r)(Pr) \quad (3)$$

where:

F = required minimum hoop tensile strength, lbf/in.,
S_i = initial design hoop tensile stress, psi,
S_r = hoop tensile stress at rated operating pressure, psi,
P = rated operating pressure class, psi, and
r = inside radius of pipe, in.

NOTE 15—A value of F less than 4 Pr results in a lower factor of safety on short term loading than required by the values in Table 8.

The value for S_i should be established by considering the variations in glass reinforcement strength and manufacturing methods, but in any case should not be less than the 95 % lower confidence value on stress at 0.1 h, as determined by the manufacturer's testing carried out in accordance with 6.4. The value for S_r should be established from the manufacturer's hydrostatic design basis.

8.6 *Longitudinal Strength:*

8.6.1 *Beam Strength*—Place a 20-ft (6.1-m) nominal length of pipe on saddles at each end. Hold the ends of the pipe round during the test. Apply beam load for the diameter of pipe shown in Table 9 simultaneously to the pipe through two saddles located at the third points of the pipe (see Fig. 2). The loads shall be maintained for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

8.6.2 *Longitudinal Tensile Strength*—Determine in accordance with Test Method D638, except the provision for maximum thickness shall not apply.

8.6.3 *Longitudinal Compressive Strength*—Determine in accordance with Test Method D695.

9. Packaging and Package Marking

9.1 Mark each length of pipe that meets or is part of a lot that meets the requirements of this specification at least once in letters not less than ½ in. (12 mm) in height and of bold-type style in a color and type that remains legible under normal handling and installation procedures. The marking shall include the nominal pipe size, manufacturer's name or trademark, this ASTM specification number: D3517, type, liner, grade, class, and stiffness in accordance with the designation code in 4.2.

9.2 Prepare pipe for commercial shipment in such a way as to ensure acceptance by common or other carriers.

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

10. Certification

10.1 See Annex A2 for certification requirements.

11. Keywords

11.1 fiberglass pipe; hydrostatic design basis; pressure pipe; RPMP; RTRP

ANNEX

(Mandatory Information)

A1. ALTERNATIVE HYDROSTATIC DESIGN METHOD

A1.1 The following symbols are used:

S = tensile stress in the glass fiber reinforcement in the hoop orientation corrected for the helix angle, psi,
P = internal pressure, psig,
P_1 = long-term hydrostatic pressure, psig,
D = nominal inside pipe diameter, in.,
t_h = actual cross-sectional area of glass-fiber reinforcement applied around the circumference of the pipe, in.^{2}/in.,
θ = plane angle between hoop-oriented reinforcement and longitudinal axis of the pipe (helix angle), and
HDB = hydrostatic-design basis, psi.

A1.2 The hydrostatic design is based on the estimated tensile stress of the reinforcement in the wall of the pipe in the circumferential (hoop) orientation that will cause failure after 50 years of continuously applied pressure as described in Procedure B of Practice D2992. Strength requirements are calculated using the strength of hoop-oriented glass reinforcement only, corrected for the helix angle of the fibers.

A1.3 *Hoop-Stress Calculation* is derived from the ISO equation for hoop stress, as follows:

$$S = PD/2(t_h \sin\theta)$$

This stress is used as the ordinate (long-term strength) in calculating the regression line and lower confidence limit in accordance with Annexes A1 and A3 of Practice D2992.

NOTE A1.1—The calculated result for S may be multiplied by the factor 6.895 to convert from psi to kPa.

A1.4 *Hydrostatic-Design Basis*—The value of S is determined by extrapolation of the regression line to or 50 years in accordance with Practice D2992.

A1.5 *Hydrostatic-Design Basis Categories*—Convert the value of the HDB to internal hydrostatic pressure in psig as follows:

$$P_1 = 2(t_h \sin\theta)(\text{HDB})/D$$

The pipe is categorized in accordance with Table A1.1.

NOTE A1.2—The calculated result P_1 may be multiplied by the factor 6.895 to convert from psig to kPa.

A1.6 *Pressure Class Rating*—The classes shown in Table A1.1 are based on the intended working pressure in psig for commonly encountered conditions of water service. The purchaser should determine the class of pipe most suitable to the installation and operating conditions that will exist on the project on which the pipe is to be used by multiplying the values of P_1 from Table A1.1 by a service (design) factor selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures in this method. The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectancy desired, and the degree of reliability selected.

NOTE A1.3—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific plastic pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

A2. CERTIFICATION

A2.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material.

A2.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specifications.

A2.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A2.4 When original identity can not be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIXES

(Nonmandatory Information)

X1. INSTALLATION

X1.1 These specifications are material performance and purchase specifications only and do not include requirements for engineering design, pressure surges, bedding, backfill or the relationship between earth cover load, and the strength of the pipe. However, experience has shown that successful performance of this product depends upon the proper type of bedding and backfill, pipe characteristics, and care in the field construction work. The purchaser of the fiberglass pressure pipe specified herein is cautioned that he must properly correlate the field requirements with the pipe requirements and provide adequate inspection at the job site.

X2. RECOMMENDED METHODS FOR DETERMINING GLASS CONTENT

X2.1 Determine glass content as follows:

X2.1.1 By ignition loss analysis in accordance with Test Method D2584 or ISO 1172.

X2.1.2 As a process control, by weight of the glass fiber reinforcement applied by machine into the pipe structure.

SPECIFICATION FOR "FIBERGLASS" (GLASS-FIBER REINFORCED THERMOSETTING-RESIN) SEWER AND INDUSTRIAL PRESSURE PIPE

SD-3754

(Identical with ASTM D3754-19 except for revisions to paras. 2.1, 6.3.1.3, 6.5.1, 6.6, 6.8, 8.5, 8.6.1, 8.7.2, 11.1, Annex A1, and Appendix X1; addition of para. 2.4, section 10, and Annex A3; renumbering section 11; and editorial corrections.)

Specification for
"Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe

1. Scope

1.1 This specification covers machine-made fiberglass pipe, 8 in. (200 mm) through 156 in. (4000 mm), for use in pressure systems for conveying sanitary sewage, storm water, and many industrial wastes, and corrosive fluids. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipes. This standard is suited primarily for pipes to be installed in buried applications, although it may be used to the extent applicable for other installations such as, but not limited to, jacking, tunnel lining and slip-lining and rehabilitation of existing pipelines. Pipe covered by this specification is intended to operate at internal gage pressures of 450 psi (3103 kPa) or less.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

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

1.3 The following precautionary caveat pertains only to the test method portion, Section 8, 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.*

NOTE 2—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C33 Specification for Concrete Aggregates
C581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
D638 Test Method for Tensile Properties of Plastics
D695 Test Method for Compressive Properties of Rigid Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D3039 Test Method for Tensile Properties of Polymer Matrix Composite Materials
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D3681 Test Method for Chemical Resistance of "Fiberglass" (Glass–Fiber–Reinforced Thermosetting-Resin) Pipe in a Deflected Condition
D3892 Practice for Packaging/Packing of Plastics
D4161 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

TABLE 1 General Designation Requirements for Fiberglass Pressure Pipe

Designation	Property	Cell Limits[A]								
1	Type	1 glass-fiber-reinforced thermosetting polyester[B] resin mortar (RPMP polyester)[B]	2 glass-fiber-reinforced thermosetting polyester[B] resin (RTRP polyester)[B]	3 glass-fiber-reinforced thermosetting epoxy resin mortar (RPMP epoxy)	4 glass-fiber-reinforced thermosetting epoxy resin (RTRP epoxy)					
2	Liner	1 reinforced thermoset liner	2 non-reinforced thermoset liner	3 thermoplastic liner	4 no liner					
3	Grade	1 Polyester resin surface layer—reinforced[B]	2 polyester[B] resin surface layer—nonreinforced[B]	3 polyester[B] resin and sand surface layer nonreinforced	4 epoxy resin surface layer—reinforced	5 epoxy resin surface layer—nonreinforced	6 No surface layer			
4	Class[C]	C50	C100	C150	C200	C250	C300	C350	C400	C450
5	Pipe Stiffness psi (kPa)	A 9 (62)	B 18 (124)	C 36 (248)	D 72 (496)[ABC]					

[A] The cell-type format provides the means of identification and specification of piping materials. This cell-type format, however, is subject to misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available products. The manufacturer should be consulted.
[B] For the purposes of this standard, polyester includes vinyl ester resin.
[C] Based on operating pressure in psig (numerals).

2.2 *ISO Standard:*
ISO 1172 Textile Glass Reinforced Plastics—Determination of Loss on Ignition

2.3 *AWWA Standard:*
AWWA C-950 Glass-Fiber Reinforced Thermosetting Resin Pressure Pipe

2.4 *ASME Standards:*
ASME NM.3.2, SD-4161 Specification for Fiberglass (Glass Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Elastomeric Seals
ASME NM.3.2, SF-477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 or Terminology F412 and abbreviations with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *fiberglass pipe*—a tubular product containing glass fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

3.2.2 *flexible joint*—a joint that is capable of axial displacement or angular rotation, or both.

3.2.3 *industrial pipe*—pipe designed for internal, or external environments, or both, commonly encountered in industrial piping systems used for many process solutions or effluents.

3.2.4 *liner*—a resin layer, with or without filler or reinforcement, or both, forming the interior surface of the pipe.

3.2.5 *qualification test*—one or more tests used to prove the design of a product. Not a routine quality control test.

3.2.6 *reinforced polymer mortar pipe*—a fiberglass pipe with aggregate.

3.2.7 *reinforced thermosetting resin pipe*—a fiberglass pipe without aggregate.

3.2.8 *rigid joint*—a joint that is not capable of axial displacement or angular rotation.

3.2.9 *surface layer*—a resin layer, with or without filler or reinforcement, or both, applied to the exterior surface of the pipe structural wall.

4. Classification

4.1 *General*—This specification covers fiberglass sewer and industrial pressure pipe defined by raw materials in the structural wall (type) and liner, surface layer material (grade), operating pressure (class), and pipe stiffness. Table 1 lists the types, liners, grades, classes, and stiffnesses that are covered.

NOTE 3—All possible combinations of types, liners, grades, classes, and stiffness may not be commercially available. Additional types, liners, grades, and stiffnesses may be added as they become commercially available. The purchaser should determine for himself or consult with the manufacturer for the proper class, type, liner, grade, and stiffness of pipe to be used under the installation and operating conditions that will exist for the project in which the pipe is to be used.

4.2 *Designation Requirements*—The pipe materials designation code shall consist of the standard designation, ASTM D3754, followed by type, liner, and grade in arabic numerals, class by the letter C with two or three arabic numerals, and pipe stiffness by a capital letter. Table 1 presents a summary of the designation requirements. Thus a complete material code shall consist of ASTM D3754, three numerals, C...and two or three numerals, and a capital letter.

NOTE 4—Examples of the designation codes are as follows: (*1*) ASTM D3754-1-1-3-C50-A for glass-fiber-reinforced aggregate and polyester resin mortar pipe with a reinforced thermoset liner and an unreinforced polyester resin and sand surface layer, for operation at 50 psi (345 kPa), and having a minimum pipe stiffness of 9 psi (62 kPa). (*2*) ASTM D3754-4-2-6-C200-C for glass-fiber-reinforced epoxy resin pipe with an unreinforced thermoset liner, no surface layer, for operation at 200 psi (1380 kPa) and having a minimum pipe stiffness of 36 psi (248 kPa).

NOTE 5—Although the "Form and Style for ASTM Standards" manual requires that the type classification be roman numerals, it is recognized that few companies have stencil-cutting equipment for this style of type, and it is therefore acceptable to mark the product type in arabic numbers.

5. Materials and Manufacture

5.1 *General*—The thermosetting resins, glass fiber reinforcements, fillers, and other materials, when combined as a composite structure, shall produce piping products that meet the performance requirements of this specification.

5.2 *Wall Composition*—The basic structural wall composition shall consist of a thermosetting resin, glass-fiber reinforcement, and, if used, an aggregate filler.

5.2.1 *Resin*—A thermosetting polyester or epoxy resin, with or without filler.

5.2.2 *Aggregate*—A siliceous sand conforming to the requirements of Specification C33, except that the requirements for gradation shall not apply.

5.2.3 *Reinforcement*—A commercial grade of glass fibers compatible with the resin used.

5.3 *Liner and Surface Layers*—A liner or surface layer, or both, when incorporated into or onto the pipe shall meet the chemical and structural requirements of this specification.

5.4 *Joints*—The pipe shall have a joining system that shall provide for fluid tightness for the intended service condition. A particular type of joint may be restrained or unrestrained and flexible or rigid depending on the specific configuration and design conditions.

5.4.1 *Unrestrained*—Pipe joints capable of withstanding internal pressure but not longitudinal forces.

5.4.1.1 *Coupling or Bell-and-Spigot Gasket Joints,* with a groove either on the spigot or in the bell to retain an elastomeric gasket that shall be the sole element of the joint to provide watertightness. For typical joint details see Fig. 1.

5.4.1.2 *Mechanical Coupling Joint,* with elsastomeric seals.

5.4.1.3 *Butt Joint*, with laminated overlay

5.4.1.4 *Flanged Joint,* both integral and loose ring.

5.4.2 *Restrained*—Pipe joints capable of withstanding internal pressure and longitudinal tensile loads.

5.4.2.1 Joints similar to those in 5.4.1.1 with supplemental restraining elements.

5.4.2.2 *Butt Joint,* with laminated overlay.

5.4.2.3 *Bell-and-Spigot,* with laminated overlay.

5.4.2.4 *Bell-and-Spigot,* adhesive-bonded-joint: Three types of adhesive-bonded joints are premitted by this standard as follows:

(1) Tapered bell-and-spigot, an adhesive joint that is manufactured with a tapered socket for use in conjunction with a tapered spigot and a suitable adhesive.

(2) Straight bell-and-spigot, an adhesive joint that is manufactured with an untapered socket for use in conjunction with an untapered spigot and a suitable adhesive.

(3) Tapered bell and straight spigot, an adhesive joint that is manufactured with a tapered socket for use with an untapered spigot and a suitable adhesive.

5.4.2.5 *Flanged Joint,* both integral and loose ring.

5.4.2.6 *Threaded Joints.*

5.4.2.7 *Mechanical Coupling,* an elastomeric sealed coupling with supplemental restraining elements.

NOTE 6—Other types of joints may be added as they become commercially available.

NOTE 7—Restrained joints typically increase service loads on the pipe to greater than those experienced with unrestrained joints. The purchaser is cautioned to take into consideration all conditions that may be encountered in the anticipated service and to consult the manufacturer regarding the suitability of a particular type and class of pipe for service with restrained joint systems.

5.5 *Gaskets*—Elastomeric gaskets, when used with this pipe, shall conform to the requirements of Specification F477, except that composition of the elastomer shall be as agreed upon between the purchaser and the supplier for the particular exposure to oily or aggressive-chemical environments.

6. Requirements

6.1 *Workmanship:*

6.1.1 Each pipe shall be free from all defects including indentations, delaminations, bubbles, pinholes, cracks, pits, blisters, foreign inclusions, and resin-starved areas that due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.1.2 The inside surface of each pipe shall be free of bulges, dents, ridges, or other defects that result in a variation of inside diameter of more than ⅛ in. (3.2 mm) from that obtained on adjacent unaffected portions of the surface. No glass-fiber reinforcement shall penetrate the interior surface of the pipe wall.

6.1.3 Joint sealing surfaces shall be free of dents, gouges, or other surface irregularities that will affect the integrity of the joints.

6.2 *Dimensions:*

6.2.1 *Pipe Diameters*—The pipe shall be supplied in the nominal diameters shown in Table 2 or Table 3. The pipe diameter tolerances shall be as shown in Table 2 or Table 3, when measured in accordance with 8.1.1.

6.2.2 *Lengths*—The pipe shall be supplied in nominal lengths of 10, 20, 30, 40, and 60 ft (3.05, 6.10, 9.15, 12.19, and 18.29 m). The actual laying length shall be the nominal length ±2 in. (±51 mm), when measured in accordance with 8.1.2. At least 90 % of the total footage of any one size and class, excluding special-order lengths, shall be furnished in the nominal lengths specified by the purchaser. Random lengths, if furnished, shall not vary from the nominal lengths by more than 5 ft (1.53 m), or 25 %, whichever is less.

6.2.3 *Wall Thickness*—The average wall thickness of the pipe shall not be less than the nominal wall thickness published in the manufacturer's literature current at the time of purchase, and the minimum wall thickness at any point shall not be less

FIG. 1 Typical Joints

TABLE 2 Nominal Inside Diameters (ID) and Tolerances Inside Diameter Control Pipe

Nominal Diameter,[A] in.	Tolerances, in.	Nominal Metric Diameter,[B] mm	ID Range,[B] mm		Tolerance[B] on Declared ID, mm
			Minimum	Maximum	
8	±0.25	200	196	204	±1.5
10	±0.25	250	246	255	±1.5
12	±0.25	300	296	306	±1.8
14	±0.25	400	396	408	±2.4
15	±0.25	500	496	510	±3.0
16	±0.25	600	595	612	±3.6
18	±0.25	700	695	714	±4.2
20	±0.25	800	795	816	±4.2
21	±0.25	900	895	918	±4.2
24	±0.25	1000	995	1020	±5.0
27	±0.27	1200	1195	1220	±5.0
30	±0.30	1400	1395	1420	±5.0
33	±0.33	1600	1595	1620	±5.0
36	±0.36	1800	1795	1820	±5.0
39	±0.39	2000	1995	2020	±5.0
42	±0.42	(2200)	2195	2220	±6.0
45	±0.45	2400	2395	2420	±6.0
48	±0.48	(2600)	2595	2620	±6.0
51	±0.51	2800	2795	2820	±6.0
54	±0.54	(3000)	2995	3020	±6.0
60	±0.60	3200	3195	3220	±7.0
66	±0.66	(3400)	3395	3420	±7.0
72	±0.72	3600	3595	3620	±7.0
78	±0.78	(3800)	3795	3820	±7.0
84	±0.84	4000	3995	4020	±7.0
90	±0.90	. . .	. . .	. . .	. . .
96	±0.96	. . .	. . .	. . .	. . .
102	±1.00	. . .	. . .	. . .	. . .
108	±1.00	. . .	. . .	. . .	. . .
114	±1.00	. . .	. . .	. . .	. . .
120	±1.00	. . .	. . .	. . .	. . .
132	±1.00	. . .	. . .	. . .	. . .
144	±1.00	. . .	. . .	. . .	. . .
156	±1.00	. . .	. . .	. . .	. . .

[A] Inside diameters other than those shown shall be permitted by agreement between purchaser and supplier.
[B] Values are taken from International Standards Organization documents. Parentheses indicate non-preferred diameters.

than 87.5 % of the nominal wall thickness when measured in accordance with 8.1.3.

6.2.4 *Squareness of Pipe Ends*—All points around each end of a pipe unit shall fall within ±¼ in. (6.4 mm) or ±0.5 % of the nominal diameter of the pipe, whichever is greater, to a plane perpendicular to the longitudinal axis of the pipe, when measured in accordance with 8.1.4.

6.3 *Chemical Requirements:*

6.3.1 *Sanitary Sewer Service:*

6.3.1.1 *Long-Term*—Pipe specimens, when tested in accordance with 8.2.1 shall be capable of being deflected, without failure, at the 50 year strain level given in Table 4 when exposed to 1.0 *N* sulfuric acid.

NOTE 8—See Appendix X1 for derivation of the minimum sanitary sewer pipe chemical requirements given in Table 4.

NOTE 9—The calculations in Table 4 and Appendix X1 assume that the neutral axis is at the pipe wall midpoint. For pipe wall constructions that produce an altered neutral axis position, it is necessary to evaluate results and establish requirements substituting $2y$ for t. (y is the maximum distance from the neutral axis to the pipe surface.)

6.3.1.2 *Control Requirements*—Test pipe specimens periodically in accordance with 8.2.1.3, following the procedure of 8.2.1.4, or alternatively, the procedure of 8.2.1.5.

6.3.1.3 When the procedure of 8.2.1.4 is used, the following three criteria shall be met: a) the average failure time at each strain level shall fall at or above the lower 95 % confidence limit of the originally determined regression line, b) no specimen-failure times may be sooner than the lower 95 % prediction limit of the originally determined regression line, and c) one-third or more of the specimen failure times shall be on or above the originally determined regression line.

NOTE 10—Determine the lower 95 % confidence limit and the lower 95 % prediction limit in accordance with to Annex A2.

6.3.1.4 When the alternative method of 8.2.1.5 is used, failure shall not occur in any specimen.

6.3.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, shall be a commercial-grade corrosion-resistant thermoset that has either been evaluated in a laminate by test, in accordance with 8.2.2, or that has been determined by previous documented service to be acceptable for the service conditions. Where service conditions have not been evaluated, a suitable resin may also be selected by agreement between the manufacturer and purchaser.

NOTE 11—The results obtained by this test shall serve as a guide only in the selection of a pipe material for a specific service application. The purchaser is cautioned to evaluate all of the various factors that may enter into the serviceability of a pipe material when subjected to chemical environment, including chemical resistance in the strained condition.

TABLE 3 Nominal Outside Diameters (OD) and Tolerances

NOTE 1—The external diameter of the pipe at the spigots shall be within the tolerances given in the table, and the manufacturer shall declare his allowable maximum and minimum spigot diameters. Some pipes are manufactured such that the entire pipe meets the OD tolerances while other pipes meet the tolerances at the spigots, in which case, if such pipes are cut (shortened) the ends may need to be calibrated to meet the tolerances.

Nominal Pipe Size, in.	Steel Pipe Equivalent (IPS) OD's, in.	Tolerance, in.	Cast Iron Pipe Equivalent OD's, in.	Tolerance, in.
8	8.625	+0.086 −0.040	9.05	
10	10.750	+0.108 −0.048	11.10	±0.06
12	12.750	+0.128 −0.056	13.20	
14	14.000	+0.140 −0.062	15.30	
16	16.000	+0.160 −0.070	17.40	
18	. . .	. . .	19.50	+0.05 −0.08
20	. . .	. . .	21.60	
24	. . .	. . .	25.80	
30	. . .	. . .	32.00	
36	. . .	. . .	38.30	
42	. . .	. . .	44.50	+0.08 −0.06
48	. . .	. . .	50.80	
54	. . .	. . .	57.56	
60	. . .	. . .	61.61	

Metric Pipe Size, mm	Ductile Iron Pipe Equivalent, mm	Tolerance Upper, mm	Tolerance Lower, mm	International O.D., mm	Tolerance Upper, mm	Tolerance Lower, mm
200	220.0	+1.0	0.0	. . .	. . .	. . .
250	271.8	+1.0	-0.2	. . .	. . .	. . .
300	323.8	+1.0	-0.3	310	+1.0	-1.0
350	375.7	+1.0	-0.3	361	+1.0	-1.2
400	426.6	+1.0	-0.3	412	+1.0	-1.4
450	477.6	+1.0	-0.4	463	+1.0	-1.6
500	529.5	+1.0	-0.4	514	+1.0	-1.8
600	632.5	+1.0	-0.5	616	+1.0	-2.0
700				718	+1.0	-2.2
800				820	+1.0	-2.4
900				924	+1.0	-2.6
1000				1026	+2.0	-2.6
1200				1229	+2.0	-2.6
1400				1434	+2.0	-2.8
1600				1638	+2.0	-2.8
1800				1842	+2.0	-3.0
2000				2046	+2.0	-3.0
2200				2250	+2.0	-3.2
2400				2453	+2.0	-3.4
2600				2658	+2.0	-3.6
2800				2861	+2.0	-3.8
3000				3066	+2.0	-4.0
3200				3270	+2.0	-4.2
3400				3474	+2.0	-4.4
3600				3678	+2.0	-4.6
3800				3882	+2.0	-4.8
4000				4086	+2.0	-5.0

TABLE 4 Minimum Sanitary Sewer Pipe Chemical Requirements

ε_{scv}

Pipe Stiffness, psi (kPa)	Minimum Strain					
	6 min	10 h	100 h	1 000	10 000	50 years
9 (62)	0.97 (t/de)	0.84 (t/d)	0.78 (t/d)	0.73 (t/d)	0.68 (t/d)	0.60 (t/d)
18 (124)	0.85 (t/d)	0.72 (t/d)	0.66 (t/d)	0.61 (t/d)	0.56 (t/d)	0.49 (t/d)
36 (248)	0.71 (t/d)	0.60 (t/d)	0.55 (t/d)	0.51 (t/d)	0.47 (t/d)	0.41 (t/d)
72 (496)	0.56 (t/d)	0.48 (t/d)	0.44 (t/d)	0.41 (t/d)	0.38 (t/d)	0.34 (t/d)

Where: *t* and *d* are the nominal total wall thickness and the mean diameter (inside diameter plus *t*) as determined in accordance with 8.1.

