Nonmetallic Materials

Part 1 — Thermoplastic 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
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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[1] 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 (FRP) 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)

[1] *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.[2] 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.3.1-2018 was approved by the American National Standards Institute (ANSI) on August 16, 2018.

[2] 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.

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, NPPS Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard 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 periodically.

The Committee welcomes proposals for revisions to this Standard. 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 documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Interpretations. Upon request, the NPPS Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the NPPS Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the NPPS Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, 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 inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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.

Attending Committee Meetings. The NPPS Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the NPPS Standards Committee.

SPECIFICATIONS LISTED BY MATERIALS

Polyethylene of Raised Temperature (PE-RT)

Polypropylene (PP)

Polytetrafluoroethylene (PTFE)

Polyvinylidene Fluoride (PVDF)

INTRODUCTION

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

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 Glass-Fiber-Reinforced Thermosetting-Resin Piping Systems: This Standard contains requirements for piping and piping components that are produced using glass-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[1] for application under its requirements. Material produced to an acceptable material specification is not limited as to country of origin.

[1] 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.

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SPECIFICATION FOR RIGID POLY(VINYL CHLORIDE) (PVC) COMPOUNDS AND CHLORINATED POLY(VINYL CHLORIDE) (CPVC) COMPOUNDS

SD-1784

(Identical with ASTM D1784-11 except for additional requirements in section 13 and Annex A1, and renumbering of sections 14 and 15.)

Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

1. Scope

1.1 This specification covers rigid PVC and CPVC compounds intended for general purpose use in extruded or molded form—including pressure piping applications and nonpressure piping applications—composed of poly(vinyl chloride), chlorinated poly(vinyl chloride), or vinyl chloride copolymers containing at least 80 % vinyl chloride, and the necessary compounding ingredients. The compounding ingredients shall be permitted to consist of lubricants, stabilizers, non-poly(vinyl chloride) resin modifiers, pigments, and inorganic fillers.

NOTE 1—Selection of specific compounds for particular end uses or applications requires consideration of other characteristics such as thermal properties, optical properties, weather resistance, etc. Specific requirements and test methods for these properties should be by mutual agreement between the purchaser and the seller.

NOTE 2—Selection of compounds for pressure piping applications requires consideration of material stress ratings that are required for determining pressure ratings, but are not addressed in this specification. Requirements for long-term material stress ratings in accordance with recognized stress rating standards, such as HDB in accordance with Test Method D2837 for pressure piping, should be included in specifications for pressure piping products or systems.

NOTE 3—The list of compounding ingredients in 1.1 is not meant to be an exhaustive list of allowable compound ingredients. In addition to the compounding ingredients listed, others may also be used. The list of compounding ingredients in 1.1 does not imply that every ingredient listed is a required ingredient. Some compounds may not contain all the ingredients listed in 1.1.

1.2 For applications involving special chemical resistance see Classification D5260.

1.3 The requirements in this specification are intended for the quality control of compounds used to manufacture finished products. These properties are based on data obtained using standard test specimens tested under specified conditions. They are not directly applicable to finished products. See the applicable ASTM standards for requirements for finished products.

1.4 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.5 Rigid PVC recycle plastics meeting the requirements of this specification may be used in some applications. Refer to the specific requirements in the materials and manufacture section of the applicable product standard.

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

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

NOTE 4—This specification is similar in content (but not technically equivalent) to ISO 1163-1:1985 and ISO 1163-2:1980.

2. Referenced Documents

2.1 *ASTM Standards:*

D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
D618 Practice for Conditioning Plastics for Testing
D635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
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
D1600 Terminology for Abbreviated Terms Relating to Plastics
D3892 Practice for Packaging/Packing of Plastics

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D5260 Classification for Chemical Resistance of Poly(Vinyl Chloride) (PVC) Homopolymer and Copolymer Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

2.2 *ISO Standards:*
ISO 1163-1:1985
ISO 1163-2:1980

3. Terminology

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

4. Classification

4.1 Means for selecting and identifying rigid PVC and CPVC compounds are provided in Table 1. The properties enumerated in Table 1 and the tests defined are expected to provide identification of the compounds selected. They are not necessarily suitable for direct application in design because of differences in shape of part, size, loading, environmental conditions, etc.

4.2 Classes are designated by the cell number for each property in the order in which they are listed in Table 1.

NOTE 5—The manner in which selected materials are identified by this classification system is illustrated by a Class 12454 rigid PVC compound having the following requirements (see Table 1). The two-digit cell limits 10 and 11 are rarely used, only for special high-temperature grades of CPVC compound:

Class 1 2 4 5 4

Identification:
Poly(vinyl chloride) homopolymer — 1
Property and Minimum Value:
Izod (34.7 J/m (0.65 ft·lbf/in.)) under notch — 2
Tensile strength (48.3 MPa (7000 psi)) — 4
Modulus of elasticity in tension (2758 MPa (400 000 psi)) — 5
Deflection temperature under load (70°C (158°F)) — 4

NOTE 6—The cell-type format provides the means for identification and close characterization and specification of material properties, alone or in combination, for a broad range of materials. This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted.

4.3 Product application chemical resistance when specified shall be classified in accordance with the classification section of Classification D5260.

5. Ordering Information

5.1 The purchase order, or inquiry, for these materials shall state the specification number and identify the class selected, for example, D1784, Class 12454.

5.2 Further definition, as may be required for the following, shall be on the basis of agreement between the purchaser and the seller:
5.2.1 Physical form and particle size (see 6.1),
5.2.2 Contamination level (see 6.2),
5.2.3 Color (see 6.3),
5.2.4 Other supplementary definition if necessary, and
5.2.5 Inspection (see 12.1).

6. Materials and Manufacture

6.1 Materials supplied under this specification shall be PVC and CPVC compounds in the form of cubes, granules, free-flowing powder blends, or compacted powder blends.

6.2 Materials shall be of uniform composition and size and shall be free of foreign matter to such level of contamination as may be agreed upon between the purchaser and the seller.

6.3 Color and transparency or opacity of molded or extruded articles formed under the conditions recommended by the seller shall be comparable within commercial match tolerances to the color and transparency or opacity of standard molded or extruded samples of the same thickness supplied in advance by the seller of the material.

7. Physical Requirements

7.1 Test values for specimens of the material prepared as specified in Section 9 and tested in accordance with Section 10 shall conform to the requirements given in Table 1 for the class selected.

8. Sampling

8.1 A batch or lot shall be considered as a unit of manufacture and may consist of a blend of two or more production runs of material.

8.2 Sample using a statistically acceptable procedure.

9. Conformance Testing

9.1 The minimum properties identified by the class designations in Table 1 specified in the purchase order (see 5.1) shall be verified by the tests described in Section 11.

9.2 Conformance with this specification shall be determined with one set of test results. If there are multiple test results, the average value for all test samples shall be used to determine conformance.

9.3 If the average test value produces values below the minimum property values of the Class designation in Table 1, the material does not conform to this specification.

10. Specimen Preparation

10.1 Compliance with the designated requirements chosen from Table 1 shall be determined with compression-molded, extruded, or injection-molded test specimens for Izod impact

TABLE 1 Class Requirements for Rigid Poly(Vinyl Chloride) (PVC) and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

NOTE 1—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell.

Designation Order No.	Property and Unit	Cell Limits											
		0	1	2	3	4	5	6	7	8	9	10	11
1	Base resin	unspecified	poly(vinyl chloride) homopolymer	chlorinated poly (vinyl chloride)	vinyl copolymer								
2	Impact resistance (Izod), min:												
	J/m of notch under notch	unspecified	<34.7	34.7	80.1	266.9	533.8	800.7					
	ft·lb/in. of notch under notch		<0.65	0.65	1.5	5.0	10.0	15.0					
3	Tensile strength, min:												
	MPa	unspecified	<34.5	34.5	41.4	48.3	55.2						
	psi		<5 000	5 000	6 000	7 000	8 000						
4	Modulus of elasticity in tension, min:												
	MPa	unspecified	<1930	1930	2206	2482	2758	3034					
	psi		<280 000	280 000	320 000	360 000	400 000	440 000					
5	Deflection temperature under load, min, 1.82 MPa (264 psi):												
	°C	unspecified	<55	55	60	70	80	90	100	110	120	130	140
	°F		<131	131	140	158	176	194	212	230	251	266	284
	Flammability	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]

[A] All compounds covered by this specification, when tested in accordance with Test Method D635, shall yield the following results: average extent of burning of <25 mm; average time of burning of <10 s.

resistance, tensile strength, tensile modulus of elasticity, deflection temperature under load, and flammability. Specimens cut from laminates of compression-molded or extruded sections (see Practice D4703) shall not be used unless it can be shown by test that complete fusion is obtained. It is understood that a material shall not be tested without also specifying the method of specimen preparation. When comparative tests of materials are desired, the greatest care shall be taken to ensure that all specimens are prepared in exactly the same way used to certify the cell class of the compound. Procedures used in preparing the test specimens shall be as recommended by the supplier for each specific compound.

NOTE 7—It is possible that a specimen taken from a finished product will not produce the same results as a specimen prepared by the method used for purposes of cell class testing and certification.

11. Test Methods

11.1 *Conditioning*—The test specimen for deflection temperature (Test Method D648) shall be conditioned in accordance with Procedure B of Practice D618, except that the minimum conditioning time in the circulating air oven shall be 24 h. All other molded test specimens shall be conditioned in accordance with Procedure A of Practice D618. The minimum conditioning time shall be 24 h.

11.2 *Test Conditions*—Unless otherwise specified in the test methods or in this specification, tests shall be conducted in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±2 % relative humidity.

11.3 *Tensile Strength and Modulus of Elasticity*—Test Method D638, using Type I specimens of 3.2 ± 0.4 mm (0.13 ± 0.02 in.) thickness and testing speed of 5.1 mm (0.20 in.)/min ± 25 %. Report tensile strength at the yield point if the material yields, otherwise at break.

11.4 *Impact Resistance (Izod)*—Method A of Test Method D256, using 3.2-mm (0.125-in.) thick specimens. The specimens may be compression-molded, extruded, or injection-molded with the provision that compression-molded or extruded specimens built up as laminates in which complete fusion is obtained shall be acceptable. Complete fusion means there shall be no evidence of fraying or delamination at the break.

11.5 *Deflection Temperature*—Test Method D648–Method A- using 127 mm (5 in.) long, 12.5 mm (0.5 in.) wide, and 3.2 mm (0.125 in.) thick specimens under 1.82 MPa (264 psi) fiber stress. Materials that require high-temperature annealing prior to testing shall be annealed at 50°C (122°F) for 24 h or at the manufacturer's recommendation. Specimens shall be cooled in accordance with Procedure B of Practice D618. The test report for annealed specimens shall include the time and temperature of annealing used.

11.6 *Flammability*—Test Method D635. All compounds covered by this specification, when tested in accordance with Test Method D635, shall yield the following results: average extent of burning of <25 mm; average time of burning of <10 s.

12. Inspection

12.1 Inspection of the material shall be made as agreed upon between the purchaser and the seller as part of the purchase contract.

13. Certification

13.1 Certification shall be as required by Annex A1.

14. Packaging and Package Marking

14.1 *Packaging*—The material shall be packaged in standard commercial containers, so constructed as to 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.

14.2 *Marking*—Unless otherwise agreed upon between the purchaser and the seller, shipping containers shall be marked with the name of the material and the name of the manufacturer; class, batch, or lot number; quantity contained therein, as defined by the contract or order under which shipment is made; the name of the seller; and the number of the contract or order.

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

15. Keywords

15.1 chlorinated poly(vinyl chloride) (CPVC); CPVC compounds; poly(vinyl chloride) (PVC); PVC compounds; recycle plastics; rigid PVC

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR POLY(VINYL CHLORIDE) (PVC) PLASTIC PIPE, SCHEDULES 40, 80, AND 120

SD-1785

(Identical with ASTM D1785-12 except for additional requirements in section 12 and Annex A1, revised marking requirements in para. 10.2.1.4, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) pipe made in Schedule 40, 80, and 120 sizes and pressure-rated for water (see Appendix X1). Included are criteria for classifying PVC plastic pipe materials and PVC plastic pipe, a system of nomenclature for PVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 1—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

NOTE 2—This standard specifies dimensional, performance and test requirements for plumbing and fluid handling applications, but does not address venting of combustion gases.

1.3 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.

1.4 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.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 9.

NOTE 3—CPVC plastic pipes, Schedules 40 and 80, which were formerly included in this specification, are now covered by Specification F441/F441M.

NOTE 4—The sustained and burst pressure test requirements, and the pressure ratings in the Appendix X1, are calculated from stress values obtained from tests made on pipe 4 in. (100 mm) and smaller. However, tests conducted on pipe as large as 24-in. (600-mm) diameter have shown these stress values to be valid for larger diameter PVC pipe.

NOTE 5—PVC pipe made to this specification is often belled for use as line pipe. For details of the solvent cement bell, see Specification D2672 and for details of belled elastomeric joints, see Specifications D3139 and D3212.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

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

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2152 Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion

D2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement

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

D3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals

F412 Terminology Relating to Plastic Piping Systems

F441/F441M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water System Components—Health Effects

3. Terminology

3.1 *Definitions:*—Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for poly(vinyl chloride) plastic is PVC.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hydrostatic design stress*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.2.2 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.2.3 *relation between dimensions, design stress, and pressure rating*—the following expression, commonly known as the ISO equation, is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

$$2S/P = (D_0/t) - 1$$

where:

S = hydrostatic design stress, psi (or MPa),
P = pressure rating, psi (or MPa),
D_0 = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

3.2.4 *standard thermoplastic pipe materials designation code*—the pipe materials designation code shall consist of the abbreviation PVC for the type of plastic, followed by the ASTM type and grade in Arabic numerals and the design stress in units of 100 psi (0.7 MPa) with any decimal figures dropped. When the design stress code contains less than two figures, a cipher shall be used before the number. Thus a complete material code shall consist of three letters and four figures for PVC plastic pipe materials (see Section 5).

4. Classification

4.1 *General*—This specification covers PVC pipe made to and marked with one of six type/grade/design stress designations (see X1.2) in Schedule 40, 80, and 120 wall sizes.

4.2 *Hydrostatic Design Stresses*—This specification covers pipe made from PVC plastics as defined by four hydrostatic design stresses which have been developed on the basis of long-term tests (Appendix X1).

5. Materials and Manufacture

5.1 *General*—Poly(vinyl chloride) plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, (*1*) short-term strength tests and (*2*) long-term strength tests.

NOTE 6—The PVC 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 odors that are no less restrictive than those included in NSF Standard No. 14. The seal or mark of the laboratory making the evaluation should be included on the pipe. See pipe marking requirement for reclaimed water systems.

5.2 *Basic Materials*—This specification covers pipe made from PVC plastics having certain physical and chemical properties as described in Specification D1784.

5.3 *Compound*—The PVC compounds used for this pipe shall equal or exceed the following classes described in Specification D1784; PVC 12454, or 14333.

5.4 *Rework Material*—The manufacturer shall use only his own clean rework pipe material and the pipe produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Dimensions and tolerances shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D2122. The tolerances for out-of-roundness shall apply only to pipe prior to shipment.

6.2 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures given in Tables 3-5 when tested in accordance with 8.4.

TABLE 1 Outside Diameters and Tolerances for PVC Plastic Pipe Schedules 40, 80, and 120, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerances		
		Average	Maximum Out-of-Roundness (maximum minus minimum diameter)	
			Schedule 40 sizes 3½ in. and over; Schedule 80 sizes 8 in. and over	Schedule 40 sizes 3 in. and less; Schedule 80 sizes 6 in. and less; Schedule 120 sizes all
⅛	0.405 (10.29)	±0.004 (±0.10)	. . .	0.016 (0.41)
¼	0.540 (13.72)	±0.004 (±0.10)	. . .	0.016 (0.41)
⅜	0.675 (17.14)	±0.004 (±0.10)	. . .	0.016 (0.41)
½	0.840 (21.34)	±0.004 (±0.10)	. . .	0.016 (0.41)
¾	1.050 (26.67)	±0.004 (±0.10)	. . .	0.020 (0.51)
1	1.315 (33.40)	±0.005 (±0.13)	. . .	0.020 (0.51)
1¼	1.660 (42.16)	±0.005 (±0.13)	. . .	0.024 (0.61)
1½	1.900 (48.26)	±0.006 (±0.15)	. . .	0.024 (0.61)
2	2.375 (60.32)	±0.006 (±0.15)	. . .	0.024 (0.61)
2½	2.875 (73.02)	±0.007 (±0.18)	. . .	0.030 (0.76)
3	3.500 (88.90)	±0.008 (±0.20)	. . .	0.030 (0.76)
3½	4.000 (101.60)	±0.008 (±0.20)	0.100 (2.54)	0.030 (0.76)
4	4.500 (114.30)	±0.009 (±0.23)	0.100 (2.54)	0.030 (0.76)
5	5.563 (141.30)	±0.010 (±0.25)	0.100 (2.54)	0.060 (1.52)
6	6.625 (168.28)	±0.011 (±0.28)	0.100 (2.54)	0.070 (1.78)
8	8.625 (219.08)	±0.015 (±0.38)	0.150 (3.81)	0.090 (2.29)
10	10.750 (273.05)	±0.015 (±0.38)	0.150 (3.81)	0.100 (2.54)
12	12.750 (323.85)	±0.015 (±0.38)	0.150 (3.81)	0.120 (3.05)
14	14.000 (355.60	±0.015 (±0.38)	0.200 (5.08)	. . .
16	16.000 (406.40)	±0.019 (±0.48)	0.320 (8.13)	. . .
18	18.000 (457.20)	±0.019 (±0.48)	0.360 (9.14)	. . .
20	20.000 (508.00)	±0.023 (±0.58)	0.400 (10.2)	. . .
24	24.000 (609.60)	±0.031 (±0.79)	0.480 (12.2)	. . .

TABLE 2 Wall Thicknesses and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120,[A,B] in. (mm)

Nominal Pipe Size	Wall Thickness[A]					
	Schedule 40		Schedule 80		Schedule 120	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
⅛	0.068 (1.73)	+0.020 (+0.51)	0.095 (2.41)	+0.020 (+0.51)	. . .	. . .
¼	0.088 (2.24)	+0.020 (+0.51)	0.119 (3.02)	+0.020 (+0.51)	. . .	. . .
⅜	0.091 (2.31)	+0.020 (+0.51)	0.126 (3.20)	+0.020 (+0.51)	. . .	. . .
½	0.109 (2.77)	+0.020 (+0.51)	0.147 (3.73)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
¾	0.113 (2.87)	+0.020 (+0.51)	0.154 (3.91)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
1	0.133 (3.38)	+0.020 (+0.51)	0.179 (4.55)	+0.021 (+0.53)	0.200 (5.08)	+0.024 (+0.61)
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.215 (5.46)	+0.026 (+0.66)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.225 (5.72)	+0.027 (+0.68)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.250 (6.35)	+0.030 (+0.76)
2½	0.203 (5.16)	+0.024 (+0.61)	0.276 (7.01)	+0.033 (+0.84)	0.300 (7.62)	+0.036 (+0.91)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.350 (8.89)	+0.042 (+1.07)
3½	0.226 (5.74)	+0.027 (+0.68)	0.318 (8.08)	+0.038 (+0.96)	0.350 (8.89)	+0.042 (+1.07)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	0.437 (11.10)	+0.052 (+1.32)
5	0.258 (6.55)	+0.031 (+0.79)	0.375 (9.52)	+0.045 (+1.14)	0.500 (12.70)	+0.060 (+1.52)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	0.562 (14.27)	+0.067 (+1.70)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	0.718 (18.24)	+0.086 (+2.18)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	0.843 (21.41)	+0.101 (+2.56)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	1.000 (25.40)	+0.120 (+3.05)
14	0.437 (11.10)	+0.053 (+1.35)	0.750 (19.05)	+0.090 (+2.29)	. . .	. . .
16	0.500 (12.70)	+0.060 (+1.52)	0.843 (21.41)	+0.101 (+2.57)	. . .	. . .
18	0.562 (14.27)	+0.067 (+1.70)	0.937 (23.80)	+0.112 (+2.84)	. . .	. . .
20	0.593 (15.06)	+0.071 (+1.80)	1.031 (26.19)	+0.124 (+3.15)	. . .	. . .
24	0.687 (17.45)	+0.082 (+2.08)	1.218 (30.94)	+0.146 (+3.71)	. . .	. . .

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

[B] These dimensions conform to nominal IPS dimensions, with the exception that Schedule 120 wall thickness for pipe sizes ½ to 3½ in. (12.5 to 87.5 mm), inclusive, are special PVC plastic pipe sizes.

6.2.1 *Accelerated Regression Test*—The accelerated regression test shall be used in place of both the sustained and burst pressure tests, at the option of the manufacturer. The test shall be conducted in accordance with 8.4.1. The pipe shall demonstrate a hydrostatic design basis projection at the 100 000-h intercept that meets the hydrostatic design basis category requirement (see Tables 3-5 and Test Method D2837) for the PVC material used in its manufacture. (*Example:* PVC 1120 pipe must have a minimum 100 000-h projection of 3830 psi (26.40 MPa) and 85 % lower confidence limit (LCL).

TABLE 3 Sustained Pressure Test Conditions for Water at 73°F (23°C) for PVC Plastic Pipe, Schedule 40

Nominal Pipe Size	Pressure Required for Test[A]			
	PVC1120 PVC1220 PVC2120	PVC2116	PVC2112	PVC2110
in.	psi			
⅛	1690	1360	1130	930
¼	1640	1310	1090	900
⅜	1310	1050	870	720
½	1250	1000	840	690
¾	1010	810	680	550
1	950	760	630	520
1¼	770	620	520	420
1½	690	560	460	380
2	580	470	390	320
2½	640	510	430	350
3	590	440	370	300
3½	500	400	340	280
4	470	370	310	260
5	410	330	270	220
6	370	300	250	200
8	330	260	220	180
10	300	240	200	160
12	280	220	180	150
14	270	220	180	150
16	270	220	180	150
18	270	220	180	150
20	260	210	170	140
24	250	200	170	140
in.	MPa			
⅛	11.65	9.38	7.79	6.41
¼	11.31	9.03	7.52	6.21
⅜	9.03	7.24	6.00	4.96
½	8.62	6.89	5.79	4.76
¾	6.96	5.58	4.69	3.79
1	6.55	5.24	4.34	3.59
1¼	5.31	4.27	3.59	2.90
1½	4.76	3.86	3.17	2.62
2	4.00	3.24	2.69	2.21
2½	4.41	3.52	2.96	2.41
3	4.07	3.03	2.55	2.07
3½	3.45	2.76	2.34	1.93
4	3.24	2.55	2.14	1.79
5	2.83	2.28	1.86	1.52
6	2.55	2.07	1.72	1.38
8	2.28	1.79	1.52	1.24
10	2.07	1.65	1.38	1.10
12	1.93	1.52	1.24	1.03
14	1.89	1.54	1.26	1.05
16	1.89	1.54	1.26	1.05
18	1.89	1.54	1.26	1.05
20	1.82	1.47	1.19	0.98
24	1.75	1.40	1.19	0.98

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa
PVC1120	4200	29.0
PVC1220	4200	29.0
PVC2120	4200	29.0
PVC2116	3360	23.2
PVC2112	2800	19.3
PVC2110	2300	15.9

TABLE 4 Sustained Pressure Test Conditions for Water at 73°F (23°C) for PVC Plastic Pipe, Schedule 80

Nominal Pipe Size	Pressure Required for Test[A]			
	PVC1120 PVC1220 PVC2120	PVC2116	PVC2112	PVC2110
in.	psi			
⅛	2570	2060	1720	1410
¼	2370	1900	1580	1300
⅜	1930	1540	1290	1060
½	1780	1430	1190	980
¾	1440	1160	960	790
1	1320	1060	880	720
1¼	1090	870	730	600
1½	990	790	660	540
2	850	680	570	460
2½	890	710	590	490
3	790	630	520	430
3½	730	580	480	400
4	680	540	450	370
5	610	490	400	330
6	590	470	390	320
8	520	410	340	280
10	490	390	330	270
12	480	380	320	260
14	470	380	320	260
16	470	370	310	260
18	460	370	310	250
20	460	370	300	250
24	450	360	300	250
in.	MPa			
⅛	17.72	14.21	11.86	9.72
¼	16.34	13.10	10.90	8.96
⅜	13.31	10.62	8.89	7.31
½	12.27	9.86	8.20	6.76
¾	9.93	8.00	6.62	5.45
1	9.10	7.31	6.07	4.96
1¼	7.52	6.00	5.03	4.14
1½	6.83	4.96	4.55	3.72
2	5.86	4.69	3.93	3.17
2½	6.14	4.90	4.07	3.38
3	5.45	4.34	3.59	2.96
3½	5.03	4.00	3.31	2.76
4	4.69	3.72	3.10	2.55
5	4.21	3.38	2.76	2.28
6	4.07	3.24	2.69	2.21
8	3.59	2.83	2.34	1.93
10	3.38	2.69	2.28	1.86
12	3.31	2.62	2.21	1.79
14	3.29	2.66	2.24	1.82
16	3.29	2.59	2.17	1.82
18	3.22	2.59	2.17	1.75
20	3.22	2.59	2.10	1.75
24	3.15	2.52	2.10	1.75

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa
PVC1120	4200	29.0
PVC1220	4200	29.0
PVC2120	4200	29.0
PVC2116	3360	23.2
PVC2112	2800	19.3
PVC2110	2300	15.9

6.3 *Burst Pressure*—The minimum burst pressures for PVC plastic pipe shall be as given in Table 6, when determined in accordance with Test Method D1599.

NOTE 7—Times greater than 60 s may be needed to bring large size specimens to burst pressure. The test is more difficult to pass using greater pressurizing times.

6.4 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 8.6.

6.5 *Extrusion Quality*—The pipe shall not flake or disintegrate when tested in accordance with Test Method D2152.

TABLE 5 Sustained Pressure Test Conditions for Water at 73°F (23°C) for PVC Plastic Pipe, Schedule 120

Nominal Pipe Size	Pressure Required for Test[A]			
	PVC1120 PVC1220 PVC2120	PVC2116	PVC2112	PVC2110
in.	psi			
½	2130	1710	1420	1170
¾	1620	1300	1080	890
1	1510	1200	1000	830
1¼	1250	1000	830	680
1½	1130	900	750	620
2	990	790	660	540
2½	980	780	650	540
3	930	750	620	510
3½	810	640	540	440
4	900	720	600	490
5	830	660	550	450
6	780	620	520	430
8	760	610	510	420
10	770	620	510	420
12	710	570	480	390
in.	MPa			
½	14.69	11.79	9.79	8.07
¾	11.17	8.96	7.45	6.14
1	10.41	8.27	6.89	5.72
1¼	8.62	6.89	5.72	4.69
1½	7.79	6.21	5.17	4.27
2	6.83	5.45	4.55	3.72
2½	6.76	5.38	4.48	3.72
3	6.41	5.17	4.27	3.52
3½	5.58	4.41	3.72	3.03
4	6.21	4.96	4.14	3.38
5	5.72	4.55	3.79	3.10
6	5.38	4.27	3.59	2.96
8	5.24	4.21	3.52	2.90
10	5.31	4.27	3.52	2.90
12	4.90	3.93	3.31	2.69

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa
PVC1120	4200	29.0
PVC1220	4200	29.0
PVC2120	4200	29.0
PVC2116	3360	23.2
PVC2112	2800	19.3
PVC2110	2300	15.9

7. Workmanship, Finish, and Appearance

7.1 The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

NOTE 8—Color and transparency or opacity should be specified in the contract or purchase order.

8. Test Methods

8.1 *Conditioning*—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, for those tests where conditioning is required.

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

8.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

8.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

8.4 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressures given in Tables 3-5, six specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) or more than 3 ft (1 m) between end closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi (±70 kPa). Condition the specimens at the test temperature of 73.4°F (23°C) to within 3.6°F (±2°C). Test in accordance with Test Method D1598, except maintain the pressure at the values given in Tables 3-5 for 1000 h. Failure of two of the six specimens tested shall constitute failure in the test. Failure of

TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Plastic Pipe, Schedules 40, 80, and 120

Nominal Pipe Size	Min Burst Pressures[A]					
	Schedule 40		Schedule 80		Schedule 120	
	PVC1120 PVC1220 PVC2120	PVC2112 PVC2116 PVC2110	PVC1120 PVC1220 PVC2120	PVC2112 PVC2116 PVC2110	PVC1120 PVC1220 PVC2120	PVC2112 PVC2116 PVC2110
in.	psi					
⅛	2580	2020	3920	3060	. . .	. . .
¼	2490	1950	3620	2830	. . .	. . .
⅜	1990	1560	2940	2300	. . .	. . .
½	1910	1490	2720	2120	3250	2540
¾	1540	1210	2200	1720	2470	1930
1	1440	1130	2020	1580	2300	1790
1¼	1180	920	1660	1300	1900	1490
1½	1060	830	1510	1180	1720	1340
2	890	690	1290	1010	1510	1180
2½	970	760	1360	1060	1490	1170
3	840	660	1200	940	1420	1110
3½	770	600	1110	860	1230	960
4	710	560	1040	810	1380	1080
5	620	390	930	720	1260	990
6	560	440	890	700	1190	930
8	500	390	790	620	1160	910
10	450	350	750	580	1170	920
12	420	330	730	570	1090	850
14	410	320	720	570	. . .	. . .
16	410	320	710	560	. . .	. . .
18	410	320	700	550	. . .	. . .
20	390	310	700	540	. . .	. . .
24	380	300	680	530	. . .	. . .
in.	MPa					
⅛	17.79	13.93	27.03	21.10	. . .	. . .
¼	17.17	13.45	24.96	19.52	. . .	. . .
⅜	13.72	10.76	20.27	15.86	. . .	. . .
½	13.17	10.27	18.76	14.62	22.41	17.52
¾	10.62	8.34	15.17	11.86	17.03	13.31
1	9.93	7.79	13.93	10.89	15.86	12.34
1¼	8.14	6.34	11.45	8.96	13.10	10.27
1½	7.31	5.72	10.41	8.14	11.86	9.24
2	6.14	4.76	8.89	6.96	10.41	8.14
2½	6.69	5.24	9.38	7.31	10.27	8.07
3	5.79	4.55	8.27	6.48	9.79	7.65
3½	5.31	4.14	7.65	5.93	8.48	6.62
4	4.90	3.86	7.17	5.58	9.51	7.45
5	4.27	2.69	6.41	4.96	8.69	6.83
6	3.86	3.03	6.14	4.83	8.20	6.41
8	3.45	2.69	5.45	4.27	8.00	6.27
10	3.10	2.41	5.17	4.00	8.07	6.34
12	2.90	2.28	5.03	3.93	7.52	5.86
14	2.87	2.24	5.04	3.99	. . .	. . .
16	2.87	2.24	4.97	3.92	. . .	. . .
18	2.87	2.24	4.90	3.85	. . .	. . .
20	2.73	2.17	4.90	3.78	. . .	. . .
24	2.66	2.10	4.76	3.71	. . .	. . .

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa
PVC1120	6400	44.1
PVC1220	6400	44.1
PVC2120	6400	44.1
PVC2116	5000	34.5
PVC2112	5000	34.5
PVC2110	5000	34.5

one of the six specimens tested in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

8.4.1 *Accelerated Regression Test*—Test in accordance with procedures in Test Method D1598, using either free end or restrained end fittings. A minimum of six samples shall be tested. Test three specimens at a single pressure that will result in failures at or below 0.10 h. Test an additional three specimens at a single pressure that will result in failures at about 200 h. Generating additional data points to improve the LTHS or LCL, or both, is acceptable. No points shall be excluded unless an obvious defect is detected in the failure area of the test sample, or there was a malfunction of the equipment. Characterize the data using the least squares regression described in Test Method D2837.

8.5 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599. The time of testing of each specimen shall be between 60 and 70 s.

8.6 *Flattening*—Flatten three specimens of the pipe each at least 2 in. (50 mm) long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe or the walls of the pipe touch, whichever occurs first. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. On removal of the load examine the specimens for evidence of splitting, cracking, or breaking.

9. Retest and Rejection

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 seller. Under such agreement, minimum requirements shall not be lowered, 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. Product Marking

10.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

10.2 *Content of Marking:*

10.2.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft (1.5 m):

10.2.1.1 Nominal pipe size (for example, 2 in. (50 mm)),

10.2.1.2 Type of plastic pipe material in accordance with the designation code prescribed in 3.2.4, for example, PVC1120,

10.2.1.3 Schedule (40, 80, or 120, whichever is applicable) and the pressure rating in pounds per square inch (megapascals) for water at 73°F (23°C) shown as the number followed by psi (for example, 200 psi (1.4 MPa)). When the indicated pressure rating is lower than that calculated in accordance with 3.2.3 (see Appendix X1), this shall be indicated by placing a star after the pressure rating,

10.2.1.4 ASME SD-1785 or both ASME SD-1785 and ASTM D1785,

10.2.1.5 Manufacturer's name (or trademark),

10.2.1.6 Production code with which the manufacturer can trace the year, month, day, shift, plant and extruder of manufacture for this product, and

10.2.1.7 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 9—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

NOTE 10—It is common practice to dual mark Schedule 40 piping for potable water and DWV usage in which compliance with each applicable standard is met.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 pressure pipe; PVC pipe; Schedule 40 pipe; Schedule 80 pipe; Schedule 120 pipe

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a regulatory authority or user calls for product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

This requirement applies only to pipe to be used in systems that have not established other provisions for identification.

S2.*Pipe Marking Requirement for Reclaimed Water Systems*—Color identification of pipe shall be by *(1)* use of purple (violet) PVC material or *(2)* by use of continuous purple stripes printed lengthwise on opposite sides of the pipe. The pipe shall be marked RECLAIMED WATER at intervals of 5 ft. or less.

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Pipe for Reclaimed-Water System*—Pipe used in these systems shall be purple (violet) in color and it shall be marked **Reclaimed Water**.

S2. *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 may 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 S2.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S3. *Packaging and Marking for U.S. Government Procurement:*

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S3.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 The hydrostatic design stresses recommended by the Plastics Pipe Institute are used to pressure rate PVC plastic pipe. These hydrostatic design stresses are 2000 psi (14 MPa), 1600 psi (11 MPa), 1250 psi (9 MPa), and 1000 psi (7 MPa) for water at 73°F (23°C). These hydrostatic design stresses apply only to pipe meeting all the requirements of this specification.

X1.2 Six PVC pipe materials are included based on the requirements of Specification D1784 and the PPI-recommended hydrostatic design stresses as follows:

X1.2.1 Type I, Grade 1 (12454-B), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC1120.

X1.2.2 Type I, Grade 2 (12454-C), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC1220.

X1.2.3 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC2120.

X1.2.4 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1600 psi (11.2 MPa), designated as PVC2116.

X1.2.5 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1250 psi (8.7 MPa), designated as PVC2112.

X1.2.6 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1000 psi (7.0 MPa), designated as PVC2110.

X1.3 The standard method for obtaining hydrostatic basis for thermoplastic pipe materials is Test Method D2837. Additional information regarding the test method and other criteria used in developing these hydrostatic design stresses may be obtained from the Plastics Pipe Institute, a division of The Society of the Plastics Industry, 355 Lexington Ave., New York, NY 10017. These hydrostatic design stresses may not be suitable for materials that show a wide departure from a straight-line plot of log stress versus log time to failure. All the data available to date on PVC pipe materials made in the United States exhibit a straight-line plot under these plotting conditions.

X1.4 The pipe is rated for use with water at 73°F (23°C) at the maximum internal pressures shown in Tables X1.1-X1.3. Lower pressure ratings than those calculated in accordance with 3.2.3 may be recommended, at the option of the pipe manufacturer, in which case the SDR shall be included in the marking. Experience of the industry indicates that PVC plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.5 The hydrostatic design stresses recommended by the Plastics Pipe Institute are based on tests made on pipe ranging in size from ½ to 2½ in. (12.5 to 63.5 mm).

TABLE X1.1 Water Pressure Ratings at 73°F (23°C) for Schedule 40 PVC Plastic Pipe

Nominal Pipe Size	Pressure Ratings[A]			
	PVC1120[B] PVC1220 PVC2120	PVC2116	PVC2112[B]	PVC2110[B]
in.	psi			
⅛	810	650	500	400
¼	780	620	490	390
⅜	620	500	390	310
½	600	480	370	300
¾	480	390	300	240
1	450	360	280	220
1¼	370	290	230	180
1½	330	260	210	170
2	280	220	170	140
2½	300	240	190	150
3	260	210	160	130
3½	240	190	150	120
4	220	180	140	110
5	190	160	120	100
6	180	140	110	90
8	160	120	100	80
10	140	110	90	70
12	130	110	80	70
14	130	100	80	60
16	130	100	80	60
18	130	100	80	60
20	120	100	80	60
24	120	90	70	60
in.	MPa			
⅛	5.58	4.48	3.45	2.76
¼	5.38	4.27	3.38	2.69
⅜	4.27	3.45	2.69	2.14
½	4.14	3.31	2.55	2.07
¾	3.31	2.69	2.07	1.65
1	3.10	2.48	1.93	1.52
1¼	2.55	2.04	1.59	1.24
1½	2.28	1.79	1.45	1.17
2	1.93	1.52	1.17	0.97
2½	2.07	1.65	1.31	1.03
3	1.79	1.45	1.10	0.90
3½	1.65	1.31	1.03	0.83
4	1.52	1.24	0.97	0.76
5	1.31	1.10	0.83	0.69
6	1.24	0.97	0.76	0.62
8	1.10	0.83	0.69	0.55
10	0.97	0.76	0.62	0.48
12	0.90	0.76	0.55	0.48
14	0.91	0.70	0.56	0.42
16	0.91	0.70	0.56	0.42
18	0.91	0.70	0.56	0.42
20	0.84	0.70	0.56	0.42
24	0.84	0.63	0.49	0.42

[A] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading PVC plastic pipe in Schedule 40 dimensions in nominal pipe sizes 6 in. (150 mm) and smaller.
[B] See Appendix X1 for code designation.

TABLE X1.2 Water Pressure Ratings at 73°F (23°C) for Schedule 80 PVC Plastic Pipe

Nominal Pipe Size, in.	psi							
	PVC1120, PVC1220, PVC2120		PVC2116		PVC2112		PVC2110	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
⅛	1230	610	980	490	770	380	610	310
¼	1130	570	900	450	710	350	570	280
⅜	920	460	730	370	570	290	460	230
½	850	420	680	340	530	260	420	210
¾	690	340	550	280	430	210	340	170
1	630	320	500	250	390	200	320	160
1¼	520	260	420	210	320	160	260	130
1½	470	240	380	190	290	150	240	120
2	400	200	320	160	250	130	200	100
2½	420	210	340	170	260	130	210	110
3	370	190	300	150	230	120	190	90
3½	350	170	280	140	220	110	170	90
4	320	160	260	130	200	100	160	80
5	290	140	230	120	180	90	140	70
6	280	140	220	110	170	90	140	70
8	250	120	200	100	150	80	120	60
10	230	120	190	90	150	70	120	60
12	230	110	180	90	140	70	110	60
14	220	. . .	180	. . .	140	. . .	110	. . .
16	220	. . .	180	. . .	140	. . .	110	. . .
18	220	. . .	180	. . .	140	. . .	110	. . .
20	220	. . .	170	. . .	140	. . .	110	. . .
24	210	. . .	170	. . .	130	. . .	110	. . .
	MPa							
⅛	8.48	4.21	6.76	3.38	5.31	2.62	4.21	2.14
¼	7.79	3.93	6.21	3.10	4.90	2.41	3.93	1.93
⅜	6.34	3.17	5.03	2.55	3.93	2.00	3.17	1.59
½	5.86	2.90	4.69	2.34	3.65	1.79	2.90	1.45
¾	4.76	2.34	3.79	1.93	2.96	1.45	2.34	1.17
1	4.34	2.21	3.45	1.72	2.69	1.38	2.21	1.10
1¼	3.59	1.79	2.90	1.45	2.21	1.10	1.79	0.90
1½	3.24	1.65	2.62	1.31	2.0	1.03	1.65	0.83
2	2.76	1.38	2.21	1.10	1.72	0.90	1.38	0.69
2½	2.90	1.45	2.34	1.17	1.79	0.90	1.45	0.76
3	2.55	1.31	2.07	1.03	1.59	0.83	1.31	0.62
3½	2.41	1.17	1.93	0.97	1.52	0.76	1.17	0.62
4	2.21	1.10	1.79	0.90	1.38	0.69	1.10	0.55
5	2.00	0.97	1.59	0.83	1.24	0.62	0.97	0.48
6	1.93	0.97	1.52	0.76	1.17	0.62	0.97	0.48
8	1.72	0.83	1.38	0.69	1.03	0.55	0.83	0.41
10	1.59	0.83	1.31	0.62	1.03	0.48	0.83	0.41
12	1.59	0.76	1.24	0.62	0.97	0.48	0.76	0.41
14	1.54	. . .	1.26	. . .	0.98	. . .	0.77	. . .
16	1.54	. . .	1.26	. . .	0.98	. . .	0.77	. . .
18	1.54	. . .	1.26	. . .	0.98	. . .	0.77	. . .
20	1.54	. . .	1.19	. . .	0.98	. . .	0.77	. . .
24	1.47	. . .	1.19	. . .	0.91	. . .	0.77	. . .

TABLE X1.3 Water Pressure Ratings at 73°F (23°C) for Schedule 120 PVC Plastic Pipe

Nominal Pipe Size, in.	psi							
	PVC1120, PVC1220, PVC2120		PVC2116		PVC2112		PVC2110	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
½	1010	510	810	410	630	320	510	250
¾	770	390	620	310	480	240	390	190
1	720	360	570	290	450	220	360	180
1¼	600	300	480	240	370	190	300	150
1½	540	270	430	210	340	170	270	130
2	470	240	380	190	290	150	240	120
2½	470	230	370	190	290	150	230	120
3	440	220	360	180	280	140	220	110
3½	380	190	310	150	240	120	190	100
4	430	220	340	170	270	130	220	110
5	400	200	320	160	250	120	200	100
6	370	190	300	150	230	120	190	90
8	380	180	290	140	230	110	180	90
10	370	180	290	140	230	110	180	90
12	340	170	270	140	210	110	170	80
	MPa							
½	6.96	3.52	5.58	2.83	4.34	2.21	3.52	1.72
¾	5.31	2.69	4.27	2.14	3.31	1.65	2.69	1.31
1	4.96	2.48	3.93	2.00	3.10	1.52	2.48	1.24
1¼	4.14	2.07	3.31	1.65	2.55	1.31	2.07	1.03
1½	3.72	1.86	2.96	1.45	2.34	1.17	1.86	0.90
2	3.24	1.65	2.62	1.31	2.00	1.03	1.65	0.83
2½	3.24	1.59	2.55	1.31	2.00	1.03	1.59	0.83
3	3.03	1.52	2.48	1.24	1.93	0.97	1.52	0.76
3½	2.62	1.31	2.14	1.03	1.65	0.83	1.31	0.69
4	2.96	1.52	2.34	1.17	1.86	0.90	1.52	0.76
5	2.76	1.38	2.21	1.10	1.72	0.83	1.38	0.69
6	2.55	1.31	2.07	1.03	1.59	0.83	1.31	0.62
8	2.62	1.24	2.00	0.97	1.59	0.76	1.24	0.62
10	2.55	1.24	2.00	0.97	1.59	0.76	1.24	0.62
12	2.34	1.17	1.86	0.97	1.45	0.76	1.17	0.55

SPECIFICATION FOR FEP-FLUOROCARBON MOLDING AND EXTRUSION MATERIALS

SD-2116

(Identical with ASTM D2116-07(R12) except for revisons in para. 7.1 and section 13, additional requirements in section 14 and Annex A1, and renumbering of section 15.)

Specification for FEP-Fluorocarbon Molding and Extrusion Materials

1. Scope

1.1 This specification covers melt processable molding and extrusion materials of FEP-fluorocarbon resin. This specification does not cover recycled FEP materials. These FEP resins are copolymers of tetrafluoroethylene and hexafluoropropylene or modified FEP-fluorocarbon resins containing not more than 2 % by weight of other fluoromonomers.

1.2 The values stated in SI units as detailed in IEEE/ASTM SI-10 are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—Although this specification and ISO 12086-1 and ISO 12086-2 differ in approach or detail, data obtained using either are technically equivalent.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1600 Terminology for Abbreviated Terms Relating to Plastics
D3295 Specification for PTFE Tubing, Miniature Beading and Spiral Cut Tubing
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3892 Practice for Packaging/Packing of Plastics
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
IEEE/ASTM SI-10 Use of the International System of Units (SI): The Modern Metric System

2.2 *ISO Standards:*

ISO 12086-1 Plastics—Fluoropolymer Dispersions and Moulding and Extrusion Materials—Part 1
ISO 12086-2 Plastics—Fluoropolymer Dispersions and Moulding and Extrusion Materials—Part 2

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—The definitions given in Terminology D883 are applicable to this specification.

3.1.2 *lot, n*—one production run or a uniform blend of two or more production runs.

3.2 *Abbreviated Terms:*

3.2.1 *General*—The abbreviated terms given in Terminology D1600 are applicable to this specification.

4. Classification

4.1 This specification covers four types of FEP-fluorocarbon resin supplied in pellet form classified according to their melt flow rate.

4.2 A one-line system shall be used to specify materials covered by this specification. The system uses predefined cells to refer to specific aspects of this specification, illustrated as follows:

Specification		
Standard Number Block :	Type :	Special notes
:	:	:
___________	___	,____

Example: Specification D2116 – XX, I

For this example, the line callout would be Specification D2116 – XX, I and would specify an FEP-fluorocarbon resin that has all of the properties listed for that type, grade, and class in the appropriate specified properties or tables, or both, in the specification identified. A comma is used as the separator between the standard number and the type. A provision for special notes is included so that other information can be provided when required. When special notes are used, precede them with a comma.

5. General Requirements

5.1 The materials shall be of uniform composition and so prepared as to conform to the requirements of this specification.

5.2 The material described in this specification shall be free of foreign matter to such a contamination level as is agreed upon between the purchaser and the seller.

TABLE 1 Detail Requirements for Test on Molding Materials

	Type I	Type II	Type III	Type IV
Melt flow rate, g/10 min:				
Load, 5000 g:				
Min	4.0	>12.0	0.8	2.0
Max	12.0	...	2.0	3.9

6. Detail Requirements

6.1 The average test result of the lot shall conform to the requirements prescribed in Table 1 and Table 2 when tested by the procedures specified herein. Table 2 lists those tests requiring a specimen molded as described in Section 8.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy requirements of Annex A1.

8. Test Specimens

8.1 Prepare a molded sheet 1.5 ± 0.3 mm (0.060 ± 0.010 in.) thick. Use a picture-frame-type chase having a suitable blanked-out section and thickness to produce the desired sheet. Use clean aluminum foil, 0.13 to 0.18 mm (0.005 to 0.007 in.) thick, in contact with the resin. A high-temperature mold release agent shall be sprayed on the aluminum foil to help prevent the foil from sticking to the sheet. Use steel molding plates at least 1.0 mm (0.040 in.) thick and of an area adequate to cover the chase.

8.2 Lay down and smoothly cover one plate with a sheet of aluminum foil. Place the mold chase on top of this assembly. Place within the mold chase sufficient molding material to produce the required sheet in such a manner that the polymer charge is a mound in the middle of the chase. Place a second sheet of aluminum foil on top of the granules and add the top mold plate. Place the assembly in a compression molding press having platens that have been heated to 372 ± 5°C (702 ± 9°F).

8.3 Bring the platens to incipient contact with the mold assembly. Hold for 2 to 4 min without pressure. Apply approximately 1 MPa (145 psi) and hold for 1 to 1.5 min. Then apply 2 to 4 MPa (290 to 580 psi) and hold for 1 to 1.5 min. Maintain the press at 372 ± 5°C (702 ± 9°F) during these steps. Remove the assembly from the press and place between two 20 ± 7-mm (0.75 ± 0.25-in.) steel plates whose temperature is less than 40°C (104°F).

8.4 When the sheet is cool enough to touch (about 50 to 60°C (122 to 140°F)), remove aluminum foil from the sheet. (If the sheet is allowed to cool to room temperature, the aluminum foil cannot be pulled free.)

9. Conditioning

9.1 For tests of specific gravity and tensile properties, condition the molded test specimens in accordance with Procedure A of Practice D618 for a period of at least 4 h prior to test. The other tests require no conditioning.

TABLE 2 Detail Requirements for Molded Test Specimens

	Type I	Type II	Type III	Type IV
Specific gravity 23/23°C (73/73°F)				
Min	2.12	2.12	2.12	2.12
Max	2.17	2.17	2.17	2.17
Melting point, °C	260 ± 20	260 ± 20	260 ± 20	260 ± 20
Tensile strength, 23°C (73°F), min:				
MPa	17.3	14.5	20.7	18.7
psi	2500	2100	3000	2700
Elongation, 23°C (73°F), min, %	275	240	275	275
Dielectric constant, max:				
At 10^3 Hz	2.15	2.15	2.15	2.15
At 10^6 Hz	2.15	2.15	2.15	2.15
Dissipation factor, max:				
At 10^3 Hz	0.0003	0.0003	0.0003	0.0003
At 10^6 Hz	0.0007	0.0009	0.0007	0.0007

9.2 Conduct tests at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3.6°F) for determination of specific gravity and tensile properties only. Since this resin does not absorb water, the maintenance of constant humidity during testing is not necessary. Conduct tests for melt flow rate and melting point under ordinary laboratory conditions.

10. Packaging and Marking

10.1 *Packaging*—The resin pellets shall be packaged in standard commercial containers so constructed as to ensure acceptance by common or other carriers for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10.2 *Marking*—Shipping containers shall be marked with the name of the material, type, and quantity contained therein.

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

11. Test Methods

11.1 *Melt Flow Rate:*

11.1.1 *Principle of Test Method*—The melt flow rate is determined at 372 ± 1°C using Procedure A or B described in Test Method D1238. The extrusion plastometer to be used is described in Test Method D1238 modified by use of corrosion resistant alloy for the barrel lining, orifice, piston tip, and orfice securing device. Use pellets or pieces of approximately the same size cut from molded or extruded forms. Strips about 6 mm (¼ in.) by 76 mm (3 in.) long also load readily into the barrel. Refer to Table 2 or Table 3 of Test Method D1238 for the amount of charge which shall be adjusted accordingly with melt density of FEP being used. Usually the charge amount is 5 to 15 g. Flow rate is measured using a load of 5000 g. Collect five successive cuts for the manual method.

11.2 *Specific Gravity*—Determine the specific gravity on a specimen approximately 25.4 by 38 mm (1 by 1.5 in.) blanked or cut from the molded plaque (Section 8) in accordance with the procedures described in Test Methods D792. Add 2 drops of a wetting agent to the water in order to reduce the surface tension and ensure complete wetting of the specimen.

11.3 *Melting Point:*

11.3.1 *Melting Characteristics by Thermal Analysis*—Use differential scanning calorimetry (DSC) as described in Test Method D3418 for this determination. For specification purposes, the test shall be run on a 10 ± 2-mg specimen cut from a pellet of the resin as sold or received. The heating rate shall be 10 ± 1°C (18 ± 1.8°F)/min. Two peaks during the initial melting test are observed occasionally. In this case, the peak temperatures shall be reported as T_l for the lower temperature and T_u for the upper temperature. The peak temperature of the peak largest in height shall be reported as the melting point if a single value is required. If a peak temperature is difficult to discern from the curves, that is, if the peak is rounded rather than pointed, straight lines shall be drawn tangent to the sides of the peak. The temperature corresponding to the point where these lines intersect beyond the peak shall be taken as the peak temperature.

11.4 *Tensile Properties*—Cut five bars with the microtensile die shown in Fig. 1. The die shall be of the steel rule or solid metal type of curvature of 5 ± 0.5 mm (0.2 ± 0.02 in.). Average the test results. Determine the tensile properties in accordance with the procedures described in Test Method D638, except that the specimens used shall be as detailed in Section 8, the initial jaw separation shall be 22.2 ± 0.13 mm (0.875 ± 0.005 in.), and the speed of testing shall be 50 ± 5 mm/min (2 ± 0.2 in./min). Clamp the specimen with essentially equal lengths in each jaw. Determine the elongation from the chart, expressing it as a percentage of the initial jaw separation.

NOTE 2—In determining elongation from the chart, drop a perpendicular from the break point to the time axis. Measure the distance along the time axis from the foot of this perpendicular to the beginning of the load-time curve. Then,

$$\text{Elongation, \%} = 100d/(22.2 \text{ or } 0.875)m \tag{1}$$

where:

d = distance on chart, mm (in.),
m = chart speed magnification,
= chart speed/crosshead speed (both in same units), and
22.2 = factor when d is in millimetres, or
0.875 = factor when d is in inches.

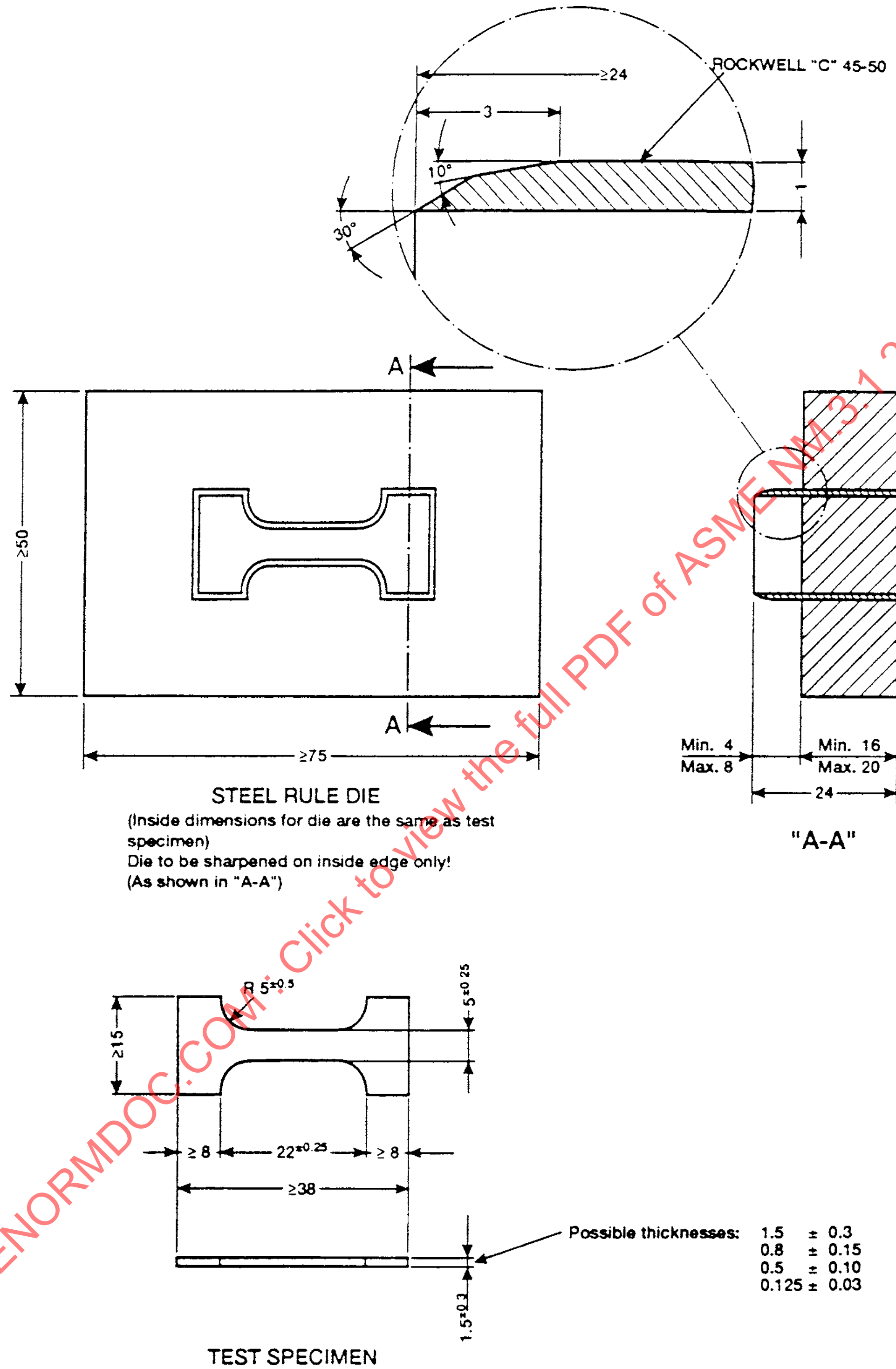
In making the test for tensile properties a full-scale load of 22.5 kg (50 lb) has been found suitable. If specimens break quickly, increase the chart speed so that each curve covers at least 51 mm (2 in.) on the time axis of the chart.

11.5 *Precision and Bias:*

11.5.1 *Precision*—Table 3 is based on a round robin conducted in 1985–1986 in accordance with Practice E691, involving seven materials tested by six laboratories. For each material, the sheeting from which the test specimens were to be cut was obtained from one source. Using a steel rule die, one set of test specimens for each laboratory was cut by one of the laboratories. Sheeting and a duplicate die were furnished each participating laboratory and used to cut a second set of test specimens. Each test result was the average of five individual determinations. Each laboratory obtained four test results on each material, two test results each on the specimens furnished and two on the specimens cut by the laboratory doing the testing.

11.5.1.1 The properties used in the analysis are tensile strength and elongation at break. (**Warning—**The following explanations of I_r and I_R (11.5.1.4-11.5.1.6) are intended only to present a meaningful way of considering the approximate precision of this test method. Do not apply rigorously the data in Table 3 to the acceptance or rejection of material as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories.)

11.5.1.2 Users of this test method shall apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 11.5.1.4-11.5.1.6 would then be valid for such data.



NOTE 1—All Dimensions are in millimetres.

FIG. 1 Microtensile Die

11.5.1.3 *Concept of I_r and I_R*—If CV_r and CV_R have been calculated from a large enough body of data, and for test results:

11.5.1.4 *I_r: Repeatability*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, the two test results shall be judged not equivalent if they differ by more than the I_r value for that material.

11.5.1.5 *I_R: Reproducibility*—In comparing two test results for the same material, obtained by different operators using

TABLE 3 Precision Summary, Tensile Strength and Elongation at Break

NOTE 1—$I_r = 2.8 \times CV_r$; $I_R = 2.8\ CR_R$.

Material	Mean, psi	CV_r, %	CV_R, %	I_r, %	I_R, %
		Tensile Strength			
FEP	4144	2.98	7.98	8.34	22.34
		Percentage Elongation at Break			
Material	Mean, %E	CV_r, %	CV_R, %	I_r, %	I_R, %
FEP	319	2.21	7.60	6.19	21.28

different equipment on different days, the two test results shall be judged not equivalent if they differ by more than the I_R value for that material.

11.5.1.6 Any judgment in accordance with 11.5.1.4 and 11.5.1.5 would have an approximate 95 % (0.95) probability of being correct.

11.5.2 *Bias*—Bias is systematic error that contributes to the difference between a test result and a true (or reference) value. There are no recognized standards on which to base an estimate of bias for this test procedure.

11.6 *Dielectric Constant*—Determine dielectric constant and dissipation factor in accordance with Test Methods D150.

12. Number of Tests

12.1 One set of test specimens as prescribed in Section 8 shall be considered sufficient for testing each sample. The average result of the samples tested shall conform to the requirements of this specification.

13. Inspection

13.1 Inspection of the material supplied under this specification shall be for conformance to the requirements specified herein.

13.1.1 *Lot-Acceptance Inspection*—Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of the melt flow rate test.

13.1.2 *Periodic-Check Inspection*—The periodic-check inspection shall consist of the tests specified for all requirements of the material under this specification.

13.1.3 *Reports*—A report of the test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment.

14. Certification

14.1 Certification shall be as required by Annex A1.

15. Keywords

15.1 extrusion material; FEP fluorocarbon polymer; fluorocarbon polymer; fluoropolymers; melt-processible fluorocarbon polymer; recycled; tetrafluoroethylene copolymers

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR POLYETHYLENE (PE) PLASTIC PIPE (SIDR-PR) BASED ON CONTROLLED INSIDE DIAMETER

SD-2239

(Identical with ASTM D2239-12a except for additional requirements in section 11 and Annex A1, revised requirements in para. 9.1.5, renumbering of section 12, and quality assurance requirement in para. 10.1 has been made mandatory.)

Specification for
Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter

1. Scope

1.1 This specification covers polyethylene (PE) pipe made in standard inside dimension ratios (SIDR) and pressure rated for water (see appendix). Included are requirements for PE compounds and requirements and test methods for workmanship, dimensions, elevated temperature sustained pressure, burst pressure, and marking.

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 text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the specification. Notes and footnotes in tables and figures, and Supplementary Requirements are requirements of the specification.

1.4 The following safety hazards caveat pertains only to the test methods 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 and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—References and PE compound descriptions for PE2305, PE2406, PE3306, PE3406, and PE3408 have been removed due to changes in Specification D3350 and PPI TR-3. For removed designations, refer to previous editions of Specification D2239, Specification D3350, PPI TR-3 and PPI TR-4. The removal of these PE compounds does not affect pipelines that are in service. PE compounds and material designations resulting from changes in Specification D3350 and PPI TR-3 are addressed in Section 5.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
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
D1603 Test Method for Carbon Black Content in Olefin Plastics
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
F412 Terminology Relating to Plastic Piping Systems
G154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.2 *APWA Standard:*

APWA Uniform Color Code

2.3 *NSF Standards:*

NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials

NSF/ANSI Standard No. 61 for Drinking Water Systems Components—Health Effects

2.4 *PPI Standards:*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for polyethylene plastic is PE.

4. Pipe Classification

4.1 *General*—This specification covers inside diameter controlled PE pipe made from PE compounds in standard inside dimension ratios and pressure rated for water. Pressure ratings for water are dependent on the PE compound in accordance with the following relationship:

$$PR = \frac{2 \times HDS}{(SIDR + 1)} \tag{1}$$

Where:

PR = pressure rating for water, psi (kPa)

HDS = hydrostatic design stress for water at 73°F (23°C), psi (kPa)

SIDR = standard inside dimension ratio

NOTE 2—PR and HDS must have the same units. See Appendix X1 for maximum pressure ratings for water.

5. Materials

5.1 *Polyethylene Compound*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall meet thermoplastic materials designation codes PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet Table 1 requirements for PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet thermal stability, brittleness temperature and elongation at break requirements in accordance with Specification D3350.

5.1.1 *Color and Ultraviolet (UV) Stabilization*—Per Table 1, polyethylene compounds shall meet Specification D3350 code C, D or E. In addition, Code C polyethylene compounds shall have 2 to 3 percent carbon black, and Code D or E polyethylene compounds shall have sufficient UV stabilizer to protect pipe from deleterious UV exposure effects during unprotected outdoor shipping and storage for at least eighteen (18) months.

TABLE 1 Polyethylene Compound Requirements

Requirement	Material Designation				
	PE1404	PE2708	PE3608	PE4608	PE4710
	Required Value				
Minimum HDB at 140°F (60°C), psi (MPa), per Test Method D2837 and PPI TR-3	[A]	800 (5.5)[B]	800 (5.5)[B]	800 (5.5)[B]	800 (5.5)[B]
HDS for water at 73°F (23°C) psi (MPa), per Test Method D2837 and PPI TR-3	400 (2.76)	800 (5.5)	800 (5.5)	800 (5.5)	1000 (6.9)
Melt flow rate per Test Method D1238	1.0 to 0.4 g/10 min Cond. 190/2.16	≤0.40 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6
Specification D3350 Cell Classification Property Requirement	Required Value				
Density (natural base resin)	1	2	3	4	4
SCG Resistance	4	7	6	6	7
Color and UV Stabilizer Code[C]	C	C, D or E	C, D or E	C, D or E	C, D or E

[A] HDB at 140°F (60°C) not required. Contact manufacturer about pipe use at temperatures other than 73°F (23°C).
[B] Contact manufacturer or see PPI TR-4 for listed value.
[C] See 5.1.1.

NOTE 3—Pipe users should consult with the pipe manufacturer about the outdoor exposure life of the product under consideration. Evaluation of UV stabilizer in Code E color PE compound using Practice D2565 or Practice G154 or Practice G155 may be useful for this purpose.

5.1.2 *Colors for solid color, an external color layer or color stripes*—In accordance with the APWA Uniform Color Code, blue shall identify potable water service; green shall identify sewer service; and purple (lavender) shall identify reclaimed water service. Yellow identifies gas service and shall not be used.

5.2 *Potable Water Requirement*—PE compound intended for contact with potable water shall be evaluated, tested, and certified for conformance with NSF/ANSI Standard No. 61 or the health effects portion of NSF/ANSI Standard No. 14 by a certifying organization acceptable to the regulatory authority having jurisdiction.

5.3 *Rework Material*—Clean polyethylene compound from the manufacturer's own pipe production that met 5.1 through 5.2 as new PE compound is suitable for re-extrusion into pipe when blended with new PE compound having the same material designation. Pipe containing rework material shall meet all the requirements of this specification.

6. Requirements

6.1 *Workmanship*—The pipe shall be homogeneous throughout and free of visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. See 5.1.2.

6.2 *Dimensions and Tolerances:*

6.2.1 *Inside Diameters*—The inside diameters and tolerances shall be as shown in Table 2 when measured in accordance with Test Method D2122.

6.2.2 *Wall Thicknesses*—Subject to 6.2.3, wall thickness and tolerance shall be as shown in Table 3 when measured in accordance with 7.4. Wall thickness shall be inclusive of all extruded concentric layers.

6.2.3 *Wall Thickness Range*—The wall thickness variation shall not exceed 12 % when measured in accordance with 7.4.

6.2.4 *Thickness of Outer Layer*—For pipe produced by simultaneous multiple extrusion, that is, pipe containing two or more concentric layers, the outer layer shall be at least 0.020-in. (0.5 mm) thick.

6.3 *Bond*—For pipe produced by simultaneous multiple extrusion, the bond between the layers shall be strong and uniform. It shall not be possible to cleanly separate any two layers with a probe or point of a knife blade at any point.

6.4 *Carbon Black*—Polyethylene pipe produced using Code C polyethylene compound per 5.1.1 shall contain 2 to 3 % carbon black when tested in accordance with 7.5.

6.5 *Burst Pressure*—The minimum burst pressure for pipe shall be in accordance with Table 4, when determined in accordance with 7.7. In addition, the failure shall be ductile.

6.6 *Sustained Pressure*—Pipe made from PE1404 compound shall be tested twice annually in accordance with 7.6. The average failure time shall be ≥80 hours at 580 psi (4.00 MPa) test pressure hoop stress, or ≥150 hours at 435 psi (3.00 MPa) test pressure hoop stress.

6.7 *Elevated Temperature Sustained Pressure*—Except as provided in 6.6, elevated temperature sustained pressure tests for each polyethylene compound designation per Table 1 used in production at the facility shall be conducted twice annually per 7.8.

6.8 Inside Surface Ductility for Pipe—Pipe shall be tested for inside surface ductility in accordance with 7.9 or 7.10.

NOTE 4—Tensile elongation testing per 7.10 provides a quantifiable result and is used for referee testing and in cases of disagreement.

7. Test Methods

7.1 *Conditioning*—Condition as specified in the test method. Where conditioning is not specified in the test method, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) without regard to humidity for not less than 4 h in accordance with Procedure A of Practice D618, or at 73.4 ± 3.6°F (23 ± 2°C) for not less than 1 h in accordance with Procedure D of Practice D618.

7.2 *Test Conditions*—Conduct tests in accordance with the conditions specified in the test method, or if not specified in the test method, at 73.4 ± 3.6°F (23 ± 2°C) without regard to relative humidity.

7.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

TABLE 2 Inside Diameters and Tolerances for SIDR-PR PE Plastic Pipe, in.

Pipe Size	Inside Diameter	Tolerance
½	0.622	+0.010 −0.010
¾	0.824	+0.010 −0.015
1	1.049	+0.010 −0.020
1¼	1.380	+0.010 −0.020
1½	1.610	+0.015 −0.020
2	2.067	+0.015 −0.020
3	3.068	+0.015 −0.030

TABLE 3 Wall Thickness and Tolerance for SIDR-PR PE Plastic Pipe, in.

Pipe Size	Wall Thickness^A											
	SIDR 19		SIDR 15		SIDR 11.5		SIDR 9		SIDR 7		SIDR 5.3	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
½	0.060	+0.020	0.060	+0.020	0.060	+0.020	0.069	+0.020	0.089	+0.020	0.117	+0.020
¾	0.060	+0.020	0.060	+0.020	0.072	+0.020	0.092	+0.020	0.118	+0.020	0.155	+0.020
1	0.060	+0.020	0.070	+0.020	0.091	+0.020	0.117	+0.020	0.150	+0.020	0.198	+0.024
1¼	0.073	+0.020	0.092	+0.020	0.120	+0.020	0.153	+0.020	0.197	+0.024	0.260	+0.031
1½	0.085	+0.020	0.107	+0.020	0.140	+0.020	0.179	+0.020	0.230	+0.028	0.304	+0.036
2	0.109	+0.020	0.138	+0.020	0.180	+0.022	0.230	+0.028	0.295	+0.035	0.390	+0.047
3	...	...	0.205	+0.020	0.267	+0.032	...	...	...	...	...	...

^{A} The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement. Wall thickness variation shall be in accordance with 6.2.3.
^{B} The 2½ to 6-in. pipe with a pressure rating of 0.70 MPa (100 psi) is not included.

TABLE 4 Minimum Burst Pressure for SIDR Pipe

SIDR	Minimum Burst Pressure^A					
	PE1404		PE2708		PE3608, PE4608, PE4710	
	psi	(kPa)	psi	(kPa)	psi	(kPa)
5.3	400	(2759)	800	(5517)	921	(6352)
7	320	(2207)	630	(4345)	725	(5000)
9	250	(1724)	504	(3476)	580	(4000)
11.5	...	...	403	(2779)	464	(3200)
15	...	...	315	(2174)	363	(2503)
19	...	...	252	(1738)	290	(2000)

^{A}Minimum burst pressure calculated in accordance with

$$P_B = \frac{2S}{\frac{D_i}{t}} + 1$$

Where:
P_B = burst test pressure, psi (kPa)
S = minimum hoop fiber stress, psi. (kPa)
S = 1260 psi (8690 kPa) for PE1404 compound
S = 2520 psi (17,370 kPa) for PE2708 compound
S = 2900 psi (20,000 kPa) for PE3608, PE4608 and PE4710 compound
D_i = measured average inside diameter, in. (mm)
t = measured minimum wall thickness, in (mm).

Test temperature tolerance ±3.6ºF (± 2ºC). Test pressure tolerance ± 5 psi (± 35 kPa)

7.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of the pipe sample that is at least one pipe diameter away from an end closure. The entire marking shall be documented in testing records.

7.4 *Dimensions and Tolerances*—Use any length of pipe to determine the dimensions. Inside diameter, wall thickness and wall thickness range shall be measured in accordance with Test Method D2122.

7.5 *Carbon Black*—For all pipe manufactured with Code C polyethylene compound, determine in duplicate the carbon black content in accordance with Test Method D1603 or Test Method D4218.

7.6 *Sustained Pressure Test*—Select six PE1404 pipe test specimens. Test in accordance with Test Method D1598 with water at 176°F (80°C). Internal test pressure shall be determined in accordance with the equation in Table 5, footnote A. Failure of two of the six specimens tested constitutes failure in the test. Failure of one of six specimens tested is cause for retest of six additional specimens. Failure of one of six specimens tested in retest constitutes failure in the test. Failure of the pipe shall be as defined in Test Method D1598.

7.7 *Burst Pressure*—The test equipment, procedures and failure definitions shall be as specified in Test Method D1599.

7.8 *Elevated Temperature Sustained Pressure Test*—Elevated temperature sustained pressure tests for each Table 1 material designation used in production of pipe in accordance with this specification at the facility shall be conducted per Test Method D1598, and Table 5 using water as the pressurizing medium. The "test sample" shall be three specimens of any pipe size or SIDR. One Table 5 Condition for the applicable material designation shall be selected for the test.

7.8.1 For the selected Table 5 Condition, passing results are *(a)* non-failure for all three specimens at a time equal to or greater than the Table 5 minimum average time before failure, or *(b)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified Table 5 minimum average time before failure for the selected Table 5 Condition, or *(c)* successful retest per 7.8.3.

TABLE 5 Elevated Temperature Sustained Pressure Test[A] Requirements

Condition	Test Temperature, °F (°C)	PE2708, PE3608, PE4608		PE4710	
		Test Pressure Hoop Stress, psi (kPa)	Minimum Average Time Before Failure, hours	Test Pressure Hoop Stress, psi (kPa)	Minimum Average Time Before Failure, hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A]A Calculate internal test pressure in accordance with

$$P = \frac{2S}{\frac{D_i}{t}} + 1$$

Where:

P = test pressure, psi (kPa)
S = test pressure hoop stress, psi. (kPa)
D_i = measured average inside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

Test temperature tolerance ± 3.6ºF (± 2ºC). Test pressure tolerance ± 5 psi (± 35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa.

NOTE-Table 5 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 compound designations, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours:

$$927 = 200 + \left((750 - 670) \times \frac{(1200 - 200)}{(750 - 640)} \right)$$

7.8.2 For the selected Table 5 Condition, failure to meet this requirement is *(a)* brittle failure of any specimen when tested at Table 5 Condition 1 through 6, or *(b)* ductile failure of all three specimens, or *(c)* unsuccessful retest per 7.8.3.

7.8.3 *Provision for Retest for* Table 5 *Conditions 1 through 5*—If a second ductile failure occurs before the Table 5 minimum average time before failure, it is permissible to conduct one retest at a Table 5 Condition of lower stress and longer minimum average time before failure for the material designation. The retest sample shall be three additional specimens of the same pipe size and material designation from the same time frame as the test sample per 7.8. For the retest, any specimen failure before the Table 5 minimum average time before failure at the retest condition constitutes failure to meet this requirement. For Table 5 Condition 6 no retest is permissible

7.9 *Bend-back Test Method:*

7.9.1 Squarely cut four 1 ⅛ to 1 ⅜ in. (29 to 35 mm) wide rings from pipe. Condition the rings per 7.1.

7.9.2 Split each ring longitudinally so that when reverse bent per 7.9.3, the pipe ID for each quadrant around the pipe will be tested.

7.9.3 In a well-lit area, perform the following procedure within 5 min: *(a)* Bend each split ring specimen so that the pipe inside surface is on the outside surface of the bend. *(b)* Using an apparatus such as a bench vise or other suitable equipment, close the legs of the specimen together. When the specimen legs are closed together, the top of the bend-back specimen shall extend above the point of closure by 3 ± ½ times the minimum wall thickness per Table 3. *(c)* With the unaided (naked) eye, visually examine the reverse-bent pipe ID surface.

7.9.4 Visible brittle cracking or crazing indicates failure.

7.10 *Elongation-at-Break Test Method:*

7.10.1 Five Test Method D638 Type III or Type IV specimens cut in the longitudinal direction from locations equally spaced around the circumference of the pipe shall be conditioned per 7.1 and tested in accordance with Test Method D2565 at a cross-head separation speed of 2 in. (50.8 mm) per min. If the specimen thickness must be reduced by machining, the pipe ID surface shall be left unaltered.

7.10.2 The percent elongation at break for each test specimen shall exceed 400 %.

NOTE 5—Specimen machining that produces smooth surfaces and uniform thickness is necessary. Surface cuts or scratches and non-uniform thickness in the specimen gage length can detrimentally affect test results.

8. Retest and Rejection

8.1 Except as provided in 7.8.3, 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, 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.

9. Marking

9.1 Marking on the pipe shall include the following information. Marking shall be spaced at intervals of not more than 5 ft (1.5 m). Marking shall be applied such that legibility is maintained after normal handling and installation.

9.1.1 Pipe size (for example, 2).

9.1.2 Pipe SIDR (for example SIDR 7).

9.1.3 The material designation code per Table 1 (for example, PE3608).

9.1.4 In accordance with 4.1, the pressure rating for water in psi or kPa (for example, 100 psi or 690 kPa).

9.1.5 ASME SD-2239 or both ASME SD-2239 and ASTM D2239.

9.1.6 Manufacturer's name (or trademark) and a code that identifies manufacturing location, PE compound source, manufacturing date and relevant production information such as extrusion line and shift. Upon request the manufacturer shall provide an explanation of the code.

9.1.7 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 6—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet all requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

12. Keywords

12.1 ID controlled pipe; IDR; inside diameter controlled pipe; PE pipe; plastic pipe; polyethylene pipe; potable water pipe; service pipe; SIDR; water pipe; water service pipe

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 Maximum pipe pressure ratings for use with water may be determined using PPI recommended hydrostatic design stress (HDS) ratings for the PE compound per Table 1. Maximum internal pressure ratings for water are shown in Table X1.1. At the option of the pipe manufacturer, other pressure ratings may be recommended for water or other media or for variations of internal or external conditions or for other temperatures.

X1.2 Information on HDS is available in Table 3, Test Method D2837, PPI TR-3 and PPI TR-4.

TABLE X1.1 Maximum Pressure Rating, PR, for SIDR-PR PE Pipe for Use With Water

SIDR	Minimum Burst Pressure[A,B] psi (kPa)					
	PE1404		PE2708, PE3608, PE4608		PE4710	
	psi	(kPa)	psi	(kPa)	psi	(kPa)
5.3	125	(860)	250	(1725)	315	(2170)
7	100	(690)	200	(1380)	250	(1725)
9	80	(550)	160	(1100)	200	(1380)
11.5	...	...	130	(895)	160	(1100)
15	...	...	100	(690)	125	(860)
19	...	...	80	(550)	100	(690)

[A]Minimum burst pressure calculated in accordance with

$$P_R = \frac{2HDS}{(SDIR+1)}$$

Where:

P_R = burst test pressure, psi (kPa)
HDS = hydrostatic design stress for water at 73°F (23°C), psi. (kPa) (Table 1)
$SIDR$ = standard inside dimension ratio

[B]Table values rounded to nearest 5 psi or 5 kPa.

SPECIFICATION FOR POLY(VINYL CHLORIDE) (PVC) PRESSURE-RATED PIPE (SDR SERIES)

SD-2241

(Identical with ASTM D2241-09 except for additional requirements in section 12 and Annex A2, revised marking requirements in para. 10.1.5, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) pipe made in standard thermoplastic pipe dimension ratios and pressure rated for water (see appendix). Included are criteria for classifying PVC plastic pipe materials and PVC plastic pipe, a system of nomenclature for PVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases, some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 1—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety hazards should a system fail for any reason.

NOTE 2—This standard specifies dimensional, performance and test requirements for plumbing and fluid handling applications, but does not address venting of combustion gases.

1.3 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.

1.4 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.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use*. A specific precautionary statement is given in Note 7.

NOTE 3—CPVC plastic pipe (SDR-PR), which was formerly included in this specification, is now covered by Specification F442/F442M.

NOTE 4—The sustained and burst pressure test requirements, and the pressure ratings in the appendix, are calculated from stress values obtained from tests made on pipe 4 in. (100 mm) and smaller. However, tests conducted on pipe as large as 24 in. (600 mm) in diameter have shown these stress values to be valid for larger diameter PVC pipe.

NOTE 5—PVC pipe made to this specification is often belled for use as line pipe. For details of the solvent cement bell, see Specification D2672 and for details of belled elastomeric joints, see Specifications D3139 and D3212.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

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

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2152 Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a

Tup (Falling Weight)
D2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
F412 Terminology Relating to Plastic Piping Systems
F442/F442M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe (SDR–PR)

2.2 *NSF Standards:*
Standard No. 14 for Plastic Piping Components and Related Materials
Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for poly(vinyl chloride) plastic is PVC.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hydrostatic design stress*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.2.2 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.2.3 *relation between standard dimension ratio, hydrostatic design stress, and pressure rating*—The following expression, commonly known as the ISO equation, is used in this specification to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

$$2S/P = R - 1 \text{ or } 2\,S/P = (D_0/t) - 1 \quad (1)$$

where:

S = hydrostatic design stress, psi (or MPa),
P = pressure rating, psi (or MPa),
D_0 = average outside diameter, in. (or mm),
t = minimum wall thickness, in. (or mm), and
R = standard thermoplastic pipe dimension ratio (D_0/t for PVC pipe), also known as SDR.

3.2.4 *standard thermoplastic pipe dimension ratio (SDR)*—the ratio of pipe diameter to wall thickness. For PVC pipe it is calculated by dividing the average outside diameter of the pipe in inches or millimetres by the minimum wall thickness in inches or millimetres. If the wall thickness calculated by this formula is less than 0.060 in. (1.52 mm), it shall be arbitrarily increased to 0.060in. (1.52 mm). The SDR values shall be rounded to the nearest 0.5.

3.2.5 *standard thermoplastic pipe materials designation code*—The pipe materials designation code shall consist of the abbreviation PVC for the type of plastic, followed by the ASTM type and grade in Arabic numerals and the design stress in units of 100 psi (0.7 MPa) with any decimal figures dropped. When the design stress code contains less than two figures, a cipher shall be used before the number, thus a complete material code shall consist of three letters and four figures for PVC plastic pipe materials.

4. Classification

4.1 *General*—This specification covers PVC pipe made and marked with one of six Type/Grade/Design Stress designations (see X1.2) in eleven standard dimension ratios.

4.2 *Standard Thermoplastic Pipe Dimension Ratios (SDR)*—This specification covers PVC pipe in eleven standard dimension ratios, namely, 13.5, 17, 21, 26, 32.5, 41, and 64 (in the body of the document) and 11, 35, 51 and 81 (in Annex A1.) Standard dimension ratios are uniform for all nominal pipe sizes for each material and pressure rating. These are referred to as SDR 11, SDR13.5, SDR17, SDR21, SDR26, SDR32.5, SDR35, SDR41, SDR51, SDR64, and SDR81, respectively. The pressure rating is uniform for all nominal pipe sizes for a given PVC pipe material and SDR (see Table X1.1).

4.3 *Hydrostatic Design Stresses*—This specification covers pipe made from PVC plastics defined by four hydrostatic design stresses developed on the basis of long-term tests (appendix).

5. Materials

5.1 *General*—Poly(vinyl chloride) plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, (*1*) short-term strength tests, and (*2*) long-term strength tests.

NOTE 6—The PVC 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 No. 14. The seal or mark of the laboratory making the evaluation should be included on the pipe. See pipe marking requirement for reclaimed water systems.

5.2 *Basic Materials*—This specification covers pipe made from PVC plastics having certain physical and chemical properties as described in Specification D1784.

5.3 *Compound*—The PVC compounds used for this pipe shall equal or exceed one of the following classes described in Specification D1784: PVC 12454 or 14333.

5.4 *Rework Material*—The manufacturer shall use only his own clean rework pipe material and the pipe produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 1 when measured in accordance with Test Method D2122. The tolerances for out-of-roundness shall apply only on pipe prior to shipment.

6.1.2 *Wall Thickness*—The wall thicknesses and tolerances shall be as shown in Table 2 when measured in accordance with Test Method D2122.

6.2 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598 at the test pressures given in Table 3 when tested in accordance with 8.4.

6.2.1 *Accelerated Regression Test*—The accelerated regression test shall be used in place of both the sustained and burst pressure tests, at the option of the manufacturer. The test shall be conducted in accordance with 8.4.1. The pipe shall demonstrate a hydrostatic design basis projection at the 100 000-h intercept that meets the hydrostatic design basis category requirement (see the table for "Hydrostatic Design Basis Categories" of Test Method D2837) for the PVC material used in its manufacture. (*Example:* PVC 1120 pipe must have a minimum 100 000-h projection of 3830 psi and 85 % lower confidence limit (LCL).)

6.3 *Burst Pressure*—The minimum burst pressures for PVC plastic pipe shall be as given in Table 4, when determined in accordance with 8.5.

6.4 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 8.6.

6.5 *Extrusion Quality*—The pipe shall not flake or disintegrate when tested in accordance with Test Method D2152.

6.6 *Impact Resistance*—The minimum impact resistance for PVC plastic pipe shall be as given in Table 5, when determined in accordance with 8.7.

NOTE 7—The impact resistance test is intended for use only as a quality control test, not as a simulated service test. This test has been found to have no quality control significance in sizes over 12 in. (305 mm).

7. Workmanship, Finish, and Appearance

7.1 The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

NOTE 8—Color and transparency or opacity should be specified in the contract or purchase order.

8. Test Methods

8.1 *Conditioning*—Unless otherwise specified in the applicable test method, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40

TABLE 1 IPS PVC Pipe—Outside Diameters and Tolerances

Nominal Pipe Size, in.	Average Outside Diameter, in. (mm)	Tolerances, in. (mm)		
			Maximum Out-of-Roundness (Maximum – Minimum Diameter)	
		For Average	SDR64, SDR41, SDR32.5, SDR26, SDR21	SDR17, SDR13.5
⅛	0.405 (10.29)	±0.004 (0.10)	0.030 (0.76)	0.016 (0.41)
¼	0.540 (13.72)	±0.004 (0.10)	0.030 (0.76)	0.016 (0.41)
⅜	0.675 (17.14)	±0.004 (0.10)	0.030 (0.76)	0.016 (0.41)
½	0.840 (21.34)	±0.004 (0.10)	0.030 (0.76)	0.016 (0.41)
¾	1.050 (26.67)	±0.004 (0.10)	0.030 (0.76)	0.020 (0.51)
1	1.315 (33.40)	±0.005 (0.13)	0.030 (0.76)	0.020 (0.51)
1¼	1.660 (42.16)	±0.005 (0.13)	0.030 (0.76)	0.024 (0.61)
1½	1.900 (48.26)	±0.006 (0.15)	0.060 (1.52)	0.024 (0.61)
2	2.375 (60.32)	±0.006 (0.15)	0.060 (1.52)	0.024 (0.61)
2½	2.875 (73.02)	±0.007 (0.18)	0.060 (1.52)	0.030 (0.76)
3	3.500 (88.90)	±0.008 (0.20)	0.060 (1.52)	0.030 (0.76)
3½	4.000 (101.60)	±0.008 (0.20)	0.100 (2.54)	0.030 (0.76)
4	4.500 (114.30)	±0.009 (0.23)	0.100 (2.54)	0.030 (0.76)
5	5.563 (141.30)	±0.010 (0.25)	0.100 (2.54)	0.060 (1.52)
6	6.625 (168.28)	±0.011 (0.28)	0.100 (2.54)	0.070 (1.78)
8	8.625 (219.08)	±0.015 (0.38)	0.150 (3.81)	0.090 (2.29)
10	10.750 (273.05)	±0.015 (0.38)	0.150 (3.81)	0.100 (2.54)
12	12.750 (323.85)	±0.015 (0.38)	0.150 (3.81)	0.120 (3.05)
14	14.000 (355.60)	±0.015 (0.38)	0.200 (5.08)	0.150 (3.81)
16	16.000 (406.40)	±0.019 (0.48)	0.320 (8.13)	0.160 (4.06)
18	18.000 (457.20)	±0.019 (0.48)	0.360 (9.14)	0.180 (4.57)
20	20.000 (508.00)	±0.023 (0.58)	0.400 (10.2)	0.200 (5.08)
24	24.000 (609.60)	±0.031 (0.79)	0.480 (12.2)	0.240 (6.10)
30	30.000 (762.00)	±0.041 (1.04)	0.600 (15.2)	0.300 (7.62)
36	36.000 (914.40)	±0.050 (1.27)	0.720 (18.3)	0.360 (9.14)

TABLE 2 Wall Thicknesses and Tolerances for PVC Plastic Pipe with IPS Outside Diameters

Nominal Pipe Size, in.	Wall Thickness,[A] in.[B]													
	SDR64		SDR41		SDR32.5		SDR26		SDR21		SDR17		SDR13.5	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
⅛	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
¼	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
⅜	...	...	...	...	...	...	...	...	...	...	...	...	0.060	+0.020
½	...	...	...	...	...	...	...	...	...	...	...	...	0.062	+0.020
¾	...	...	...	...	...	...	...	...	0.060	+0.020	0.062	+0.020	0.078	+0.020
1	...	...	...	...	...	...	0.060	+0.020	0.063	+0.020	0.077	+0.020	0.097	+0.020
1¼	...	...	...	...	0.060	+0.020	0.064	+0.020	0.079	+0.020	0.098	+0.020	0.123	+0.020
1½	...	...	...	...	0.060	+0.020	0.073	+0.020	0.090	+0.020	0.112	+0.020	0.141	+0.020
2	...	...	...	...	0.073	+0.020	0.091	+0.020	0.113	+0.020	0.140	+0.020	0.176	+0.020
2½	...	...	...	...	0.088	+0.020	0.110	+0.020	0.137	+0.020	0.169	+0.020	0.213	+0.026
3	...	...	0.085	+0.020	0.108	+0.020	0.135	+0.020	0.167	+0.020	0.206	+0.025	0.259	+0.031
3½	...	...	0.098	+0.020	0.123	+0.020	0.154	+0.020	0.190	+0.023	0.235	+0.028	0.296	+0.036
4	0.070	+0.020	0.110	+0.020	0.138	+0.020	0.173	+0.020	0.214	+0.026	0.265	+0.032	0.333	+0.040
5	0.087	+0.020	0.136	+0.020	0.171	+0.021	0.214	+0.027	0.265	+0.032	0.327	+0.039	0.412	+0.049
6	0.104	+0.020	0.162	+0.020	0.204	+0.024	0.255	+0.031	0.316	+0.038	0.390	+0.047	0.491	+0.059
8	0.135	+0.020	0.210	+0.025	0.265	+0.032	0.332	+0.040	0.410	+0.049	0.508	+0.061	...	...
10	0.168	+0.020	0.262	+0.031	0.331	+0.040	0.413	+0.050	0.511	+0.061	0.632	+0.076	...	...
12	0.199	+0.024	0.311	+0.037	0.392	+0.047	0.490	+0.059	0.606	+0.073	0.750	+0.090	...	...
14	...	...	0.341	+0.048	0.430	+0.052	0.538	+0.064	0.666	+0.080	0.823	+0.099	...	...
16	...	...	0.390	+0.055	0.492	+0.059	0.615	+0.074	0.762	+0.091	0.941	+0.113	...	...
18	...	...	0.439	+0.061	0.554	+0.066	0.692	+0.083	0.857	+0.103	1.059	+0.127	...	...
20	...	...	0.488	+0.068	0.615	+0.074	0.769	+0.092	0.952	+0.114	1.176	+0.141	...	...
24	...	...	0.585	+0.082	0.738	+0.088	0.923	+0.111	1.143	+0.137	1.412	+0.169	...	...
30	...	...	0.732	+0.102	0.923	+0.111	1.154	+0.138	1.428	+0.171	1.765	+0.212	...	...
36	...	...	0.878	+0.123	1.108	+0.133	1.385	+0.166	1.714	+0.205	2.118	+0.254	...	...

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.
[B] 1 in. = 25.4 mm (exact).

TABLE 3 Sustained Pressure Test Conditions for Water at 73°F (23°C) for PVC Plastic Pipe

SDR	Pressure[A] Required for Test							
	PVC 1120, PVC 1220, PVC 2120		PVC 2116		PVC 2112		PVC 2110	
	psi	MPa (bar)	psi	MPa (bar)	psi	MPa (bar)	psi	MPa (bar)
13.5	670	4.62 (46.2)	540	3.72 (37.2)	450	3.10 (31.0)	370	2.55 (25.5)
17	530	3.65 (36.5)	420	2.90 (29.0)	350	2.41 (24.1)	290	2.00 (20.0)
21	420	2.90 (29.0)	340	2.34 (23.4)	280	1.93 (19.3)	230	1.59 (15.9)
26	340	2.34 (23.4)	270	1.86 (18.6)	220	1.52 (15.2)	180	1.24 (12.4)
32.5	270	1.86 (18.6)	210	1.45 (14.5)	180	1.24 (12.4)	150	1.03 (10.3)
41	210	1.45 (14.5)	170	1.17 (11.7)	140	0.97 (9.7)	120	0.83 (8.3)
64	130	0.90 (9.0)	110	0.76 (7.6)	90	0.62 (6.2)	70	0.48 (4.8)

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa (bar)
PVC 1120, PVC 1220, PVC 2120	4200	29.0 (290)
PVC 2116	3360	23.2 (232)
PVC 2112	2800	19.3 (193)
PVC 2110	2300	15.9 (159)

Some minor adjustments have been made to keep the test pressures uniform to simplify testing.

h prior to test in accordance with Procedure A of Practice D618 for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct the tests in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

8.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

8.4 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressures given in Table 3, six specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) or more than 3 ft (1000 mm) between end

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Plastic Pipe

SDR	Minimum Burst Pressure[A]			
	PVC 1120, PVC 1220, PVC 2120		PVC 2116, PVC 2112, PVC 2110	
	psi	MPa (bar)	psi	MPa (bar)
13.5	1000	6.89 (68.9)	800	5.52 (55.2)
17	800	5.52 (55.2)	630	4.34 (43.4)
21	630	4.34 (43.4)	500	3.45 (34.5)
26	500	3.45 (34.5)	400	2.76 (27.6)
32.5	400	2.76 (27.6)	315	2.17 (21.7)
41	315	2.17 (21.7)	250	1.72 (17.2)
64	200	1.38 (13.8)	160	1.10 (11.0)

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	MPa (bar)
PVC 1120, PVC 1220, PVC 2120	6400	44.1 (441)
PVC 2116, PVC 2112, PVC 2110	5000	34.5 (345)

TABLE 5 Impact Resistance at 73°F (23°C) for PVC Plastic Pipe

Size, in.	Impact Resistance, ft·lbf (J) All SDRs	Size, in.	Impact Resistance, ft·lbf (J) All SDRs
1⁄4	10 (13.6)	21⁄2	40 (54.2)
1⁄2	10 (13.6)	3	60 (81.3)
3⁄4	15 (20.3)	31⁄2	70 (94.9)
1	20 (27.1)	4	90 (122.0)
11⁄4	20 (27.1)	5	100 (135.6)
11⁄2	30 (40.7)	6	120 (162.7)
2	30 (40.7)	8 or larger	160 (216.9)

closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi (±70 kPa). Condition the specimens at the test temperature of 73.4°F (23°C) to within ±3.6°F (2°C). Maintain the test temperature at 73.4 ± 3.6°F (23 ± 2°C). Test in accordance with Test Method D1598, except maintain the pressure at the values given in Table 3 for 1000 h. Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens tested in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

8.4.1 *Accelerated Regression Test*—Test in accordance with procedures in Test Method D1598, using either free end or restrained end fittings. A minimum of six specimens shall be tested. Test three specimens at a single pressure that result in failures at or below 0.10 h. Test an additional three specimens at a single pressure that will result in failures at about 200 h. Generating additional data points to improve the LTHS or LCL, or both, is acceptable. No points shall be excluded unless an obvious defect is detected in the failure area of the test sample, or there was a malfunction of test equipment. Characterize the data using the least squares regression described in Test Method D2837.

8.5 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599, having the lengths specified in 8.4. The time of testing of each specimen shall be not less than 60 s.

NOTE 9—Times greater than 60 s may be needed to bring large size specimens to the burst pressure. The test is more difficult to pass using greater pressurizing times.

8.6 *Flattening*—Flatten three specimens of the pipe, 2 in. (50 mm) long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. On removal of the load, examine the specimens for evidence of splitting, cracking, or breaking.

8.7 *Impact Resistance*—Determine the impact resistance in accordance with the specification requirement section of Test Method D2444. Test at 73.4 ± 3.6°F (23 ± 2°C) using a Tup B and flat plate support. Use a 20-lb (9-kg) tup.

8.7.1 *Test Specimens*—Specimens of pipe for impact testing shall be cut to lengths required in Test Method D2444.

8.7.2 *Test Requirements* (1⁄4 to 12 in.)—For pipe sizes 1⁄4 in. (6 mm) through 12 in. (300 mm), ten specimens shall be tested. If nine or more pass, the lot passes. If two or more fail, the lot fails.

9. Retest and Rejection

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 seller. Under such agreement, minimum requirements shall not be lowered, 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. Product Marking

10.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft (1.5 m):

10.1.1 Nominal pipe size (for example, 2 in. (50 mm)),

10.1.2 The outside diameter system (IPS or PIP) on sizes 14 in. (350 mm) and over (for example, IPS 14 in. (350 mm) or PIP 21 in. (500 mm)),

10.1.3 Type of plastic pipe material in accordance with the designation code given in 3.2.5 (for example, PVC1120),

10.1.4 Standard thermoplastic pipe dimension ratio in accordance with the designation code given in 3.2.4 (for example, SDR21), or the pressure rating in pounds per square inch for water at 73°F (23°C) shown as the number followed by psi (for example, 200 psi (1.4 MPa)), except that when intended for pressure applications, the pressure rating shall be shown (for example, 200 psi (1.4 MPa)). When the indicated pressure rating is lower than that calculated in accordance with 3.2.3 (see appendix), the SDR shall also be included in the marking code,

10.1.5 ASME SD-2241 or both ASME SD-2241 and ASTM D2241,

10.1.6 Manufacturer's name (or trademark),

10.1.7 Production code with which the manufacturer can trace the year, month, day shift, plant and extruder of manufacture for this product, and

10.1.8 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 10—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A2.

13. Keywords

13.1 pressure pipe; pressure rated; PVC; SDR

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a regulatory authority or user calls for product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

This requirement applies only to pipe to be used in systems that have not established other provisions for identification.

S2. *Pipe Marking Requirement for Reclaimed Water Systems*—Color Identification of pipe shall be by: (1) use of purple (violet) PVC material or (2) by use of continuous purple stripes printed lengthwise on opposite sides of the pipe. The pipe shall be marked RECLAIMED WATER at intervals of 5 ft. or less.

ANNEXES

(Mandatory Information)

A1. PVC PRESSURE RATED PIPES HAVING OTHER THAN IPS OUTSIDE DIAMETERS

A1.1 As the use of PVC pipe has expanded, a need for pipe diameters and dimension ratios other than those listed in the main body of this specification has developed. These include small diameter (2-in. and under) CTS sizes and larger diameter (6 in. and over) PIP sizes. The IPS outside diameter pipes and the standard dimension ratios included in the body of this specification provide the format onto which these additional sizes are fitted.

A1.2 Pipe sizes listed in this Annex shall be tested to verify they meet the requirements shown in Tables A1.1-A1.7 and all other requirements of the specification.

TABLE A1.1 CTS Outside Diameters and Tolerance for PVC Plastic Pipe

Nominal Tube Size, in.	Average Outside Diameter, in. (mm)	Tolerances, in. (mm)	
		Average	Maximum Out-of-Roundness
½	0.625 (15.9)	± 0.003 (0.08)	0.008 (0.20)
¾	0.875 (22.2)	± 0.003 (0.08)	0.010 (0.26)
1	1.125 (28.6)	± 0.003 (0.08)	0.012 (0.30)
1¼	1.375 (34.9)	± 0.003 (0.08)	0.014 (0.36)
1½	1.625 (41.3)	± 0.004 (0.10)	0.016 (0.40)
2	2.125 (54.0)	± 0.004 (0.10)	0.020 (0.50)

TABLE A1.2 PIP Outside Diameters and Tolerance for PVC Plastic Pipe

Nominal Tube Size, in.	Average Outside Diameter, in. (mm)	Tolerances, in. (mm)	
		Average	Maximum Out-of-Roundness
6	6.140 (155.96)	±0.011 (0.28)	0.100 (2.54)
8	8.160 (207.26)	±0.15 (0.38)	0.150 (3.81)
10	10.200 (259.08)	±0.15 (0.38)	0.150 (3.81)
12	12.240 (310.90)	±0.15 (0.38)	0.150 (3.81)
15	15.300 (388.62)	± .016 (0.41)	0.294 (7.46)
18	18.701 (475.00)	± .020 (0.51)	0.360 (9.14)
21	22.047 (559.99)	± .025 (0.64)	0.420 (10.66)
24	24.803 (629.99)	± .032 (0.81)	0.480 (12.20)
27	27.953 (710.00)	± .038 (0.96)	0.540 (13.72)

TABLE A1.3 Sustained Pressure Test Conditions for Water 73.4°F (23°C) for PVC Plastic Pipe[A]

SDR	Pressure Required for Test—PVC 1120		
	psi	MPa	Bars
11	840	5.79	57.9
35	247	1.70	17.0
51	168	1.16	11.6
81	105	0.725	7.25

[A] The fiber stress used to derive this test was 4200 psi (29.0 MPa).

TABLE A1.4 Burst Pressure Test Conditions for Water at 73.4°F (23°C) for PVC Plastic Pipe[A]

SDR	Pressure Required for Test—PVC 1120		
	psi	MPa	Bars
11	1280	8.82	88.2
35	380	2.62	26.2
51	260	1.79	17.9
81	160	1.085	10.85

[A] The fiber stress used to derive this test was 6400 psi (44.1 MPa).

TABLE A1.5 Water Pressure Ratings (PR) at 73°F (23°C) for Nonthreaded PVC Plastic Pipe

SDR	PVC 1120 PVC 1220 PVC 2120		
	psi	MPa	Bars
11	400	2.75	27.5
35	118	0.81	8.1
51	80	0.55	5.5
81	50	0.34	3.4

TABLE A1.6 Wall Thicknesses and Tolerances for PVC Plastic pipe with CTS Outside Diameters[A]

Nominal Tube Size, in.	Wall Thickness, in. (mm)[B]							
	SDR 21		SDR 17		SDR 13.5		SDR 11	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
½	. . .	. . .	. . .	. . .	0.060	+0.020	0.060	+0.020
¾	. . .	. . .	0.060	+0.020	0.065	+0.020	0.080	+0.020
1	0.060	+0.020	0.066	+0.020	0.083	+0.020	0.102	+0.020
1¼	0.065	+0.020	0.081	+0.020	0.102	+0.020	0.125	+0.020
1½	0.077	+0.020	0.096	+0.020	0.120	+0.020	0.148	+0.020
2	0.101	+0.023	0.125	+0.023	0.157	+0.023	0.193	+0.023

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross-section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum tolerance.
[B] 1 in. = 25.4 mm (exact).

TABLE A1.7 Wall Thicknesses and Tolerances for PVC Plastic Pipe with PIP Outside Diameters[A]

Nominal Pipe Size, in.	Wall Thickness, in. (mm)[B]													
	SDR81		SDR51		SDR41		SDR35		SDR32.5		SDR26		SDR21	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
6	0.076	+0.020	0.120	+0.020	0.150	+0.020	...	...	0.189	+0.023	...	...	...	...
8	0.101	+0.020	0.160	+0.020	0.199	+0.024	...	...	0.251	+0.030	...	...	...	...
10	0.126	+0.020	0.200	+0.024	0.249	+0.030	...	...	0.314	+0.038	...	...	...	...
12	0.151	+0.020	0.240	+0.029	0.299	+0.036	...	...	0.377	+0.045	...	...	...	...
15	0.189	+0.023	0.300	+0.042	0.373	+0.052	0.437	+0.052	0.471	+0.056	0.588	+0.070	0.728	+0.087
18	...	...	0.366	+0.051	0.456	+0.064	0.534	+0.064	0.575	+0.069	0.719	+0.086	...	...
21	...	...	0.432	+0.060	0.538	+0.075	0.630	+0.076	0.678	+0.081	0.848	+0.102	...	...
24	...	...	0.486	+0.068	0.605	+0.085	0.709	+0.085	0.763	+0.092	0.954	+0.115	...	...
27	...	...	0.548	+0.077	0.682	+0.095	0.799	+0.096	0.860	+0.103	1.075	+0.129	...	...

[A] 1 in. = 25.4 mm (exact).
[B] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

A2. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 The hydrostatic design stresses recommended by the Plastics Pipe Institute are used to pressure rate PVC plastic pipe. These hydrostatic design stresses are 2000 psi (14 MPa), 1600 psi (11.0 MPa), 1250 psi (8.6 MPa), and 1000 psi (6.9 MPa) for water at 73.4°F (23°C). These hydrostatic design stresses apply only to pipe meeting all the requirements of this specification.

X1.2 Six PVC pipe materials are included based on the requirements of Specification D1784 and the PPI-recommended hydrostatic design stresses as follows:

X1.2.1 Type I, Grade 1 (12454-B), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC1120.

X1.2.2 Type I, Grade 2 (12454-C), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC1220.

X1.2.3 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 2000 psi (14 MPa), designated as PVC2120.

X1.2.4 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1600 psi (11.0 MPa), designated as PVC2116.

X1.2.5 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1250 psi (8.6 MPa), designated as PVC2112.

X1.2.6 Type II, Grade 1 (14333-D), with a hydrostatic design stress of 1000 psi (7 MPa), designated as PVC2110.

X1.3 The standard method for obtaining hydrostatic basis for thermoplastic pipe materials is Test Method D2837. Additional information regarding the criteria used in developing these hydrostatic design stresses may be obtained from the Plastics Pipe Institute. These hydrostatic design stresses may not be suitable for materials that show a wide departure from a straight line plot of log stress versus log time to failure. All the data available to date on PVC pipe materials made in the United States exhibit a straight-line plot under these plotting conditions.

X1.4 The pipe is rated for use with water in 73°F (23°C) at the maximum internal pressures shown in Table X1.1. Lower pressure ratings than those calculated in accordance with 3.2.3 may be recommended, at the option of the pipe manufacturer, in which case the SDR shall be included in the marking. Experience of the industry indicates that PVC plastic pipe meeting the requirements of this specification give satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements (6.3) are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.5 The hydrostatic design stresses recommended by the Plastic Pipe Institute are based on tests made on pipe ranging in size from ½ to 2½ in. (12.5 to 50 mm).

TABLE X1.1 Standard Thermoplastic Pipe Dimension Ratios (SDR) and Water Pressure Ratings (PR) at 73°F (23°C) for Nonthreaded PVC Plastic Pipe[A]

	Pressure Rating of PVC Pipe Materials[A]							
SDR	PVC 1120, PVC 1220, PVC 2120		PVC 2116		PVC 2112		PVC 2110	
	psi	MPa (bar)	psi	MPa (bar)	psi	MPa (bar)	psi	MPa (bar)
13.5	315	2.17 (21.7)	250	1.72 (17.2)	200	1.38 (13.8)	160	1.10 (11.0)
17	250	1.72 (17.2)	200	1.38 (13.8)	160	1.10 (11.0)	125	0.86 (8.6)
21	200	1.38 (13.8)	160	1.10 (11.0)	125	0.86 (8.6)	100	0.69 (6.9)
26	160	1.10 (11.0)	125	0.86 (8.6)	100	0.69 (6.9)	80	0.55 (5.5)
32.5	125	0.86 (8.6)	100	0.69 (6.9)	80	0.55 (5.5)	63	0.43 (4.3)
41	100	0.69 (6.9)	80	0.55 (5.5)	63	0.43 (4.3)	50	0.34 (3.4)
64	63	0.43 (4.3)	50	0.34 (3.4)	NPR[C]	NPR[C]	NPR[C]	NPR[C]

Pressure Rating[ABC]		Standard Dimension Ratio of PVC Pipe Materials			
psi	MPa (bar)	PVC 1120, PVC 1220, PVC 2120	PVC 2116	PVC 2112	PVC 2110
315	27.17 (21.7)	13.5	...	...	...
250	1.72 (17.2)	17	13.5	...	...
200	1.38 (13.8)	21	17	13.5	...
160	1.10 (11.0)	26	21	17	13.5
125	0.86 (8.6)	32.5	26	21	17
100	0.69 (6.9)	41	32.5	26	21
80	0.55 (5.5)	...	41	32.5	26
63	0.43 (4.3)	64	...	41	32.5
50	0.34 (3.4)	...	64	...	41

[A] These pressures ratings do not apply for threaded pipe.
[B] See 3.2.5 and 5.3 for code designation.
[C] NPR = not pressure rated.

SPECIFICATION FOR THREADED POLY(VINYL CHLORIDE) (PVC) PLASTIC PIPE FITTINGS, SCHEDULE 80

SD-2464

(Identical with ASTM D2464-13 except for additional requirements in section 12 and Annex A1, revised marking requirements in paras. 10.2.1.5 and 10.3, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) threaded Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—Threaded CPVC plastic pipe fittings, Schedule 80, which were formerly included in this standard, are now covered by Specification F437.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety hazards should a system fail for any reason.

1.3 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.

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

1.5 The following safety hazards 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F437 Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 General—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers threaded Schedule 80 PVC pipe fittings, made from four PVC plastic compounds and intended for use with threaded Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

5. Materials and Manufacture

5.1 This specification covers PVC pipe fittings made from two PVC plastics as classified in Specification D1784. These are cell classifications 12454 and 14333.

NOTE 3—Mechanical strength, heat deflection temperature, and flammability requirements are covered in Specification D1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 The dimensions and tolerances of the fittings shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D2122. Minimum dimensions have zero negative tolerances. Bushings shall have thread lengths applicable to the corresponding sizes. Counterbore is optional, is not shown in Table 1, and is not included in the center-to-end or end-to-end dimensions.

6.1.2 *Fittings Not Illustrated*—All fittings, whether illustrated in Table 1 and Table 2 or not, shall have wall thicknesses and thread dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_O\ t)/2t \tag{1}$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

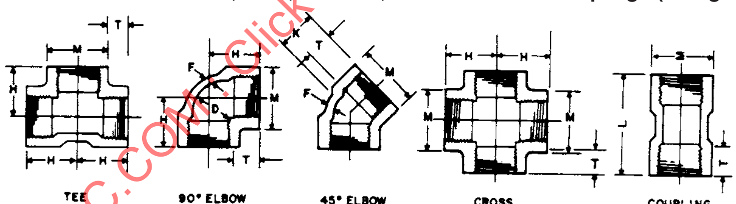
Fittings tested in accordance with 8.4 shall withstand the minimum burst pressure shown in Table 3.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The

TABLE 1 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses,[B] *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[B] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
⅛	0.688 (17.48)	0.38 (9.65)	0.625 (15.88)	0.171 (4.34)	0.108 (2.74)	0.645 (16.40)	0.813 (20.65)
¼	0.812 (20.63)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.30)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.50)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.26)	1.500 (38.10)	1.500 (38.10)
1	1.500 (38.10)	0.81 (20.57)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (33.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.54)	1.438 (36.53)	1.446 (36.73)	0.270 (6.86)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.580 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.48)	2.820 (71.65)	0.405 (10.29)	4.300 (104.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B] This dimension locates the end of the fitting.

TABLE 2 Dimensions of Plugs and Caps, in.[A]

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
⅛	0.31 (7.87)	0.38 (9.65)	0.469 (11.19)	0.108 (2.74)	0.188 (4.76)	0.625 (15.88)	0.645 (16.38)
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.76)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (14.05)	0.144 (3.66)	0.188 (4.76)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.45)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.76)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.97)	0.65 (16.51)	1.125 (28.58)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (36.80)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.86)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.45)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.73)	1.875 (47.63)	0.369 (9.37)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (44.45)	4.250 (107.90)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.80)	5.350 (134.62)
6	1.44 (36.58)	1.50 (38.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.70)	2.125 (53.98)	7.625 (193.00)

[A] The sketches and designs of fittings shown are illustrative only.
[B] At the manufacturer's option the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 3 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Threaded Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength[A]			
	Class 12454		Class 14333	
	psi	MPa	psi	MPa
¼	3620	(24.96)	2830	(19.51)
⅜	2940	(20.27)	2300	(15.86)
½	2720	(18.75)	2120	(14.62)
¾	2200	(15.17)	1720	(11.86)
1	2020	(13.93)	1580	(10.89)
1¼	1660	(11.44)	1300	(8.96)
1½	1510	(10.41)	1180	(8.14)
2	1290	(8.89)	1010	(6.96)
2½	1360	(8.38)	1060	(7.31)
3	1200	(8.27)	940	(6.48)
4	1040	(7.17)	810	(5.51)
6	890	(6.19)	700	(4.83)

[A] This table was calculated for Schedule 80 pipe using the ISO formula and the stress levels for materials as follows:

	psi	MPa
Class 12454	6400	44.1
Class 14333	5000	34.5

fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between purchaser and supplier need be conducted.

8.4 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599. Join the fittings to the pipe sufficiently strong and in such a manner that no failures shall occur in the assembly at a pressure less than the pressure requirement given in Table 3. The time of testing each assembly shall be between 60 and 70 s.

9. Retest and Rejection

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 seller. Under such agreement, minimum requirements shall not be lowered, 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. Product Marking

10.1 *Quality of Marking*—The marking shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking:*

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material identification PVC I for cell classification 12454 or PVC II for cell classification 14333,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact.

10.2.1.4 Size, and

10.2.1.5 ASME SD-2464 or both ASME SD-2464 and ASTM D2464.

10.3 Where the size of the fittings does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

The following requirements apply only to federal/military procurement, not domestic sales or transfers.

S1. *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 may use his own or any other suitable facilities for 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR POLY(VINYL CHLORIDE) (PVC) PLASTIC PIPE FITTINGS, SCHEDULE 40

SD-2466

(Identical with ASTM D2466-13 except for additional requirements in section 12 and Annex A1, revised marking requirements in para. 10.1.5, renumbering of section 13 and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) Schedule 40 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—Socket-type CPVC plastic pipe fittings, Schedule 40, which were formerly included in this standard, are now covered by Specification F438.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases, some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 Fitting such as unions, flanges, special plastic-to-metal transitions and appurtenances intended for use with PVC piping are covered under specification F1970.

1.4 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.

1.5 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.

1.6 The following safety hazards 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F438 Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

F1970 Specification for Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Systems

2.2 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 General—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers Schedule 40 PVC pipe fittings, made from four PVC plastic compounds and intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by welding are not included in this specification.

5. Materials

5.1 This specification covers PVC pipe fittings made from five PVC plastics as classified in Specification D1784. These are PVC 12454, 12454, 13354, 11443, and 14333.

5.2 *Compound*—The PVC plastic compound shall meet the requirements of PVC 12454, 12454, 11443, or 14333, as described in Specification D1784.

NOTE 3—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D1784.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Fitting sockets inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Table 1, Table 2, and Table 3 when measured in accordance with Test Method D2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional (See XA/XB in Table 3). Any point measured along the outside diameter of the bushing (between points XA and XB) shall not fall below minimum pipe OD.

6.1.3 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 40 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 40 pipe. For any threaded fitting the minimum wall thickness of the threaded portion shall be at least equal to the thickness of material under the thread root of threaded Schedule 80 pipe of the same size.

6.1.4 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 40 pipe. Any fitting having a male thread shall have an internal diameter not larger than Schedule 80 pipe of the same size.

6.1.5 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_O - t)/2t \qquad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 4.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

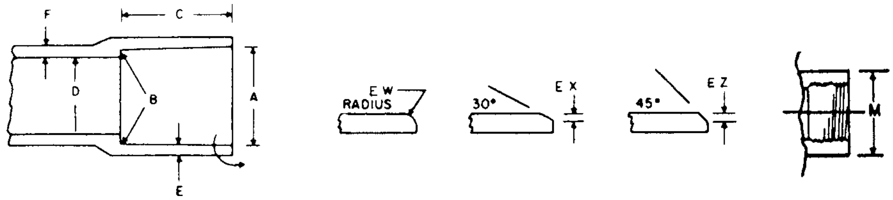
8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D1599. The pressure shall be applied at a uniform rate such that the minimum allowable burst pressure is attained in 60 or 70 s.

NOTE 5—The time-to-failure may exceed 70 s.

8.5.1 *Apparatus*—Fittings shall be tested while held in a test jig constructed in such a manner as to seal the socket by means of O-rings, or gaskets but not to reinforce or support the fittings, except where contact is necessary because of the shape of the fitting to keep the fitting in the test jig. Such contact shall be held to the minimum. The socket plug portion of the test

TABLE 1 Tapered Sockets for PVC Pipe Fittings, Schedule 40, in.[A]



Nominal Pipe Size	*A* Socket Entrance Diameter			*B* Socket Bottom Diameter			*C*[B] Socket Length, min	*D*[C] Inside Diameter, min	Wall Thickness, min		Min Outside Diameter of Hub, M	Entrance, min	
	Diameter	Tolerance on Diameter	Max Out-of-Round	Diameter	Tolerance on Diameter	Max Out-of-Round			E	F		EW	EX, EZ
1/8	0.417	±0.004	0.016 (0.41)	0.401	±0.004	0.016 (0.41)	0.500	0.225	0.068	0.085	0.526	1/64	1/64
1/4	0.552	±0.004	0.016 (0.41)	0.536	±0.004	0.016 (0.41)	0.500	0.320	0.088	0.110	0.672	1/64	1/64
3/8	0.687	±0.004	0.016 (0.41)	0.671	±0.004	0.016 (0.41)	0.594	0.449	0.091	0.114	0.821	1/32	1/32
1/2	0.848	±0.004	0.016 (0.41)	0.836	±0.004	0.016 (0.41)	0.688	0.578	0.109	0.136	0.998	1/32	1/32
3/4	1.058	±0.004	0.020 (0.51)	1.046	±0.004	0.020 (0.51)	0.719	0.740	0.113	0.141	1.221	1/32	1/32
1	1.325	±0.005	0.020 (0.51)	1.310	±0.005	0.020 (0.51)	0.875	0.990	0.133	0.166	1.504	1/16	1/16
1 1/4	1.670	±0.005	0.024 (0.61)	1.655	±0.005	0.024 (0.61)	0.938	1.335	0.140	0.175	1.871	1/16	1/16
1 1/2	1.912	±0.006	0.024 (0.61)	1.894	±0.006	0.024 (0.61)	1.094	1.564	0.145	0.181	2.127	1/16	1/16
2	2.387	±0.006	0.024 (0.61)	2.369	±0.006	0.024 (0.61)	1.156	2.021	0.154	0.193	2.634	1/16	1/16
2 1/2	2.889	±0.007	0.030 (0.76)	2.868	±0.007	0.030 (0.76)	1.750	2.414	0.203	0.254	3.170	3/32	1/8
3	3.516	±0.008	0.030 (0.76)	3.492	±0.008	0.030 (0.76)	1.875	3.008	0.216	0.270	3.841	3/32	1/8
3 1/2	4.016	±0.008	0.030 (0.76)	3.992	±0.008	0.030 (0.76)	2.000	3.486	0.226	0.283	4.374	3/32	1/8
4	4.518	±0.009	0.030 (0.76)	4.491	±0.009	0.030 (0.76)	2.000	3.961	0.237	0.296	4.907	3/32	1/8
5	5.583	±0.010	0.060 (1.52)	5.553	±0.010	0.060 (1.52)	3.000	4.975	0.258	0.323	6.039	3/32	1/8
6	6.647	±0.011	0.060 (1.52)	6.614	±0.011	0.060 (1.52)	3.000	5.986	0.280	0.350	7.203	1/8	3/16
8	8.655	±0.015	0.090 (2.29)	8.610	±0.015	0.090 (2.29)	4.000	7.888	0.322	0.403	9.320	1/8	3/16
10	10.780	±0.015	0.100 (3.05)	10.735	±0.015	0.100 (3.05)	5.000	9.917	0.365	0.456	11.614	1/8	3/16
12	12.780	±0.015	0.120 (3.81)	12.735	±0.015	0.120 (3.81)	6.000	11.825	0.406	0.508	13.786	1/8	3/16

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.4.

fixture must extend one third to two thirds of the socket depth. Failure of any part of the test apparatus does not constitute failure of the fittings.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, 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.

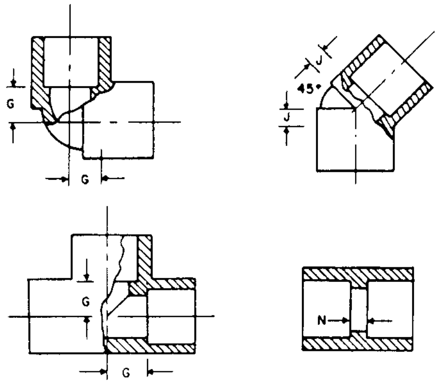
10. Marking

10.1 Fittings shall be marked with the following:

10.1.1 Manufacturer's name or trademark,

10.1.2 Material designation PVC I for PVC 12454-B, PVC 12 for PVC 12454-C, PVC 13 for PVC 13354-C and 11443-B, and PVC II for PVC 14333-D,

TABLE 2 Minimum Dimension from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, PVC Socket-Type Pipe Fittings, Schedule 40, in.[A]



Nominal Pipe Size	*G*, min	*J*, min	*N*, min
1⁄8	1⁄4	1⁄8	1⁄16
1⁄4	5⁄16	5⁄32	1⁄16
3⁄8	3⁄8	3⁄16	3⁄32
1⁄2	1⁄2	1⁄4	3⁄32
3⁄4	9⁄16	5⁄16	3⁄32
1	11⁄16	5⁄16	3⁄32
1 1⁄4	7⁄8	3⁄8	3⁄32
1 1⁄2	1	7⁄16	3⁄32
2	1 1⁄4	5⁄8	3⁄32
2 1⁄2	1 1⁄2	11⁄16	3⁄16
3	1 13⁄16	3⁄4	3⁄16
3 1⁄2	2 1⁄8	1	3⁄16
4	2 5⁄16	1	3⁄16
5	3	1 3⁄8	3⁄16
6	3 1⁄2	1 3⁄4	1⁄4
8	4 1⁄2	2	1⁄4
10	5 13⁄16	2 9⁄16	1⁄4
12	6 15⁄16	3 1⁄16	1⁄4

[A] The sketches and designs of fittings are illustrative only.

10.1.3 Fittings intended for the transport of potable water shall include the seal or mark of the laboratory making the evaluation for this purpose.

10.1.4 Size, and

10.1.5 ASME SD-2466 or both ASME SD-2466 and ASTM D2466.

10.2 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.3 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.4 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

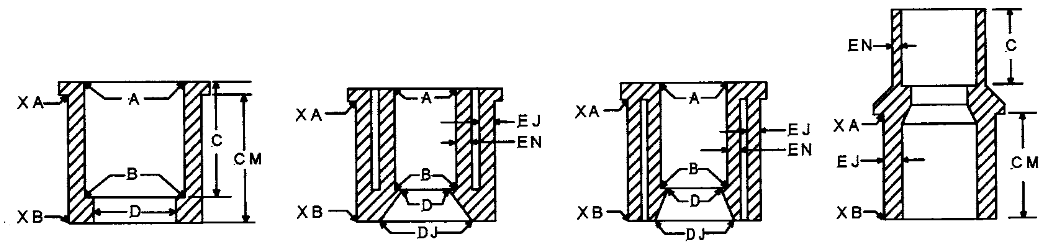
12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 fittings; pressure; PVC; Sch 40; sockets; threads

TABLE 3 Dimensions of Reducer Bushings, PVC Socket-Type Pipe Fittings, Schedule 40,[A] in. (mm)



Nominal Size	Outside Diameter *XA*	Tolerance on Outside Diameter	Outside Diameter *XB*	Tolerance on Outside Diameter	Maximum Out-of-Roundness (max. minus min.)
¼ by ⅛	0.540 (13.72)	+0.007 – 0.004 (0.18 – 0.10)	0.540 (13.72)	±0.004 (0.10)	0.016 (0.41)
⅜ by ¼, ⅛	0.675 (17.41)	+0.007 – 0.004 (0.18 – 0.10)	0.675 (17.41)	±0.004 (0.10)	0.016 (0.41)
½ by ⅜, ¼	0.840 (21.34)	+0.007 – 0.004 (0.18 – 0.10)	0.840 (21.34)	±0.004 (0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050 (26.67)	+0.007 – 0.004 (0.18 – 0.10)	1.050 (26.67)	±0.004 (0.10)	0.020 (0.51)
1 by ½, ¾	1.315 (33.40)	+0.008 – 0.005 (0.20 – 0.13)	1.315 (33.40)	±0.005 (0.13)	0.020 (0.51)
1¼ by ½, ¾, 1	1.660 (42.16)	+0.008 – 0.005 (0.20 – 0.13)	1.660 (42.16)	±0.005 (0.13)	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900 (48.26)	+0.010 – 0.006 (0.25 – 0.15)	1.900 (48.26)	±0.006 (0.15)	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375 (60.33)	+0.010 – 0.006 (0.25 – 0.15)	2.375 (60.33)	±0.006 (0.15)	0.024 (0.61)
2½ by 2	2.875 (73.03)	+0.012 – 0.007 (0.30 – 0.18)	2.875 (73.03)	±0.007 (0.18)	0.030 (0.76)
3 by 2½, 2	3.500 (88.90)	+0.013 – 0.008 (0.33 – 0.20)	3.500 (88.90)	±0.008 (0.20)	0.030 (0.76)
3½ by 2½, 2	4.000 (101.60)	+0.013 – 0.008 (0.33 – 0.20)	4.000 (101.60)	±0.008 (0.20)	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500 (114.30)	+0.015 – 0.009 (0.38 – 0.23)	4.500 (114.30)	±0.009 (0.23)	0.030 (0.76)
5 by 4	5.563 (141.30)	+0.017 – 0.010 (0.43 – 0.25)	5.563 (141.30)	±0.010 (0.25)	0.060 (1.52)
6 by 5	6.625 (168.28)	+0.018 – 0.011 (0.46 – 0.28)	6.625 (168.28)	±0.011 (0.28)	0.070 (1.78)
8 by 6	8.625 (219.08)	+0.025 – 0.015 (0.64 – 0.38)	8.625 (219.08)	±0.015 (0.38)	0.090 (2.29)
10 by 6	10.750 (273.05)	+0.025 – 0.015 (0.64 – 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
10 by 8	10.750 (273.05)	+0.025 – 0.015 (0.64 – 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
12 by 6	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 8	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 10	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)

[A] The sketches and designs of fittings are illustrative only, see Symbols D2749.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Socket-Type Pipe Fittings, Schedule 40

Nominal Size, in.	Min Burst Strength,[A]			
	Classes 12454, 13354-C, and 11443		Class 14333	
	psi	(MPa)	psi	(MPa)
⅛	2580	(17.79)	2020	(13.93)
¼	2490	(17.17)	1950	(13.44)
⅜	1990	(13.72)	1560	(10.76)
½	1910	(13.17)	1490	(10.27)
¾	1540	(10.62)	1210	(8.34)
1	1440	(9.93)	1130	(7.79)
1¼	1180	(8.14)	920	(6.34)
1½	1060	(7.31)	830	(5.72)
2	890	(6.14)	690	(4.76)
2½	970	(6.69)	760	(5.24)
3	840	(5.79)	660	(4.55)
3½	770	(5.31)	600	(4.14)
4	710	(4.90)	560	(3.86)
5	620	(4.27)	490	(3.38)
6	560	(3.86)	440	(3.03)
8	500	(3.45)	390	(2.69)
10	450	3.10	. . .	. . .
12	420	2.90	. . .	. . .

[A] This table was calculated for Schedule 40 pipe using the formula and the stress levels for materials as follows:

	psi	MPa
Classes 11443, 13354-C, and 12454	6400	44.1
Class 1433	5000	34.5

SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S1. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR POLY(VINYL CHLORIDE) (PVC) PLASTIC PIPE FITTINGS, SCHEDULE 80

SD-2467

(Identical with ASTM D2467-13a except for additional requirements in section 12 and Annex A1, revised marking requirements in paras. 10.2.4 and 10.3, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—CPVC plastic pipe fittings, which were formerly included in this standard, are now covered in Specification F439.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases, some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy, which present serious safety hazards should a system fail for any reason.

1.3 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 this specification.

1.4 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.

1.5 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F439 Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *National Sanitation Foundation Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 General—Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for poly(vinyl chloride) plastic is PVC.

4. Classification

4.1 *General*—This specification covers Schedule 80 PVC pipe fittings, socket-type, made from four PVC plastic compounds and intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe. (See Specification D1785.)

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, and the like, shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

5. Materials and Manufacture

5.1 This specification covers PVC pipe fittings made from five PVC plastics as classified in Specification D1784. These are PVC 12454, 11443, and 14333.

5.2 *Compound*—The PVC plastic compound shall meet the requirements of PVC 12454, 11443, or 14333, as described in Specification D1784.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Fitting sockets inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Tables 1-5 when measured in accordance with Test Method D2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 4) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional (see XA/XB in Table 3). Any point measured along the outside diameter of the bushing (between points XA and XB) shall not fall below minimum pipe OD.

6.1.3 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 80 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 80 pipe.

6.1.4 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 80 pipe. This is calculated as follows:

$$(\textit{minimum OD}) - 2 \times (\textit{maximum wall}) = \textit{minimum ID} \qquad (1)$$

6.1.5 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation and using a stress of 6400 psi for 8-in. and smaller fittings, and a stress of 5100 psi for fittings larger than 8-in. when the cell class is 12454, 13354 and 11443. When the cell class is 14333 a stress of 5000 psi is used in the equation for fittings 8-in. and smaller:

$$S = P(D_O - t)/2t \qquad (2)$$

S = hoop stress, psi (MPa)
P = internal pressure, psi (MPa),
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm)

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 6.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—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, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 3—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between purchaser and seller need be conducted.

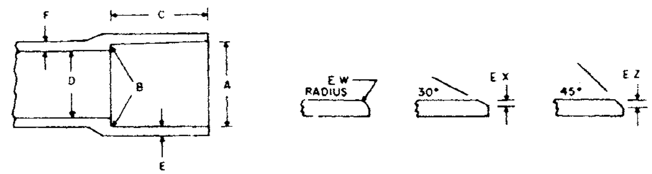
8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D1599, Procedure B. The pressure shall be applied at a uniform rate such that the minimum allowable burst pressure is attained in 60 to 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, changed, or modified, nor shall specification limits be changed.

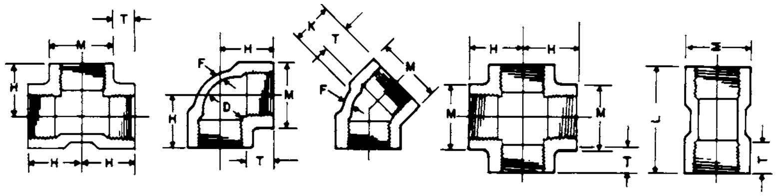
TABLE 1 Tapered Sockets for PVC Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	*A* Socket Entrance Diameter: Diameter	Tolerance on Nominal Diameter	Max Out-of-Round	*B* Socket Bottom Diameter: Diameter	Tolerance on Nominal Diameter	Max Out-of-Round	*C*[B] Socket Length, min	*D*[C] Inside Diameter, min	Wall Thickness, min: *E*	*F*	Entrance, min: *EW*	*EX*	*EZ*
1/8	0.417 (10.59)	±0.004 (0.10)	0.016 (0.41)	0.401 (10.18)	±0.004 (0.10)	0.016 (0.41)	0.500 (12.7)	0.171 (4.34)	0.095 (2.41)	0.118 (3.00)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
1/4	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.61)	±0.004 (0.10)	0.016 (0.41)	0.625 (15.88)	0.258 (6.55)	0.119 (3.02)	0.149 (3.78)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
3/8	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.750 (19.05)	0.379 (9.63)	0.126 (3.20)	0.160 (4.06)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
1/2	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.875 (22.22)	0.502 (12.75)	0.147 (3.73)	0.185 (4.70)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
3/4	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	1.000 (25.40)	0.698 (17.73)	0.154 (3.91)	0.195 (4.95)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
1	1.325 (33.65)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	1.125 (28.58)	0.911 (23.14)	0.179 (4.55)	0.225 (5.72)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
1 1/4	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	1.250 (31.75)	1.227 (31.17)	0.191 (4.85)	0.239 (6.07)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
1 1/2	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.11)	±0.006 (0.15)	0.024 (0.61)	1.375 (34.93)	1.446 (36.73)	0.200 (5.08)	0.250 (6.35)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.500 (38.10)	1.881 (47.78)	0.218 (5.54)	0.275 (6.99)	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)
2 1/2	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.250 (57.15)	0.276 (7.01)	0.345 (8.76)	3/32 (2.38)	1/8 (3.18)	1/8 (3.18)
3	3.516 (89.31)	±0.008 (0.20)	0.030 (0.76)	3.492 (88.70)	±0.008 (0.20)	0.030 (0.76)	1.875 (47.63)	2.820 (71.63)	0.300 (7.62)	0.375 (9.53)	3/32 (2.38)	1/8 (3.18)	1/8 (3.18)
3 1/2	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.4)	±0.008 (0.20)	0.030 (0.76)	2.125 (53.98)	3.280 (83.31)	0.318 (8.08)	0.400 (10.16)	3/32 (2.38)	1/8 (3.18)	1/8 (3.18)
4	4.518 (114.76)	±0.009 (0.23)	0.030 (0.76)	4.491 (114.1)	±0.009 (0.23)	0.030 (0.76)	2.250 (57.15)	3.737 (94.92)	0.337 (8.56)	0.420 (10.67)	3/32 (2.38)	1/8 (3.18)	1/8 (3.18)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.0)	±0.010 (0.25)	0.060 (1.52)	2.625 (66.68)	4.703 (119.46)	0.375 (9.53)	0.470 (11.94)	3/32 (2.38)	1/8 (3.18)	1/8 (3.18)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.0)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.646 (143.41)	0.432 (10.97)	0.540 (13.72)	1/8 (3.18)	3/16 (4.76)	3/16 (4.76)
8	8.655 (219.84)	±0.015 (0.38)	0.090 (2.29)	8.610 (218.7)	±0.015 (0.38)	0.090 (2.29)	4.000 (101.60)	7.490 (190.25)	0.500 (12.70)	0.625 (15.88)	1/8 (3.18)	3/16 (4.76)	3/16 (4.76)
10	10.780 (273.81)	±0.015 (0.38)	0.100 (2.54)	10.735 (272.67)	±0.015 (0.38)	0.100 (2.54)	5.000 (127.00)	9.407 (238.94)	0.593 (15.06)	0.741 (18.82)	1/8 (3.18)	3/16 (4.76)	3/16 (4.76)
12	12.780 (324.61)	±0.015 (0.38)	0.120 (3.05)	12.735 (323.47)	±0.015 (0.38)	0.120 (3.05)	6.000 (152.40)	11.197 (284.40)	0.687 (17.45)	0.859 (21.82)	1/8 (3.18)	3/16 (4.76)	3/16 (4.76)

[A] The sketches and designs of fittings are illustrative only (taken from Symbols D2749).
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.4.