6.4 *Soundness*—Unless otherwise agreed upon between purchaser and supplier, test each length of pipe up to 96 in. (2400 mm) diameter hydrostatically without leakage or cracking, at the internal hydrostatic proof pressures specified for the applicable class in Table 5 when tested in accordance with 8.3. For sizes over 96 in. (2400 mm), the frequency of hydrostatic leak tests shall be as agreed upon by purchaser and supplier.

6.5 *Hydrostatic Design Basis:*

6.5.1 *Long-Term Hydrostatic Pressure*—The pressure classes shall be based on long-term hydrostatic pressure data obtained in accordance with 8.4 and categorized in accordance with Table 6. Pressure classes are based on extrapolated strengths at 50 years. For pipe subjected to longitudinal loads or circumferential bending, the effect of these conditions on the hydrostatic design pressure classification of the pipe shall be considered.

6.5.2 *Control Requirements*—Test pipe specimens periodically in accordance with the reconfirmation procedures described in Practice D2992.

NOTE 12—Hydrostatic design basis (HDB—extrapolated value at 50 years) determined in accordance with Procedure A of Practice D2992, may be substituted for the Procedure B evaluation required by 8.4. It is generally accepted that the Procedure A value multiplied by 3 is equivalent to the Procedure B value.

6.6 Stiffness—Each length of pipe shall have sufficient strength to exhibit the minimum pipe stiffness ($F/\Delta y$) specified in Table 7 when tested in accordance with 8.5.

$$PS = F/\Delta y \quad (1)$$

where:

PS = pipe stiffness, psi (kPa)
F = load, lbs,/lineal-in. (N/mm)
Δy = pipe deflection, in. (mm)

At deflection level A per Table 8, there shall be no visible damage in the test specimen evidenced by surface cracks. At deflection level B per Table 8, there shall be no indication of structural damage as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall.

NOTE 13—This is a visual observation (made with the unaided eye) for quality control purposes only, and should not be considered a simulated service test. Table 8 values are based on an in-use long-term deflection limit of 5 % and provide an appropriate uniform safety margin for all pipe stiffnesses. Since the pipe-stiffness values ($F/\Delta y$) shown in Table 7 vary, the percent deflection of the pipe under a given set of installation conditions will not be constant for all pipes. To avoid possible misapplication, take care to analyze all conditions that might affect performance of the installed pipe.

TABLE 5 Hydrostatic Pressure Test

Pressure Class	Hydrostatic Proof Pressure	
	Pipe Diameters up to and including 54 in.	Pipe Diameters >54 in. up to and including 96 in.
(psi)	psi (kPa)	psi (kPa)
C50	100 (689)	75 (517)
C100	200 (1379)	150 (1034)
C150	300 (2068)	225 (1551)
C200	400 (2757)	300 (2068)
C250	500 (3447)	375 (2585)
C300	600 (4136)	450 (3102)
C350	700 (4826)	525 (3619)
C400	800 (5515)	600 (4136)
C450	900 (6205)	675 (4654)

TABLE 6 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

TABLE 7 Minimum Stiffness at 5 % Deflection

Nominal Diameter, in.	Pipe Stiffness, psi (kPa)			
	Designation			
	A	B	C	D
8	. . .	. . .	36 (248)	72 (496)
10	. . .	18 (124)	36 (248)	72 (496)
12 and greater	9 (62)	18 (124)	36 (248)	72 (496)

TABLE 8 Ring Deflection Without Damage or Structural Failure

	Nominal Pipe Stiffness, psi			
	9	18	36	72
Level A	18 %	15 %	12 %	9 %
Level B	30 %	25 %	20 %	15 %

6.6.1 For other pipe stiffness levels, appropriate values for Level A and Level B deflections (Table 8) may be computed as follows:

$$\text{Level A at new PS} = \left(\frac{72}{\text{new PS}}\right)^{0.33}(9) \quad (2)$$

$$\text{Level B at new PS} = \text{new Level A} \div 0.6 \quad (3)$$

6.6.2 Since products may have use limits of other than 5 % long-term deflection, Level A and Level B deflections (Table 8) may be proportionally adjusted to maintain equivalent in-use safety margins. For example, a 4 % long-term limiting deflection would result in a 20 % reduction of Level A and Level B deflections, while a 6 % limiting deflection would result in a 20 % increase in Level A and Level B deflection values. However, minimum values for Level A and Level B deflections shall be equivalent to strains of 0.6 and 1.0 % respectively (as computed by Eq X1.1 in Appendix X1).

6.6.3 For high stiffness pipes, 5% deflection will likely be above the use limit and the adjusted level A test deflection. For very high stiffness pipes, 5% deflection may also be greater than the adjusted level B test deflection. In such cases, the pipes may be damaged or fail prior to determining the pipe stiffness at 5% deflection. Therefore, it is permitted to set the pipe stiffness test deflection equal to the adjusted level A deflection, but not greater than 5%. See Note 14 for additional information and further clarification.

NOTE 14—Depending upon the product modulus and allowable ring bending strain, this will likely begin affecting pipes with stiffness between 200 and 400 psi. For example, a pipe with pipe stiffness of PS360 may have a use limit of 4.3 %, an adjusted level A deflection of 4.5 % and an adjusted level B deflection of 7.5 %. Therefore, the new pipe stiffness test deflection would be 4.5 %. Another possible product with pipe stiffness of PS900 may have a use limit of 2.8 %, an adjusted level A deflection of 2.7% and an adjusted level B deflection of 4.5 %. Therefore, the new pipe stiffness test deflection would be 2.7 %.

6.7 *Hoop-Tensile Strength*—All pipe manufactured under this specification shall meet or exceed the hoop-tensile strength shown for each size and class in Table 9 and Table 10, when tested in accordance with 8.6.

6.7.1 *Alternative Requirements*—When agreed upon by the purchaser and the supplier, the minimum hoop tensile strength shall be as determined in accordance with 8.6.1.

6.8 *Joint Tightness*—All joints shall meet the laboratory performance requirements of Specification D4161. Unrestrained joints shall be tested with a fixed end closure condition and restrained joints shall be tested with a free end closure condition. Rigid joints shall be exempt from angular deflection requirements of Specification D4161 (ASME SD-4161). Rigid joints typically include butt joints with laminated overlay, bell-and-spigot joints with laminated overlay, flanged, bell-and-spigot adhesive bonded and threaded.

6.9 *Longitudinal Strength:*

6.9.1 *Beam Strength*—For pipe sizes up to 27 in. (686 mm), the pipe shall withstand, without failure, the beam loads specified in Table 11, when tested in accordance with 8.7.1. For pipe sizes larger than 27 in., and alternatively for smaller sizes, adequate beam strength is demonstrated by tensile and compression tests conducted in accordance with 8.7.2 and 8.7.3 respectively, for pipe wall specimens oriented in the longitudinal direction, using the minimum tensile and compression strengths specified in Table 11.

6.9.2 *Longitudinal Tensile Strength*—All pipe manufactured under this specification shall have a minimum axial tensile elongation at failure of 0.25% and meet or exceed the longitudinal tensile strength shown for each size and class in Table 12 and Table 13, when tested in accordance with 8.7.2.

NOTE 15—The values listed in Table 12 are the minimum criteria for products made to this standard. The values may not be indicative of the axial strength of some products, or of the axial strength required by some installation conditions and joint configurations.

6.9.3 Conformance to the requirements of 6.9.1 shall satisfy the requirements of 6.9.2 for those pipe sizes and classes where the minimum longitudinal tensile strength values of Table 11 are equal to the values of Table 12. Conformance to the

TABLE 9 Minimum Hoop Tensile Strength of Pipe Wall

NOTE 1—The values in this table are equal to 2*PD*, where *P* is the pressure class in psi and *D* is the nominal diameter in inches.

Inch-Pound Units									
Nominal Diameter (in.)	Hoop Tensile Strength, lbf/in. Width								
	Pressure Class								
	C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	800	1600	2400	3200	4000	4800	5600	6400	7200
10	1000	2000	3000	4000	5000	6000	7000	8000	9000
12	1200	2400	3600	4800	6000	7200	8400	9600	10 800
14	1400	2800	4200	5600	7000	8400	9800	11 200	12 600
15	1500	3000	4500	6000	7500	9000	10 500	12 000	13 500
16	1600	3200	4800	6400	8000	9600	11 200	12 800	14 400
18	1800	3600	5400	7200	9000	10 800	12 600	14 400	16 200
20	2000	4000	6000	8000	10 000	12 000	14 000	16 000	18 000
21	2100	4200	6300	8400	10 500	12 600	14 700	16 800	18 900
24	2400	4800	7200	9600	12 000	14 400	16 800	19 200	21 600
27	2700	5400	8100	10 800	13 500	16 200	18 900	21 600	24 300
30	3000	6000	9000	12 000	15 000	18 000	21 000	24 000	27 000
33	3300	6600	9900	13 200	16 500	19 800	23 100	26 400	29 700
36	3600	7200	10 800	14 400	18 000	21 600	25 200	28 800	32 400
39	3900	7800	11 700	15 600	19 500	23 400	27 300	31 200	35 100
42	4200	8400	12 600	16 800	21 000	25 200	29 400	33 600	37 800
45	4500	9000	13 500	18 000	22 500	27 000	31 500	36 000	40 500
48	4800	9600	14 400	19 200	24 000	28 800	33 600	38 400	43 200
51	5100	10 200	15 300	20 400	25 500	30 600	35 700	40 800	45 900
54	5400	10 800	16 200	21 600	27 000	32 400	37 800	43 200	48 600
60	6000	12 000	18 000	24 000	30 000	36 000	42 000	48 000	54 000
66	6600	13 200	19 800	26 400	33 000	39 600	46 200	52 800	59 400
72	7200	14 400	21 600	28 800	36 000	43 200	50 400	57 600	64 800
78	7800	15 600	23 400	31 200	39 000	46 800	54 600	62 400	70 200
84	8400	16 800	25 200	33 600	42 000	50 400	58 800	67 200	75 600
90	9000	18 000	27 000	36 000	45 000	54 000	63 000	72 000	81 000
96	9600	19 200	28 800	38 400	48 000	57 600	67 200	76 800	86 400
102	10 200	20 400	30 600	40 800	51 000	61 200	71 400	81 600	91 800
108	10 800	21 600	32 400	43 200	54 000	64 800	75 600	86 400	97 200
114	11 400	22 800	34 200	45 600	57 000	68 400	79 800	91 200	10 2600
120	12 000	24 000	36 000	48 000	60 000	72 000	84 000	96 000	108 000
132	13 200	26 400	39 600	52 800	66 000	79 200	92 400	105 600	118 800
144	14 400	28 800	43 200	57 600	72 000	86 400	100 800	115 200	129 600
156	15 600	31 200	46 800	62 400	78 000	93 600	109 200	124 800	140 400

TABLE 10 Minimum Hoop Tensile Strength of Pipe Wall

SI Units									
Hoop Tensile Strength N/mm Width									
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	138	276	414	552	690	828	966	1104	1241
250	173	345	517	690	862	1035	1207	1380	1552
300	207	413	620	827	1034	1241	1448	1655	1862
350	242	482	724	965	1207	1448	1690	1931	2172
375	259	517	776	1034	1293	1552	1811	2069	2327
400	276	551	827	1103	1379	1655	1931	2207	2482
450	311	620	931	1241	1552	1862	2173	2483	2793
500	345	689	1034	1379	1724	2069	2414	2759	3103
550	380	758	1137	1517	1896	2276	2655	3035	3413
600	414	827	1241	1655	2069	2483	2897	3311	3724
700	483	965	1448	1931	2414	2897	3380	3863	4344
750	518	1034	1551	2069	2586	3104	3621	4139	4655
850	587	1171	1758	2344	2931	3517	4104	4690	5275
900	621	1240	1861	2482	3103	3724	4345	4966	5585
1000	690	1378	2068	2758	3448	4138	4828	5518	6206
1100	759	1516	2275	3034	3793	4552	5311	6070	6827
1150	794	1585	2378	3172	3965	4759	5552	6346	7137
1200	828	1654	2482	3310	4138	4966	5794	6622	7447
1300	897	1791	2688	3585	4482	5379	6276	7173	8068
1400	966	1929	2895	3861	4827	5793	6759	7725	8688
1500	1035	2067	3102	4137	5172	6207	7242	8277	9309
1700	1173	2343	3516	4689	5862	7035	8208	9381	10 550
1800	1242	2480	3722	4964	6206	7448	8690	9932	11 171
2000	1380	2756	4136	5516	6896	8276	9656	11 036	12 412
2200	1518	3032	4550	6068	7586	9104	10 622	12 140	13 653
2300	1587	3169	4756	6343	7930	9517	11 104	12 691	14 274
2400	1656	3307	4963	6619	8275	9931	11 587	13 243	14 894
2600	1794	3583	5377	7171	8965	10 759	12 553	14 347	16 136
2800	1932	3858	5790	7722	9654	11 586	13 518	15 450	17 377
2900	2001	3996	5997	7998	9999	12 000	14 001	16 002	17 997
3000	2070	4134	6204	8274	10 344	12 414	14 484	16 554	18 618
3400	2346	4685	7031	9377	11 723	14 069	16 415	18 761	21 100
3600	2484	4961	7445	9929	12 413	14 897	17 381	19 865	22 342
4000	2760	5512	8272	11 032	13 792	16 552	19 312	22 072	24 824

requirements of 6.9.2 shall satisfy the longitudinal tensile strength requirements of 6.9.1.

7. Sampling

7.1 *Lot*—Unless otherwise agreed upon by the purchaser and the supplier, one lot shall consist of 100 lengths of each type, grade, and size of pipe produced.

7.2 *Production Tests*—Select one pipe at random from each lot and take one specimen from the pipe barrel to determine conformance of the material to the workmanship, dimensional, and strength requirements of 6.1, 6.2, 6.6, and 6.7 respectively. Unless otherwise agreed upon between purchaser and supplier, all pipes (up to 54 in. diameter) shall meet the soundness requirements of 6.4.

7.3 *Qualification Tests*—Sampling for qualification tests is not required unless otherwise agreed upon by the purchaser and the supplier. Qualification tests, for which a certification and test report shall be furnished when requested by the purchaser, include the following:

7.3.1 Sanitary sewer service, long-term chemical test.

7.3.2 Industrial service resin component chemical test. A copy of the resin manufacturer's test report may be used as the basis of acceptance for this test as agreed upon by the purchaser and the supplier.

7.3.3 Long-term hydrostatic pressure test.

7.3.4 Joint-tightness test, see 6.8.

7.3.5 Longitudinal strength test, including:

7.3.5.1 Beam strength, and

7.3.5.2 Longitudinal tensile strength.

7.4 *Control Tests*—The following tests are considered control requirements and shall be performed as agreed upon between the purchaser and the supplier.

7.4.1 *Soundness Test*—102 in. (2600 mm) diameter pipe and larger.

7.4.2 Perform sampling and testing for the control requirements for sanitary sewer service at least once annually.

7.4.3 Perform sampling and testing for the control requirements for hydrostatic design basis at least once every two years.

7.5 For individual orders, conduct only those additional tests and number of tests specifically agreed upon between purchaser and supplier.

TABLE 11 Beam Strength Test Loads

Nominal Diameter, in.	Beam Load, *P*,		Minimum Longitudinal Tensile Strength, per Unit of Circumference		Minimum Longitudinal Compressive Strength, per Unit of Circumference	
	lbf	(kN)	lbf/in.	(kN/m)	lbf/in.	(kN/m)
8	800	(3.6)	580	(102)	580	(102)
10	1200	(5.3)	580	(102)	580	(102)
12	1600	(7.1)	580	(102)	580	(102)
14	2200	(9.8)	580	(102)	580	(102)
15	2600	(11.6)	580	(102)	580	(102)
16	3000	(13.3)	580	(102)	580	(102)
18	4000	(17.8)	580	(102)	580	(102)
20	4400	(19.6)	580	(102)	580	(102)
21	5000	(22.2)	580	(102)	580	(102)
24	6400	(28.5)	580	(102)	580	(102)
27	8000	(35.6)	580	(102)	580	(102)
30	. . .	. . .	580	(102)	580	(102)
33	. . .	. . .	640	(111)	640	(111)
36	. . .	. . .	700	(122)	700	(122)
39	. . .	. . .	780	(137)	780	(137)
42	. . .	. . .	800	(140)	800	(140)
45	. . .	. . .	860	(150)	860	(150)
48	. . .	. . .	920	(161)	920	(161)
51	. . .	. . .	980	(171)	980	(171)
54	. . .	. . .	1040	(182)	1040	(182)
60	. . .	. . .	1140	(200)	1140	(200)
66	. . .	. . .	1260	(220)	1260	(220)
72	. . .	. . .	1360	(238)	1360	(238)
78	. . .	. . .	1480	(260)	1480	(260)
84	. . .	. . .	1600	(280)	1600	(280)
90	. . .	. . .	1720	(301)	1720	(301)
96	. . .	. . .	1840	(322)	1840	(322)
102	. . .	. . .	1940	(340)	1940	(340)
108	. . .	. . .	2060	(360)	2060	(360)
114	. . .	. . .	2180	(382)	2180	(382)
120	. . .	. . .	2280	(400)	2280	(400)
132	. . .	. . .	2520	(440)	2520	(440)
144	. . .	. . .	2740	(480)	2740	(480)
156	. . .	. . .	2964	(519)	2964	(519)

8. Test Methods

8.1 *Dimensions:*

8.1.1 *Diameters:*

8.1.1.1 *Inside Diameter*—Take inside diameter measurements at a point approximately 6 in. (152 mm) from the end of the pipe section using a steel tape or an inside micrometer with graduations of 1⁄16 in. (1 mm) or less. Take two 90° opposing measurements at each point of measurement and average the readings.

8.1.1.2 *Outside Diameter*—Determine in accordance with Test Method D3567.

8.1.2 *Length*—Measure with a steel tape or gage having graduations of 1⁄16 in. (1 mm) or less. Lay the tape or gage on or inside the pipe and measure the overall laying length of the pipe.

8.1.3 *Wall Thickness*—Determine in accordance with Test Method D3567.

8.1.4 *Squareness of Pipe Ends*—Rotate the pipe on a mandrel or trunions and measure the runout of the ends with a dial indicator. The total indicated reading is equal to twice the distance from a plane perpendicular to the longitudinal axis of the pipe. Alternatively, when the squareness of the pipe ends is rigidly fixed by tooling, the tooling may be verified and reinspected at intervals frequent enough to assure that the squareness of the pipe ends is maintained within tolerance.

8.2 *Chemical Tests:*

8.2.1 *Sanitary-Sewer Service*—Test the pipe in accordance with Test Method D3681.

8.2.1.1 *Long-Term*—To find if the pipe meets the requirements of 6.3.1, determine at least 18 failure points in accordance with Test Method D3681.

8.2.1.2 *Alternative Qualification Procedure*—Test four specimens each at the 10 and 10 000 h minimum strains given in Table 4 and test five specimens each at the 100 and 1000 h minimum strains given in Table 4. Consider the product qualified if all 18 specimens are tested without failure for at least the prescribed times given in Table 4 (that is, 10, 100, 1000 or 10 000 h respectively).

8.2.1.3 *Control Requirements*—Test at least six specimens in accordance with one of the following procedures and record the results.

8.2.1.4 Test at least 3 specimens at each of the strain levels corresponding to the 100- and 1000-h failure times from the product's regression line established in 8.2.1.

8.2.1.5 When the alternative method described in 8.2.1.2 is used to qualify the product, test at least three specimens each at the 100 and 1000 h minimum strains given in Table 4 for at least 100 and 1000 h respectively.

8.2.1.6 The control test procedures of 8.2.1.5 may be used as an alternative procedure to the reconfirmation procedure described in Test Method D3681 for those products evaluated by the alternative qualification procedure described in 8.2.1.2.

TABLE 12 Longitudinal Tensile Strength of Pipe Wall

Nominal Diameter (in.)	Inch-Pound Units								
	Longitudinal Tensile Strength lbf/in. of Circumference								
	Pressure Class								
	C50 (psi)	C100 (psi)	C150 (psi)	C200 (psi)	C250 (psi)	C300 (psi)	C350 (psi)	C400 (psi)	C450 (psi)
8	580	580	580	580	580	624	700	800	900
10	580	580	580	580	650	780	875	1000	1125
12	580	580	580	624	780	936	1050	1200	1350
14	580	580	609	728	910	1092	1225	1400	1575
15	580	580	653	780	975	1170	1313	1500	1688
16	580	580	696	832	1040	1248	1400	1600	1800
18	580	580	783	936	1170	1404	1575	1800	2025
20	580	580	870	1040	1300	1560	1750	2000	2250
21	580	609	914	1092	1365	1638	1838	2100	2363
24	580	696	1044	1248	1560	1800	2100	2400	2700
27	580	783	1175	1404	1688	2025	2363	2700	3038
30	580	870	1305	1560	1875	2250	2625	3000	3375
33	627	957	1436	1716	2063	2475	2888	3300	3713
36	684	1044	1566	1800	2250	2700	3150	3600	4050
39	741	1131	1697	1872	2340	2808	3276	3744	4212
42	798	1218	1827	2016	2520	3024	3528	4032	4536
45	855	1305	1958	2160	2700	3240	3780	4320	4860
48	912	1392	2088	2304	2880	3456	4032	4608	5184
51	969	1479	2219	2448	3060	3672	4284	4896	5508
54	1026	1566	2349	2592	3240	3726	4347	4968	5589
60	1140	1740	2520	2880	3600	4140	4830	5520	6210
66	1254	1914	2673	3036	3795	4554	5313	5808	6534
72	1368	2088	2916	3312	4140	4968	5796	6336	7128
78	1482	2106	3159	3432	4290	5148	6006	6864	7722
84	1596	2268	3402	3696	4620	5292	6174	7056	7938
90	1710	2430	3645	3960	4950	5670	6615	7380	8303
96	1824	2592	3888	4224	5280	6048	7056	7680	8640
102	1938	2754	4131	4488	5610	6426	7497	8160	9180
108	2052	2916	4374	4752	5940	6804	7938	8640	9720
114	2166	3078	4617	5016	6270	7182	8379	9120	10 260
120	2280	3240	4860	5280	6600	7560	8820	9600	10 800
132	2508	3564	5346	5808	7260	8316	9702	10 560	11 880
144	2736	3888	5832	6336	7920	9072	10 584	11 520	12 960
156	2964	4212	6318	6864	8580	9828	11 466	12 480	14 040

8.2.2 *Industrial Service*—The resin component of the liner or of the surface layer, or both, to be subjected to an aggressive service environment, shall be tested in accordance with Test Method C581, except that the specimens tested shall be representative of the laminate construction used in the liner or surface layer, or both.

8.3 *Soundness*—Determine soundness by a hydrostatic proof test procedure. Place the pipe in a hydrostatic pressure testing machine that seals the ends and exerts no end loads. Fill the pipe with water, expelling all air, and apply internal water pressure at a uniform rate not to exceed 50 psi (345 kPa)/s until the test pressure shown in Table 5 for the applicable class is reached. Maintain this pressure for a minimum of 30 s. The pipe shall show no visual signs of weeping, leakage, or fracture of the structural wall.

8.4 *Long-Term Hydrostatic Pressure*—Determine the long-term hydrostatic pressure at 50 years in accordance with Procedure B of Practice D2992, with the following exceptions permitted:

8.4.1 Test at ambient temperatures within the limits of 50°F (10°C) and 110°F (43.5°C) and report the temperature range experienced during the tests.

NOTE 16—Tests indicate no significant effects on long-term hydrostatic pressure within the ambient temperature range specified.

8.4.2 Determine the hydrostatic design basis for the glass-fiber reinforcement in accordance with the method in Annex A1.

8.4.3 Calculate the long-term hydrostatic pressure and categorize by class in accordance with Table 6. Annex A1.6 explains how to calculate the long-term hydrostatic pressure.

8.5 *Stiffness*—Determine the pipe stiffness [per eq. (1)] at 5% deflection or the adjusted level determined in accordance with 6.6.3 for the specimen, using the apparatus and procedure of Test Method D2412, with the following exceptions permitted:

8.5.1 Measure the wall thickness to the nearest 0.01 in. (0.25 mm).

8.5.2 Load the specimen to 5 % deflection or the adjusted level determined in accordance with 6.6.3 and record the load. Then load the specimen to deflection level A per Table 8 or to the adjusted level A determined in accordance with 6.6.1 and 6.6.2 and examine the specimen for visible damage evidenced by surface cracks. Then load the specimen to deflection level B per Table 8 or to the adjusted level B determined in accordance with 6.6.1 and 6.6.2 and examine for evidence of structural damage, as evidenced by interlaminar separation, separation of the liner or surface layer (if incorporated) from the structural wall, tensile failure of the glass-fiber reinforcement, fracture, or buckling of the pipe wall. Calculate the pipe stiffness at 5 %

TABLE 13 Longitudinal Tensile Strength of Pipe Wall

SI Units									
Longitudinal Tensile Strength N/mm of Circumference									
Pressure Class	C50	C100	C150	C200	C250	C300	C350	C400	C450
Nominal Diameter (mm)	345 (kPa)	689 (kPa)	1034 (kPa)	1379 (kPa)	1724 (kPa)	2069 (kPa)	2414 (kPa)	2759 (kPa)	3103 (kPa)
200	102	102	102	102	102	109	123	140	158
250	102	102	102	102	114	137	153	175	197
300	102	102	102	109	137	164	184	210	236
350	102	102	107	127	159	191	215	245	276
375	102	102	114	137	171	205	230	263	296
400	102	102	122	146	182	219	245	280	315
450	102	102	137	164	205	246	276	315	355
500	102	102	152	182	228	273	306	350	394
550	102	107	160	191	239	287	322	368	414
600	102	122	183	219	273	315	368	420	473
700	102	137	206	246	296	355	414	473	532
750	102	152	229	273	328	394	460	525	591
850	110	168	251	301	361	433	506	578	650
900	120	183	274	315	394	473	552	630	709
1000	130	198	297	328	410	492	574	656	738
1100	140	213	320	353	441	530	618	706	794
1150	150	229	343	378	473	567	662	757	851
1200	160	244	366	403	504	605	706	807	908
1300	170	259	388	429	536	643	750	857	965
1400	180	274	411	454	567	652	761	870	979
1500	200	305	441	504	630	725	846	967	1087
1700	220	335	468	532	665	797	930	1017	1144
1800	240	366	511	580	725	870	1015	1110	1248
2000	260	369	553	601	751	902	1052	1202	1352
2200	279	397	596	647	809	927	1081	1236	1390
2300	299	426	638	693	867	993	1158	1292	1454
2400	319	454	681	740	925	1059	1236	1345	1513
2600	339	482	723	786	982	1125	1313	1429	1608
2800	359	511	766	832	1040	1192	1390	1513	1702
2900	379	539	809	878	1098	1258	1467	1597	1797
3000	399	567	851	925	1156	1324	1545	1681	1891
3400	439	624	936	1017	1271	1456	1699	1849	2080
3600	479	681	1021	1110	1387	1589	1853	2017	2270
4000	519	738	1106	1202	1503	1721	2008	2185	2459

deflection or at the adjusted test deflection level determined in accordance with 6.6.3.

8.5.3 For production testing, only one specimen need be tested to determine the pipe stiffness.

8.5.4 The maximum specimen length may be 12 in. (305 mm), or the length necessary to include stiffening ribs if they are used, whichever is greater.

NOTE 17—As an alternative to determining pipe stiffness using the apparatus and procedure of Test Method D2412, the supplier may submit to the purchaser for approval a test method and test evaluation based on Test Method D790 accounting for the substitution of curved test specimens and measurement of stiffness at 5 % deflection or at the adjusted test deflection level determined in accordance with 6.6.3.

8.6 *Hoop-Tensile Strength*—Determine hoop tensile strength by Test Method D2290, except that the sections on apparatus and test specimens may be modified to suit the size of the specimens to be tested, and the maximum load rate may not exceed 0.10 in./min (2.54 mm/min). Alternatively, Test Method D638 may be employed. Specimen width may be increased for pipe wall thickness greater than 0.55 in (13.97 mm). Means may be provided to minimize the bending moment imposed during the test. Three specimens shall be cut from the test sample. Record the load to fail each specimen and determine the specimen width as close to the break as possible. Use the measured width and failure load to calculate the hoop-tensile strength.

8.6.1 *Alternative Minimum Hoop-Tensile Strength Requirement*—As an alternative, the minimum hoop-tensile strength values may be determined through the use of the following formula:

$$F = (S_i/S_r)(P_r) \quad (4)$$

where:

F = required minimum hoop-tensile strength, lbf/in. (kN/M),
S_i = initial design hoop tensile stress, psi (kPa),
S_r = hoop tensile stress at rated operating pressure, psi (kPa),
P = rated operating pressure class, psi (kPa), and
r = inside radius of pipe, in (mm).

The value for S_i should be established by considering the variations in glass reinforcement strength and manufacturing methods, but in any case, should not be less than the 95 % lower confidence value on stress at 0.1 h, as determined by the manufacturer's testing carried out in accordance with 6.5. The value for S_r should be established from the manufacturer's hydrostatic design basis.

NOTE 18—A value of *F* less than 4 *Pr* results in a lower factor of safety on short term loading than required by the values in Table 9.

8.7 *Longitudinal Strength:*

8.7.1 *Beam Strength*—Place a 20-ft (6.1-m) nominal length of pipe on saddles at each end. Hold the ends of the pipe round during the test. Apply the beam load for the diameter of pipe shown in Table 11 simultaneously to the pipe through two saddles located at the third points of the pipe (see Fig. 2). Maintain the loads for not less than 10 min with no evidence of failure. The testing apparatus shall be designed to minimize stress concentrations at the loading points.

8.7.2 *Longitudinal Tensile Strength*—Determine in accordance with Test Method D638 or D3039 except the provisions for maximum thickness shall not apply.

8.7.3 *Longitudinal Compressive Strength*—Determine in accordance with Test Method D695.

9. Packaging, Marking, and Shipping

9.1 Mark each length of pipe that meets or is part of a lot that meets the requirements of this specification at least once, in letters not less than ½ in. (12 mm) in height and of bold-type style in a color and type that remains legible under normal handling and installation procedures. Include in the marking the nominal pipe size, manufacturer's name or trademark, ASTM Specification number D3754, type, liner, grade, class, and stiffness in accordance with the designation code in 4.2.

9.2 Prepare pipe for commercial shipment in such a way as to ensure acceptance by common or other carriers.

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

10. Certification

10.1 See Annex A3 for certification requirements.

11. Keywords

11.1 fiberglass pipe; sewer pipe; industrial pipe; pressure pipe; strain corrosion; hydrostatic design basis; pipe stiffness

ANNEXES

(Mandatory Information)

A1. ALTERNATIVE HYDROSTATIC DESIGN METHOD

A1.1 The following symbols are used:

S = tensile stress in the glass-fiber reinforcement in the hoop orientation corrected for the helix angle, psi (kN/M),
P = internal pressure, psig (kPa),
P_l = long-term hydrostatic pressure, psig (kPa),
D = nominal inside pipe diameter, in. (mm),
t_h = actual cross-sectional area of glass-fiber reinforcement applied around the circumference of the pipe, in.^{2}/in. (mm^2/mm),
θ = plane angle between hoop-oriented reinforcement and longitudinal axis of the pipe (helix angle), and
HDB = hydrostatic design basis, psi (kPa).

A1.2 The hydrostatic design is based on the estimated tensile stress of reinforcement in the wall of the pipe in the circumferential (hoop) orientation that will cause failure after 50 years of continuously applied pressure, as described in 8.4 and Practice D2992, Procedure B. Strength requirements are calculated using the strength of hoop-oriented glass reinforcements only, corrected for the helix angle of the fibers.

A1.3 *Hoop-Stress Calculation,* derived from the ISO formula for hoop stress, is as follows:

$$S = PD/2(t_h \sin\theta) \tag{A1.1}$$

This stress is used as the ordinate (long-term strength) in calculating the regression line and lower confidence limit in accordance with Practice D2992, Annexes A1 and A3.

NOTE A1.1—The calculated result for S may be multiplied by the factor 6.985 to convert from psi to kPa.

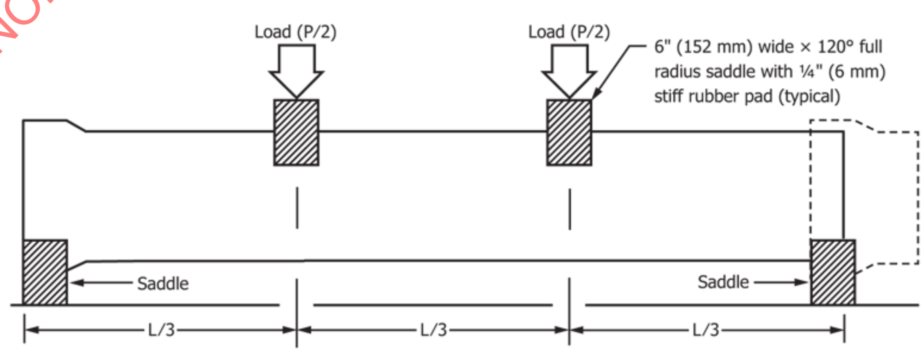


FIG. 2 Beam Strength-Test Setup

TABLE A1.1 Long-Term Hydrostatic Pressure Categories

Class	Minimum Calculated Values of Long-Term Hydrostatic Pressure gage, psi (kPa)
C50	90 (621)
C100	180 (1241)
C150	270 (1862)
C200	360 (2482)
C250	450 (3103)
C300	540 (3722)
C350	630 (4343)
C400	720 (4963)
C450	810 (5584)

A1.4 *Hydrostatic Design Basis*—The value of S is determined by extrapolation of the regression line to 50 years in accordance with Practice D2992.

A1.5 *Hydrostatic Design Basic Categories*—Convert the value of the HDB to internal hydrostatic pressure in psig as follows:

$$P_1 = 2\left(t_h \sin\theta\right)(\mathrm{HDB})/D \quad \text{(A1.2)}$$

The pipe is categorized in accordance with Table A1.1.

NOTE A1.2—The calculated result P_1 may be multiplied by the factor 6.895 to convert from psig to kPa.

A1.6 *Pressure Class Rating*—The classes shown in Table A1.1 are based on the intended working pressure in psig for commonly encountered conditions of water service. The purchaser should determine the class of pipe most suitable to the installation and operating conditions that will exist on the project on which the pipe is to be used by multiplying the values of P_1 from Table A1.1 by a service (design) factor selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures in this method. The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectancy desired, and the degree of reliability selected.

NOTE A1.3—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific pipe material under consideration. Recommended service (design) factors will not be developed or issued by ASTM.

A2. CALCULATIONS OF LOWER CONFIDENCE (LCL) AND LOWER PREDICTION (LPL) LIMITS

$$h_{LCL} = \left(a + bf_o\right) - ts\sqrt{\frac{\left(f_o - F\right)^2}{U} + \frac{1}{N}} \quad \text{(A2.1)}$$

$$h_{LPL} = \left(a + bf_o\right) - ts\sqrt{\frac{\left(f_o - F\right)^2}{U} + \frac{1}{N} + 1} \quad \text{(A2.2)}$$

where all symbols are as defined in Annexes A1 and A3 of Practice D2992 except:

f_o = logof stress (strain) level of interest

NOTE A2.1—Of the expected failures at stress (strain) f_o 97.5 % will occur after h_{LPL}. The average failure time at stress (strain) f_o will occur later than h_{LCL} 97.5 % of the time.

A3. CERTIFICATION

A3.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material.

A3.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A3.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A3.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN CORROSION PERFORMANCE REQUIREMENTS

X1.1 From Molin and Leonhardt, the expression for bending strain is given as: $\varepsilon_b = D_f\,(t/d)\,(\delta v/d)$. With the common acceptance that these pipes must be capable of withstanding 5 % deflection long-term, the maximum installed bending strain may be expressed as:

$$\varepsilon_b \max = (0.05)\,(D_f)\,(t/d) \qquad \text{(X1.1)}$$

Using the AWWA C-950 long-term bending factor of safety of 1.50, the minimum strain corrosion performance extrapolated to 50 years must be:

$$E_{scv} \geq (0.075)\,(D_f)\,(t/d) \qquad \text{(X1.2)}$$

X1.2 The shape factor, D_f, is dependent on both the pipe stiffness and the installation (for example, backfill material, backfill density, compaction method, haunching, trench configuration, native-soil characteristics and vertical loading). Assuming conservatively, installations achieved by tamped compaction with inconsistent haunching that will limit long-term deflections to 5 %, the following values of D_f have been selected to be realistic, representative and limiting. Substituting these values in the above equation for E_{SCV} yields the minimum required strain corrosion performances given below and in Table 4.

Pipe Stiffness (psi)	D_f	Minimum E_{SCV} Performance
9	8.0	0.60 (*t*/*d*)
18	6.5	0.49 (*t*/*d*)
36	5.5	0.41 (*t*/*d*)
72	4.5	0.34 (*t*/*d*)

NOTE X1.1—Products may have used limits of other than 5 % long-term deflection. In such cases, the requirements should be proportionally adjusted. For example, a 4 % long-term limiting deflection would result in a 50 year requirement of 80 % of Table 4, while a 6 % limiting deflection would yield a requirement of 120 % of Table 4.

X1.3 *Alternative Strain Corrosion Test Requirements:*

X1.3.1 At 0.1 h (6 min), the required strain corrosion performance is based on the level B deflections from Table 6 as follows:

$$\varepsilon \text{ test} \geq Df\left[\frac{t}{d+\delta V/2}\right]\left[\frac{\delta V}{d+\delta V/2}\right] \qquad \text{(X1.3)}$$

or

$$\varepsilon \text{ test} \geq Df\,(t/d)\,(\delta V/d)\left(\frac{1}{1+\delta V/2d}\right)^2 \qquad \text{(X1.4)}$$

Df for parallel plate loading is 4.28. Making the other substitutions yield:

Pipe Stiffness (psi)	Level B $\delta v\,/\,d$ (%)	Minimum Test
9	30	0.97 (*t*/*d*)
18	25	0.85 (*t*/*d*)
36	20	0.71 (*t*/*d*)
72	15	0.56 (*t*/*d*)

X1.3.2 The minimum strain values at 10, 100, 1000, and 10 000 h given in Table 4 are defined by a straight line connecting the points at 6 min and 50 years on a log-log plot.

X2. INSTALLATION

X2.1 This specification is a material performance and purchase specification only and does not include requirements for engineering design, pressure surges, bedding, backfill, or the relationship between earth cover load, and the strength of the pipe. However, experience has shown that successful performance of this product depends upon the proper type of bedding and backfill, pipe characteristics, and care in the field construction work. The purchaser of the fiberglass pressure pipe specified herein is cautioned that he must properly correlate the field requirements with the pipe requirements and provide adequate inspection at the job site.

X3. RECOMMENDED METHODS OF DETERMINING GLASS CONTENT

X3.1 Determine glass content as follows:

X3.1.1 By ignition loss analysis in accordance with Test Method D2584 or ISO 1172.

X3.1.2 As a process control, by weight of the glass fiber reinforcement applied by machine into the pipe structure.

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SPECIFICATION FOR MACHINE MADE "FIBERGLASS" (GLASS-FIBER REINFORCED THERMOSETTING RESIN) FLANGES

SD-4024

(Identical with ASTM D4024-15 except for revisions to paras. 2.2, 8.1.1, and 11.1.1, and Note 4; addition of section 13, Annex A1; and editorial changes.)

Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges

1. Scope

1.1 This specification covers reinforced-thermosetting resin flanges other than contact-molded flanges. Included are requirements for materials, workmanship, performance, and dimensions.

1.2 Flanges may be produced integrally with a pipe or fitting, may be produced with a socket for adhesive bonding to a pipe or fitting, or may be of the type used in conjunction with either a metallic or nonmetallic backup ring.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only. In cases where materials, products, or equipment are available only in SI units, inch-pound units are omitted.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 10, 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.*

NOTE 1—Contact molded flanges are covered in Specification D5421 and referenced in Specification D5685.

NOTE 2—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings

D1600 Terminology for Abbreviated Terms Relating to Plastics

D5421 Specification for Contact Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges

D5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

2.2 *ASME Standards:*

ASME B16.1 Cast Iron Pipe Flanges and Flanged Fitting s

ASME B16.5 Pipe Flanges and Flanged Fittings

ASME NM.3.2, SD-5421 Specification for Contact Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Flanges

ASME NM.3.2, SD-5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pressure Pipe Fittings

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 or Terminology F412. Abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for reinforced-thermosetting-resin pipe is RTRP.

4. Classification

4.1 *General*—This specification covers machine-made reinforced-thermosetting-resin flanges defined by type (method of manufacture), grade (generic type of resin), class (configuration of joining system), and pressure rating. Flanges complying with this specification are also given numerical classifications relating to burst pressure, sealing test pressure, and bolt torque limit.

4.1.1 *Types:*

4.1.1.1 *Type 1*—Filament-wound flanges manufactured by winding continuous fibrous glass strand roving or roving tape, either preimpregnated or impregnated during winding, into a flange cavity under controlled tension.

4.1.1.2 *Type 2*—Compression-molded flanges made by applying external pressure and heat to a molding compound that is confined within a closed mold.

4.1.1.3 *Type 3*—Resin-transfer-molded flanges manufactured by pumping a thermosetting resin into glass reinforcements that have been cut to size and clamped between matched molds.

4.1.1.4 *Type 4*—Centrifugally-cast flanges are made by applying resin and reinforcement to the inside of a mold that is rotated and heated, subsequently polymerizing the resin system.

4.1.2 *Grades:*

4.1.2.1 *Grade 1*—Epoxy resin.

4.1.2.2 *Grade 2*—Polyester resin.

4.1.2.3 *Grade 3*—Phenolic resin.

4.1.2.4 *Grade 4*—Vinylester resin.

4.1.2.5 *Grade 7*—Furan resin.

4.1.3 *Classes:*

4.1.3.1 *Class 1*—Integrally-molded flange manufactured directly on a pipe section, pipe stub, or fitting.

4.1.3.2 *Class 2*—Taper to taper adhesive joint flange manufactured with a tapered socket to be used in conjunction with a pipe or fitting with a tapered spigot section and a suitable adhesive. This joining method provides an interference fit over the entire length of the bond line.

4.1.3.3 *Class 3*—Straight-taper adhesive joint flange manufactured with a tapered socket to be used with a pipe or fitting with an untapered spigot section and a suitable adhesive. This joining method provides an interference fit at the bottom of the socket.

4.1.3.4 *Class 4*—Straight adhesive joint flange manufactured with an untapered socket for use with a pipe or fitting with an untapered spigot and a suitable adhesive. This joint provides a pipe stop and may have an interference fit at the bottom of the socket.

4.1.4 *Pressure Rating*—Pressure rating shall be categorized by a single letter designation. Pressure designations are shown in Table 1.

4.1.5 Burst pressure, sealing test pressure, and bolt torque limit shall be categorized by single capital letter designations as indicated by the cell classification system of Table 2.

4.2 *Designation Code*—The flange designation code shall consist of the abbreviation RTR, followed by the type, grade, and class in arabic numerals, the pressure rating category as a capital letter, and three capital letters identifying the cell classification designations of the burst pressure, sealing test pressure, and the bolt torque limit, respectively. Thus, a complete flange designation code shall consist of three letters, three numerals and one letter, and three letters.

4.2.1 *Example*—RTR-112E-EED. This designation describes a filament-wound, glass fiber-reinforced epoxy resin flange with a taper to taper adhesive joining system. The flange has a 150 psi (1.40 MPa) pressure rating, a burst pressure in excess of 600 psi (4.1 MPa), a sealing test pressure of 225 psi (1.6 MPa), and a bolt torque limit greater than 75 lbf·ft (102 N·m).

NOTE 3—Flanges with identical classification from different manufacturers may not be interchangeable due to nonstandardization of pipe or socket diameter, socket length, taper angle, or combination thereof.

TABLE 1 Pressure Categories

Designation	Pressure Rating	
	psi	MPa
A	50	0.35
B	75	0.52
C	100	0.69
D	125	0.86
E	150	1.04
F	175	1.21
G	200	1.38
H	225	1.55
J	250	1.73
K	300	2.07
L	350	2.42
M	400	2.76
N	450	3.11
P	500	3.45
R	550	3.80
S	600	4.14
T	650	4.49
U	700	4.83
V	750	5.18
W	800	5.52

5. Materials and Manufacture

5.1 Flanges manufactured in accordance with this specification shall be composed of reinforcement imbedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes.

5.2 The resins, reinforcements, and other materials, when combined as composite structure, shall produce a flange that will meet the performance requirements of this specification.

6. Performance Requirements

6.1 The following performance requirements are intended to provide classification and performance criteria for the purpose of qualification testing and rating of prototype constructions and periodic reevaluation of the manufacturer's stated ratings. They are not intended as routine quality assurance requirements for production runs of rated flanges.

6.2 Flanges shall meet the following performance requirements when joined for testing according to the manufacturer's recommended practice for field installation:

6.2.1 *Sealing*—Flanges shall withstand a pressure of at least 1.5 times the rated design pressure without leakage when tested in accordance with 10.4.

6.2.2 *Short-Term Rupture Strength*—Flanges shall withstand a hydrostatic load of at least four times their rated design pressure without damage to the flange when tested in accordance with 10.5.

6.2.3 *Bolt Torque*—Flanges shall withstand, without visible sign of damage, a bolt torque of at least 1.5 times that recommended by the manufacturer for sealing of the flange at its rated pressure when tested in accordance with 10.6.