TABLE 2 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses,[B] *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[B] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
⅛	0.688 (17.48)	0.38 (9.65)	0.625 (15.88)	0.215 (5.46)	0.118	0.645 (16.40)	0.813 (20.65)
¼	0.812 (20.63)	0.50 (12.70)	0.688 (17.48)	0.302 (7.67)	0.149	0.840 (21.30)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.423 (10.74)	0.160	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.550 (13.97)	0.185	1.280 (32.50)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.750 (19.05)	0.195	1.500 (38.10)	1.500 (38.10)
1	1.500 (38.10)	0.81 (20.57)	1.125 (28.58)	0.960 (24.38)	0.225	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (33.35)	1.280 (32.51)	0.261	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.54)	1.438 (36.53)	1.500 (38.10)	0.270	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.940 (49.28)	0.297	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.320 (58.93)	0.345	3.580 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.48)	2.900 (73.66)	0.405	4.300 (104.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.830 (97.28)	0.450	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.761 (146.33)	0.540	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B] This dimension locates the end of the fitting.

If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

10. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking*—Fittings shall be marked with the following:

10.2.1 Material designation PVC I for PVC 12454, PVC 13 11443, and PVC II for PVC–14333,

10.2.2 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.3 Size, and

10.2.4 ASME SD-2467 or both ASME SD-2467 and ASTM D2467.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.4 Marking or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case does marking cause cracks or reduce the wall thickness below the minimum specified.

11. Quality Assurance

11.1 *Quality Assurance*—The manufacturer affirms that the product was inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

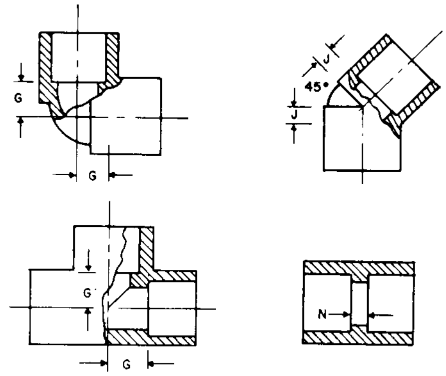
12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 blunt start thread; fittings; IPS; PVC; Schedule 80; sockets; thread

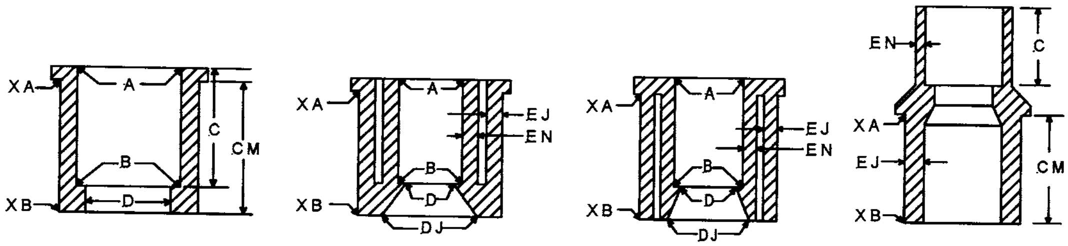
TABLE 3 Minimum Dimensions from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, PVC Socket-Type Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	*G*, min	*J*, min	*N*, min
1/8	1/4 (6.35)	1/8 (3.18)	1/16 (1.59)
1/4	5/16 (7.94)	5/32 (3.97)	1/16 (1.59)
3/8	3/8 (9.53)	3/16 (4.76)	3/32 (2.38)
1/2	1/2 (12.70)	1/4 (6.35)	3/32 (2.38)
3/4	9/16 (14.29)	5/16 (7.94)	3/32 (2.38)
1	11/16 (17.46)	5/16 (7.94)	3/32 (2.38)
1 1/4	7/8 (22.22)	3/8 (9.53)	3/32 (2.38)
1 1/2	1 (25.40)	7/16 (11.11)	3/32 (2.38)
2	1 1/4 (31.75)	5/8 (15.88)	3/32 (2.38)
2 1/2	1 1/2 (38.10)	11/16 (17.46)	3/16 (4.76)
3	1 13/16 (46.04)	3/4 (19.05)	3/16 (4.76)
3 1/2	2 1/8 (53.98)	1 (25.40)	3/16 (4.76)
4	2 5/16 (58.74)	1 (25.40)	3/16 (4.76)
5	3 (76.20)	1 3/8 (34.93)	3/16 (4.76)
6	3 1/2 (88.90)	1 3/4 (44.45)	1/4 (6.35)
8	4 1/2 (114.30)	2 (50.80)	1/4 (6.35)
10	5 11/16 (144.46)	2 1/4 (57.15)	1/4 (6.35)
12	6 7/8 (174.63)	2 1/2 (63.50)	3/8 (9.53)

[A] The sketches and designs of fittings are illustrative only (taken from Symbols D2749).

TABLE 4 Symbols for Dimensions of Reducer Bushings, PVC Socket-Type Pipe Fittings, Schedule 80,[A] in. (mm)



Nominal Size	Outside Diameter *XA*	Tolerance on Outside Diameter	Outside Diameter *XB*	Tolerance on Outside Diameter	Maximum Out-of-Roundness (max., minus min.)
¼ by ⅛	0.540 (13.72)	+0.007 – 0.004 (0.18 – 0.10)	0.540 (13.72)	±0.004 (0.10)	0.016 (0.41)
⅜ by ¼, ⅛	0.675 (17.41)	+0.007 – 0.004 (0.18 – 0.10)	0.675 (17.41)	±0.004 (0.10)	0.016 (0.41)
½ by ⅜, ¼	0.840 (21.34)	+0.007 – 0.004 (0.18 – 0.10)	0.840 (21.34)	±0.004 (0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050 (26.67)	+0.007 – 0.004 (0.18 – 0.10)	1.050 (26.67)	±0.004 (0.10)	0.020 (0.51)
1 by ½, ¾	1.315 (33.40)	+0.008 – 0.005 (0.20 – 0.13)	1.315 (33.40)	±0.005 (0.13)	0.020 (0.51)
1¼ by ½, ¾, 1	1.660 (42.16)	+0.008 – 0.005 (0.20 – 0.13)	1.660 (42.16)	±0.005 (0.13)	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900 (48.26)	+0.010 – 0.006 (0.25 – 0.15)	1.900 (48.26)	±0.006 (0.15)	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375 (60.33)	+0.010 – 0.006 (0.25 – 0.15)	2.375 (60.33)	±0.006 (0.15)	0.024 (0.61)
2½ by 2	2.875 (73.03)	+0.012 – 0.007 (0.30 – 0.18)	2.875 (73.03)	±0.007 (0.18)	0.030 (0.76)
3 by 2½, 2	3.500 (88.90)	+0.013 – 0.008 (0.33 – 0.20)	3.500 (88.90)	±0.008 (0.20)	0.030 (0.76)
3½ by 2½, 2	4.000 (101.60)	+0.013 – 0.008 (0.33 – 0.20)	4.000 (101.60)	±0.008 (0.20)	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500 (114.30)	+0.015 – 0.009 (0.38 – 0.23)	4.500 (114.30)	±0.009 (0.23)	0.030 (0.76)
5 by 4	5.563 (141.30)	+0.017 – 0.010 (0.43 – 0.25)	5.563 (141.30)	±0.010 (0.25)	0.060 (1.52)
6 by 5	6.625 (168.28)	+0.018 – 0.011 (0.46 – 0.28)	6.625 (168.28)	±0.011 (0.28)	0.070 (1.78)
8 by 6	8.625 (219.08)	+0.025 – 0.015 (0.64 – 0.38)	8.625 (219.08)	±0.015 (0.38)	0.090 (2.29)
10 by 6	10.750 (273.05)	+0.025 – 0.015 (0.64 – 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
10 by 8	10.750 (273.05)	+0.025 – 0.015 (0.64 – 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
12 by 6	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 8	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 10	12.750 (323.85)	+0.025 – 0.015 (0.64 – 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)

[A] The sketches and designs of fittings are illustrative only (taken from Symbols D2749).

TABLE 5 Dimensions of Plugs and Caps, in.

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[A] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
⅛	0.31 (7.87)	0.38 (9.65)	0.469 (11.19)	0.108 (2.74)	0.188 (4.76)	0.625 (15.88)	0.645 (16.38)
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.76)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (14.05)	0.144 (3.66)	0.188 (4.76)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.45)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.76)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.97)	0.65 (16.51)	1.125 (28.58)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (36.80)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.86)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.45)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.73)	1.875 (47.63)	0.369 (9.37)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (44.45)	4.250 (107.90)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.80)	5.350 (134.62)
6	1.44 (36.58)	1.50 (38.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.70)	2.125 (53.98)	7.625 (193.00)

[A] At the manufacturer's option the head of the plug may be hexagonal, octagonal, square, or round. The sketches and designs of fittings shown are illustrative only.

TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for PVC Socket-Type Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength			
	Classes 12454, 13354, and 11443		Class 14333	
	psi	MPa	psi	MPa
⅛	3920	27.03	3060	21.10
¼	3620	24.96	2830	19.51
⅜	2940	20.27	2300	15.86
½	2720	18.75	2120	14.62
¾	2200	15.17	1720	11.36
1	2020	13.93	1580	10.89
1¼	1660	11.44	1300	8.96
1½	1510	10.41	1180	8.14
2	1290	8.89	1010	6.96
2½	1360	9.38	1060	7.31
3	1200	8.27	940	6.48
3½	1110	7.65	860	5.93
4	1040	7.17	810	5.58
5	930	6.41	720	4.96
6	890	6.14	700	4.83
8	790	5.45	620	4.27
10	600	4.14	. . .	. . .
12	580	4.00	. . .	. . .

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILITARY PROCUREMENT

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

S1. *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 may 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 S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1— The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR POLYETHYLENE (PE) GAS PRESSURE PIPE, TUBING, AND FITTINGS

SD-2513

(Identical with ASTM D2513-14e1 except for additional requirements in section 9 and Annex A3, revision to para. 1.4, revised marking requirements in paras. 7.1, 7.2 and 7.5, changes from "ANSI" to "ASME" in paras. 2.2, 3.2, and 5.15 and paras. X1.3.4, X1.5.1, and X1.6.1, and quality assurance requirement in para. 8.1 has been made mandatory.)

Specification for
Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

1. Scope

1.1 This specification covers requirements and test methods for material dimensions and tolerances, hydrostatic burst strength, chemical resistance, and rapid crack resistance of polyethylene pipe, tubing, and fittings for use in fuel gas mains and services for direct burial and reliner applications. The pipe and fittings covered by this specification are intended for use in the distribution of natural gas. Requirements for the qualifying of polyethylene systems for use with liquefied petroleum gas are also covered.

1.1.1 This specification does not cover threaded pipe. Design considerations are discussed in Appendix X1. In-plant quality control programs are specified in Annex A1 and Annex A2.

1.1.2 See Specification F2619/F2619M for polyethylene piping for pressure or non-pressure oil and gas producing applications to convey fluids such as oil, dry or wet gas, multiphase fluids, and non-potable oilfield water.

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 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.

1.4 The following is an index of the annexes and appendix in this specification:

Annex	Subject
Annex A1	In-Plant Quality Control for all materials up to 12 in.
Annex A2	In-Plant Quality Control for PE materials 14 in. and larger
Annex A3	Certification

Appendixes	Subject
Appendix X1	Design Consideration

1.5 The following precautionary caveat pertains only 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

2.1.1 *Terminology:*

D1600 Terminology for Abbreviated Terms Relating to Plastics

F412 Terminology Relating to Plastic Piping Systems

2.1.2 *Test Methods for:*

D638 Test Method for Tensile Properties of Plastics

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe

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

F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

2.1.3 *Practices for:*

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D618 Practice for Conditioning Plastics for Testing

D1435 Practice for Outdoor Weathering of Plastics

D1898 Practice for Sampling of Plastics (Withdrawn 1998)

D2774 Practice for Underground Installation of Thermoplastic Pressure Piping
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.1.4 *Specification for:*

D2683 Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
D3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
F1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
F1563 Specification for Tools to Squeeze-off Polyethylene (PE) Gas Pipe or Tubing
F2138 Specification for Excess Flow Valves for Natural Gas Service
F2619/F2619M Specification for High-Density Polyethylene (PE) Line Pipe
F2897 Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)

2.2 *ASME Standards:*

B 16.40 Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems
B 31.8 Gas Transmission and Distribution Piping Systems

2.3 *Federal Specifications:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
OPS 49 CFR Part 192 Title 49, Code of Federal Regulations

2.4 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-1235 (ORD) Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection by Attributes

2.5 *ISO Standards*:

ISO 4437 Buried polyethylene (PE) pipes for the supply of gaseous fuels-Metric series-Specifications
ISO 9080 Thermoplastics Pipes for the Transport of Fluids—Methods of Extrapolation of Hydrostatic Stress Rupture Data to Determine Long-Term Hydrostatic Strength of Thermoplastic Pipe Materials
ISO 12162 Thermoplastic Materials for Pipes and Fittings for Pressure Applications—Classification and Designation—Overall Service (Design) Coefficient
ISO 13477 Thermoplastics pipes for the conveyance of fluids – Determination of resistance to rapid crack propagation (RCP) – Small scale steady-state test (S4 test)
ISO 13478 Thermoplastics pipe for the conveyance of fluids – Determination of resistance to rapid crack propagation (RCP) – Full-scale test (FST)

2.6 *Plastic Pipe Institute*

PPI TR-3 HDB/HDS /PDB/ SDB/MRS Policies
PPI TR-4 HDB/HDS/SDB/PDB/MRS Listed Materials
PPI TR-33 Generic Butt Fusion Joining for Polyethylene Gas Pipe
PPI TR-41 Generic Saddle Fusion Joining Procedure for Polyethylene Gas Piping
PPI TN-30/2006 Requirements for the Use of Rework Materials in Polyethylene Gas Pipe
PPI TR-9 Recommended Design Factors and Design Coefficients for Thermoplastic Pressure pipe

2.7 *Other Documents:*

National Fire Protection Association: NFPA 58 Storage and Handling Liquefied Petroleum Gases

3. Terminology

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

3.2 The gas industry terminology used in this specification is in accordance with ASME B31.8 or OPS 49 CFR Part 192, unless otherwise indicated.

3.3 The term *pipe* used herein refers to both pipe and tubing unless specifically stated otherwise.

3.4 *re-rounding equipment*—equipment used to reform the pipe and permanently reduce ovality to 5 % or less.

3.5 *rounding equipment*—equipment, devices, clamps, and so forth, used to temporarily hold the pipe round while out-of-roundness measurements are made, or a joining procedure (heat fusion, electrofusion, or mechanical) is performed.

3.6 *pipe material designated code*—the pipe material designation code shall consist of the abbreviation for the type of plastic (PE) followed by Arabic numerals which describe the short term properties in accordance with applicable Specification D3350, the hydrostatic design stress for water at 73.4°F (23°C) in units of 100 psi with any decimal figures dropped. Where the hydrostatic design stress code contains less than two figures, a zero is used before the number. Thus, a complete material designation code shall consist of PE and four figures for PE materials. For example, PE2708 is a grade PE27 polyethylene with an 800psi design stress for water at 73.4°F (23°C). The hydrostatic design stresses for gas are not used in this designation code.

3.7 *dimension ratio (DR)*—the ratio of pipe diameter to wall thickness. It is calculated by dividing the specified outside diameter of the pipe, in inches (mm), by the minimum specified wall thickness, in inches (mm). The standard dimension ratio (SDR) is a common numbering system which is derived from the ANSI preferred number series R 10.

3.8 *toe-in*—a small reduction of the outside diameter at the cut end of a length of thermoplastic pipe.

4. Materials

4.1 *General*—The PE used to make pipe and fittings shall be PE or reworked PE (see 4.2 and 4.4) and shall have a Plastics Pipe Institute (PPI) long-term hydrostatic design stress and hydrostatic design basis rating.

4.2 *Rework Material*—Clean rework material of the same commercial designation, generated from the manufacturer's own pipe and fitting production shall not be used unless the pipe and fitting produced meet all the requirements of this specification. The use of these rework materials shall be governed by the requirements of 4.3 and PPI TN-30/2006. In pipe, rework materials shall be limited to a maximum of 30 % by weight.

NOTE 1—The requirements for rework materials herein are intended to incorporate prudent specifications to ensure that the potential for contamination in gas piping products, that meet this specification, is reduced to the extent possible. It is imperative to emphasize that rework materials have not been identified as the cause of any field failures. The requirements for rework materials were developed by the consensus of interested parties including product manufacturers, gas utility companies, and regulatory agencies.

4.3 *Documentation*—A documentation system to allow for traceability of raw materials including percentage and material classification (or designation, if applicable) of rework materials used in the manufacture of the pipe product meeting the requirements of this specification shall exist and be supplied to the purchaser, if requested.

4.4 *Classification*—Polyethylene materials suitable for use in the manufacture of pipe and fittings under this specification shall meet Table 1 requirements for the applicable pipe material designation code.

NOTE 2—References and material descriptions for PE 2306, PE 2406, PE 2606, PE 3306, PE 3406, PE 3408, PE 3608, PE 3710, and PE 4608 have been removed from D2513. Elimination of these materials does not affect the pipelines that are in service. They can still be used for gas distribution. The main reason for removing these materials from this standard is to reflect the current state of the art in PE gas distribution piping.

4.5 *Resistance to Slow Crack Growth (SCG)*—Use Test Method F1473 on compression molded plaques at a stress of 2.4 MPa based on the unnotched area and a test temperature of 80°C. Notch depth shall be in accordance with Table 1 in Test Method F1473. Materials shall meet the Slow Crack Growth Resistance requirements in Table 1.

4.6 *Additive Classes*—Polyethylene material compounds shall meet Specification D3350 code C or E. Code C material compounds shall have 2 to 3 percent carbon black. Code E material compounds shall be yellow with UV stabilizer.

4.7 *Thermal Stability*—The PE material shall contain sufficient antioxidant so that the minimum induction temperature shall be 428°F (220°C) when tested in accordance with Specification D3350. The sample shall be representative of the cross section of the pipe or fittings.

4.8 *Hydrostatic Design Basis (HDB) Substantiation* —The HDB for PE materials at 73°F (23°C) shall be substantiated to be linear to 50 years as per Test Method D2837, Section 5.7.

NOTE 3—The long-term hydrostatic strength at 50 years in accordance with Test Method D2837 is not to be used for any pressure rating calculations. The MAOP is still calculated using the HDB obtained from Test Method D2837 long-term hydrostatic strength at 100 000 h. PE compounds with a thermoplastic pipe material designation code of PE 2708 and PE 4710 as well as those compounds denoted in PPI TR-4 with an asterisk (*) meet the substantiation requirement of Test Method D2837.

4.9 *Resistance to Rapid Crack Propagation (RCP) for Material* —The PE material classification (formulation) used in the manufacture of pipe and fittings under this specification shall be tested for resistance to failure by RCP in accordance with the procedures set forth in ISO 13477 (S4 Test) or ISO 13478 (Full Scale Test (FST)). The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others. The values obtained are applicable to all pipes with the wall thickness of the pipe tested and all thinner wall pipes. In case of conflict, the RCP results of ISO 13478 shall apply.

NOTE 4—While S4 or FST testing of any combination of outside diameter and SDR is permitted in fulfillment of the requirement for testing

TABLE 1 Polyethylene Compound Requirements

	Pipe Material Designation Code	
	PE 2708	PE 4710
Density Cell Classification per Specification D3350	2	4
SCG Resistance Cell Classification per Specification D3350	7	7
HDS for water at 73°F (23°C) per Test Method D2837 and PPI TR-3, psi (MPa)	800 (5.5)	1000 (6.9)
Color and UV Stabilizer Code per Speciification D3350	C or E	C or E
Melt flow rate per Test Method D1238, g/10 min	≤0.40 Cond. 190/2.16 or ≤20 Cond. 190/21.6	≤0.15 Cond. 190/2.16 or ≤20 Cond. 190/21.6
HDB at 73ºF (23ºC) per Test Method D2837 and PPI TR-3, psi (MPa)	1250 (8.6)	1600 (11.0)
Minimum HDB at 140ºF (60ºC) per Test Method D2837 and PPI TR-3, psi (MPa)	800 (5.5)	800 (5.5)

PE material resistance to RCP, S4 testing of SDR 9 or SDR 11 PE pipe specimens is currently the most common industry practice.

NOTE 5—Caution should be exercised in applying the RCP test results obtained on one SDR or DR of pipe across a series of pipe SDR's or DR's produced from the same PE material classification (formulation). Industrial research to clarify the relationships between FST and S4 testing is ongoing at this time, particularly as it relates to the applicability of RCP test results obtained on one SDR or DR of pipe to other SDR's or DR's of pipe produced from the same PE material classification (formulation). Consult the resin manufacturer regarding the applicability of RCP test results across diameters or SDR's, or both. Additional information regarding the use of RCP data is presented in ISO 4437.

4.10 *UV Resistance*—PE materials shall be Code C or E as defined in Specification D3350. Code C material shall contain 2 to 3 percent well dispersed carbon black, and due to the absorptive properties of the carbon black, is considered to be stabilized against deterioration from unprotected exposure to UV for not less than 10 years. Code E material shall be stabilized and protected against deterioration from unprotected UV exposure for not less than 3 years.

4.10.1 PE compounds designated as Code C containing 2 to 3% carbon black shall be considered stabilized against deterioration for not less than 10 years without the need for additional testing.

4.10.2 PE compounds designated as Code E shall be considered stabilized against deterioration from unprotected exposure to UV for not less than 3 years when meeting the following criteria following exposure to actual outdoor (natural sunlight) weathering for up to 3 years in accordance with Practice D1435 or accelerated weathering in accordance with Practice D2565 and Practice G155 for the equivalent of at least 3 years natural sunlight: (a) all tensile bar specimens tested in accordance with Test Method D638 shall have an elongation at break value greater than 400% indicating the equivalency of the PE material before and after UV exposure against the elongation at break requirement in Specification D3350; and (b) all tensile bar specimens tested in accordance with Test Method D638 shall retain a minimum of 50% of their original elongation at break values. Test data shall be made available from the manufacturer upon request.

NOTE 6—Studies have shown HDPE exposed to Xenon Arc via Practice G155-A Cycle 1 give approximately 4.4 times the acceleration to outdoor Florida exposure. Therefore approximately 2000 hours Xenon Arc testing would equal about 1-year outdoor exposure in Florida or 2-years in southern Canada.

NOTE 7—The determination for UV resistance is often based on measuring the ductility properties of the pipe material exposed to artificial weathering. These requirements and test methods are based on expected UV exposure levels in North America. Alternate requirements and alternate determination methods may be appropriate in other regions of the world. As an example ISO 4437 standard requires a minimum resistance to an accumulation of 3.6GJ for non-black polyethylene materials.

4.11 *Qualification for LPG Service*—Materials that qualify for natural gas service and that carry a recommended HDB for 140°F in accordance with 5.6, also qualify for LPG service without the need for further testing.

NOTE 8—The terms LPG and LPG gas are synonymous and only apply to a particular kind of fuel gas. For compositions and properties of LPG gases see NFPA 58, Appendix B.

5. Requirements

5.1 *General*—Pipe shall be supplied in either coils or straight lengths. Any pipe supplied in coils must meet the same requirements before and after coiling.

5.2 *Workmanship*—The pipe and fittings shall be homogeneous throughout and free of visible cracks, holes, foreign inclusion, blisters, and dents, or other injurious defects. The pipe and fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

5.3 *Pipe and Tubing Dimensions and Tolerances:*

5.3.1 *Dimension*—The dimensions shall be specified by wall thickness and outside diameter.

5.3.1.1 *Diameters*—The outside diameter shall meet the requirements given in Table 2 or Table 3 when measured in accordance with 6.5.

5.3.1.2 *Toe-In*—When measured in accordance with 6.5.1.1, the outside diameter at the cut end of the pipe shall not be more than 1.5 % smaller than the undistorted outside diameter. Measurement of the undistorted outside diameter shall be made no closer than 1.5 pipe diameters or 11.8 in. (300 mm), whichever distance is less, from the cut end of the pipe. Undistorted outside diameter shall meet the requirements of Table 2 or Table 3.

5.3.1.3 *Wall Thickness*—The wall thickness shall be as specified in Table 3 or Table 4 when measured in accordance with 6.5.1.2. The minimum wall thickness at any point of measurement shall be not less than the minimum wall thickness specified in Table 3 or Table 4.

5.3.1.4 *Wall Thickness Eccentricity Range*—The wall thickness eccentricity range shall be within 12 % when measured in accordance with 6.5.1.3.

5.3.1.5 *Ovality*—The ovality (cross section) of 3 in. IPS (88.9 mm) and smaller pipe shall not exceed 5 % when measured in accordance with 6.5.3. Measurements of coiled pipe shall be made on a sample cut from the coil, and in case of disagreement, conditioned per 6.3.

NOTE 9—Other factors, that is, installation compaction, static soil loading, and dynamic vehicular loads may increase the ovality; therefore, 5 % was chosen as the limit for the amount contributed by manufacturing, packing, in-plant storage, and shipping. For further information, see (**1**).

(1) Before or during installation, coiled pipe larger than 3 in. IPS (88.9 mm) shall be processed by the installer through re-rounding equipment that corrects ovality to 5 % or less.

NOTE 10—Ovality is a packaging condition that occurs when roundable pipe is wound into a coil—the pipe flattens out as it is coiled. Ovality is corrected when joining equipment is applied to roundable pipe, or by field processing roundable pipe through re-rounding and straightening equipment during installation.

5.3.1.6 *Length*—The pipe shall be supplied in straight lengths or coils as agreed upon between the manufacturer and the purchaser. The length shall not be less than the minimum length agreed upon when corrected to 73°F (23°C).

5.3.1.7 When sizes other than those listed in Table 2, Table 3 or Table 4 are used, tolerances shall be: for outside diameter,

TABLE 2 Outside Diameters and Tolerances for Plastic Pipe, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerance	Maximum Out-of-Roundness			
			SDR 32.5	SDR 26	SDR 21	SDR 17 SDR 13.5 SDR 11
½	0.840 (21.3)	±0.004 (±0.102)	...	...	0.03(0.762)	0.016(0.406)
¾	1.050 (26.7)	±0.004 (±0.102)	...	...	0.03(0.762)	0.02(0.508)
1	1.315 (33.4)	±0.005 (±0.127)	...	...	0.03(0.762)	0.02(0.508)
1¼	1.660 (42.1)	±0.005 (±0.127)	...	...	0.03(0.762)	0.024(0.61)
1½	1.900 (48.3)	±0.006 (±0.152)	...	...	0.06(1.524)	0.024(0.61)
2	2.375 (60.3)	±0.006 (±0.152)	...	...	0.06(1.524)	0.024(0.61)
2½	2.875 (73.0)	±0.007 (±0.179)	...	...	0.06(1.524)	0.03(0.762)
3	3.500 (88.9)	±0.008 (±0.203)	...	...	0.06(1.524)	0.03(0.762)
3½	4.000 (101.6)	±0.008 (±0.203)	...	...	0.1(2.5)	0.03(0.762)
4	4.500 (114.3)	±0.009 (±0.229)	...	...	0.1(2.5)	0.03(0.762)
5	5.563 (141.3)	±0.010 (±0.254)	...	...	0.1(2.5)	0.06(1.524)
6	6.625 (168.3)	±0.011 (±0.279)	0.12(3)	0.11(2.74)	0.1(2.5)	0.07(1.778)
8	8.625 (219.1)	±0.013 (±0.330)	0.24(6.1)	0.16(4.06)	0.12(3)	0.08(2.04)
10	10.750 (273.0)	±0.015 (±0.381)	0.24(6.1)	0.2(5.08)	0.14(3.58)	0.1(2.5)
12	12.750 (323.8)	±0.017 (±0.432)	0.28(7.12)	0.2(5.08)	0.14(3.58)	0.1(2.5)
14	14.000 (355.6)	±0.063 (±1.60)	0.308(7.82)	0.224(5.68)	0.154(3.91)	0.112(2.84)
16	16.000 (406.4)	±0.072 (±1.83)	0.352(8.94)	0.256(6.50)	0.176(4.47)	0.128(3.25)
18	18.000 (457.2)	±0.081 (±2.06)	0.396(10.05)	0.288(7.31)	0.198(5.02)	0.144(3.65)
20	20.000 (508.0)	±0.090 (±2.29)	0.44(11.1)	0.32(8.12)	0.22(5.58)	0.16(4.06)
22	22.000 (558.8)	±0.099 (±2.51)	0.484(12.29)	0.352(8.94)	0.242(6.14)	0.176(4.47)
24	24.000 (609.6)	±0.108 (±2.74)	0.528(13.41)	0.384(9.75)	0.264(6.70)	0.192(4.87)

TABLE 3 PE Tubing-Diameters, Wall Thicknesses, and Tolerances, in. (mm)

Nominal Tubing Size (CTS)	Outside Diameter	Tolerance	Minimum Wall Thickness	Wall Thickness Tolerance
¼	0.375 (9.52)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
⅜	0.500 (12.7)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
½	0.625 (15.9)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
½	0.625 (15.9)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
½	0.625 (15.9)	±0.004 (±0.10)	0.104 (2.64)	+0.010 (+0.25)
¾	0.875 (22.2)	±0.004 (±0.10)	0.062 (1.58)	+0.006 (+0.15)
¾	0.875 (22.2)	±0.004 (±0.10)	0.077 (1.95)	+0.008 (+0.20)
¾	0.875 (22.2)	±0.004 (±0.10)	0.090 (2.27)	+0.009 (+0.23)
1	1.125 (28.6)	±0.005 (±0.13)	0.062 (1.58)	+0.007 (+0.18)
1	1.125 (28.6)	±0.005 (±0.13)	0.090 (2.27)	+0.011 (+0.28)
1	1.125 (28.6)	±0.005 (±0.13)	0.099 (2.51)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.101 (2.56)	+0.012 (+0.31)
1	1.125 (28.6)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.062 (1.58)	+0.007 (+0.18)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.090 (2.27)	+0.011 (+0.28)
1¼	1.375 (34.9)	±0.005 (±0.13)	0.121 (3.07)	+0.015 (+0.38)
1¾	1.875 (47.6)	±0.006 (±0.15)	0.062 (1.58)	+0.007 (+0.18)

use same tolerance of next smaller size; for wall thickness, use same tolerance percentage as shown in the tables.

5.4 *Minimum Hydrostatic Burst Pressure/Apparent Tensile Strength (Quick Burst)*—The pipe or system shall fail in a ductile manner when tested in accordance with Test Method D1599. For pipe sizes above 4-in. nominal diameter, the testing lab shall be allowed to replace the quick burst test (Test Method D1599) by the apparent ring tensile strength test (Test Method D2290). The minimum apparent tensile strength at yield when determined in accordance with 6.8 shall be 2520 psi (17.4 MPa) for PE 2708 pipe or 2900 psi (20.0 MPa) for PE 4710 pipe.

NOTE 11—The requirements in 5.3.1.1 and 5.3.1.3 are for laboratory proof testing only and should not be interpreted as applicable to on-site testing for acceptance of installed systems larger than 12 in. See appropriate installation standards or manufacturer's recommendations for field test procedures.

5.5 *Chemical Resistance*—The pipe and fittings shall not increase in weight more than 0.5 % (1.0 % for toluene in methanol). Where the test specimen is a pipe ring, the material shall not change more than ±12 % in apparent tensile yield strength when measured in accordance with 6.9. Where the test specimen is a plaque, the material shall not change more than ±12 % in tensile strength at yield when measured in accordance with Test Method D638.

NOTE 12—This pipe test is only an indication of what will happen as a result of short term exposure to these chemicals. For longterm results, additional testing is required.

5.6 *Melt Index*—Melt index is the flow rate of PE material when measured in accordance with Test Method D1238, condition 190/2.16 (formerly Condition E). Materials that record zero flow under condition 190/2.16 shall be measured in accordance with condition 190/21.6 (formerly condition F). The melt index of pipe/fitting shall meet the designated category in Table 5. The sample shall be representative of the cross section of the pipe or fitting and diced to an appropriate size by a method not producing heat.

5.7 *Sustained Pressure 73°F (23°C)*—Fittings shall not fail in less than 1000 h when tested in accordance with Test Method D1598. For PE 2708 materials, the stress shall be 1320 psi, for PE 4710 materials, the stress shall be 1600 psi.

TABLE 4 Wall Thicknesses and Tolerances for Plastic Pipe, in (mm)[A,B]

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
½	[D]	0.062 (1.58)	+0.007 (+0.178)
	11.0	0.076 (1.93)	+0.009 (+0.229)
	9.33	0.090 (2.29)	+0.011 (+0.279)
¾	[D]	0.090 (2.29)	+0.011 (+0.279)
	11.0	0.095 (2.41)	+0.011 (+0.279)
	Sch 40	0.113 (2.87)	+0.014 (+0.356)
1	[D]	0.090 (2.29)	+0.011 (+0.279)
	13.5	0.097 (2.46)	+0.012 (+0.305)
	11.0	0.120 (3.05)	+0.014 (+0.356)
	9.9	0.133 (3.38)	+0.016 (+0.406)
	9.33	0.140 (3.56)	+0.017 (+0.432)
1¼	[D]	0.090 (2.29)	+0.011 (+0.279)
	17.0	0.098 (2.49)	+0.012 (+0.305)
	13.5	0.123 (3.12)	+0.015 (+0.381)
	Sch 40	0.140 (3.56)	+0.017 (+0.432)
	11.0	0.151 (3.84)	+0.018 (+0.457)
	10.0	0.166 (4.22)	+0.020 (+0.508)
	9.33	0.178 (4.52)	+0.021 (+0.533)
	6.0	0.277 (7.04)	+0.033 (+0.838)
1½	[D]	0.090 (2.29)	+0.011 (+0.279)
	17	0.112 (2.85)	+0.013 (+0.330)
	13.5	0.141 (3.58)	+0.017 (+0.432)
	Sch 40	0.145 (3.68)	+0.017 (+0.432)
	11	0.173 (4.39)	+0.021 (+0.533)
2	21	0.113 (2.87)	+0.014 (+0.356)
	17	0.140 (3.56)	+0.017 (+0.432)
	Sch 40	0.154 (3.91)	+0.018 (+0.457)
	13.5	0.176 (4.47)	+0.021 (+0.533)
	11	0.216 (5.49)	+0.026 (+0.660)
	9.33	0.255 (6.48)	+0.031 (+0.787)
2½	21	0.137 (3.48)	+0.016 (+0.406)
	17	0.169 (4.29)	+0.020 (+0.508)
	13.5	0.213 (5.41)	+0.026 (+0.660)
	11	0.261 (6.63)	+0.031 (+0.787)
3	21	0.167 (4.24)	+0.020 (+0.508)
	17	0.206 (5.23)	+0.025 (+0.635)
	Sch 40	0.216 (5.49)	+0.026 (+0.660)
	13.5	0.259 (6.58)	+0.031 (+0.787)
	11.5	0.304 (7.72)	+0.036 (+0.914)
	11	0.318 (8.08)	+0.038 (+0.965)
	9.33	0.375 (9.53)	+0.045 (+1.143)
3½	21	0.190 (4.83)	+0.023 (+0.584)
	17	0.236 (5.99)	+0.028 (+0.711)
	13.5	0.296 (7.52)	+0.036 (+0.914)
	11	0.363 (9.22)	+0.044 (+1.118)
4	21	0.214 (5.44)	+0.026 (+0.660)
	19	0.237 (6.02)	+0.028 (+0.711)
	17	0.265 (6.73)	+0.032 (+0.813)
	13.5	0.333 (8.46)	+0.040 (+1.016)
	11.5	0.391 (9.93)	+0.047 (+1.194)
	11.0	0.409 (10.39)	+0.049 (+1.246)
	9.33	0.482 (12.24)	+0.058 (+1.473)
5	21.6	0.258 (6.55)	+0.031 (+0.787)
	21	0.265 (6.73)	+0.032 (+0.813)
	17	0.327 (8.31)	+0.039 (+0.991)
	13.5	0.412 (10.46)	+0.050 (+1.270)
	11	0.506 (12.85)	+0.061 (+1.549)
6	32.5	0.204 (5.18)	+0.024 (+0.610)
	26	0.255 (6.48)	+0.031 (+0.787)
	23.7	0.280 (7.11)	+0.034 (+0.864)
	21	0.315 (8.00)	+0.038 (+0.965)
	17	0.390 (9.91)	+0.047 (+1.194)
	13.5	0.491 (12.47)	+0.059 (+1.499)

TABLE 4 *Continued*

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
	11.5	0.576 (14.63)	+0.069 (+1.753)
	11.0	0.602 (15.29)	+0.072 (+1.829)
8	32.5	0.265 (6.73)	+0.032 (+0.813)
	26	0.332 (8.43)	+0.040 (+1.016)
	21	0.411 (10.44)	+0.049 (+1.245)
	17	0.507 (12.90)	+0.061 (+1.549)
	13.5	0.639 (16.23)	+0.077 (+1.956)
	11.5	0.750 (19.05)	+0.090 (+2.286)
	11	0.784 (19.91)	+0.094 (+2.388)
10	32.5	0.331 (8.41)	+0.040 (+1.016)
	26	0.413 (10.49)	+0.050 (+1.270)
	21	0.512 (13.00)	+0.061 (+1.549)
	17	0.632 (16.05)	+0.076 (+1.930)
	13.5	0.796 (20.22)	+0.096 (+2.438)
	11.5	0.935 (23.75)	+0.112 (+2.845)
	11	0.977 (24.82)	+0.117 (+2.972)
12	32.5	0.392 (9.96)	+0.047 (+1.194)
	26	0.490 (12.45)	+0.059 (+1.499)
	21	0.607 (15.42)	+0.073 (+1.854)
	17	0.750 (19.05)	+0.090 (+2.286)
	13.5	0.944 (23.98)	+0.113 (+2.870)
	11.5	1.109 (28.17)	+0.133 (+3.378)
	11	1.159 (29.44)	+0.139 (+3.531)
14†	32.5	0.431 (10.942)	+0.052 (+1.313)
	26	0.538 (13.677)	+0.065 (+1.641)
	21	0.667 (16.933)	+0.080 (+2.032)
	17	0.824 (20.918)	+0.099 (+2.510)
	13.5	1.037 (26.341)	+0.124 (+3.161)
	11.5	1.217 (30.922)	+0.146 (+3.711)
	11	1.273 (32.327)	+0.153 (+3.879)
16	32.5	0.492 (12.505)	+0.059 (+1.501)
	26	0.615 (15.631)	+0.074 (+1.876)
	21	0.762 (19.352)	+0.091 (+2.322)
	17	0.941 (23.906)	+0.113 (+2.869)
	13.5	1.185 (30.104)	+0.142 (+3.612)
	11.5	1.391 (35.339)	+0.167 (+4.241)
	11	1.455 (36.945)	+0.175 (+4.433)
18	32.5	0.554 (14.068)	+0.066 (+1.688)
	26	0.692 (17.585)	+0.083 (+2.110)
	21	0.857 (21.771)	+0.103 (+2.613)
	17	1.059 (26.894)	+0.127 (+3.227)
	13.5	1.333 (33.867)	+0.160 (+4.064)
	11.5	1.565 (39.757)	+0.188 (+4.771)
	11	1.636 (41.564)	+0.196 (+4.988)
20	32.5	0.615 (15.631)	+0.074 (+1.876)
	26	0.769 (19.538)	+0.092 (+2.345)
	21	0.952 (24.190)	+0.114 (+2.903)
	17	1.176 (29.882)	+0.141 (+3.586)
	13.5	1.481 (37.630)	+0.178 (+4.516)
	11.5	1.739 (44.174)	+0.209 (+5.301)
	11	1.818 (46.182)	+0.218 (+5.542)
22	32.5	0.677 (17.194)	+0.081 (+2.063)
	26	0.846 (21.492)	+0.102 (+2.579)
	21	1.048 (26.610)	+0.126 (+3.193)
	17	1.294 (32.871)	+0.155 (+3.944)
	13.5	1.630 (41.393)	+0.196 (+4.967)
	11.5	1.913 (48.591)	+0.230 (+5.831)
	11	2.000 (50.800)	+0.240 (+6.096)
24	32.5	0.738 (18.757)	+0.089 (+2.251)
	26	0.923 (23.446)	+0.111 (+2.814)
	21	1.143 (29.029)	+0.137 (+3.483)

TABLE 4 *Continued*

Nominal Pipe Size (IPS)	DR[C]	Minimum	Tolerance
	17	1.412 (35.859)	+0.169 (+4.303)
	13.5	1.778 (45.156)	+0.213 (+5.419)
	11.5	2.087 (53.009)	+0.250 (+6.361)
	11	2.182 (55.418)	+0.262 (+6.650)

[A] The sizes listed in Table 4 are those commercially available sizes used by the gas industry.
[B] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.
[C] The DR shown are designations commonly accepted by the gas industry and do not calculate exactly.
[D] These wall thicknesses are minimum and are not a function of the dimension ratios.
† Nominal pipe sizes 14–24 were editorially added in April 2014.

TABLE 5 Pipe Category

Property	Test Method	Category							
		A	B	C	D	E	F	G	H
Temperature, °F (°C)	. . .	100 (38)	120 (49)	140 (60)	160 (71)	180 (82)	200 (93)	. . .	...
Hydrostatic Design Basis, psi (MPa)	D2837	400 (2.8)	500 (3.4)	630 (4.3)	800 (5.5)	1000 (6.9)	1250 (8.6)	1600 (11.0)	2000 (13.8)
Melt Index[A]	D1238	>0.5	0.2–0.5	0.01–0.3	<0.01[B]	[C]	. . .	. . .	...

Examples: CDB - At 140ºF (60ºC) the HDB is 800 psi (5.5 MPa). The approximate melt index range is 0.2 to 0.5 g/10 min for this PE pipe.
DF - At 160ºF (71ºC) the HDB is 1250 psi (8.6 MPa)[A] .

[A] The Melt Index information in this table is intended to provide guidance relating to heat fusion joining of PE materials, not for classification of materials. This property is not applicable to non-PE materials or to mechanical fittings. See 7.5.
[B] Typically melt flow measured under condition 190/21.6 is less than 4.01 g/10 min.
[C] When a PE pipe or fitting is marked per 7.2 or 7.5 with the letter "E," it affirms that the manufacturer has verified the applicability of generic fusion joining with their products in accordance with PPI TR-33 and PPI TR-41 by joining to itself and to other "E" materials and testing the joints in accordance with applicable regulations. However, qualification of joining procedures by operators in accordance with applicable regulations may still be required. Information about manufacturers who have verified PPI TR-33 and PPI TR-41 generic fusion joining with their products is found in PPI TR-33 and PPI TR-41. Consult PPI and the manufacturer for additional information.

5.8 *Elevated Temperature Service*—piping materials intended for use at temperatures above 100°F (38°C) shall have the PPI hydrostatic design basis (HDB) determined at the specific temperature in accordance with Test Method D2837. The 100 000-h intercept (long-term strength) shall be categorized in accordance with Table 5 and be listed as the "hydrostatic design basis of XXX psi at XXX °F (C°) for (compound name)."

NOTE 13—Many design factors for elevated temperature service cannot be covered in this specification. Users should consult applicable codes for limitations on pertinent maximum temperatures.

NOTE 14—In the absence of an HDB established at the specified temperature, the HDB of a higher temperature may be used in determining a design pressure rating at the specified temperature by arithmetic interpolation.

5.9 *HDB Validation for PE Pipe*—The 73°F (23°C) Hydrostatic Design Basis (HDB) of PE pipe shall be validated by the pipe producer using the PE validation procedure as outlined in Test Method D2837. For MDPE materials, the HDB of 1250 psi shall be validated; for HDPE materials, the HDB of 1600 psi shall be validated.

5.10 *Resistance to Rapid Crack Propagation (RCP) for Pipe*—Additional testing for resistance to RCP is required when the wall thickness of the pipe being produced in accordance with this standard exceeds that of the pipe used to establish the resistance to RCP for the PE compound. In these circumstances, additional testing for resistance to failure by RCP in accordance with the procedures set forth in ISO 13477 (S4 Test) or ISO 13478 (Full Scale Test (FST)) shall be conducted. In cases of conflict, the RCP results of ISO 13478 shall apply. The data obtained shall be made available upon request without limitations on disclosure, and shall not subsequently be subject to disclosure limitations when used by others.

NOTE 15—The requirements and testing for resistance to RCP specified in this specification do not provide information for all possible conditions of use. The user should consult with the manufacturer and other appropriate sources such as resin suppliers, research, academia, etc., to determine that the RCP resistance provided by the pipe producer is sufficient for the intended use.

5.11 *Inside Surface Ductility for Pipe*—The inside surface of pipe shall be ductile as shown by testing in accordance with 5.11.1, 5.11.2, and 5.11.3. Before testing, specimens shall be conditioned in accordance with Practice D618 for 40 h at 73.4 ± 3.6°F (23 ± 2°C) and 50 % relative humidity.

NOTE 16—ID ductility testing may also be conducted for quality control purposes, however, there is no known data that identifies one test as inferior, equal, or superior to the others, therefore, results from one test should not be evaluated against the results from either of the other two tests.

5.11.1 *Bend-back Test Method:*

5.11.1.1 From the pipe, squarely cut a ring of pipe with a minimum width of 1¼ (32 mm). The entire wall thickness may be tested, or material may be removed from the OD surface of the pipe, while maintaining an undisturbed ID surface, to produce a ring with ⅜-in. (9.5-mm) wall thickness.

NOTE 17—The ring may be tested in its entirety, or may be cut into representative sectors to produce bend-back test specimens.

5.11.1.2 In a well-lit area at 73.4 ± 3.6°F (23 ± 2°C) perform the following procedure within 5 min: *(a)* Bend the specimen inside-out (reverse-bend so that the pipe ID surface is on the outside surface of the bent specimen). *(b)* Using an apparatus such as a vise or other suitable bending equipment, close the legs of the specimen together. When the specimen legs are closed together, the top of the bend-back specimen shall protrude 1 to 1¼ in. (25 to 32 mm) or two wall thicknesses, whichever is greater, above the point of closure (jaws). *(c)* With the unaided (naked) eye, visually examine the protruding reverse-bent pipe ID surface for signs of brittle cracking or crazing.

5.11.1.3 Any indication of brittle cracking or crazing indicates failure.

5.11.2 *Elongation-at-Break Test Method* :

5.11.2.1 Five Test Method D638 Type IV specimens cut in the longitudinal direction from locations equally spaced around the circumference of the pipe shall be tested in accordance with Test Method D638 at a cross-head separation speed of 2 in. (50.8 mm) min, and at 73.4 ± 3.6°F (23 ± 2°C). If the specimen thickness must be reduced by machining, the pipe ID surface shall be left unaltered.

NOTE 18—If the specimen thickness is reduced, the machined side of the specimen must be smooth and the thickness of the specimen in the gage length must be uniform. Surface cuts or scratches and nonuniform thickness in the specimen gage length can detrimentally affect test results.

5.11.2.2 The percent elongation at break for each test specimen shall exceed 400 %.

5.11.3 *Thermal Stability Test Method*—Specimens of the pipe inside wall surface not more than 0.005 in. (0.13 mm) thick shall demonstrate a minimum induction temperature of 428°F (220°C) when tested in accordance with the Test Method for Thermal Stability in Specification D3350.

5.12 *Squeeze-Off*—This requirement is limited to pipe sizes, wall thicknesses, squeeze procedures, and conditions deemed suitable for squeeze-off in service by the pipe manufacturer. There shall be no leakage or visual evidence of splitting, cracking, breaking or reduction in 1000-h sustained pressure category when pipe is tested as follows:

5.12.1 Prepare six randomly selected pipe specimens in accordance with Test Method D1598 except they shall be unfilled.

5.12.2 The squeeze-off shall be effected at the mid-point of the test specimen, 90° to the point of the measured minimum wall thickness. Close the squeeze bars to the gap stop in Specification F1563 and hold in constraint for 4 h. Remove squeeze bars and reround pipe by closing squeeze bars at a point 90° from the squeeze area.

5.12.3 Immediately upon removal of the squeeze-off tool, fill the specimens with ambient temperature water, that is, 67 ± 10°F (19.4 ± 5.6°C), condition, and test in accordance with 6.6.

5.13 *Joints:*

5.13.1 *Heat Fusion:*

5.13.1.1 Heat fusion joints of thermoplastic pipe and fittings shall be made in accordance with Practice F2620 and the user's written procedure.

5.13.1.2 PE butt fusion joining shall be between components (pipes, fittings, or valves) having the same SDR or DR. Butt fusion between unlike SDR or DR components shall be allowed only if it has been demonstrated that long term performance is not adversely affected. The minimum requirement to demonstrate long term performance shall be the validation procedure for PE in Test Method D2837. The Hydrostatic Design Basis (HDB) of the PE material shall be validated using specimens containing butt fusion joints resulting from different SDRs or DRs. Pipe/pipe joints of the given PE material that pass shall validate pipe/pipe, pipe/fitting, or fitting/fitting joints of the same SDR ratio for that PE material.

5.13.2 *Mechanical*—Mechanical fittings shall be installed in accordance with the user's written procedures and the fitting manufacturer's installation instructions. The joint shall be tested in accordance with the specific design category as outlined in 6.10.

5.13.3 *Electrofusion*—Electrofusion joints shall be made in accordance to user's written procedures and the fitting manufacturer's installation instructions.

5.14 *Fittings:*

5.14.1 Socket-type fusion fittings shall meet the requirements of Specification D2683.

5.14.2 Butt-type fusion fittings shall meet the requirements of Specification D3261.

5.14.3 Electrofusion fittings should meet the requirements of Specification F1055.

5.15 *PE Valves*—All PE gas valves shall meet the requirements of ASME Standard B 16.40.

5.16 *Excess Flow Valves*—All excess flow valves shall meet the requirements of Specification F2138.

6. Test Methods

6.1 *General*—The test methods in this specification cover plastic pipe and fittings to be used for gas distribution. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to that particular test.

6.2 *Sampling*—Take a representative sample of the pipe and fittings sufficient to determine conformance with this specification. About 40 ft (12 m) of pipe is required to perform all the tests prescribed. The number of fittings required varies, depending upon the size and type of fitting. A sampling plan shall be agreed upon by the purchaser and the manufacturer (see Practice D1898).

6.2.1 *Pipe Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

6.3 *Conditioning*—For those tests where conditioning is required or unless otherwise specified, condition the specimens prior to testing for a minimum of 1h in water or 4h in air at 73.4 ± 3.6°F (23 ± 2°C).

6.4 *Test Conditions*—Conduct the test in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified.

6.5 *Dimensions and Tolerances:*

6.5.1 *Pipe*—Any length of pipe is used to determine the dimensions. Coiled pipe shall be measured in the natural springback condition, unless specified otherwise.

6.5.1.1 *Diameter*—Measure the diameter of the pipe in accordance with Test Method D2122. The average outside diameter for nonroundable pipe is the arithmetic average of the maximum and minimum diameters at any cross section on the length of the pipe. For roundable pipe, out-of-roundness tolerance applies to measurements made while the pipe is rounded with the manufacturer's recommended equipment. Measure out-of-roundness within one-half pipe diameter or 2 in. (50 mm), whichever is closer, of the rounding equipment. See Test Method D2122 for definitions of nonroundable and roundable pipe.

(1) The pipe surface shall be free of gross imperfections such as, deep scratches, grooves, or high or low (flat) spots around the pipe circumference.

NOTE 19—Excessive out-of-roundness may be caused by manufacturing irregularities around the circumference of the pipe, such as deep scratches, gouges, flat spots, and high spots. Such defects could detrimentally affect joining. To simulate field joining of roundable pipe, out-of-roundness is checked by fitting a rounding device on the pipe, then measuring diameter.

6.5.1.2 *Wall Thickness*—Make a minimum of six measurements at each cross section in accordance with Test Method D2122.

6.5.1.3 *Wall Thickness Eccentricity Range*—Measure in a manner such that the maximum, A, and the minimum, B, wall thickness at single points of each cross section measured are obtained. Calculate the wall thickness eccentricity range, E, in percent for each cross section as follows:

$$E = \left[(A - B)/A\right] \times 100 \tag{1}$$

6.5.1.4 *Length*—Measure pipe length and other linear dimensions with a steel tape or other device, accurate to $\pm 1/32$ in. (±1 mm) in 10 ft (3 m).

6.5.2 *Fittings*—Measure the dimensions of fittings in accordance with Test Method D2122.

6.5.3 *Ovality*—Determine percent ovality in accordance with Test Method D2122.

6.6 *Sustained Pressure Test:*

6.6.1 Select six test specimens of pipe at random, condition at the standard laboratory test temperature and humidity, and pressure test in accordance with Test Method D1598.

6.6.1.1 Test specimens shall be prepared so that the minimum length of pipe on each side of the fitting is equal to 5 times the diameter of the pipe but in no case less than 12 in. (304 mm) for sizes less than 6 in. For sizes 6 in. and larger, the minimum length shall be equal to 3 times the diameter or 30 in. (762 mm), whichever is shorter.

6.6.1.2 Pressures used shall be calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress, whichever is greater. Piping intended for use at temperatures of 100°F (38°C) and higher shall be tested at both 73°F (23°C) and the maximum design temperature. The test fiber stress shall be 90 % of the hydrostatic design basis (HDB).

NOTE 20—Air, methane, or nitrogen may be substituted for water as the test medium.

6.6.2 Maintain the specimens at the pressures required, held to ±10 psi (0.07 MPa), for a period of 1000 h at the test temperature ±3.6°F (±2°C) as specified in 6.6.1.

6.6.3 Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

6.7 *Minimum Hydrostatic Burst Pressure (Quick Burst)*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599. Pressures shall be calculated using the pipe's actual measured minimum wall thickness, outside diameter, and the applicable fiber stress, whichever is greater.

6.8 *Apparent Tensile Properties*—The procedure and test equipment shall be as specified in Test Method D2290, Procedure B. The speed of testing shall be 0.5 in. (12.7 mm)/min. Cut "ring" specimens from pipe. Test a minimum of five specimens. This method is applicable to all pipe of nominal 3/4-in. (19.0-mm) outside diameter and larger.

6.9 *Chemical Resistance*—Determine the resistance to the following chemicals in accordance with Test Method D543. Where available, the test specimen shall be a ring 2 in. SDR 11 pipe cut to the ring dimensions specified in 6.8. For materials that are not readily available as 2 in. SDR 11 pipe, the test specimen shall be a plaque of material 1/4 by 2 by 4 in. (6.3 by 50.8 by 101.6 mm) with a 1 in. (25.4 mm) wide reduced section.

Chemicals	Concentration (% by volume)
Mineral oil (USP)	100
Tertiary-butyl mercaptan	5 in mineral oil
Antifreeze agents (at least one shall be used):	
Methanol, or	100
Ethylene glycol	100
Toluene	15 in methanol

Test five specimens with each chemical. Weigh the specimens to the nearest 0.005 g and completely immerse them in the chemicals for 72 h. On removal from the chemicals, wipe the specimens with a clean dry cloth. Condition in air for 2 to 2 1/4 h and reweigh. Calculate the increase in weight to the nearest 0.01 % on the basis of initial weight. Test the specimen in tension in accordance with 6.8 within 1/2 h after weighing. Examine the weight and apparent tensile strength of each specimen for conformance to the requirement in 5.5. (**Warning—**Because of the possible toxicity of these reagents, refer to the Material Safety Data Sheet on each of these reagents before using or handling them.)

6.10 *Categorization of Mechanical Joints*—The following test methods provide a uniform procedure for qualification or categorization of mechanical joints using short term pullout resistance tests and burst tests. The mechanical joint categories and test methods are as follows:

6.10.1 *Category 1*—A mechanical joint design that provides a seal plus a resistance to a force on the pipe end equal to or greater than that which will cause a permanent deformation of the pipe.

6.10.1.1 The apparatus and report shall be as specified in Test Method D638. The test shall be conducted at ambient temperatures, that is, 67 ± 10°F (19.4 ± 5.6°C). The speed of the testing shall be 0.2 in. (5 mm)/min ±25 %. Five specimens shall be prepared following the manufacturer's published installation instructions. Length of the specimens shall be such that the unreinforced distance between the grip of the apparatus and the end of the stiffener is at least five times the nominal outside diameter of the pipe size being tested. Apply a load until permanent deformation (yield) occurs in the unreinforced area of the piping.

6.10.1.2 Results obtained from the above method pertain only to the specific outside diameter, wall thickness, and compound of the piping used in the test and specific fitting design tested.

NOTE 21—The ability to restrain pipe to its yield as specified above does not guarantee that a properly installed joint will prevent pullout under actual long-term field conditions. Joints that cannot pass this test would be expected to pullout under actual long term field conditions. To date, this test is the best available for disqualifying unsound joints.

6.10.2 *Category 2*—A mechanical joint design that provides a seal only (see Appendix X1.5.5). A mechanical joint designed for this category excludes any provisions in the design or installation of the joint to resist any axial pullout forces; therefore, tensile tests are not required.

6.10.2.1 The test assembly shall meet the burst test requirements of 5.5 when tested in accordance with Test Method D1599 with end closures designed in accordance with Test Method D1599.

6.10.3 *Category 3*—A mechanical joint design that provides a seal plus a pipe restraint rating equivalent to the anticipated thermal stresses occurring in a pipeline (see Appendix X1.4). This category has a manufacturer's rated pipe end restraint less than the value required to yield the pipe as outlined in 6.10.1 (Category 1).

6.10.3.1 The procedures and testing shall be the same as outlined in 6.10.1 (Category 1) except the test tensile values shall meet the rated values published by the mechanical fitting manufacturer.

7. Marking

7.1 *Pipe*—All required marking shall be legible, visible, and permanent. To ensure permanence, marking shall be applied so it can only be removed by physically removing part of the pipe wall. The marking shall *(1)* not reduce the wall thickness to less than the minimum value for the pipe, *(2)* not have any effect on the long-term strength of the pipe, and *(3)* not provide leakage channels when elastomeric gasket compression fittings are used to make the joints. These marking shall consist of the word GAS, the designation ASME SD-2513 or both ASME SD-2513 and ASTM D2513, the manufacturer's name or trademark, the nominal pipe size including the sizing system used (IPS, CTS, or OD), DR or minimum wall thickness, material designation, and date of manufacture.

NOTE 22—Earlier editions of Specification D2513 included PE material designations PE2406 and PE3408. Changes to Specification D3350 led to changes in the PE material designation codes that resulted in the PE material designations PE2406 and PE3408 being superceded by newer material designations. Additionally, OPS 49 CFR Part 192 may not reference the most current version of D2513 and as a result may require marking with material designation codes that are no longer included in this Specification. For these reasons two material designations may be present. For example, PE4710 pipes were previously described as PE3408 pipes and may be marked PE3408/4710. Similarly PE2708 pipes were previously described as PE2406 pipes and may be marked PE2406/2708.

7.1.1 In addition to 7.1, the pipe marking shall include a coding that will enable the manufacturer to determine the location of manufacture, pipe production and resin lots, and any additional information which is agreed upon between the manufacturer and purchaser. The manufacturer shall maintain such records for fifty years or for the design service life of the pipe, whichever is longer.

7.1.2 All the markings in 7.1 and 7.1.1 shall be repeated at intervals not exceeding 2 ft (0.61 m). For indented printing, either the indented print line shall be in a color that contrasts with that of the pipe, or a separate print line shall be in a color that contrasts with the pipe. When color is applied such as with color stripes, a color shell or solid color pipe, yellow color shall be used.

7.2 Pipe intended for natural gas service at elevated temperatures greater than 73°F (23°C) shall be marked with additional code letters from Table 5 (the first code letter to identify the temperature of pressure rating, the second code letter to identify HDB at highest rated temperature, and the third code letter to identify the melt index).

NOTE 23—The non-mandatory, preferred order for all the items required in the print line in the marking sections 7.1 and 7.2 are:
(1) Pipe size including sizing system (IPS, CTS or OD),
(2) SDR (DR) or minimum wall thickness,
(3) Manufacturer's name or trademark,
(4) GAS,
(5) Pipe material designation code,
(6) Elevated temperature code from Table 5,
(7) ASME SD-2513 or both ASME SD-2513 and ASTM D2513,
(8) Manufacturer's lot code (includes date of manufacture in some cases), and
(9) Additional information, including date of manufacture, coil number sequential footage, third party certification mark etc.
Example: 2 in. IPS SDR 11 MANUFACTURER NAME GAS PE 2708 CEC ASME SD-2513 LOT CODE INFO 02JAN98 coil #506.

7.3 PE pipe shall be marked with the melt index category in accordance with Table 5 in addition to the marking requirements of 7.1.

7.4 Markings for potable water, sewer, reclaimed water, communications or electrical use are prohibited.

7.5 *Fittings*—Fittings shall be marked ASME SD-2513 or both ASME SD-2513 and ASTM D2513, as well as with the applicable fitting specification. All fittings shall be marked on the body or hub. The markings shall consist at least of the manufacturer's name or trademark, or both, the size, the symbol for the type of material, and the three-letter code from Table 5 (as described in 7.2). In addition, the fittings markings shall include code that will enable the manufacturer to determine the date of manufacture, the location of manufacture, fitting production and resin lots, and any additional information which may be agreed upon between the manufacturer and purchaser. The manufacturer shall maintain such records for 50 years or for the design service life of the fittings, whichever is longer.

NOTE 24—7.5 is applicable to fusion type fittings only. The marking requirements in 7.5 are not applicable to mechanical fittings.

7.6 All PE pipe, tubing, and fusion fittings meeting the requirements of this specification for gas distribution systems shall be marked with the 16-character gas distribution component tracking and traceability identifier in accordance with Specification F2897. The 16-character code shall be expressed in alphanumeric format and Code 128 bar code format with a minimum bar thickness value of 0.005 in. or an alternative 1D or 2D bar code symbology as agreed upon between manufacturer and end user. All fittings shall have the 16-character codes marked or affixed to the product, product packaging, or any manner agreed upon between manufacturer and end user.

8. Quality Assurance

8.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

9. Certification

9.1 Certification shall be as required by Annex A3.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for performance of all inspection and test requirements specified herein. The producer shall 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practices in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD 129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEXES

A1. IN-PLANT QUALITY CONTROL PROGRAM FOR PE PLASTIC PIPE AND FITTINGS UP TO AND INCLUDING 12 IN. NOMINAL DIAMETER

A1.1 Quality Control

A1.1.1 The following in-plant quality control program shall be used to assure compliance with this specification. The pipe and fittings producers shall maintain records on all aspects of this program and supply these to the purchaser, if requested.

A1.1.2 *In-Plant Quality Control Test Methods*—Test methods other than those specified in Section 6 are used as long as they provide equivalent results. In case of disagreement, those test methods in the applicable ASTM standard shall be used.

A1.2 Pipe Tests

A1.2.1 *Material and Extrusion Process Qualification*—Sustained pressure tests shall be made on one pipe size in the range of 2 in., or less, and on one pipe size in the range of 2½ in., or greater. This test shall also be made on pipe from each particular commercial plastic resin initially, and at least twice a year thereafter for material and extrusion process qualification and not as a quality control on the product. This test shall be made in accordance with A1.2.1.1 using any of the test conditions in Table A1.1.

A1.2.1.1 *Elevated Temperature Sustained Pressure Test Method*—Select six random specimens produced at the manufacturer's facility using the Table A1.1 polyethylene pipe material designation code. Test these pipe samples in accordance with Test Method D1598 using water as the internal test medium.

A1.2.1.2 Passing results are *(1)* non-failure for all six specimens at a time equal to or greater than the Table A1.1 "minimum average time before failure," or *(2)* not more than one ductile specimen failure and the average time before

TABLE A1.1 Elevated Temperature Sustained Pressure Test Requirements[A]

Condition	Test Temperature °F (°C)	Pipe Material Designation Code PE 2708		Pipe Material Designation Code PE 4710	
		Test Temperature Hoop Stress[A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours	Test Pressure Hoop Stress[A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A] Calculate internal test pressure in accordance with :

$$P = \frac{2S}{\left(\frac{Do}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa);
S = test pressure hoop stress, psi. (kPa)
D_O = measured outside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

[B] Test temperature tolerance ±3.6°F (±2°C). Test pressure tolerance ± 5psi (±35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa.

failure for all specimens shall be greater than the specified "minimum average time before failure" for the selected Table A1.1 Condition. If more than one ductile failure occurs before the Table A1.1 "minimum average time before failure," it is permissible to conduct one retest at a Table A1.1 Condition of lower stress and longer minimum average time before failure for the material designation except that for Table A1.1 Condition 6 no retest is permissible. Brittle failure of any specimen in the test sample when tested at Table A1.1 Condition 1 through 6 constitutes failure to meet this requirement and no retest is allowed.

A1.2.1.3 *Provision for retest (if needed)*—The retest sample shall be six specimens of the same pipe or tubing size and material designation from the same time frame as the test sample per A1.2.1.2. For the retest, any specimen failure before the "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

NOTE A1.1—Table A1.1 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE 4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) × ((1200 – 200) / (750 – 640)) = 927).

A1.2.2 *Product Quality Control* (Note A1.2) The tests in Table A1.2 shall be made per size per extrusion die at the denoted frequencies and the test results recorded and filed for inspection on request.

NOTE A1.2—When the pipe fails to meet this specification in any test, additional tests shall be made on the pipe produced back to the previous acceptable result to select the pipe produced in the interim that does pass the requirement. Pipe that does not meet the requirement shall be rejected.

TABLE A1.2 Product Quality Control Tests

Property	Frequency
Diameter	Once every hour or every coil, whichever is less frequent
Wall thickness	Once every hour or every coil, whichever is less frequent
Ring tensile or burst pressure	Testing shall commence at the beginning of production of a particular pipe or tubing size, and shall continue weekly thereafter. If production is interrupted, testing shall recommence after the interruption as though at the beginning of production.

NOTE A1.3—For pipe sizes above 4-in. nominal diameter, the quick burst test (Test Method D1599) may be replaced by the Apparent Ring Tensile Strength Test (Test Method D2290) if agreed to between the purchaser and the manufacturer.

A1.3 Fittings Tests

A1.3.1 The fittings tests listed in the following subparagraphs shall be conducted at the frequencies indicated.

NOTE A1.4—When any fitting fails to meet the requirements of this specification, or the applicable referenced fitting specification, additional tests should be made on fittings produced back to previous acceptable result to select the fittings produced in the interim that do meet the requirements. Fittings that do not meet the requirements shall be rejected.

A1.3.2 *Dimensions:*

A1.3.2.1 *Socket Fittings:*

(a) *Socket Entrance, Bottom and Minimum Internal Diameters*—Once an hour or one out of ten fittings, whichever is less frequent.

(b) *Wall Thickness*—At the beginning of each production setup for each cavity.

A1.3.2.2 *Butt Fusion Fittings:*(a) *Outside Diameter and Wall Thickness*—Once an hour or one out of ten fittings, whichever is less frequent.

A1.3.3 *Other Tests:*

A1.3.3.1 *PE Fittings*—At the start of each production run, whenever production conditions have changed, or when the resin lot is changed, but not less frequently than once per 500 fittings thereafter, the following tests shall be made:

(a) The knit line strength for at least one fitting from each cavity shall be demonstrated by one of the following tests:

[1] Crushing a fitting, or a portion of a fitting, in a manner that applies load in the direction normal to the knit line. See Note A1.5.

[2] Apparent tensile strength tests of a ring cut from a fitting, with the load oriented normal to the knit line. See Note A1.6.

[3] Burst testing of the fitting. See Note A1.6.

(b) The integrity of at least one part from each mold cavity shall be verified, using a method selected by the manufacturer as appropriate for this specific product and process.

Note A1.5—Separation in the knit constitutes a failure.

Note A1.6—In tests 2 and 3 the strength requirements shown in the annexes must be met.

A2. IN-PLANT QUALITY CONTROL PROGRAM FOR 14-IN. AND LARGER DIAMETER POLYETHYLENE PIPE

A2.1 Visual inspection of every length of pipe for workmanship defects shall be carried out at the manufacturer's plant. Measurements of outside diameter and wall thickness shall be made for each hour's production or each length of pipe, whichever is less frequent.

A2.2 Lengths of pipe that are shorter than standard shipping lengths are butt-fused to produce standard lengths. Such build-up lengths must otherwise meet all of the product requirements of this specification.

A2.3 Manufacturers of pipe shall conduct such other quality control tests as are appropriate to their manufacturing operations that will provide assurance that the product requirements of Section 5 will be met in place of the actual performance of the specified tests.

Note A2.1—The pressure tests required under product requirements are tests for performance. These tests are not adaptable to in-plant quality control. Quality control tests have not been standardized because the requirements for such tests vary substantially from one manufacturing plant to another.

A3. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

X1. DESIGN CONSIDERATIONS

X1.1 General

X1.1.1 The design of a PE piping system for natural gas service must include consideration of the combined effects of time, internal and external stress, and environment as an overall basis for selecting a specific kind and size of PE pipe. The design stress for PE pipe used for distribution of natural gas and petroleum fuels is regulated by the U.S. Department of Transportation as published in OPS 49 CFR Part 192 of the Code of Federal Regulations.

X1.2 Design Equations

X1.2.1 *Relationship Between Pipe Stress and Pressure*—The following expression is used to relate stress, pressure, pipe size, and wall thickness:

$$P = 2S/(DR - 1) \tag{X1.1}$$

or

$$2S/[(D_o/t) - 1]$$

where:

S = stress in the circumferential or hoop direction, psi (MPa),
P = internal pressure, psig (MPa),
DR = dimension ratio,
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

X1.2.2 The following expression can be used to determine the burst pressure or sustained pressures needed in testing:

$$P_b = 2S_y/(DR - 1) \tag{X1.2}$$

where:

P_b = burst pressure, psig (MPa),
S_y = yield stress, psi (MPa), and
DR = dimension ratio.

$$P_s = 2S_f/(DR - 1) \tag{X1.3}$$

where:

P_s = sustained pressure, psig (MPa),
S_f = fiber stress psi (MPa), and
DR = dimension ratio.

X1.2.3 *Relation between Hydrostatic Design Basis (HDB) and Hydrostatic Design Stress (HDS)*—The *HDS* is determined by multiplying the *HDB* by a design factor, *f*. The design factor, *f*, has a value less than 1.0.

$$HDS = (HDB)(f) \tag{X1.4}$$

NOTE X1.1—The actual choice of design factor for a given installation must be reviewed by the design engineer taking into account federal, state, and local code requirements. For example, the design factor for gas pipelines under the jurisdiction of the Department of Transportation is 0.32.

NOTE X1.2—In some countries, the ISO MRS method is used to determine the maximum operating pressure (MOP) using the formula MOP = 2 MRS/(DR-1) C, which incorporates the pipe DR (dimension ratio), the MRS (minimum required strength) of the pipe material as determined by ISO 9080 and ISO 12162 and the design coefficient (C). Guidance on selection for the value of C is provided in the following references: ISO 4437, ISO 12162, and PPI TR-9.

X1.3 Design Stress and Internal Pressure for Natural Gas

X1.3.1 The design stresses for natural gas pipe are based on the hydrostatic design basis at 73°F (23°C) obtained in accordance with Test Method D2837. The test medium should be natural gas or simulated natural gas except that water may be used where previous tests have shown that for the particular type of plastic, water and natural gas give essentially the same test results. The hydrostatic design basis of the PE presently included in the applicable ASTM specifications are as follows:

PE Pipe Material Designation	Hydrostatic Design Basis at 73°F (23°C), psi (MPa)
PE2708	1250 (8.6)
PE4710	1600 (11.0)

X1.3.2 The design stresses for natural gas at service temperatures above 73°F (23°C) should be based on hydrostatic design basis of the pipe that are applicable for the particular use temperature.

X1.3.3 The design stress for PE pipe for fuel gases other than natural gas should be based on hydrostatic design basis categories that have been established with the intended gas as the pressurizing medium (see X1.7.2 for information on the effect of common LPG fuels on the long-term strength of PE pipes).

NOTE X1.3—Water may be used in lieu of a particular fuel gas where previous tests have shown that the results obtained with water are equivalent.

X1.3.4 The design stresses for natural gas are obtained by multiplying the hydrostatic design basis by design factors or service factors according to the class of location as described in Chapter IV of ASME B31.8, or, for gas operators in the United States, Subpart C of the Minimum Federal Safety Standards for Transportation of Natural and Other Gas by Pipeline, OPS 49 CFR Part 192.

X1.3.5 For liquefied petroleum gas (LPG) applications, a maximum operating pressure of 30 psig (206 kPa) is recommended in NFPA 58 by the members of the National Liquefied Petroleum Gas Association. Liquefied petroleum gas has a higher condensation temperature than does natural gas; this maximum pressure is recommended to ensure that plastic pipe is not subjected to excessive exposure to LPG condensates. (See X1.7.1.)

X1.4 Thermal Stress

X1.4.1 Calculate the longitudinal stress (theoretical) induced in a pipe member between fixed points as follows:

$$S = E \times C \times \Delta t \quad (X1.5)$$

where:

S = stress, psi (MPa),
E = modulus of elasticity, psi (MPa), instantaneous, at 73°F (23°C),
C = coefficient of expansion, in./in./°F, (mm/mm/°C), and
Δt = maximum temperature minus minimum temperature, °F (°C).

X1.4.1.1 The measured stress has been determined to be less than that calculated. This difference is caused by the stress relaxation in viscoelastic materials.

X1.4.2 Calculate the theoretical force sustained at the fixed points (typically joints) in a pipe member as follows:

$$F = S \times A \quad (X1.6)$$

where:

F = force, lbf (N),
S = stress, psi (MPa), and
A = cross-sectional pipe wall area, in.^{2} (mm^2).

X1.4.3 Calculate pipe contraction in unrestrained pipe caused by a reduction in temperature as follows:

$$\Delta L = k \times L \times C \times \Delta t \quad (X1.7)$$

where:

ΔL = change in length,
k = 1000 for ΔL (mm), L (m), C (°C^{-1}), Δt (°C), or
k = 12 for ΔL (in.), L (ft), C (°F^{-1}), Δt (°F),
L = original length,
C = coefficient of linear expansion, and
Δt = temperature change.

X1.5 Installation Procedure

X1.5.1 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 (**2**)) 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 side of the pipe will be developed and maintained. It is also recognized that internal pressures may be valuable in minimizing the deflection caused by earth loads. Installation procedures described in Recommended Practice D2774, ASME B31.8, and the AGA Plastic Pipe Manual for Gas Service are recommended.

X1.5.2 Unrestrained PE pipe expands and contracts from thermal change significantly more than metallic pipe. This ratio may be of the magnitude of ten to one. Typical coefficients of thermal expansion for unrestrained pipe for PE is 9.0 × 10^{-5} (in./in.)/°F 24.30 (mm/mm)°C.

X1.5.2.1 Mains and service lines installed by insertion are considered to approximate unrestrained conditions inside the casing pipe except at end connections. Direct-burial pipe is considered to be partially restrained by passive soil pressures except in the vicinity of joints.

X1.5.3 Internal pressure, earth settlement, ground movement, and thermal contraction impose stresses on the pipe that can be transmitted to joints. These stresses are additive. Installation practices should reflect the need for continuous support and containment of the pipe through suitable bedding and backfilling procedures. Attention should be given to all joints, particularly to transition joints between PE and metal pipe.

X1.5.4 It is desirable to have pipe joints that are as strong as the pipe itself in the longitudinal (axial) direction. Thermal fusion, and mechanical joints outlined in 6.10, Category 1 can provide such joint strength. The joint strength is a function of the assembly procedure, the design of the fitting, and the pipe material and dimensions (see X1.5.5).

X1.5.5 For those mechanical devices that are not designed to restrain the pipe against pullout forces, provisions must be made in the field to prevent pullout, keeping in mind that mechanical joints are vulnerable to the effects of internal pressure, temperature changes, earth settlement, and ground movement. A somewhat limited alternative is to use long sleeve-type fittings that permit limited movement without loss of pressure seal. Otherwise, provisions must be made in the field to prevent pullout through suitable anchoring at the joint.

X1.5.6 Plastic pipe joined with mechanical connectors that utilize a compression-type gasket must be reinforced by means of a tubular stiffener that extends at least under the section of pipe being compressed by the gasket and the gripping device (where used). The stiffener shall be nonsplit-type design to meet the performance requirements recommended by the manufacturer of the fitting in which it is used, and the joint shall meet the test requirements outlined in 6.10.

X1.5.7 Kinks found in the pipe shall be cut out. Pipe with kinks shall not be placed in service.

X1.6 Repair Considerations

X1.6.1 Repairs may be made to PE pipe under appropriate circumstances. Selection and installation considerations for the use of full encirclement band clamps are available in ASTM Guide F1025. Additional information on repair of PE pipe may be found in manufacturers' literature, the AGA Plastic Pipe Manual for Gas Service, ASME B31.8 Gas Transmission and Distribution Piping Systems, and in the ASME Guide for Gas Transmission and Distribution Piping Systems.

X1.7 Environmental Effects

X1.7.1 *Natural Gas*—The natural gas of commerce consists of methane as the principal constituent with minor amounts of other gases, which can include other hydrocarbons (for example, ethane, propane, butane, pentane), inert gases (for example, nitrogen, carbon dioxide), and odorants. The long term effect of natural gas (methane, but with minor amounts of other gases) at 73°F (23°C) has been shown (**3,4**) to be essentially equivalent to that of water at 73°F (23°C) for PE pipe.

X1.7.2 *Other Fuel Gases*—In accordance with this specification, PE materials must have not less than a 1250 psi HDB for 73.4°F, for methane. It has been shown (**5, 6,** and **7**) that aliphatic gaseous fuels of higher molecular weights than methane (natural gas) somewhat reduce the long-term strength of PE pipe materials compared to when using methane or water as the pressurizing medium. The reduction in PE's long-term strength caused by gaseous propane, propylene and butane is modest, well under 20 %. On this basis one report (**5**) considers an HDB of 1000 psi, for 73.4°F, as a reasonable and conservative design basis for PE piping materials intended for LPG fuel gas service.

X1.7.2.1 However, it has also been shown by the above referenced studies that propane, propylene and butane, when in the liquid phase, can cause a greater reduction in long-term strength, up to 40 %. Accordingly, the use of PE piping to convey LPG gaseous fuels should recognize this effect and the design and operation of such piping should consider the possibility for the occurrence of condensates. Extensive experience has shown that the NFPA maximum recommended operating pressure of 30 psig for LPG systems (see X1.3.4) both minimizes the possible occurrence of condensates and gives adequate consideration of the effect of LPG fuels on the long-term strength of PE piping.

X1.7.2.2 It has been reported **(8,9)** and **(10)**, that during the heat fusion joining of PE piping that has been in service conveying fuel gases that consist of, or that include heavier hydrocarbons, the PE surfaces being heated in preparation for fusion sometimes exhibit a *bubbly* appearance. This bubbling is the result of the rapid expansion (by heat) and passage of absorbed heavier hydrocarbon gases through the molten material. Heat fusion (butt, socket, saddle, or electrofusion) joint strength may be reduced by the presence of the heavier hydrocarbons. Pimputkar et al **(8)** conclude that for a system operating at 50psi and conveying a mixture of as high as 16 volume percent in methane the propane concentration in PE will be under 0.2 percent, sufficient to sometimes show some bubbling, but not high enough to effect any significant degradation in fusion strength. However, if the concentration of propane in PE exceeds 0.2 percent, there is the risk of a rapid and large drop in fusion strength. Field tests to verify the level of contamination and subsequent degradation of joint strength are not currently available. Therefore, in the case of PE pipe that has previously been installed in these types of services, one should use mechanical fittings to join or repair the pipe.

NOTE X1.4—PPI Technical Report TR 22–88 (**5**) lists maximum operating pressures for various minimum operating temperatures at which condensates will not form in LPG systems in which the primary fuels are propane and butane.

SPECIFICATION FOR SOCKET-TYPE POLYETHYLENE FITTINGS FOR OUTSIDE DIAMETER-CONTROLLED POLYETHYLENE PIPE AND TUBING

SD-2683

(Identical with ASTM D2683-14 except for additional requirements in section 11 and Annex A1, revised marking requirements in para. 9.1.5, and quality assurance requirement in para. 10.1 has been made mandatory.)

Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing

1. Scope

1.1 This specification covers polyethylene socket-type fittings for use with outside diameter-controlled polyethylene pipe as specified by Specifications D3035 and D2513. Requirements for materials, workmanship, dimensions, and pressure performance are included. Where applicable in this specification, " pipe" shall mean "pipe and tubing."

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 and health 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

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

D2657 Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings

D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *Plastic Pipe Institute*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe7

PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation of polyethylene plastic is PE.

3.2 *standard thermoplastic pipe dimension ratio (SDR)*—the ratio of pipe outside diameter to wall thickness. It is calculated by dividing the average outside diameter of the pipe by the minimum wall thickness.

4. Classification

4.1 This specification covers polyethylene fittings of the socket type made as specified in 5.1 and 5.2

4.1.1 Fittings covered by this specification are normally molded. In-line fittings such as couplings, unions, bushings, caps, nipples, etc., may be extruded or machined from extruded stock. Special fittings such as transition fittings and tapping teets shall be assembled and fabricated in accordance with procedures agreed upon between the manufacturer and the purchaser.

4.1.2 Fittings covered by this specification are intended to be joined by heat fusion to PE pipe.

4.1.3 Fittings intended for use in the distribution of natural gas or petroleum fuels shall also meet the requirements of Specification D2513.

5. Materials

5.1 *Polyethylene Compound*—Polyethylene material compounds suitable for use in the manufacture of fittings under this specification shall meet Specification D3350 and shall meet the Specification D3350 classification and property requirements in Table 1, and shall have PPI TR-4 HDB and HDS listings at 73°F (23°C) and HDB listings 140°F (60°C) in accordance with Table 1.

5.2 *Color and Ultraviolet (UV) Stabilization*—Polyethylene material compounds shall meet Specification D3350 code C or E. Code C material compounds shall have 2 to 3 percent carbon black. Code E material compounds shall be colored with UV stabilizer.

5.3 *Rework Material*—Clean polyethylene compound from the manufacturer's own production that met 5.1 and 5.2 as virgin material is suitable for remolding into fittings, either alone or blended with new compound of the same cell classification or material designation. Fittings containing the rework material shall meet the material and product requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Fittings, sockets, dimensions, and tolerances shall be as shown in Table 2 and Table 3 when measured in accordance with 8.4. For reducing fittings, socket and inside diameter minimums for the appropriate size shall apply.

6.1.1.1 *Laying Lengths*—Laying lengths shall be in accordance with manufacturer's specifications.

6.1.2 The maximum angular variation of any opening shall not be more than 2° off the true centerline axis.

6.1.3 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the pipe with which they are designed to be joined. For reducing fittings, the smallest size wall thickness shall be 125 % of the smallest pipe wall.

6.2 *System Pressure Test Requirements:*

6.2.1 *Short-Term Rupture Strength*—The minimum short-term rupture strength of the fitting and fused pipe shall not be less than the minimum short-term rupture strength of the pipe or tubing in the system when tested in accordance with 8.5.2. The test pressures shall be as shown in Table 4. Test specimens shall be prepared for testing as described in 8.5.1.

6.2.2 *Sustained Pressure*—The fitting(s) and fused pipe or tubing shall not fail (as defined in the Descriptions of Terms Section of Test Method D1598) at the test pressures given in Table 5 when tested in accordance with 8.5.3. To ensure uniformity in preparation of assemblies for sustained pressure evaluation, all test joints shall be made in accordance with heat fusion practices found in D2657.

7. Workmanship, Finish, and Appearance

7.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) for 40 h minimum prior to test in accordance with Procedure A of Methods D618, for those tests where conditioning is required and in all cases of disagreement.

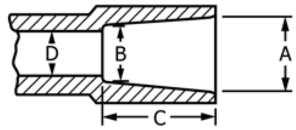
8.2 *Test Conditions*—Conduct tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C).

TABLE 1 Specification D3350 Classification of Polyethylene Fittings Materials

Physical Properties	Cell Classification and Properties for Polyethylene Pipe Materials							
	PE2606	PE2706	PE2708	PE3608	PE3708	PE3710	PE4708	PE4710
Density	2	2	2	3	3	3	4	4
Melt Index	3 or 4	3 or 4	3 or 4	4	4	4	4	4
Flexural modulus	≥4	≥4	≥4	≥4	≥4	≥4	≥4	≥5
Tensile Strength	≥3	≥3	≥3	≥4	≥4	≥4	≥4	≥4
Slow crack growth resistance (F1473)	6	7	7	6	7	7	7	7
Hydrostatic strength classification	3	3	3	4	4	4	4	4
Color and UV Stabilizer[A]	C or E	C or E	C or E	C or E	C or E	C or E	C or E	C or E
HDB at 140°F (60°C), PPI TR-4, psi (MPa)	[B]	[B]	[B]	[B]	[B]	[B]	[B]	[B]
HDB at 73°F (23°C), PPI TR-4, psi (MPa)	630 (4.34)	630 (4.34)	800 (5.52)	800 (5.52)	800 (5.52)	1000 (6.90)	800 (5.52)	1000 (6.90)

[A]See 5.2.
[B]Listing required; consult manufacturer for listed value.

TABLE 2 Fittings for Outside Diameter-Controlled Polyethylene Pipe[A]



Nominal Pipe Size, in.,	*A* Socket Entrance Diameter[B]			*B* Socket Bottom Diameter[C,D]			*C*	*D*	
	Average Diameter	Tolerance on Diameter	Maximum Out-of-Round	Average Diameter	Tolerance on Diameter	Maximum Out-of-Round	Socket Depth, min	Inside Diameter min	Inside Diameter max
	in. (mm)								
½	0.810 (20.57)	+0.005 (+0.127) −0.010 (−0.254)	±0.008 (±0.203)	0.804 (20.42)	+0.005 (+0.127) −0.026 (−0.660)	±0.008 (±0.203)	0.625 (15.88)	0.648 (16.46)	0.804 (20.42)
¾	1.020 (25.91)	±0.008 (±0.203)	±0.010 (±0.254)	1.012 (25.70)	+0.008 (+0.203) −0.012 (−0.305)	±0.010 (±0.254)	0.625 (15.88)	0.814 (20.68)	1.020 (25.91)
1	1.275 (32.38)	±0.008 (±0.203)	±0.010 (±0.254)	1.267 (32.18)	+0.008 (+0.203) −0.012 (−0.305)	±0.010 (±0.254)	0.687 (17.4)	1.020 (25.91)	1.275 (32.38)
1¼	1.620 (41.15)	±0.008 (±0.203)	±0.012 (±0.305)	1.612 (40.94)	+0.008 (+0.203) −0.016 (−0.406)	±0.012 (±0.305)	0.875 (22.22)	1.301 (33.04)	1.620 (41.15)
1½	1.860 (47.24)	±0.010 (±0.254)	±0.012 (±0.305)	1.849 (46.96)	+0.010 (+0.254) −0.020 (−0.508)	±0.012 (±0.305)	0.875 (22.22)	1.496 (38.0)	1.859 (47.22)
2	2.335 (59.31)	±0.010 (±0.254)	±0.012 (±0.305)	2.324 (59.03)	+0.010 (+0.254) −0.020 (−0.508)	±0.012 (±0.305)	0.875 (22.22)	1.885 (47.88)	2.334 (59.28)
3	3.455 (87.76)	±0.015 (±0.381)	±0.015 (±0.381)	3.439 (87.35)	+0.015 (+0.381) −0.025 (−0.635)	±0.015 (±0.381)	1.000 (25.4)	2.780 (70.61)	3.454 (87.73)
4	4.450 (113.03)	±0.015 (±0.381)	±0.015 (±0.381)	4.434 (112.62)	+0.015 (+0.381) −0.035 (−0.889)	±0.015 (±0.381)	1.125 (28.58)	3.575 (90.80)	4.449 (113.00)

[A] Minimum dimensions have zero negative tolerance. The sketches and designs of fittings are illustrative only. Entrance chamfer or radius is optional.
[B] Measured at top of socket wall taper, just below entrance radius.
[C] Dimensions of tools should be checked for consistency with fittings used. Socket bottom diameter must be equal to or smaller than entrance diameter.
[D] Measured at bottom of socket wall taper, just above bottom radius.

8.3 *Sampling*—Select at random sufficient quantity of fittings from each lot of shipment and test to determine that the basic properties and dimensions are in conformance with this specification.

NOTE 1—For individual orders or specifications, only those tests and numbers of tests specifically agreed upon between the purchaser and the manufacturer need be conducted.

8.4 *Dimensions*—Measure in accordance with Test Method D2122.

8.4.1 Maximum out-of-round tolerance on sockets applies to the actual measured average inside diameter.

NOTE 2—*Example*—In the 1-in. IPS size, if the actual measured average inside socket entrance diameter was 1.281 in. (32.54 mm) then the extreme measured diameters due to ovality can be 1.291 in. (32.79 mm) maximum and 1.271 in. (32.28 mm) minimum when the out-of-round tolerance is ±0.010 in. (2.54 mm).

8.5 *Pressure Test:*

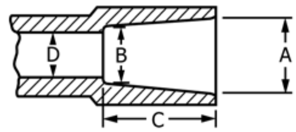
8.5.1 Prepare test assemblies in such a manner that each, whether individual fittings or groups of fittings, is a system incorporating at least one length of pipe or tubing and one or more fittings in addition to end closures. Fuse all fittings' outlets with the appropriate size pipe or tubing. One piece of pipe in the system shall have a minimum length equal to five pipe diameters.

8.5.2 *Short-Term Rupture Test*—The test equipment, procedures, and failure definition shall be as specified in Test Method D1599. Increase the hydrostatic pressure at a uniform rate such that the specimen fails between 60 and 70 s from the start of the test. Minimum failure pressures are shown in Table 4.

8.5.3 *Sustained Pressure Test*—Prepare six fitting specimens as prescribed in 8.5.1

8.5.3.1 Sustained pressure tests shall be conducted in accordance with Table 5 and Test Method D1598 using water as the

TABLE 3 Fittings for Outside Diameter-Controlled Polyethylene Tubing[A]



Nominal Tubing Size, in.	*A* Socket Entrance Diameter[B]			*B* Socket Bottom Diameter[C,D]			*C*	*D*	
	Average Diameter	Tolerance on Diameter	Maximum Out-of-Round	Average Diameter	Tolerance on Diameter	Maximum Out-of-Round	Socket Depth, min	Inside Diameter min	Inside Diameter max
	in. (mm)								
½	0.585 (14.86)	+0.010 (+0.25) −0.007 (−0.18)	±0.010 (±0.25)	0.575 (14.61)	+0.010 (+0.25) −0.007 (−0.18)	±0.010 (±0.25)	0.625 (15.88)	0.500 (12.70)	0.585 (14.86)
¾	0.835 (21.21)	±0.010 (±0.25)	±0.010 (±0.25)	0.825 (20.96)	±0.010 (±0.25)	±0.010 (±0.25)	0.625 (15.88)	0.750 (19.05)	0.835 (21.21)
1	1.075 (27.30)	±0.008 (±0.20)	±0.008 (±0.20)	1.070 (27.18)	+0.008 (+0.20) −0.012 (−0.30)	±0.008 (±0.20)	0.625 (15.88)	0.850 (21.59)	1.078 (27.38)
1¼	1.330 (33.78)	±0.008 (±0.20)	±0.010 (±0.25)	1.322 (33.58)	±0.008 (±0.20)	±0.010 (±0.25)	0.687 (17.45)	1.250 (31.75)	1.330 (33.78)

[A] Minimum dimensions have zero negative tolerance. The sketches and designs of fittings are illustrative only. Entrance chamfer or radius is optional.
[B] Measured at top of socket wall taper, just below entrance radius.
[C] Dimensions of tools should be checked for consistency with fittings used. Socket bottom diameter must be equal to or smaller than entrance diameter.
[D] Measured at bottom of socket wall taper, just above bottom radius.

TABLE 4 Quick Burst Minimum Hoop Stress Requirements for Water At 73°F (23°C) for SDR-PR PE Plastic Pipe Fittings[A,B]

Material	psi	(MPa)
Density Class 2 materials	2500	(17.24)
Density Class 3 and 4 materials	2900	(20.00)

[A] For outside diameter controlled pipe, calculate internal test pressure in accordance with the following formula:

$$P = \frac{2S}{\left(\frac{D_o}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi. (kPa)
D_O = measured outside diameter, in. (mm), and
t = measured minimum wall thickness, in (mm)

[B] Fiber Stress listed are to be calculated on the pipe being used in the test, not the fitting.

pressurizing medium. The "test sample" shall be three specimens. Select one Table 5 Condition for the material designation and test the three specimen test sample.

8.5.3.2 Passing results are *(a)* non-failure for all three specimens at a time equal to or greater than the "minimum average time before failure", or *(b)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified "minimum average time before failure" for the selected Table 5 Condition. For Table 5 Conditions 1 through 5: if more than one ductile failure occurs before the "minimum average time before failure", it is permissible to conduct one retest at a Table 5 Condition of lower stress and longer minimum average time before failure for the material designation. For Table 5 Condition 6 no retest is permissible. Brittle failure of any specimen before the Table 5 "minimum average time before failure" constitutes failure to meet this requirement and no retest is allowed.

8.5.3.3 Provision for retest (if needed). The retest sample shall be three specimens of the same pipe or tubing size and material designation from the same time frame as the "test sample". For the retest, any specimen failure before the "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

9. Packaging and Package Marking

9.1 Fittings shall be marked with the following:

9.1.1 Manufacturer's name or trademark,

9.1.2 Material designation (such as, PE 27086, PE 3608, or PE 4710),

NOTE 3—Earlier editions of Specification D2683 included PE material designations PE2406, PE3406, PE3407 and PE3408. Changes to Specification D3350 and PPI TR-3 led to changes in thermoplastic material designation codes, resulting in material designation PE2406 being superseded by material designations PE2606 and PE2708, material designation PE3406 being superseded by PE3606, material designation PE3407 being discontinued, and material designation PE3408 being superseded by material designations PE3608, PE3708, PE3710, PE4708 and PE4710. Recognizing that a period of time is necessary for the dissemination of information and to update specifications and literature, during the transitional period, product markings that include both older and newer materials designations, for example PE2406/PE2606, may occur.

9.1.3 Fittings intended for the transport of potable water shall include the seal or mark of the laboratory making the evaluation for this purpose,

9.1.4 Size, and

9.1.5 ASME SD-2683 or both ASME SD-2683 and ASTM D2683.

TABLE 5 Elevated Temperature Sustained Pressure Test Requirements[A,B]

Condition	Test Temperature, ºF (ºC)B	PE2606, PE2706, PE2708 PE3608 PE3708, PE4708		PE3710, PE4710	
		Test Pressure Hoop Stress [A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours[B]	Test Pressure Hoop Stress[A], psi (kPa)[B]	Minimum Average Time Before Failure, Hours[B]
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A]A Calculate internal test pressure in accordance with

$$P = \frac{2S}{\left(\frac{D_o}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi. (kPa)
D_O = measured outside diameter, in. (mm), and
t = measured minimum wall thickness, in (mm)

[B]Test temperature tolerance ± 3.6ºF (± 2ºC). Test pressure tolerance ± 5 psi (± 35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa. Note: Table 5 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) x ((1200 – 200) / (750 – 640)) = 927).

9.2 Where the size of the fitting does not allow complete marking, identification marking may be omitted in the following sequence: size, designation number, material designation.

9.3 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices. If indentation is used, it shall not reduce the wall thickness to less than the minimum value for the fittings, and it should be demonstrated that these marks have no effect on the long-term strength of the fittings. In addition to the above, the fittings shall bear an appropriate code number that will assure identification on the fittings as to month of production and resin formulas used in the production of said fittings. The manufacturer shall maintain such additional records as are necessary to confirm identification of all coded fittings.

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

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 may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

Packaging and Marking for U.S. Government Procurement

Packaging —Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classifications rules or National Motor Freight Classifications rules.

Marking—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Federal Government procurement requirements should not be construed as an indication that the U.S. Federal Government uses or endorses the products described in this specification.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for the product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 or the health effects portion of NSF Standard 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR POLYETHYLENE (PE) PLASTIC TUBING

SD-2737

(Identical with ASTM D2737-12a except for additional requirements in section 11 and Annex A1, revised marking requirements in para. 9.1.5, renumbering of section 12, and quality assurance requirement in para. 10.1 has been made mandatory.)

Specification for Polyethylene (PE) Plastic Tubing

1. Scope

1.1 This specification covers polyethylene (PE) plastic tubing in outside diameters and SDR's that are pressure rated for water. Included are requirements for PE compounds, and requirements and test methods for PE plastic tubing workmanship, dimensions, elevated temperature sustained pressure, burst pressure and marking.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the specification. Notes and footnotes in tables and figures, and Supplementary Requirements are requirements of the specification.

1.3 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.

NOTE 1—Joining PE plastic tubing with fittings that require flaring the tubing is not recommended because Practice D3140, the technique used to make the flare has been withdrawn (discontinued).

NOTE 2—References and PE compound descriptions for PE2305, PE2406, PE3306, PE3406, and PE3408 have been removed due to changes in Specification D3350 and PPI TR-3. For removed designations, refer to previous editions of Specification D2737, Specification D3350, PPI TR-3 and PPI TR-4. The removal of these PE compounds does not affect pipelines that are in service. PE compounds and material designations resulting from changes in Specification D3350 and PPI TR-3 are addressed in Section 5.

1.4 The following safety hazards caveat pertains only to the test methods 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 and health 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
D638 Test Method for Tensile Properties of Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
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
D1603 Test Method for Carbon Black Content in Olefin Plastics
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D3140 Practice For Flaring Polyolefin Pipe And Tubing
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
F412 Terminology Relating to Plastic Piping Systems
G154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

2.2 *APWA Standard:*
APWA Uniform Color Code

2.3 *NSF Standards:*

NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials

NSF/ANSI Standard No. 61 for Drinking Water Systems Components—Health Effects

2.4 *PPI Standards:*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 *Definitions*—Unless otherwise specified, definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600.

4. Tubing Classification

4.1 *General*—This specification covers PE plastic tubing made from PE compounds in three standard dimension ratios and pressure rated for water. Pressure ratings for water are dependent on the PE compound in accordance with the following relationship:

$$PR = \frac{2 \times HDS}{(SDR + 1)} \tag{1}$$

Where:

PR = pressure rating for water, 73°F (23°C), psi (kPa)
HDS = hydrostatic design stress for water at 73°F (23°C), psi (kPa)
SDR = standard dimension ratio

NOTE 3—PR and HDS must have the same units. See Appendix X1 for maximum pressure ratings for water.

4.2 This specification covers PE tubing in standard dimension ratios SDR 7.3, SDR 9, and SDR 11.

5. Materials

5.1 *Polyethylene Compound*—Polyethylene compounds suitable for use in the manufacture of tubing under this specification shall meet thermoplastic materials designation codes PE2708 or PE3608 or PE4608 or PE4710, and shall meet Table 1 requirements for PE2708 or PE3608 or PE4608 or PE4710, and shall meet thermal stability, brittleness temperature and elongation at break requirements in accordance with Specification D3350.

5.1.1 *Color and Ultraviolet (UV) Stabilization*—Polyethylene compounds shall meet Specification D3350 code C, D or E. In addition, Code C polyethylene compounds shall have 2 to 3 percent carbon black, and Code D or E polyethylene compounds shall have sufficient UV stabilizer to protect tubing from deleterious UV exposure effects during unprotected outdoor shipping and storage for at least eighteen (18) months.

NOTE 4—Pipe users should consult with the pipe manufacturer about the outdoor exposure life of the product under consideration. Evaluation of UV stabilizer in Code D or E PE compound using Practice D2565 or Practice G154 or Practice G155 may be useful for this purpose.

TABLE 1 Polyethylene Compound Requirements

Requirement	Material Designation			
	PE2708	PE3608	PE4608	PE4710
	Required Value			
Minimum HDB at 140ºF (60ºC), psi (MPa), per Test Method D2837 and PPI TR-3	800 (5.5)[A]	800 (5.5)[A]	800 (5.5)[A]	800 (5.5)[A]
HDS for water at 73°F (23°C) psi (MPa), per Test Method D2837 and PPI TR-3[A]	800 (5.5)	800 (5.5)	800 (5.5)	1000 (6.9)
Melt flow rate per Test Method D1238	≤0.40 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6
Specification D3350 Cell Classification Property Requirement	Required Value			
Density (natural base resin)	2	3	4	4
SCG Resistance	7	6	6	7
Color and UV Stabilizer Code[B]	C, D or E	C, D or E	C, D or E	C, D or E

[A] Contact manufacturer or see PPI TR-4 for listed value.
[B] See 5.1.1.

5.1.2 *Colors for solid color, an external color layer or color stripes*—In accordance with the APWA Uniform Color Code, blue shall identify potable water service; green shall identify sewer service; and purple (lavender) shall identify reclaimed water service. Yellow identifies gas service and shall not be used.

5.2 Products intended for contact with potable water shall be evaluated, tested and certified for conformance with NSF/ANSI Standard No. 61 or the health effects portion of NSF/ANSI Standard No. 14 by a certifying organization acceptable to the authority having jurisdiction.

5.3 *Rework Material*—Clean polyethylene compound from the manufacturer's own tubing production that met 5.1 through 5.2 as new PE compound is suitable for re-extrusion into tubing when blended with new PE compound having the same material designation. Tubing containing rework material shall meet all the requirements of this specification.

6. Requirements

6.1 *Workmanship*—The tubing shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The tubing shall be as uniform as commercially practicable in color, opacity, density, and other physical properties. See 5.1.2.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 2 when measured in accordance with 7.4.

6.2.1.1 *Out-of-roundness*—Out of roundness shall be in accordance with Table 2 as extruded, but before coiling for packaging when measured in accordance with 7.4.

NOTE 5—Coiling may increase out-of-roundness, depending on the coiling method and coil dimensions.

6.2.2 *Wall Thicknesses*—The wall thicknesses and tolerance shall be as shown in Table 3 when measured in accordance with 7.4. Wall thickness shall be inclusive of all extruded concentric layers.

6.2.3 *Wall Thickness Variation*—The wall thickness variation shall not exceed 12 % when measured in accordance with 7.4.

6.2.4 *Thickness of Outer Layer*—For tubing produced by simultaneous multiple extrusion, the outer concentric layer shall be at least 0.020 in (0.5 mm) thick.

6.3 *Bond*—For tubing produced by simultaneous multiple extrusion, the bond between the layers shall be strong and uniform. It shall not be possible to cleanly separate any two layers with a probe or point of a knife blade at any point.

6.4 *Carbon Black*—Polyethylene tubing produced using Code C polyethylene compound per 5.1.1 shall contain 2 to 3% carbon black when tested in accordance with 7.5.

6.5 *Burst Pressure*—The minimum burst pressure for tubing shall be as given in Table 4, when determined in accordance with 7.6 using a minimum hoop stress of 2520 psi (17.4 MPa) for Table 1 density cell 2 polyethylene compound or 2900 psi (20.0 MPa) for Table 1 density cell 3 or 4 polyethylene compound. In addition, the failure shall be ductile.

6.6 *Elevated Temperature Sustained Pressure*—Elevated temperature sustained pressure tests for each polyethylene compound designation per Table 1 used in production at the facility shall be conducted twice annually per 7.7.

6.7 Inside Surface Ductility for Tubing—Tubing shall be tested for inside surface ductility in accordance with 7.8 or 7.9.

NOTE 6—Tensile elongation testing per 7.9 provides a quantifiable result and is used for referee testing and in cases of disagreement.

7. Test Methods

7.1 *Conditioning*—Condition as specified in the test method. Where conditioning is not specified in the test method, condition the test specimens at 73 ± 3.6°F (23 ± 2°C) without regard to relative humidity for not less than 4 h prior to the test in accordance with Procedure A of Practice D618, or at 73 ± 3.6°F (23 ± 2°C) for not less than 1 h in accordance with Procedure D of Practice D618.

7.2 *Test Conditions*—Conduct tests in accordance with the conditions specified in the test method, or if not specified in the test method, at 73.4 ± 3.6°F (23 ± 2°C) without regard to relative humidity.

7.3 *Sampling*—The number and selection of samples shall be as specified in the test method, or if not specified in the test method, sample selection shall be as agreed upon by the purchaser and seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

7.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of the tubing sample that is at least one pipe diameter away from an end closure. The entire marking shall be documented in testing records.

TABLE 2 Outside Diameters and Tolerances for PE Plastic Tubing

Tubing Size	Outside Diameter, in. (mm)	Outside Diameter Tolerance, in. (mm)	Out-of-Roundness, in. (mm)
½	0.625 (15.87	±0.004 (±0.10)	0.030 (0.76)
⅝	0.750 (19.05)	±0.004 (±0.10)	0.030 (0.76)
¾	0.875 (22.23)	±0.004 (±0.10)	0.030 (0.76)
1	1.125 (28.58)	±0.005 (±0.13)	0.030 (0.76)
1¼	1.375 (34.93)	±0.005 (±0.13)	0.030 (0.76)
1½	1.625 (41.23)	±0.006 (±0.15)	0.030 (0.76)
2	2.125 (53.98)	±0.006 (±0.15)	0.030 (0.76)

TABLE 3 Wall Thickness and Tolerances for PE Plastic Tubing

	Wall Thickness, in.^{A}											
	SDR 7.3				SDR 9				SDR 11			
	in.		(mm)		in.		(mm)		in.		(mm)	
Tubing Size, in.	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
½	0.086	+0.010	(2.18)	(0.25)	0.069	+0.010	(1.75)	(0.25)	0.062	+0.010	(1.57)	(0.25)
⅝	0.103	+0.010	(2.62)	(0.25)	0.083	+0.010	(2.11)	(0.25)	0.068	+0.010	(1.73)	(0.25)
¾	0.120	+0.012	(3.05)	(0.30)	0.097	+0.010	(2.46)	(0.25)	0.080	+0.010	(2.03)	(0.25)
1	0.154	+0.015	(3.91)	(0.38)	0.125	+0.012	(3.18)	(0.30)	0.102	+0.010	(2.59)	(0.25)
1¼	0.188	+0.019	(4.78)	(0.48)	0.153	+0.015	(3.89)	(0.38)	0.125	+0.012	(3.18)	(0.30)
1½	0.233	+0.022	(5.92)	(0.56)	0.181	+0.018	(4.60)	(0.46)	0.148	+0.015	(3.76)	(0.38)
2	0.291	+0.029	(7.39)	(0.74)	0.236	+0.024	(5.99)	(0.61)	0.193	+0.019	(4.90)	(0.48)

^{A} The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement. Wall thickness variation shall be in accordance with 6.2.3.

TABLE 4 Minimum Burst Pressure for PE Plastic Tubing Pipe

SDR	Minimum Burst Pressure^A psi (kPa)			
	PE2708		PE3608, PE4608, PE4710	
	psi	(kPa)	psi	(kPa)
7.3	800	(5517)	921	(6352)
9	630	(4345)	725	(5000)
11	504	(3476)	580	(4000)

^{A}Minimum burst pressure calculated in accordance with:

$$P_B \frac{2S}{\frac{D_o}{t}} - 1$$

Where:

P_B = burst test pressure, psi (kPa)
S = minimum hoop fiber stress, psi. (kPa)
S = 2520 psi (17,370 kPa) for Specification D3350 density cell 2 PE compound per Table 2.
S = 2900 psi (20,000 kPa) for Specification D3350 density cell 3 and 4 PE compound per Table 2.
D_o = measured average inside diameter, in. (mm)
t = measured minimum wall thickness, in (mm).

Test temperature tolerance ±3.6ºF (± 2ºC). Test pressure tolerance ± 5 psi (± 35 kPa);

7.4 *Dimensions and Tolerances*—Use any length of tubing to determine the dimensions. Outside diameter, out-of-roundness, and wall thickness shall be measured in accordance with Test Method D2122.

7.4.1 *Outside Diameter*—Measure the outside diameter of the tubing in accordance with Test Method D2122. The average outside diameter is the arithmetic average of the maximum and minimum diameter at any cross section. The tolerance for out-of-roundness shall apply only to tubing prior to shipment.

7.5 *Carbon Black*—For all tubing manufactured with Code C polyethylene compound, determine in duplicate the carbon black content in accordance with Test Method D1603 or Test Method D4218.

7.6 *Burst Pressure*—The test equipment, procedures and failure definitions shall be as specified in Test Method D1599.

7.7 *Elevated Temperature Sustained Pressure Test*—Elevated temperature sustained pressure tests for each Table 1 material designation used in production of tubing in accordance with this specification at the facility shall be conducted per D1598, and Table 5 using water as the pressurizing medium. The "test sample" shall be three specimens of any tubing size or SDR. One Table 5 Condition for the applicable material designation shall be selected for the test.

7.7.1 For the selected Table 5 Condition, passing results are *(a)* non-failure for all three specimens at a time equal to or greater than the "minimum average time before failure", or *(b)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified "minimum average time before failure" for the selected Table 5 Condition, or *(c)* successful retest per 7.7.3.

7.7.2 For the selected Table 5 condition, failure to meet this requirement is *(a)* brittle failure of any specimen when tested at Table 5 Condition 1 through 6, or *(b)* ductile failure of all three specimens.

7.7.3 *Provision for Retest for* Table 5 *Conditions 1 through 5*—If a second ductile failure occurs before the "minimum average time before failure", it is permissible to conduct one retest at a Table 5 Condition of lower stress and longer minimum average time before failure for the material designation. The retest sample shall be three additional specimens of the same tubing size and material designation from the same time frame as the test sample per 7.7. For the retest, any specimen failure before the "minimum average time before failure" at the retest condition constitutes failure to meet this requirement. For Table 5 Condition 6 no retest is permissible.

7.8 *Bend-back Test Method:*

TABLE 5 Elevated Temperature Sustained Pressure Test[A] Requirements

Condition	Test Temperature, ºF (ºC)	PE2708, PE3608, PE4608		PE4710	
		Test Pressure Hoop Stress, psi (kPa)	Minimum Average Time Before Failure, hours	Test Pressure Hoop Stress, psi (kPa)	Minimum Average Time Before Failure, hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A]A Calculate internal test pressure in accordance with

$$P = \frac{2S}{\frac{D_o}{t}} - 1$$

Where:

P = test pressure, psi (kPa)
S = test pressure hoop stress, psi. (kPa)
D_o = measured average inside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

Test temperature tolerance ± 3.6ºF (± 2ºC). Test pressure tolerance ± 5 psi (± 35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa.

Table 5 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 compound designations, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours:

$$927 = 200 + \left((750 - 670) \times \frac{(1200 - 200)}{(750 - 640)} \right)$$

7.8.1 Squarely cut four 1 ⅛ to 1 ⅜ in. (29 to 35 mm) wide rings from tubing. Condition the rings per 7.1.

7.8.2 Split each ring longitudinally so that when reverse bent per 7.8.3, the pipe ID for each quadrant around the tubing will be tested.

7.8.3 In a well-lit area, perform the following procedure within 5 min: *(a)* Bend each split ring specimen so that the tubing inside surface is on the outside surface of the bend. *(b)* Using an apparatus such as a bench vise or other suitable equipment, close the legs of the specimen together. When the specimen legs are closed together, the top of the bend-back specimen shall extend above the point of closure by 3 ± ½ times the minimum wall thickness per Table 3. *(c)* With the unaided (naked) eye, visually examine the reverse-bent tubing ID surface.

7.8.4 Visible brittle cracking or crazing indicates failure.

7.9 *Elongation-at-Break Test Method:*

7.9.1 Five Test Method D638 Type III or Type IV specimens cut in the longitudinal direction from locations equally spaced around the circumference of the tubing shall be conditioned per 7.1 and tested in accordance with Test Method D638 at a cross-head separation speed of 2 in. (50.8 mm) min. If the specimen thickness must be reduced by machining, the tubing ID surface shall be left unaltered.

7.9.2 —The percent elongation at break for each test specimen shall exceed 400 %.

NOTE 7—Specimen machining that produces smooth surfaces and uniform thickness is necessary. Surface cuts or scratches and non-uniform thickness in the specimen gage length can detrimentally affect test results.

8. Retest and Rejection

8.1 Except as provided in 7.7.3, 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, 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.

9. Marking

9.1 Marking on the tubing shall include the following information. Marking shall be spaced at intervals of not more than 5 ft (1.5 m). Marking shall be applied such that legibility is maintained after normal handling and installation.

9.1.1 Tubing size (for example, 1 TUBING).

9.1.2 Tubing SDR

9.1.3 The PE material designation in accordance with the material designation prescribed in Table 1 (for example, PE3608).

9.1.4 Pressure rating for water in psi or kPa, (for example, 160 psi. or 1103 kPa)

9.1.5 ASME SD-2737 or both ASME SD-2737 and ASTM D2737.

9.1.6 The manufacturer's name (or trademark) and a code that identifies manufacturing location, PE compound source, manufacturing date and relevant production information such as extrusion line and shift. Upon request the manufacturer shall provide an explanation of the code.

9.1.7 Tubing intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 8—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

12. Keywords

12.1 CTS; CTS tubing; DR; OD controlled; PE pipe; PE tubing; plastic pipe; plastic tubing; potable water pipe; polyethylene pipe; polyethylene tubing; potable water tubing; service pipe; service tubing; SDR; water pipe; water tubing; water service pipe; water service tubing

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 Maximum tubing pressure ratings for use with water may be determined using PPI recommended hydrostatic design stress (HDS) ratings for the PE compound per Section 5 and Table 1. Maximum internal pressure ratings for cold water are shown in Table X1.1. At the manufacturer's discretion and responsibility, other pressure ratings may be recommended for water or other media, or for variations of internal or external conditions.

X1.2 Information on HDS is available in Table 1, Test Method D2837, PPI TR-3 and PPI TR-4.

TABLE X1.1 Maximum Pressure Rating, PR, for SDR-PR PE Pipe for Use With Water

SDR	Nominal Pressure Rating[A,B] psi (kPa)			
	PE2708, PE3608, PE4608		PE4710	
	psi	(kPa)	psi	(kPa)
7.3†	250	(1725)	315	(2170)
9†	200	(1380)	250	(1725)
11†	160	(1100)	200	(1380)

[A]Minimum burst pressure calculated in accordance with

$$PR = \frac{2HDS}{(SDR - 1)}$$

Where:

P_R = burst test pressure, psi (kPa)
HDS = hydrostatic design stress for water at 73°F (23°C), psi. (kPa) (Table 1)
SDR = standard inside dimension ratio

[B]Table values rounded to nearest 5 psi or 5 kPa.
Editorially corrected in February 2012.

SPECIFICATION FOR CHLORINATED POLY(VINYL CHLORIDE) (CPVC) PLASTIC HOT- AND COLD-WATER DISTRIBUTION SYSTEMS

SD-2846/SD-2846M

(Identical with ASTM D2846/D2846M-14 except for additional requirements in section 15 and Annex A1, revised marking requirements in para. 12.2.3, renumbering of section 16, and quality assurance requirement in para. 14.1 has been made mandatory.)

Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems

1. Scope

1.1 This specification covers requirements, test methods, and methods of marking for chlorinated poly(vinyl chloride) plastic hot- and cold-water distribution system components made in one standard dimension ratio and intended for water service up to and including 180°F (82°C). These components comprise pipe and tubing, socket-type fittings, street fittings, plastic-to-metal transition fittings, solvent cements, and adhesives. Requirements and methods of test are included for materials, workmanship, dimensions and tolerances, hydrostatic sustained pressure strength, and thermocycling resistance. The components covered by this specification are intended for use in residential and commercial, hot and cold, potable water distribution systems.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 1—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety hazards should a system fail for any reason.

1.3 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.

1.4 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.

NOTE 2—Suggested hydrostatic design stresses and hydrostatic pressure ratings for pipe, tubing, and fittings are listed in Appendix X1. Design, assembly, and installation considerations are discussed in Appendix X2. An optional performance qualification and an in-plant quality control program are recommended in Appendix X3.

1.5 The following safety hazards caveat pertains only to the test method portion, Sections 9 and 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

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

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

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

F402 Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings

F412 Terminology Relating to Plastic Piping Systems

F493 Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

F1960 Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Cross-linked Polyethylene (PEX) Tubing

F1961 Specification for Metal Mechanical Cold Flare Compression Fittings with Disc Spring for Crosslinked Polyethylene (PEX) Tubing

F1807 Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

F2080 Specification for Cold-Expansion Fittings with Metal Compression-Sleeves for Crosslinked Polyethylene (PEX) Pipe

F2098 Specification for Stainless Steel Clamps for Securing SDR9 Cross-linked Polyethylene (PEX) Tubing to Metal Insert and Plastic Insert Fittings

F2159 Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing

F2434 Specification for Metal Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Cross-linked Polyethylene/Aluminum/Cross-linked Polyethylene (PEX-AL-PEX) Tubing

F2735 Specification for Plastic Insert Fittings For SDR9 Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing

2.2 *ANSI Standards:*

ANSI Z17.1-1958 Preferred Numbers

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.5 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions used in this specification are in accordance with Terminology F412, unless otherwise specified. The abbreviation for chlorinated poly(vinyl chlo-ride) is CPVC. Plastic tubing denotes a particular diameter schedule of plastic pipe in which the outside diameter of the tubing is equal to the nominal size plus ⅛ in. (3.18 mm).

3.1.2 *relation between standard dimension ratio, stress, and internal pressure*—the following expression is used to relate standard dimension ratio, stress, and internal pressure for pipe and tubing:

$$2S/P = R - 1 \tag{1}$$

or

$$2\ S/P = (D_0 / t\ ) - 1 \tag{2}$$

where:

S = stress in circumferential or hoop direction, psi (MPa),
P = internal pressure, psi (MPa),
D_0 = average outside diameter, in. (mm),
t = minimum wall thickness, in. (mm), and
R = standard dimension ratio, SDR

3.1.3 *standard dimension ratio (SDR)*—a selected series of numbers in which the average outside diameter to minimum wall thickness dimension ratios are constant for all sizes of pipe and tubing in each standard dimension ratio, and which are the ANSI Z17.1 Preferred Number Series 10 modified by +1. SDR fittings shall by definition be equivalent in minimum socket wall thickness to the minimum wall thickness of the corresponding SDR and size of pipe or tubing, and the minimum body wall thickness shall be 125 % of that value.

3.1.4 *standard material designation code*—the chlorinated poly(vinyl chloride) material designation code shall consist of the abbreviation CPVC followed by two digits indicating the ASTM type and grade in Arabic numerals. Where necessary, a third and fourth digit shall be added to indicate the hydrostatic design stress for water at 73°F [23°C] in units of 100 psi [0.69 MPa].

4. Classification

4.1 *Pipe, Tubing, and Fittings*—This specification classifies CPVC 4120 pipe, tubing, and fittings by a single standard dimension ratio which shall be SDR 11, by a maximum continuous use temperature which shall be 180°F [82°C] and by nominal pipe or tubing diameters from ¼ in. [9.5 mm] through 2 in. [50 mm].

4.2 *Transition Fittings*—This specification classifies transition fittings intended for use up to and including 180°F [82°C] as CPVC-180°F on the basis of resistance to failure by thermocycling.

4.3 *Solvent Cements and Adhesives*—This specification classifies solvent cements and adhesives meeting the requirements contained herein as CPVC Solvent Cement or CPVC Adhesive.

NOTE 3—This specification does not include requirements for pipe fittings intended to be used to vent combustion gases.

5. Materials

5.1 *Basic Materials Description*—Chlorinated poly(vinyl chloride) plastics used to make pipe, tubing, and fittings meeting the requirements of this specification are categorized by two criteria; namely, basic short-term properties, and long-term hydrostatic strength. Sections 5.1.1 and 5.1.2 respectively define these categories.

5.1.1 *Basic Short-Term Properties*—This specification covers CPVC 41 pipe, tubing, and fittings made from plastic materials meeting the mechanical strength, heat resistance, flammability, and chemical resistance requirements for CPVC 23447 in Specification D1784.

TABLE 1 Outside Diameters, Wall Thicknesses, and Tolerances for CPVC 41, SDR 11, Plastic Pipe and Tubing[A]

Nominal Tube or Pipe Size		Outside Diameter, in. [mm] Average	Tolerance on Average	Max Out-of-Round[C]	Wall Thickness, in. [mm][B] SDR 11 Min	Tolerance
¼ Tubing		0.375 [9.5]	±0.003 [±0.08]	±0.003 [±0.08]	0.055 [1.40][D]	+0.020 [+0.51]
⅜ Tube	[10]	0.500 [12.7]	±0.003 [±0.08]	±0.003 [±0.08]	0.060 [1.52][D]	+0.020 [+0.51]
½ Tube	[15]	0.625 [15.9]	±0.003 [±0.08]	±0.004 [±0.10]	0.060 [1.52][D]	+0.020 [+0.51]
¾ Tube	[20]	0.875 [22.2]	±0.003 [±0.08]	±0.005 [±0.13]	0.080 [2.03]	+0.020 [+0.51]
1 Tube	[25]	1.125 [28.6]	±0.003 [±0.08]	±0.006 [±0.15]	0.102 [2.59]	+0.020 [+0.51]
1¼ Tube	[32]	1.375 [34.9]	±0.003 [±0.08]	±0.007 [±0.18]	0.125 [3.18]	+0.020 [+0.51]
1½ Tube	[40]	1.625 [41.3]	±0.004 [±0.10]	±0.008 [±0.20]	0.148 [3.76]	+0.020 [+0.51]
2 Tube	[50]	2.125 [54.0]	±0.004 [±0.10]	±0.010 [±0.25]	0.193 [4.90]	+0.023 [+0.58]
1½ Pipe	[40]	1.900 [48.6]	+0.006, −0.002 [+0.15, −0.05]	±0.008 [±0.20]	0.173 [4.39]	+0.021 [+0.53]
2 Pipe	[50]	2.375 [60.7]	+0.006, −0.002 [+0.15, −0.05]	±0.010 [±0.25]	0.216 [5.49]	+0.026 [+0.66]

[A] All dimensions are in inches and millimetres. (1 in. = 25.4 mm.)
[B] The minimum is the lowest wall thickness at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All wall tolerances are on the plus side of the minimum requirement.
[C] The maximum out-of-roundness applies to the average measured outside diameter.
[D] For tubing sizes of ½ in. and below, wall thickness minimums are not a function of SDR.

NOTE 4—CPVC 23447 was formerly designated as CPVC Type IV Grade 1, and is herein designated as CPVC 41. This is also used in marking pipe, tubing, or fittings.

5.1.2 *Long-Term Hydrostatic Strength*—This specification covers CPVC 41 pipe, tubing, and fittings which are further defined by hydrostatic design stress as CPVC 4120. Pipe and tubing are so defined on the basis of long-term hydrostatic strength tests and are made from compounds having an established 180°F [82°C] hydrostatic design stress of 500 psi [3.45 MPa] or greater in accordance with Test Method D2837. Fittings are so defined by hydrostatic sustained pressure tests on fitting assemblies, required by this specification (see 6.2), based on the hydrostatic strength of the corresponding pipe or tubing.

NOTE 5—No hydrostatic design stress, as such, exists for fittings until such time as long-term hydrostatic strength test methods for fittings are developed.

5.2 The PEX fitting ends of CPVC to PEX transition fittings shall meet the material and dimensional requirements of the corresponding PEX fitting standard.

5.3 The PERT fitting ends of CPVC to PERT transition fittings shall meet the material and dimensional requirements of the corresponding PERT fitting standard.

5.4 *Rework Material*—Clean rework plastic material generated from the manufacturer's own plastic tube or fitting production may be used by the same manufacturer provided the pipe, tubing, or fittings meet all the requirements of this specification.

6. Requirements for Pipe, Tubing and Fittings

6.1 *Dimensions and Tolerances:*

6.1.1 *General:*

6.1.1.1 *Wall Minimums*—Table 1 and Table 2 show wall thickness minimums. Calculated SDR 11 fitting wall thicknesses that fall below 0.102 in. [2.59 mm] for the fitting socket bottom, or 0.128 in. [3.25 mm] for the fitting body, shall be arbitrarily increased to these values.

6.1.1.2 *Interference Fit*—The diameters and tolerances in Table 1 and Table 2 provide for socket-type joints having an interference fit based on the major diameter of pipe and tubing having a degree of out-of-roundness.

6.1.1.3 *Out-of-Roundness*—The maximum out-of-roundness requirements shown in Table 1 and Table 2 for pipe, tubing, and fittings apply to the average measured diameter.

NOTE 6—*Example*: In the 1-in. [25 mm] tubing size, if the measured average tubing diameter was 1.123 in. [28.52 mm], then the extreme measured diameters due to ovality could be 1.129 in. [28.68 mm] maximum and 1.117 in. [28.37 mm] minimum.

6.1.2 *Pipe and Tubing:*

6.1.2.1 *Outside Diameter and Wall Thickness*—The outside diameters and wall thicknesses for pipe and tubing shall meet the requirements for dimension and tolerance given in Table 1 when measured in accordance with Test Method D2122.

6.1.2.2 *Wall Thickness Range*—The wall thickness range for pipe and tubing shall be within 12 % when measured in accordance with Test Method D2122.

6.1.2.3 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 9.2.

6.1.2.4 *Length*—Pipe and tubing supplied in straight lengths shall have a tolerance on any specified length of +½, −0 in. [+12.5, −0 mm].

6.1.3 *Socket-Type Fittings:*

6.1.3.1 *Dimensions*—Fitting sockets, inside diameters (waterways), wall thicknesses, laying lengths, and reducing bushing minimums shall meet the requirements for dimension and tolerance given in Table 2, Table 3, and Table 4 when measured in accordance with Test Method D2122. The spigot ends of street fittings shall meet the outside diameter and minimum wall requirements of Table 1.

6.1.3.2 *Alignment*—The maximum angular variation of any socket opening shall not exceed ½ ° off the true centerline axis.

6.1.4 *Plastic-to-Metal Transition Fittings:*

6.1.4.1 *Basic Dimensions*—Plastic parts of plastic-to-metal transition fittings shall meet the dimensional requirements of Table 1 and Table 2, where applicable, with the following exceptions. Such parts shall be exempted from the requirements for inside diameter (waterway) and wall thickness tolerance.

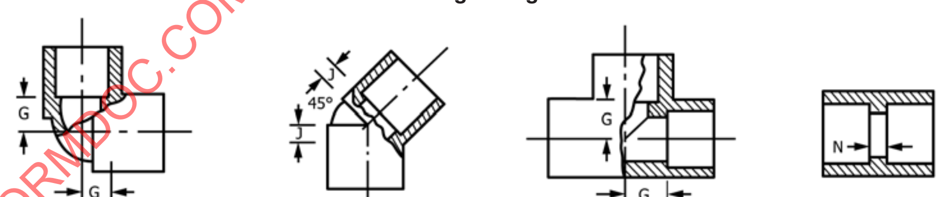
TABLE 2 Tapered Socket Dimensions for CPVC 41, SDR 11, Plastic Pipe and Tubing Fittings[A,B]

Nominal Tube or Pipe Size		*A* Socket Entrance Diameter, in. [mm]			*B* Socket Bottom Diameter, in. [mm]		
		Average	Tolerance on Average	Max Out-of-Round [C]	Average	Tolerance on Average	Max Out-of-Round [C]
⅜ Tube	[10]	0.508 [12.90]	±0.003 [±0.08]	±0.003 [±0.08]	0.494 [12.55]	±0.003 [±0.08]	±0.003 [±0.08]
½ Tube	[15]	0.633 [16.08]	±0.003 [±0.08]	±0.004 [±0.10]	0.619 [15.72]	±0.003 [±0.08]	±0.004 [±0.10]
¾ Tube	[20]	0.884 [22.45]	±0.003 [±0.08]	±0.005 [±0.13]	0.870 [22.10]	±0.003 [±0.08]	±0.005 [±0.13]
1 Tube	[25]	1.135 [28.83]	±0.003 [±0.08]	±0.006 [±0.15]	1.121 [28.47]	±0.003 [±0.08]	±0.006 [±0.15]
1¼ Tube	[32]	1.386 [35.20]	±0.003 [±0.08]	±0.007 [±0.18]	1.372 [34.85]	±0.003 [±0.08]	±0.007 [±0.18]
1½ Tube	[40]	1.640 [41.66]	±0.004 [±0.10]	±0.008 [±0.20]	1.622 [41.20]	±0.004 [±0.10]	±0.008 [±0.20]
2 Tube	[50]	2.141 [54.38]	±0.004 [±0.10]	±0.010 [±0.25]	2.123 [53.92]	±0.004 [±0.10]	±0.010 [±0.25]
1½ Pipe	[40]	1.918 [48.72]	±0.004 [±0.10]	±0.008 [±0.20]	1.900 [48.26]	±0.004 [±0.10]	±0.008 [±0.20]
2 Pipe	[50]	2.393 [60.78]	±0.004 [±0.10]	±0.010 [±0.25]	2.375 [60.33]	±0.004 [±0.10]	±0.010 [±0.25]

C Socket Length, min, in. [mm]	*D* Inside Diameter, min, in. [mm]	Wall Thickness, min,[D] in. [mm]			Entrance; min *EW EX EZ*, in. [mm]
		(E_a) Socket Entrance	(E_b) Socket Bottom	*F*	
0.500 [12.70]	0.364 [9.25]	0.068 [1.73]	0.102 [2.59]	0.128 [3.25]	0.034 [0.86]
0.500 [12.70]	0.489 [12.42]	0.068 [1.73]	0.102 [2.59]	0.128 [3.25]	0.034 [0.86]
0.700 [17.78]	0.715 [18.16]	0.080 [2.03]	0.102 [2.59]	0.128 [3.25]	0.034 [0.86]
0.900 [22.86]	0.921 [23.39]	0.102 [2.59]	0.102 [2.59]	0.128 [3.25]	0.034 [0.86]
1.100 [27.94]	1.125 [28.58]	0.125 [3.18]	0.125 [3.18]	0.156 [3.96]	0.042 [1.07]
1.300 [33.02]	1.329 [33.76]	0.148 [3.76]	0.148 [3.76]	0.185 [4.70]	0.049 [1.24]
1.700 [43.18]	1.739 [44.17]	0.193 [4.90]	0.193 [4.90]	0.241 [6.12]	0.064 [1.63]
1.375 [34.92]	1.494 [37.95]	0.173 [4.39]	0.173 [4.39]	0.216 [5.49]	0.058 [1.47]
1.500 [38.10]	1.933 [49.10]	0.216 [5.49]	0.216 [5.49]	0.270 [6.86]	0.072 [1.83]

[A] All dimensions are in inches and millimetres. (1 in. = 25.4 mm.)
[B] All sketches and designs of fittings are illustrative only.
[C] Maximum out-of-roundness applies to the average measured inside diameter.
[D] The minimum is the lowest wall thickness at any cross section.

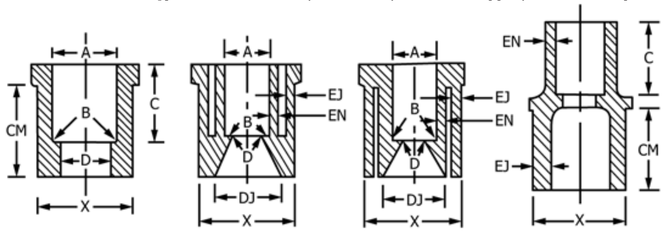
TABLE 3 Minimum Dimensions from Center to End of Socket (Laying Length) for CPVC 41, SDR 11 Plastic Pipe and Tubing Fittings[A,B,C]



Nominal Tube or Pipe Size		*G* Min[D], in. [mm]	*J* Min[D], in. [mm]	*N* Min[D], in. [mm]
⅜ Tube	[10]	0.359 [9.12]	0.174 [4.42]	0.102 [2.59]
½ Tube	[15]	0.382 [9.70]	0.183 [4.65]	0.102 [2.59]
¾ Tube	[20]	0.507 [12.88]	0.235 [5.97]	0.102 [2.59]
1 Tube	[25]	0.633 [16.08]	0.287 [7.29]	0.102 [2.59]
1¼ Tube	[32]	0.758 [19.25]	0.339 [8.61]	0.102 [2.59]
1½ Tube	[40]	0.884 [22.45]	0.391 [9.93]	0.102 [2.59]
2 Tube	[50]	1.134 [28.83]	0.495 [12.57]	0.102 [2.59]
1½ Pipe	[40]	1.022 [25.96]	0.448 [11.38]	0.102 [2.59]
2 Pipe	[50]	1.260 [32.00]	0.547 [13.89]	0.102 [2.59]

[A] All dimensions are in inches and millimetres. (1 in. = 25.4 mm.)
[B] All dimensions not shown shall be in accordance with those in Table 2.
[C] The sketches and designs of fittings are illustrative only.
[D] Minimum dimensions have zero negative tolerance.

TABLE 4 Dimensions of Reducer Bushings for CPVC 41, SDR 11, Socket-Type, Plastic Pipe and Tubing Fittings[A,B,C,D]



[A] Tubing socket dimensions, *A*, *B*, and *C*, and tolerances on these dimensions shall be the same as in Table 2. The minimum length of the male end of the bushing or coupling, *CM*, shall be the same as *C* in Table 2, but in any case the male end shall bottom in the mating fitting. Minimum waterway dimensions, *D* and *DJ*, shall be the same as *D* in Table 2. Minimum wall dimensions, *EJ* and *EN*, apply to the larger and smaller sizes joined respectively, and shall be the same as the corresponding values for E_a in Table 2.
[B] The minimum socket wall thickness for reducing bushings shall be 102 in. [2.59 mm]. If the socket wall thickness exceeds the total of *EJ* and *EN* calculated from the appropriate E_b values in Table 2 and the reducer bushing is cored, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending the full depth of the coring.
[C] The transition from *D* to *DM* shall be straight, tapered as shown, or radiused, at the discretion of the manufacturer.
[D] A taper on the male end of a bushing is optional. If a taper is used, it shall be a positive taper in the same direction as the taper in the socket. Whether a taper is used or not, all diameters *X* shall conform to the diameter and tolerance for the corresponding size of tubing shown in Table 1.

6.1.4.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 9.5.

6.1.5 *CPVC to PEX and CPVC to PERT Transition Fittings:*

6.1.5.1 Basic Dimensions:

(1) CPVC spigot-ends of CPVC to PEX and CPVC to PERT fittings shall meet the dimensional requirements of Table 1, where applicable, with the following exceptions. Such parts shall be exempted from the requirements for inside diameter (waterway) and wall thickness tolerance and,

(2) CPVC tapered socket-ends of CPVC to PEX and CPVC to PERT transition fittings shall meet the dimensional requirements of Table 2 where applicable.

(3) The PEX fitting end of CPVC to PEX and CPVC to PERT transition fittings shall meet the applicable requirements of the corresponding ASTM fitting standard. See the following specifications for these requirements: F1960, F1961, F1807, F2080, F2098, F2159, F2434 and F2735.