TABLE 2 Burst Pressure, Sealing Test Pressure, and Bolt Torque Limit

Property	X[A]	A	B	C	D	E	F	G	H	J	K
Burst pressure, psi		200	300	400	500	600	700	800	900	1000	1200
(MPa)		1.38	2.07	2.76	3.45	4.14	4.83	5.52	6.21	6.90	8.27
Sealing test pressure, psi		75	115	150	190	225	265	300	340	375	450
(MPa)		0.52	0.79	1.03	1.31	1.55	1.83	2.07	2.34	2.59	3.10
Bolt torque limit, lbf·ft.		20	30	50	75	100	125	150	175	200	225
(N·m)		27.1	40.7	67.8	101.7	135.6	169.5	203.4	237.3	271.2	305.1

Property	L	M	N	P	R	S	T	U	V	W
Burst pressure, psi	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
(MPa)	9.65	11.03	12.41	13.79	15.17	16.55	17.93	19.31	20.69	22.06
Sealing test pressure, psi	525	600	675	750	825	900	975	1050	1125	1200
(MPa)	3.62	4.14	4.65	5.17	5.69	6.21	6.72	7.24	7.76	8.27
Bolt torque limit, lbf·ft.	250	275	300							
(N·m)	339.0	372.9	406.8							

[A] X = unspecified

7. Content Requirements

7.1 *Recycled or Reprocessed Thermosetting Plastics*—Flanges shall not contain any recylced or reprocessed thermosetting plastics which might otherwise be added as fillers.

8. Dimensions

8.1 *Dimensions and Tolerances:*

8.1.1 *Flange and Bolt Dimensions*—Flanges of 24 in. (610 mm) or smaller diameter shall conform to the values given in Table 3A or 3B for bolt circle, number and size of bolt holes, and outside diameter. Flanges larger than 24 in. (610 mm) in diameter shall conform to the values for bolt circle, number and size of bolt holes, and outside diameter for Class 125 cast iron flanges in ASME B16.1. The tolerances for the flange dimensions provided in Table 3A and 3B shall be the same as those contained in ASME B16.5. For all size flanges other flange and bolt dimensions which meet internationally recognized standards such as ISO, DIN, JIS, BS, or GB can be used as long as they are agreed to by the buyer and seller.

8.1.2 *Flange Face*—The flange face shall be perpendicular to the axis of the fitting within ½°. The sealing surface of flat face or serrated face flanges shall be flat to ±1/32 in. (1 mm) for sizes up to and including 18 in. (457 mm) diameter and ±1/16 in. (2 mm) for larger diameters.

8.1.3 *Washer Bearing Surface*—Washer bearing surface shall be flat and parallel to the flange face within ±1°.

8.2 *Pipe Stop*—Each adhesive joined flange shall provide sufficient taper or a diametric constriction to act as a stop during adhesive joining so that the pipe stub cannot project beyond the face of the flange.

TABLE 3 A Flange Dimensions, in. (mm)[A]

Nominal Pipe, Size[B]	Outside Diameter of Flange	Drilling			
		Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts
½	3.50 (88.9)	2.38 (60.5)	0.62 (15.75)	4	½ (12.70)
¾	3.88 (98.6)	2.75 (69.9)	0.62 (15.75)	4	½ (12.70)
1	4.25 (107.9)	3.12 (79.2)	0.62 (15.75)	4	½ (12.70)
1¼	4.62 (117.3)	3.50 (88.9)	0.62 (15.75)	4	½ (12.70)
1½	5.00 (127.0)	3.88 (98.6)	0.62 (15.75)	4	½ (12.70)
2	6.00 (152.4)	4.75 (120.6)	0.75 (19.0)	4	⅝ (15.9)
2½	7.00 (177.8)	5.50 (139.7)	0.75 (19.0)	4	⅝ (15.9)
3	7.50 (190.5)	6.00 (152.4)	0.75 (19.0)	4	⅝ (15.9)
3½	8.50 (215.9)	7.00 (177.8)	0.75 (19.0)	8	⅝ (15.9)
4	9.00 (228.6)	7.50 (190.5)	0.75 (19.0)	8	⅝ (15.9)
5	10.00 (254.0)	8.50 (215.9)	0.88 (22.4)	8	¾ (19.0)
6	11.00 (279.4)	9.50 (241.3)	0.88 (22.4)	8	¾ (19.0)
8	13.50 (342.9)	11.75 (298.4)	0.88 (22.4)	8	¾ (19.0)
10	16.00 (406.4)	14.25 (361.9)	1.00 (25.4)	12	⅞ (22.2)
12	19.00 (482.6)	17.00 (431.8)	1.00 (25.4)	12	⅞ (22.2)
14	21.00 (533.4)	18.75 (476.2)	1.12 (28.4)	12	1 (25.4)
16	23.50 (596.9)	21.25 (539.8)	1.12 (28.4)	16	1 (25.4)
18	25.00 (635.0)	22.75 (577.8)	1.25 (31.7)	16	1⅛ (28.6)
20	27.50 (698.5)	25.00 (635.0)	1.25 (31.7)	20	1⅛ (28.6)
24	32.00 (812.8)	29.50 (749.3)	1.38 (35.1)	20	1¼ (31.7)

[A] Dimensions conform to ANSI B16.5 for Class 150 steel flanges.
[B] For larger sizes, see 8.1.1.

TABLE 3 B Flange Dimensions, in. (mm)[A] *(continued)*

Nominal Pipe Size	Outside Diameter of Flange	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts
½	3.75 (95.3)	2.62 (66.5)	0.62 (15.75)	4	½ (12)
¾	4.62 (117.3)	3.25 (82.6)	0.75 (19.0)	4	⅝ (16)
1	4.88 (124.0)	3.50 (88.9)	0.75 (19.0)	4	⅝ (16)
1¼	5.25 (133.4)	3.88 (98.6)	0.75 (19.0)	4	⅝ (16)
1½	6.12 (155.4)	4.50 (114.3)	0.88 (22.4)	4	¾ (18)
2	6.50 (165.1)	5.00 (127.0)	0.75 (19.0)	8	⅝ (16)
2½	7.50 (190.5)	5.88 (149.4)	0.88 (22.4)	8	¾ (18)
3	8.25 (209.6)	6.62 (168.1)	0.88 (22.4)	8	¾ (18)
3½	9.00 (228.6)	7.25 (184.2)	0.88 (22.4)	8	¾ (18)
4	10.00 (254.0)	7.88 (200.2)	0.88 (22.4)	8	¾ (18)
5	11.00 (279.4)	9.25 (235.0)	0.88 (22.4)	8	¾ (18)
6	12.50 (317.5)	10.62 (269.7)	0.88 (22.4)	12	¾ (18)
8	15.00 (381.0)	13.00 (330.2)	1.00 (25.4)	12	⅞ (22)
10	17.50 (444.5)	15.25 (387.4)	1.12 (28.4)	16	1 (24)
12	20.50 (520.7)	17.75 (450.9)	1.25 (31.7)	16	1⅛ (24)
14	23.00 (584.2)	20.25 (514.4)	1.25 (31.7)	20	1⅛ (24)
16	25.50 (647.7)	22.50 (571.5)	1.38 (35.1)	20	1¼ (30)
18	28.00 (711.2)	24.75 (628.7)	1.38 (35.1)	24	1¼ (30)
20	30.50 (774.7)	27.00 (685.8)	1.38 (35.1)	24	1¼ (30)
24	36.00 (914.4)	32.00 (812.8)	1.62 (41.1)	24	1½ (36)

[A]Dimensions conform to ANSI B16.5 for Class 300 steel flanges.

9. Workmanship, Finish, and Appearance

9.1 Flanges shall be free as commercially practical of defects, including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas.

10. Test Methods

10.1 *Conditioning*—When conditioning is required, and in all cases of disagreement, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 10 % relative humidity for not less than 40 h prior to test, in accordance with Procedure A of Practice D618.

10.2 *Test Conditions*—The tests may be conducted at ambient temperature and humidity conditions. When controlled environment testing is specified, tests shall be conducted in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 10 % relative humidity. When elevated temperature testing is specified, the tests shall be conducted at the design operating temperature ±5.4°F (3°C).

10.3 *Dimensions and Tolerances*—Flange dimensions shall be measured with a micrometer of vernier calipers, or other suitable measuring devices accurate to within ±0.001 in. (±0.02 mm). Diameters shall be determined by averaging a minimum of four measurements, equally spaced circumferentially.

10.4 *Sealing*—Flanged components in general arrangement with Fig. 1 shall be bolted together using the gasket and bolt torque recommended for standard field installation by the flange manufacturer. The assembly shall then be pressure tested and be required to hold the test pressure for a period of 168 hours without leakage. Retorque to the manufacturer's specified level after initial pressurization is permitted.

10.5 *Short-Term Rupture Strength*—Flanged components shall be tested in accordance with Test Method D1599 with

Ⓐ - END PLATE, END CAP OR QUICK CLOSURE WITH COUPLING FOR PRESSURE SOURCE/VENT LINE.
Ⓑ - REINFORCED THERMOSETTING RESIN PIPE (RTRP).
Ⓒ - TEST FLANGE SET.
Ⓓ - END PLATE, END CAP OR QUICK CLOSURE.

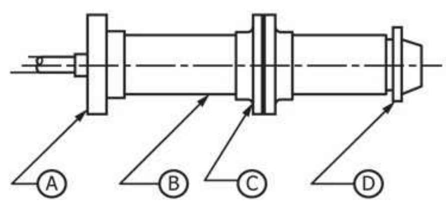

FIG. 1 Test Assembly Configuration

free-end closure except as herein noted. The pressure in the specimen shall be increased until failure of the flange occurs. Pressure testing in an atmospheric environment is permissible. Minimum failure time shall be 60 s; no restriction shall be placed on maximum time-to-failure. Leaking past the gasket interface is permissible during this test. Bolt torque may be increased as necessary during the test in order to minimize gasket leaking and to achieve the pressure necessary to cause flange failure. The assembly used for the test in 10.4 may be used for this test. (**Warning—**Do not test with any pressurized gas.)

10.6 *Maximum Bolt Torque*—Using the gasket and hardware recommended by the flange manufacturer, bolt the flange against a flat face steel flange. Tighten the nuts by hand until they are snug. Prior to fit-up, the nuts, bolts, and washers should be well lubricated, using a nonfluid thread lubricant. Establish uniform pressure over the flange face by tightening bolts in 5 lbf·ft (7 N·m) increments according to the sequence shown in Fig. 2. For flanges with more than 20 bolts, similar alternating bolt tightening sequences shall be used. Increase the bolt torque uniformly until flange failure occurs or until all bolts have been torqued to five times the level recommended by the manufacturer for field installation practice to establish the bolt torque cell classification of the flange. Any sign of flange damage (crumbling, flaking, cracking, or other breaking) shall constitute failure.

NOTE 4—The torque limits determined by 10.6 apply only to flanges bolted up against a flat sealing surface. Significantly lower bolt torque value will normally be obtained when RTR flanges are bolted up against raised-faced flanges. When RTR flanges shall be used against raised steel flange face, the RTR flange manufacturer should be contacted for his torque and installation recommendations.

11. Product Marking

11.1 Each flange shall be marked with the following information:

11.1.1 The designation "ASTM D4024" or "ASME SD-4024" indicating compliance with this specification,

11.1.2 Identification of the flange in accordance with the designation code in 4.2,

11.1.3 Nominal flange size, and

11.1.4 Manufacturer's name (or trademark) and product designation.

11.2 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices.

12. Precision and Bias

12.1 No precision and bias statement can be made for this test method, since controlled round robin test programs have not been run.

NOTE 5—The wide variation in raw materials and constructions allowed in this specification make round robin testing difficult to apply.

13. Certification

13.1 See Annex A1 for certification requirements.

14. Keywords

14.1 centrifugally-cast; compression-molded; filament-wound; furan; machine-made; phenolic; polyester; resin-transfer; vinyl ester

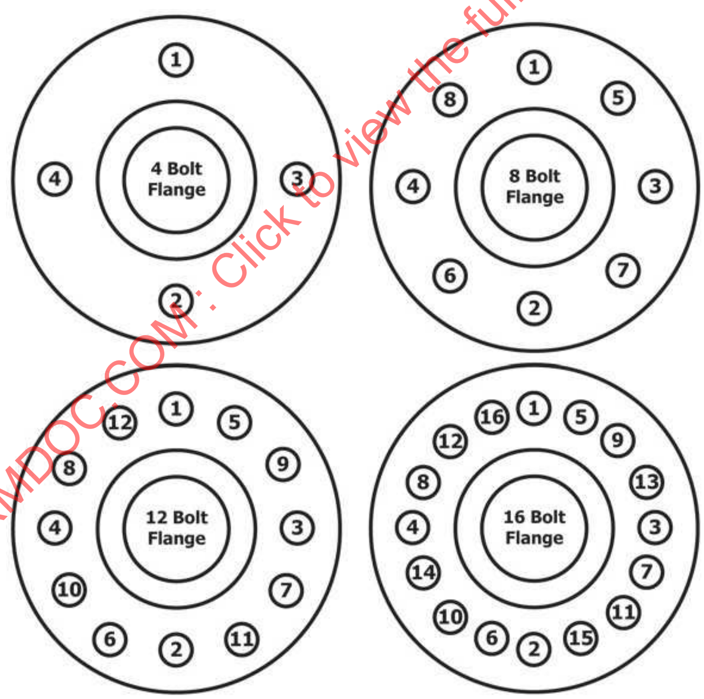

FIG. 2 Bolt Torquing Sequence

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

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SPECIFICATION FOR "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PIPE JOINTS USING FLEXIBLE ELASTOMERIC SEALS

SD-4161

(Identical with ASTM D4161-14(R19) except for revisions to para. 5.1; addition of paras. 2.2, 2.3, section 9, Annex A1; and editorial changes.)

Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals

1. Scope

1.1 This specification covers axially unrestrained bell-and-spigot gasket joints including couplings required for machine-made "fiberglass" (glass-fiber-reinforced thermosetting-resin) pipe systems, 8 in. (200 mm) through 156 in. (4000 mm), using flexible elastomeric seals to obtain soundness. The pipe systems may be pressure (typically up to 250 psi) or nonpressure systems for water or for chemicals or gases that are not deleterious to the materials specified in this specification. This specification covers materials, dimensions, test requirements, and methods of test.

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

NOTE 1—There is a similar but technically different ISO Standard (ISO 8639).

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *ISO Standard:*
ISO 8639 Glass-reinforced thermosetting (GRP) pipes and fittings — Test methods for leak-tightness of flexible joints

2.3 *ASME Standard:*
ASME NM.3.2, SF-477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions and abbreviations are in accordance with Terminology D883 or Terminology F412, and Terminology D1600 unless otherwise indicated.

4. Types of Joints

4.1 This specification covers two types of axially unrestrained joints based on effecting soundness of the joint through compression of an elastomeric seal or ring:

4.1.1 Bell-and-spigot or coupling joint with the gasket placed in the bell in circumferential compression. An elastomeric gasket joint design featuring a continuous elastomeric ring gasket placed in an annular space provided in the bell or socket of the pipe or fitting. The spigot end of the pipe or fitting is forced into the bell, thereby compressing the gasket radially to form a positive seal.

4.1.2 Bell-and-spigot or coupling joint with the gasket placed on the spigot in circumferential tension: A push on joint design featuring a continuous elastomeric ring gasket placed in an annular space provided on the spigot end of the pipe or fitting. The spigot is forced into the bell of the pipe or fitting, thereby compressing the gasket radially to form a positive seal.

NOTE 2—A coupling joint of these types is a loose double-bell sleeve used to connect pipes which have spigots at both ends (see Fig. 1). All references to bells in this specification are applicable to the sleeve coupling as well as to the integral bell of a bell-and-spigot gasket joint.

5. Materials and Manufacture

5.1 The gasket shall be a continuous elastomeric ring of circular or other geometric cross section and shall meet the requirements of Specification F477 (ASME SF-477), unless otherwise specified in this specification. When a splice is used in the manufacture of the gasket, no more than two splices shall be made in anyone gasket.

5.1.1 The chemical composition of the gasket shall be compatible with the type of environment to which it will be

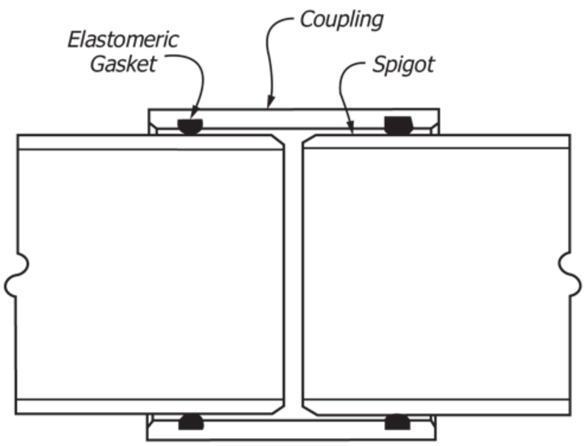


FIG. 1 Typical Coupling Joint Detail

subjected. Selection of the gasket composition shall be in accordance with a purchaser and seller agreement.

NOTE 3—Consult the gasket manufacturer for advice as to the suitability of specific rubber compounds for the intended service and joint configurations. Items such as cold set when the joint is deflected under low-temperature conditions and maximum and minimum stretch in the gasket may be dependent upon the specific chemical compounds used.

5.2 Materials in the bell and spigot of the joint shall meet the requirements of the applicable ASTM specification for the pipe or fitting of which the joint is a part.

6. Requirements

6.1 *Joint Surfaces*—All surfaces of the joint upon or against which the gasket may bear shall be smooth and free of cracks, fractures, or other imperfections that would adversely affect the performance of the joint.

6.2 *Joint Geometry*—The design of the joint shall include a means to retain the gasket and prevent it from being unintentionally displaced, either during assembly of the joint or during operation of the completed pipe system.

6.3 *Dimensions and Tolerances*—The provisions of 6.3.1.1 apply only to a joining system utilizing a gasket of circular cross section retained in a rectangular groove. Manufacturers may submit to the purchaser detailed designs for joints utilizing gaskets or grooves, or both, of other geometric shape or for joints not meeting the criteria of 6.3.1. Joints not meeting the requirements of this section shall meet the test requirements of Section 7; such joints shall be acceptable, provided the design is approved by the purchaser prior to manufacture and provided the test pipe complies with the specified test requirements. Test results may be extended to other diameters with the same joint configuration, gasket shape and gasket composition provided substantially similar gasket compressions and gasket hardness are maintained. Gasket dimensions may be increased or decreased provided joint geometry is also appropriately proportioned so that critical relationships like gasket confinement are equal or superior to the tested joint. Design submissions shall include joint geometry, tolerances, gasket characteristics, proposed plant tests, and such other information as required by the purchaser to evaluate the joint design for field performance.

6.3.1 *Joints Using Circular Gasket Cross Sections:*

6.3.1.1 The volume of the annular space provided for the gasket, with the engaged joint at normal joint closure in concentric position, and neglecting ellipticity of the bell and spigot, shall not be less than the design volume of the gasket furnished. For a rectangular gasket groove, the cross-sectional area of annular space shall be calculated for minimum bell inside diameter, maximum spigot outside diameter, minimum width of groove at surface of spigot, and minimum depth of groove. The volume of the annular space shall be calculated at the centerline of the groove and considering the centroid of the cross-sectional area to be at the midpoint between the surface of the groove on which the gasket is seated and the surface of the bell, if the groove is on the spigot, or the surface of the spigot, if the groove is in the bell.

6.3.1.2 When the design volume of the gasket is less than 75 % of the volume of the annular space in which the gasket is confined, the dimensions and tolerances of the gasket, bell, and spigot shall be such that, when the outer surface of the spigot and the inner surface of the bell come into contact at some point in their periphery, the deformation in the gasket shall not exceed 40 % at the point of contact nor be less than 15 % at any point. If the design volume of the gasket is 75 % or more of the volume of the annular space, the deformation of the gasket, as prescribed above, shall not exceed 50 % nor be less than 15 %. The cross-sectional area of annular space shall be calculated for average bell diameter, average spigot diameter, average width of groove at surface of spigot, and average depth of groove. The volume of the annular space shall be calculated at the centerline of the groove and considering the centroid of the cross-sectional area to be at the midpoint between the surface of the groove on which the gasket is seated and the surface of the bell, if the groove is on the spigot, or the surface of the spigot, if the groove is in the bell.

NOTE 4—It is recognized that a relationship exists between the water-tightness of a joint, the gasket deformation, and the ratio of gasket volume to space volume. For high-pressure applications, it may be necessary to provide a very high-volume ratio to obtain a sound joint. Some manufacturers also have developed satisfactory joints with very little gasket deformation, but meet the requirements of Section 6 by utilizing a very high-volume ratio.

6.3.1.3 When determining the maximum percent deformation of the gasket, the minimum depth of groove and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. When determining the minimum percent deformation of the gasket, the maximum bell diameter, the minimum spigot diameter, the maximum depth of groove, and the stretched gasket diameter shall be used and calculations made at the centerline of the groove. For gasket deformation calculations, if the gasket is placed on the spigot in circumferential tension, the stretched gasket diameter shall be determined as being the design diameter of the gasket divided by the square root of $(1 + x)$ where x equals the design percent of gasket stretch divided by 100. If the gasket is placed in the bell in circumferential compression, the design diameter of the gasket shall be used.

6.3.1.4 The taper on all sealing surfaces of the bell and spigot on which the elastomeric gasket may bear after closure of the joint and at any degree of partial closure, except within the gasket groove, shall form an angle of not more than 2° with the longitudinal axis of the pipe. If the joint design does not incorporate a mechanical locking feature, the joint shall be designed and manufactured in such a way that at the position of normal joint closure, the parallel surfaces upon which the gasket may bear after closure will extend not less than 0.75 in. (20 mm) away from the edges of the gasket groove.

6.3.1.5 *Circular Gaskets:*

(1) In a joint in which the gasket is placed in the bell in circumferential compression, the circumferential length of the gasket shall be such that, when inserted into the gasket groove, the amount of circumferential compression will be less than 4 %. In larger pipe diameters, an adhesive may be required to hold the gasket in place prior to installation.

(2) In an elastomeric joint in which the gasket is placed on the spigot in circumferential tension, the circumferential length of the gasket shall be such that, when installed in the gasket groove, the amount of stretch shall not exceed 30 %.

(3) Compute the amount of compression or stretch by comparing the circumferential length of the centroid of the relaxed gasket with the circumferential length of the centroid of the compressed or stretched gasket after installation in the bell or on the spigot.

(4) Each gasket shall be manufactured to provide the volume of elastomer required by the pipe manufacturer's joint design, with a tolerance of ±1 % for gaskets of 1.0-in. (25-mm) diameter and larger. The allowable percentage tolerance shall vary linearly between ±3 % and ±1 % for gasket diameters between 0.5 and 1.0 in. (13 and 25 mm).

6.3.2 The tolerances permitted in the construction of the joint shall be those stated in the pipe manufacturer's design as approved.

6.3.3 *Drawings*—The manufacturer shall furnish drawings of the joint and gasket, including dimensions and tolerances, if requested by the purchaser.

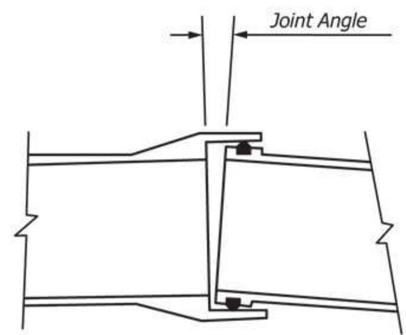
7. Laboratory Performance Requirements

7.1 *General:*

7.1.1 The gasket shall be the sole element depended upon to make the joint leakproof. The assembled joints shall pass the performance tests listed in this section. The tests shall be performed with components selected to provide minimum compression in the gasket. The internal hydrostatic pressures required in 7.2 and 7.3 shall be two times the rated pressure, if the pipe is manufactured for pressure service, or 29 psi (200 kPa), if the pipe is manufactured for nonpressure service.