6.2 *Hydrostatic Sustained Pressure:*

6.2.1 *General*—Pipe, tubing, and fittings (tested as assemblies) shall meet the minimum hydrostatic sustained pressure requirements of both test conditions shown in Table 5 when tested in accordance with 9.3.

6.2.2 *Pipe and Tubing Quality*—Test Condition B shall be termed the primary sustained pressure test for pipe and tubing and shall be used for quality control (see Appendix X3). Test Condition A shall be termed the secondary sustained pressure test for pipe and tubing and shall be used for periodic performance qualification. Failure to pass either test is cause for rejection.

6.2.3 *Fitting Quality*—Test Condition A shall be termed the primary sustained pressure test for fittings and shall be used for quality control (see Appendix X3). Test Condition B shall be termed the secondary sustained pressure test for fittings and shall be used for periodic performance qualification. Failure to pass either test is cause for rejection.

NOTE 7—Drop weight impact resistance is correlatable with hydrostatic sustained pressure resistance for CPVC 41 components, and may be useful for predicting compliance with the sustained pressure requirements of Table 5. Such correlations will necessarily differ with the size, wall thickness, and geometry of individual components. Test Method D2444 using Tup A and Holder A is suggested for nominal diameters of 1 in. [25 mm] and above. For smaller components, a guided mandrel type of impacter such as the Gardner Impacter equipped with a ½ in. [12.7 mm] radius mandrel is suggested. Drop impact is not included in this specification directly as a quality requirement because of the wide test scatter normally associated with this test, and also because of the wide differences in value over the range of sizes and components covered in this specification.

TABLE 5 Minimum Hydrostatic Sustained Pressure Requirements for CPVC 4120, SDR 11, Pipe, Tubing, and Fitting Assemblies Tested in Either Water or Air Bath External Environment at 180°F [82°C][A]

Test Condition	Test Duration	Hydrostatic Test Pressure	
		Water Bath	Air Bath
A	6 min	521 psi [3 590 kPa]	551 psi [3 800 kPa]
B	4 h	364 psi (2 510 kPa)	403 psi [2 780 kPa]

[A] Test conditions were calculated from the following experimentally derived, 95 % confidence, rupture pressure versus time relationships for CPVC 41, SDR 11, pipe and tubing at 180°F [82°C]. Pressure, *P*, and time, *t*, are in psi and h respectively. The 50 % confidence relationships are given for information only.

$\log P = -\ 0.085155 \log t + 2.726805$ (50 % confidence in air)
$\log P = -0.085155 \log t + 2.656225$ (95 % confidence in air)
$\log P = -0.097269 \log t + 2.690464$ (50 % confidence in water)
$\log P = -0.097269 \log t + 2.619884$ (95 % confidence in water)

6.3 *Thermocycling*—Transition fittings (other than metal socket-type transitions for use with adhesives), assembled according to the manufacturer's instructions, shall not separate or leak when thermocycled 1000 times between the temperatures of 60°F and 180°F [16°C and 82°C] in accordance with 9.3.

TABLE 6 Minimum Hydrostatic Burst Strength Requirements for Nominal 2-in. [50-mm] CPVC Solvent Cemented Joints after 2 h Drying at Test Temperature

Temperature	Burst Pressure
73.4°F [23°C]	400 psi [2 760 kPa]
180°F [82°C]	200 psi [1 380 kPa]

7. Requirements for Solvent Cement and Adhesive Joints

7.1 *CPVC Solvent Cements:*

NOTE 8—CPVC solvent cements may exist which meet the requirements of the specification when used in accordance with the manufacturer's recommendations, without a primer or cleaner. It is recommended that those CPVC solvent cements which may be used without a primer or cleaner be clear or yellow in color. Otherwise, it is recommended that CPVC solvent cement requiring the use of a primer or cleaner be orange in color. Color identification is recommended to facilitate cement recognition, to prevent the misuse of the cement and to minimize the unintentional use of other cements that may fail at elevated service temperatures.

7.1.1 *General*—CPVC solvent cements, for use in CPVC 41, plastic-to-plastic, socket-type joints shall meet the requirements set forth in Specification F493.

7.1.2 *Hydrostatic Burst Strength*—2-in. [50-mm] CPVC solvent cement joints shall exceed the minimum hydrostatic burst strength requirements given in Table 6 after a maximum drying interval of 2 h when tested in accordance with 10.1.1. Failure to pass the burst requirement at either temperature is cause for rejection.

7.1.3 *Hydrostatic Sustained Pressure Strength*—½-in. [15-mm] CPVC solvent cement joints shall meet the requirements of 6.2 when tested in accordance with 9.3.

7.1.4 *Safe Handling of Solvent Cement*—Refer to Practice F402.

7.2 *CPVC Adhesives:*

7.2.1 *General*—CPVC adhesives (other than CPVC solvent cement), shall qualify for use in CPVC socket-type joints by a rigorous simulated use testing program as further defined in 7.2.2 and 7.2.3. CPVC adhesives shall be tested in the largest size joint and in the exact type of joint for which they are intended; that is, 2-in. [50-mm] plastic-to-metal or 2-in. [50-mm] plastic-to-plastic.

7.2.2 *Hydrostatic Sustained Pressure Strength*—Socket-type CPVC adhesive joints, made and cured according to the adhesive manufacturer's instructions, shall not separate or leak when tested in accordance with 10.2 at the hydrostatic sustained pressure condition given in Table 7.

7.2.3 *Thermocycling*—Socket-type CPVC adhesive joints, made and cured according to the adhesive manufacturer's instructions, shall not separate or leak when thermocycled 10 000 times between the temperatures of 60°F and 180°F [16°C and 82°C] in accordance with 10.2.

8. Workmanship, Finish, and Appearance

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

TABLE 7 Minimum Hydrostatic Sustained Pressure Requirements for CPVC Socket-Type Adhesive Joint Assemblies Tested Either in Water Bath or Air Bath External Environment at 180°F [82°C][A]

Test Duration, h	Test Pressure	
	Water Bath	Air Bath
10 000	170 psi [1 170 kPa]	207 psi (1 430 kPa)

[A] Test conditions were calculated from the experimentally derived, 95 % confidence limit, rupture pressure versus time relationships for CPVC 41, SDR 11, pipe and tubing noted in Table 5. It is implied that CPVC adhesive joints meeting the sustained pressure requirements of 7.2.2 would necessarily pass the less rigorous requirements of 6.2.1.

9. Test Methods for Pipe, Tubing, and Fittings

9.1 *Sampling*—A sufficient quantity of pipe, tubing, or fittings, as agreed upon between the purchaser and the seller, shall be selected at random from each lot or shipment and tested to determine conformance with this specification. In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

9.1.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

9.2 *Flattening*—Flatten three specimens of the pipe, 2 in. [50-mm] long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe or the walls of the pipe touch, whichever occurs first. The rate of loading shall be uniform and such that the compression is completed within 5 min. Upon removal of the load, examine the specimens for evidence of splitting, cracking, or breaking.

9.3 *Hydrostatic Sustained Pressure:*

9.3.1 *Summary of Test Method*—This test method describes a pass-fail test for CPVC 41 pipe, tubing, or fittings (tested as assemblies) subjected to a constant internal hydrostatic pressure for a predetermined period of time. Test conditions are based on known rupture pressure versus time relationships for standard CPVC 41 components (see footnote to Table 5). The external test environment shall be either water or air; however, test pressures differ depending on the environment selected (see Table 5).

9.3.2 *Apparatus:*

9.3.2.1 *Constant-Temperature Environment*—Either a water bath or an air bath capable of maintaining a constant and uniform temperature of 180 ± 1.8°F [82 ± 1°C] throughout.

9.3.2.2 *Pressurizing System*—A pressure source capable of rapidly and continuously applying a constant hydrostatic pressure, controlled to ±10 psi [±69 kPa] or better, to the test specimens.

9.3.2.3 *Timing Device*—Any clock capable of accuracy to within 1 % of the total test time.

9.3.2.4 *Closure Fittings*—Any suitable specimen closure that allows "free-end" mounting, is free of leaks, and will not contribute to end failures.

NOTE 9—Various types of compression and flared, metal fittings have

TABLE 8 Minimum Suggested Drying Times for Solvent Cemented Fitting Assemblies in Air at 180°F [82°C]

Test Condition (from Table 5)	Suggested Drying Time at 180°F [82°C], h
A	4
B	16

been found to be acceptable. Socket-type CPVC 41 caps are also acceptable provided that the necessary solvent cemented or adhesive joints are suitably dried or cured (refer to 9.3.3.2).

9.3.3 *Sampling and Specimen Preparation:*

9.3.3.1 *Pipe and Tubing*—Select at random specimens of at least seven times the nominal diameter in length, but in any case not shorter than 10 in. [250 mm]. Take three specimens for quality control testing. Take six specimens for qualification or referee testing.

9.3.3.2 *Fittings*—Select specimens at random. Take three specimens for quality control testing. Take six specimens for qualification or referee testing. Assemble the fittings, individually or collectively, using suitable lengths of CPVC 41 pipe or tubing and CPVC solvent cement or CPVC adhesive. Use only pipe or tubing and solvent cement or adhesive meeting the requirements of this specification. Assemble the joints in accordance with the cement manufacturer's instructions. Allow solvent cemented fitting assemblies to dry at elevated temperature, up to 180°F [82°C] maximum, in a forced-air oven until all joints are sufficiently strong to eliminate joint failures during the test. Minimum suggested drying times are shown in Table 8. Cure assemblies prepared with CPVC adhesives according to the adhesive manufacturer's instructions until the adhesive joints are sufficiently strong to eliminate joint failures during the test. In no case, however, should adhesive joints be cured at a temperature higher than 180°F [82°C].

9.3.4 *Procedure*—After curing all cemented or adhesive joints used, attach suitable end closures where necessary. Fill the specimen with water, making certain to avoid entrapment of air. Condition the test specimen at 180 ± 1.8°F [82 ± 1°C] for a minimum of 30 min if using a water bath, or 4 h if using an air bath. Attach the specimen to the pressure source, and place it on test at 180 ± 1.8°F [82± 1°C] under the proper hydrostatic pressure selected from Table 5. Start the timer immediately. Hold the test pressure and temperature as close as possible to the specified values, but in any case to within ± 10 psi [±69 kPa] and 1.8°F [1°C] respectively. At the end of the specified minimum time interval, isolate the specimen from the pressure source and check for any continuous loss of pressure resulting from transmission of water through the specimen. Any such continuous loss of pressure, resulting from bursting or weeping of the test specimens as defined in Test Method D1598, shall constitute failure. If joint leakage or joint separation has occurred, the test shall be repeated using a longer joint drying or curing cycle.

9.3.5 *Interpretation of Results:*

9.3.5.1 *For Quality Control*—Failure of any one of three specimens tested shall constitute failure in this test.

9.3.5.2 *For Performance Qualification*—Failure of any one of six specimens tested shall constitute failure in this test.

9.4 *Thermocycling:*

9.4.1 *Summary of Method*—This method describes a pass-fail test for thermally cycling CPVC plastic-to-metal transition fitting assemblies over a critical temperature range for a selected number of cycles while subjected to a nominal internal pressure. The test provides a measure of resistance to failure due to the combined effects of differential thermal expansion and creep for CPVC plastic-to-metal transition fittings intended for continuous use up to and including 180°F [82°C].

9.4.2 *Apparatus*—A nitrogen or air source capable of maintaining a nominal internal pressure of 100 ± 10 psi [690 ± 69 kPa) on the specimens is required. The immersion system shall consist of two water reservoirs controlled at 60 ± 3.6°F [16 ± 2°C] and 180 ± 3.6°F [82 ± 2°C]. The specimens shall be cycled from one reservoir to the other or the hot and cold water shall be alternately cycled over the test specimens automatically and returned to the proper reservoir.

NOTE 10—Automatic cycling may be accomplished by pumping from each reservoir through a delivery system having timer-actuated valves to a specimen water trough having synchronized, timer-actuated return drains. Any automatic apparatus shall provide for complete immersion of the test specimens in the trough.

9.4.3 *Sampling and Specimen Preparation*— Select at random six specimens of the type and size of CPVC plastic-to-metal transition fitting to be tested. Assemble the fittings with suitable lengths of pipe or tubing meeting the requirements of this specification, and attach to a common manifold. Assemble strictly according to the instructions of the transition fitting manufacturer. If plastic threads are to be mated to metal threads, use the thread sealant intended for use with the threaded transition. Close the specimen assembly with any suitable end closures that allow "free-end" mounting and will not leak under the thermocycling conditions, and connect the specimen assembly to the pressure source.

9.4.4 *Procedure*—Pressure the specimen assembly with nitrogen in air 100 ± 10 psi [690 ± 69 kPa]. Immerse in 60 ± 3.6°F [16 ± 2°C] water to determine if there are any initial leaks. All leaks shall be eliminated before the thermocycling test is started. Thermally cycle the specimen assembly either manually or automatically, and under an internal pressure of 100 ± 10 psi [690± 69 kPa] alternately between 60 ± 3.6°F [16 ± 2°C] and 180 ± 3.6°F [82 ± 2°C] by means of immersion in water using the following test cycle:

Water immersion at 180°F [82°C]	2 minutes (min)
Air immersion at ambient	2 minutes (max)
Water immersion at 60°F [16°C]	2 minutes (min)
Air immersion at ambient	2 minutes (max)

Upon the completion of 1000 thermal cycles, immerse the specimen assembly again in 60 ± 3.6°F [16 ± 2°C] water and check for any sign of gas leakage. Any evidence of leakage at the transition fitting or separation of the transition fitting from the pipe or tubing constitutes a failure.

9.4.5 *Interpretation of Results*—Failure of any one of six specimens tested shall constitute failure in this test.

9.5 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

10. Tests for Solvent Cement and Adhesive Joints

10.1 *Test for Solvent Cement Joints:*

10.1.1 *Hydrostatic Burst Strength*—Determine the minimum hydrostatic burst strength for CPVC solvent cemented joints according to Test Method D1599, except as herein specified. Test assemblies containing at least six nominal 2-in. [50-mm] solvent cemented joints prepared for CPVC 41 pipe or tubing and fittings meeting the requirements of this specification. Assemble the joints in accordance with the solvent cement manufacturer's instructions. After attaching end closures, fill the specimen assembly with water and condition in water at the test temperature for 2 h maximum. Then test immediately. Increase the internal pressure at a constant rate so as to reach the minimum burst requirement in 60 to 70 s. Leakage or separation at any of the joints tested at less than the minimum hydrostatic burst requirement specified in Table 6 shall constitute failure in this test.

10.2 *Test for Adhesive Joints:*

10.2.1 *General*—Prepare a test assembly containing at least six adhesive joints of the largest nominal diameter and the exact type (plastic-to-plastic, or plastic-to-metal) for which the adhesive is intended to qualify. Make and cure the adhesive joints in accordance with the adhesive manufacturer's instructions, but in no case above 180°F [82°C]. The CPVC 41 pipe or tubing and fittings used in the assembly shall meet the requirements of this specification.

10.2.2 *Hydrostatic Sustained Pressure for Adhesive Joints*—Test in accordance with 9.2, but at the conditions in Table 7 which require a test duration of 10 000 h. Any evidence of leaking or separation at the adhesive joint, or adhesive-related bursting, weeping, or ballooning of the CPVC 41 components adjacent to the joint, shall constitute failure. Failure of any one of six joint specimens tested shall constitute failure in this test.

10.2.3 *Thermocycling for Adhesive Joints*—Test in accordance with 9.3, but carry the test to 10 000 cycles. Any evidence of leakage or separation at the adhesive joint constitutes a failure. Failure of any one of six joint specimens tested shall constitute failure in this test.

11. Retest and Rejection

11.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, 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.

NOTE 11—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

12. Product Marking

12.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

12.2 *Content of Marking:*

12.2.1 Manufacturer's name (or trademark), and production code,

12.2.2 Components intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory,

12.2.3 ASME SD-2846/SD-2846M or both ASME SD-2846/SD-2846M and ASTM D2846/D2846M,

12.2.4 Material designation in accordance with 5.1.2 (CPVC 4120),

12.2.5 Pressure rating (see Appendix X1) at 180°F [82°C].

12.2.6 Nominal size,

12.2.7 Standard dimension ratio (SDR 11), and

12.2.8 A code number identifying the compound and the date of manufacture.

12.3 *Pipe and Tubing*—Markings 12.2.1 through 12.2.7 shall be required on pipe and tubing at intervals of not more than 5 ft [1.5 m]. Marking shall be applied without indentation in some permanent manner so as to remain legible under normal handling and installation practice.

12.4 *Socket-Type Fittings*—Markings 12.2.1 through 12.2.4 shall be required on socket-type fittings, except where size makes such marking impractical. Where markings are omitted, fittings shall be identified by some symbol which is defined in the manufacturer's trade literature. Marking on fittings shall be molded, hot stamped, or applied in some other permanent manner so as to remain legible under normal handling and installation practice. Where recessed marking is used, care shall be taken to see that wall thicknesses are not reduced below the specified minimums.

12.5 *Transition Fittings*—Markings 12.2.1 through 12.2.3 shall be required on CPVC plastic-to-metal transition fittings in addition to the designation CPVC.

12.6 *CPVC to PEX and CPVC to PERT Transition Fittings*—Markings 12.1 through 12.2.3 shall be required to be marked on the transition fittings in addition to the standard number to which the PEX or PERT fitting end portion of the transition is manufactured.

12.7 *Solvent Cements and Adhesives*—Solvent cements and adhesives shall be labeled in accordance with 12.2.1 through 12.2.3 in addition to the designation CPVC Solvent Cement or CPVC Adhesive.

NOTE 12—Certain regional air quality districts have established criteria regarding limits on volatile organic content levels for certain products, including CPVC solvent cement. Both the cement producer and user should ensure that the product complies with the specific air quality district requirements as determined by the test methods specified by that air quality district. It is recommended that the air quality district and the air quality district's regulation to which the cement conforms be indicated on the label.

13. Safe Handling of Solvent Cement

13.1 Refer to Practice F402 for information on safe handling of solvent cements.

14. Quality Assurance

14.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

15. Certification

15.1 Certification shall be as required by Annex A1.

16. Keywords

16.1 cold-water pipe; CPVC piping; hot-water pipe; water distribution piping

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

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

S1. *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 may 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 S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. HYDROSTATIC DESIGN STRESS

X1.1 Hydrostatic design stresses recommended by the Plastics Pipe Institute are used to pressure rate CPVC plastic pipe and tubing. These design stresses are based on the 100 000-h hydrostatic strength of the pipe and tubing obtained in accordance with Test Method D2837. Additional information regarding the method of test and other criteria used in developing these hydrostatic design stresses may be obtained from the Plastics Pipe Institute, Division of the Society of the Plastics Industry, 355 Lexington Ave., New York, NY 10017.

X1.2 Independent methods for determining the hydrostatic design stress of fittings have yet to be developed due to the complicating effects of fitting geometry. Instead, fittings and assembled systems carry an implied pressure rating equivalent to that of the corresponding pipe or tubing on the basis of actual equivalent hydrostatic performance of assembled systems for periods exceeding 10 000 h. The sustained pressure requirements of 6.2 for fittings, tested as assembled systems, are derived from the rupture pressure-time relationship for pipe and tubing (see footnote to Table 5).

X1.3 The hydrostatic design stresses and pressure ratings in Table X1.1 apply to systems assembled from CPVC 4120, SDR 11, components meeting the requirements of this specification.

X1.4 These hydrostatic design stresses are not suitable for materials that show a negative departure from a straight-line plot of log stress versus log time-to-failure. All of the data available to date on CPVC materials made in the United States and tested in the form of pipe, tubing, or cured fitting assemblies meet this requirement. Experience of the industry indicates that CPVC hot- and cold-water distribution systems made from components meeting the requirements of this specification give satisfactory service under normal conditions at this temperature-pressure rating.

TABLE X1.1 Hydrostatic Design Stresses and Pressure Ratings for CPVC 4120, SDR 11, Hot-Water Distribution Systems

Rated Temperature	Hydrostatic Design Stress	Pressure Rating for Water
73.4°F [23°C]	2000 psi [13.8 MPa]	400 psi [2.8 MPa]
180°F [82°C]	500 psi [3.5 MPa]	100 psi [0.7 MPa]

X2. DESIGN, ASSEMBLY, AND INSTALLATION CONSIDERATIONS

X2.1 Design

X2.1.1 *Thermal Expansion*—The linear thermal expansion rate for CPVC is approximately ½ in. for each 10°F temperature change for each 100 ft [8 mm for each 10°C temperature change for each 10 m] of pipe or tubing. When installing long runs of pipe allow 1⁄16 to 3⁄32 in. longitudinal clearance per foot [5 to 7 mm per metre] of run to accommodate thermal expansion. Proper design includes offsets of 12 in. [300 mm] or more every 10 ft [3 m] on vertical risers if they are restrained by horizontal branches at each floor level. Pipe should not be anchored rigidly to a support but rather be secured with broad, smooth hangers providing for a degree of movement.

X2.1.2 *Support Spacing*—The maximum recommended spacing between supports is 3 ft [1 m] for sizes 1 in. or smaller and 4 ft [1.2 m] for larger sizes.

X2.1.3 *Water Heaters*—Components covered by this specification are not intended for use at temperatures above 180°F [82.2°C]. Hence, they may not be suitable for use with the instantaneous type (coil or immersion) water heater. They are suitable for use with storage type water heaters with connections made in an approved manner.

X2.1.4 *Sweating*—Even though the thermal conductivity of CPVC is several orders of magnitude lower than that of metal, sweating or condensation at a slow rate may occur under certain temperature and humidity conditions.

X2.1.5 *Water Hammer and Surge*—A CPVC hot-water system will withstand repeated pressure surges well in excess of its rated pressure, but water hammer arrestors may be advisable when solenoid valves or other quick closing devices are used in the system. In designing for such situations it is advisable to consult the pipe or fitting manufacturer for recommended surge pressure limits. Water hammer and surge pressure calculations are reviewed in AWWA Manual M11, "Steel Pipe Design and Installation," 1964, Chapter 7, American Water Works Association Inc., 2 Park Ave., New York, NY 10016.

X2.2 Assembly

X2.2.1 *Solvent Cemented Joints:*

X2.2.1.1 *Interference Fit*—Components meeting the dimensional requirements of this specification are designed to have an interference fit. Before making a cemented joint, it is advisable to check for an interference dry-fit. A good interference dry-fit exists when the pipe or tubing makes contact with the fitting socket wall between one third and two thirds of the way into the socket.

X2.2.1.2 *Cutting*—Pipe and tubing may be cut to length with tubing cutters. Tubing cutters with thin cutting wheels designed specially for plastic are recommended. Where tubing cutters are not available, a saw and mitre box may be used. Burrs and ridges caused by handling or cutting must be removed before assembling a joint.

X2.2.1.3 *Solvent Cleaning*—When recommended by the cement manufacturer, organic liquids can be used as a cleaning solvent for CPVC 41 components. These organic liquids should have a low solvation power for CPVC, to prevent mistaken use of the cleaning solvent for a cement. Uncemented joints with a good solvent. THF for instance, will pass the usual cold water pressure check but are likely to fail later in hot water service.

X2.2.1.4 *Step-by-Step Assembly*—Correct assembly consists of the following steps: (*1*) cut the pipe square; (*2*) remove burrs; (*3*) check for interference fit; (*4*) clean both pipe end and fitting socket with a recommended CPVC cleaner or by light sanding, or both; (5) apply a liberal coat of CPVC solvent cement to the pipe and apply a light coat of cement to the fitting socket; (*6*) assemble immediately by bottoming the pipe in the socket and rotating a quarter turn as the joint is assembled; and (*7*) remove excess cement from the joint. If a joint has been properly made, a small bead of cement will always appear at the juncture between the pipe or tubing and the fitting.

X2.2.2 *Adhesive Joints*—Assemble according to the manufacturer's instructions paying particular attention to whether sanding of the pipe or tubing is recommended to eliminate the interference fit.

X2.2.3 *Plastic-to-Metal Transitions*—Assemble in accordance with the manufacturer's instructions. Union and compression type transition fittings are likely to include ferrules or O-rings, or both, which form an essential part of the fitting assembly and should not be omitted. Plastic socket-to-male threaded adapters should be installed with a recommended thread sealant.

X2.3 Installation

X2.3.1 *Storage and Handling*—CPVC pipe, tubing, and fittings should be stored under cover to avoid unnecessary dirt accumulation and long-term exposure to sunlight. Pipe and tubing should be stored with continuous support in straight, uncrossed bundles. Care should be used in handling to ensure that unnecessary abuse such as abrasion on concrete or crushing is avoided.

X2.3.2 *Installation Temperature*—Extra care must be taken at temperatures of 40°F or lower and 110°F or higher. Always follow the manufacturer's installation instructions carefully.

X2.3.3 *Pressure Testing*—CPVC piping systems made of ½ through 2-in. sizes in accordance with this specification, and utilizing a solvent cement requiring a primer or cleaner, can be pressure tested (using cold tap water only) at line pressure (150 psi maximum) after the solvent cement joints have cured for at least the following amount of time:

Ambient Temperature	Minimum Cure Times, h ½ in. to 1 in.	1¼ in. to 2 in.
over 60°F	1	2
40° to 60°F	2	4

For cements not requiring a primer or cleaner, refer to the manufacturer's recommended cure times specific to that cement.

X2.3.4 *Repairs*—If a leak is discovered, that portion of the system should be drained and the joint and fitting should be cut out. The pipe should be thoroughly dried and a new fitting should be installed using couplings and short lengths of pipe.

X2.3.5 *Soldering in the Area*—Soldered metal joints should not be made closer than 18 in. (460 mm) to an installed plastic-to-metal adapter in the same water line.

X3. OPTIONAL PERFORMANCE QUALIFICATION AND IN-PLANT QUALITY CONTROL PROGRAM FOR CPVC HOT-WATER DISTRIBUTION SYSTEM COMPONENTS

X3.1 Scope

X3.1.1 The following program covers performance qualification and in-plant quality control for component design and manufacture respectively to provide reasonable assurance that CPVC hot-water distribution system components supplied under this specification shall consistently meet its requirements.

X3.2 Performance Qualification

X3.2.1 Performance qualification tests shall be run initially on each component design, size, and formulation according to the requirements of this specification. The test results shall be independently certified, and shall be made available to the purchaser on request.

X3.3 In-Plant Quality Control

X3.3.1 *Material*—The pipe, tubing, and fittings shall be manufactured only from CPVC 4120 materials, as defined in Section 5 of this specification. The manufacturer shall so certify.

X3.3.2 *Quality Control Testing*—Pipe, tubing, and fitting quality control tests shall be run for each extrusion line or mold cavity in accordance with the requirements of this specification at a frequency agreed upon between the purchaser and the manufacturer. The program outlined in Table X3.1 is recommended. The test results shall be recorded and filed for inspection on request. Should a component fail to meet the specification in any test, production should be sampled back to the previous acceptable test result and tested to determine which components produced in the interim do not meet the requirement. Components that do not meet the requirements of this specification shall be rejected.

TABLE X3.1 Suggested Quality Control Program

Component	Property	Frequency	Method
Pipe and tubing	outside diameter	hourly	6.1.2.1
	wall thickness	hourly	6.1.2.1
	sustained pressure	daily	6.2
			6.1.3
Fittings	socket diameter	hourly	6.1.4.2
	external threads	hourly	6.2
	sustained pressure	daily	6.2

X3.3.3 *Marking*—A code number shall be included on the pipe, tubing, and fittings that can be used to identify the manufacturer, the compound, and the date of manufacture.

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SPECIFICATION FOR POLYETHYLENE (PE) PLASTIC PIPE (DR-PR) BASED ON CONTROLLED OUTSIDE DIAMETER

SD-3035

(Identical with ASTM D3035-14a except for additional requirements in section 11 and Annex A1, revised marking requirements in para. 9.1.5, renumbering of section 12, and quality assurance requirement in para. 10.1 has been made mandatory.)

Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

1. Scope

1.1 This specification covers polyethylene (PE) pipe made in thermoplastic pipe dimension ratios based on outside diameter and pressure rated for water (see Appendix X1). Included are requirements for polyethylene compounds and PE plastic pipe, a system of nomenclature for PE plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, and burst pressure. Methods of marking are also given.

1.2 All pipes produced under this specification are intended for use as the distribution and transmission of potable and non-potable water, grey water, reclaimed water, wastewater, force main and gravity municipal sewage, etc. The user should consult the manufacturer to determine whether the material being transported is compatible with polyethylene pipe and will not affect the service life beyond limits acceptable to the user.

1.3 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.

1.4 The following safety hazards caveat pertains only to the test methods 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 and health 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

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe

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

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

2.2 *NSF International Standards:*

NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials

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

2.3 *Other Documents:*

TR-4 Listing of Hydrostatic Design Bases (HDB), Strength Design Bases (SDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

APWA Uniform Color Code

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

TABLE 1 Polyethylene Compound Requirements

Requirement	PE1404	PE2708	PE3608	PE4608	PE4710
	Material Designation				
	Required Value				
HDB at 140ºF (60ºC), psi (MPa), per ASTM D2837 and PPI TR-3	[A]	800 (5.5)[B]	800 (5.5)[B]	800 (5.5)[B]	800 (5.5)[B]
HDS for water at 73°F (23°C) psi (MPa), per ASTM D2837 and PPI TR-3[C]	400 (2.76)	800 (5.5)	800 (5.5)	800 (5.5)	1000 (6.9)
Melt flow rate per ASTM D1238	1.0 to 0.4 g/10 min Cond. 190/2.16	≤0.40 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6
Specification D3350 Cell Classification Property	Required Value				
Density (natural base resin)	1	2	3	4	4
SCG Resistance	4	7	6	6	7
Color and UV Stabilizer Code[D]	C	C, D, or E	C, D, or E	C, D, or E	C, D, or E

[A] HDB at 140°F (60°C) not required. Contact manufacturer about pipe use at temperatures other than 73°F (23°C).
[B] Minimum value.
[C] Contact manufacturer or see PPI TR-4 for listed value.
[D] See 5.1.1.

3.2.1 *relation between dimension ratio, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation, is used in this specification to relate dimension ratio, hydrostatic design stress, and pressure rating:

$$2S/P = DR - 1 \text{ or } 2S/P = (D_0/t) - 1 \quad (1)$$

where:

S = hydrostatic design stress for water at 73°F (23°C), psi (MPa),
P = pressure rating, psi (MPa),
D_0 = average outside diameter, in. (mm)
t = minimum wall thickness, in. (mm), and,
DR = thermoplastic pipe dimension ratio (D_0/t for PE pipe).

4. Pipe Classification

4.1 *General*—This specification covers PE pipe made from PE plastic pipe materials in various dimension ratios and water pressure ratings.

4.2 *Thermoplastic Pipe Dimension Ratios* (DR)—This specification covers PE pipe in various dimension ratios such as, but not limited to, DR 11, DR 13.5, DR 17, and DR 21. The pressure rating is uniform for all nominal sizes of pipe for a given PE pipe material and DR. (See Table X1.1.)

4.3 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable in engineered products when mutually agreed

TABLE 2 IPS Pipe-Outside Diameter[A] and Tolerance

IPS Size	Outside Diameter, in. (mm)	Tolerances, in. (mm)
½	0.840 (21.34)	±0.004 (0.10)
¾	1.050 (26.7)	±0.004 (0.10)
1	1.315 (33.4)	±0.005 (0.13)
1¼	1.660 (42.2)	±0.005 (0.13)
1½	1.900 (48.3)	±0.006 (0.15)
2	2.375 (60.3)	±0.006 (0.15)
3	3.500 (88.9)	±0.008 (0.20)
4	4.500 (114.3)	±0.009 (0.23)
6	6.625 (168.28)	±0.011 (0.28)
8	8.625 (219.08)	±0.013 (0.33)
10	10.750 (273.05)	±0.015 (0.38)
12	12.750 (323.85)	±0.017 (0.43)
14	14.000 (355.60)	±0.063 (1.60)
16	16.000 (406.40)	±0.072 (1.83)
18	18.000 (457.20)	±0.081 (2.06)
20	20.000 (508.00)	±0.090 (2.29)
22	22.000 (558.80)	±0.099 (2.51)
24	24.000 (609.60)	±0.108 (2.74)
26	26.000 (660.4)	±0.117 (2.97)
28	28.000 (711.2)	±0.126 (3.20)
30	30.000 (762.0)	±0.135 (3.43)
32	32.000 (812.8)	±0.144 (3.66)
34	34.000 (863.6)	±0.153 (3.89)
36	36.000 (914.4)	±0.162 (4.11)
42	42.000 (1066.8)	±0.189 (4.80)
48	48.000 (1219.2)	±0.216 (5.49)
54	54.000 (1371.6)	±0.243 (6.17)
63	63.000 (1600.2)	±0.284 (6.71)
65	65.000 (1651.0)	±0.293 (7.44)

[A] For a distance to the cut end of the pipe that is the lesser of 11.8-in (300 mm) or 1.5 times the outside diameter, a diameter reduction of up to 1.5% shall be acceptable.

upon by the customer and manufacturer if (*1*) the pipe is manufactured from plastic compounds meeting the material requirements of this specification and (*2*) the strength and design requirements are calculated on the same basis as those used in this specification.

5. Materials

5.1 *Polyethylene Compounds*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall meet thermoplastic materials designation codes PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet Table 1 requirements for PE1404 or PE2708 or PE3608 or PE4608 or PE4710, and shall meet thermal stability, brittleness temperature and elongation at break requirements in accordance with Specification D3350

5.1.1 *Color and Ultraviolet (UV) Stabilization*—Per Table 3, polyethylene compounds shall meet Specification D3350 code C, D or E. In addition, Code C polyethylene compounds shall have 2 to 3 percent carbon black, and Code E polyethylene compounds shall have sufficient UV stabilizer to protect pipe from deleterious UV exposure effects during unprotected outdoor shipping and storage for at least eighteen (18) months.

5.1.2 Colors for solid color, a color shell layer, or color stripes–In accordance with the APWA Uniform Color Code, blue shall identify potable water service; green shall identify sewer service; purple (lavender) shall identify reclaimed water service. Yellow identifies gas service and shall not be used.

5.2 *Potable Water Requirement*—When required by the regulatory authority having jurisdiction, products intended for contact with potable water shall be evaluated, tested, and certified for conformance with NSF/ANSI Standard No. 61 or the health effects portion of NSF/ANSI Standard No. 14 by an acceptable certifying organization.

5.3 *Rework Material*—Clean, rework material from the manufacturer's own pipe production that met 5.1 through 5.2 as new compound is suitable for use when blended with new compound of the same material designation. Pipe containing the rework material shall meet the requirements of this specification.

6. Requirements

6.1 *Workmanship*—The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 2 or Table 7 when measured in accordance with Test Method D2122. For diameters not shown in Table 2 or Table 7, the tolerances shall be the same percentage of the outside diameter as those for the closest listed diameter.

6.2.2 *Wall Thicknesses*—The wall thicknesses and tolerances shall be as shown in Table 3 or Table 7 when measured in accordance with Test Method D2122. For wall thicknesses (DRs) not shown in Table 3 or Table 7, the tolerances shall be the same percentage of the calculated minimum wall as for the closest listed minimum wall thickness.

6.2.3 *Wall Thickness Range*—The wall thickness range shall be within 12 % when measured in accordance with Test Method D2122.

6.3 *Short-term Properties*—Specimens of pipe shall be tested in accordance with either Test Method D1599 or Test Method D2290. The test method used, Test Method D1599 or Test Method D2290, is determined by the pipe size and the availability of appropriate test equipment. Test Method D1599 is generally used for 4 in. (114 mm) and smaller sizes and Test Method D2290 for 2 in. (60 mm) and larger sizes. Short-term hoop stress and failure mode data is provided by either test.

6.3.1 *Burst Pressure*—The minimum burst pressure for PE plastic pipe shall be as given in Table 4, when determined in accordance with Test Method D1599 and 7.6. The failure mode shall be ductile.

6.3.2 *Apparent Ring Tensile Strength*—The minimum apparent ring tensile strength at yield shall be 1250 psi (8.62 MPa) for PE 1404, 2520 psi (17.37 MPa) for Table 1 density cell 2 polyethylene pipe materials, and 2900 psi (20.00 MPa) for Table 1 density cell 3 and 4 polyethylene pipe materials when tested in accordance with Test Method D2290, Procedure B and 7.7. The failure shall be ductile.

6.4 *Sustained Pressure at Ambient and Elevated Temperature for PE1404*—PE1404 pipes shall be tested in accordance with 7.4 at the stresses and temperatures specified in Table 6. Tests may be conducted on any pipe size, but tests conducted on 6 in. (168 mm) nominal size pipe shall be considered representative of all pipe sizes. At 176°F (80°C) pipes shall be tested at either stress. If ductile failures occur at the higher stress at 176°F (80°C), testing shall be repeated at the lower stress. Acceptable results are non-failure at the minimum average test time, or brittle failure at times exceeding the minimum average test time.

6.5 *Elevated Temperature Sustained Pressure for Pipes Other Than PE1404*—Elevated temperature sustained pressure tests for each Table 1 polyethylene pipe material (material designation) used in production at the facility shall be conducted twice annually per 7.5.

NOTE 1—Elevated temperature sustained pressure tests are intended to verify extrusion processing and are conducted in accordance with the manufacture's quality program.

6.5.1 Passing results are *(1)* non-failure for all three specimens at a time equal to or greater than the Table 8 "minimum average time before failure" for the selected Table 8 Condition, or *(2)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified "minimum average time before failure" for the selected Table 8 Condition. If more than one ductile failure occurs before the "minimum average time before failure", it is permissible to conduct one retest at a Table 8 Condition of lower stress and longer minimum average time before failure for the material designation except that for Table 8 Condition 6 no retest is permissible. Brittle failure of any

TABLE 3 IPS Pipe[A] Minimum Wall Thickness and Tolerance

IPS Size	DR 32.5		DR 26		DR 21		DR 17		DR 15.5		DR 13.5		DR 11		DR 9		DR 7	
	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.	Min.	Tol.
	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)	in. (mm)
½	...	...	...	...	...	...	...	...	...	...	0.062 (1.57)	0.020 (0.51)	0.076 (1.93)	0.020 (0.51)	0.093 (2.36)	0.020 (0.51)	0.120 (3.05)	0.020 (0.51)
¾	...	...	...	...	...	...	0.062 (1.57)	0.020 (0.51)	0.068 (1.73)	0.020 (0.51)	0.078 (1.98)	0.020 (0.51)	0.095 (2.41)	0.020 (0.51)	0.117 (2.97)	0.020 (0.51)	0.150 (3.81)	0.020 (0.51)
1	...	...	0.062 (1.57)	0.020 (0.51)	0.063 (1.60)	0.020 (0.51)	0.077 (1.96)	0.020 (0.51)	0.085 (2.16)	0.020 (0.51)	0.097 (2.46)	0.020 (0.51)	0.120 (3.05)	0.020 (0.51)	0.146 (3.71)	0.020 (0.51)	0.188 (4.78)	0.023 (0.58)
1¼			0.064 (1.63)	0.020 (0.51)	0.079 (2.01)	0.020 (0.51)	0.098 (2.49)	0.020 (0.51)	0.107 (2.72)	0.020 (0.51)	0.123 (3.12)	0.020 (0.51)	0.151 (3.84)	0.020 (0.51)	0.184 (4.67)	0.022 (0.56)	0.237 (6.02)	0.028 (0.71)
1½	0.062 (1.57)	0.020 (0.51)	0.073 (1.85)	0.020 (0.51)	0.090 (2.29)	0.020 (0.51)	0.112 (2.84)	0.020 (0.51)	0.123 (3.12)	0.020 (0.51)	0.141 (3.58)	0.020 (0.51)	0.173 (4.39)	0.021 (0.53)	0.211 (5.36)	0.025 (0.64)	0.271 (6.88)	0.033 (0.84)
2	0.073 (1.85)	0.020 (0.51)	0.091 (2.31)	0.020 (0.51)	0.113 (2.87)	0.020 (0.51)	0.140 (3.56)	0.020 (0.51)	0.153 (3.89)	0.020 (0.51)	0.176 (4.47)	0.021 (0.53)	0.216 (5.49)	0.026 (0.66)	0.264 (6.71)	0.032 (0.81)	0.339 (8.61)	0.041 (1.04)
3	0.108 (2.74)	0.020 (0.51)	0.135 (3.43)	0.020 (0.51)	0.167 (4.24)	0.020 (0.51)	0.206 (5.23)	0.025 (0.64)	0.226 (5.74)	0.027 (0.69)	0.259 (6.58)	0.031 (0.79)	0.318 (8.08)	0.038 (0.97)	0.389 (9.88)	0.047 (1.19)	0.500 (12.70)	0.060 (1.52)
4	0.138 (3.51)	0.020 (0.51)	0.173 (4.39)	0.021 (0.53)	0.214 (5.44)	0.026 (0.66)	0.265 (6.73)	0.032 (0.81)	0.290 (7.37)	0.035 (0.89)	0.333 (8.46)	0.040 (1.02)	0.409 (10.39)	0.049 (1.24)	0.500 (12.70)	0.060 (1.52)	0.643 (16.33)	0.077 (1.96)
6	0.204 (5.18)	0.024 (0.61)	0.255 (6.48)	0.031 (0.79)	0.315 (8.00)	0.038 (0.97)	0.390 (9.91)	0.047 (1.19)	0.427 (10.85)	0.051 (1.30)	0.491 (12.47)	0.059 (1.50)	0.602 (15.29)	0.072 (1.83)	0.736 (18.69)	0.088 (2.24)	0.946 (24.03)	0.114 (2.90)
8	0.265 (6.73)	0.032 (0.81)	0.332 (8.43)	0.040 (1.02)	0.411 (10.44)	0.049 (1.24)	0.507 (12.88)	0.061 (1.55)	0.556 (14.12)	0.067 (1.70)	0.639 (16.23)	0.077 (1.96)	0.784 (19.91)	0.094 (2.39)	0.958 (24.33)	0.115 (2.92)	1.232 (31.29)	0.148 (3.76)
10	0.331 (8.41)	0.040 (1.02)	0.413 (10.49)	0.050 (1.27)	0.512 (13.00)	0.061 (1.55)	0.632 (16.05)	0.076 (1.93)	0.694 (17.63)	0.083 (2.11)	0.796 (20.22)	0.096 (2.44)	0.977 (24.82)	0.117 (2.97)	1.194 (30.33)	0.143 (3.63)	1.536 (39.01)	0.184 (4.67)
12	0.392 (9.96)	0.047 (1.19)	0.490 (12.45)	0.059 (1.50)	0.607 (15.42)	0.073 (1.85)	0.750 (19.05)	0.090 (2.29)	0.823 (20.90)	0.099 (2.51)	0.944 (23.98)	0.113 (2.87)	1.159 (29.44)	0.139 (3.53)	1.417 (35.99)	0.170 (4.32)	1.821 (46.25)	0.219 (5.56)
14	0.431 (10.95)	0.052 (1.32)	0.538 (13.67)	0.065 (1.65)	0.667 (16.94)	0.080 (2.03)	0.824 (20.93)	0.099 (2.51)	0.903 (22.94)	0.108 (2.74)	1.037 (26.34)	0.124 (3.15)	1.273 (32.33)	0.153 (3.89)	1.556 (39.52)	0.187 (4.75)	2.000 (50.80)	0.240 (6.10)
16	0.492 (12.50)	0.059 (1.50)	0.615 (15.62)	0.074 (1.88)	0.762 (19.35)	0.091 (2.31)	0.941 (23.90)	0.113 (2.87)	1.032 (26.21)	0.124 (3.15)	1.185 (30.10)	0.142 (3.61)	1.455 (36.96)	0.175 (4.45)	1.778 (45.16)	0.213 (5.41)	2.286 (58.06)	0.274 (6.96)
18	0.554 (14.07)	0.066 (1.68)	0.692 (17.58)	0.083 (2.11)	0.857 (21.77)	0.103 (2.62)	1.059 (26.90)	0.127 (3.23)	1.161 (29.49)	0.139 (3.53)	1.333 (33.86)	0.160 (4.06)	1.636 (41.55)	0.196 (4.98)	2.000 (50.80)	0.240 (6.10)	2.571 (65.30)	0.309 (7.85)
20	0.615 (15.62)	0.074 (1.88)	0.769 (19.53)	0.092 (2.34)	0.952 (24.18)	0.114 (2.90)	1.176 (29.87)	0.141 (3.58)	1.290 (32.77)	0.155 (3.94)	1.481 (37.62)	0.178 (4.52)	1.818 (46.18)	0.218 (5.54)	2.222 (56.44)	0,267 (6.78)	2.857 (72.57)	0.343 (8.71)
22	0.677 (17.20)	0.081 (2.06)	0.846 (21.49)	0.102 (2.59)	1.048 (26.62)	0.126 (3.20)	1.294 (32.87)	0.155 (3.94)	1.419 (36.04)	0.170 (4.32)	1.630 (41.40)	0.196 (4.98)	2.000 (50.80)	0.240 (6.10)	2.444 (62.08)	0.293 (7.44)	3.143 (79.83)	0.377 (9.58)
24	0.738 (18.75)	0.089 (2.26)	0.923 (23.44)	0.111 (2.82)	1.143 (29.03)	0.137 (3.48)	1.412 (35.86)	0.169 (4.29)	1.548 (39.32)	0.186 (4.72)	1.778 (45.16)	0.213 (5.41)	2.182 (55.42)	0.262 (6.65)	2.667 (67.74)	0.320 (8.13)	3.429 (87.10)	0.411 (10.44)
26	0.800 (20.32)	0.096 (2.44)	1.000 (25.40)	0.120 (3.05)	1.238 (31.45)	0.149 (3.78)	1.529 (38.84)	0.183 (4.65)	1.677 (42.60)	0.201 (5.11)	1.926 (48.92)	0.231 (5.87)	2.364 (60.05)	0.284 (7.21)	2.889 (73.38)	0.347 (8.81)	...	...
28	0.862 (21.89)	0.103 (2.62)	1.077 (27.36)	0.129 (3.28)	1.333 (33.86)	0.160 (4.06)	1.647 (41.83)	0.198 (5.03)	1.806 (45.87)	0.217 (5.51)	2.074 (52.68)	0.249 (6.32)	2.545 (64.64)	0.305 (7.75)	3.111 (79.02)	0.373 (9.47)	...	...
30	0.923 (23.44)	0.111 (2.82)	1.154 (29.31)	0.138 (3.51)	1.429 (36.30)	0.171 (4.34)	1.765 (44.83)	0.212 (5.38)	1.935 (49.15)	0.232 (5.89)	2.222 (56.44)	0.267 (6.78)	2.727 (69.27)	0.327 (8.31)	3.333 (84.66)	0.400 (10.16)	...	...
32	0.985 (25.02)	0.118 (3.00)	1.231 (31.27)	0.148 (3.76)	1.524 (38.71)	0.183 (4.65)	1.882 (47.80)	0.226 (5.74)	2.065 (52.45)	0.248 (6.30)	2.370 (60.20)	0.284 (7.21)	2.909 (73.89)	0.349 (8.86)	3.556 (90.32)	0.427 (10.85)	...	...
34	1.046 (26.57)	0.126 (3.20)	1.308 (33.22)	0.157 (3.99)	1.619 (41.12)	0.194 (4.93)	2.000 (50.80)	0.240 (6.10)	2.194 (55.73)	0.263 (6.68)	2.519 (63.98)	0.302 (7.67)	3.091 (78.51)	0.371 (9.42)	...	...	...	...
36	1.108 (28.14)	0.133 (3.38)	1.385 (35.18)	0.166 (4.22)	1.714 (43.54)	0.206 (5.23)	2.118 (53.80)	0.254 (6.45)	2.323 (59.00)	0.279 (7.09)	2.667 (67.74)	0.320 (8.13)	3.273 (83.13)	0.393 (9.98)	...	...	...	...
42	1.292 (32.82)	0.155 (3.94)	1.615 (41.02)	0.194 (4.93)	2.000 (50.80)	0.240 (6.10)	2.471 (62.76)	0.297 (7.54)	2.710 (68.83)	0.325 (8.26)	3.111 (79.02)	0.373 (9.47)	...	...	...	...	...	...
48	1.477 (37.52)	0.177 (4.50)	1.846 (46.89)	0.222 (5.64)	2.286 (58.06)	0.274 (6.96)	2.824 (71.73)	0.339 (8.61)	3.097 (78.66)	0.372 (9.45)	3.556 (90.32)	0.427 (10.85)	...	...	...	...	...	...
54	1.662 (42.21)	0.199 (5.05)	2.077 (52.76)	0.249 (6.32)	2.571 (65.30)	0.309 (7.85)	3.176 (80.67)	0.381 (9.68)	3.484 (88.49)	0.418 (10.62)	...	...	...	...	...	...	...	...
63	1.938 (49.23)	0.233 (5.92)	2.423 (61.54)	0.291 (7.39)	3.000 (76.20)	0.360 (9.14)	...	...	...	...	...	...	...	...	...	...	...	...
65	2.000 (50.80)	0.240 (6.10)	2.500 (63.50)	0.300 (7.62)	3.095 (78.61)	0.371 (9.42)	...	...	...	...	...	...	...	...	...	...	...	...

[A]See 4.3 for sizes not shown.
[B]For IPS sizes greater than 24, tolerance applies to the minimum wall thickness obtained when measuring pipe.

specimen in the test sample when tested at Table 8 Condition 1 through 6 constitutes failure to meet this requirement and no retest is allowed.

6.5.2 *Provision for retest (if needed)*—The retest sample shall be three specimens of the same pipe or tubing size and material designation from the same time frame as the test

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for DR-PR PE Plastic Pipe

Dimension Ratio	Min Burst Pressure,[A] psi (MPa)					
	PE 3608, PE 4608, PE 4710		PE 2708		PE 1404	
	psi	(MPa)	psi	(MPa)	psi	(MPa)
7	967	(6.67)	840	(5.79)	417	(2.87)
9	725	(5.00)	630	(4.34)	313	(2.16)
11	580	(4.00)	504	(3.47)	250	(1.72)
13.5	464	(3.20)	403	(2.78)	200	(1.38)
15.5	400	(2.76)	348	(2.40)	172	(1.19)
17	363	(2.50)	315	(2.13)	156	(1.08)
21	290	(2.00)	252	(1.74)	125	(0.86)
26	232	(1.60)	202	(1.39)	100	(0.69)
32.5	184	(1.27)	160	(1.10)	79	(0.55)

[A] The fiber stresses used to derive these test pressures are as follows:

	psi	(MPa)
PE 3608, PE 4608, PE 4710	2900	(20.00)
PE 2708	2520	(17.37)
PE 1404	1250	(8.62)

TABLE 5 Apparent Tensile Strength at Yield of Ring Specimens Cut from Pipe

Material	psi	(MPa)
PE 2708	2520	(17.37)
PE 3608, PE 4608, PE 4710	2900	(20.00)
PE 1404	1250	(8.62)

sample per 7.5. For the retest, any specimen failure before the Table 8 "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

7. Test Methods

7.1 *Conditioning*—Condition the test specimens for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 73 ± 3.6°F (23 ± 2°C), unless otherwise specified in the test methods or in this specification.

7.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, random samples as selected by the testing laboratory shall be deemed adequate.

7.4 *Sustained Pressure Test at Ambient and Elevated Temperature*—Select three specimens of pipe at random and test each specimen individually with water at controlled temperatures under the stresses given in Table 6. Each specimen shall be at least ten times the nominal diameter in length, but not less than 10 in. (250 mm) or more than 3 ft (1000 mm) between end closures and containing the permanent marking on the pipe. Condition the specimens for at least 2 h at test temperature ± 3.6°F (2°C) prior to test. Test for the minimum failure time specified in Table 6 in accordance with Test Method D1598, at the stress and temperature values given in Table 6. Maintain the specimens at the test pressures ±10 psi (±70 kPa) and the test temperatures ± 3.6°F (± 2°C). Failure of one of the three specimens tested is cause for retest of three additional specimens. Failure of one of three specimens tested in retest constitutes failure in the test. Test and retest specimens shall be from the same production lot. Failure of the pipe test specimen shall be as defined in Test Method D1598. When testing at 176 ± 3.6°F (80 ± 2°C) at the higher stress, if ductile failure occurs before the minimum time, rerunning the test at the lower stress condition is not considered a retest.

7.5 *Elevated Temperature Sustained Pressure Test*—The "test sample" shall be three specimens of a generally representative pipe or tubing size produced at the manufacturer's facility using the Table 1 polyethylene pipe material (material designation). Select one Table 8 Condition for the Table 1 polyethylene pipe material (material designation) and test the three specimen test sample in accordance with Test Method D1598 using water as the internal test medium.

7.6 *Hydrostatic Burst Pressure*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599.

7.7 *Apparent Ring Tensile Strength at Yield*—The method and test equipment shall be as specified in Test Method D2290, Procedure B. Test a minimum of five specimens.

8. Retest and Rejection

8.1 Except as specified in 6.4, 6.5, 6.5.1 and 6.5.2, if the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or

TABLE 6 Stress and Time Requirements for Sustained Pressure Test[A]

Pipe Material	Minimum Hours Before Failure at 73°F (23°C)	Minimum Average Hours to Failure at 176°F (80°C)		
	S = 800 psi (5.5 MPa)	S = 670 psi (4.6 MPa)	S = 580 psi (4 MPa)	S = 435 psi (3 MPa)
PE 1404	1000		80	150

[A] Calculate internal pressure in accordance with the following formula:

$$P = \frac{2S}{\frac{D_o}{t} - 1}$$

where:

P = pressure, psig (MPa),
S = hoop stress, psi (MPa),
D_o = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

TABLE 7 PE4710 DIPS PR-DR Plastic Pipe—Outside Diameter and Wall Thickness

DIPS Size	Outside Diameter[A]		Wall Thickness, in. (mm)											
			PR 300 7.7		PR 250 DR 9		PR 200 DR 11		PR 150 DR 14.3		PR 125 DR 17		PR 100 DR 21	
	Average	± Tol.	Min.	Tol.[B]	Min.	Tol.[B]	Min.	Tol.[B]	Min.	Tol.[B]	Min.	Tol.[B]	Min.	Tol.[B]
3	3.960	0.018	0.514	0.062	0.440	0.053	0.360	0.043	0.277	0.033	0.233	0.028	0.189	0.023
	(100.58)	(0.46)	(13.06)	(1.57)	(11.18)	(1.35)	(9.14)	(1.09)	(7.04)	(0.84)	(5.92)	(0.71)	(4.80)	(0.58)
4	4.800	0.022	0.623	0.075	0.533	0.064	0.436	0.052	0.336	0.040	0.282	0.034	0.229	0.027
	(121.92)	(0.56)	(15.82)	(1.91)	(13.54)	(1.63)	(11.07)	(1.32)	(8.53)	(1.02)	(7.16)	(0.86)	(5.82)	(0.69)
6	6.900	0.031	0.896	0.108	0.767	0.092	0.627	0.075	0.483	0.058	0.406	0.049	0.329	0.039
	(175.26)	(0.79)	(22.76)	(2.74)	(19.48)	(2.34)	(15.93)	(1.91)	(12.27)	(1.47)	(10.31)	(1.24)	(8.36)	(0.99)
8	9.050	0.041	1.175	0.141	1.006	0.121	0.823	0.099	0.633	0.076	0.532	0.064	0.431	0.052
	(229.87)	(1.04)	(29.85)	(3.58)	(25.55)	(3.07)	(20.90)	(2.51)	(16.08)	(1.93)	(13.51)	(1.63)	(10.95)	(1.32)
10	11.100	0.050	1.442	0.173	1.233	0.148	1.009	0.121	0.776	0.093	0.653	0.078	0.529	0.063
	(281.94)	(1.27)	(36.63)	(4.39)	(31.32)	(3.76)	(25.63)	(3.07)	(19.71)	(2.36)	(16.59)	(1.98)	(13.44)	(1.60)
12	13.200	0.059	1.714	0.206	1.467	0.176	1.200	0.144	0.923	0.111	0.776	0.093	0.629	0.075
	(335.28)	(1.50)	(43.54)	(5.23)	(37.26)	(4.47)	(30.48)	(3.66)	(23.44)	(2.82)	(19.71)	(2.36)	(15.98)	(1.91)
14	15.300	0.069	1.987	0.238	1.700	0.204	1.391	0.167	1.070	0.128	0.900	0.108	0.729	0.087
	(388.62)	(1.75)	(50.47)	(6.05)	(43.18)	(5.18)	(35.33)	(4.24)	(27.18)	(3.25)	(22.86)	(2.74)	(18.52)	(2.21)
16	17.400	0.078	2.260	0.271	1.933	0.232	1.582	0.190	1.217	0.146	1.024	0.123	0.829	0.099
	(441.96)	(1.98)	(57.40)	(6.88)	(49.10)	(5.89)	(40.18)	(4.83)	(30.91)	(3.71)	(26.01)	(3.12)	(21.06)	(2.51)
18	19.500	0.088	2.532	0.304	2.167	0.260	1.773	0.213	1.364	0.164	1.147	0.138	0.929	0.111
	(495.30)	(2.24)	(64.31)	(7.72)	(55.04)	(6.60)	(45.03)	(5.41)	(34.65)	(4.17)	(29.13)	(3.51)	(23.60)	(2.82)
20	21.600	0.097	2.805	0.337	2.400	0.288	1.964	0.236	1.510	0.181	1.271	0.153	1.029	0.123
	(548.64)	(2.46)	(71.25)	(8.56)	(60.96)	(7.32)	(49.89)	(5.99)	(38.35)	(4.60)	(32.28)	(3.89)	(26.14)	(3.12)
24	25.800	0.116	3.351	0.402	2.867	0.344	2.345	0.281	1.804	0.216	1.518	0.182	1.229	0.147
	(655.32)	(2.95)	(85.12)	(10.21)	(72.82)	(8.74)	(59.56)	(7.14)	(45.82)	(5.49)	(38.56)	(4.62)	(31.22)	(3.73)
30	32.000	0.144	4.156	0.499	3.556	0.427	2.909	0.349	2.238	0.269	1.882	0.226	1.524	0.183
	(812.80)	(3.66)	(105.56)	(12.67)	(90.32)	(10.85)	(73.89)	(8.86)	(56.85)	(6.83)	(47.80)	(5.74)	(38.71)	(4.65)
36	38.300	0.172	4.974	0.597	4.256	0.511	3.482	0.418	2.678	0.321	2.253	0.270	1.824	0.219
	(972.82)	(4.37)	(126.34)	(15.16)	(108.10)	(12.98)	(88.44)	(10.62)	(68.02)	(8.15)	(57.23)	(6.86)	(46.33)	(5.56)
42	44.500	0.200	5.779	0.693	4.944	0.593	4.045	0.485	3.112	0.373	2.618	0.314	2.119	0.254
	(1130.30)	(5.08)	(146.79)	(17.60)	(125.58)	(15.06)	(102.74)	(12.32)	(79.04)	(9.47)	(66.50)	(7.98)	(53.82)	(6.45)
48	50.800	0.229	6.597	0.792	5.644	0.677	4.618	0.554	3.552	0.426	2.988	0.359	2.419	0.290
	(1290.32)	(5.82)	(167.56)	(20.12)	(143.36)	(17.20)	(117.30)	(14.07)	(90.22)	(10.82)	(75.90)	(9.12)	(61.44)	(7.37)

[A] For a distance to the cut end of the pipe that is the lesser of 11.8–in. (300 mm) or 1.5 times the outside diameter, a diameter reduction of up to 1.5% shall be acceptable.
[B] For DIPS sizes greater than 24, tolerance applies to the minimum wall thickness obtained when measuring pipe.

by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in the specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

9. Marking

9.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft (1.5 m):

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

9.1.2 Type of plastic pipe material in accordance with the materials designation code given in per 5.1 (for example, PE 3608),

9.1.3 Thermoplastic pipe dimension ratio in accordance with 4.2 (for example, DR 11),

9.1.4 The pressure rating in pounds-force per square inch for water at 73°F (23°C) shown as the number followed by psi (kPa), for example, 100 psi or 690 kPa,

TABLE 8 Elevated Temperature Sustained Pressure Test Requirements

		PE2708, PE3608, PE4608		PE4710	
Condition	Test Temperature °F (°C)[A]	Test Pressure Hoop Stress[B] psi (kPa)[A]	Minimum Average Time Before Failure Hours	Test Pressure Hoop Stress[B] psi (kPa)[A]	Minimum Average Time Before Failure Hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A]Test temperature tolerance ± 3.6ºF (+/- 2ºC). Test pressure tolerance ± 5 psi (±35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa.

Note: Table 2 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) · ((1200 – 200) / (750 – 640)) = 927).

[B]Calculate internal test pressure in accordance with:

$$P = \frac{2s}{\left(\frac{D_o}{t} - 1\right)}$$

where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi. (kPa)
D_o = measured outside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

9.1.5 ASME SD-3035 or both ASME SD-3035 and ASTM D3035,

9.1.6 Manufacturer's name (or trademark) and code, and

9.1.7 Pipe intended for transporting potable water shall also include the seal of an accredited laboratory.

NOTE 2—Earlier editions of Specification D3035 included PE materials designations PE 2406, PE 3406, and PE 3408. Changes to Specification D3350 and PPI TR-3 led to changes in thermoplastic materials designation codes, resulting in materials designation PE 2406 being superseded by materials designations PE 2606 and PE 2708, materials designation PE 3406 being superseded by PE 3606 and materials designation PE 3408 being superseded by materials designations PE 3608, PE 3708, PE 3710, PE 4608, PE 4708, and PE 4710. Recognizing that a period of time is necessary for the dissemination of information and to update specifications and literature, during the transitional period, product markings that include both older and newer materials designations, for example PE 2406/PE 2606, may occur.

NOTE 3—Manufacturers using the seal of approval of an accredited laboratory must obtain prior authorization from the laboratory concerned.

9.2 *Using Color*—When color is applied, such as with stripes, a color shell layer or a solid color; blue shall identify potable water; green shall identify sewer; and purple (violet, lavender) shall identify reclaimed water. Yellow identities gas and shall not be used.

9.3 Markings that identify gas, communications or electrical use are prohibited.

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

12. Keywords

12.1 DR; OD controlled; PE pipe; plastic pipe; potable water pipe; polyethylene pipe; service pipe; SDR; water pipe; water service pipe

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. PIPE PRESSURE RATINGS

X1.1 The pipe is rated for use with water at 73°F (23°C) at the maximum internal pressures shown in Table X1.1. Lower pressure ratings than those calculated in accordance with 3.2.1 may be recommended by the pipe manufacturer where unusually high pressure surges, elevated temperatures, or unusual installation conditions exist. Pressure ratings at 73°F (23°C) are generally suitable for use at service temperatures not exceeding 80°F (27°C). Pressure ratings are reduced at temperatures above 80°F (27°C), and materials having an elevated temperature HDB should be used when service at temperatures above 80°F (27°C) is anticipated. Consult the pipe manufacturer for information about elevated temperature service and pressure ratings. Industry experience indicates that satisfactory long-term service can be provided by PE plastic pipe meeting this specification that is properly installed and operated within the identified pressure and temperature ratings. The sustained pressure requirements (see 6.4) are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.2 The hydrostatic design stress recommended by the Plastics Pipe Institute are based on tests made on pipe ranging in size from ½ to 3 in. (12.7 to 50.8 mm).

TABLE X1.1 Thermoplastic Pipe Dimension Ratios (DR) and Water Pressure Ratings (PR) at 73°F (23°C) for DR-PR PE Plastic Pipe

Dimension Ratio	PE Pipe Materials[A]					
	PE4710		PE 2708, PE 3608, PE 4608		PE 1404	
	Pressure Rating, psi (MPa)		Pressure Rating, psi (MPa)		Pressure Rating, psi (MPa)	
7	333	(2.3)	267	(1.84)	133	(0.92)
7.7	300	(2.1)	...	...	...	...
9	250	(1.7)	200	(1.38)	100	(0.69)
11	200	(1.4)	160	(1.10)	80	(0.55)
13.5	160	(1.1)	128	(0.88)	64	(0.44)
14.3	150	(1.0)	...	...	...	...
15.5	138	(1.0)	110	(0.76)	55	(0.38)
17	125	(0.9)	100	(0.69)	50	(0.34)
21	100	(0.7)	80	(0.55)	40	(0.28)
26	80	(0.6)	64	(0.44)	32	(0.22)
32.5	63	(0.4)	51	(0.35)	25	(0.17)

[A] Hydrostatic Design Stress values obtained from PPI TR4. Other design factors may be appropriate under certain conditions. Values rounded to the nearest 5 psi (0.03 MPa)

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SPECIFICATION FOR UNMODIFIED POLY(VINYLIDENE FLUORIDE) (PVDF) MOLDING EXTRUSION AND COATING MATERIALS

SD-3222

(Identical with ASTM D3222-05(R10) except for revisions in para. 7.1 and section 12, and additional requirements in section 13 and Annex A1, and renumbering of sections 14 and 15.)

Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials

1. Scope

1.1 This specification covers melt processable molding and extrusion materials, as well as coating materials of poly(vinylidene fluoride) fluoroplastic, commonly abbreviated PVDF (or PVF_2 in scientific literature). This specification covers thermoplastic resin materials supplied in pellet or powder form.

1.2 This specification applies only to the virgin homopolymer prepared from vinylidene fluoride, not copolymers, reinforced, filled grades or special grades with additives or treatments for modification of attributes.

1.3 The tests involved are intended to provide information for specification of unmodified PVDF homopolymer resins. It is not the purpose of this specification to provide engineering data for design purposes.

1.4 PVDF fluoroplastics melt between 156 and 180°C (312 and 356°F) and are thermally stable up to about 370°C (698°F). (**Warning—**Evolution of corrosive and toxic hydrogen fluoride can occur under certain conditions.)

1.5 The values stated in SI units, as detailed in IEEE/ASTM S-10, are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—PVDF exhibits polymorphism. The type and extent of crystalline structure varies with the thermomechanical history of the sample. Specimens prepared by techniques different than prescribed in this specification can have properties that vary from the values specified.

1.6 *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.* Specific precautionary statements are given in Section 10.

NOTE 2—There is no equivalent ISO standard for this specification. Information in this specification is technically equivalent to related information in ISO 12086-1 and ISO 12086-2.

2. Referenced Documents

2.1 *ASTM Standards:*

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D542 Test Method for Index of Refraction of Transparent Organic Plastics
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer
D3892 Practice for Packaging/Packing of Plastics
IEEE/ASTM S-10 Use of the International System of Units

TABLE 1 Classification of PVDF Resins

Property		Typical Values or Ranges		
		Type I		Type II
		Grade 1	Grade 2	
Specific Gravity	Gms/cc	1.75-1.79	1.75-1.79	1.76-1.79
Peak Melting Endotherm	°C	156-162	162-170	164-180
Melt Flow Rate	g/10 min (wt in Kg)			
	Ultra High Viscosity	...	...	0.5-10[A]
	High Viscosity	0.5-8[A]	5-8[B]	0.5-10[C]
	Medium Viscosity	4-18[A]	5-36[B]	0.5-30[D]
	Low Viscosity	...	3.5-45[E]	0.5-60[F]
Apparent Melt Viscosity	Pa's:[G]			
	High Viscosity	2800-3800	2800-3700	2500-4000
	Medium Viscosity	2300-2800	1300-2800	1300-2500
	Low Viscosity	...	350-1300	250-1300

Note: For measuring MFR values of PVDF, the load must be selected based on the viscosity as follows:

[A]= 21.6 Kg
[B]= 12.5 Kg
[C]= 10.0 Kg
[D]= 5 Kg
[E]= 3.8 Kg
[F]= 2.16 Kg
[G] Reported for a shear rate of 100 s^{-1} determined by capillary rheometry at 232°C (450°F) using 0.027 radian (60°) entrance angle die with L/D of 15 and in accordance with procedures of Test Method D3835. Multiply the pascal second values by ten to obtain poise values.