7.1.2 Laboratory hydrostatic pressure tests on joints shall be made on an assembly of two sections of pipe properly connected in accordance with the joint design. Suitable bulkheads may be provided within the pipe adjacent to and on either side of the joint, or the outer ends of the two jointed pipe sections may be bulkheaded. Restraints may be provided at the joint to resist transverse thrust. No coatings, fillings, or packings shall be placed prior to the hydrostatic tests.

7.2 *Pipes in Angularly Deflected Position*—Using a pipe and joint system as described in 7.1.2, the test sections shall be deflected angularly, as shown in Fig. 2, and subjected to the appropriate internal hydrostatic test pressure for 10 min without leakage. The angle defined by the joint openings given in Fig. 2 is the angle between the axis of the two joined pipes.



Pipe Size	Joint Angle
≤ 20 in.	3°
>20 in. ≤ 33 in.	2°
>33 in. ≤ 60 in.	1°
> 60 in.	½ °

NOTE 1—Joint opening shall not exceed the maximum unstressed limit permitted by dimensional clearance between spigot and bell.

FIG. 2 Typical Bell-and-Spigot Gasket Joint Detail

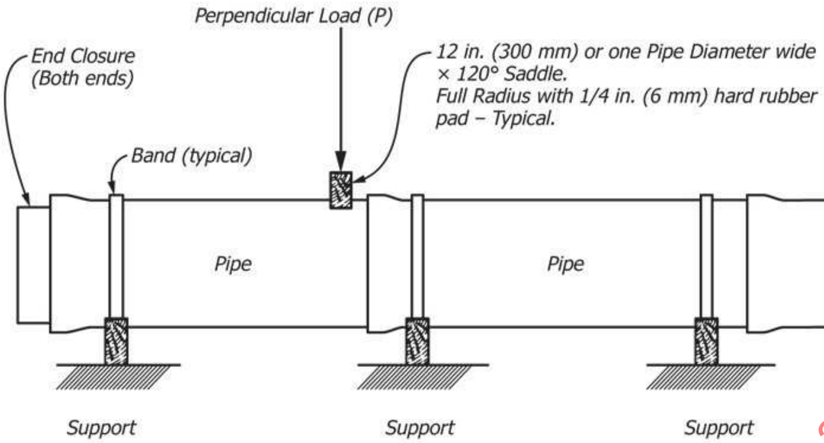
7.2.1 Joints intended for use of pressures greater than 250 psi may have lower allowable angular deflections than those given in Fig. 2 by manufacturer purchaser agreement. The joints shall be tested at the manufacturers maximum allowed angular deflection.

7.2.2 Determine the joint opening by scribing a circumferential index mark on the outside of the pipe a sufficient distance from the spigot end to be visible when the pipe is joined. Measure the maximum and minimum distance from the end of the bell to the mark. The difference equals the joint opening. Fig. 2 illustrates a typical joint in closed and deflected positions and the index mark.

NOTE 5—This test is a laboratory performance test of joint integrity and is not indicative of allowable angular deflections in field installations. In actual installations, deflections greater than the manufacturer's recommended maximum should be avoided, and elbows, bends, or special fittings should be used in such cases.

7.3 *Pipes in Laterally Offset Position (Shear Loading)*—Using a pipe and joint system as described in 7.1.2, the test sections shall be deflected while the pipe units are in a horizontal position, as shown in Fig. 3, by applying a perpendicular load. The load shall be 100 lb/in. (17.5 kN/m) in diameter. The load shall be uniformly applied over an arc of not more than 120° along a longitudinal distance equal to one pipe diameter or 12 in. (300 mm), whichever is the smaller, at the unsupported spigot end of the pipe immediately adjacent to the bell of the assembled joint. The pipe in the test shall be supported on adequate blocks placed immediately behind or on the bells, as indicated in Fig. 3. Bands may be required to secure the pipe to the blocks. There shall be no leakage when the appropriate internal hydrostatic test pressure is applied for 10 min after application of the load.

7.4 *Vacuum or External Pressure Test*—The assembled joint shall withstand an external pressure of 11.6-psi (80-kPa) gage or an internal vacuum of −11.6-psi (−80-kPa) gage while in the



NOTE 1—The load shall be applied perpendicular to the axis of the pipe. It may be applied vertically, as shown in this figure, or at any other circumferential orientation.

FIG. 3 Shear Loading-Test Setup

angularly deflected position, as in 7.2, and in the laterally offset position, as in 7.3. Allow the pressure to stabilize for 30 min, then seal off for a minimum of 10 min. The maximum permissible pressure increase inside of the pipe during the seal-off period shall be 0.1 psi (0.7 kPa). Some grades of pipe may not have the capability in the pipe wall of withstanding the above vacuum or external pressure. In such cases, the joint design may be considered as meeting these criteria if a pipe and joint system, incorporating a geometrically identical joint and heavier-walled pipe, meets the criteria satisfactorily.

8. Retesting

8.1 If any failure occurs during performance of the tests specified in Section 7, the joint may be retested to establish conformity in accordance with agreement between the purchaser and the manufacturer.

9. Certification

9.1 See Annex A1 for certification requirements.

10. Keywords

10.1 angular deflection, bell and spigot; certification; coupling, elastomeric seals; flexible gaskets; glass-fiber reinforced; pipe joints; specification; thermosetting resin

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

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SPECIFICATION FOR CONTACT MOLDED "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING RESIN) FLANGES

SD-5421

(Identical with ASTM D5421-15 except for revisions to paras. 2.2, 4.3.1, 8.1; addition of section 13, Annex A1; and editorial changes.)

Specification for Contact Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges

1. Scope

1.1 This specification covers circular contact-molded fiberglass reinforced-thermosetting-resin flanges for use in pipe systems and tank nozzles. Included are requirements for materials, workmanship, performance, and dimensions.

1.2 Flanges (see Fig. 1) may be produced as integral flanges, Type A, or flange-on-pipe, Type B.

1.3 This specification is based on flange performance and does not cover design.

1.4 These flanges are designed for use with pipe and tanks that are manufactured to Specifications D2996, D2997, D3262, D3299, D3517, D3754, and D4097.

1.5 Selection of gaskets is not covered in this specification, refer to the manufacturer's recommendation.

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

1.7 The following precautionary caveat pertains only to the test methods portion, Section 9, 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.*

NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C582 Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
D883 Terminology Relating to Plastics
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D3262 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe
D3299 Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks
D3517 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe
D3754 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe
D4097 Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks

2.2 *ASME Standards:*

ASME B16.1 Cast Iron Pipe Flanges and Flanged Fittings
ASME B16.5 Pipe Flanges and Flanged Fittings
ASME B18.21.1 Type "A" Narrow Washers
ASME NM.3.2, SC-582 Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
ASME NM.3.2, SD-2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe
ASME NM.3.2, SD-2997 Specification for Centrifigally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Sewer Pipe
ASME NM.3.2, SD-3262 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pressure Pipe
ASME NM.3.2, SD-3754 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Sewer and Industrial Pressure Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology D883. Abbreviations are in accordance with Terminology D1600,

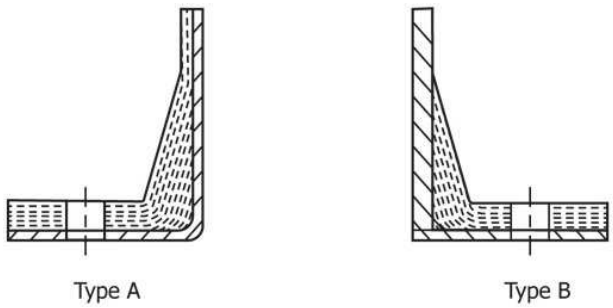


FIG. 1 Flange Types

unless otherwise indicated. The abbreviation for reinforced-thermosetting-resin pipe is RTRP.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contact molding (CM)*—a method of fabrication wherein the glass fiber reinforcement is applied to the mold in the form of all chopped-strand mat, or chopped-strand mat and woven roving, in alternate plies by hand with the resin matrix applied by brush or roller and the laminate consolidated by a roller.

3.2.2 *fiberglass pipe*—a tubular product containing glass-fiber reinforcements embedded in or surrounded by cured thermosetting resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments or dyes; thermoplastic or thermosetting liners or coatings may be included.

4. Classification

4.1 *General*—This specification covers reinforced-thermosetting-resin flanges defined by type (method of manufacture), grade (generic type of resin), class (pressure end thrust capability), and pressure rating. Flanges complying with this specification are also given numerical classifications relating to rupture pressure and sealing test pressure.

4.1.1 *Types:*

4.1.1.1 *Type A*—Integral flange, contact molded with the stub integral with the flange.

4.1.1.2 *Type B*—Flange on pipe, contact molded onto an existing pipe or fitting.

4.1.2 *Grades:*

4.1.2.1 *Grade 1*—Epoxy resin.

4.1.2.2 *Grade 2*—Polyester resin.

4.1.2.3 *Grade 3*—Phenolic resin.

4.1.2.4 *Grade 4*—Vinylester resin.

4.1.2.5 *Grade 5*—Furan resin.

4.1.3 *Classes:*

4.1.3.1 *Class I*—Hoop and axial-pressure.

4.1.3.2 *Class II*—Hoop pressure only.

NOTE 2—All combinations of type, liner, grade, and class may not be commercially available. Additional type, liner, grade, and class may be added as they become commercially available. The purchaser should solely determine or consult with the manufacturer for the proper class, type, liner, and grade to be used under the installation and operating conditions that will exist for the project in which the flange is to be used.

4.1.4 *Pressure Rating*—Pressure rating shall be categorized by single-letter designation. Pressure designations are shown in Table 1.

TABLE 1 Pressure Categories

Designation	Pressure Rating[A]	
	psi	MPa
A	25	0.173
B	50	0.345
C	75	0.517
D	100	0.690
E	125	0.862
F	150	1.034

[A] Flanges with higher pressure ratings are available by agreement between the purchaser and the manufacturer.

4.1.5 Short-term rupture pressure and sealing-test pressure limits shall be categorized by single arabic number designations as indicated by the cell classification system of Table 2.

4.2 *Designation Code*—The flange-designation code shall consist of the abbreviation for contact molded (CM) followed by the type as a capital letter, grade as an Arabic numeral, class as a Roman numeral, and the pressure-rating category as a capital letter and two Arabic numbers identifying the cell-classification designations of the short-term rupture pressure and sealing-test pressure, respectively. Thus, a complete flange-designation code shall consist of three letters, one Arabic numeral, one Roman numeral, one letter and two numerals.

4.2.1 *Example*—Contact molded fiberglass is CM-AIID-46. This designation described a stub flange, made using glass-fiber-reinforced epoxy resin for full-axial pressure thrust. The flange has a 100-psi (0.69-MPa) pressure rating, a short-term rupture pressure of 400-psi (2.76-MPa), and a sealing-test pressure of 225-psi (1. 55-MPa).

4.3 *Attachment of Flanges to Pipe, Pipe Fittings, or Tanks:*

4.3.1 Type "A" flanges are to be butt and strap welded to pipe described in Specifications D2996 (ASME SD-2996), D2997 (ASME SD-2997), D3262 (ASME SD-3262), D3517 (ASME SD3517), D3754 (ASME SD-3754), and D3982 (ASME SD-3982) or using overlay joint into a tank as described in Specifications D3299 (ASME SD-3299) and D4097 (ASME SD-4097).

4.3.2 Type "B" flanges are built onto elbows, reducers, or other parts where the use of an integral flange (Type "A") is not practical or required.

5. Materials and Manufacture

5.1 Flanges manufactured in accordance with this specification shall be composed of reinforcement embedded in or surrounded by cured thermosetting resin.

5.2 The resins, reinforcements, and other materials, when combined into composite structure, shall produce a flange that will meet the performance requirements of this specification.

TABLE 2 Short-Term Rupture Pressure and Sealing-Test Pressure[A]

Property/Cell Classification	1	2	3	4	5	6
Short-Term Rupture Pressure, psi (MPa)	100 (0.69)	200 (1.38)	300 (2.07)	400 (2.76)	500 (3.45)	600 (4.14)
Sealing-test pressure, psi (MPa)	37.5 (0.26)	75 (0.52)	112.5 (0.78)	150 (1.03)	187.5 (1.29)	225 (1.55)

[A]Refer to Test Method D1599 for explanation of failure.

NOTE 3—The term "other materials" does not include recycled or reprocessed thermosetting plastics which might otherwise be added as fillers.

5.3 Flanges manufactured in accordance with this specification shall have an inner corrosion barrier fabricated with the same resin, reinforcement, ply sequence, and nominal glass/resin ratio as required in the applicable ASTM standard for the tank or pipe on which the flange will be used.

6. Performance Requirements

6.1 The following performance requirements are intended to provide classification and performance criteria for the purpose of qualification testing and rating of prototype constructions and periodic reevaluation of the manufacturer's stated ratings. They are not intended as routine quality assurance requirements for production runs of rated flanges:

6.1.1 *Sealing*—Flanges shall withstand a pressure of at least 1.5 times the pressure rating without leakage when tested in accordance with 9.4.

6.1.2 *Short-Term Rupture Strength*—Flanges shall withstand a hydrostatic load of at least four times their pressure rating when tested in accordance with 9.5 using flat-faced steel closure and using the gasket or "O" ring designated by the flange manufacturer.

6.1.3 *Bolt Torque*—Flanges shall withstand, without visible sign of damage, a bolt torque of two times that recommended by the manufacturer. The use of a non-fluid thread lubricant is recommended on all bolts.

7. Dimensions and Tolerances

7.1 *Flange and Bolt Dimensions*—Flanges of 24 in. (610 mm) or smaller diameter shall conform to the values for bolt circle and number and size of bolt holes, for Class-150 cast iron flanges in ASME B 16.5. Flanges larger than 24 in. (610 mm) in diameter shall conform to the values for bolt circle, number and size of bolt holes, for Class-125 cast-iron flanges in ASME B 16.1 as shown in Table 3. The tolerance for these flange dimensions shall be the same as those contained in ASME B 16.1 and B 16.5. A flat washer is to be used under all bolt heads and nuts.

NOTE 4—Interference between the hub and bolt spot face may occur, especially in high-pressure flanges. The use of ASME B18.21.1 narrow washers is suggested because of their smaller outside diameter. The customer should be notified when these washers with smaller outside diameter are to be used.

NOTE 5—For special-design large flanges, it may be desirable to provide the required bolt area by using smaller bolts spaced closer together than is normally used for steel flanges. The minimum bolt size shall be ⅝ in. (16 mm). Flange dimensions shall be by purchaser-manufacturer agreement.

7.1.1 *Flange Face for Full-Faced Gaskets*— The flange face shall be perpendicular to the axis of the fitting within ½ °, and shall be flat to 1⁄32 in. (1 mm) for sizes up to and including 18-in. (457-mm) diameter and 1⁄16 in. (2 mm) for larger diameters. For other sealing systems the tolerances must be established to meet the requirements of 6.1.1.

7.1.2 *Washer-Bearing Surface*—Washer-bearing surface shall be flat and parallel to the flange face within 1°.

7.1.3 *Flange Outside Diameter*—Outside diameter of flanges is to be at least equal to that of ASME B 16.5 for up to 24-in. (610-mm) inside diameter and ASME B 16.1 for larger flanges. It is accepted practice to increase all flange outside diameters to provide greater strength at the bolt holes.

TABLE 3 Flange Dimensions

Nominal Pipe Size, in.[A]	Outside Diameter, min, in.[A]	Drilling			
		Bolt Circle Diameter[A]	Number of Holes	Diameter of Holes[A]	Diameter of Bolts[A]
1	4 ¼	3 ⅛	4	⅝	½
1 ½	5	3 ⅞	4	⅝	½
2	6	4¾	4	¾	⅝
2 ½	7	5 ½	4	¾	⅝
3	7 ½	6	4	¾	⅝
3 ½	8 ½	7	8	¾	⅝
4	9	7 ½	8	¾	⅝
5	10	8 ½	8	⅞	¾
6	11	9 ½	8	⅞	¾
8	13 ½	11 ¾	8	⅞	¾
10	16	14 ¼	12	1	⅞
12	19	17	12	1	⅞
14	21	18 ¾	12	1 ⅛	1
16	23 ½	21 ¼	16	1 ⅛	1
18	25	22 ¾	16	1 ¼	1 ⅛
20	27 ½	25	20	1 ¼	1 ⅛
24	32	29 ½	20	1 ⅜	1 ¼
26	34 ¼	31 ¾	24	1 ⅜	1 ¼
28	36 ½	34	28	1 ⅜	1 ¼
30	38 ¾	36	28	1 ⅜	1 ¼
32	41 ¾	38 ½	28	1 ⅝	1 ½
34	43 ¾	40 ½	32	1 ⅝	1 ½
36	46	42 ¾	32	1 ⅝	1 ½
38	48 ¾	45 ¼	32	1 ⅝	1 ½
40	50 ¾	47 ¼	36	1 ⅝	1 ½
42	53	49 ½	36	1 ⅝	1 ½
44	55 ¼	51 ¾	40	1 ⅝	1 ½
46	57 ¼	53 ¾	40	1 ⅝	1 ½
48	59 ½	56	44	1 ⅝	1 ½
50	61 ¾	58 ¼	44	1 ⅞	1 ¾
52	64	60 ½	44	1 ⅞	1 ¾
54	66 ¼	62 ¾	44	1 ⅞	1 ¾
60	73	69 ¼	52	1 ⅞	1 ¾
66	80	76	52	1 ⅞	1 ¾
72	86 ½	82 ½	60	1 ⅞	1 ¾
84	99 ¾	95 ½	64	2 ⅛	2
96	113 ¼	108 ½	68	2 ⅜	2 ¼
102	120	114.50	72	2.625	2.50
108	126.75	120.75	72	2.625	2.50
114	133.50	126.75	76	2.875	2.75
120	140.25	132.75	76	2.875	2.75
126	147	139.25	80	3.125	3.00
132	153.75	145.75	80	3.125	3.00
144	167.25	158.25	84	3.375	3.25

[A] 1 in. = 25.4 mm.

8. Workmanship, Finish, and Appearance

8.1 Workmanship and appearance shall conform to Table 5 on visual acceptance criteria of standard C582 (ASME SC-582) for the process side, and shall be as free as commercially practical of defects including indentations, delaminations, bubbles, pinholes, foreign inclusions, and resin-starved areas in the structural layer and outer surface as agreed upon between the purchaser and the manufacturer.

9. Test Methods

9.1 *Conditioning*—When conditioning is required, and in all cases of disagreement, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) for not less than 40 h prior to test, in accordance with Procedure A of Test Methods D618.

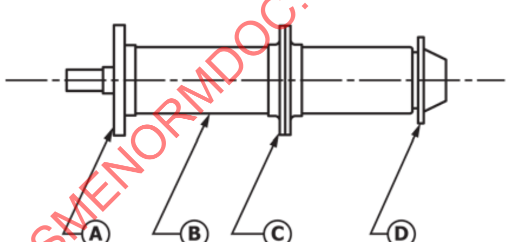
9.2 *Test Conditions*—The tests may be conducted at ambient temperature and humidity conditions. When controlled-environment testing is specified, conduct test at 73.4 ± 3.6°F (23 ± 2°C). When elevated-temperature testing is specified, conduct the tests at the design operating temperature, with a tolerance of ±3.6°F (2°C).

9.3 *Dimensions and Tolerances*—Measure flange dimensions with a micrometer, vernier calipers, or other suitable measuring devices accurate to within 50 % of the required tolerance. Determine diameters by averaging a minimum of four measurements, equally spaced circumferentially.

9.4 *Sealing*—Bolt together flanged components in general agreement with Fig. 2 using the gasket and bolt torque recommended for standard field installation by the flange manufacturer. Then pressure test the assembly and require it to hold the test pressure for a period of 168 h without leakage. Retorquing to the manufacturer's specified level after initial pressurization is permitted.

9.5 *Short-Term-Rupture Strength*—Hydrostatically test flanged components in accordance with Test Method D1599 with free-end closure for Class I flanges and fixed-end closure for Class II flanges except as herein noted. Increase the pressure in the specimen until failure of the flange occurs. Pressure testing in an atmospheric environment is permissible. Minimum-failure time shall be 60 s; no restriction shall be placed on maximum time-to-failure. Leaking past the gasket interface is permissible during this test. Bolt torque may be increased as necessary during the test in order to minimize gasket leaking and to achieve the pressure necessary to cause flange failure. The assembly used for the test in 9.4 may be used for this test. (**Warning—**DO NOT TEST WITH AIR PRESSURE.)

9.6 *Maximum Bolt Torque*—Using the gasket and hardware recommended by the flange manufacturer, bolt the flange against a flat-face steel flange. Tighten the nuts by hand until they are snug. Prior to fit-up, the nuts, bolts and washers should be well lubricated, using a non-fluid thread lubricant. Establish uniform pressure over the flange face by tightening bolts in 10-lb·ft (14-N·m) increments according to the sequence shown in Fig. 3. For flanges with 20 or more bolts, similar alternating bolt-tightening sequences shall be used. Increase the bolt torque uniformly until flange failure occurs, or until all bolts have been torqued to 2 times the level recommended by the manufacturer for field-installation practice to establish the bolt torque cell classification of the flange. Any sign of flange damage (crumbling, flaking, cracking, or other breaking) shall constitute failure.



A—End plate, end cap, or quick closure with coupling for pressure source/vent line.
B—Reinforced thermosetting resin pipe (RTRP).
C—Test flange set.
D—End plate, end cap, or quick closure.

FIG. 2 Test-Assembly Configuration

NOTE 6—The torque limits determined by 11.6 apply only to flanges bolted up against a flat sealing surface. Significantly lower bolt-torque values will normally be allowed when contact-molded flanges are bolted up against other than flat sealing surfaces. When fiberglass flanges must be used against other than flat sealing surfaces, the flange manufacturer should be contacted for his torquing and installation recommendations.

10. Proof of Design

10.1 Test one each of 150-psi (1.03-MPa) flanges 8, 12, and 24 in. (203, 305, and 610 mm) as described in 6.1.2 and 9.5, to establish that the design calculations meet the test requirements and to establish rating data for the particular construction for all sizes of 150 psi or lower pressure ratings. Any change in calculation or construction will require retesting.

10.2 For individual orders conduct only those tests specifically agreed upon between the purchaser and the manufacturer prior to manufacture of flanges.

11. Product Marking

11.1 Flanges for use or installation by other than the flange manufacturer shall be marked with the following information:

11.1.1 The designation "ASTM D5421" with which the flange complies,

11.1.2 Identification of the flange in accordance with the designation code in 4.2,

11.1.3 Nominal flange size, and

11.1.4 Manufacturer's name (or trademark) and product designation.

11.2 Flanges for use and installation by the flange manufacturer shall be identified on the fabrication and assembly drawings with the following information:

11.2.1 The designation "ASTM D5421," and

11.2.2 Pressure rating.

NOTE 7—Through a quality-assurance and surveillance program the manufacturer shall ensure that the flanges used are of the designated grade and pressure rating.

12. Precision and Bias

12.1 No precision and bias statement can be made for the test methods outline in this standard since controlled round-robin test programs have not been run. The wide variations in raw materials and construction between manufacturers make round-robin testing difficult to apply.