(SI): The Modern Metric System

2.2 *IEC and ISO Standards:*

ISO 12086-1 Plastics—Fluoropolymer Dispersion and Moulding and Extrusion Materials—Part 1: Designation and Basis for Specification

ISO 12086-2 Plastics—Fluoropolymer Dispersion and Molding and Extrusion Materials—Part 2: Preparation of Test Specimens and Determination of Properties

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of plastics terms used in this specification, see Terminology D883.

3.1.2 *lot, n*—one production run or a uniform blend of two or more production runs.

4. Classification

4.1 This specification covers two types of natural, unmodified PVDF fluoroplastics supplied in pellet form for molding and extrusion, and in powder form for solutions, dispersions, or coatings.

4.1.1 *Type I*—PVDF fluoroplastics are polymerized in emulsion. Depending upon the polymerization conditions, the peak melting point of the resin can be varied between 156 and 170°C. The diameter of the primary particle isolated from the emulsion is typically less than 1 μm; the dried powder has an average agglomerate diameter range of 3 to 15 μm.

4.1.1.1 Two distinctly different Type I emulsion PVDF resins are available commercially. These are differentiated by peak melting endotherm values, as shown in Table 1, and this difference is the basis for subdividing Type I resins into Grades 1 and 2. Table 1 shows the melt viscosity ranges encompassing resin grades available from several sources and are provided for information purposes only.

4.1.2 *Type II*—PVDF fluoroplastics are polymerized in suspension. Peak melting temperatures of these resins range from 164 to 180°C. The particles isolated from suspension are spherical and range typically from 20 to 150 μm in diameter.

4.1.2.1 Type II resins are available commercially, and the data of Table 1 reflect ranges encompassing values typical for the properties of available grades.

4.2 The system uses predefined cells to refer to specific aspects of this specification, as illustrated below.

Specification				
Standard Number Block	Type	Grade	Class	Special Notes
Example: Specification D3222 – 05	I	2	...	...

For this example (D3222 – 05, I2), the line callout describes a PVDF resin polymerized in emulsion, having a specific gravity between 1.75 and 1.79, and a peak melting endotherm between 162 to 170°C. A comma is used as the separator between the Standard Number and the Type. Separators are not needed between the Type, Grade, and Class. Provision for Special Notes is included so that other information, such as a preferred viscosity range, can be provided when required. When special notes are used, they shall be preceded by a comma.

5. General Requirements

5.1 The material shall be of uniform composition and free of foreign matter.

6. Detail Requirements

6.1 *General Attributes:*

6.1.1 *Peak Melting Endotherm*—The material covered by this specification shall have a minimum peak melting endotherm for the type and class as shown in Table 1 when tested in accordance with Test Method D3418. For Type I resins, this shall involve heating a solid specimen of 5 ± 1 mg from room temperature to 200°C at 10°C/min, maintaining the temperature at 200°C for 5 min, followed by cooling at a controlled rate of 10°C/min to about 30°C, then reheating at 10°C/min to 200°C. Record the peak melting endotherm during the second melting cycle.

6.1.1.1 *Temperature*—Test Type II resins likewise except that the maximum is 250°C.

6.1.2 *Specific Gravity*—A solid specimen of the material covered by this specification shall have the minimum specific gravity indicated in Table 1 (1.75 for Type I, Class 1 and 1.76 for all others) when tested in accordance with Test Method D792.

NOTE 3—Test attached to the specimen upon immersion. Dipping the specimens in a very dilute solution (less than 0.1 weight percent) of an ammonium perfluorooctanoate surfactant minimizes this problem.

6.1.3 *Refractive Index*—The material covered in this specification shall have a refractive index of 1.42 when measured at the sodium D line at 25°C (77°F) in accordance with the refractometer procedure in Test Methods D542, using specimens that have not been subjected to any processes which induce orientation of the polymer chains or crystal-lites. Compression-molded specimens at least 2-mm (0.079-in.) thick that have been quenched rapidly in water are preferred.

6.1.4 *Limiting Oxygen Index*—The material covered in this specification shall have a minimum limiting oxygen index of 42 when tested in accordance with Test Method D2863.

NOTE 4—If a column with a restricted opening is used, position the top of the specimen 40 mm below the opening.

6.2 *Processing Related Attributes:*

6.2.1 *Flow Rate*—Materials conforming to this specification shall be tested for melt flow rate in accordance with Test Method D1238 using loads shown in parentheses in Table 1.

6.2.2 *Rheological Properties*—The apparent melt viscosity of these materials shall be tested in accordance with Test Method D3835 at 231 ± 1°C (450°F) using a die with an entrance angle of 60° (cone angle of 120°) and a minimum capillary L/D of 15. See Table 1.

6.3 *Mechanical Properties:*

6.3.1 *Tensile Properties*—The material covered in this specification shall have a tensile yield strength exceeding 36 MPa (5200 psi) at 23°C (74°F) and a minimum elongation at break of 10 % when tested in accordance with Test Method D638 at 51 mm (2 in.)/min, using Type I specimens 3.2-mm (0.125-in.) thick as specified in Test Method D638. Preferably, compression-molded samples are used (see Section 8), but injection molded specimens also are used, providing that the samples yield and rupture in the gage region and not near the heel. Specimens shall be molded under conditions specified by the resin suppliers. Generally, injection molded specimens show low and variable elongation values compared to compression-molded specimens. Typically, the melt temperature is 30 to 60°C higher than the upper peak melting endotherm value depending on the grade. Mold temperature is 120 ± 10°F.

6.3.2 *Flexural Properties*—The material covered in this specification shall have a minimum flexural modulus of 1.38 GPa (190 × 10^3 psi) when tested in accordance with Method I of Test Methods D790, using 6.4-mm (0.25-in.) thick specimens prepared by injection molding under conditions specified by the resin supplier. Alternatively, compression-molded samples are used (see Section 8) and tested after the 16-h conditioning period.

6.3.3 *Impact Resistance*—Type I material covered in this specification shall have a minimum impact strength of 80.0 J/m (1.50 ft·lbf/in.) determined by Test Methods D256 using 6.4-mm (0.25-in.) thick specimens prepared by injection molding under conditions specified by the manufacturer. Alternatively, specimens are compression-molded and tested after the conditioning period as specified above. For Type II material, impact testing is not required.

6.4 *Electrical Properties:*

6.4.1 *D-C Resistance*—The material covered in this specification shall have a d-c volume resistivity greater than 1.2Ω·m (1.2 × 10^{14} Ω·cm) when tested as a 0.76-mm (0.030-in.) compression-molded specimen (see Section 8) in accordance with Test Methods D257.

6.4.2 *Dielectric Strength*—The material covered in this specification shall have a dielectric strength in air no less than 57 kV/mm (1280 V/0.001 in.) by the "short-time" method of Test Methods D149 with 0.13-mm (0.05-in.) thick compression-molded specimens (see Section 8) tested in air using 25.4-mm (1-in.) Type 3 electrodes.

6.4.3 *Dielectric Constant*—The material covered in this specification shall have a dielectric constant less than 11.0 at 100 Hz and greater than 5.8 at 1 MHz when tested as a 3.2-mm (0.125-in.) thick compression-molded specimen (see Section 8) in accordance with Test Methods D150 at 23°C (73°F).

6.4.4 *Dissipation Factor*—The material covered in this specification shall have a dissipation factor of less than 0.045 at 100 Hz and less than 0.24 at 1 MHz when tested as 3.2-mm (0.125-in.) compression-molded specimens (see Section 8) in accordance with Test Methods D150 at 23°C (73°F).

NOTE 5—Since this material has very low water-absorption characteristics, maintenance of constant humidity during testing or specimen preparation is not necessary except as required for a specific test method. However, no moisture shall be present in the resin when preparing specimens for testing. Heat the resin sample at 110°C (230°F) in an air-circulating oven until the adventitious moisture is removed.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy the requirements of Annex A1.

8. Preparation of Compression Molded Specimens

8.1 *Equipment:*

8.1.1 Press with approximately 180 kN (20 ton) capacity and heating capability for maintaining platens between 220 and 240°C (428 to 464°F).

8.1.2 Two smooth chromium-finished plates with approximate dimensions 150 by 250 by 5 mm (10 by 10 by 0.02 in.), or, if more appropriate to the press type, 150 by 150 by 5 mm (6 by 6 by 0.02 in.).

8.1.3 Flat open-cavity steel molds, that is, frames, to provide the shape and thicknesses requisite for the specific tests.

8.1.4 Timing device.

8.1.5 Appropriate equipment to handle the hot mold assembly when removed from the press.

8.1.6 Balance and containers for weighing the resin samples.

8.1.7 Water-filled container to quench-cool the samples in the mold frame.

8.1.8 Aluminum foil approximately 0.1-mm thick (0.004-in.).

8.2 *Compression Molding Specimens Less Than 2 mm (0.08 in.):*

8.2.1 For the given mold cavity establish, by initial trial preparations, the amount of material necessary to overfill slightly and yield a minimum flash after forming.

8.2.2 Place the appropriate amount of material in the center of the mold between thin sheets of polished aluminum foil.

8.2.3 Place the assembly between the chrome-finished plates.

8.2.4 Place the mold assembly in the press so that it is in contact with the hot platens, using a ram force that barely registers on the force gage and hold for a 5-min period at a temperature of 230 ± 2°C (446 ± 4°F).

8.2.5 After the preheat period, slowly increase the ram force to 130 kN (30 000 lbf) and hold for 1 min.

8.2.6 Remove the sandwiched material and immediately quench in cold water.

8.2.7 After standing for 1 min, disassemble and remove the molded plaque from the frame.

NOTE 6—The alternative method of allowing the assembly to cool at ambient room temperature under a heavy weight, or under pressure in a cold press, results in specimens having properties that vary from values in specification tests.

8.2.8 If the mold shape is not appropriate for the test, cut test specimens from the molded sample.

NOTE 7—The edges of the specimen affect performance in mechanical tests. Die-cutting is the preferred method to prepare such specimens; the cutting edges shall be leveled and sharp.

8.3 *Compression Molding Specimens Thicker Than 2 mm (0.08 in.):*

8.3.1 Pellets of PVDF can be compression-molded directly in thick sections without difficulty.

8.3.2 Powdered PVDF samples tend to entrap air when thick sections are molded under compression. Such specimens are not suitable for any tests in this specification. The preferred method to obtain bubble-free thick moldings involves preparation of thin compression-molded sheets, as described in 8.2, and a subsequent second molding cycle filling the thick section mold with several layers of the thin sheet specimens cut to fill the mold dimension. To assure complete filling, the stack of thin samples must be slightly higher than the mold cavity thickness.

9. Test Conditions

9.1 *Specific Gravity, Mechanical Properties, and Electrical Properties:*

9.1.1 Condition the molded test specimens in accordance with Procedure A of Practice D618, except that the period shall be at least 16 h prior to test.

9.1.2 Conduct tests at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F).

NOTE 8—PVDF is a partially crystalline polymer. Unless molded and conditioned equivalently for a sufficient period to assure consistent crystallinity, samples prepared by any other method give variable results.

10. Handling

10.1 As is the case with any synthetic resin, it is advisable to wear a dust mask when handling large quantities of powder grades to prevent ingestion.

11. Packaging

11.1 The packing, packaging, and marking provisions of Practice D3892 shall apply to this specification.

12. Inspection

12.1 Inspection of the material supplied with reference to this specification shall be for conformance to the requirements specified herein.

12.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of all the requirements.

12.3 Periodic check inspection with reference to this specification shall consist of the tests for all requirements of the material under this specification.

12.4 A report of test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

13. Certification

13.1 Certification shall be as required by Annex A1.

14. Precision and Bias

14.1 The precision and bias statements of ASTM test methods referenced herein apply to the specific tests required in this specification.

15. Keywords

15.1 extrusion materials; fluorohydrocarbon plastics; fluoropolymers; molding materials; polyvinylidene fluoride (PVDF)

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR BUTT HEAT FUSION POLYETHYLENE (PE) PLASTIC FITTINGS FOR POLYETHYLENE (PE) PLASTIC PIPE AND TUBING

SD-3261

(Identical with ASTM D3261-12e1 except for additional requirements in section 13 and Annex A1, revised marking requirements in para. 11.1.1, renumbering of section 14, and quality assurance requirement in para. 12.1 has been made mandatory.)

Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

1. Scop

1.1 This specification covers polyethylene (PE) butt fusion fittings for use with polyethylene pipe (IPS, DIPS, and ISO) and tubing (CTS). Included are requirements for materials, workmanship, dimensions, marking, sustained pressure, and burst pressure.

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.

2. Referenced Documents

2.1 *ASTM Standards:*

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *National Sanitation Foundation Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials

2.5 *Plastic Pipe Institute*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *dimension ratio (DR) for thermoplastic pipe*—the ratio of diameter to wall thickness. For this specification it is calculated by dividing the specified outside diameter by the specified wall thickness of the fitting at its area of fusion. DRs are rounded and do not calculate exactly.

4. Classification

4.1 *General*—This specification covers butt fusion fittings intended for use with polyethylene pipe and tubing.

4.1.1 Fittings covered by this specification are normally molded. Fittings may be machined from extruded or molded stock.

4.1.2 Fittings fabricated by thermal welding are not included in this specification.

4.1.3 Fittings intended for use in the distribution of natural gas or petroleum fuels shall also meet the requirements of Specification D2513.

5. Ordering Information

5.1 When ordering fittings under this specification, the following should be specified:

5.1.1 Polyethylene compound (material designation or trade name)

5.1.2 Style of fitting (tee, 90° ell, and the like)

5.1.3 Size:

5.1.3.1 Nominal diameter.

5.1.3.2 CTS, IPS, DIPS, or schedule.

5.1.3.3 Dimension ratio number or schedule number.

6. Materials

6.1 *Polyethylene Compound*—Polyethylene material compounds suitable for use in the manufacture of fittings under this specification shall meet Specification D3350 and shall meet the Specification D3350 classification and property requirements inTable 1 and shall have PPI TR-4 HDB and HDS listings at 73°F (23°C) and HDB listings 140°F (60°C) in accordance with Table 1.

6.2 *Color and Ultraviolet (UV) Stabilization*—Polyethylene material compounds shall meet Specification Table 1 code C or E. Code C material compounds shall have 2 to 3 percent carbon black. Code E material compounds shall be colored with UV stabilizer.

6.3 *Rework Material*—Clean polyethylene compound from the manufacturer's own production that met 6.1 and 6.2 as virgin material is suitable for remolding into fittings, either alone or blended with new compound of the same cell classification or material designation. Fittings containing the rework material shall meet the material and product requirements of this specification.

7. Requirements

7.1 *Dimensions and Tolerances:*

7.1.1 *Outside Diameter*—Nominal outside diameters of butt fusion fittings shall conform to the nominal iron pipe size (IPS), ductile iron pipe size (DIPS)or copper tubing size (CTS) dimensions at area of fusion. These dimensions and tolerances shall be as shown in Table 2, Table 3, Table 4 and of this specification.

7.1.2 *Inside Diameter (CTS Fittings Only)*—Inside diameters of butt fusion fittings for tubing at area of fusion shall conform to the dimensions of the tubing being joined. The dimensions and tolerances for the fittings are shown in Table 5.

7.1.3 *Wall Thickness*—The wall thicknesses of butt fusion fittings shall not be less than the minimum specified for the pipe or tubing. The wall thicknesses and tolerances at the area of fusion shall be as shown in Table 5, Table 6, Table 7, and Table 8 of this specification.

7.1.4 *Measurements*—These shall be made in accordance with Test Method D2122 for roundable pipe.

7.1.5 *Design Dimensions*—Overall fitting dimensions may be as preferred from a design standpoint by the manufacturer and accepted by the purchaser consistent with 7.1.3.

7.1.6 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the fitting is manufactured from plastic compounds meeting the material requirements of this specification, and the strength and design requirements are calculated on the same basis as those used in this specification. For diameters not shown in Table 2, Table 3 or Table 4, the tolerance shall be the same percentage as that shown in the corresponding tables for the next smaller listed size. Minimum wall thickness for these special sizes shall not be less than the minimum wall specified for the pipe or tubing the fitting is designed to be used with. The maximum wall thickness allowed shall not be greater than 20 % thicker than the specified minimum wall, and shall be determined by 10.4.3 of this specification.

7.2 *Pressure Test Requirements :*

7.2.1 *Short-Term Rupture Strength for Fittings ½ to 12 in. and 90 to 315 mm, Nominal Diameter*—The minimum short-term rupture strength of the fitting and fused pipe or tubing

TABLE 1 Specification D3350 Classification of Polyethylene Fittings Materials

Physical Properties	Cell Classification and Properties for Polyethylene Pipe Materials							
	PE2606	PE2706	PE2708	PE3608	PE3708	PE3710	PE4708	PE4710
Density	2	2	2	3	3	3	4	4
Melt Index	3 or 4	3 or 4	3 or 4	4	4	4	4	4
Flexural modulus	≥4	≥4	≥4	≥4	≥4	≥4	≥4	≥5
Tensile Strength	≥3	≥3	≥3	≥4	≥4	≥4	≥4	≥4
Slow crack growth resistance (F1473)	6	7	7	6	7	7	7	7
Hydrostatic strength classification	3	3	3	4	4	4	4	4
Color and UV Stabilizer[A]	C or E	C or E	C or E	C or E	C or E	C or E	C or E	C or E
HDB at 140°F (60°C), PPI TR-4, psi (MPa)	[B]	[B]	[B]	[B]	[B]	[B]	[B]	[B]
HDB at 73°F (23°C), PPI TR-4, psi (MPa)	630 (4.34)	630 (4.34)	800 (5.52)	800 (5.52)	800 (5.52)	1000 (6.90)	800 (5.52)	1000 (6.90)

[A] See 6.2.

[B] Listing required; consult manufacturer for listed value.

TABLE 2 IPS Sizing System Outside Diameters and Tolerances for Fittings for Use with Polyethylene Pipe, in.

Nominal Pipe Size	Average Outside Diameter at Area of Fusion[A]	Tolerance
½	0.840	±0.008
¾	1.050	±0.008
1	1.315	±0.010
1¼	1.660	±0.010
1½	1.900	±0.010
2	2.375	±0.010
3	3.500	±0.012
4	4.500	±0.015
6	6.625	±0.018
8	8.625	±0.025
10	10.750	±0.027
12	12.750	±0.036
14	14.000	±0.063
16	16.000	±0.072
18	18.000	±0.081
20	20.000	±0.090
21.5	21.500	±0.097
22	22.000	±0.099
24	24.000	±0.108
28	28.000	±0.126
32	32.000	±0.144
36	36.000	±0.162
42	42.000	±0.189
48	48.000	±0.216

[A] Defined as measured ¼ to ½ in. (6.4 to 12.7 mm) from fitting outlet extremity.

TABLE 3 DIPS Sizing System Outside Diameters and Tolerances for Fittings for Use with Polyethylene Pipe, in.

Nominal Pipe Size	Average Outside Diameter at Area of Fusion	Tolerance[A]
3	3.96	±0.016
4	4.80	±0.022
6	6.90	±0.031
8	9.05	±0.041
10	11.10	±0.050
12	13.20	±0.059
14	15.30	±0.069
16	17.40	±0.078
18	19.50	±0.088
20	21.60	±0.097
24	25.80	±0.116
30	32.000	±0.144
36	38.30	±0.172
42	44.50	±0.200
48	50.80	±0.229

[A] Defined as measured ¼ to ½ in. (6.4 to 12.7) from fitting outlet extremity.

shall not be less than the minimum short-term rupture strength of the pipe or tubing in the system when tested in accordance with 10.5.3. These minimum pressures shall be as shown in Table 9 of this specification. Test specimens shall be prepared for testing in the manner described in 10.5.1 of this specification. The test equipment, procedures, and failures definitions shall be as specified in Test Method D1599.

7.2.2 *Short-Term Strength for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—Fittings shall not fail when tested in accordance with 10.5.4. The minimum pressure shall be as shown in Table 9 of this specification. Test specimens shall be prepared for testing in the manner described in 10.2 of this specification. The test equipment and procedures shall be as specified in Test Method D1599.

TABLE 4 ISO Sizing System (ISO 161/1) Outside Diameters and Tolerances for Fit for Use with Polyethylene Pipe, mm

Nominal Pipe Size	Average Outside Diameter at Area of Fusion	
	Min	Max[A]
90	90.0	90.8
110	110.0	111.0
160	160.0	161.4
200	200.0	201.8
250	250.0	252.3
280	280.0	282.5
315	315.0	317.8
355	355.0	358.2
400	400.0	403.6
450	450.0	454.1
500	500.0	504.5
560	560.0	565.0
630	630.0	635.7
710	710.0	716.4
800	800.0	807.2
900	900.0	908.1
1000	1000.0	1009.0
1200	1200.0	1210.8
1400	1400.0	1412.6
1600	1600.0	1614.4

[A] Specified in ISO 3607.

7.2.3 *Sustained Pressure*—The fitting and fused pipe or tubing shall not fail, as defined in Test Method D1598, when tested at the time, pressures, and test temperatures selected from test options offered in Table 10. The test specimens shall be prepared for testing in the manner prescribed in 10.5.1.

8. Workmanship, Finish, and Appearance

8.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

9. Sampling

9.1 Parts made for sale under this specification should be sampled at a frequency appropriate for the end use intended. When the fittings are to be installed under a system specification (such as Specification D2513 for gas), the minimum requirements of that specification must be satisfied.

10. Test Methods

10.1 *General*—The test methods in this specification cover fittings to be used with pipe and tubing for gas, water, and other engineered piping systems. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to the particular test. Certain special test methods applicable to this specification only are explained in the appropriate paragraph.

10.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) for not less than 6 h in air, or 1 h in water, for those tests where conditioning is required and in all cases of disagreement. Newly molded fittings shall be conditioned 40 h prior to test.

TABLE 5 Diameter, Wall Thickness, and Tolerances for Fittings for Use with Plastic Tubing

Tubing Type in. (mm)	Nominal Tubing Size, in.	Diameter at Area of Fusion[A]				Minimum Wall Thickness, in. (mm)
		Outside, in. (mm)		Inside, in. (mm)		
		Average	Tolerance	Average	Tolerance	
0.062 (1.57)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.495 (12.58)	±0.004 (±0.10)	0.062 (1.58)
	¾ CTS	0.875 (22.22)	± 0.010 (±0.26)	0.745 (18.92)	....	...
0.090 (2.29)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.437 (11.10)	±0.004 (±0.10)	0.090 (2.28)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.687 (17.44)	±0.004 (±0.10)	0.090 (2.28)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.937 (23.80)	±0.005 (±0.12)	0.090 (2.28)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.187 (30.14)	±0.005 (±0.12)	0.090 (2.28)
DR 11	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.715 (18.16)	±0.004 (±0.10)	0.077 (1.96)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.915 (23.24)	±0.005 (±0.12)	0.101 (2.56)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.125 (28.58)	±0.005 (±0.12)	0.121 (3.08)
DR 9.3	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.483 (12.26)	±0.004 (±0.10)	0.067 (1.70)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.679 (17.24)	±0.004 (±0.10)	0.094 (2.38)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.873 (22.18)	±0.005 (±0.12)	0.121 (3.08)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.069 (27.16)	±0.005 (±0.12)	0.148 (3.76)

[A] Defined as measured ¼ to ½ in. (6.4 to 12.7 mm) from fitting outlet extremity.

TABLE 6 IPS Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyethylene Pipe, in.[A,B,C]

Nominal Pipe Size	Minimum Wall Thickness										
	SCH 40	SCH 80	SDR 21	SDR 17	SDR 13.5	DR 10	DR 11.5	SDR 11	DR 9.3	SDR 9	DR7
½	0.109	0.147	...	...	...	...	...	0.076	0.090	...	0.120
¾	0.113	0.154	...	...	...	...	...	0.095	0.113	0.117	0.150
1	0.133	0.179	...	...	...	...	...	0.119	0.142	0.146	0.188
1¼	0.140	0.191	...	...	...	0.166	...	0.151	0.179	0.184	0.237
1½	0.145	0.200	...	...	...	...	...	0.173	0.204	0.211	0.271
2	0.154	0.218	...	...	...	...	...	0.216	0.256	0.264	0.339
3	0.216	0.300	...	...	0.259	...	0.305	0.318	0.377	0.389	0.500
4	0.237	0.337	...	0.264	0.333	...	0.392	0.409	0.484	0.500	0.643
6	0.280	0.432	0.316	0.390	0.491	...	0.576	0.603	0.713	0.736	0.946
8	0.322	...	0.410	0.508	0.639	...	0.750	0.785	0.928	0.958	1.232
10	0.365	...	0.511	0.633	0.797	...	0.935	0.978	1.156	1.194	1.536
12	0.406	...	0.608	0.750	0.945	...	1.109	1.160	1.371	1.417	1.821
14	...	...	0.667	0.824	...	...	...	1.273	1.505	1.556	2.000
16	...	...	0.762	0.941	...	...	...	1.455	1.720	1.778	2.286
18	...	...	0.857	1.059	...	...	...	1.636	1.935	2.000	2.571
20	...	...	0.952	1.176	...	...	...	1.818	2.151	2.222	2.857
21.5	...	...	1.024	1.265	...	...	...	...	...	...	3.071
22	...	...	1.048	1.294	...	...	...	2.000	2.366	2.444	3.143
24	...	...	1.143	1.412	...	...	...	2.182	2.581	...	3.429
28	...	...	1.333	1.647	...	...	...	2.545	...	...	4.000
32	...	...	1.524	1.882	...	...	...	2.909	...	...	4.571
36	...	...	1.714	2.118	...	...	...	...	...	...	5.143
42	...	...	2.000	2.471	...	...	...	...	...	...	6.000
48	...	...	2.286	...	...	...	...	...	...	...	6.857

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapping thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001 in.

10.3 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified.

10.4 *Dimensions and Tolerances:*

10.4.1 *Outside Diameter*—Measure the outside diameter of the fittings at the area of fusion in accordance with the Wall Thickness section of Method D2122 by use of a circumferential tape readable to the nearest 0.001 in. (0.02 mm).

10.4.2 *Inside Diameter (CTS Fittings Only)*—Use a stepped plug gage to determine the inside diameter of the CTS end of the fitting. The plug gage shall be of the go/no go type and shall have ½-in. (12.7-mm) land lengths cut to the minimum inside diameter and maximum inside diameter. A fitting is unacceptable (no go) if it fits snugly on the minimum inside diameter land of the gage or if it fits loosely on the maximum diameter land of the gage.

10.4.3 *Wall Thickness*—Make a series of measurements using a cylindrical anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thicknesses to the nearest 0.001 in. (0.02 mm) have been determined. Make a minimum of six measurements at each cross section.

TABLE 7 ISO Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyethylene Pipe, mm[A,B,C]

Nominal Pipe Size	Minimal Wall Thickness					
	DR 41	DR 32.5	DR 26	DR 21	DR 17	DR 11
90	...	...	3.5	4.3	5.3	8.2
110	...	3.4	4.2	5.2	6.5	10.0
160	...	4.9	6.2	7.6	9.4	14.5
200	...	6.2	7.7	9.5	11.8	18.2
250	...	7.7	9.6	11.9	14.7	22.7
280	...	8.6	10.8	13.3	16.5	25.5
315	....	9.7	12.1	15.0	18.5	28.6
355	...	10.9	13.7	16.9	20.9	32.3
400	...	12.3	15.4	19.0	23.5	36.4
450	...	13.8	17.3	21.4	26.5	...
500	...	15.4	19.2	23.8	29.4	...
560	...	17.2	21.5	26.7	32.9	...
630	...	19.4	24.2	30.0	37.1	...
710	...	21.8	27.3	33.8	41.8	...
800	...	24.6	30.8	38.1	47.1	...
900	...	27.7	34.6	42.9	...	...
1000	24.4	30.8	38.5	47.6	...	...
1200	29.3	36.9	46.2	...	...	...
1400	34.1	43.1	...	...	...	...
1600	39.0	49.2	...	...	...	...

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapped thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001.

10.5 *Pressure Testing:*

10.5.1 *Preparation of Specimens for Pressure Testing*—Prepare test specimens in such a manner that each, whether individual fittings or groups of fittings, is a system incorporating at least one length of pipe or tubing. Fuse all fitting outlets with the appropriate size pipe or tubing. At least one piece of pipe or tubing in the system shall have a minimum length equal to five pipe diameters.

10.5.2 *Sustained Pressure Test:*

10.5.2.1 Sustained pressure tests shall be conducted in accordance with Table 10 and Test Method D1598 using water as the pressurizing medium. The "test sample" shall be three specimens. Select one Table 10 Condition for the material designation and test the three specimen test sample.

10.5.2.2 Passing results are: *(a)* non-failure for all three specimens at a time equal to or greater than the "minimum average time before failure," or *(b)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified "minimum average time before failure" for the selected Table 10 Condition. For Table 10 Conditions 1 through 5: if more than one ductile failure occurs before the "minimum average time before failure," it is permissible to conduct one retest at a Table 10 Condition of lower stress and longer minimum average time before failure for the material designation. For Table 10 Condition 6 no retest is permissible. Brittle failure of any specimen before the Table 10 "minimum average time before failure" constitutes failure to meet this requirement and no retest is allowed.

10.5.2.3 Provision for retest (if needed). The retest sample shall be three specimens of the same pipe or tubing size and material designation from the same time frame as the "test sample." For the retest, any specimen failure before the "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

10.5.3 *Minimum Hydrostatic Burst Pressure for Fittings ½ to 12 in. and 90 to 315 mm, Nominal Diameter*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599. The hydrostatic pressure shall be increased at a uniform rate such that the specimen fails between 60 and 70 s from start of test. Minimum failure pressures are shown in Table 9.

10.5.4 *Minimum Hydrostatic Pressure for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—The test equipment and procedures shall be as specified in Test Method D1599. The hydrostatic pressure shall be increased at a uniform rate such that the test pressure is reached within 60 to 70 s from the start of the test. No failure should occur in the sample during the test period.

11. Product Marking

11.1 Fittings shall be marked with the following:

11.1.1 ASME SD-3261 or both ASME SD-3261 and ASTM D3261.

11.1.2 Manufacturer's name or trademark,

11.1.3 Material designations (such as PE2708 or PE4710),

NOTE 1—Earlier editions of Specification D3261 included PE material designations PE2406, PE3406, PE3407 and PE3408. Changes to Specification D3350 and PPI TR-3 led to changes in thermoplastic material designation codes, resulting in material designation PE2406 being superseded by material designations PE2606 and PE2708, material designation PE3406 being superseded by PE3606, material designation PE3407 being discontinued, and material designation PE3408 being superseded by material designations PE3608, PE3708, PE3710, PE4708 and PE4710. Recognizing that a period of time is necessary for the dissemination of information and to update specifications and literature, during the transitional period, product markings that include both older and newer materials designations, for example PE2406/PE2606, may occur.

11.1.4 Date of manufacture or manufacturing code,

11.1.5 Size.

11.2 Where the physical size of the fitting does not allow complete marking, marking may be omitted in the following sequence: size, date of manufacture, material designation, manufacturer's name or trademark.

11.3 Where recessed marking is used, take care not to reduce the wall thickness below the minimum specified.

12. Quality Assurance

12.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

13. Certification

13.1 Certification shall be as required by Annex A1.

14. Keywords

14.1 butt fusion fittings; fittings; polyethylene fittings; polyethylene pipe; polyethylene tubing

TABLE 8 DIPS Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyethylene Pipe, in.[A,B,C]

Nominal Pipe Size	Minimum Wall Thickness							
	SDR 32.5	DR 26	DR 21	SDR 17	DR 13.5	SDR 11	SDR 9	SDR 7
3	0.122	0.153	0.189	0.233	0.294	0.360	0.440	0.566
4	0.148	0.185	0.229	0.283	0.356	0.437	0.534	0.686
6	0.213	0.266	0.329	0.406	0.512	0.628	0.767	0.946
8	0.279	0.348	0.431	0.533	0.670	0.823	1.006	1.293
10	0.342	0.427	0.529	0.653	0.823	1.009	1.234	1.586
12	0.407	0.508	0.629	0.777	0.978	1.200	1.467	1.886
14	0.471	0.589	0.729	0.900	1.134	1.391	1.700	2.186
16	0.536	0.670	0.829	1.024	1.289	1.582	1.934	2.486
18	0.600	0.750	0.929	1.147	1.445	1.773	2.167	2.786
20	0.665	0.831	1.029	1.271	1.600	1.964	2.400	3.086
24	0.794	0.993	1.229	1.518	1.912	2.346	2.867	3.686
30	0.985	1.231	1.524	1.883	2.371	2.909	3.556	4.571
36	1.179	1.473	1.824	2.253	2.837	3.482	4.256	5.471
42	1.370	1.712	2.119	2.618	3.297	4.046	4.945	6.357
48	1.563	1.954	2.419	2.989	3.763	4.619	5.645	7.257

[A] Tolerance +20 %, 0 %.
[B] For those SDR groups having overlapping thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001

TABLE 9 Burst Pressure Requirements at 73.4°F for Common Fitting Sizes[A]

Wall Thickness, DR, or Schedule	Nominal Diameter	Minimum Pressure, psi (MPa)	Minimum Pressure, Density 3 or 4 Materials psi (MPa)
DR 7	ALL[B]	833 (5.744)	967 (6.667)
SDR 9	ALL[B]	625 (4.309)	725 (4.999)
DR 9.3	ALL[B]	602 (4.151)	699 (4.820)
SDR 11	ALL[B]	500 (3.448)	580 (3.999)
DR 11.5	ALL[B]	476 (3.282)	552 (3.806)
DR 15.5	ALL[B]	345 (2.379)	400 (2.758)
SDR 17	ALL[B]	313 (2.158)	363 (2.503)
SDR 21	ALL[B]	250 (1.724)	290 (2.000)
DR 26	ALL[B]	200 (1.379)	232 (1.600)
DR 32.5	ALL[B]	159 (1.096)	184 (1.269)
0.062 in. (1.575 mm)	½ CTS	551 (3.799)	639 (4.406)
0.062 in. (1.575 mm)	¾ CTS	381 (2.627)	442 (3.048)
0.062 in. (1.575 mm)	1 CTS	292 (2.013)	639 (4.406)
0.090 in. (2.286 mm)	½ CTS	841 (5.799)	976 (6.730)
0.090 in. (2.286 mm)	¾ CTS	573 (3.951)	665 (4.585)
0.090 in. (2.286 mm)	1 CTS	435 (2.999)	504 (3.475)
0.090 in. (2.286 mm)	1¼ CTS	350 (2.413)	406 (2.799)
SCH 40	½ IPS	746 (5.144)	865 (5.964)
SCH 40	¾ IPS	603 (4.158)	699 (4.820)
SCH 40	1 IPS	563 (3.882)	653 (4.502)
SCH 40	1¼ IPS	461 (3.179)	534 (3.682)
SCH 40	1½ IPS	413 (2.848)	479 (3.303)
SCH 40	2 IPS	347 (2.393)	402 (2.772)
SCH 40	3 IPS	326 (2.268)	381 (2.672)
SCH 40	4 IPS	278 (1.917)	322 (2.220)
SCH 40	6 IPS	221 (1.524)	256 (1.765)
SCH 40	8 IPS	194 (1.338)	225 (1.551)
SCH 40	10 IPS	176 (1.214)	204 (1.407)
SCH 40	12 IPS	164 (1.131)	191 (1.317)
SCH 40	16 IPS	164 (1.129)	190 (1.309)
SCH 40	20 IPS	154 (1.060)	178 (1.230)

[A] Fiber stress of 2520 psi (17.4 MPa) for PE2406 and PE3408.
[B] Refers to IPS, DIPS and ISO diameters shown in Table 2, Table 3 and Table 4.

TABLE 10 Elevated Temperature Sustained Pressure Test Requirements[A,B]

Condition	Test Temperature, ºF (ºC)B	PE2606, PE2706, PE2708 PE3608 PE3708, PE4708		PE3710, PE4710	
		Test Pressure Hoop Stress,[A] psi (kPa)[B]	Minimum Average Time Before Failure, Hours[B]	Test Pressure Hoop Stress,[A] psi (kPa)[B]	Minimum Average Time Before Failure, Hours[B]
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A] A Calculate internal test pressure in accordance with

$$P = \frac{2S}{\left(\frac{D_o}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi. (kPa)
D_O = measured outside diameter, in. (mm), and
t = measured minimum wall thickness, in (mm)

[B] Test temperature tolerance ±3.6ºF (±2ºC). Test pressure tolerance ±5 psi (±35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa. Note: Table 10 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) x ((1200 – 200) / (750 – 640)) = 927).

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILITARY PROCUREMENT

These requirements apply *only* to federal / military procurement, not domestic sales or transfers.

S1. *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 may 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a Regulatory Authority or ser calls for the product to be used to convey or to be in contact with potable water.

S3. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 or the health effects portion of NSF Standard 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR PERFLUOROALKOXY (PFA)-FLUOROCARBON RESIN MOLDING AND EXTRUSION MATERIALS

SD-3307

(Identical with ASTM D3307-10 except for revisions in paras. 5.2, 7.1, and section 10, and additional requirements in section 11 and Annex A1, and renumbering of sections 12 and 13.)

Specification for Perfluoroalkoxy (PFA)-Fluorocarbon Resin Molding and Extrusion Materials

1. Scope

1.1 This specification covers melt processable molding and extrusion materials of PFA-perfluoro(alkoxy alkane) fluorocarbon resin. The materials are copolymers of TFE-fluorocarbon resins containing perfluoroalkoxy side chains. These materials were formerly the subject of this specification and Specification D6314.

1.2 This specification is intended to provide a means for calling out plastic materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection should be made by those having expertise in the plastics field after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the costs involved, and the inherent properties of the material other than those covered by this specification.

1.3 This specification does not cover recycled plastics.

1.4 The tests involved are intended to provide information for identifying the materials covered. It is not the function of this specification to provide engineering data for design purposes. Specimens prepared by injection molding or extrusion could yield test results that may vary from the values in this specification.

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

1.6 The following precautionary caveat pertains only to the test methods portions, Sections 8 and 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 and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This specification, ISO 12086–1(2006), and ISO 12086–2(2006) differ in approach or detail. Data obtained using either may not be technically equivalent.

2. Referenced Documents

2.1 *ASTM Standards:*

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens
D2116 Specification for FEP-Fluorocarbon Molding and Extrusion Materials
D3892 Practice for Packaging/Packing of Plastics
D4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry
D4895 Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion
D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)
D6314 Specification for Fluorocarbon Perfluoromethoxy (MFA) Resin Molding and Extrusion Materials (Withdrawn 2002)

TABLE 1 Detail Requirements for Test on Molding and Extrusion Materials

	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Type IX	Type X	Type XI	Type XII	Type XIII	Type XIV
Melt flow,[A] g/10min:														
min	>7	1	>3	>10	1	>3	10	2	>24	1	≥4	≥8	≥18	≥63
max	19	3	7	30	3	10	17	5	≤50	4	8	18	40	81
Melting endotherm peak temperature,[B] min, °C	300	300	300	285	285	285	280	280	300	265	265	265	265	290

[A]See 9.3 of this specification.
[B]See 9.4 of this specification.

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *ISO Standards:*

ISO 12086–1 Plastics–Fluoropolymer Dispersions and Moulding and Extrusion Materials–Part 1

ISO 12086–2 Plastics–Fluoropolymer Dispersions and Moulding and Extrusion Materials–Part 2

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D883 and D1600.

3.1.1 *lot, n*—one production run or a uniform blend of two or more productions runs.

4. Classification

4.1 This specification covers 14 types of PFA-fluorocarbon resins supplied in pellet form for molding and extrusion.

4.2 A one-line system may be used to specify materials covered by this specification. The system uses predefined cells to refer to specific aspects of this specification, illustrated as follows:

Specification				
Standard Number Block	Type	Grade	Class	Special Notes
Example: Specification D3307 – 06,	I			

In this standard, the only specifications are type; no grade or class is required. A comma is used as the separator between the standard number and the type.

5. General Requirements

5.1 The materials shall be of uniform composition and so prepared as to conform to the requirements of this specification.

5.2 The materials described in this specification shall be free of foreign matter to such a contamination level as may be required in Annex A1.

6. Detail Requirements

6.1 The materials covered by this specification shall conform to the requirements prescribed in Table 1 and Table 2 when tested by the procedures specified herein. Table 2 lists those tests requiring a specimen molded as described in 9.1.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy the requirements of Annex A1.

8. Number of Tests

8.1 One set of test specimens as prescribed in Section 9 shall be considered sufficient for testing each sample. The average result of the specimens tested shall conform to the requirements of this specification.

9. Test Methods

9.1 *Test Specimens:*

9.1.1 Prepare a molded sheet 1.50 ± 0.25-mm (0.060± 0.010-in.) thick. Use a picture-frame-type chase having a suitable blanked-out section and thickness to produce the desired sheet. Use clean aluminum foil, 0.13 to 0.18 mm (0.005 to 0.007 in.) thick, in contact with the resin. A high temperature mold release agent may be sprayed on the aluminum foil to help prevent the foil from sticking to the sheet. Use steel molding plates at least 1.0 mm (0.040 in.) thick and of an area adequate to cover the chase.

9.1.2 Lay down and smoothly cover one plate with a sheet of aluminum foil. Place the mold chase on top of this assembly. Place within the mold chase sufficient molding material to produce the required sheet in such manner that the polymer charge is a mound in the middle of the chase. Place a second sheet of aluminum foil on top of the granules and add the top mold plate. Place the assembly in a compression molding press having platens that have been heated to 380 ± 5°C (716 ± 10°F).

9.1.3 Bring the press platens to incipient contact with the mold assembly. Hold for 2 to 4 min without pressure. Apply approximately 1 MPa (145 psi) and hold for 1 to 1.5 min. Then apply 2 to 4 MPa (290 to 580 psi) and hold for 1 to 1.5 min. Maintain the press at 380 ± 5°C (716 ± 10°F) during these steps. Remove the assembly from the press and place between two 20 ± 7-mm (0.75 ± 0.25-in.) steel plates whose temperature is less than 40°C (104°F).

9.1.4 When the sheet is cool enough to touch (about 50 to 60°C (122 to 140°F)), remove the aluminum foil from the

TABLE 2 Detailed Requirements for Molded Specimens

	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Type IX	Type X	Type XI	Type XII	Type XIII	Type XIV
Tensile strength, min, 23°C (73.4°F):[A]														
MPa	20.68	25.00	20.68	22.75	25.51	22.75	20.68	26.20	20.68	20.68	20.68	20.68	17.24	20.00
psi	3000	3625	3000	3300	3700	3300	3000	3800	3000	3000	3000	3000	2500	2900
Elongation, 23°C (73.4°F), min, %[A]	275	300	275	275	260	275	275	300	275	275	275	275	275	230
Note: The following properties are the same for all types except as noted.														
Specific gravity, 23°C (73.4°F):[B]	All 2.12-2.17													
Dielectric constant, max:[C]	All 2.2 at 10^2 Hz and 10^6 Hz													
Dissipation factor, max:[C]														
10^2	All 0.0003													
10^6	All 0.0005 except Type 7, which is 0.0003													

[A]See 9.6 of this specification.
[B]See 9.5 of this specification.
[C]See 9.7 of this specification.

sheet. (If the sheet is allowed to cool to room temperature, the aluminum foil cannot be pulled free.)

9.2 *Conditioning:*

9.2.1 For tests of specific gravity, tensile properties, and electrical properties, condition the molded test specimens in accordance with Procedure A of Practice D618 for a period of at least 4 h prior to test. The other tests require no conditioning.

9.2.2 Conduct tests at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3.6°F) for determination of specific gravity, tensile properties, and electrical properties only. Since the resin does not absorb water, the maintenance of constant humidity during testing is not necessary. Conduct tests for melt flow rate and melting endotherm under ordinary laboratory conditions.

9.3 *Melt Flow Rate*—Determine the melt flow rate in accordance with Test Method D1238, Test Method A or B, with a temperature of 372 ± 1°C and using a total load, including piston, of 5000 g. The same requirements apply for the use of corrosion-resistant alloy for the barrel lining, orifice, and piston tip.

9.4 *Melting Endotherm Peak Temperature:*

9.4.1 Determine the melting endotherm peak temperature using techniques in Test Method D4591 and Specification D4895. Place a 20-mg specimen in a 4-mm tube with a thermocouple. Premelt the specimen at 325°C, and push the thermocouple into intimate contact with the melt. Cool the sample in air. Run the differential thermal analysis at 10°C/min with glass beads as a reference to a maximum temperature of 350°C. Extend straight lines down tangent to both sides of the melting endotherm, and take the temperature at which the lines intersect (peak minimum) as the melting endotherm peak temperature.

9.4.2 *Precision*—The single instrument precision of the differential thermal analysis applied to this material is ±1.2°C (2S) as defined in Practice E177.

9.5 *Specific Gravity*—Cut two specimens from the compression molded sheet and test in accordance with Test Method D792.

9.6 *Tensile Properties*—Cut five specimens with the microtensile die shown in Fig. 1, which is exactly the same as Fig. 1 of Test Method D1708. The die shall be of the steel-rule type of curvature of 5 ± 0.5-mm (0.20 ± 0.02-in.) type. Determine the tensile properties in accordance with the procedures described in Test Method D638, except that the specimens used shall be as detailed above, the initial jaw separation shall be 22 ± 0.13 mm (0.866 ± 0.005 in.), and the speed of testing shall be 50 mm/min (2 in./min). Clamp the specimens with essentially equal lengths in each jaw. Determine the elongation from the chart, expressing it as a percentage of the initial jaw separation. Details appear in the Tensile Properties section of Specification D2116.

9.7 *Dielectric Constant and Dissipation Factor*—Determine dielectric constant and dissipation factor on three specimens, each 101.6 mm (4 in.) in diameter in accordance with Test Methods D150. Testing shall be at 10^2 Hz and 10^6 Hz.

10. Inspection

10.1 Inspection of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

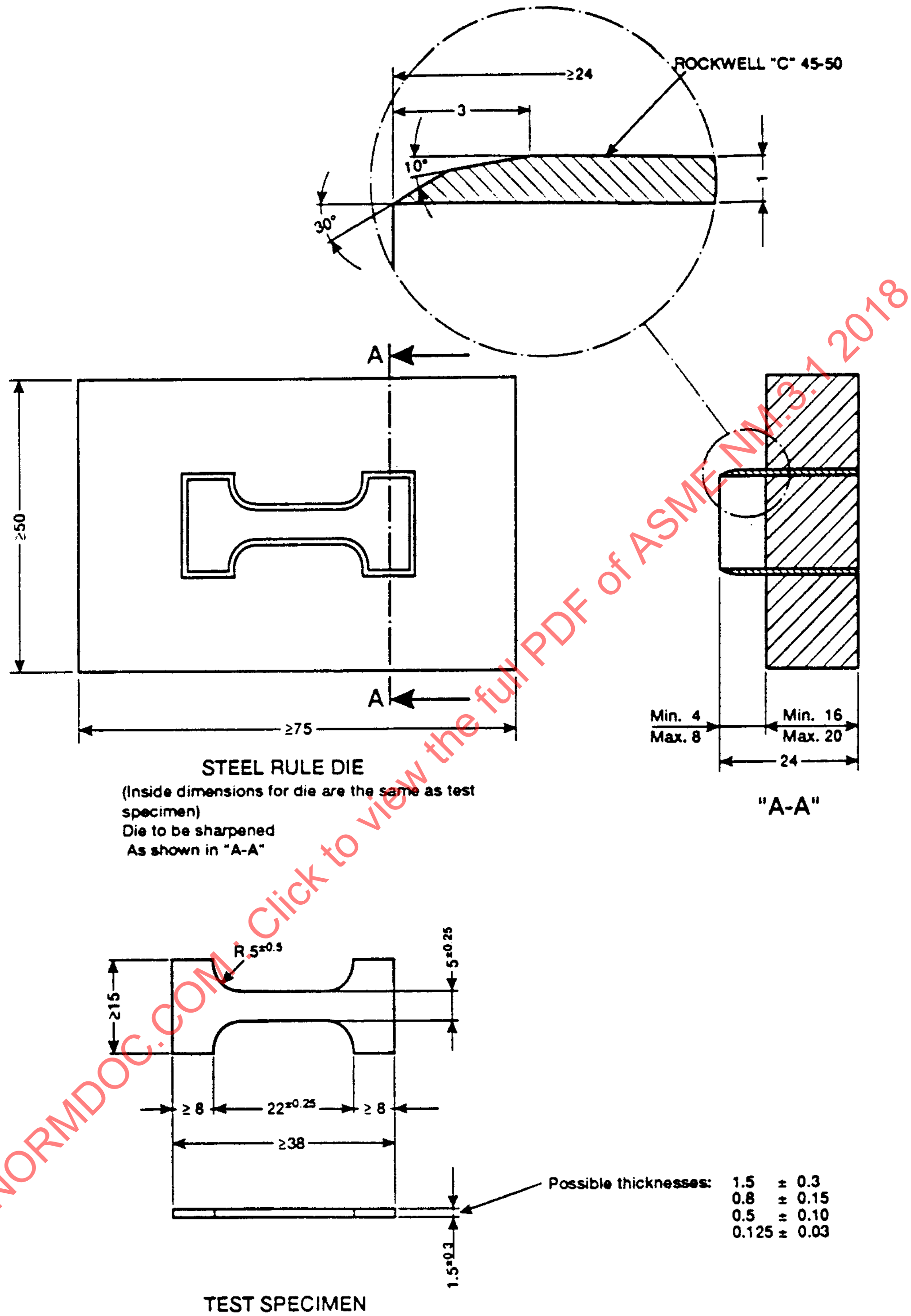
10.2 Lot-acceptance shall be the basis on which acceptance or rejection of the lot is made. The lot acceptance inspection shall consist of melting endotherm peak temperature and melt flow rate.

10.3 Periodic check inspection with reference to a specification based on this classification system shall consist of the test for all requirements of the material in accordance with this specification.

10.4 A report of test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

11. Certification

11.1 Certification shall be as required by Annex A1.



NOTE 1—All dimensions are in millimetres.

FIG. 1 Microtensile Die and Test Specimen

12. Packaging and Package Marking

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

13. Keywords

13.1 extrusion; injection molding; fluoropolymer, perfluoroalkoxy; PFA-fluorocarbon resin; tetrafluoroethylene copolymer; TFE-fluorocarbon

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR POLYETHYLENE PLASTICS PIPE AND FITTINGS MATERIALS

SD-3350

(Identical with ASTM D3350-14 except for additional requirements in section 14 and Annex A1, and renumbering of section 15.)

Specification for
Polyethylene Plastics Pipe and Fittings Materials

1. Scope

1.1 This specification covers the identification of polyethylene plastic pipe and fittings materials in accordance with a cell classification system. It is not the function of this specification to provide specific engineering data for design purposes, to specify manufacturing tolerances, or to determine suitability for use for a specific application.

1.2 Polyethylene plastic materials, being thermoplastic, are reprocessable and recyclable (Note 2). This specification allows for the use of those polyethylene materials, provided that all specific requirements of this specification are met.

NOTE 1—The notes in this specification are for information only and shall not be considered part of this specification.

NOTE 2—See Guide D5033 for information and definitions related to recycled plastics.

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

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

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

1.5 For information regarding molding and extrusion materials see Specification D4976. For information regarding wire and cable materials see Specification D1248.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1603 Test Method for Carbon Black Content in Olefin Plastics
D1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics
D1898 Practice for Sampling of Plastics (Withdrawn 1998)
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D2839 Practice for Use of a Melt Index Strand for Determining Density of Polyethylene
D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
D3892 Practice for Packaging/Packing of Plastics
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D4976 Specification for Polyethylene Plastics Molding and Extrusion Materials
D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)
F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F2263 Test Method for Evaluating the Oxidative Resistance

of Polyethylene (PE) Pipe to Chlorinated Water

2.2 *ISO Standard:*

ISO 12162 Thermoplastic Materials for Pipes and Fittings for Pressure Applications—Classification and Designation—Overall Service (Design) Coefficient

3. Terminology

3.1 *Definitions:*

3.1.1 Terms as described in Terminology D883 shall apply in this specification.

3.1.2 *polyethylene plastics*—as defined by this specification, plastics or resins prepared by the polymerization of no less than 85 % ethylene and no less than 95 % of total olefins with additional compounding ingredients.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *materials*—polyethylene (PE) resins with the added compounding ingredients.

3.2.2 *PE compounds*—has the same meaning as PE plastics materials, compounds, and plastics.

3.3 Historical usage and user group conventions have resulted in inconsistent terminology used to categorize and describe polyethylene resins and compounds. The following terminology is in use in ASTM specifications pertaining to polyethylene:

3.3.1 *Specification D1248:*

3.3.1.1 Type (0, I, II, III, IV) = density ranges (same, respectively, as Class in Specification D4976).

3.3.1.2 Class (A, B, C, D) = composition and use.

3.3.1.3 Category (1, 2, 3, 4, 5) = melt index ranges (same as Grade in Specification D4976).

3.3.1.4 Grade (E, J, D, or W followed by one or two digits) = specific requirements from tables.

3.3.2 *Specification D3350:*

3.3.2.1 Type (I, II, III) = density ranges (same as Types I, II, and III in Specification D1248 and Classes 1, 2, and 3 in Specification D4976).

3.3.2.2 Class = a line callout system consisting of "PE" followed by six cell numbers from Table 1 plus a letter (A, B, C, D, E) denoting color and UV stabilizer.

3.3.2.3 Grade = simplified line callout system using "PE" followed by density and slow crack growth cell numbers from Table 1.

3.3.3 *Specification D4976:*

3.3.3.1 Group (1, 2) = branched or linear polyethylene.

3.3.3.2 Class (0, 1, 2, 3, 4) = density ranges (same, respectively, as Type in Specification D1248).

3.3.3.3 Grade (1, 2, 3, 4, 5) = melt index ranges (same as Category in Specification D1248).

4. Classification

4.1 Polyethylene plastic pipe and fittings compounds are classified in accordance with density, melt index, flexural modulus, tensile strength at yield, slow crack growth resistance, and hydrostatic strength classification in Table 1.

NOTE 4—It has been a long-standing practice to use the following terms in describing polyethylene plastics:

Type I (0.910 to 0.925) = Low Density
Type II (0.926 to 0.940) = Medium Density
Type III (0.941 to 0.965) = High Density

NOTE 5—The manner in which materials are identified in the cell classification is illustrated for Class PE233424B as follows (refer also to Table 1 and 6.2):

Property	Class
Density (0.926–0.940 g/cm^3)	2
Melt Index (<0.4–0.15)	3
Flexural Modulus (276–<552 MPa)	3
Tensile Strength at yield (21–<24 MPa (3000–<3500 psi))	4
Slow Crack Growth Resistance I. ESCR D1693 Condition B, 24 h, 50% max failure II. PENT F1473 Average 1 h failure	2
Hydrostatic design basis at 23°C (11.03 MPa (1600 psi))	4
Color and UV stabilizer (colored)	B

4.2 Materials used in polyethylene plastic pipe and fittings shall use a cell-type format for the identification, close characterization, and specification of material properties. The information from the format is to be used alone or in combination.

NOTE 6—This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted. Additionally, the appropriate ASTM standard specification should be reviewed to assure materials utilized will meet all the material and piping requirements as specified in the standard.

4.3 *Grade*—A code for polyethylene pipe and fittings materials that consists of the two letter abbreviation for polyethylene (PE) followed by two numbers that designate the density cell (Property 1) and the slow crack growth resistance cell (Property 5), as defined by either Test Method F1473 or Test Method D1693, of the thermoplastic, as specified in Table 1. For the requirements of Property 5 (slow crack growth resistance), consult the materials section of the appropriate ASTM standard specification for the end-use application.

NOTE 7—Grade designations were adapted from Specification D1248 – 84 prior to the removal of pipe material from D1248 - 84. Former Specification D1248 – 84 grades for PE pipe materials were P14, P23, P24, P33, and P34. Equivalent Specification D3350 grade designations for these materials are PE11, PE20, PE23, PE30, and PE33, respectively.

5. Materials and Manufacture

5.1 The molding and extrusion material shall be polyethylene plastic in the form of powder, granules, or pellets.

5.2 The molding and extrusion materials shall be as uniform in composition and size and as free of contamination as is achieved by good manufacturing practice. If necessary, the level of contamination may be agreed upon between the manufacturer and the purchaser.

5.3 When specified, the color and translucence of molded or extruded pieces formed, under the conditions specified by the manufacturer of the materials, shall be comparable within commercial match tolerances to the color and translucence of standard samples supplied in advance by the manufacturer of the material.

TABLE 1 Primary Properties^A —Cell Classification Limits

Property	Test Method	0	1	2	3	4	5	6	7	8
1. Density, g/cm^3	D1505	Unspecified	0.925 or lower	>0.925-0.940	>0.940-0.947	>0.947-0.955	>0.955	. . .	Specify Value	
2. Melt index	D1238	Unspecified	>1.0	1.0 to 0.4	<0.4 to 0.15	<0.15^B	^{C}		Specify Value	
3. Flexural modulus, MPa (psi)	D790	Unspecified	<138 (<20 000)	138-<276 (20 000 to <40 000)	276-<552 (40 000 to 80 000)	552-<758 (80 000 to 110 000)	758-<1103 (110 000 to <160 000)	>1103 (>160 000)	Specify Value	
4. Tensile strength at yield, MPa (psi)	D638	Unspecified	<15 (<2200)	15-<18 (2200-<2600)	18-<21 (2600-<3000)	21-<24 (3000-<3500)	24-<28 (3500-<4000)	>28 (>4000)	Specify Value	
5. Slow Crack Growth Resistance										
I. ESCR	D1693	Unspecified								
a. Test condition (100% Igepal.)^D			A	B	C	C	. . .	. . .	. . .	Specify Value
b. Test duration, h			48	24	192	600				
c. Failure, max, %		Unspecified	50	50	20	20				
II. PENT (hours)	F1473									
Molded plaque, 80°C, 2.4 MPa		Unspecified	. . .	. . .	. . .	10	30	100	500	Specify Value
Notch depth, F1473, Table 1		Unspecified								
6. Hydrostatic Strength Classification										
I. Hydrostatic design basis, MPa (psi), (23°C)	D2837	NPR^E	5.52 (800)	6.89 (1000)	8.62 (1250)	11.03 (1600)	. . .	. . .		
II. Minimum required strength, MPa (psi), (20°C)	ISO 12162	. . .	. . .	. . .	. . .	. . .	8 (1160)	10 (1450)		

^{A}Compliance with physical properties in accordance with Section 8 is required including requirements for cell classification, color, and ultraviolet (UV) stabilizer, thermal stability, brittleness temperature, density, tensile strength at yield, and elongation at break.
^{B}Refer to 10.1.4.1.
^{C}Refer to 10.1.4.2.
^{D}There are environmental concerns regarding the disposal of Nonylphenoxy poly(ethyleneoxy) ethanol (CAS 68412-54-4) for example, Igepal CO-630. Users are advised to consult their supplier or local environmental office and follow the guidelines provided for the proper disposal of this chemical.
^{E}NPR = Not Pressure Rated.

6. Physical Properties

6.1 *Cell Classification*—Test values for specimens of the PE material prepared as specified in Section 9 and tested in accordance with Section 10 shall conform to the requirements given in Table 1. A typical property value for a PE material is to be the average value from testing numerous lots or batches and determines the cell number. When, due to manufacturing tolerances and testing bias, individual lot or batch values fall into the adjoining cell, the individual value shall not be considered acceptable unless the user, or both the user and the producer, determine that the individual lot or batch is suitable for its intended purpose.

6.2 *Color and Ultraviolet (UV) Stabilizer*—The color and UV stabilization shall be indicated at the end of the cell classification by means of a letter designation in accordance with the following code:

Code Letter	Color and UV Stabilizer
A	Natural
B	Colored
C	Black with a carbon black in the range as noted in 6.2.1 and 6.2.2
D	Natural with UV stabilizer
E	Colored with UV stabilizer

6.2.1 For PE compounds with a hydrostatic strength classification cell class 0 (not pressure-rated), the carbon black content shall be in the range of 2.0 % to 4.0 %.

6.2.2 For PE compounds with a hydrostatic strength classification other than cell class 0, the carbon black content shall be in the range of 2.0 % to 3.0 %.

6.3 *Thermal Stability*—The PE material shall contain sufficient antioxidant so that the minimum induction temperature shall be 220°C when tested in accordance with 10.1.9.

6.4 *Brittleness Temperature*—The brittleness temperature shall not be warmer than −60°C when tested in accordance with Test Method D746.

6.5 *Density*—The density used to classify the material shall be the density of the PE base resin (uncolored PE) determined in accordance with 10.1.3. When the average density of any lot or shipment falls within ±0.002 g/cm^3 of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.5.1 For black compounds, containing carbon black, determine the density, Dp, and calculate the resin density, Dr, as follows:

TABLE 2 Minimum Log Average Test Times for Oxidative Resistance Classification

Categorization	90°C (194°F) Test Temperature		
	Test Stress 2.48 MPa (360 psi) Time (h)	Test Stress 2.76 MPa (400 psi) Time (h)	Test Stress 3.10 MPa (450 psi) Time (h)
CC0	Unspecified	Unspecified	Unspecified
CC1	2700	1900	1200
CC2	7400	5100	3400
CC3	16 200	11 100	7400

$$Dr = Dp - 0.0044C$$

where:

C = weight percent of carbon black.

6.5.2 For colored compounds, the nominal density of the base resin shall be provided by the manufacturer, on request.

6.6 *Tensile Strength at Yield*—The tensile strength at yield used to classify the material shall be the tensile strength at yield of the PE resin determined in accordance with 10.1.6. When the average tensile strength at yield of any lot or shipment falls within ±3.45 MPa (±500 psi) of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.7 *Elongation at Break*—As tested in accordance with 10.1.6, all pressure rated materials shall have a minimum extension at break of 400 %.

6.8 *Oxidative Resistance Classification:*

6.8.1 The Oxidative Resistance Classification is a classification of a PE compound's resistance to the oxidative effects of chlorinated potable water. The classification is only for PE compounds intended for potable water pressure piping applications as noted in the materials requirement section of the appropriate ASTM standard specification. In addition to the class specified in 3.3.2.2, the user shall specify an oxidative resistance requirement by appending the category designation requirement (Table 2) to the line call out.

6.8.2 The oxidative resistance time used to classify the PE compound shall be determined in accordance with 10.1.11 and be classified in accordance with Table 2.

7. Sampling

7.1 A batch or lot shall be considered as a unit of manufacture and shall consist of one production run or as a blend of two or more production runs of material.

7.2 Unless otherwise agreed upon between the manufacturer and the purchaser, the material shall be sampled in accordance with the procedure described in Sections 9 through 12 of Practice D1898. Adequate statistical sampling prior to packaging shall be considered an acceptable alternative.

NOTE 8—A sample taken from finished product may not necessarily represent the original batch or lot.

8. Number of Tests

8.1 The requirements identified by the material designation and otherwise specified in the purchase order shall be verified by tests made in accordance with 11.1. For routine inspection, only those tests necessary to identify the material to the satisfaction of the purchaser shall be required. One sample shall be sufficient for testing each batch or lot provided that the average values for all of the tests made on that batch or lot comply with the specified requirements.

9. Specimen Preparation

9.1 Unless otherwise specified in Section 10, the test specimens shall be molded in accordance with Procedure C of Annex A1 of Practice D4703.

9.2 When pipe or fitting test specimens are required, they shall be extruded or molded in accordance with the specifications of the material manufacturer.

10. Test Methods

10.1 The properties enumerated in this specification shall be determined in accordance with the following test methods:

10.1.1 *Conditioning*—Unless otherwise specified in the test methods or in this specification, for those tests where conditioning is required, condition the molded test specimens in accordance with Procedure A of Practice D618.

10.1.2 *Test Conditions*—Unless otherwise specified in the test methods or in this specification, conduct tests at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F).

10.1.3 *Density*—Test Method D1505 or alternative methods referenced in 2.1 (see D792, D2839, and D4883) providing equivalent accuracy. Make duplicate determinations using two separate portions of the same molding or from two moldings. The molded specimen thickness portions shall be 1.9 ± 0.2 mm (0.075 ± 0.008 in.). Calculate the average value.

10.1.4 *Melt Index*—Test Method D1238, using Condition 190/2.16. Make duplicate determinations on the material in the form of powder, granules, or pellets, and calculate the average; no conditioning is required.

10.1.4.1 For materials having a melt index less than 0.15 (Cell 4), the manufacturer shall report a flow rate not greater than 20 g/10 min and not less than 4.0 g/10 min when tested in accordance with Test Method D1238, Condition 190/21.6.

10.1.4.2 Classify materials having a melt index less than 0.15 (Cell 4) as Cell 5 only if they have a flow rate not greater than 4.0 g/10 min when tested in accordance with Test Method D1238, Condition 190/21.6.

NOTE 9—For materials having a melt index less than 0.40 to 0.15 g/10 min (Cell 3), the manufacturer may report a flow rate value when tested in accordance with Test Method D1238, Condition 190/21.6. For non-pressure applications, if agreed upon between the manufacturer and the purchaser, the manufacturer may report only the melt index.

NOTE 10—Flow rate is the general term used for all results obtained with Test Method D1238. Although the flow rate of polyethylene plastics may be measured under any of the conditions listed for it under 7.2 of Test Method D1238, only measurements made at Condition 190/2.16 may be identified as "Melt Index."

10.1.5 *Flexural Modulus*—Test Methods D790, using Method 1, Procedure B, and a 50-mm (2-in.) test span. Test five specimens, each 3.2 by 12.7 mm (⅛ by ½ in.) flatwise at a crosshead speed of 12.7 mm/min (0.5 in./min) and the average value of the secant modulus calculated at 2 % strain in the outer fibers.

10.1.5.1 The deflection of the test specimen corresponding to 2 % strain (0.02 mm/mm or in./in.) is calculated as follows:

$$D = rL^2/6d$$

where:

D = deflection of the center of the beam test specimen at 2 % strain, in.,
r = strain in the outer fibers = 0.02 mm/mm (0.02 in./in.),
L = test span = 50 mm (2 in.), and
d = specimen depth = 3.2 mm (⅛ in.).

10.1.5.2 The stress corresponding to 2 % strain is calculated as follows:

$$S = 3\ PL/2\ bd^2$$

where:

S = stress in the outer fiber at 2 % strain,
P = load corresponding to 2 % strain, N (lbf),
L = test span = 50 mm (2 in.),
d = specimen depth = 3.2 mm (⅛ in.), and
b = specimen width = 12.7 mm (½ in.).

The secant modulus at 2 % strain is the ratio of stress to strain or S/0.02.

10.1.6 *Tensile Strength at Yield*—The tensile strength at yield and elongation at break shall be determined in accordance with Test Method D638. The speed of testing shall be 500 mm/min (20 in./min for materials in the density range from 0.910 to 0.925 g/cm^3) and 50 mm/min (2 in./min for all others). Specimens shall conform to the dimensions given for Type IV in Test Method D638 with a thickness of 1.9 ± 0.2 mm (0.075 ± 0.008 in.). Specimen shall be either die cut or machined.

10.1.7 *Slow Crack Growth Resistance*—One method shall be used to classify this material property.

10.1.7.1 *Slow Crack Growth Resistance*—The material's resistance shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method D1693.

10.1.7.2 *Slow Crack Growth Resistance*—The average failure time from two test specimens shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method F1473. Test at least four specimens in case of a dispute.

10.1.8 *Hydrostatic Strength Classification*—One method shall be used to classify this material property.

10.1.8.1 *Hydrostatic Design Basis*—Determine the hydrostatic design basis in accordance with Test Method D2837, on pipe extruded from three different lots of material. Subject specimens from one lot for at least 10 000 h. Terminate the tests on the two additional lots after 2000 h. The results from each of the three lots shall be within the same or next higher cell limits.

NOTE 11—For pressure application at elevated temperatures, the hydrostatic design basis should be determined at that temperature in accordance with Test Method D2837. The 100 000-h intercept should be categorized in accordance with Table 1 of Test Method D2837.

10.1.8.2 *Minimum Required Strength*—Determine the minimum required strength in accordance with ISO 12162.

10.1.9 *Thermal Stability*—Test specimens taken from pipe or fittings made from the virgin material with a differential scanning calorimeter (DSC). The directions of the instrument manufacturer regarding calibration and operation shall be followed except when in conflict with other parts of this section.

NOTE 12—This test requires accurate temperature and atmosphere control on the DSC specimen compartment. The DSC manufacturers offer choices in cell configuration and temperature control parameters that may affect this required control. For example, in some power compensation DSCs, use of the two-hole platinum specimen holder lids with a special "flow-through" swing-away block cover is required. Therefore, the user may wish to consult equipment-specific literature and with the equipment manufacturer to optimize the operation of individual DSCs for this test.

10.1.9.1 *Specimens*—Press small pieces of the pipe into films 0.127 ± 0.013 mm (0.0050 ± 0.0005 in.) thick. Cut at least three disks 6.35 ± 0.13 mm (0.250 ± 0.005 in.) in diameter from the film.

10.1.9.2 *Procedure*—Place the disk of film in a small aluminum cup used in the DSC in a stretched condition, as shown in Fig. 1(*a*). Place a small piece of indium (melting point 156.6°C) or anisic acid (melting point 183.0°C) for a temperature reference standard contained in a similar cup (see Fig. 1(*b*)) in the reference position. Use an oxidized copper reference disk for black, filled, or dark brown test specimens and an aluminum disk for natural or light pigmented polymers. Place the specimen and reference standard cups in the instrument which is preset at approximately 150°C. The bottoms of the cups shall be pressed and rubbed securely against the flat surface so as to ensure that thermal contact is made. Allow 5 min for the cups to reach thermal equilibrium. Begin the programmed heating at approximately 150°C at a heating rate of 10.0°C/min in static air. Test at least three film specimens from each sample and use the average value for the induction temperature.

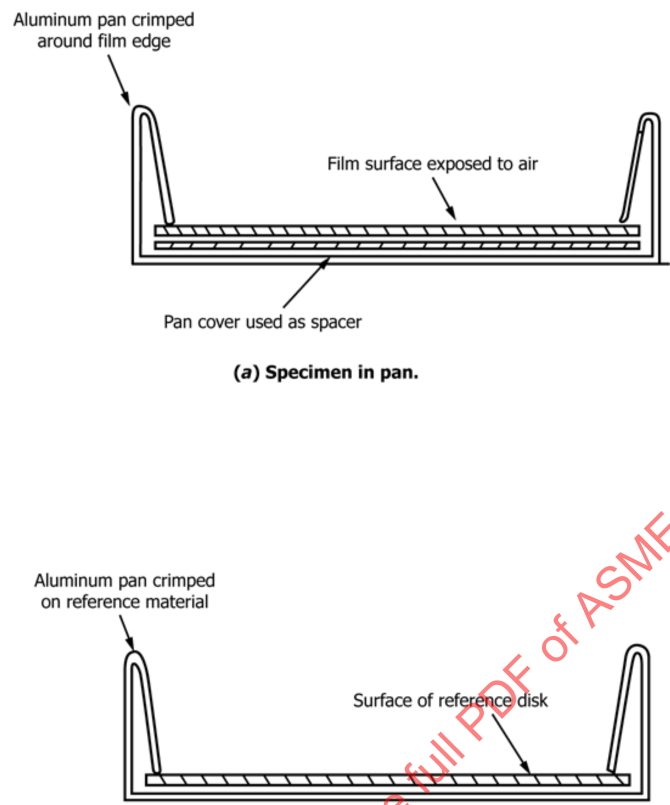
NOTE 13—Since the indium standard may change with use, it should not be used more than 30 times without confirming that no significant change in melting point has occurred. This check can be made by comparison with a fresh piece of indium.

10.1.9.3 *Results*—The temperature change (ΔT) or heat absorption rate (J/s) in the specimen plotted against temperature shall produce a line with a clear rise in slope. The induction temperature (degradation onset) is the intersection of the extended base line and a line tangent to the leading slope of the exothermic decomposition peak (see Fig. 2).

10.1.10 *Carbon Black Content*—Test Method D1603 or Test Method D4218 shall be used. Make duplicate determinations from a sample of the material in the form of powder, granules, or pellets.

10.1.11 *Oxidative Resistance Test*—Test specimens shall consist of extruded 4-in. DR11 IPS pipe meeting the dimensional requirements of Specification D3035. All specimens shall be from the same lot of pipe. Test a minimum of five (5) specimens in accordance with Test Method F2263 at one of the temperature and stress combinations of Table 2.

NOTE 14—If a selected temperature/stress condition results in premature failures, testing may be conducted at a lower stress as shown in Table 2.



(*a*) Specimen in pan.

(*b*) *Reference*—Temperature standard shall be placed under reference disk in reference pan or alternatively under pan cover (spacer).

FIG. 1 Mounting Film Specimen in Cup

10.1.11.1 *Calculation*—Calculate the log average test time using all failures and non-failures. All specimens shall have been tested at the same nominal test stress. Data from not less than five specimens are required for compound classification.

10.1.11.2 *Significance*—Testing is only required to be performed on representative pipe samples for the original validation of a particular compound.

11. Inspection

11.1 Inspection of the material shall be made as agreed upon between the purchaser and the manufacturer as part of the purchase contract.

12. Retest and Rejection

12.1 If any failure occurs, and when specified by the manufacturer, the material shall be retested to establish conformity in accordance with the agreement between the purchaser and the manufacturer.

13. Packaging and Marking

13.1 *Packaging*—The material shall be packaged in standard commercial containers, so constructed as to 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.

13.2 *Marking*—Unless otherwise agreed upon between the seller and the purchaser, shipping containers shall be marked with the name of the material, identification in accordance with this specification, the lot or batch number and quantity contained therein, as defined by the contract or order under which shipment is made, and the name of the manufacturer.

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

14. Certification

14.1 Certification shall be as required by Annex A1.

15. Keywords

15.1 cell classification system; pipe and fittings material; polyethylene; recycled

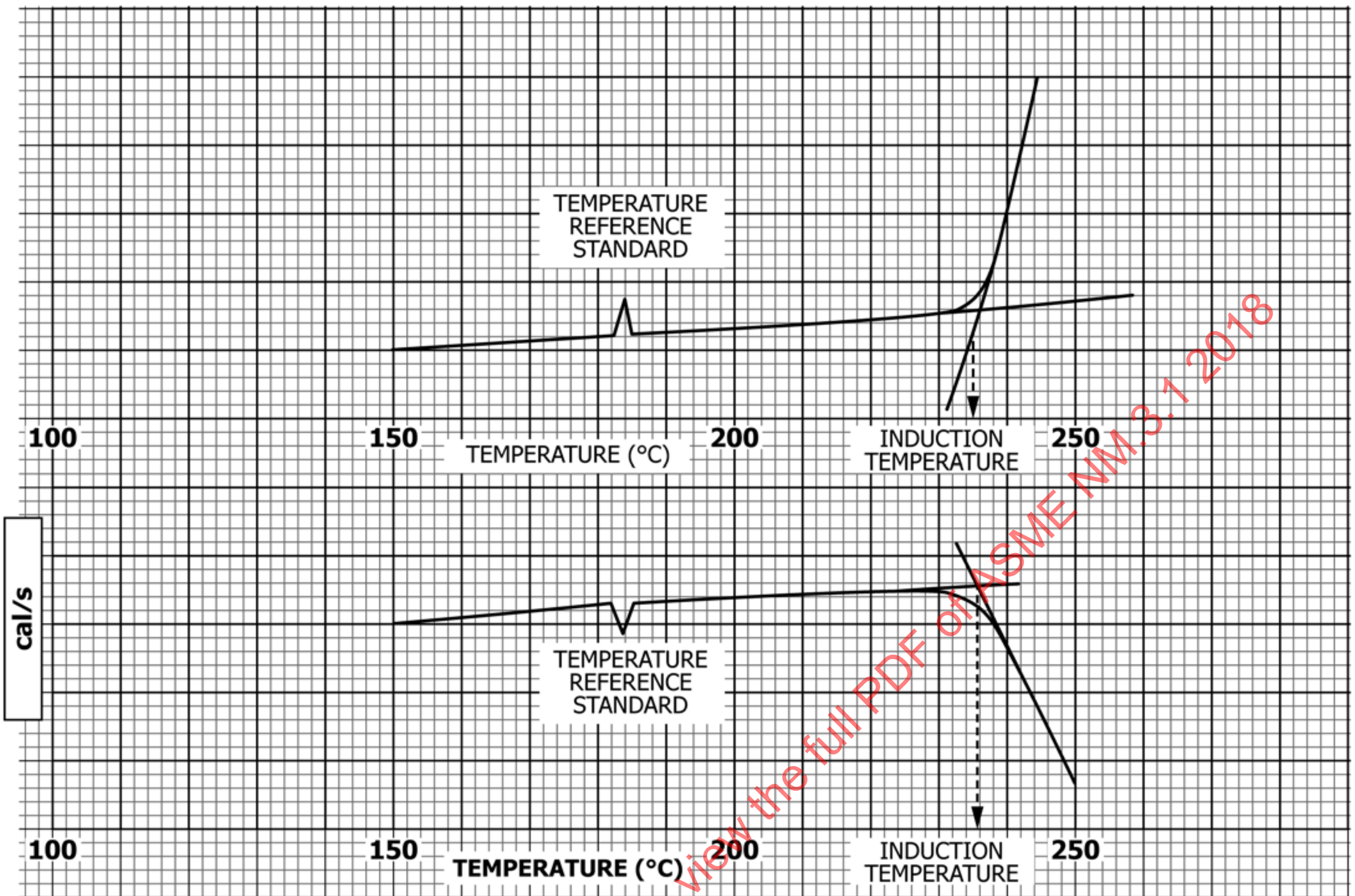


FIG. 2 Typical DSC Plots

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR POLYPROPYLENE INJECTION AND EXTRUSION MATERIALS

SD-4101

(Identical with ASTM D4101-11 except for changes in section 14, additional requirements in section 15 and Annex A1, and renumbering of sections 16, 17, and 18.)

Specification for
Polypropylene Injection and Extrusion Materials

INTRODUCTION

This specification is not intended for the selection of materials but only as a means to call out plastic materials to be used for the manufacture of parts. The selection of these materials is to be made by personnel with expertise in the plastics field where the environment, inherent properties of the materials, performance of the part, part design, manufacturing process, and economics are considered.

1. Scope

1.1 This specification covers polypropylene materials suitable for injection molding and extrusion. Polymers consist of homopolymer, copolymers, and elastomer compounded with or without the addition of impact modifiers (ethylene-propylene rubber, polyisobutylene rubber, and butyl rubber), colorants, stabilizers, lubricants, or reinforcements.

1.2 This specification allows for the use of those polypropylene materials that can be recycled, reconstituted, and reground, provided that: (*1*) the requirements as stated in this specification are met, and (*2*) the material has not been modified in any way to alter its conformance to food contact regulations or similar requirements. The proportions of recycled, reconstituted, and reground material used, as well as the nature and the amount of any contaminant, cannot be practically covered in this specification. It is the responsibility of the supplier and the buyer of recycled, reconstituted, and reground materials to ensure compliance. (See Guide D7209.)

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

NOTE 1—The properties included in this specification are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specific applications. These will be designated by using the suffixes given in Section 1.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 13, 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 and health 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:*

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
D523 Test Method for Specular Gloss
D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D570 Test Method for Water Absorption of Plastics
D618 Practice for Conditioning Plastics for Testing
D635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
D638 Test Method for Tensile Properties of Plastics

D648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D695 Test Method for Compressive Properties of Rigid Plastics
D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
D732 Test Method for Shear Strength of Plastics by Punch Tool
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1435 Practice for Outdoor Weathering of Plastics
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1525 Test Method for Vicat Softening Temperature of Plastics
D1531 Test Methods for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Fluid Displacement Procedures
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D1898 Practice for Sampling of Plastics (Withdrawn 1998)
D2117 Test Methods for Carbon Black—Surface Area by Nitrogen Adsorption (Withdrawn 1999)
D2240 Test Method for Rubber Property—Durometer Hardness
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D3012 Test Method for Thermal-Oxidative Stability of Polypropylene Using a Specimen Rotator Within an Oven
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
D3763 Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors
D3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position
D3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer
D3892 Practice for Packaging/Packing of Plastics
D4000 Classification System for Specifying Plastic Materials
D4329 Practice for Fluorescent UV Exposure of Plastics
D4364 Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight
D4805 Terminology for Plastics Standards (Withdrawn 2002)
D4812 Test Method for Unnotched Cantilever Beam Impact Resistance of Plastics
D5279 Test Method for Plastics: Dynamic Mechanical Properties: In Torsion
D5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)
D5630 Test Method for Ash Content in Plastics
D5740 Guide for Writing Material Standards in the Classification Format
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D6110 Test Method for Determining the Charpy Impact Resistance of Notched Specimens of Plastics
D6290 Test Method for Color Determination of Plastic Pellets
D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
E831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis

2.2 *Military Standard:*

MIL-STD-105 Sampling Procedure and Tables for Inspection by Attributes

2.3 *DOT Standard:*

MVSS-302 Federal Motor Vehicle Safety Standard 302 Flammability of Interior Materials

2.4 *UL Standard:*

UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

2.5 *SAE Standards:*

SAE J1545 Instrumental Color Difference Measurement for Exterior Finishes, Textiles and Color Trim

SAE J1767 Instrumental Color Difference Measurement for Colorfastness of Automotive Interior Trim Materials
SAE J1885 Accelerated Exposure of Automotive Interior Materials Using Controlled Irradiance Water Cooled Xenon-Arc Apparatus
SAE J1960 Accelerated Exposure of Automotive Exterior Materials Using Controlled Irradiance Water Cooled Xenon-Arc Apparatus
SAE J1976 Outdoor Weathering of Exterior Materials

3. Terminology

3.1 *Definitions*— See Terminologies D883 and D4805 for definitions of terms related to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *back pressure, n*—the constant pressure that is applied to the end of the screw while the screw is rotating and retracting to prepare for the next injection.

3.2.2 *brittle failure, n*—one where the specimen test area is broken into two or more pieces, with sharp edges and shows almost no plastic flow.

3.2.3 *cooling time, n*—the time in which the material is in the closed mold with no pressure applied.

3.2.4 *cycle time, n*—the time required to complete a full injection molding cycle, including injection time, cooling time, and mold open time.

3.2.5 *ductile brittle transition temperature, n*—the temperature at which a 80% of the specimens exhibit ductile failure

3.2.6 *ductile failure, n*—one where the specimen deforms plastically before fracturing. One where the puncture of the test plaque does not have cracks radiating more than 10 mm beyond the center of the impact point.

3.2.7 *injection pressure, n*—the constant pressure that is applied to the end of the screw causing the melted material to fill the mold. The injection pressure along with the injection speed determines the volumetric fill rate of the mold.

3.2.8 *injection speed, n*—the forward velocity of the screw during the injection step.

3.2.8.1 *Discussion*—Injection speed is a set position on the injection molding machine ranging from slow to fast. The injection speed along with the injection pressure determines the volumetric fill rate of the mold.

3.2.9 *injection time, n*—the time in which a constant specified pressure is applied to the melted material.

3.2.10 *melt temperature, n*—the temperature of the material as it is being injected into the mold, measured by a pyrometer.

3.2.11 *mold open time, n*—the time beginning when the mold is opened and ending when the mold is closed.

3.2.12 *mold temperature, n*—the temperature of the mold during the molding cycle, measured in all mold cavities and on both platens.

3.2.13 *polypropylene (PP)*—a propylene plastic prepared by the polymerization of propylene or propylene with other alpha olefins. (See also PP-B, PP-H, and PP-R.)

3.2.14 *polypropylene heterophasic copolymers (PP-B, PP+EPR, or PP+EPDM)*—a propylene plastic consisting of two or more separate phases. The phases consist of a polypropylene homopolymer (PP-H) or a polypropylene random copolymer (PP-R) matrix containing a dispersed olefinic elastomer having no other functional group, added in situ or physically blended into the polypropylene matrix.

3.2.15 *polypropylene homopolymer (PP-H)*—a propylene plastic prepared by the polymerization of propylene only.

3.2.16 *polypropylene random copolymer (PP-R)*—a propylene plastic containing another olefinic monomer (or monomers) having no functional group other than the olefinic group copolymerized with propylene. Polypropylene random copolymers containing more than one additional monomer are often called "terpolymers."

4. Classification

4.1 Unreinforced polypropylene materials are classified into groups according to basic composition. These groups are subdivided into classes and grades, as shown in Table PP.

NOTE 3—An example of this classification system is as follows. The designation PP0113 would indicate: PP = polypropylene, as found in Terminology D1600, 01 (group) = homopolymer, 1 (class) = general purpose, and 3 (grade) = with requirements given in Table PP.

4.1.1 To facilitate the incorporation of future or special materials not covered by Table PP, the "other/unspecified" category for group (00), class (0), and grade (0) is shown on the table with the basic properties to be obtained from Table A, Table B, Table C, Table G, Table H, and Table T, as they apply (see 4.3).

4.2 Reinforced versions of the polypropylene materials are classified in accordance with Table PP, Table A, Table C, Table G, and Table T. Table PP, Table B, and Table H specify the properties of the unreinforced material, and Tables A, C, G, or T specify the properties after the addition of reinforcements, pigments, fillers, or lubricants, at the nominal level indicated (see 4.2.1)

4.2.1 *Reinforcements and Additive Materials*—A symbol (single letter) will be used for the major reinforcement or combinations thereof, along with two numbers that indicate the percentage of addition by mass, with the tolerances as tabulated as follows:

Symbol	Material	Tolerance
G	Glass reinforced—	
	<15 %	±2 percentage points
	>15 %	±3 percentage points
L	Lubricant (that is, graphite, silicone, and stearates)	to be specified
M	Mineral-reinforced—	
	<15 %	±2 percentage points
	>15 %	±3 percentage points
R	Reinforced-combinations/ mixtures of reinforcements or other fillers/reinforcements	±3 percentage points based on the total reinforcement

NOTE 4—This part of the system uses the type and percentage of additive to designate the modification of the base material. To facilitate this designation, the type and percentage of additive can be shown on the supplier's Technical Data Sheet, unless it is proprietary in nature. If necessary, additional requirements shall be indicated by the use of the suffix part of the system as given in Section 5.

4.2.2 Specific requirements for reinforced, pigmented, filled, or lubricant polypropylene materials will be shown by a six-character designation. The designation will consist of the letter A, B, C, G, or T and the five digits comprising the cell numbers for the property requirements in the order in which they appear in Table A, Table B, Table C, Table G, or Table T. For Table H the designation will consist of the letter H and three digits comprising the cell numbers for the property requirements in the order in which they appear in Table H.

4.2.2.1 Although the values listed are necessary to include the range of properties available in existing materials, they should not be interpreted as implying that every possible combination of the properties exists or can be obtained.

4.2.3 When the grade of the basic materials is not known or is not important, the use of “0” grade classification will be used for reinforced materials in this system. (See Note 5.)

NOTE 5—An example of this classification system for a reinforced-polypropylene material is as follows. The designation PP0110M20A21130 would indicate the following, with the material requirements from Table A:

PP0110 = General-purpose polypropylene homopolymer from Table PP
M20 = Mineral reinforced, 20 %,
A = Table A property requirements.
2 = 35-MPa tensile stress, min,
1 = 1000-MPa flexural modulus (1 % secant), min,
1 = 15-J/m Izod impact, min,
3 = 110°C deflection temperature, min, and
0 = Unspecified.

If no properties are specified, the designation would be PP0110M20-A00000.

4.3 Table B has been incorporated into this specification to facilitate the classification of special materials where Table PP does not reflect the required properties of that unreinforced material. This table will be used in a manner similar to Tables A, C, G, and T. Table H has been incorporated into this specification to improve the callout of random copolymers and impact copolymers. Table H has a reduced callout based on flexural modulus, Izod impact, and the Multiaxial Impact Ductile-Brittle Transition Temperature. If a full line callout is required, use Table B.

NOTE 6—Mechanical properties of polypropylene materials with pigments or colorants can differ from the mechanical properties of natural material, depending on the choice and the concentration.

NOTE 7—An example of a special material using this classification system is as follows. The designation PP0110B67253 would indicate the following with the material requirements from Table B:

PP0110 = homopolymer, general purpose, other,
B = Table B property requirements,
6 = 30-MPa tensile stress at yield, min,
7 = 1500-MPa flexural modulus, min,
2 = 50-J/m Izod impact resistance, min,
5 = 90°C deflection temperature, min, and
3 = >1.0 to 3.0 nominal melt flow rate.

NOTE 8—An example of a polypropylene copolymer material using Table H would be as follows. The designation PP0500H585 would indicate a material with the following requirements:

PP0500 = copolymer or impact modified,
H = Table H property requirements,
5 = 1200-MPa flexural modulus, min,
8 = Izod impact resistance, non-break failure mode, no value reported, and
5 = <–30°C ductile-brittle transition temperature

5. Suffixes

5.1 When additional requirements are needed for the materials covered in this specification that are not covered in Table PP, Table A, Table B, Table C, Table G, Table H, and Table T, those requirements shall be designated through the use of suffixes. The primary suffix list can be found in Suffix Requirements, Section 7, of Classification D4000. Other suffixes that pertain only to the material requirements in this specification are listed as follows. In general, the suffix letter indicates the requirement needed; the first number (digit) indicates the test condition, and the second number (digit) indicates the specimen requirement.

NOTE 9—Suffixes from Classification D4000 will contain two letters followed by three digits while suffixes from this specification will contain a single letter followed by two or three numbers. An example would be weatherability; a designation of WA510 would indicate that it is a Classification D4000 suffix with the following requirements:

W = Weather resistant,
A = Practice D1435,
5 = Elongation properties, and
10 = 10 % change.

A designation of W110 would indicate that it is a Specification D4101 suffix with the following requirements:

W = Weatherability,
1 = Practice D2565, Test Cycle 1, specimens exposed in a xenon-arc accelerated test apparatus,
1 = 200-h exposure, and
0 = Change in properties to be specified.

Suffixes:

E = Electrical requirements as designated by the following digits:

First Digit

0 = To be specified by user.
1 = Specimens preconditioned 40 h at 23°C and 50 % relative humidity, then 14 days in distilled water at 23 ± 1°C.

Second Digit

0 = To be specified by user.
1 = Insulation resistance, dielectric constant, and dissipation factor meet property limits as shown below. These are electrical limits usually applied to unreinforced polypropylene when control of their electrical properties is required.

Electrical Properties:

Dielectric constant, max	Test Methods D1531 or D150	2.30
Dissipation factor, max	Test Methods D1531	0.0005
Insulation resistance, min, Ω	Test Methods D257	1×10^{15}
Water immersion stability	Test Methods D1531 or D150	Shall meet the dielectric constant and dissipation factor requirements

W = Weatherability requirements as designated by the following digits:

First Digit

0 = To be specified.
1 = Specimens exposed in a xenon arc accelerated test apparatus that conforms to Practice D2565 using Test Cycle 1 for exterior applications.
2 = Specimens exposed in a fluorescent UV/condensation accelerated test apparatus that conforms to Practice D4329 using Test Cycle A for exterior applications.
3 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J1960 or equivalent for exterior applications.
4 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J1885 or equivalent for interior applications.
5 = Specimens exposed to concentrated natural sunlight in accordance with Practice D4364 without water spray.
6 = Specimens exposed to concentrated natural sunlight in accordance with Practice D4364 with water spray (Table 1, Cycle 1).
7 = Specimens exposed to natural sunlight in accordance with Practice D1435 using a rack angle of 45° from the horizontal facing the equator , unless specified otherwise.
8 = Specimens exposed to natural sunlight in accordance with SAE J1976 Procedure A, unless specified otherwise.

Second Alphanumeric

0 = To be specified by user.
1 = 200-h exposure.
2 = 500-h exposure.
3 = 1000-h exposure.
4 = 2000-h exposure.
5 = 1240.8 kJ/(m^2.nm) at 340 nm.
6 = 2500 kJ/(m^2.nm) at 340 nm.
7 = 1000 MJ/m^2 solar total UV irradiation (approximately 3 years).
8 = 336-h exposure
9 = 720-h exposure
A = 5000-h exposure
B = 10000-h exposure
C = 225.6 kJ/(m^2.nm) at 340 nm
D = 601.6 kJ/(m^2.nm) at 340 nm.

NOTE 10—Conversion from hours to kilojoules (kJ) varies with irradiance and the light/dark cycle. Conversion to kJ from actual light hours (h) is based on the following relation:

$$kJ = Irradiance\ in\ Watts \times 3.6\ kJ/h \times h\ of\ light$$

Thus, at an irradiance level of 0.55 W/(m^2.nm) at 340 nm, the multiplication factor for converting light hours to kJ is 1.98 (0.55×3.6). Therefore, 100 light hours is equivalent to 396 kJ/(m^2.nm) at 340 nm at this irradiance level.

Third Alphanumeric

0 = To be specified by user.
1 = The exposed specimens shall not exhibit surface changes (such as dulling and chalking) or deep-seated changes (such as checking, crazing, warping, and discoloration).
2 = The tensile strength after exposure must be no less than 50 % of the original.
3 = The tensile strength after exposure must be no less than 90 % of the original.
4 = American Association of Textile Chemists and Colorists (AATCC) rating 4 to 5.
5 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 2.5 max.
6 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 2.0 max.
7 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 3.0 max.
8 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 2.5 max.
9 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 3.0 max.
Z = Other special requirement characteristics (for example, internal mold release agent) not covered by existing call-out capabilities may be assigned. These will be spelled out in detail and identified in sequence, that is, 01 UV-stabilized, 02 special color, and 03, etc.

Additional suffixes will be added to this specification as test methods and requirements are developed or requested, or both.

6. Basic Requirements

6.1 Basic requirements from property or cell tables, as they apply, are always in effect unless these requirements are superseded by specific suffix requirements in the "Line Call-Out."

7. General Requirements

7.1 The plastic composition shall be uniform and shall conform to the requirements specified herein. The color and form of the material shall be specified. Note specification changes due to the effects of colorants and, when necessary, cover them by suffixes.

7.2 For recycled, reconstituted, and reground materials the level of contamination by nonpolymeric materials other than fillers and additives shall not be of a significant level that it prevents the product from meeting the performance criteria for which it was manufactured.

8. Detail Requirements

8.1 Test specimens for the various materials shall conform to the requirements prescribed in Table PP, Table A, Table B, Table C, Table G, Table H, Table T and to the suffix requirements as they apply.

8.2 Observed or calculated values obtained from analysis, measurement, or test shall be rounded in accordance with Practice E29 to the nearest unit in the last right-hand place of figures used in expressing the specified limiting value. The value obtained is compared directly with the specified limiting value. Conformance or nonconformance with the specification is based on this comparison.

9. Sampling

9.1 Unless otherwise specified, the materials shall be sampled in accordance with the sampling procedure prescribed in Practice D1898. Adequate statistical sampling shall be considered an acceptable alternative. A batch or lot of resin shall be considered as a unit of manufacture as prepared for shipment and may consist of a blend of two or more production runs of material.

10. Number of Tests

10.1 The number of tests conducted shall be consistent with the requirements of Section 13.

11. Specimen Preparation

11.1 All test specimens other than those for heat stability testing (see 11.2) shall be injection molded in accordance with the following specific procedures:

NOTE 11—Physical and mechanical properties are dependent upon the technique of specimen preparation. Specimen preparation by means other than those described as follows can lead to significant variation in test results, with resultant departure from specification values.

NOTE 12—Limited data have shown that, for Polypropylenes, mechanical test values can be significantly affected by the cross sectional area of the runner. Specimens molded using the specified minimum runner size of 5 mm D (~20 mm^2) exhibited lower values of most mechanical properties than specimens molded using runners with cross-sectional areas of 50 and 80 mm^2. Higher viscosity (lower MFR) materials appear to be more sensitive. This effect needs to be considered when comparing data obtained from different sources.

11.1.1 *Specimen Mold*—Molds designed in compliance with Practice D3641 to mold the following test specimens:

11.1.1.1 A Test Method D638, Type I tension test specimen with a thickness of 3.2 ± 0.1 mm.

11.1.1.2 A rectangular bar, with dimensions of 127 mm by 12.7 mm by 3.2 ± 0.1 mm.

11.1.1.3 Plate, with minimum dimensions of 100 mm^2 or 100-mm diameter with a thickness of 3.2 ± 0.2 mm.

11.1.2 *Mold Temperature*—The temperature of the mold shall be 60 ± 3°C. Temperature measurements shall be made in each cavity of the mold after machine conditions are at equilibrium and shall be made with a surface-type pyrometer, or equivalent, to an accuracy of ±2°C after equilibrium or cycle conditions have been established.

11.1.3 *Cycle*—The total molding cycle time shall be 45 s, consisting of 20-s injection, 20-s cooling, and 5-s mold open.

11.1.4 *Melt Temperature*—The melt temperature for molding test specimens for materials with melt flows of 1 to 30 g/10 min shall correlate with the polymer melt flow (Test Method D1238, Condition 230/2.16) as shown in Table 1. Melt temperatures shall be measured on cycle by taking the temperatures of several successive free shots with a needle-type pyrometer to an accuracy of ±3°C. The needle should be moved around in the plastic mass, and a sufficient number of measurements be made to establish a reliable result. To minimize heat loss from the plastic during measurement, the mass should be collected in a heated container, or in one made from material of low thermal conductivity. The quantity of plastic in the free shot should be controlled to be equivalent to the weight of a complete injection-molded shot. To avoid excessive thermal history the shot size shall be kept to a minimum; therefore, the cushion shall be 5 to 10 mm.

NOTE 13—For materials with melt flows less than 1 g/10 min, the temperature of the melt should be raised in 5°C increments from 250°C until the part weight of the entire shot is equivalent to the part weight of a 1 to 5-g/10 min material. Due to degradation and thermal expansion of the material do not exceed 270°C. If unable to obtain the weight at 270°C, make slight adjustments in the injection pressure to achieve the proper weight. The melt temperature shall be 190°C for materials with melt flows greater than 30 g/10 min.

Since the needle-type pyrometer technique is somewhat tedious, a second technique using an infrared pyrometer may be used. The infrared pyrometer used must have an accuracy of 1 % of reading or ±1°F or ±1°C, a response time of at least 0.5 s, and a distance to target ratio of at least 30:1. It is recommended that the infrared pyrometer have a laser beam to establish the position being measured on the molten mass of polymer. This second technique shall only be used after a correlation between the needle-type pyrometer and the infrared pyrometer has been established. This correlation shall be verified at least every six months. The correlation shall be re-established each time either pyrometer is recalibrated.

11.1.5 *Back Pressure*—The back pressure shall be set at 0.7 MPa (gage).

11.1.6 *Injection Pressure and Speed*—All materials less than 30-g/10 min melt flow shall be molded using a single stage pressure. For a given machine and a given mold, the injection pressure and the injection speed controls shall be set to produce equal part weights, including sprue and runners (±2 %) regardless of material flow rates. The injection speed and injection pressure shall be set to minimize sink and flash. The maximum amount of flash shall not exceed 1 mm and will only be acceptable in the nontesting area. Once the injection speed and pressure are determined for a given machine and mold they shall not be varied by more than ±2 %.

NOTE 14—A single stage pressure can be obtained in two different ways: (*1*) Injection pressure may be set to reach a specified pressure then allowed to shift over to a hold pressure; the hold pressure maintains the pressure at the maximum pressure generated by the injection pressure, and (*2*) The cavity may be filled using hold pressure only; the first method is the preferred method. For materials with melt flow rates above 30 g/10 min the injection and hold pressures may be set to different pressures. Normally the hold pressure is set lower than the injection pressure, but must be high enough to finish filling out the molded part. For these high melt flow rate materials the injection and hold pressure shall be specified by the manufacturer.

NOTE 15—It is recommended that screw rotation speed be set to a minimum to allow the screw to rotate for 17 to 19 s of the 20-s cooling time. This slower screw speed will provide greater uniformity of the melt with respect to viscosity and temperature. It may be necessary to adjust the screw rotation speed for the various material types in order to achieve the 17 to 19-s time frame. The rate of screw movement backwards away from the mold is dependent on the back pressure, frictional effects, various additive types, and melt viscosity.

11.1.7 *Reporting*—Report the injection molding conditions in accordance with Practice D3641.

11.2 Prepare test specimens for heat stability testing in accordance with Test Method D3012.

12. Conditioning

12.1 *Conditioning:*

12.1.1 Once specimens are molded, they shall be moved to a standard laboratory atmosphere or a controlled laboratory atmosphere. For natural unfilled polypropylene the controlled laboratory atmosphere shall be 23 ± 2°C. Specimens shall be stored in storage medium, such as boxes, paper bags or envelopes, plastic bags, or racks, whichever is most practical for the laboratory storing the specimens. It is recommended that specimens be allowed to cool for about 30 min on a bench or in a rack before they are placed in any container where the specimens might come in contact with each other. For filled and reinforced polypropylene or polypropylene blends, which contain a hydrophilic comonomer or modifier the specimens shall be conditioned in a standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity, unless sufficient testing has been conducted that indicates that specific material type's properties are not affected by humidity. In those cases, the storage medium can be the same as for unfilled materials. Materials whose properties are affected by humidity, must be stored in accordance with Practice D618, Procedure A. For all materials to be conditioned for electrical testing, conditioning shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during the conditioning period.

NOTE 16—When the temperature in the molding area exceeds 28°C or the humidity level exceeds 60 % (applies only to filled materials) specimens shall be moved as quickly as possible to the standard laboratory atmosphere.

12.1.2 Testing, except for those tests where a test time is specified, shall be conducted not less than 40 h after molding. The aging times as specified in this and subsequent sections shall apply to all testing conducted for development of a line callout, data for publication, or for cases of dispute over testing values.

12.1.3 Specimens that are to be tested for Izod or Charpy impact shall be notched within 1 to 16 h after molding. Once notched the specimens shall condition for a minimum of 40 h before testing.

NOTE 17—Data have shown that, for some polypropylene impact copolymers with higher xylene solubles or higher rubber content, Izod impact values can vary significantly over time.

12.1.4 Specimens that are to be tested for tensile or flexural properties shall be tested within 40 to 96 h after molding.

NOTE 18—Polypropylene properties change with time as a result of amorphous densification and, in some cases, due to a small degree of secondary crystallization in the rubbery phase.

12.2 *Test Conditions*—Natural unfilled polypropylene shall be tested in a controlled laboratory atmosphere of 23 ± 2°C. For filled and reinforced polypropylene and polypropylene blends, which contain a hydrophilic comonomer or modifier the specimens shall be tested in a standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity, unless sufficient testing has been conducted that indicates that specific materials type's properties are not affected by humidity. For all materials to be tested for electrical properties, the laboratory shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during testing.

13. Test Methods

13.1 Determine the properties enumerated in this specification in accordance with the ASTM test methods as they apply, unless otherwise stated herein.

13.1.1 *Flow Rate*—Condition 230/2.16 of Test Method D1238. Make two determinations on the material in the form that it is to be molded (such as powder, pellets, or granules).

NOTE 19—This test method serves to indicate the degree of uniformity of the flow rate of the polymer of a single manufacturer as made by an individual process and, in this case, may be indicative of the degree of uniformity of molded specimens, and therefore other properties. However, uniformity of flow rate among various polymers of various manufacturers as made by various processes does not, in the absence of other tests, indicate uniformity of other properties and vice versa.

13.1.2 *Measurement of Test Specimen Dimensions*—The width and thickness of the test specimen shall be measured to an incremental discrimination of at least 0.025 mm. Measurements shall be made with a micrometer, preferably with ratchet, having a movable circular contact foot and a lower anvil foot, both 6.35 ± 0.025 mm in diameter. Specimens shall be measured in accordance with Test Methods D5947.

13.1.3 *Tensile Stress*—Test Type I specimens using Test Method D638. The material shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.

13.1.4 *Flexural Modulus (1 % Secant)*—Test Methods D790, Method I, Procedure A, with a 50-mm span, a 5.0 ± 0.1-mm radius support and loading nose, and a 1.3-mm/min testing speed using the center test region of a Test Method D638, Type I specimen. It is mandatory that the toe correction be made to correct for the slack in the test fixture and load cell. Center the specimen between the span flatwise and test with a crosshead speed of 1.3 mm/min. Calculate the average value of the flexural modulus (1 % secant) at 1 % strain in the outer surface of the test specimen.

NOTE 20—If the Test Method D638 Type I specimens were molded on a mold containing a draft angle, the specimens will be trapezoidal.

Therefore the flexural modulus may vary slightly depending on which side is placed away from the loading nose.

13.1.4.1 Calculate the deflection of the test specimen corresponding to 1 % strain (0.01 mm/mm) as follows:

$$D = rL^2/6d \tag{1}$$

where:

D = deflection of the center of the test specimen at 1 % strain, mm
r = strain in the outer surface of the test specimen = 0.01 mm/mm,
L = test span = 50 mm, and
d = specimen depth = 3.2 mm (nominal).

Warning—The load measured must be a minimum of 1 % of the load cell capacity. The test span shall be known to an accuracy of 0.05 mm, and this value shall be used in the calculations in 13.1.4.1. The loading nose shall be precisely centered between the supports. The test specimen shall be aligned perpendicular to the supports to an accuracy of 2° and the center of the specimen shall be directly below the center of the loading nose.

13.1.4.2 Calculate the stress corresponding to 1 % strain as follows:

$$S = 3PL/2bd^2 \tag{2}$$

where:

S = stress in the outer surface of the test specimen at 1 % strain, MPa,
P = load corresponding to 1 % strain, N
L = test span = 50 mm,
d = specimen depth = 3.2 mm (nominal), and
b = specimen width = 12.7 mm (nominal).

The secant modulus at 1 % strain is the ratio of stress to strain or S/0.01.

13.1.5 *Impact Resistance (Izod)*—Test Method D256 (A) shall be used for notched specimens tested at 23°C. Specimens shall be cut from the center section of the Test Method D638, Type I tensile test specimen. Before cutting the test specimen from the tensile bar, draw a symbol of any design in the straight center section of the bar to indicate which is the gate end of the specimen. Cut out the 57.2 mm straight center-section of the bar. The specimens shall be notched in accordance with Test Method D256 for tests at 23°C. Specimens shall be notched such that the notch is off-center on the 57.2 ± 1 mm long specimen. When notched, the apex of the notch shall be 25.4 ± 2 mm from the non-gated end and 31.8 ± 1 mm from the gated end of the specimen. The more critical dimension is the 31.8 ± 1 mm from the gated end of the specimen. Notched specimens must be conditioned after notching for a minimum of 40 h before testing. The specimen shall be inserted in the clamp with the 25.4 ± 2 mm in the clamp and the 31.8 ± 1 mm length above the clamp. When testing, the specimen shall be clamped in the grips with the minimum pressure necessary to prevent any movement of the specimen upwards or downwards during impact. Should this pressure deform the specimen, then the clamp pressure may be reduced.

NOTE 21—Although the 57.2 mm length of specimen does not comply with the minimum specimen length of 61.5 mm specified by Test Method D256, studies with numerous types of polypropylene specimens has shown that clamp lengths as short as 19 mm are acceptable, with no change in test results. What is critical is that the length of material above the clamp, which is specified as 31.8 ± 1 mm. Failure to maintain the 31.8 ± 1 mm above the clamp will result in reduced or increased Izod impact values depending on whether the specimen length above the clamp is longer or shorter than that specified by Test Method D256, Method A.

NOTE 22—With the design of each clamping system and the capacity of the pendulum used different from instrument to instrument it is difficult to specify a pressure will hold the specimen securely. What is important is that the clamp pressure be maintained constant from specimen to specimen and be sufficient to prevent specimen movement during the impact. Too low a clamp pressure may result in slightly higher Izod values with a wider scatter of impact values within a set of specimens. Too high a clamp pressure will induce stress in the specimen resulting in lower than expected test values. This is particularly true of propylene plastics when tested at sub-ambient temperatures close to their brittleness temperature.

Set up the test instrument with the lowest capacity pendulum recognized by Test Method D256, which is the 2.7 J (2 ft-lb) pendulum. This pendulum shall be used for all Izod impact resistance measurements where the specimen exhibits a complete, hinge, or partial break. For specimens showing non-break behavior, progressively increase the hammer capacity to move the type of break from non-break with the 2.7 J hammer to complete, hinge, or partial break so that an impact value may be reported. Conformance or nonconformance with the specifications detailed in the Tables shall be based on a material having a complete, hinge, or partial break.

13.1.6 *Deflection Temperature*—Test Method D648 shall be used to test a rectangular specimen 3.2 by 12.7 by 127 mm with a load applied at the center to give maximum fiber stresses of 455 kPa.

13.1.7 *Multiaxial Impact Ductile-Brittle Transition Temperature*—Test Method D3763 shall be used to test specimens equal to or greater in dimensions than 100 mm^2 or 100 mm in diameter and 3.2 ± 0.2 mm in thickness. The test speed shall be 2.2 m/s with the 12.7-mm diameter impact dart and 76-mm support ring. The temperature at which 80 % of the specimens exhibit ductile failure shall be determined based on the definitions listed in Section 3. This temperature shall be determined by either a standard graphical method or through a probability graphical method. When using the standard graphic method to determine the 80 % passing temperature, it is necessary to repeat this procedure of testing ten specimens at a series of temperatures differing by uniform increments of 5°C. The transition region of the curve shall be established using either 5°C or 10°C increments, but -5°C increments must be used when testing in the transition temperature region. When using probability graph paper, it is not necessary to obtain the lowest no-failure temperatures, at which no failure is obtained, or the highest failure temperature. Draw a straight line through a minimum of four points, two above and two below the 50 % failure point. The temperature indicated at the intersection of the data line with the 20 % failure line shall be reported as the ductile-brittle temperature or 80 % passing temperature.

NOTE 23—In addition to visually examining the plaques for ductile failure, review the load versus time or load versus displacement curve for the impact for signs of ductility.

13.1.8 *Reinforcement and Additive Concentrations:*

13.1.8.1 *Glass Percentage*— Use Test Method D2584.

13.1.8.2 *All Others*—Method to be specified.

13.1.8.3 Additional testing methods and conditions, refer to Appendix X1.

14. Inspection

14.1 Inspection of the material supplied uner this specification shall conform to the requirements specified herein and in Classification D4000, Section 15.

15. Certification

15.1 Certification shall be as required by Annex A1.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. If any failure occurs, the materials may be retested to establish conformity. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of the test, a claim for a rehearing may be made.

17. Packaging and Package Marking

17.1 Provisions of Practice D3892 apply for packaging, packing, and marking of plastic materials.

18. Keywords

18.1 injection and extrusion materials; materials specification; polypropylene; polypropylene test methods; recycled plastics

TABLE PP Requirements for Unreinforced Polypropylene (Natural Color Only)

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] Test Method D1238, Condition 230/2.16, g/10 min	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Temperature at 455-KPa Stress,[G] Test Method D648[H], min, °C
01	Homopolymer	1	General purpose	1	. . .	<0.3	27.5	1050	32	81
				2	. . .	>0.2 to ≤1.0	27.5	1000	27	81
				3	. . .	>1.0 to ≤3.0	27.5	1000	25	74
				4	. . .	>3.0 to ≤10	27.5	950	20	71
				5	. . .	>10 to ≤20	26	850	16	71
				6	. . .	>20 to ≤40	25	800	14	64
				7	. . .	>40 to ≤100	24	800	12	64
				8	. . .	>100 to ≤200	23	850	12	64
				9	. . .	>200	21	850	8	74
				0	Other					
		2	Nucleated	1	. . .	>1.0 to ≤3.0	33.5	1350	27	100
				2	. . .	>1.0 to ≤3.0	30.5	1150	27	90
				3	. . .	>3.0 to ≤10	30.5	1150	22	100
				4	. . .	>3.0 to ≤10	30.5	1150	21	90
				5	. . .	>10 to ≤30	30	1150	20	95
				6	. . .	>10 to ≤30	30	1150	16	85
				7	. . .	>30	28.5	1050	16	80
				0	Other					
		3	High-crystallinity	1	. . .	<1.0	38	2000	21	100
				2	. . .	>1.0 to ≤5.0	36	1800	21	100
				3	. . .	>5.0 to ≤10	36	1600	21	100
				4	. . .	>10 to ≤20	33	1400	22	95
				5	. . .	>20 to ≤40	30	1300	24	90
				6	. . .	>40	26	1300	26	90
				0	Other					
		0	Other	0	Other					
02	Random Copolymers		Refer to Appendix X2							
03	Copolymers or Impact-Modified		Refer to Appendix X2							
05	Copolymers or impact modified	0	Other	0	Other	Use Table H for a reduced line callout of materials where only the ratio of stiffness to impact is important. Use Table B when a full line callout is required.				

[A]Nominal flow rate is as supplied by the manufacturer of the material. Maximum allowable tolerance = ±30 % per individual lot.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi.
[D]Test specimens are the center of the unannealed Test Method D638,, Type I tensile bars with a nominal 3.2 by 12.7-mm cross section. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[E]Test specimens are nominal 3.2 mm in width and are at the center section of unannealed Test Method D638, Type I tensile bar.
[F]J/m = ft·lbf/in. × 53.38.
[G]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[H]Minimum values are based on testing the material by Test Method D648, Method A (test span 101.6 mm).

TABLE A Detail Requirements[A] of Polypropylene Not Called Out by Tables B, C, G, and T

Designation or Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at yield,[B] Test Method D638, min, MPa[C]	Unspecified	20	35	50	65	80	95	110	125	Specify value[D]
2	Flexural modulus (1 % secant),[E] Test Methods D790 (A), min, MPa[C]	Unspecified	1000	2000	3000	4000	5000	6000	7000	8000	Specify value[D]
3	Izod impact resistance[F] at 23°C, Test Method D256, min, J/m[G]	Unspecified	15	30	45	60	90	135	190	250	Specify value[D]
4	Deflection temperature at 455 kPa,[H] Test Method D648, min, °C	Unspecified	80	95	110	130	150	170	90	210	Specify value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[F]Test specimens are nominal 3.2 mm in thickness and are at the center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873 × 10^{-2}) = ft · lb/in. or J/m = ft · lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.

TABLE B Detail Requirements[A] of Unfilled and Unreinforced Polypropylene

Designation or Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at yield,[B] Test Method D638, min, MPa[C]	Unspecified	5	10	15	20	25	30	35	40	Specify value[D]
2	Flexural modulus (1 % secant),[E] Test Methods D790, (A), min, MPa[C]	Unspecified	100	250	500	750	1000	1250	1500	1750	Specify value[D]
3	Izod impact resistance[F] at 23°C, Test Method D256, min, J/m[G]	Unspecified	10	50	100	200	300	400	500	700	Specify value[D]
4	Deflection temperature at 455 kPa,[H] Test Method D648, min, °C	Unspecified	50	60	70	80	90	100	110	120	Specify value[D]
5	Flow rate,[I] Test Method D1238, Condition 230/2.16, g/10 min	Unspecified	≤0.3	>0.3-1.0	>1.0-3.0	>3.0-10	>10-20	>20-40	>40-100	>100	Specify value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[F]Test specimens are nominal 3.2 mm in thickness and are at the center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873 × 10^{-2}) = ft · lb/in. or J/m = ft · lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[I]Nominal flow rate is as supplied by the manufacturer of the material. Allowable tolerance ±30 % per individual lot.

TABLE C Detail Requirements[A] of Calcium Carbonate Filled Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	10	14	17	21	24	27	31	34	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	800	1100	1400	1700	1900	2200	2500	2700	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	75	90	110	135	255	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	75	80	85	90	95	100	105	110	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F]Test specimens are a nominal 3.2 mm in thickness and are cut from the center of a Test Method D638, Type I tensile bar.
[G]J/m × (1.873 × 10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.

TABLE G Detail Requirements[A] of Glass Reinforced Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	24	32	40	48	57	65	74	82	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	1000	1900	2800	3700	4600	5500	6400	7300	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	80	100	130	150	170	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	80	90	100	110	120	130	140	150	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638 Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F]Test specimens are a nominal 3.2 mm in thickness and are cut from center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873 × 10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H]Test specimens are a nominal 3.2 by 12.7 mm cross section and shall be unannealed.

TABLE H Detail Requirements[A] of Unfilled and Unreinforced Polypropylene Copolymers

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Flexural Modulus (1 % secant)[B] Test Method D790 (A), min, MPa[C]	Unspecified	100	300	600	900	1200	1500	1800	2100	Specify Value[D]
2	Izod impact resistance[E] at 23°C Test Method D256, min, J/m[F]	Unspecified	20	40	70	120	180	260	400	Non Break[G]	Specify Value[D]
3	Multiaxial Impact Ductile-Brittle Transition Temperature, °C[H]	Unspecified	<10	<0	<-10	<-20	<-30	<-40	<-50	<-60	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 mm in thickness and are cut from center section of unannealed Test Method D638, Type I tensile bar.
[F]J/m × (1.873 × 10^{-2}) = ft • lb/in. or J/m = ft • lb/in. × 53.38.
[G]Izod impact resistance, non-break failure mode, no value reported
[H]Plate with thickness 3.2 ± 0.2 mm.

TABLE T Detail Requirements[A] of Talc Filled Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	12	16	20	24	28	32	36	40	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	650	1000	1350	1700	2050	2400	2750	3100	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	75	95	115	135	155	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	70	80	90	100	110	120	130	140	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7 mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F]Test specimens are a nominal 3.2 mm in thickness and are at the center of a Test Method D638, Type I tensile bar.
[G]J/m × (1.873 × 10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7 mm cross section and shall be unannealed.

TABLE 1 Melt Temperature Requirements for Molding

Flow Rate, g/10 min	Melt Temperature, °C
1.0–1.5	250
1.6–2.5	240
2.6–4.0	230
4.1–6.5	220
6.6–10.5	210
10.6–17.5	200
17.6-30.0	190

SUPPLEMENTARY REQUIREMENTS

The following supplementary items may become part of this specification, when applicable, as agreed upon between the user and the supplier.

S1. Approval

S1.1 Material submitted by a new supplier must be approved by the user. Material or test specimens submitted by the supplier and intended for evaluation shall be accompanied by the supplier's laboratory test report.

S2. New Sources

S2.1 The user may elect to temporarily accept shipment on the supplier's certification.

S3. Infrared Spectrophotometry or Thermal Analysis, or Both

S3.1 At the option of the user, infrared or thermal analysis, or both, may be conducted on material/parts supplied to this specification. The curves established for initial approval shall constitute the reference standard and shall be kept on file at the user's laboratory. All samples shall produce curves that correspond to the reference standard within agreed upon tolerances when tested under the same conditions as those specified on the master set of curves.

S3.2 In the event such tests are to be designated as requirements to be tested by the supplier, this must appear on the part drawing or purchase contract, or both.

S4. Quality Assurance Provisions for Government/Military Procurement

S4.1 Selection of Acceptable Quality Level (AQL) and of Inspection Level (IL) shall be made with consideration of the specific use requirements. This is discussed in Sections 7 and 8 of Practice D1898, with reference to MIL-STD-105. In the absence of contrary requirements, the following values shall apply:

	IL	AQL
Testing (Polymer, Unfabricated)	S–1[A]	. . .

[A]Samples shall be drawn from the required number of units and pooled for preparation of molded samples for property evaluation.

S5. Government/Military Packaging

S5.1 (Text of this section will be the same as presently being balloted by Subcommittee D20.94.)

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. ADDITIONAL TEST METHODS AND CONDITIONS

X1.1 Table X1.1 specifies the other test methods and conditions, other than the five standard test methods, that can be used to characterize polypropylene.

TABLE X1.1 Test Methods and Conditions[A]

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
1.	Rheological properties						
1.1	Melt flow rate	D1238	Granules or powder		g/10 min	VC2	Test temperature 230°C, 2.16 kg load
1.2	Melt rheology	D3835	Granules or powder		Pa-s		Test temperatures 190, 210, and 230°C
2.	Mechanical properties						
2.1	Tensile stress at yield	D638	Type I, thickness = 3.2	Injection	MPa	KY	Test at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %
2.2	Tensile elongation at yield				%	LY	
2.3	Tensile modulus				MPa		Speed of 5 mm/min with Class B-2 or better extensometer
2.4	Tensile creep modulus	D2990	Type I, thickness = 3.2	Injection	MPa		At room temperature and at least two elevated temperatures for 1000 h at three stress levels
2.5	Flexural modulus	D790	Center of Type I bar, 63.5 by 12.7 by 3.2	Injection	MPa	UC	1 % secant, 50 mm span, 1.3 mm/min speed 5 ± 0.1 mm radius support rods and loading nose at yield if yield occurs at less than 5 % strain, otherwise report value at 5 %
2.6	Flexural strength				MPa	NA	
2.7	Flexural creep modulus	D2990	Center of Type I bar, 63.5 by 12.7 by 3.2	Injection	MPa		At room temperature and at least two elevated temperatures for 1000 h at three stress levels
2.8	Compressive strength	D695	12.7 by 12.7 by 25.4 prism or 12.7 mm diameter by 25.4 mm long right cylinder	Injection	MPa	QA	Speed 1.3 mm/min (strain rate 0.05 mm/mm/min)
2.9	Compressive modulus		12.7 by 12.7 by 50.8 prism or 12.7 mm diameter by 50.8 mm long right cylinder		MPa		Slenderness ratio 11 to 16 to 1, speed 1.3 mm/min (strain rate 0.025 mm/mm/min)
2.10	Compressive creep modulus	D2990	12.7 by 12.7 prism or 12.7 mm diameter length (must be sufficient to meet slenderness ratio or 11 to 15)	Injection			At room temperature and at least two elevated temperatures for 100 h at three stress levels
2.11	Shear strength	D732	50 disk or 50 by 50 by 50 square with thickness of 3.2	Injection	MPa		Speed 1.3 mm/min
2.12	Shear modulus	D5279	76 by 13 by 3.2	Injection	Pa		−150°C to Tg+20°C or Tm+10°C @ 1 Hz
					Pa	SM	
2.13	Izod impact resistance	D256	Center of Type I bar, 57.2 by 12.7 by 3.2	Injection	J/m	PA	Use a 2.7 J pendulum for all materials, unless at 2.7 J non-break behavior is observed.
2.14	Charpy impact resistance	D6110	127 by 12.7 by 3.2	Injection	J/m	PB	
2.15	Cantilever beam impact	D4812	Center of Type I bar, 63.5 by 12.7 by 3.2		J/m		
2.16	Tensile impact resistance	D1822	Type S, thickness = 3.2	Injection	kJ/m^2		

TABLE X1.1 *Continued*

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
2.17	Gardner impact	D5420	Minimum 50 by 50 by 3.2 square or 50 diameter by 3.2 disk[B]	Injection	J	PG3	Geometry GC at +23°C, or −30°C, or both
2.18	Puncture properties	D3763	Minimum 100 by 100 by 3.2 square or 100 diameter by 3.2	Injection	J		Test speed 2.2 m/s. Report energy at peak load and total energy at 50 % of the peak load. Primary test temperature +23°C. If the temperature at which the material transitions from ductile to brittle failure is required, recommended test temperatures for initial evaluation are +0°C, -15°C, -30°C and -40°C.
2.19	Rockwell hardness	D785	Minimum 25 by 25 square by 6 or 25 diameter disk by 6 thick	Injection compression	HRR		Rockwell R scale (thickness of specimen may be achieved by plying specimens or thinner specimens may be used if hardness is shown not to be changed)
2.20	Shore A or D hardness	D2240	Minimum 25 by 25 square by 6 or 25 diameter disk by 6 thick	Injection compression	Shore A or D		Shore A or D scale (thickness of specimen may be achieved by plying specimens or thinner specimens may be used if hardness is shown not to be changed). Values at 1 s.
3.	Thermal properties						
3.1	Melting temperature	D2117	Any material form		°C	CE	Fisher-Johns
		D3418				CD	DSC/DTA
3.2	Heat deflection temperature	D648	127 by 13 by 3.2	Injection	°C	YA	Unannealed specimen, 1820 kPa stress.
						YD	Unannealed specimen, 455 kPa stress.
3.3	Vicat softening temperature	D1525	Minimum 12 by 12 by 3 square or 12 diameter disk	Injection	°C	CB	Rate A, 50°C/h
3.4	Coefficient of linear thermal expansion	D696	Between 50 and 120 length, other dimensions depend on test apparatus	Injection	µm/(m·°C)		Dilatometer, between −30° and +30°C (use E228 for temperatures other than −30 and +30°C)
		E831	Between 2 and 10 length and less than 10 lateral dimension	Injection	µm/(m·°C)		Report over ranges from −30 to 0°C, 0 to +30°C, and +30 to +60°C
3.5	Thermal conductivity	C177	Depends on test apparatus	Injection	cal/s/cm^2/°C/cm		
3.6	Brittleness temperature	D746	Length minimum 20 + minimum 5 in clamp by 6.35 by 1.91	Injection	°C	PL	Procedure A
3.7	Flammability	D635	127 by 12.7 by 3.2	Injection	mm/min	FA	
		D2863	127 by 6.5 by 3.2	Injection	%	FB	
		D3801	127 by 12.7 by 3.2	Injection	s	FC	Generate rating based on burning time and glow time
		MVSS-302	355 by 102 by 1.25	Injection	mm/min		
4.	Electrical properties						
4.1	Volume resistivity	D257	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression	Ohm·cm	EG	Electrification for 60 s with applied voltage of 500 V
4.2	Dielectric strength	D149	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression	kV/mm	EA	Method A—short time
						ED	Method B—step by step
4.3	Dielectric constant	D150	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression		ED	Test at 1 MHz
4.4	Dissipation factor					EE	
4.5	Arc resistance	D495	Dependent on test apparatus, thickness 3.2	Compression	s	EF	
5.	Optical						
5.1	Yellowness index[A]	E313	Minimum 63.5 by 63.5 by 3.2 or minimum 63.5 diameter disk by 3.2	Injection	YI		Reflectance with specular light included
5.2	Yellowness index	D6290	Pellets		YI		Reflectance, specular light excluded, Illuminant C, 2° observer calculate YI with E313 equation
5.3	Gloss	D523	150 by 75 by 3.2	Injection			At 45 and 60°

TABLE X1.1 *Continued*

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
6.							
6.1	Natural weathering	D1435	Type I tensile bar for physical testing and minimum 65.5 by 63.5 square or 63.5 diameter disk by 3.2 for color change.	Injection		W7	Angle of exposure 45°, report exposure time, % retention of physical properties and total solar radiant energy. See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J1976	Type I tensile bar for physical testing and minimum 65.5 by 63.5 square or 63.5 diameter disk by 3.2 for color change.	Injection		W8	Angle of exposure 5°, report exposure time, % retention of physical properties and total solar radiant energy. See Third Alphanumeric Suffixes for evaluations and failure criteria.[C]
6.2	Accelerated weathering	D2565	same as for 6.1	Injection		W1	Xenon-arc test as described in First Digit 1. Exposure for 720 h.[D] See Third Digit Alphanumeric for evaluations of exposure and failure criteria.[C]
		D4329	same as for 6.1	Injection		W2	Fluorescent UV/condensation test as described in First Digit 2.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J1885	same as for 6.1	Injection		W4	Xenon-arc test as described in First Digit 4. Radiant exposure of 1240.8 kJ/(m^2.nm) at 340 nm.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J1960	same as for 6.1	Injection		W3	Xenon-arc test as described in First Digit 3. Radiant exposure of 2500 kJ/(m^2.nm) at 340 nm.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		D4364	same as for 6.1	Injection		W5, W6	UV radiant exposure below 385 nm of 1000 MJ/m^2 (approximately 3 years).[D] Specify whether First Digit is 5 or 6. See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
6.3	Oven aging	D3012	50 by 10 by 1.0	Compression or Injection	Days	SA	Test temperature = 150°C
7.	Other						
7.1	Water absorption	D570	50.8 by 3.2 disk	Injection	%		24 h immersion at ambient temperature
7.2	Water absorption	D570	50.8 by 3.2 disk	Injection	%		Long-term immersion to saturation
7.3	Chemical resistance	D543	50.8 by 3.2 thick disk or Type I bar, 3.2 thickness	Injection	%		Disk for weight and dimensional changes
				Injection	%		Type I for mechanical properties retention, 7 day immersion
7.4	Density	D792	37 by 12.7 by 3.2	Injection	kg/m^3	GC	
		D1505	Pellet or section of molded or extruded sample		kg/m^3	GD	
7.5	Ash	D5630	Granules or pellets		%		

[A]The measurement of yellowness index of molded flat specimens for comparison between other laboratories is not as reproducible as with pellets due to the difference in molding techniques to make the specimen; the additional heat history applied to the material; differences in design of the colorant measurement systems; the level of specimen transparence, translucence, or opaqueness; and the color of the background backing up the specimen.

[B]The Gardner impact resistance of a material is dependent on the size and shape of the specimen, gating of the mold, and the material flow pattern in the mold during injection molding. When the impact failure mode is ductile the specimen dimensions do not make a significant difference, but when the impact failure mode is brittle, larger specimens of the same thickness will yield higher impact results. In cases of non-agreement, customer and supplier shall agree on specimen and dimensions used.

[C]Failure shall be when the material loses tensile strength or Izod impact properties. If color change is critical, ΔE cannot exceed 3.0.

[D]The minimum exposure time shall be that necessary to produce a statistically significant change in the property measured, that is, tensile strength, impact resistance or color, in the least stable material being evaluated.

X2. TABLE PP REQUIREMENTS FOR UNREINFORCED POLYPROPYLENE GROUPS 02 AND 03 (NATURAL COLOR ONLY)

X2.1 Table X2.1 is the former Table PP for the line call out of random copolymers (Group 2) and copolymers and impact modified materials (Group 03). Groups 02 and 03 have been replaced by Group 05 in the main document. A material previously classified with these groupings may continue to be used. All new materials shall be called out with the Group 5 classification.

TABLE X2.1 PP Requirements for Unreinforced Polypropylene (Natural Color Only)

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] Test Method D1238, Condition 230/2.16, g/10 min	Density, max Test Methods D1505 or D792, kg/m³	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Temperature at 455-KPa Stress,[G] Test Method D648[H], min, °C
02	Random copolymer	1	General purpose	1	. . .	. . .	910	24	1000	30	78
				2	. . .	. . .	910	24	800	30	67
				3	. . .	. . .	910	22	700	30	67
				4	. . .	. . .	910	20	600	40	62
				5	. . .	. . .	910	17	500	45	62
				6	. . .	. . .	910	16	400	50	60
				7	. . .	. . .	910	15	350	50	60
				0	Other						
		2	Nucleated	1	. . .	. . .	915	26	975	35	87
				2	. . .	. . .	915	24	675	40	77
				3	. . .	. . .	915	22	575	40	73
				4	. . .	. . .	915	21	375	50	67
				0	Other						
		0	Other	0	Other						
03	Copolymers or impact modified	1	Low impact	1	. . .	. . .	905	26	1000	10	80
				2	. . .	. . .	905	21	850	10	65
				3	. . .	. . .	905	23	850	30	70
				4	. . .	. . .	905	18	650	30	65
				5	. . .	. . .	905	17	450	30	60
				6	. . .	. . .	905	24	800	50	75
				7	. . .	. . .	905	22	750	50	70
				8	. . .	. . .	905	20	750	50	70
				9	. . .	. . .	905	18	650	50	65
				0	Other						
		2	Moderate impact	1	. . .	. . .	905	27	1000	60	85
				2	. . .	. . .	905	25	850	70	80
				3	. . .	. . .	905	23	850	70	75
				4	. . .	. . .	905	21	750	70	70
				5	. . .	. . .	905	19	550	70	70
				6	. . .	. . .	905	19	550	70	60
				7	. . .	. . .	905	22	700	90	75
				8	. . .	. . .	905	17	650	90	65
				9	. . .	. . .	905	15	550	90	60
				0	Other						
		3	Medium impact	1	. . .	. . .	905	25	1000	100	75
				2	. . .	. . .	905	23	900	120	70
				3	. . .	. . .	905	19	700	120	65
				4	. . .	. . .	905	17	500	120	60
				5	. . .	. . .	905	17	600	150	65
				6	. . .	. . .	905	25	850	200	70
				7	. . .	. . .	905	20	850	200	70
				8	. . .	. . .	905	20	700	200	70
				9	. . .	. . .	905	16	500	200	60
				0	Other						
		4	High impact	1	. . .	. . .	905	24	800	300	80
				2	. . .	. . .	905	21	800	300	75
				3	. . .	. . .	905	21	550	300	70
				4	. . .	. . .	905	17	500	300	65
				5	. . .	. . .	905	15	450	300	60
				6	. . .	. . .	905	16	500	400	65
				7	. . .	. . .	905	24	750	600	70
				8	. . .	. . .	905	20	700	600	65
				9	. . .	. . .	905	19	500	600	60
				0	Other						
		5	Nucleated	1	. . .	. . .	905	29	1000	10	77
				2	. . .	. . .	905	27	1300	30	95

TABLE X2.1 *Continued*

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] Test Method D1238, Condition 230/2.16, g/10 min	Density, max Test Methods D1505 or D792, kg/m^3	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Tempera-ture at 455-KPa Stress,[G] Test Method D648[H], min, °C
				3	. . .	. . .	905	23	950	30	90
				4	. . .	. . .	905	21	850	30	85
				5	. . .	. . .	905	23	1050	50	85
				6	. . . .	. . .	905	19	800	50	85
				7	. . .	. . .	905	26	1150	80	85
				8	. . .	. . .	905	22	850	80	80
				9	. . .	. . .	905	19	550	100	80
				0	Other						
		0	Other	0	Other						

[A]Nominal flow rate is as supplied by the manufacturer of the material. Maximum allowable tolerance = ±30 % per individual lot.
[B]Test specimens are unannealed Test Method D638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.
[C]MPa × 145 = psi.
[D]Test specimens are the center of the unannealed Test Method D638,, Type I tensile bars with a nominal 3.2 by 12.7-mm cross section. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[E]Test specimens are nominal 3.2 mm in width and are at the center section of unannealed Test Method D638, Type I tensile bar.
[F]J/m = ft·lbf/in. × 53.38.
[G]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[H]Minimum values are based on testing the material by Test Method D648, Method A (test span 101.6 mm).