13. Certification

13.1 See Annex A1 for certification requirements

14. Keywords

14.1 butt weld; certification; contact molded; flange on pipe; furan; integral flange; polyester; vinylester

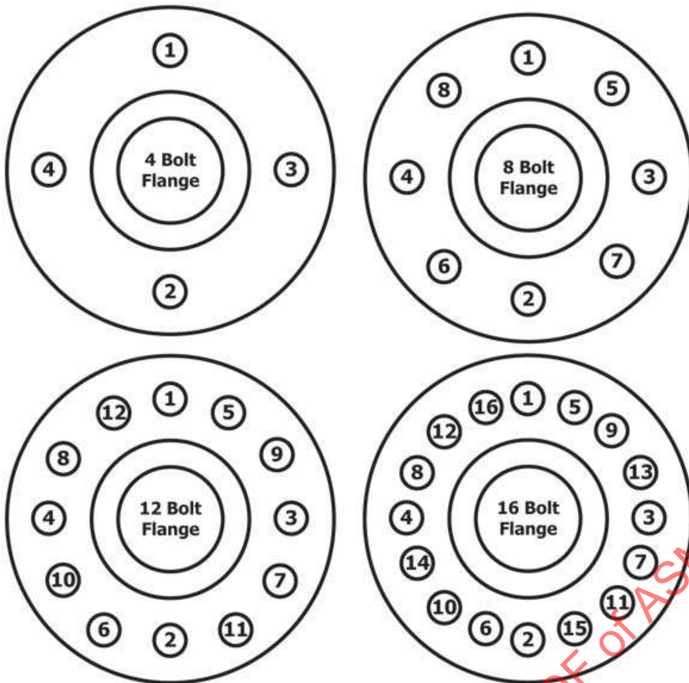


FIG. 3 Bolt Torquing Sequence

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

SPECIFICATION FOR FIBERGLASS (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PIPE AND PIPE FITTINGS, ADHESIVE BONDED JOINT TYPE, FOR AVIATION JET FUEL LINES

SD-5677

(Identical with ASTM D5677-17 except for revisions to title, paras. 1.1, 2.3, 3.2.1, 6.1.4; addition of para. 11.2 and Annex A1; and editorial changes.)

Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Pipe Fittings, Adhesive Bonded Joint Type, for Aviation Jet Fuel Lines

1. Scope

1.1 This specification covers a reinforced plastic pipe and fittings system made from epoxy resin and glass-fiber reinforcement, together with adhesive for joint assembly, intended for service up to 150°F (65.6°C) and 150-psig (1034-kPa) operating pressure and surges up to 275 psig (1896 kPa) in aviation jet fuel lines installed below ground.

1.2 The dimensionless designator NPS has been substituted in this specification for such traditional terms as *nominal diameter*, *size*, and *nominal size*.

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

1.4 The following safety hazards caveat pertains only to the test method portion, Section 9, 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.*

NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D381 Test Method for Gum Content in Fuels by Jet Evaporation
D883 Terminology Relating to Plastics
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1655 Specification for Aviation Turbine Fuels
D2310 Classification for Machine-Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe (Withdrawn 2017)
D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
D3241 Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D3951 Practice for Commercial Packaging
D5685 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings
F412 Terminology Relating to Plastic Piping Systems
F1173 Specification for Thermosetting Resin Fiberglass Pipe Systems to Be Used for Marine Applications

2.2 *Military Specification:*

MIL-T-5624 Turbine Fuel, Aviation, Grades JP-4, JP-5 and JP-5/JP-8 ST

2.3 *ASME Standards:*

ASME B16.5, Steel Pipe Flanges and Flanged Fittings
ASME NM.3.2, SF-1173 Specification for Thermosetting Resin Fiberglass Pipe Systems to Be Used for Marine Applications

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D883 and F412, and abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *conductive*—a pipe or fitting that meets the requirements for conductivity listed in Section 6 of Specification F1173 (ASME SF-1173).

3.3 *Abbreviations:*

3.3.1 *RTRP, n*—reinforced thermosetting resin pipe.

4. Classification

4.1 *General:*

4.1.1 Pipe meeting this specification is classified by type, grade, and class similar to Classification D2310.

4.1.2 Fittings meeting this specification are also classified by type (method of manufacture) and grades (generic type of resin).

4.2 *Pipe:*

4.2.1 Type I Filament-Wound Pipe Nonconductive

4.2.2 Type Ia Filament-Wound Pipe Conductive

4.2.3 Type II Centrifugally Cast Pipe

4.3 *Fittings:*

4.3.1 Type I Filament-Wound Fittings Nonconductive

4.3.2 Type Ia Filament Wound Fittings Conductive

4.3.3 Type Il Molded Fittings Nonconductive

4.4 *Grade:*

4.4.1 Grade 1 Glass-Fiber-Reinforced Epoxy Resin (Pipe and Fittings)

4.5 *Classes (Pipe Only):*

4.5.1 Class A No Liner

4.5.2 Class C Epoxy Resin Liner Nonreinforced

4.5.3 Class F Epoxy Resin Liner Reinforced

5. Materials and Manufacture

5.1 *General*—The fiberglass pipe shall be round and straight, and the pipe and fittings shall be of uniform density, resin content, and surface finish. All pipe ends shall be cut at right angles to the axis of the pipe and any sharp edges removed. The bore of the pipe and fittings shall have a smooth, uniform surface with no exposed fibers and is permitted to contain a liner. The liner, if used, shall be composed of an epoxy resin formulation and is permitted to contain a reinforcement.

5.2 *Material*—The pipe and fittings shall be made from epoxy resins and glass-fiber reinforcement of commercial first quality. Fillers, colorants, and other materials are permitted to be added, provided the pipe and fittings meet all the requirements of this specification. Epoxy pipe shall be joined only with epoxy fittings.

5.3 *Adhesive*—Adhesive for joint assembly shall be a material suitable for providing a seal between the pipe and fittings in continuous service up to 150°F (65°C) and 150 psig (1034 kPa) with surges to 275 psig (1896 kPa). The adhesive shall be supplied as a kit which includes containers of all components in the amounts needed for each adhesive mixture. Instructions for use shall be marked on each container or listed on an instruction sheet included in each adhesive kit. When specified in the contract or purchase order, adhesive kits shall be furnished in a sufficient quantity for the particular procurement of pipe and fittings.

6. Dimensions

6.1 *Pipe*—The pipe shall be 1, 1.5, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, and 24-in. (25, 40, 50, 80, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 550, and 600-mm) nominal sizes as specified and shall have the dimensions and tolerances shown in Table 1 unless otherwise agreed upon by the purchaser and seller.

6.1.1 *Length*—Unless other lengths are specified on the purchase order, the length of the pipe shall be 20 ft (6.1 m), 30 ft (9.2 m), or 40 ft (12.2 m) with a plus tolerance of 2 ft (0.6 m) and a minus tolerance of 5 ft (1.5 m).

6.1.2 *Wall Thickness*—The minimum wall thickness of the pipe shall be not less than 87.5 % of the average wall thickness of the pipe as measured in Section 8 and tested in Section 9.

6.1.3 *Fittings*—Fittings shall be 1, 1.5, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16-in. (25, 40, 50, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, and 600-mm) nominal sizes, as specified, and

TABLE 1 Dimensions of Pipe

NOTE 1—Nominal pipe diameters of 14 in. (350 mm), 16 in. (400 mm), 18 in. (450 mm), 20 in. (500 mm), 22 in. (550 mm), and 24 (600 mm) are available and approved with outside diameters or inside diameters as specified in Table 1.

Nominal Pipe Diameter		Outside Diameter		Tolerance, Type I and Type Ia		Tolerance, Type II	
in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
1	(25)	1.315	(33.40)	+0.060 −0.016	(+1.52 −0.41)	±0.009	(±0.229)
1.5	(40)	1.900	(48.26)	+0.060 −0.018	(+1.52 −0.46)	±0.009	(±0.229)
2	(50)	2.375	(60.32)	+0.060 −0.018	(+1.52 −0.46)	±0.012	(±0.30)
3	(75)	3.500	(88.90)	±0.060 −0.018	(+1.52 −0.46)	±0.012	(±0.30)
4	(100)	4.500	(114.30)	±0.060 −0.018	(+1.52 −0.46)	±0.015	(±0.38)
5	(125)	5.563	(141.30)	±0.060 −0.028	(+1.68 −0.71)	±0.025	(±0.64)
6	(150)	6.625	(168.28)	±0.066 −0.028	(+1.68 −0.71)	±0.025	(±0.64)
8	(200)	8.625	(219.08)	±0.086 −0.040	(+2.28 −1.02)	±0.025	(±0.64)
10	(250)	10.750	(273.05)	±0.108 −0.048	(+2.74 −1.22)	±0.025	(±0.64)
12	(300)	12.750	(323.05)	±0.128 −0.056	(+3.25 −1.42)	±0.025	(±0.64)
14	(350)	14.000	(355.60)	±0.145 −0.064	(+3.68 −1.63)	±0.035	(±0.89)
16	(400)	16.000	(406.40)	±0.165 −0.074	(+4.19 −1.88)	±0.035	(±0.89)
18	(450)	18.000	(457.20)	±0.250	±6.35		
20	(500)	20.000	(508.00)	±0.250	±6.35		
22	(550)	22.000	(558.80)	±0.250	±6.35		
24	(600)	24.000	(609.60)	±0.250	±6.35		

shall have dimensions suitable for joining to the pipe and enabling the pipe and fitting joint to meet the requirements of this specification. For purposes of this specification, fittings shall include couplings and flanges.

6.1.4 *Flanges*—Flanges shall conform to the bolt hole sizes and pattern for 150-lb steel flanges in accordance with ASME B16.5.

7. Performance Requirements

7.1 *Joint Strength*—Pipe, fittings, adhesive, and joints shall show no porosity or other evidence of failure when tested in accordance with 9.2.2.

7.2 *Hydrostatic Strength*—Pipe, fittings, adhesive, and joints shall withstand a hydrostatic pressure of 300 psi (2068 kPa) without any indication of porosity, delamination, splitting, or other evidence of failure when tested in accordance with 9.2.3.

7.3 *Impact Resistance*—Pipe and fittings shall show no porosity or visual evidence of damage that would affect serviceability when tested in accordance with 9.2.4.

7.4 *Boil Resistance*—Pipe and fittings shall show no evidence of delamination or other impairment and shall have a weight gain no greater than 1.0 % when tested in accordance with 9.2.5.

7.5 *External Load Resistance*—When tested as specified in 9.2.6, the pipe shall show no visual evidence of cracking, crazing, or other damage that could allow leakage of fuel through the pipe wall at 5 % deflection and no visual evidence of delamination, rupture, or other structural damage at 10 % deflection.

7.6 *Degradation Resistance:*

7.6.1 *Pipe and Fittings*—Pipe and fittings exposed to JP-5 and JP-5/JP-8 ST fuels, or Jet A and Jet A-1, in accordance with 9.2.7, shall exhibit no visual evidence of deterioration as a result of exposure to the fuels and shall have short-time rupture strengths of not less than 90 % of the short-time rupture strengths of unexposed pipe and fittings when tested in accordance with 9.2.7.1.

7.6.2 *Fuels*—JP-5 and JP-5/JP-8 ST, or Jet A and Jet A-1 fuels contained within pipe and fittings in accordance with 4.2 and 4.3, shall not vary from control samples of the fuels in thermal stability and existent gum properties when tested, as specified, in accordance with 9.2.7.2.

7.6.3 *Hydrostatic Proof Test*—Pipe and fittings shall withstand a hydrostatic pressure of 275 psi (1551 kPa) without any indication of porosity when tested in accordance with 9.2.8.

8. Workmanship

8.1 *Pipe and Fittings*—The pipe and fittings shall be free from all defects including delaminations, cracks, indentations, bubbles, pinholes, porosity, and resin-rich and resin-starved areas which, due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the pipe and fittings. The liner, if used in the pipe or fittings, shall be free of cracks, chips, or other damage.

8.2 *Examination:*

8.2.1 *Sampling*—A sufficient quantity of pipe, fittings, and adhesive kits, in accordance with accepted statistical practice and as agreed upon between the purchaser and the seller, shall be selected from each lot or shipment and examined to determine conformance with this specification. In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

8.2.2 *Pipe and Fittings*—Sample pipe and fittings selected shall be examined for the following defects: incorrect dimensions; ends of pipe not cut at right angles to the axis; exposed fibers or nonuniform surface on bore of pipe or fittings; cracked or chipped liner (if used); bubbles, pinholes, delaminations, cracks, indentations, resin-rich or resin-starved areas in the outer wall that will affect the strength and performance of the product; and incorrect or missing identification marking. Any sample pipe or fitting having one or more of the defects listed shall be considered a defective unit.

8.2.3 *Dimensions*—Pipe and fitting dimensions shall be determined in accordance with the applicable sections of Practice D3567.

8.2.4 *Adhesive*—Sample adhesive kits selected shall be examined for missing adhesive components and instructions for use, and missing or incorrect identification marking. Any sample adhesive kit having one or more of the defects listed shall be considered a defective unit.

9. Test Methods

9.1 *Sampling*—All pipe and fittings shall be tested to determine conformance to the hydrostatic proof test requirements of 7.6.3 unless otherwise agreed upon by the purchaser and the seller. The rate of sampling for the destructive tests specified in 9.2.2 to 9.2.6 (joint strength, impact resistance, boil resistance, beam strength, and cycling resistance) other tests listed shall be in accordance with the accepted statistical practice unless otherwise agreed upon between the purchaser and the seller. In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

9.2 *Tests*—Sample pipe, fittings, and adhesive kits selected shall be subjected to the tests in accordance with 9.2 through 9.2.8. Any sample failing to pass any of these tests shall be considered a defective unit.

9.2.1 *Test Conditions*—Unless otherwise specified in the test method, test specimens shall be conditioned for not less than 48 h in a room maintained at 60 to 90°F (15 to 32°C) and tested at the same temperature range. Unless otherwise specified, the test pressure in the individual test methods shall have a tolerance of +10 −0 psig (68.9 kPa) and −0 psig (0 kPa).

9.2.2 *Joint Strength*—Joint assemblies containing the pipe, fittings, and adhesive shall be fabricated. The adhesive shall be applied and cured as under field conditions in accordance with the manufacturer's printed instructions. The completed test section shall be either an assembly containing the pipe and each kind of fitting to be furnished under a contract, or simply one fitting joined between two pieces of pipe. When a section containing just one fitting is used, then similar test sections containing the other kinds of fittings to be furnished must also be tested. If the test section containing the one fitting is used, the longest end-to-end dimension shall be 18 in. (457 mm) or seven times the outside diameter of the pipe, whichever is greater, but no longer than 84 in. (2.1 m). If the test section contains more than one fitting, the pipe length between fittings shall be 6 in. (152 mm) or three times the outside diameter of the pipe, whichever is greater. Specimens for test shall be the maximum product size in each pressure class for each method of manufacture. The manufacturer is entitled to test a smaller product size to qualify that size and smaller. The test section shall be subjected to a hydrostatic pressure of 275 psig (1896 kPa) at 150°F (65°C) for 168 h. The liquid medium shall be water and shall contain a soluble fluorescent dye. Observations with an ultraviolet lamp shall be made each 24 h for porosity or other evidence of failure of the pipe, fittings, or joints. Pipe, fittings, adhesive, and joints shall show no evidence of failure or porosity as required in 7.1. Alternatively, products qualified to Specification D5685 at pressures and temperatures equal to, or greater than, that required by this standard shall be considered as having met the requirements of 9.2.2.

9.2.3 *Hydrostatic Strength*—The test consists of filling a pipe and fitting test assembly, bonded with the adhesive to be furnished, with fresh water containing a soluble fluorescent dye at room temperature and cycling the pressure between 0 and 300 psig (2068 kPa) for 1000 cycles. The assembly shall contain one or more of the fittings to be furnished under a contract. The minimum test assembly size shall be 6 ft (1.8 m) if one fitting is tested. If multiple fittings are tested in the assembly, the pipe length between fittings shall be 2 ft (0.6 m), minimum. Specimens for test shall be the maximum product size in each pressure class for each method of manufacture. The manufacturer is entitled to test a smaller product size to qualify that size and smaller. Approximately 5 to 10 s shall be used to apply the 300-psig pressure followed by a 30-s dwell at that pressure and then immediate removal of the pressure followed by a 30-s dwell at zero pressure. The specimen shall have failed the test if it cannot maintain the 300-psig pressure before the completion of the 1000 pressure cycles. If the 1000 pressure cycles are completed, the specimen shall be pressurized to 300 psig for 2 h, at the end of which time the specimen shall be examined with an ultraviolet lamp for porosity. The pressure shall then be removed and the specimen emptied of water and visually examined for other evidence of failure. Pipe, fittings, adhesive, and joints shall conform to the requirements in 7.2.

9.2.4 *Impact Resistance*—Pipe and fittings shall be subjected to a falling ball test and a drop test in accordance with 9.2.4.1 and 9.2.4.2 and shall conform to the requirements in 7.3. Specimens for test shall be the minimum product size in each pressure class for each method of manufacture. The manufacturer can elect to test a larger product size to qualify that size and larger.

9.2.4.1 *Falling Ball Test*—A steel ball 2 in. (50 mm) in diameter and weighing approximately 1.2 lb (0.54 kg) shall be dropped squarely onto the surface of the pipe or fitting specimen with a free fall (which is potentially guided) from a height of 1 ft (0.3 m). The pipe specimen shall be a minimum of 2 ft (0.6 m) in length and the fitting specimen shall be the complete fitting. It is acceptable for the ball to be caught or deflected after the hit so that the rebound does not hit the specimen. The specimen shall be full of water containing a soluble fluorescent dye, but not pressurized. The test shall be made at room temperature and the specimen shall be supported on a solid, flat support. Four drops shall be made on randomly selected areas of the pipe specimen, 90° clockwise from each other. One drop shall be made on the fitting specimen. The specimen shall then be pressurized to 275 psig (1896 kPa) and shall remain at this pressure for 168 h. At the end of this time, the specimen shall be examined for porosity with an ultraviolet lamp and then emptied and examined for evidence of damage.

9.2.4.2 *Drop Test*—Specimens of pipe and fittings shall be dropped onto a concrete floor from a height of 4 ft (1.2 m). The pipe specimen shall be a minimum of 2 ft (0.6 m) in length and the fitting specimen shall be the complete fitting. The test shall be conducted at room temperature. The specimen shall be empty and shall be dropped parallel to the floor. All bore center lines of the fitting specimen shall be horizontal when striking the floor. Following the drop, the specimen shall be examined for evidence of damage and then filled with water containing a soluble fluorescent dye and pressurized to 275 psig (1896 kPa). The specimen shall remain at this pressure for 168 h and then be examined for porosity with an ultraviolet lamp.

9.2.5 *Boil Resistance*—A test specimen 1.5 in. (38.5 mm) in length shall be cut from the sample pipe. Fittings shall be tested using either the whole fitting or a 1.5-in. length cut from the fitting. The test specimens shall be conditioned for 8 h at 200°F (93.3°C), desiccated, and an initial weighing made. The specimens shall be suspended in a boiling distilled water bath for 3 h. The specimens shall be removed one at a time, blotted dry of excess water, and weighed. This weighing shall be made within 1.5 min after removal from the bath. After weighing, the specimens shall be visually examined for delamination or other evidence of impairment and the percentage weight gain of the specimens shall be calculated as follows:

$$\text{Weight gain, \%} = \frac{(B - A)}{A} \times 100 \qquad (1)$$

where:

A = initial weight, and
B = weight after immersion.

Tested specimens shall meet weight gain and visual inspection requirements in accordance with 7.4.

9.2.6 *External Load Resistance*—The pipe shall be tested in accordance with Test Method D2412. Specimens for test shall be the maximum product size in each pressure class for each method of manufacture. The manufacturer is entitled to test a smaller product size to qualify that size and smaller. The test specimens shall be visually examined at 5 % deflection for evidence of cracking, crazing, or other damage that could allow leakage of fuel through the pipe wall, and examined again at 10 % deflection for evidence of delamination, rupture, or other structural damage. When tested as specified, the pipe shall meet visual inspection criteria in accordance with 7.5.

9.2.7 *Degradation Resistance*—Test specimens of pipe and fittings shall be filled with JP-5 and JP-5/JP-8 ST, or Jet A and Jet A-1, fuels and stored for 90 days at 75 ± 15°F (24 ± 8°C). If all nominal sizes of pipe are fabricated in the same way and with the same materials, only one size of pipe need be tested. Test specimens shall be obtained from samples of that size selected. If all nominal sizes of fittings are fabricated in the same way and with the same materials, only elbows and tees of one size need be tested. One end of the pipe test specimens shall be sealed utilizing the adhesive for joint assembly so that the adhesive will be in contact with the fuels. The JP-5 and JP-5/JP-8 ST fuels shall conform to MIL-T-5624. The Jet A and Jet A-1 fuels shall conform to Specification D1655. Following the 90-day storage period, the fuels shall be poured into stainless steel cans labeled with the type of fuel and the pipe or fitting from which the fuel was poured. The pipe, fittings, and fuels shall then be tested in accordance with 9.2.7.1 and 9.2.7.2.

9.2.7.1 *Pipe and Fittings*—The test specimens from which the fuels were removed shall be examined for visual evidence of deterioration from contact with the fuels and then shall be tested in accordance with Test Method D1599 to determine their short-time rupture strengths. The same test shall be performed on similar test samples maintained in the same room during the 90-day storage period, but not in contact with the test fuels. The percent difference between the rupture strengths of the exposed and unexposed specimens shall be determined. Visual inspections and rupture strengths shall meet the criteria of 7.6.1.

9.2.7.2 *Fuels*—The JP-5 and JP-5/JP-8 ST, or Jet A and Jet A-1 fuels removed from the pipe and fitting test specimens shall be tested for thermal stability in accordance with Test Method D3241 and for existent gum in accordance with Test Methods D381. The same tests shall also be performed on fuels that had been stored in stainless steel cans in the same room as the filled pipe and fitting specimens during the 90-day storage period. The thermal stability and existent gum properties of the exposed and unexposed fuels shall be compared and must comply with 7.6.2.

9.2.8 *Hydrostatic Proof Test*—The pipe and fittings shall be filled with water and pressurized to 275 psig (1896 kPa). The test shall be conducted at room temperature. The pipe and fittings shall remain under pressure for not less than 5 min and then shall be examined for porosity while still under pressure. The pipe and fittings tested shall conform to the requirements of 7.6.3.

10. Inspection

10.1 Inspection of the material shall be made as agreed upon between the purchaser and the supplier as part of the purchase order.

10.2 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. The producer is permitted to use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless the purchaser disapproves. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

NOTE 2—In U.S. Federal contracts the contractor is responsible for inspection.

11. Certification

11.1 Unless otherwise specified on the purchase contract, a certificate of compliance from an independent commercial laboratory or factory inspection agency acceptable to the purchaser will be accepted as proof that the requirements in 7.1 to 7.5 for the destructive tests specified in 9.2.2 to 9.2.6 (joint strength, impact resistance, boil resistance, beam strength, and cycling resistance) have been met. The certificate of compliance shall be accompanied by a certification from the manufacturer that the tests have been performed on products manufactured from the same materials and by the same manufacturing processes as the items being offered, and that any proposed changes in material or processes will be promptly reported to the purchaser. The purchaser reserves the right to require additional testing and certification when such changes are made or when otherwise deemed necessary.

11.2 See Annex A1 for certification requirements

12. Product Marking

12.1 *Pipe*—Each length of pipe shall be marked at intervals of not more than 15 ft (6 m). Each marking shall include at least the manufacturer's name or trademark, the nominal pipe size, and the type of reinforced plastic pipe. Designate the type of reinforced plastic pipe in accordance with Classification D2310 or some other easily identifiable system. The marking shall be of a contrasting color and a type that remains legible under normal handling and installation procedures.

12.2 *Fittings*—Each fitting shall be marked with at least the manufacturer's name or trademark and the nominal size. The marking shall be of a contrasting color and a type that remains legible under normal handling and installation procedures.

12.3 *Adhesive*—Each container shall be marked with at least the manufacturer's name or trademark, adhesive component type, expiration date, special storage conditions, handling precautions, and instructions for use (if a separate instruction sheet is not included in the adhesive kit).

13. Packaging

13.1 Unless otherwise specified in the contract or order, the preservation, packing, and marking shall be in accordance with Practice D3951.

14. Keywords

14.1 beam strength; boil resistance; centrifugally cast; cycling resistance; epoxy resins; filament wound; impact resistance; jet fuel; joint strength; molded

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

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SPECIFICATION FOR "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING-RESIN) PRESSURE PIPE FITTINGS

SD-5685

(Identical with ASTM D5685-19 except for revisions to paras. 1.1, 2.2, 4.5.5, 4.5.6, 4.5.7, 6.2, 7.4.1, 8.1.1, and 10.1; addition of section 9 and Annex A2; and editorial changes.)

Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe Fittings

1. Scope

1.1 This specification covers "fiberglass" (glass-fiber-reinforced thermosetting-resin) fittings for use with filament wound or centrifugally cast fiberglass pipe, or both, in sizes 1 in. through 24 in. for pipe manufactured to Specification D2996 (ASME SD-2996) or D2997 (ASME SD-2997), or both.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following safety hazard caveat pertains only to the test method portion, Section 7, of this specification:

1.4 *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.*

NOTE 1—The term "fiberglass pipe" as described in Section 3 of this specification applies to both reinforced thermosetting resin pipe (RTRP) and reinforced polymer mortar pipe (RPMP).

NOTE 2—For the purposes of this standard, polymer does not include natural polymers.

NOTE 3—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings
D2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D2997 Specification for Centrifugally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *ASME Standards:*

ASME B16.5, Steel Pipe Flanges, Flanged Valves and Fittings
ASME NM.3.2, SD-2996 Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASME NM.3.2, SD-2997 Specification for Centrifigally Cast "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASME NM.3.2, SD-4024 Specification for Machine Made "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Flanges
ASME NM.3.2, SF-477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 or F412. Abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for fiberglass pipe is RTRP and the abbreviation for fiberglass fittings is RTRF.

3.1.2 *"fiberglass" pipe*—tubular product containing glass fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners or coatings may be included.

3.1.3 *reinforced thermosetting resin pipe*—fiberglass pipe without aggregate (RTRP).

3.1.4 *reinforced polymer mortar pipe*—fiberglass pipe with aggregate (RPMP).

3.1.5 *reinforced thermosetting resin fitting*—fiberglass fitting without aggregate (RTRF).

3.1.6 *reinforced polymer mortar fitting*—fiberglass fitting with aggregate (RPMF).

4. Classification

4.1 This specification covers fiberglass fittings defined by type (method of manufacture), grade (general resin type), class (general liner type), category (configuration of joining system), and pressure rating (a single letter designating the pressure class and method of manufacture).

4.2 *Types:*

4.2.1 *Type 1*—Filament-wound fittings manufactured by winding continuous fibrous-glass strand roving or roving tape, either pre-impregnated or impregnated during winding, onto a mandrel, or a liner corresponding to the fitting shape.

4.2.2 *Type 2*—Compression molded fittings made by applying external pressure and heat to a molding compound that is confined within a closed mold.

4.2.3 *Type 3*—Resin transfer molded fittings manufactured by pumping a thermosetting resin into glass reinforcements that have been cut to size and clamped between matched molds.

4.2.4 *Type 4*—Centrifugally cast fittings made by applying resin and reinforcement to the inside of a mold that is rotating and heated, subsequently polymerizing the resin system.

4.2.5 *Type 5*—Contact molded fittings made by applying resin and reinforcement to a mold or to mitered filament wound stock or centrifugally cast pipe stock. This procedure shall also cover "spray-up" fittings which are made by spraying resin and reinforcement on a mold or over mitered pipe wound stock. "Contact molding" includes both hand lay-up and spray-up manufacturing processes.

4.2.6 Fittings of Type 1 through Type 5 which require thrust blocking or external axial restraint when installed shall have the letter "R" appended to the type of designation. (For instance, a contact molded fitting requiring thrust blocking when installed would be designated a type "5R".)

4.3 *Grades:*

4.3.1 *Grade 1*—Epoxy-resin.

4.3.2 *Grade 2*—Polyester-resin.

4.3.3 *Grade 3*—Phenolic-resin.

4.3.4 *Grade 4*—Vinylester resin.

4.3.5 *Grade 7*—Furan resin.

4.4 *Classes:*

4.4.1 *Class A*—No liner.

4.4.2 *Class B*—Polyester-resin liner (nonreinforced).

4.4.3 *Class C*—Epoxy-resin liner (nonreinforced).

4.4.4 *Class D*—Phenolic resin liner (nonreinforced).

4.4.5 *Class E*—Polyester-resin liner (reinforced).

4.4.6 *Class F*—Epoxy-resin liner (reinforced).

4.4.7 *Class G*—Phenolic resin liner (reinforced).

4.4.8 *Class H*—Thermoplastic-resin liner (specify).

4.4.9 *Class I*—Furan-resin liner (reinforced).

4.4.10 *Class J*—Vinylester resin liner (nonreinforced).

4.4.11 *Class K*—Vinylester resin liner (reinforced).

4.5 *Joint Categories (Method of Joining):*

4.5.1 *Category 1*—Taper-to-taper adhesive-bonded joint fittings manufactured with a tapered socket to be used in conjunction with a pipe or fitting with a matching spigot section and a suitable adhesive. This joining method provides an interference fit over the entire length of the bond line.

4.5.2 *Category 2*—Straight-taper adhesive-bonded joint fitting manufactured with a tapered socket to be used with a pipe or fitting with an untapered spigot section and a suitable adhesive. This joining method provides an interference fit at the bottom of the socket.

4.5.3 *Category 3*—Straight adhesive bonded joint fitting manufactured with an untapered socket for use with a pipe or fitting with an untapered spigot and a suitable adhesive. This joining provides no interference fit.

4.5.4 *Category 4*—Butt and strap joint made by a contact molding process which involves hand lay-up with glass-woven roving or chopped strand mat, or both, which is saturated with resin.

4.5.5 *Category 5*—Flanged fittings are available as all outlets flanged or as flange-by-joint specified in this specification. Flanges are in compliance with Specification D4024 (ASME SD-4024).

4.5.6 *Category 6*—Elastomeric (gasket) sealed joints with sealant manufactured in compliance with Specification F477 (ASME SF-477) for joints which have integral longitudinal restraint and do not require thrust blocking or external longitudinal restraint.

4.5.7 *Category 7*—Elastomeric (gasket) sealed joints with seals manufactured in compliance with Specification F477 (ASME SF-477) for joints which require thrust blocking or external longitudinal restraint.

4.5.8 *Category 8*—Threaded joint fittings with thread specification to be as agreed upon between purchaser and manufacturer.

4.6 *Pressure Rating*—Pressure rating shall be categorized by a single letter designation. Pressure designations are shown in Table 1. The pressure ratings are applicable for the tempera-

TABLE 1 Pressure Categories

Designation	Pressure Rating[A], psig (kPa)
A	25 (172)
B	50 (345)
C	100 (690)
D	150 (1034)
E	200 (1380)
F	250 (1724)
G	300 (2068)
H	400 (2759)
I	500 (3448)
J	750 (5171)
K	1000 (6895)

[A] Pressure ratings are applicable only for the temperature at which the fittings were tested and for lower temperatures.

ture at which the fittings were tested and for lower temperatures down to −50°F (−46°C). When agreed upon between purchaser and manufacturer, pressure ratings determined by tests conducted following Practice D2992 are acceptable.

4.7 *Designation Code*—The fitting designation code shall consist of the abbreviation RTRF or RPMF followed by the type, grade, class, and category in Arabic numerals and the pressure rating category as a capital letter.

NOTE 4—An example is RTRF 21A2E. This designation describes a (Type 2) compression molded fitting with a (Grade 1) epoxy-resin without a liner (Class A), which is joined with a (Category 2) straight-taper adhesive joining system and has a 200 psig (1380 kPa) pressure rating.

NOTE 5—Fittings with identical classification from different manufacturers may not be interchangeable due to non-standardization of pipe or socket diameter, socket length, taper angle, or combination thereof.

5. Materials

5.1 Fittings manufactured in accordance with this specification shall be composed of reinforcement embedded in or surrounded by cured thermosetting-resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes.

5.2 The resins, fiberglass reinforcements, and other materials, when combined into a composite structure, shall produce a fitting that will meet the performance requirements of this specification.

6. Requirements

6.1 *Workmanship*—The fittings shall be free of all defects including indentations, delaminations, bubbles, pin holes, foreign inclusions, and resin starved areas, which, due to their nature, degree, or extent, detrimentally affect the strength and serviceability of the fitting. The fitting shall be as uniform as commercially practicable in color, opacity, and other physical properties.

6.2 *Dimensions and Tolerances*—All flanged fittings shall conform to the center line to flange face dimensions, hole size and hole pattern, and tolerances of ASME B16.5 short or long radius type, or otherwise as agreed upon between the manufacturer and purchaser. Fitting center line to end dimensions, taper angles, taper length, or combinations thereof, will vary for non-flanged joining systems and the individual manufacturers shall be consulted for dimensions. Dimensions shall be measured in accordance with 7.3.

NOTE 6—Fittings with short radii which are not in compliance with ASME B16.5 radius tolerances may be available.

6.3 *Fittings and Connections Pressure Test Requirements*—Fittings, couplings, and connections shall meet the following qualification requirements when tested with restrained ends for Type 6 fittings, and unrestrained ends for other type fittings, in accordance with 7.4.1 for short term hydrostatic strength tests, and 7.4.2 for cyclic or static tests.

6.3.1 Each type of component and its field-jointed configuration shall be capable of sustaining a short-time hydrostatic pressure, of at least four times its cyclic-rated pressure or three times its static-rated pressure for 1 min without visible weeping or leakage.

6.3.2 Each component shall meet or exceed the cyclic or static-test requirements of 7.4.2.

6.4 *Glass Transition Temperature (Tg)*—The Tg for each resin used, as determined by some thermal analysis method, shall be no less than a minimum statistically significant value established by the manufacturer. Samples shall be taken from manufactured fittings when thermal analysis testing is accomplished by differential-scanning-calorimeter (DSC). Test in accordance with 7.5.

6.5 Factory leak tests shall be conducted at a pressure of 1.5 times pressure rating and at a frequency determined by an agreement between the purchaser and the seller.

6.6 For individual orders, only those additional test and number of tests specifically agreed upon between the purchaser and the seller need be conducted.

7. Test Methods

7.1 *Conditioning*—When conditioning is required, and in all cases of disagreement, condition the test specimens in accordance with Procedure A of Practice D618.

7.2 *Test Conditions*—The tests may be conducted at ambient temperature and humidity conditions. When controlled environment testing is specified, tests shall be conducted in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 10 % relative humidity. When elevated temperature testing is specified, conduct the tests at the design temperature ± 5.4°F (3°C).

7.3 *Dimensions and Tolerances*—Measure fitting dimensions in accordance with applicable documents and Practice D3567. Measure flange dimensions with a micrometer or vernier calipers, or other suitable measuring devices accurate to within ±0.001 in. (0.02 mm). Diameters shall be determined by averaging a minimum of four measurements, equally spaced circumferentially.

7.4 *Pressure Tests:*

7.4.1 *Short-Term Hydrostatic Strength Test*—Short-term hydrostatic failure pressure tests to determine compliance with 6.3 performed at ambient temperature in accordance with Test Method D1599 using specimens and sizes as described in 7.4.3. Leaking past the gasket interface of flanged fittings and elastomeric sealed fittings is permissible during this test, provided the pressure is at least two times the rating when the leak occurs. The bolt torquing sequence of Specification D4024 (ASME SD-4024), Fig. 2 shall be used when testing flaged fittings. Fittings without flanges shall be tested with the pipe they are to be used with joined to the fitting. Bending or shape restraint during the test is permitted to the extent applicable to its anticipated installed conditions. This information shall be contained in the test report.

7.4.2 *Cyclic or Static Pressure Test:*

7.4.2.1 For cyclic pressure tests, the gage pressure at the peak pressure of the cycle shall be not less than 2 times the pressure rating of the fitting. The cycle amplitude pressure shall be at least 80 % of the selected peak pressure.

7.4.2.2 For static pressure tests, the gage pressure shall be no less than 2 times the fitting static pressure rating.

7.4.2.3 Test each component specimen as required above with unrestrained ends and in accordance with Test Methods D2143 for cyclic tests, or D1598 for static tests at the components temperature rating.

7.4.2.4 Each component specimen must withstand a minimum of 168 h for static tests or 252,000 cycles for cyclic tests, without failure.

7.4.3 *Test Specimens and Sample Size Requirements for Pressure Tests*—Test specimens shall include at least one fitting in each configuration, for example: elbow (90° qualifies lesser angle variants), tee (equal tee qualifies branch reducer tee), flange, concentric reducer, eccentric reducer, coupling (includes integral coupling) etc., joined to pipe sections at least 18 in. (0.5 m) long or 2 diameters, whichever is longer, using the joining method, design, and adhesive intended for field assembly. Specimen diameters for test in each configuration shall include the maximum product size in each pressure class and for each method of manufacture. In addition, smaller sizes in the pressure rating shall be tested as follows:

Product Size Range Nominal, in.[A]	Test Size, Nominal, in.
1, 1½, 2, 2½, 3	3
4, 6	6
8,10,12	12
14,16	16

[A] In each range of size, the manufacturer may elect to test a smaller product size to qualify only the smaller size.

7.4.4 *Requalification Tests for Fittings, Couplings, Connections, and Adhesives*—The qualification tests in 6.3 shall be repeated after any change in manufacturing process, construction, or type of materials.

NOTE 7—Fiberglass fittings short-term hydrostatic strength at ambient temperature is not necessarily greater than its short-term hydrostatic strength at all higher temperatures.

7.5 *Glass Transition Temperature*—Determine by using the procedure in Annex A1.

8. Marking

8.1 Mark each fitting with the following information:

8.1.1 The designation "ASTM D5685" or "ASME SD-5685" with which the fitting complies.

8.1.2 Identification of the fitting in accordance with the designation code in 4.2,

8.1.3 Nominal fitting size,

8.1.4 Manufacturer's name (or trademark) and product designation,

8.1.5 Pressure rating (cyclic or static), psig, and

8.1.6 Traceability information such as lot# or date of manufacture.

8.2 All required markings shall be legible and applied so as to remain legible under normal handling and installation practices.

9. Certification

9.1 See Annex A2 for certification requirements.

10. Keywords

10.1 centrifugally cast; certification; compression molded; contact molded; degree of cure; epoxy-resin; filament-wound; furan-resin; glass transition temperature; percent extractable material; polyester-resin; pressure-rating; transfer molded

ANNEX

(Mandatory Information)

A1. METHOD OF TEST FOR THE DETERMINATION OF DEGREE OF CURE BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)

A1.1.1 This test determines whether the degree of cure of a fiberglass fitting test specimen meets the quality control requirements determined by statistical analysis of typical production products.

A1.2. Terminology

A1.2.1 *Definition:*

A1.2.1.1 *glass transition temperature*—the midpoint of the inflection temperature at the DSC curve (heat flow versus temperature).

A1.3. Apparatus

A1.3.1 *Differential Scanning Calorimeter (DSC).*

A1.4. Test Specimens

A1.4.1 *Size*—The size of the specimen is limited by the size of the DSC sample pan. All specimens can be a chip or filed into a fine powder to provide easy weighing and uniform contact with the pan.

A1.4.2 *Location*—For any given fitting, a sample should be taken 0 to 10 mils (0 to 0.025 m) from the outer surface, as well as 0 to 10 mils from the inner surface. If the fitting has a liner, a specimen should be taken from the liner, as well as the inner and outer edges of the overwrap.

A1.5. Procedure

A1.5.1 The maximum heating rate is 41°F (23°C)/min. The Tg is dependent upon heating rate, therefore a consistent heating rate shall be used for all testing.

A1.5.2 Run the scan from room temperature to at least 22°F (12°C) above the expected glass transition temperature and no more than 482°F (250°C).

A1.5.3 Obtain the Tg_1 (midpoint of the inflection in the DSC curve).

A1.5.4 If the Tg is not within 16°F (9°C) of statistically significant value, cool down the DSC and run another sample again from room temperature to 54°F (30°C) above Tg_1 to obtain Tg_2.

A1.5.5 The values Tg_1 and Tg_2 obtained with the test sample should be compared to those statistically significant values obtained from typical production product. The measured and typical values should be within 16°F (9°C).

A1.6. Report

A1.6.1 Report the following information:

A1.6.1.1 Complete identification of the specimens, including material, manufacturer's name, and lot number.

A1.6.1.2 Fitting dimensions, including nominal size, minimum reinforced wall thickness, and average outside diameter of reinforced wall. Unreinforced thickness (that is, liner) shall also be reported.

A1.6.1.3 Number of specimens tested and where the specimens were taken from the fitting.

A1.6.1.4 Heat-up rate for DSC initial temperature and final temperature for both scans.

A1.6.1.5 Record glass transition temperature (inflection value) for the first scan as Tg_1.

A1.6.1.6 Record glass transition temperature (inflection value) for the second scan as Tg_2, if applicable.

A1.6.1.7 Date of test.

A2. CERTIFICATION

A2.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance of material.

A2.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A2.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A2.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

SPECIFICATION FOR CONTACT-MOLDED "FIBERGLASS" (GLASS-FIBER-REINFORCED THERMOSETTING RESIN) CORROSION RESISTANT PIPE AND FITTINGS

SD-6041

(Identical with ASTM D6041-18 except for revisions to para. 2.2, 2.3, Notes 3 and 4, paras. 5.1.1, 5.1.2, 6.1.2, 6.1.2.4, 6.3.4, 7.2, 9.1, 10.6, 11.1.1, 13.1, and X2.3; addition of section 12 and Annex A1; and editorial changes.)

Specification for Contact-Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Corrosion Resistant Pipe and Fittings

1. Scope

1.1 This specification covers pipe and fittings fabricated by contact molding, for pressures to 150 psi and made of a commercial-grade polyester resin. Included are requirements for materials, properties, design, construction, dimensions, tolerances, workmanship, and appearance.

1.2 This specification does not cover resins other than polyester, reinforcing materials other than glass fibers or fabrication methods other than contact molding.

NOTE 1—For the purposes of this specification, the term polyester resin will include both polyester and vinylester resins.

1.3 This specification does not cover the design of pipe and fittings intended for use with liquids heated above their flash points.

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

1.5 The following precautionary caveat pertains only to Section 10, the test methods portion, 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.*

NOTE 2—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
C582 Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D883 Terminology Relating to Plastics
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D3681 Test Method for Chemical Resistance of "Fiberglass" (Glass–Fiber–Reinforced Thermosetting-Resin) Pipe in a Deflected Condition
D5421 Specification for Contact Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Flanges
F412 Terminology Relating to Plastic Piping Systems

2.2 *ASME Standards:*

ASME B16.1 Cast Iron Pipe Flanges and Flanged Fittings
ASME B16.5 Pipe Flanges and Flanged Fittings
ASME B18.22 Type "B" Narrow Washers
ASME NM.3.2, SC-582 Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment
ASME NM.3.2, SD-5421 Specification for Contact-Molded Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Flanges

2.3 *NSF International Standard:*

NSF Standard 61 Drinking Water System Components—Health Effects

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology D883 and Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for reinforced thermosetting resin pipe is RTRP.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contact molding, n*—a process for molding reinforced plastics in which reinforcement and resin are placed on an open mold or mandrel by either the "hand lay-up"(where resin and glass mat are applied by hand), or the "spray-up" manufacturing processes (where resin and chopped glass fibers are sprayed under pressure), or a combination of the two. The resulting laminate is then consolidated by rolling and cured without the application of pressure.

3.2.2 *fiberglass pipe, n*—a tubular product containing glass fiber reinforcements embedded in or surrounded by cured thermosetting resin. The composite structure may contain granular or platelet fillers, thixotropic agents, pigments, or dyes. Thermoplastic or thermosetting liners may be included.

3.2.3 *polyester, n*—resins produced by the polycondensation of dihydroxy glycols and dibasic organic acids or anhydrides, wherein at least one component contributes ethylenic unsaturation yielding resins that can be compounded with styrol monomers and reacted to give highly crosslinked thermoset copolymers.

3.2.4 *vinyl ester, n*—resins characterized by reactive unsaturation located predominately in terminal positions that can be compounded with styrol monomers and reacted to give highly crosslinked thermoset copolymers.

4. Materials and Manufacture

NOTE 3—Specification C582 (ASME SC-582) provides additional information on the materials and manufacturing of contact–molded laminates.

NOTE 4—Fiberglass pipe intended for use in the transport of potable water should be evaluated and certified as safe for this purpose by a testing agency acceptable to the local health authority. The evaluation should be in accordance with requirements for chemical extraction, taste, and odor that are no less restrictive than those included in NSF Standard 61. The seal or mark of the laboratory making the evaluation should be included on the fiberglass pipe.

4.1 *Resin System:*

4.1.1 The resin used shall be a commercial grade, corrosion-resistant polyester that has been determined to be acceptable for the service either by test, (see Practice C581), or by previous documented service. Where service conditions have not been evaluated a suitable resin may also be selected by agreement between manufacturer and purchaser.

NOTE 5—The use of "previous documented service" needs to be approached carefully. It is not uncommon for specified operating conditions to be overstated in an attempt to achieve a higher safety margin.

4.1.1.1 The use of one resin in the corrosion barrier and a different resin in the structural layer (see Section 6) is permitted with the acceptance of the purchaser.

4.1.2 *Additives*, such as additional styrene, fillers, dyes, pigments, or flame retardants may be used when agreed upon between the manufacturer and purchaser. Thixotropic agents may be added to the resin for viscosity control.

NOTE 6—The addition of fillers, dyes, pigments, flame retardants, and thixotropic agents may interfere with visual inspection of laminate quality.

NOTE 7—Chemical resistance can be affected by the catalyst/promoter system, diluents, dyes, fillers, flame retardants, or thixotropic agents used in the resin.

NOTE 8—Antimony compounds or other fire-retardant agents may be added to halogenated resins for improved fire resistance, if agreed upon between the manufacturer and the purchaser. These compounds do not improve the flame retardancy of non-halogenated resins.

4.1.3 *Ultraviolet Absorbers* may be added for improved weather resistance when agreed upon between the manufacturer and the purchaser.

4.1.4 *Resin Putty*, used where necessary to fill crevices at joints prior to applying the joint laminate shall not be subject to the limitations of 4.1.3. Putty shall be made with resin and fillers. The resin used in the putty must be compatible with the resin used in the pipe and fittings.

4.2 *Fiber Reinforcements:*

4.2.1 *Surfacing Mat (Veil)* is a thin mat of fine fibers used primarily to produce a smooth and corrosion–resistant resin–rich surface on a reinforced plastic laminate.

4.2.1.1 Veils are made from chemical resistant (type "C") glass or organic fiber. The use of an organic-fiber surface mat is recommended for environments that attack glass. The veil used in a laminate shall be determined to be acceptable for the chemical service either by Practice C581 or by verified case history.

4.2.1.2 The veil shall be a minimum of 10 mils in dry thickness and produce a thickness of 0.010 to 0.020 in. (0.25 to 0.50 mm) when saturated with resin.

NOTE 9—The primary chemical resistance of the RTR pipe is provided by the resin. In combination with the cured resin, the surfacing veil helps determine the thickness of the resin-rich layer, and reduces micro cracking.

4.2.2 *Chopped-strand Reinforcements* shall be "E"-type or "ECR"-type glass fibers 1 to 2 in. (25 to 50 mm) long applied in a uniform layer with random orientation. The fibers shall have a sizing compatible with the selected resin. Chopped strand reinforcements may be purchased and applied as a mat or as continuous strand roving which is chopped into short lengths and sprayed onto the laminate in a process known as "spray up." Either form is most commonly applied in layers weighing 1½ oz/ft^2 (450 g/m^2) although other weights are available and may be used.

4.2.3 *Woven Roving*, shall be "E"-type or "ECR"-type glass roving, woven into a fabric. The sizing on the roving shall be compatible with the selected resin. The most common woven roving has a 5 by 4 weave and a weight of 24 oz/yd^2 (832 g/m^2).

4.2.4 *Non-woven Roving* "E type or "ECR" glass reinforcing fabrics such as biaxials and uni-directionals may be used in special applications such as reinforcing tees and other fittings or to improve the physical properties of the laminate in a specific direction.

4.2.5 *Multiple Layer Reinforcements* are fabrics composed of two or more layers of reinforcement combined into one fabric. A common form is one layer of 1 ½ oz/ft^2 chopped strand mat combined with one layer of 24 oz/yd^2 woven roving. The pipe manufacturer must use extra caution to ensure proper laminate quality is maintained when using multiple layer reinforcements.

5. Design

5.1 *Design Basis:*

5.1.1 *Class A*—For pipe to be manufactured using Type I or Type II laminates as described in Specification C582 (ASME SC-582), the Ultimate Tensile Strengths shown in Specification C582 (ASME SC-582) may be used for the design basis.

5.1.2 *Class B*—For pipe manufactured with other than Type I or Type II laminates (in accordance with Specification C582) (ASME SC-582), or for Ultimate Tensile Strengths greater than those shown in C582 (ASME SC-582), testing in accordance with 10.5 or 10.6 is required to establish a design basis for each laminate type used by the pipe manufacturer. Testing shall be performed on a sample laminate or pipe of the same type and construction as will be used on the actual pipe and fittings. The thickness of the laminate sample will be ⅜ in. (9.5 mm) or the maximum thickness to be provided in the pipe and fittings, whichever is less. If testing in accordance with 10.6, testing is required in both directions if the reinforcement is not applied equally in both directions. The laminate sample shall not include a corrosion barrier. Laminates greater than ⅜ in. (9.5 mm) thick are to be constructed with standard repeating sequences of reinforcement such as those described in Specification C582 (ASME SC-582). Results from previously tested laminates may be used provided that such laminates were manufactured with the same resin, laminate type, and thickness within the previous five years.

NOTE 10—Reinforcements such as 24 oz/yd^2 (832 g/m^2) produced with a 5 by 4 weave are considered equal in both directions for the purpose of 5.1.2.

5.1.3 *Temperature Limits*—Service temperature shall be considered in the design of RTRP pipe unless the service temperature is the lower of 150°F (65°C) or 35°F (19°C) below the resin Heat Deflection Temperature (HDT) in accordance with Test Method D648. When the service temperature exceeds these limits, testing in accordance with 10.4 shall be performed at the service temperature with samples conditioned in accordance with Practice D618.

NOTE 11—The use of ambient temperature property values for elevated temperature service when using polyester resins should be considered carefully. Some combinations of temperature, chemical environment and laminate stress(strain) may result in the need to use reduced properties or increased safety factors to achieve the desired performance.

5.2 *Wall Thickness*—The required wall thickness due to internal pressure shall be determined by the following formula. Other loads such as thermal expansion and bending between supports should also be considered. The minimum wall thickness shall be the greater of 0.18 in. (4.5 mm) or 1 % of the pipe inside diameter.

$$t = \frac{(P*ID)}{(2*S - P)}$$

where:

t = calculated wall thickness, in. (mm) (see 6.1.2.3),
P = design pressure, psi (kPa),
ID = inside diameter of the pipe, in. (mm),
S = allowable stress (not to exceed ¹⁄₁₀ of the Class A design basis per 5.1.1 or ⅙ of the Class B design basis per 5.1.2), psi (kPa).

5.3 Standard pressure classes are 25, 50, 75, 100, 125, and 150 psi, however, custom classes are allowed.

NOTE 12—Special design consideration should be given to pipe and fittings subject to vacuum or superimposed mechanical forces, or both, such as earthquakes, wind load, or burial loads, and to pipe and fittings subject to service temperature in excess of 180°F (82°C).

6. Laminates

6.1 *Laminate Construction*—The laminate comprising the pipe wall shall consist of a corrosion barrier comprised of an inner surface and interior layer, a structural layer, and an outer surface.

6.1.1 The *Corrosion Barrier*, consisting of the inner surface and interior layers, shall be included in the total thickness for all design calculations unless otherwise specified.

6.1.1.1 *Inner Surface*—The inner surface exposed to the chemical environment shall be resin-rich and reinforced with at least one layer of a suitable surfacing veil in accordance with 4.2.1. Some chemical environments may warrant the use of a second layer of surfacing veil. This resin-rich inner surface will contain less than 20 % by weight of reinforcing material and have a thickness between 0.010 and 0.020 in. (0.25 to 0.50 mm)

6.1.1.2 *Interior Layer*—The inner surface layer shall be followed with a layer composed of resin reinforced only with non-continuous glass-fiber strands. This reinforcement shall be applied as chopped strand mat or as chopped roving (spray up process) (either in accordance with 4.2.2) resulting in a minimum reinforcement weight of 1 ½ oz/ft^2 (459 g/m^2). The combined thickness of the inner surface and interior layer shall not be less than 0.05 in. Depending on the chemical environment, multiple 1 ½ oz/ft^2 (459 g/m^2) layers of chopped strand applied as mat or spray up may be required. Two layers are most commonly used with as many as four or five layers occasionally used in severe environments. When multiple layers are used, each ply of mat or pass of chopped roving shall be well rolled to eliminate all trapped air prior to the application of additional reinforcement. Glass content of the inner surface and the interior layer combined shall be 27 ± 5 % by weight, when tested in accordance with 10.4.

6.1.2 *Structural Layer*—Subsequent reinforcement shall be Type I or Type II or "other" as described below. Types I and II are described in further detail including laminate sequences and thicknesses in Specification C582 (ASME SC-582).

6.1.2.1 *Type I* laminates consist of multiple layers of 1.5 oz/ft^2 (0.46 kg/m^2) chopped strand mat or equivalent weight of chopped roving as required to achieve the thickness as calculated according to Section 5. Each successive ply or pass of reinforcement shall be well-rolled prior to the application of additional reinforcement. The exterior surface shall be relatively smooth with no exposed fibers or sharp projections and enough resin shall be present to prevent fiber show.

6.1.2.2 *Type II* laminates consist of multiple layers of 1.5 oz/ft^2 (0.46 kg/m^2) chopped strand mat or equivalent weight of chopped roving alternating with layers of 24 oz/yd^2 (814 g/m^2) woven or non-woven roving as required to achieve the thickness as calculated according to Section 5. Each successive ply or pass of reinforcement shall be well-rolled prior to the application of additional reinforcement. The exterior surface shall be relatively smooth with no exposed fibers or sharp projections and enough resin shall be present to prevent fiber show.

6.1.2.3 *Other* laminates may consist of similar layers to those used in Types I and II except for the use of different configurations and weights of reinforcements. A common example is the use of ¾ oz/ft^2 (230 g/m^2) chopped strand mat in a Type II laminate. Other options include the use of reinforcements listed in 4.2.4 and 4.2.5. Each successive ply or pass of reinforcement shall be well-rolled prior to the application of additional reinforcement. The exterior surface shall be relatively smooth with no exposed fibers or sharp projections and enough resin shall be present to prevent fiber show.

6.1.2.4 With all types of laminate, the first and last layer shall be chopped strand mat or spray up, 1 ½ oz/ft^2 (460 g/m^2). Interruption of the laminating process to allow the resin to exotherm and cool shall only follow a mat layer and lamination shall restart with a mat layer. Adjacent layers of roving reinforcements such as woven or unidirectional roving must be separated by a minimum of ¾ oz/ft^2 (230 g/m^2) of chopped strand. Each successive ply or pass of reinforcement shall be well-rolled prior to the application of additional reinforcement.

6.1.3 *Outer Surface*—The exterior surface shall be relatively smooth with no exposed glass fibers. The final ply shall be mat or chopped roving equivalent. A surfacing mat is not required unless specified. Surface resin may require the addition of paraffin or may be sealed with a sprayed, wrapped, or overlaid film, as required or approved by the resin producer, to ensure proper surface cure.

6.1.3.1 When pigmentation is required, it shall be incorporated only in the resin used for the final surface coating. Pigmented resin may be used in the laminate only if agreed to with the purchaser.

6.1.3.2 Piping used for outdoor service or otherwise subject to ultraviolet exposure shall incorporate provisions to minimize ultraviolet degradation. Suitable methods include the use of ultraviolet absorbers or screening agents, incorporation of pigment of sufficient opacity in the outer surface of the resin rich layer, or use of resins inherently resistant to ultraviolet degradation.

6.2 *Joints*

6.2.1 Laminated butt joints shall be considered the standard means to join pipe to pipe or to join pipe to fittings. The thickness of the structural joint overlay shall be as determined in Section 5.

6.2.2 The minimum width of the first layer of joint overlay shall be 3 in. (76 mm). Successive layers shall increase in width to form a uniform taper. The total width of the joint laminate shall be at least twelve times the joint thickness plus the width of the first layer and shall be centered on the joint.

6.2.3 A highly filled resin paste (resin putty) shall be placed in the crevices between joined pieces, leaving a smooth surface for lay-up. Excess putty shall be removed by abrading the surface prior to applying the joint laminate. No resin paste is to be left inside the pipe.

6.2.4 The cured resin surfaces of parts to be joined shall be roughened to remove surface gloss. This roughened area shall extend beyond the lay-up areas so that no reinforcement is applied to an unprepared surface. Surfaces shall be clean and dry before lay-up. The entire roughened area shall be finished in accordance with 6.1.3.

6.2.5 All joints in pipe 24 in. (610 mm) in diameter or larger shall receive an inside sealing overlay. The inside overlay of a joint shall consist of a minimum of two plies of 1.5 oz/ft^2 (0.46 kg/m^2) chopped strand mat reinforcement followed by a resin-rich layer reinforced with surfacing mat. This overlay shall be a minimum of 4 in. (100 mm) wide and shall be the equivalent of 6.1.1 and 6.1.2 combined, and shall be centered on the joint. It shall be finished in accordance with 6.1.3. Inside overlays less than 0.18 in. (4.5 mm) thick shall not be considered in meeting joint strength requirements.

NOTE 13—Any resin spilled on unprepared surface on the inside of the pipe must be removed to avoid clogging of pumps, filters, etc.

6.3 *Fittings*—All fittings such as elbows, laterals, tees, and reducers shall be equal or superior in strength to the adjacent pipe section and shall have the same inside diameter as the adjacent pipe. Tolerance on angles of fittings shall be ± 1° through 24 in. (600 mm) in diameter and ±½ ° for 30-in. diameter and above.

6.3.1 *Elbows*—Standard elbows shall have a centerline radius of one and one-half times the diameter except 2 and 3 in. elbows which shall have a centerline radius of two times the diameter. Elbows may be smooth turn or of mitered construction using pipe for the mitered sections. The laminates from adjacent joints may overlap each other. Mitered elbows 30° or less will be one-miter, two sections. Elbows above 30° and less than 60° shall have two miters. Elbows 60° to 90° shall have three miters. If specified by the purchaser, elbows with more miters may be provided. Incorporation of straight pipe extensions on elbows is permissible.

6.3.2 *Reducers*—Reducers of either concentric or eccentric style will have a length at least 2.5 times the difference in diameters.

6.3.2.1 When reducers are produced with a flange on the small end, the flange neck shall have enough length to allow for installation and tightening of flange bolts. See 6.3.4.2.

6.3.3 *Tees and Laterals*—shall have sufficient free length to accommodate the laminate used to join the fitting to adjacent pipe and any reinforcing laminate which may be required.

6.3.4 *Flanges*—All flanges shall meet the requirements of Specification D5421 (ASME SD-5421). The use of flanges shall normally be kept to a minimum with the butt joint being used as the standard means of joining pipe sections.

6.3.4.1 *Flange Attachment*—The minimum flange shear surface shall be four times the flange thickness. The thickness of the flange hub measured at the top of the fillet radius shall be at least one-half the flange thickness and shall be tapered uniformly the length of the hub. The fillet radius, where the back of the flange meets the hub, shall be ⅜ in. minimum (see Fig. 1).

6.3.4.2 *Flange Neck Length*—Flanges shall have sufficient free length to accommodate the laminate used to join the flange to adjacent pipe or fittings.

6.3.5 All cut edges directly in contact with the chemical being contained and any machined flange faces shall be coated with resin. The resin used shall be the same as the resin used in the equipment laminate and must contain paraffin to ensure adequate cure.

7. Requirements

7.1 *Proof of Design:*

7.1.1 Pipe, and fittings shall be pressure tested using free end closures to ensure loading in both the hoop and longitudinal directions using the procedures described in Test Method D1599. The test pipe and fittings shall be made with the same laminate type and resin as used on the production pipe. The minimum diameter shall be 8 in. (200 mm) and it shall have a minimum wall thickness of ¼ in. (6.5 mm). The actual diameter and thickness tested shall be agreed upon between the purchaser and the manufacturer.

7.1.1.1 The pipe may be tested using ambient temperature (50 to 80°F) (10 to 25°C) water as a test medium in lieu of the conditions required by Test Method D1599. For Proof of Design, the pipe or fitting, or both must withstand four times design pressure for one hour without leaking. Testing to destruction is not required.

7.1.1.2 Results from previously manufactured and tested pipe may be accepted by the purchaser provided that such pipe was manufactured with the same resin, laminate type, and thickness range within the previous five years.

NOTE 14—The test results for pipe manufactured with a non-structural corrosion barrier must be modified to determine the ultimate strength of the structural portion alone.

7.1.1.3 The intent of the testing is to demonstrate that the laminate type and thickness range used to fabricate the pipe meets the ultimate strength used in design. It is not necessary to test all diameters or thicknesses. The minimum testing is as follows: when ultimate strength is affected by thickness within a given laminate type, the thinnest laminate within each ultimate strength grade shall be tested, and, the diameter of the pipe used to test a given laminate shall be at least 15 times the laminate thickness. If the production pipe has a diameter to thickness ratio less than 15, then that ratio will be the minimum for the test pipe.

7.1.2 Pipe manufactured according to Design Basis Class A (See 5.1.1) and using a minimum design factor of ten need not be proof tested unless specified by the purchaser.

7.2 *Joints*—Joint strength shall be demonstrated by testing in accordance with 10.5. A representative joint shall withstand 4 times design pressure for one hour without leaking.

7.3 *Degree of Cure:*

7.3.1 *Barcol Hardness*—Degree of cure of the laminate shall be found by determining the Barcol hardness in accordance with Test Method D2583. The minimum Barcol hardness shall be 90 % of the resin manufacturer's published value.

NOTE 15—The use of organic reinforcing materials may reduce the Barcol hardness readings without necessarily indicating undercure.

NOTE 16—*Acetone Sensitivity*—A convenient check for the surface cure of polyester resins is as follows: remove mold release or paraffin wax, if present, and wipe clean of dust. Rub four or five drops of acetone on the laminate surface until it evaporates. If the surface becomes softened or tacky, it is an indication of undercure.

8. Dimensions and Tolerances

8.1 Standard diameters, based on internal measurements are 2, 3, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 30, 36, 42, and 48 in. (50, 75, 100, 150, 200, 250, 300, 355, 400, 460, 510, 610, 760, 915, 1065, 1220 mm). The tolerance for out-of-roundness, shall be ± 1⁄16 in. (± 1.5 mm) for pipe up to and including 6-in. (150 mm) inside diameter and ± ⅛ in. (± 3 mm) or ± 1 %, whichever is greater, for pipe exceeding 6 in. (150 mm) in inside diameter. This measurement shall be made at the point of manufacture with the pipe in an unstrained horizontal position.

8.2 *Wall Thickness*—The minimum average wall thickness of the pipe shall be as calculated in accordance with Section 5. For pipe walls less than ⅝ in. (16 mm) thick, the minimum wall thickness at any point shall not be less than 80 % of the

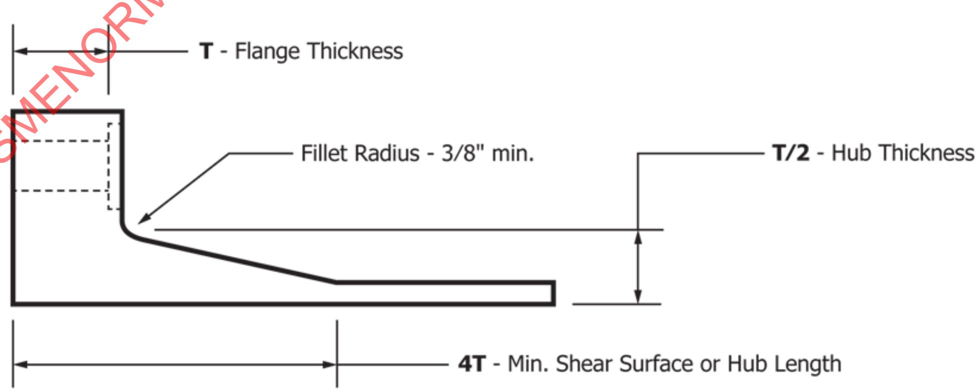

FIG. 1 Flange Dimensions

specified thickness. For pipe walls ⅝ in. (16 mm) or thicker, the minimum thickness at any point shall be ⅛ in. (3 mm) less than the specified wall thickness. Wall thickness shall be measured in accordance with Practice D3567.

8.3 *Length*—The length of each piece of plain end pipe shall not vary more than ±2 in. (± 50 mm) from the ordered length unless arrangements are made to allow for trim in the field.

8.4 *Squareness of Ends*—All unflanged pipe shall be cut square with the axis of the pipe within ±⅛ in. (±3 mm) up to and including 24 in. (610 mm) diameter and to within ±3⁄16 in. (5 mm) for all diameters above 24 in. (610 mm).

8.5 *Flange Faces*—Tolerance on perpendicularity and flatness shall be as specified in Test Method D5421. Other dimensions shall be as described in 6.3.3.

8.6 *Elbows, Tees, and Laterals*— The tolerance on the angles of elbows, tees, and laterals shall be ±1° for fittings through 24 in. in diameter and ±½ ° for larger diameters.

9. Workmanship, Finish, and Appearance

9.1 The minimum acceptable level for workmanship and finish of the finished laminate shall conform to the requirements specified in Specification C582 (ASME SC-582).

NOTE 17—A representative laminate sample may be used for determination of an acceptable surface finish and acceptable level of visual imperfections.

10. Test Methods

10.1 *Test Conditions*—Conduct the test at a laboratory temperature of 70 to 77°F (21 to 25°C) unless otherwise specified.

10.2 *Chemical Resistance of Resin*—Determine the chemical resistance of the resin in accordance with Practice C581, by documented experience provided by the pipe manufacturer or resin supplier (see 4.1.1), or recommendation from the resin supplier.

10.3 *Glass Content*—When required by the purchaser, determine the glass content in accordance with Test Method D2584.

10.4 *Tensile Strength*—Tensile strength of the laminate shall be determined using procedures in accordance with Test Method D638 with no upper limit on thickness.

10.5 *Short-time Hydraulic Failure Pressure* of the laminate shall be determined in accordance with Test Method D1599 using free end closures to ensure loading in both the hoop and longitudinal directions. The pipe may be tested at ambient temperature using ambient temperature (50 to 80°F) (10 to 25°C) water as a test medium in lieu of the conditions required by Test Method D1599.

10.6 *Physical Properties*—Where required, physical properties shall be determined in accordance with the test methods listed in Specification C582 (ASME SC-582).

11. Marking

11.1 Pipe shall be marked at least once per section with the following information in such a manner that it remains legible under normal handling and installation practices:

11.1.1 ASTM D6041 or ASME SD-6041 with which the pipe complies,

11.1.2 Nominal pipe size (for example, 12 in. (305 mm) diameter),

11.1.3 Pressure rating (for example, 150 psi (1034 kpa)),

11.1.4 Manufacturer's name or trademark, and

11.1.5 A 12 in. (305 mm) diameter 150 psi (1034 kpa) rated pipe would have the following marking: "ASTM D6041– 12" (305 mm) Dia. 150 psi (1034 kpa) XYZ Manufacturing Co."

12. Certification

12.1 See Annex A1 for certification requirements.

13. Keywords

13.1 certification; chemical resistant; contact molded; fiberglass; fittings; glass–fiber–reinforced thermosetting plastic; pipe

ANNEX

(Mandatory Information)

A1. CERTIFICATION

A1.1 When agreed upon in writing between the purchaser and the seller, a certification shall be made on the basis of acceptance material.

A1.2 Certification shall consist of a copy of the manufacturer's test report or a statement by the seller (accompanied by a copy of the test results) that the material has been sampled, tested, and inspected in accordance with the provisions of the specification.

A1.3 Each certification so furnished shall be signed by an authorized agent of the seller or manufacturer.

A1.4 When original identity cannot be established, certification can only be based on the sampling procedure provided by the applicable specification.

APPENDIXES

(Nonmandatory Information)

X1. INSTALLATION

X1.1 *Pipe Hangers*—Hangers shall be band type hangers contacting a minimum of 120° of the pipe surface. The width of the hanger band shall be based on the pipe diameter and wall thickness and the total load supported by the hanger.

X1.2 *Underground Installation*—Special consideration must be given to installing pipe underground. It is recommended that the manufacturer be consulted for installation and design procedures.

X1.3 *Expansion*—Since the expansion rate of this plastic pipe is several times that of steel, proper consideration should be given to any pipe installation to accommodate the overall linear expansion.

X1.4 *Bolts, Nuts, and Washers*—Bolts, nuts, and washers shall be furnished by the customer. Metal washers shall be used under all nut and bolt heads. All nuts, bolts, and washers shall be of materials suitable for use in the exterior environment.

X1.5 *Gaskets*—Gaskets shall be furnished by the customer. Recommended gasketing materials shall be a minimum of ⅛ in. (3 mm) in thickness with a suitable chemical resistance to the service environment. Gaskets should have a Shore A or Shore A2 Hardness of 40 to 70.

X2. HANDLING

X2.1 The following normal precautions should be taken in handling the pipe at the destination:

X2.2 Proper rigging practices should be observed at all times. Hoisting equipment operators should attach a guide line to prevent pipe from swinging out of control.

X2.3 Under no conditions should chains or cables be allowed to contact a pipe. Full protection shall be provided when using chains or cables. Do not attach lifting devices to any fitting.

X2.4 The pipe should not be dropped or allowed to strike any other object. Damage caused by dropping or striking other objects may result in cracking the inner corrosion-resistant liner as well as the structural portion of the pipe.

X2.5 The pipe should not be rolled or slid on rough ground. Never set pipe upon a fitting or other protrusion that may be attached to it.

X2.6 In working around pipe care should be exercised to prevent tools, scaffolding, or other objects from striking the pipe or being dropped on or inside the pipe. Soft-soled shoes should be worn by workmen entering large pipe.

SPECIFCATION FOR ELASTOMERIC SEALS (GASKETS) FOR JOINING PLASTIC PIPE

SF-477

(Identical with ASTM F477-14 except for revisions to paras. 7.11, 11.1; addition of paras. 2.3, 9.2, and Annex A1; and editorial changes.)