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SPECIFICATION FOR POLYTETRAFLUOROETHYLENE (PTFE) GRANULAR MOLDING AND RAM EXTRUSION MATERIALS

SD-4894

(Identical with ASTM D4894-07(R12) except for revisions in para. 7.1 and section 11, and additional requirements in section 12 and Annex A1, and renumbering of sections 13 and 14.)

Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials

1. Scope

1.1 This specification covers granular resins and test methods for polytetrafluoroethylene (PTFE) that have never been preformed or molded and are normally processed by methods similar to those used in powder metallurgy or ceramics, or by special extrusion processes. These PTFE resins are homopolymers of tetrafluoroethylene, or, in some cases, modified homopolymers containing not more than one percent by weight of other fluoromonomers. The usual methods of processing thermoplastics generally are not applicable to these materials because of their viscoelastic properties at processing temperatures. The materials included herein do not include mixtures of PTFE resin with additives such as colorants, fillers or plasticizers; nor do they include reprocessed or reground resin or any fabricated articles. The methods and properties included are those required to identify the various types of resins. Additional procedures are provided in the Appendix for further characterization of the resins.

1.2 The values stated in SI units as detailed in IEEE/ASTM SI-10 are to be regarded as the standard, and the practices of IEEE/ASTM SI-10 are incorporated herein.

1.3 The following precautionary caveat pertains only to the Specimen Preparation section, Section 9, and the Test Methods section, Section 10, of this specification: *This specification 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.* See Notes 3 and 9 for specific cautionary statements.

NOTE 1—Information in this specification is technically equivalent to related information in ISO 12086-1 and ISO 12086-2.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

D638 Test Method for Tensile Properties of Plastics

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D883 Terminology Relating to Plastics

D1895 Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials

D3295 Specification for PTFE Tubing, Miniature Beading and Spiral Cut Tubing

D3892 Practice for Packaging/Packing of Plastics

D4441 Specification for Aqueous Dispersions of Polytetrafluoroethylene

D4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry

D4745 Specification for Filled Compounds of Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials

D4895 Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *ISO Standards:*

ISO 12086-1 Plastics—Fluoropolymer Dispersions and Moulding and Extrusion Materials—Part 1: Designation System and Basis for Specification

ISO 12086-2 Test Methods for Fluoropolymers

TABLE 1 Detail Requirements for Tests on Resins[A]

Type	Grade	Bulk Density, g/L	Particle Size, Average Diameter, µm	Water Content, max, %	Melting Peak Temperature	
					Initial °C	Second °C
I	1	700 ± 100	500 ± 150	0.04	[A]	327 ± 10
	2	675 ± 50	375 ± 75	0.04	[A]	327 ± 10
II	. . .	. . .	<100	0.04	[A]	327 ± 10
III	1	400 ± 125	<100	0.04	[A]	327 ± 10
	2	850 ± 100	500 ± 150	0.04	[A]	327 ± 10
IV	1	650 ± 150	550 ± 225	0.04	[A]	327 ± 10
	2	>800	. . .	0.04	[A]	327 ± 10
	3	580 ± 80	200 ± 75	0.04	[A]	327 ± 10
V	. . .	635 ± 100	500 ± 250	0.04	327 ± 10	327 ± 10
VI	. . .	650 ± 150	800 ± 250	0.04	[A]	327 ± 10

[A] >5°C above the second melting peak temperature.

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology given in Terminology D883 is applicable to this specification.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *bulk density*—the mass (in grams) per litre of resin measured under the conditions of the test.

3.2.2 *extended specific gravity (ESG)*—the specific gravity of a specimen of PTFE material molded as described in this specification and sintered (g.v.) for an extended period of time, compared to the sintering time for the measurement of standard specific gravity (SSG), using the appropriate sintering schedule given in this specification.

3.2.3 *lot, n*—one production run or a uniform blend of two or more production runs.

3.2.4 *preforming*—compacting powdered PTFE material under pressure in a mold to produce a solid object, called a preform, that is capable of being handled. Molding and compaction are terms used interchangeably with preforming for PTFE.

3.2.5 *reground resin*—that produced by grinding PTFE material that has been preformed but has never been sintered.

3.2.6 *reprocessed resin*—that produced by grinding PTFE material that has been both preformed and sintered.

3.2.7 *sintering*—as it applies to PTFE, a thermal treatment during which the PTFE is melted and recrystallized by cooling with coalescence occurring during the treatment.

3.2.8 *skiving*—a machining operation during which a continuous film of PTFE material is peeled from the lateral surface of a cylindrical sintered molding.

3.2.9 *standard specific gravity (SSG)*—the specific gravity of a specimen of PTFE material molded as described in this specification and sintered using the appropriate sintering schedule given in this specification.

3.2.10 *thermal instability index (TII)*—a measure of the decrease in molecular weight of PTFE material which has been heated for a prolonged period of time.

4. Classification

4.1 This specification covers the following six types of PTFE generally used for compression molding or ram extrusion, or both:

4.1.1 *Type I*—Resin used for general-purpose molding and ram extrusion.

4.1.2 *Type II*—Finely divided resin with an average particle size less than 100 micrometres.

4.1.3 *Type III*—Modified resins, either finely divided or free-flowing, typically used in applications requiring improved resistance to creep and stress-relaxation in end-use.

4.1.4 *Type IV*—Free-flowing resins. Generally made by treatment of finely divided resin to produce free-flowing agglomerates.

4.1.5 *Type V*—Presintered. Resin that has been treated thermally at or above the melting point of the resin at atmospheric pressure without having been previously preformed.

4.1.6 *Type VI*—Resin, not presintered, but for ram extrusion only.

NOTE 2—See Tables 1 and 2 for division of Types by Grades, and footnotes to Tables 1 and 2 (and Table X2.1 in Appendix X2.) for former classifications.

4.2 A line callout system is used to specify materials in this standard. The system uses predefined cells to refer to specific aspects of this specification, illustrated as follows:

Specification								
Standard Number Block	:	Type	:	Grade	:	Class	:	Special notes
:		:		:		:		:
Example: ASTM D4894 – 04		III		2				

For this example, the line callout would be ASTM D4894 – 04, III2, and would specify a granular polytetrafluoroethylene that has all of the properties listed for that Type and Grade in the appropriate specified properties, Tables, or both, in this specification. In this case there is no Class item so the cell position for class is left blank. A comma is used as the separator between Standard Number and Type. Separators are not needed between Type, Grade, and Class. Provision for Special Notes is included so that other information will be provided when required. An example would be in Specification D3295 where dimensions and tolerances are specified for each AWG size within Type and Class. When Special Notes are used, they shall be preceded by a comma.

TABLE 2 Detail Requirements for Tests on Molded Specimens

Type	Grade	Thermal Instability Index, max	Standard Specific Gravity		Tensile Strength, min		Elongation at break min %
			min	max	MPa	psi	
I	1	50	2.13	2.18	13.8	2000	140
	2	50	2.13	2.18	17.2	2500	200
II	. . .	50	2.13	2.19	27.6	4000	300
III	1	50	2.14	2.22	28.0	4060	450
	2	50	2.14	2.18	20.7	3000	300
IV	1	50	2.13	2.19	25.5	3700	275
	2	50	2.13	2.19	27.6	4000	300
	3	50	2.15	2.18	27.6	4000	200
V	. . .	NA[A]	NA[A]	NA[A]	NA[A]	NA[A]	NA[A]
VI[B]	. . .	NA[A]	NA[A]	NA[A]	NA[A]	NA[A]	NA[A]

[A] NA: Not Applicable by molding techniques included in this specification.
[B] Extrusions of this resin show different degrees of clarity from the others.

5. Mechanical Properties

5.1 The resins covered by this specification shall conform to the requirements prescribed in Tables 1 and 2 when tested by the procedures specified herein. Table 1 lists tests to be carried out on resins. Table 2 lists tests requiring specimens molded as described in Section 9.

6. Other Requirements

6.1 The resin shall be uniform and shall contain no additives or foreign material.

6.2 The color of the material as shipped by the seller shall be white.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy the requirements of Annex A1.

8. Number of Tests

8.1 Lot inspection shall include tests for bulk density, particle size and standard specific gravity. Periodic tests shall consist of all the tests specified in Tables 1 and 2 and shall be made at least one per year.

8.2 The tests listed in Tables 1 and 2, as they apply, are sufficient to establish conformity of a material to this specification. One set of tests specimens as prescribed in Section 7 shall be considered sufficient for testing each sample. The average of the results for the specimens tested shall conform to the requirements of this specification.

9. Specimen Preparation

9.1 *Test Disks:*

9.1.1 Use the die shown in Fig. 1 for the molding of test disks. The test resin shall be near ambient temperature prior to molding (Note 5). **Warning—**PTFE can evolve small quantities of gaseous products when heated above 204°C (400°F). Some of these gases are harmful. Consequently, exhaust ventilation must be used whenever the resins are heated above this temperature, as they are during the sintering operations that are a part of this specification. Since the temperature of burning tobacco exceeds 204°C (400°F), those working with PTFE resins should ensure that tobacco is not contaminated.

9.1.2 Screen 14.5 g (for tensile properties) or 7.25 g (for electrical properties discussed in Appendix X1.7) of PTFE resin through a No. 10 hand sieve into the die. Adjust the lower plug height to allow the resin in the die can be leveled by drawing a straightedge in contact with the top of the die across the top of the die cavity. Insert the die in a suitable hydraulic press and apply pressure gradually (Note 3) until a total of 34.5 MPa (5000 psi) is attained. Hold this pressure for 3 min. Remove the disk identification on the disk at this time.

NOTE 3—As a guide, increasing the pressure at a rate of 3.45 MPa (500 psi)/min is suggested until the desired maximum pressure is attained.

9.1.3 Sinter the preforms in accordance with Table 3 (Note 4).

9.1.3.1 Use Procedure B for Types I, II and IV and Procedure C for Type III.

NOTE 4—Although the rate of heating application is not critical, the cooling cycle is most important and the conditions cited in these procedures must be followed very closely. If they are not followed, the crystallinity of the disks and the resulting physical properties will be markedly changed. Therefore, the use of a programmed oven is recommended for the most precise sintering cycle control so that the hood window will be left down during the entire sintering procedure, the latter being an important safety consideration.

9.2 *Test Specimens for Standard Specific Gravity (SSG) and Extended Specific Gravity (ESG):*

9.2.1 A cylindrical preforming die, 28.6 mm (1⅛ in.) internal diameter by at least 76.2 mm (3 in.) deep, is used to prepare the preforms. End plug clearances shall be sufficient to ensure escape of air during pressing. The test resin shall be near ambient temperature prior to molding (Note 5).

NOTE 5—For maximum precision, the weighing and preforming operations shall be carried out at 23 ± 2°C (73.4 ± 3.6°F) (the "near ambient" temperature referred to herein). These operations shall not be preformed at temperatures below 21°C (70°F) due to the crystalline transition that occurs in PTFE in this temperature region which leads to possible cracks in sintered specimens and differences in specimen density (as well as changes in other physical properties). Problems caused by the effects of temperature on the specific gravity or density of PTFE will be minimized when the measurement is made using immersion procedures if a sensitive thermometer (for example, one reading ±0.1°C) is used in the liquid and the temperature is adjusted to be at least 22°C.

9.2.2 Weigh out 12.0 ± 0.1 g of resin and place it in the die. Screen non-free-flowing resins through a No. 10 sieve. Break up compacted resins by hand-shaking cold resin in a half-filled

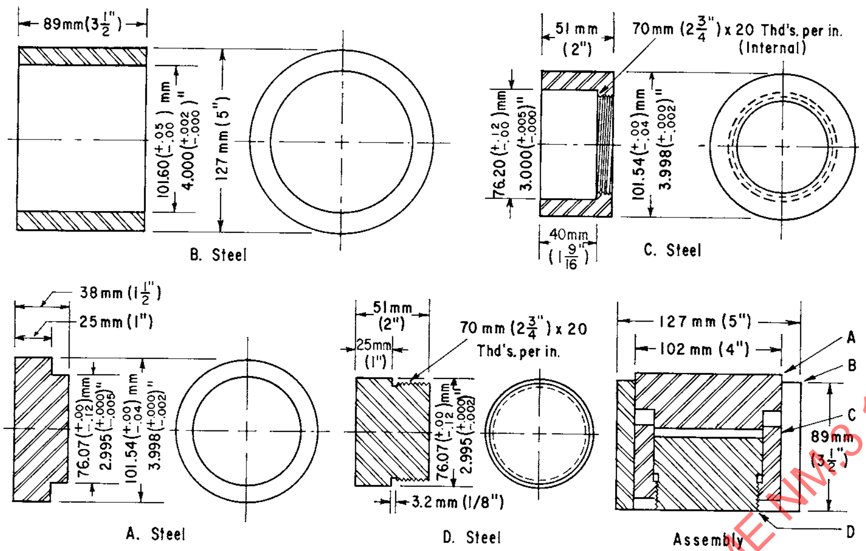


FIG. 1 Assembly and Details of Die for Molding Test Specimens

TABLE 3 Sintering Procedures

	B	C	D	E	F	G	H	I
Initial temperature, °C (°F)	290 (554)	290 (554)	238 (460)	238 (460)	290 (554)	238 (460)	238 (460)	238 (460)
Rate of heating, °C/h (°F/h)	120 ± 10 (216 ± 18)	120 ± 10 (216 ± 18)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	120 ± 10 (216 ± 18)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)
Hold temperature, °C (°F)	380 ± 6 (716 ± 10)	357 ± 8 (675 ± 15)	371 ± 6 (700 ± 10)	360 ± 6 (685 ± 10)	380 ± 6 (716 ± 10)	357 ± 8 (675 ± 5)	380 ± 6 (716 ± 10)	371 ± 6 (700 ± 10)
Hold time, min	30 + 2, −0	30 + 2, −0	240 ± 15	240 ± 15	360 ± 5	240 ± 15	960 ± 15	120 ± 5
Cooling rate, °C/h (°F/h)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)
Final or second hold temperature, °C (°F)	294 ± 6 (561 ± 10)	294 ± 6 (561 ± 10)	238 ± 6 (460 ± 10)	238 ± 6 (460 ± 10)	294 ± 6 (561 ± 10)	238 ± 6 (460 ± 10)	238 ± 6 (460 ± 10)	238 ± 6 (460 ± 10)
Second hold time, min	24 + 0.5, −0	24 + 0.5, −0	NA[A]	NA[A]	24 + 0.5, −0	NA[A]	NA[A]	NA[A]
Period to room temperature, min, h	½	½	6	6	½	6	6	6

[A] NA, Not applicable.

sealed glass container. Condition the resin in the sealed glass container in a freezer or dry-ice chest. After breaking up resin lumps, allow the sealed container to equilibrate to near ambient temperature. Then screen and weigh the 12.0 ± 0.1-g sample. Insert the die in a suitable hydraulic press and apply pressure gradually (Note 3) until a pressure of 34.5 MPa (5000 psi) is attained. Hold this pressure for 2 min. Remove the preform from the die. Write the sample identification number using an appropriate marker that will not effect the PTFE during sintering on the preform at this time.

9.2.3 Sinter the preforms in accordance with Table 3 (Note 4).

9.2.3.1 For SSG specimens use Procedure B for Types I, II and IV and Procedure C for Type III.

9.2.3.2 For ESG specimens use Procedure F for Types I, II and IV and Procedure G for Type III.

NOTE 6—Improved precision in SSG and ESG test results has been obtained with the use of an upright, cylindrical oven and an aluminum sintering rack. The cylindrical oven has an inside diameter of 140 mm (5.5 in.) and an inside depth of 203 mm (8 in.) plus additional depth to accommodate a 50.8-mm (2-in.) thick cover, and is equipped with suitable heaters and controllers to sinter specimens in accordance with the Procedures in Table 3. The rack, as shown in Fig. 2, allows preforms to be placed symmetrically in the center region of the oven. Place six preforms

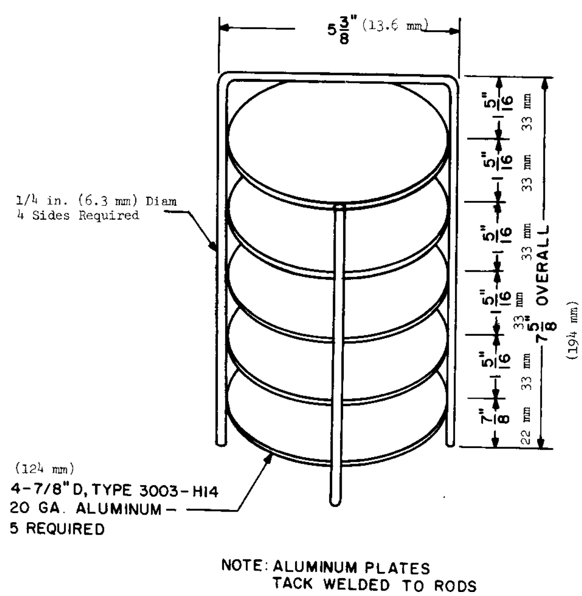


FIG. 2 SSG Samples Sintering Rack

on each of the middle oven rack shelves (if six or fewer preforms are to

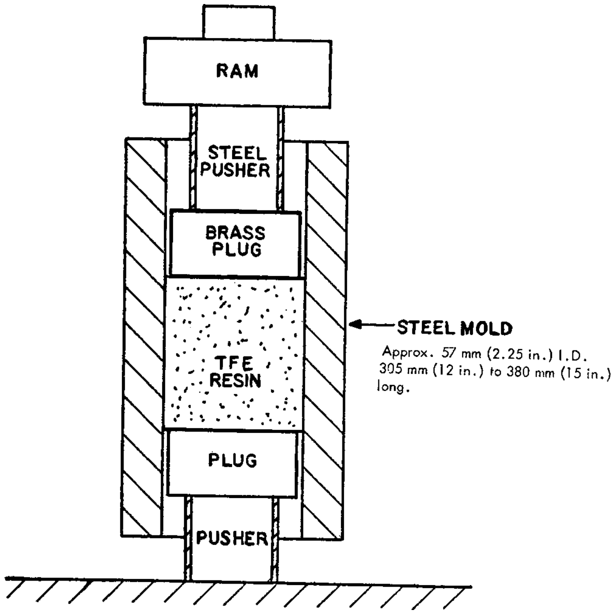


FIG. 3 Preforming of PTFE Test Billet

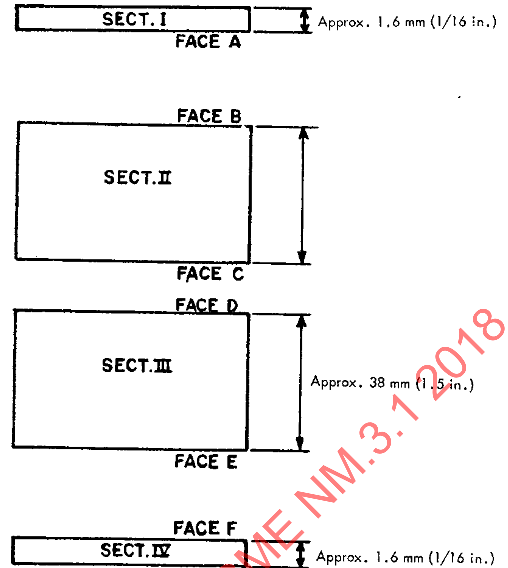


FIG. 4 Sectioned PTFE Test Billet

be sintered, place them on the middle rack, filling in with "dummies" as needed). Place "dummies" on the top and bottom shelves. Specimens must be spaced evenly in a circle on each shelf, with none of them touching. An oven load must be no less than 18 pieces including "dummies." "Dummies" are defined as normal 12-g specimens that have previously been through the sintering cycle. "Dummies" must only be used for an additional two or three thermal cycles, due to eventual loss of thermal stability and physical form.

9.2.4 Remove all flash from each specimen so that no air bubbles will cling to the edges when the specimen is immersed in the solution for weighing during the standard specific gravity and thermal instability index tests. It is recommended for this section and during testing that cotton gloves be worn while handling test specimens.

9.3 *Test Billets:*

9.3.1 Use test specimens cut or skived from billets may be used as alternatives to the test disks described in 9.1 and 9.2 for Types I, II, III and IV resins.

9.3.2 Mold test billets in a mold similar to Fig. 3, having an inside diameter of 57 mm (2.25 in.) and of sufficient height to contain the resin sample. Plug clearance shall be sufficient to ensure escape of air during pressing. A 254-mm (10-in.) mold cavity fill depth will produce a billet approximately 76 mm (3 in.) long from a resin charge of 400 ± 50 g. Vary the billet length in accordance with the testing to be done. The test resin shall be near ambient temperature prior to molding (Note 4).

9.3.2.1 Adjust the lower plug position using a support ring to position the mold shell so that the resin level will not come within 13 mm (0.5 in.) of the top of the mold cavity. Add the resin to the mold, insert the top plug, and apply hand pressure. Remove the support ring, and place the mold in a hydraulic press.

9.3.2.2 Apply an initial pressure of 3.45 MPa (500 psi) ±10 % and hold for 1 to 2 min. Increase the pressure smoothly to the final preforming pressure in 3 to 5 min. Do not allow the mold shell to contact either press platen at any time during this preforming step. The final pressure attained, if not recommended by the manufacturer of the particular material, shall be 34.5 MPa (5000 psi) for Type I and 17.2 MPa (2500 psi) for Types II, III and IV. Hold under maximum pressure for 2 to 5 min. Release the pressure by gradually "cracking" the pressure release valve without an apparent movement of the press platens. Remove the top pusher and force the preform vertically out of the mold shell using a continuous, smooth movement.

NOTE 7—Remove the mold in a careful smooth movement from the die to prevent cracking.

9.3.3 Sinter the preform in accordance with Table 3 (Note 4).

9.3.3.1 Use Procedure D for Types I, II and IV and Procedure E for Type III—except for ESG specimens.

9.3.3.2 For ESG specimens use Procedure H for Types I, II, and IV and Procedure I for Type III.

9.3.4 Divide the test billet into sections by making transverse cuts by machining, or by a suitable alternate procedure, in accordance with Fig. 4. Use a saw for the rough cuts between Sections I and II and between sections III and IV, but Faces C and D must be prepared by machining. Prepare five test specimens for the determination of tensile properties from 0.8-mm (1⁄32-in.) thick slices machined from Section II, Face C, and machine a slice of suitable thickness for standard specific gravity measurements as described in 10.5. Care shall be taken to avoid wedge-shaped cuts. Use the remainder of Section II to prepare tape specimens by skiving 0.13 mm (5 mils) thick. Discard the initial five revolutions of skived tape before taking the test sample. Use the tape for the determination of tensile properties, as an alternative to machined disks. If electrical properties, discussed in the Appendix, are to be determined on tape, Sections II and III must be left together in order that a tape of sufficient width is obtained to allow the cutting of a 50.8-mm (2-in.) diameter electrical test specimen.

9.4 *Conditioning Test Specimens:*

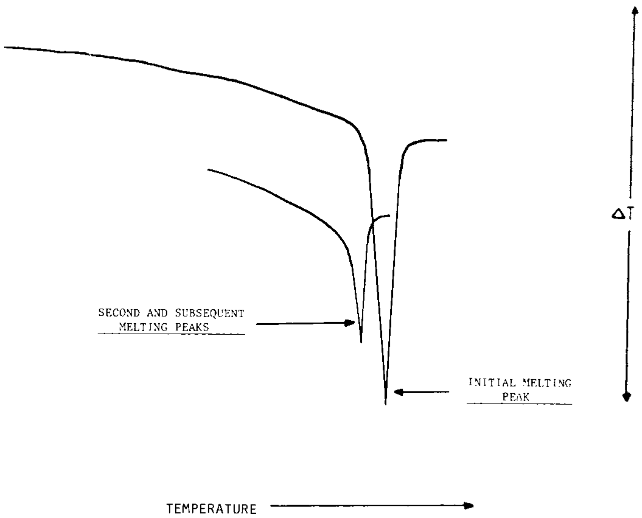


FIG. 5 Melting Characteristics by Thermal Analysis

9.4.1 For tests of tensile properties and all tests requiring the measurement of specific gravity condition the test specimens in general accordance with Procedure A of Practice D618, with the following deviations therefrom: a) the aging period shall be a minimum of 4 h immediately prior to testing, b) the laboratory temperature shall be 23 ± 2°C (73.4 ± 3.6°F), and c) there shall be no requirement respecting humidity. The other tests require no conditioning of the molded test specimens.

9.5 *Test Conditions:*

9.5.1 Tests shall be conducted at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F). See Note 5 for additional details. Since these resins do not absorb water, the maintenance of constant humidity during testing is not required.

10. Test Methods

10.1 *Melting Characteristics by Thermal Analysis:*

10.1.1 *Significance and Use*—Most of the PTFE resins that fall within the scope of this specification have never been melted (the only exception is Type V resin). These resins have higher melting peak temperatures on initial melting than on second or subsequent meltings. Since PTFE resins that have been melted prior to use behave differently from those that have not, the melting characteristics of resins provide important distinctions among them. Melting peak temperatures (see Fig. 5) are used to make these distinctions, and determine conformance of a resin to the melting peak temperature requirements given in Table 1 of this specification. A resin that has been melted is not compatible with this specification, except for Type V.

10.1.2 *Apparatus*—Use apparatus described in Test Method D4591.

10.1.3 *Procedure:*

10.1.3.1 Measure melting peak temperatures in accordance with the procedures given in Method D4591. An initial melting peak temperature above the melting peak temperature obtained on the second and subsequent melting (defined as the second melting peak temperature) indicates that the resin was not melted before the test. The second melting peak temperature occurs at about 327°C (621°F). Usually the difference between the initial and second melting peak temperatures is greater than 5°C (9°F), as seen in Table 1. If peak temperatures are difficult to discern from the curves, that is, if the peaks are rounded rather than pointed, straight lines shall be drawn tangent to the sides of the peak. Where these lines intersect beyond the peak shall be taken as the peak temperature. Where more than one peak occurs during the initial melting test, the presence of any peak corresponding to the second melting peak temperature indicates the presence of some previously melted material.

10.2 *Bulk Density:*

10.2.1 *Significance and Use*—Bulk density gives some indication of how a resin will perform during feeding of molding and ram extrusion equipment. PTFE resins have a tendency to compact during shipment and storage, and even though the material is broken up by screening or some other means, original "as produced" results are not guaranteed. Because of this tendency to pack under small amounts of compression or shear, Test Method D1895 is not applicable to these resins. The procedure given in the following paragraphs must be used to measure this property.

10.2.2 *Apparatus:*

10.2.2.1 *Funnel*—A funnel arrangement as shown in Fig. 6.

10.2.2.2 *Feeder* —A feeder with a No. 8 wire screen placed over approximately the top two-thirds of the trough. The funnel shall be mounted permanently in the feeder outlet.

10.2.2.3 *Controller*

10.2.2.4 *Volumetric Cup and Cup Stand* (Fig. 7)—The volumetric cup shall be calibrated initially to 250 mL by filling it with distilled water, placing a planar glass plate on top, drying the outside of the cup, and weighing. The net weight shall be 250 ± 0.5 g. The top and bottom faces of the volumetric cup and the cup stand shall be machined plane and parallel.

10.2.2.5 *Leveling Device*—The leveler (Fig. 8) shall be affixed permanently to the table and adjusted so that the sawtooth edge of the leveler blade passes within 0.8 mm (1⁄32 in.) of the top of the volumetric cup.

10.2.2.6 *Work Surface*—The work surface for holding the volumetric cup and leveler shall be essentially free from vibration. The feeder, therefore, must be mounted on an adjoining table or wall bracket.

10.2.2.7 *Balance*—The balance having an extended beam shall have a capacity of 500 g and a sensitivity of 0.1 g or equivalent.

10.2.3 *Procedure:*

10.2.3.1 Place the clean, dry volumetric cup on the extended beam of the balance and adjust the tare to zero. Select about 500 mL of the resin to be tested, place it on the feeder screen and vibrate all of the resin through the screen and back into the sample container twice to break up any lumps. Put the cup in the cup stand and place the assembly such that the distance of

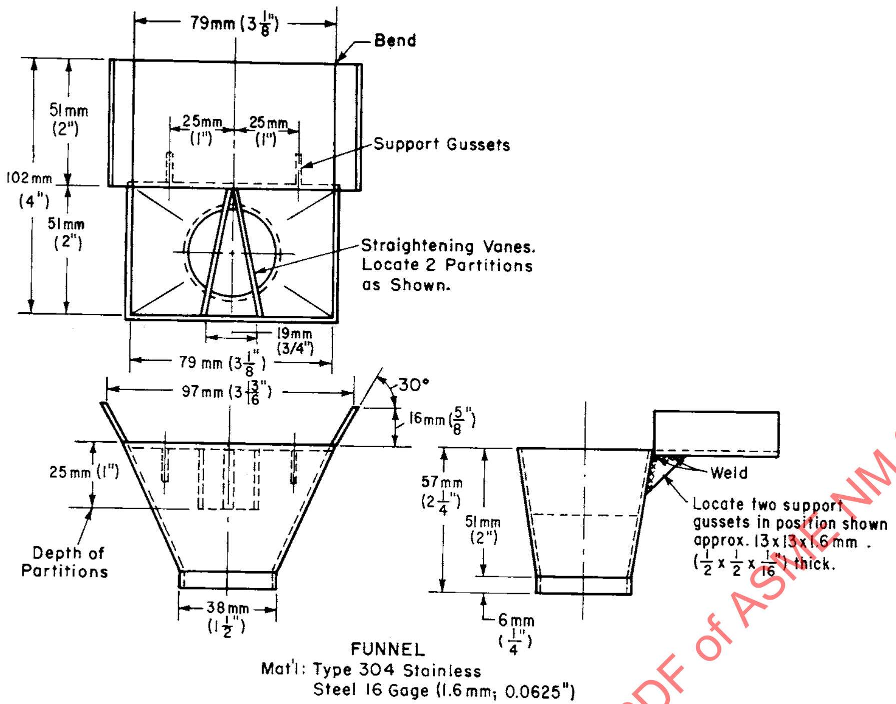


FIG. 6 Details of Funnel for Bulk Density Test

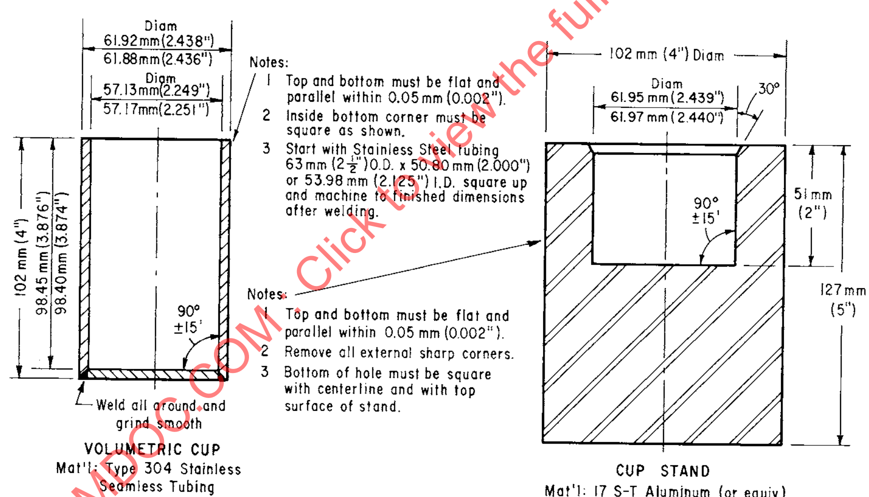


FIG. 7 Volumetric Cap and Cap Stand for Bulk Density Test

free polymer fall from the feeder outlet to the top rim of the cup shall be 38.1 ± 3.2 mm (1½ ± ⅛ in.). Increased fall causes packing in the cup and higher Bulk Density values. Set the controller so that the cup is filled in 20 to 30 s. Pour the sample on the vibrating screen and fill the cup so that the resin forms a mound and overflows. Let the resin settle for about 15 s and then gently push the cup and its stand beneath the leveler. Exercise care to avoid agitation of the resin and cup before leveling. Weigh the resin to the nearest 0.1 g.

10.2.4 *Calculation*—Calculate the bulk density as follows:

$$\text{Grams of resin} \times 4 = \text{bulk density (grams per litre)}$$

10.2.5 *Precision and Bias*—A precision statement for use with this procedure is under development. The procedure in this test method has no bias because the value of bulk density is defined only in terms of a test method.

10.3 *Particle Size:*

10.3.1 *Significance and Use*—The fabrication of PTFE resins either by molding or extrusion is affected significantly by particle (or agglomerate) size and size distribution. (See Appendix X1. for further details on particle characteristics.) The average particle size of PTFE resins is determined by fractionation of the material with a series of sieves. Fractionation is facilitated by spraying with perchloroethylene which breaks up lumps and prevents clogging of the sieve openings. (**Warning—**Perchloroethylene is under investigation by government agencies and industry for its carcinogenic effects.

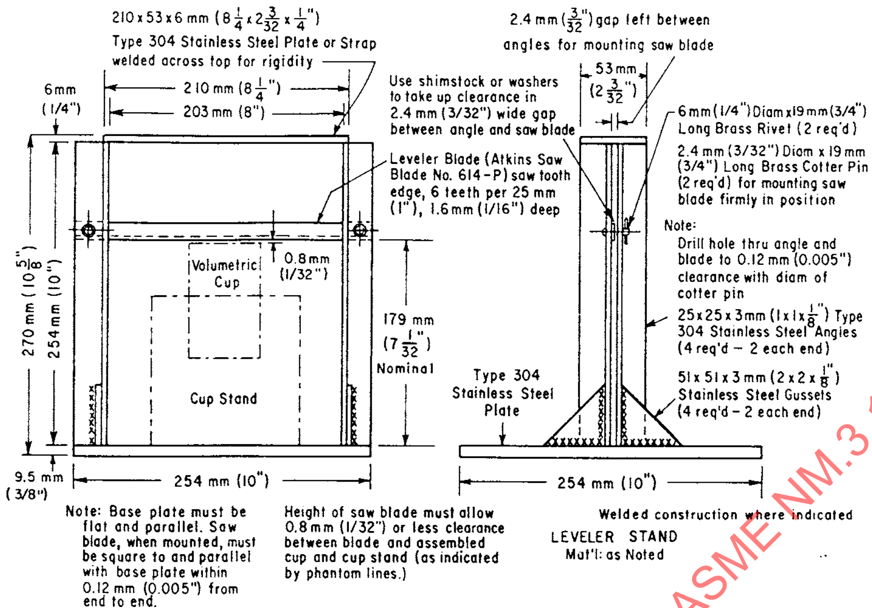


FIG. 8 Leveler Stand for Bulk Density Test

Protective nitrile or butyl gloves shall be worn to prevent skin contact and adequate ventilation provided to remove the vapors.)

10.3.2 *Apparatus:*

10.3.2.1 *Balance*—capable of weighing to ±0.1 g.

10.3.2.2 *Sieves*—U.S. Standard Sieve Series, 203-mm (8-in.) diameter conforming to Specification E11. Sieve Numbers shall be selected from Table 4.

10.3.2.3 *Ventilated Hood.*

10.3.2.4 *Beakers*—Six tared, 150-mL beakers.

NOTE 8—As an alternative, sieves are tared, dried, and weighed on a balance to avoid transferring of fractionated samples to the tared beakers.

10.3.2.5 *Apparatus for Sieving and Spraying*—A suggested arrangement of an apparatus for recirculating perchloroethylene is shown in Fig. 9 (*a*). This must be located in a ventilated hood or adequately ventilated area.

10.3.3 *Reagents—Perchloroethylene,* 20 L (5 gal). The use of other liquids, their applicability and hazards associated with their use must be thoroughly investigated.

10.3.4 *Procedure:*

10.3.4.1 Select the appropriate sample size and combination of sieves from Table 4 for the type of resin under test. Adjust the flow rate of the perchloroethylene to 6 ± 0.5 L/min.

10.3.4.2 Place the weighed resin on the top sieve and spray it with perchloroethylene for 1 ± 0.2 min. The shower-head shall be about level with the top of the sieve and be moved in a circular fashion. Take care to break up all of the lumps and to wash the material from the sides of the sieve.

10.3.4.3 Remove the top sieve and place it in the hood to dry.

10.3.4.4 Repeat the procedure specified in 10.3.4.2 and 10.3.4.3 until all the sieves have been sprayed. Air-dry the sieves in the hood for 30 min or longer, or oven-dry at 90°C (194°F) for 15 min and then cool to room temperature. Remove the resin from each sieve by tapping on a piece of paper as shown in Fig. 9 (*b*). Pour each fraction into a tared beaker and weigh to ±0.1 g (See Note 8).

10.3.4.5 Record the weight of resin on each sieve.

10.3.4.6 Clean the sieve by inverting it over filter paper and spraying with perchloroethylene. Take care to prevent the resin from getting into the perchloroethylene.

10.3.5 *Calculation*—Calculate the net percentage of resin on each sieve as follows:

$$\text{Net percentage on sieve } Y = F \times \text{weight of resin in grams on sieve } Y.$$

where:

F = 2 for 50-g sample, and
F = 10 for 10-g sample.

10.3.5.1 Calculate the cumulative percentage of resin on each sieve as follows:

Cumulative percentage on sieve Y = sum of net percentages on sieve Y and sieves having numbers smaller than Y.

NOTE 9—Example—Cumulative percentage on 500 µm (No. 35) sieve for a Type V resin = net percentage on 1.00 mm (No. 18) plus net percentage on 710 µm (No. 25) plus net percentage on 500 µm (No. 35) sieves.

10.3.5.2 Plot the cumulative percentage versus the sieve opening size (or sieve number) on log-probability paper as shown in the sample plot (Fig. 10). The sieve numbers and sieve opening sizes in micrometres are indicated below the figure. Draw the best straight line through the points and read the Particle Size at the 50 % cumulative percentage point (d_{50}).

10.3.5.3 Calculate the Particle Size, Average Diameter, $\bar{d}$ as follows:

$$\bar{d} = d_{50} \text{ (micrometres)}$$

10.3.6 *Precision and Bias:*

TABLE 4 Sieving Requirements[A]

Sieve Number (opening)	Type I	Type II[B]	Type III 1[B]	Type III 2	Type IV	Type V	Type VI
14 (1.40 mm)	X			X	X		X
18 (1.00 mm)	X			X	X	X	X
25 (710 μm)	X	X	X	X	X	X	X
35 (500 μm)	X			X	X	X	X
45 (355 μm)	X			X	X	X	X
60 (250 μm)	X			X	X		X
80 (180 μm)	X			X	X	X	X
120 (125 μm)						X	
170 (90 μm)		X	X				
200 (75 μm)		X	X				
230 (63 μm)		X	X				
270 (53 μm)		X	X				
325 (45 μm)		X	X				
400 (38 μm)		X	X			X	
Sample size, g							
10 ± 0.1	X		X				
50 ± 0.1	X			X	X	X	X

[A] It is suggested that the sieves and sample size checked in a "Type Grade" column be used when performing the sieve analysis on that particular type grade.
[B] A discussion of the particular characteristics of finely divided resins is found in Appendix X1.

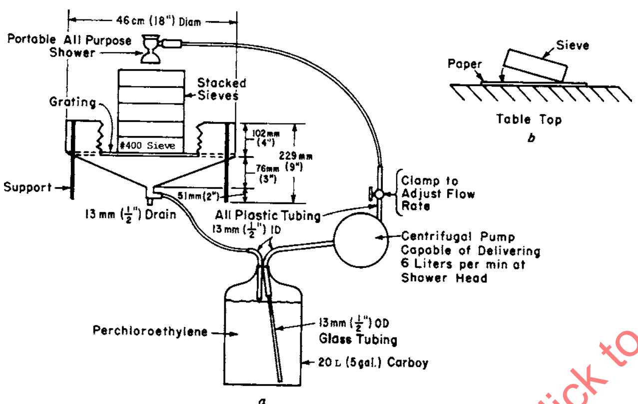
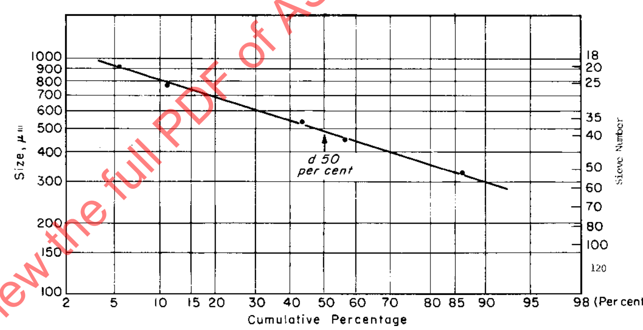


FIG. 9 Apparatus for Particle Size Test



Sieve. No.	Sieve Opening, μm	Sieve No.	Sieve Opening, μm
14	1400		
18	1000	80	180
25	710	120	125
35	500	170	90
45	355	200	75
60	250	230	63
		270	53
		325	45
		400	38

FIG. 10 Sample Plot of Cumulative Percent Versus Sieve Opening Size for Determination of Particle Size

10.3.6.1 Because the resin particles have complex shapes, and because on each sieve there is a distribution of particle sizes, the values for particle size and particle size distribution obtained will be only relative numbers. The 95 % confidence limits based on a limited series of tests are ±2.8 % for the average particle size. Since there is no accepted reference material suitable for determination of the bias for this test procedure, no statement on bias is being made.

10.3.7 Alternative methods for particle size are available. *Light Scattering Instruments/Light Defraction Instruments* (see ISO 12086-2, 8.6.4) and *Electron Zone Sensing Instruments,* which is a resistance-variation tester, (see ISO 12086-2, 8.6.3) are used as long as there is a direct correlation to the Particle Size Analysis in 10.3 of this specification.

10.3.7.1 This alternative method is very dependent on particle shape and is only recommended for processes that are stable and that have regular spherical type shape particles. Also, it is recommended that each manufacturing processor do an analysis to determine their own correlation.

10.4 *Water Content:*

10.4.1 *Significance and Use*—The presence of an excessive amount of water in PTFE resin has a significant adverse effect upon the processing characteristics of the resin and the quality of products made using the resin. A sample of PTFE resin of known weight is dried in a vacuum oven in a tared aluminum weighing dish. When the resin is dry, it is removed from the oven, placed in a desiccator, allowed to cool, and then reweighed. Water content is calculated from the weight lost during drying.

10.4.2 *Apparatus:*

10.4.2.1 *Balance,* capable of weighing to the nearest 0.0001 g.

10.4.2.2 *Vacuum Oven.*

10.4.2.3 *Aluminum Weighing Dishes,* with lids.

10.4.3 *Procedure* (Note 10):

10.4.3.1 Wash the aluminum weighing dishes with water and rinse with acetone. When the acetone has evaporated from the dishes, dry them thoroughly in an oven at 50 to 80°C (122 to 176°F), then store in a desiccator until ready for use. Obtain the tare weight, B, of an aluminum weighing dish, plus lid, to the nearest 0.0001 g. Place 35 to 40 g of PTFE resin in the tared aluminum weighing dish and record the weight (including lid), A, to the nearest 0.0001 g (Note 10). Dry to constant weight in a vacuum oven (635 mm (25 in.) Hg) at 150°C (302°F), with the dish lid removed. Remove the dish from the oven, replace the lid on the weighing dish, and allow to cool in the desiccator for at least 30 min. Reweigh the dish (plus the resin and lid), C, and calculate the weight loss.

NOTE 10—Select one sample from each group of samples and run duplicate water content determinations on it. If the difference between the duplicate results exceeds 0.01 %, the entire group of samples must be run over.

NOTE 11—When a group of samples is run at the same time, it is good practice to place the lids from the weighing dishes directly under their corresponding dishes while the samples are drying in the oven. This eliminates the possibility of introducing errors in the tare weights. Also, overnight drying in a circulating air oven is used if the data are shown to be equivalent to those obtained with the above procedure.

10.4.4 *Calculation:*

10.4.4.1 Calculate the water content as follows:

$$\text{water content, \%} = (A - C)/(A - B) \times 100$$

where:

A = weight of resin, dish, and lid, g, before drying
B = weight of dish and lid, g and,
C = weight of resin, dish, and lid after drying, g.

10.4.5 *Precision and Bias:*

10.4.5.1 The precision of this test is ±0.0063 % (two sigma limits). Since there is no accepted reference material for determining the bias in this test procedure, no statement on bias is being made.

10.5 *Standard Specific Gravity (SSG):*

10.5.1 *Significance and Use*—The specific gravity of an article made from a PTFE resin is affected both by the particular resin used and by the way the resin is processed. Therefore, a test method that measures the specific gravity of an article prepared in a precisely defined way provides valuable resin characterization data. The specific gravity of a specimen of PTFE resin prepared in accordance with all of the requirements of 9.2.3.1 or 9.3.3.1 defines the SSG for that resin specimen.

10.5.2 *Procedure:*

10.5.2.1 Determine, in accordance with 10.5.2.4, the specific gravity of specimens prepared in 9.2.3.1 or 9.3.3.1.

10.5.2.2 If specimens from 9.2.3.1 are to be tested, use them as is.

10.5.2.3 If specimens from 9.3.3.1 are to be tested, use the center portion of the sintered billet (Section II of Fig. 4). From it, cut an approximately cubical shape which weighs at least 10 g (for example, a cube about 17 mm (0.67 in.) on a side).

10.5.2.4 Make specific gravity determinations in accordance with the procedures described in Test Methods D792, Method A-1. Add two drops of a wetting agent to the water in order to reduce the surface tension and ensure complete wetting of the specimen.

10.6 *Thermal Instability Index (TII):*

10.6.1 *Significance and Use*—This test method compares the SSG of a resin (determined in 10.5) to its Extended Specific Gravity (ESG) (determined here). Specimens used to determine ESG are identical to those used to determine SSG, except for the differences in thermal history described in 9.2.3 and 9.3.3. The specific gravity of a specimen prepared in accordance with all of the requirements of 9.2.3.2 or 9.3.3.2 defines the ESG for that resin specimen.

10.6.2 *Procedure:*

10.6.2.1 Determine, in accordance with 10.5.2.4, the specific gravity of specimens prepared in 9.2.3.2 or 9.3.3.2.

10.6.2.2 If specimens from 9.2.3.2 are to be tested, use them as is.

10.6.2.3 If specimens from 9.3.3.2 are to be tested, use the center portion of the billet (Section III of Fig. 4).

10.6.3 *Calculation*—Calculate the thermal instability index (TII) as

$$\text{TII} = (\text{ESG} - \text{SSG}) \times 1000$$

10.7 *Tensile Properties:*

10.7.1 *Procedure:*

10.7.1.1 Cut five tensile specimens from a disk prepared in accordance with all of the requirements of 9.1.3.1 (or from a billet prepared in accordance with all of the requirements of 9.3.3.1 and cut or skived as in 9.3.4), with the microtensile die described in Fig. 11. Determine the tensile strength in accordance with the procedures described in Test Method D638, except that the initial jaw separation shall be 22.2 ± 0.13 mm (0.875 ± 0.005 in.), and the speed of testing shall be 50 mm (2 in.)/min. Clamp the specimen with essentially equal lengths in each jaw. Determine elongation at break from the chart, expressed as a percentage of the initial jaw separation.

10.7.2 *Precision and Bias:*

10.7.2.1 A precision and bias statement for use with this procedure is under development and will be included when it has been approved by the balloting process.

11. Inspection

11.1 Inspection of the material supplied with reference to this specification shall be for conformance to the requirements specified herein.

11.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of the following:

11.2.1 Bulk density,
11.2.2 Particle size,
11.2.3 Water content, and
11.2.4 Standard Specific Gravity.

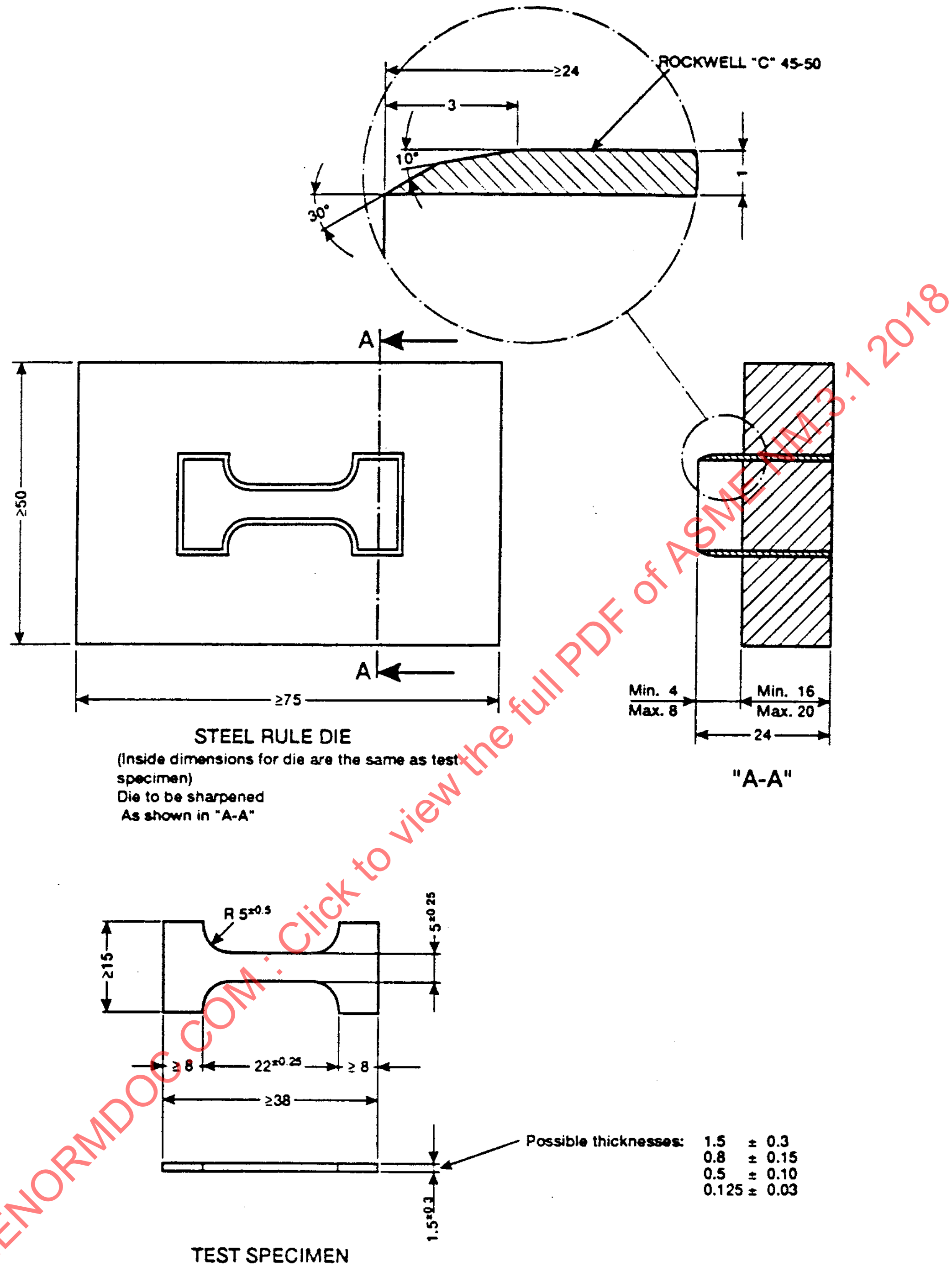


FIG. 11 Microtensile Die

11.3 Periodic check inspection with reference to a specification shall consist of the tests for all requirements of the material under the specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with Annex A1.

11.4 A report of test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

12. Certification

12.1 Certification shall be as required by Annex A1.

13. Packaging and Package Marking

13.1 *Packaging*—The resin shall be packaged in standard commercial containers so constructed as to ensure acceptance by common or other carriers for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

13.2 *Package Marking*—Shipping containers shall be marked with the name of the resin, type, and quantity contained therein.

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

14. Keywords

14.1 fluoropolymers; granular polytetrafluoroethylene; polytetrafluoroethylene; PTFE

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. *Ordering Information*—The purchase order shall state this ASTM designation and year of issue, and which type and grade is desired.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL USEFUL TESTS

X1.1 Scope

X1.1.1 In addition to their use for specification purposes, the tests described in this specification have utility for characterizing PTFE resins. Other useful properties of PTFE can be measured by adding a few details to the specification tests. The purpose of this Appendix is to provide the details needed to determine these additional characteristics. The scope is summarized in Table X1.1.

X1.2 Referenced Documents

X1.2.1 *ASTM Standards:*

X1.2.1.1 The following standards are referenced herein, in addition to those already listed in Section 1.1 of the Standard:

D150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials

D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics

D3293 Specification for PTFE Resin Molded Sheet

D3294 Specification for PTFE Resin Molded Basic Shapes

D3308 Specification for PTFE Resin Skived Tape

D3369 Specification for TFE-Fluorocarbon Resin Cast Film

X1.3 Dimensional Changes During Molding (Shrinkage and Growth)

X1.3.1 Measure the inside diameter (ID) to ±0.00254 mm (0.0001 in.) of the die used to make the preform in 9.1, 9.2, or 9.3. Measure the diameter and height at the preform. After the piece has been sintered and cooled to ambient temperature, measure the diameter and height of the sintered piece.

X1.3.2 *Calculation:*

X1.3.2.1 Percent mold shrinkage = [(diameter of sintered piece/ID) − 1] × 100

TABLE X1.1

Specification Test Reference	Specification Property Measured	Additional Information Available
10.5	Standard Specific Gravity	Dimensional change during molding (shrinkage and growth)
10.1	Melting Characteristics by Thermal Analysis	Heats of fusion and crystallization
10.3	Particle Size	(a) Average Particle Size for resins smaller than those covered by the standard specification (b) Percent coarse particles (percent >63 μm) in small particle size resins
10.7	Tensile Properties	Yield stress and tangent modulus at rupture Electrical Properties: Dielectric constant Dissipation factor Dielectric breakdown voltage Dielectric strength Tensile creep strain

X1.3.2.2 Percent preform shrinkage = [(diameter of sintered piece/diameter of preform) − 1] × 100

X1.3.2.3 Percent growth = [(height of sintered piece/height of preform) − 1] × 100

X1.3.2.4 Positive values reflect an increase in the dimension during sintering. Negative values reflect a decrease in the dimension during sintering.

X1.4 Size and Distribution of Size of Particles or Agglomerates in PTFE Resins

X1.4.1 *Average Size of Fine-Particle Size PTFE*—Wet-sieve analysis, while having disadvantages, can be used to measure the average size of Type II and Type III PTFE resins. The procedure of 10.3 shall be followed using the set of sieves listed in Table 4 and a sample size of 10.0 g.

X1.4.2 *Material Retained on 63-µm (No. 230) Sieve:*

X1.4.2.1 *Scope*—A wet sieving is performed with the apparatus used for the determination of particle size, except that only three sieves are employed. This method is applicable to ultrafine resins such as Type II resins. The resin is sieved on a 63 µm (No. 230) sieve by spraying with perchloroethylene which breaks up agglomerates and prevents clogging of the sieve openings (See Note 7).

X1.4.2.2 *Apparatus*—Same as in 10.3.2, except that the following sieves are used: U.S. Standard Sieves, 850 µm (No. 20), 63 µm (No. 230), and 45 µm (No. 325).

X1.4.2.3 *Procedure:*

X1.4.2.4 Weigh 10 ± 0.01 g of resin. Assemble the sieves as shown in Fig. 10 (*a*). Adjust the flow rate of the perchloroethylene to 6 ± 0.5 L/min.

X1.4.2.5 Place the weighed sample on the 850 µm (No. 20) sieve and spray with perchloroethylene for exactly 1 min using a timer. This step assists in breaking up agglomerates. Move the shower-head in a circular fashion, taking care to break up all the agglomerates and to wash the material from the sides of the sieve.

X1.4.2.6 Remove the 850 µm (No. 20) sieve and spray the 63 µm (No. 230) sieve for exactly 6 min, using a timer. Wash the material to the side of the sieve during the last minute.

X1.4.2.7 Dry the sieve and retained resin in an oven for 20 min or longer at 80 to 120°C (176 to 248°F). The No. 20 sieve does not require drying.

X1.4.2.8 Remove the material from the 63 µm (No. 230) sieve by inverting on a piece of filter paper and tapping to free dry polymer. Use a stiff brush to help free all the material from the sieve. Pour the dried resin into a tared weighing dish and weigh to ±0.01 g. Alternatively, determined the tare weight of the resin retained on the sieve from the difference between the gross weight after sieving and the tare weight of the sieve before sieving. A balance with a sensitivity of about 0.01 g is required for good precision.

X1.4.2.9 *Calculation*—the percentage of resin retained on the No. 230 sieve is calculated as follows:

$$\text{Amount retained, \%} = (\text{weight retained/sample weight}) \times 100$$

X1.4.3 *Distribution of Particle or Agglomerate Sizes in PTFE Resin:*

X1.4.3.1 *Procedure*—Using the graph plotted in accordance with 10.3.5.2 or 10.3.5.3, draw the best smooth curve through the data points and read the values for the sizes at cumulative percentages of 16 and 84. These values, identified as $d16$ and $d84$, are, respectively, the size of the resin at the average diameter ($\bar{d}$) plus 1 sigma and ($\bar{d}$) minus 1 sigma. Calculate a distribution factor (DF) and skewness (SKEW) as follows:

$$\text{DF} = d16/d50$$

$$\text{SKEW} = \text{DF}/(d50/d84)$$

X1.4.3.2 *Precision and Bias*—Because the resin particles have complex shapes, and because on each sieve there is a distribution of particle sizes, the values for particle size and particle size distribution obtained will be only relative numbers. The 95 % confidence limits based on a limited series of tests are ±2.8 % for the average particle size and ±6 % for the particle size distribution function. Since there is no accepted reference material suitable for determination of the bias for this test procedure, no statement on bias is being made.

X1.5 Yield Behavior and Tangent Modulus at Rupture

X1.5.1 Most of the PTFE resins covered in this standard do not show a yield stress as defined in Test Method D638. Rather than the stress-strain curve having a zero slope, the rate of increase of stress with strain decreases and then increases again. An approximate yield stress shall be reported as the stress at the intersection of the two lines that best represent the initial "linear" part of the stress strain curve and the second "linear" part of the curve.

X1.5.2 *Tangent Modulus at Rupture*—The shapes of tensile stress-strain curves for PTFE resins are highly dependent on the crystallinity of the test specimen. Values for tensile strength and elongation at break do not reflect these shapes clearly. The value of the tangent to the recorded stress-strain curve measured as the best straight line from the point of rupture back along the curve is a convenient measure of the relative crystallinity of the test specimen. High values for the tangent modulus at rupture (>7.6 MPa (1200 psi)) indicate relatively low crystalline contents. As the crystallinity increases, the tangent modulus at rupture decreases until it approaches zero at high levels of crystallinity.

X1.6 Heats of Fusion and Crystallization

X1.6.1 If the melting characteristics of the PTFE resin, as determined by Section 10.1, are determined by differential scanning calorimetry (DSC) rather than in DTA mode, additional quantitative information will be obtained on the nature of the resin.

X1.6.2 Following the procedures given in Test Method D4591 for determining heats of fusion (delta Hf) and heat of crystallization (delta Hc), measure and report delta Hf for the initial and second endotherms and delta Hc for the exotherm that is observed during controlled cooling between the two heating steps. These heats of transition, especially delta Hc, provide additional characterization of crystalline content and relative molecular weight of PTFE resins.

TABLE X1.2 Typical Electrical Properties from Tests on Molded Specimens

	Type II	Type III
Dielectric constant, max, 1 kHz	2.1	2.1
Dissipation factor, max, 1 kHz	0.0003	0.0003

X1.7 Electrical Properties

X1.7.1 Determine dielectric constant and dissipation factor in accordance with Test Method D150. Determine dielectric breakdown voltage and dielectric strength in accordance with Test Method D150. Typical property values for dielectric constant and dissipation factor are listed in Table X1.2. Standards for dielectric strength of sheet, basic shapes, skived tape, and film are described in Specifications D3293, D3294, D3308, and D3369, respectively.

X1.8 Tensile Creep

X1.8.1 Determine the tensile creep of Type III materials on Test Method D638 Type II tensile bars die cut or machined from the sheets produced in X1.8.2. Make measurements in accordance with Test Method D2990. Conditions of test shall be 5.52 MPa (800 psi) stress at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3°F) for a test duration of a minimum of 100 h. Typical values for moldings of Type III resins would be a maximum of 4.0 % tensile creep strain after 100 h.

X1.8.2 Mold test sheets for Type III resins for tensile creep measurements in a picture frame mold having inside dimensions of 203 mm (8.0 in.) square and of sufficient height to contain the sample. A frame 102 mm (4 in.) in height has been found adequate when using 25-mm (1-in.) thick pusher plugs to produce a sheet approximately 3 mm (⅛ in.) in thickness from a resin charge of 300 g. Take care to level the resin charge in the mold. The molded sheet thickness shall be 3 mm (⅛ in.).

X1.8.3 Sinter the preform in accordance with procedure E of Table 3.

SPECIFICATION FOR POLYTETRAFLUOROETHYLENE (PTFE) RESIN PRODUCED FROM DISPERSION

SD-4895

(Identical with ASTM D4895-10 except for revisions in section 11, additional requirements in section 12 and Annex A1, and renumbering of sections 13 and 14.)

Specification for Polytetrafluoroethylene (PTFE) Resin Produced From Dispersion

1. Scope

1.1 This specification covers dry-powder resins of polytetrafluoroethylene (PTFE) that have been prepared from dispersions of PTFE by manufacturing techniques that involve controlled coagulation of the dispersion. These resins are generally known as "fine-powder" resins or "coagulated-dispersion powder" resins. The conversion of these resins to finished products normally involves a process called "paste extrusion," and sometimes involves formative processes such as calendering. A volatile liquid is present as a processing aid during these formative stages of conversion, and is subsequently removed during the finishing stages of conversion. These PTFE resins are homopolymers of tetrafluoroethylene, or, in some cases, modified homopolymers containing not more than 1 % by weight of other fluoromonomers. The usual methods of processing thermoplastics generally are not applicable to these materials because of their viscoelastic properties. The materials covered herein do not include mixtures of PTFE with additives such as colors, fillers, or plasticizers; nor do they include reprocessed or reground resin or any fabricated articles because the properties of such materials have been irreversibly changed when they were fibrillated or sintered. The methods and properties included are those required to identify the various resins. An additional procedure is provided in the appendix for further characterization of the resins.

1.2 The values stated in SI units as detailed in IEEE/ASTM SI-10 are to be regarded as standard. The values given in parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the Specimen Preparation Section, Section 9, and the Test Methods Section, 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 and health practices and determine the applicability of regulatory limitations prior to use.* See Warning note in 9.1.1 for a specific hazards statement.

NOTE 1—Information in this specification is technically equivalent to related information in ISO 12086-1 and ISO 12086-2.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1895 Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials
D3892 Practice for Packaging/Packing of Plastics
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4441 Specification for Aqueous Dispersions of Polytetrafluoroethylene
D4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry
D4894 Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
IEEE/ASTM SI-10 Use of the International System of Units (SI): The Modern Metric System

2.2 *ISO Standards:*

ISO 12086-1 Plastics Fluoropolymer Dispersions and Molding and Extrusion Materials—Part 1: Designation and Specification

ISO 12086-2 Plastics Fluoropolymer Dispersions and Molding and Extrusion Materials—Part 2: Preparation of Test Specimens and Determination of Properties

3. Terminology

3.1 *Definitions*—The definitions given in Terminology D883 are applicable to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulk density, n*—the mass in grams per litre of resin measured under the conditions of the test.

3.2.2 *extended specific gravity (ESG), n*—the specific gravity of a specimen of PTFE material molded as described in this specification and sintered (see 3.2.7) for an extended period of time, compared to the sintering time for the measurement of SSG (see 3.2.8), using the appropriate sintering schedule given in this specification.

3.2.3 *lot, n*—one production run or a uniform blend of two or more production runs.

3.2.4 *preforming, vb*—compacting powdered PTFE material under pressure in a mold to produce a solid object, called a preform, that is capable of being handled. Molding and compaction are terms used interchangeably with preforming for PTFE.

3.2.5 *reground resin, n*—resin produced by grinding PTFE material that has been preformed but has never been sintered.

3.2.6 *reprocessed resin, n*—resin produced by grinding PTFE material that has been preformed and sintered.

3.2.7 *sintering, n—as it applies to PTFE,* a thermal treatment during which the PTFE is melted and recrystallized by cooling with coalescence occurring during the treatment.

3.2.8 *standard specific gravity (SSG), n*—the specific gravity of a specimen of PTFE material molded as described in this specification and sintered using the appropriate sintering schedule given in this specification.

3.2.9 *strained specific gravity (strained SG), n*—the specific gravity of a specimen of PTFE material molded, sintered, and strained as described in this specification.

3.2.10 *stretching void index (SVI), n*—a measure of the change in specific gravity of PTFE material which has been subjected to tensile strain as described in this specification.

3.2.11 *thermal instability index (TII), n*—a measure of the decrease in molecular weight of PTFE material which has been heated for a prolonged period of time.

3.2.12 *unstrained specific gravity (USG), n*—the specific gravity, prior to straining, of a specimen of PTFE material used in the Stretching Void Index Test (see 10.9) of this specification.

4. Classification

4.1 This specification covers the following types of PTFE:

4.1.1 *Type I and Type II*—Resin produced from dispersion and normally used with a volatile processing aid. Each type of resin has the same requirements for bulk density, particle size, water content, melting peak temperature, tensile, and elongation. Each type of resin is divided into grades in accordance with standard specific gravity (SSG), Thermal Stability Index (TII), and Stretching Void Index (SVI). Grades are divided into classes according to extrusion pressure.

NOTE 2—See Tables 1 and 2 for details about grades and classes.

4.2 A line callout system is used to specify materials in this specification. The system uses predefined cells to refer to specific aspects of this specification, as illustrated as follows:

Specification				
Standard Number Block	Type	Grade	Class	Special Notes
Example: Specification D4895 - XX	I	2	C	

For this example, the line callout would be Specification D4895 - XX, I2C, and would specify a coagulated dispersion form of polytetrafluoroethylene that has all of the properties listed for that type, grade, and class in the appropriate specified properties or tables, or both, in the specification identified. A comma is used as the separator between the standard number and the type. Separators are not needed between the type, grade, and class.

TABLE 1 Detail Requirements for all Types,[A] Grades and Classes

Type	Bulk Density, g/L	Particle Size Average Diameter, µm	Water Content, max, %	Melting Peak Temperature, °C		Tensile Strength, min, MPa	Elongation at Break, min, %
				Initial	Second		
I	550 ± 150	500 ± 200	0.04	[B]	327 ± 10	19	200
II	550 ± 150	1050 ± 350	0.04	[B]	327 ± 10	19	200

[A] The types, grades, and classes are not the same as those in previous editions of Specification D4895.
[B] Greater than 5.0°C above the second melting peak temperature.

TABLE 2 Detail Requirements for All Types,[A] Grades and Classes

Type	Grade	Class	Standard Specific Gravity min	Standard Specific Gravity max	Extrusion Pressure, MPa	Thermal Instability Index, max	Stretching Void Index, max
I	1	A	2.14	2.18	5 to <15[B]	50	NA[C]
		B	2.14	2.18	15 to <55[D]	50	NA[C]
		C	2.14	2.18	15 to <75[E]	50	NA[C]
	2	A	2.17	2.25	5 to <15[B]	50	NA[C]
		B	2.17	2.25	15 to <55[D]	50	NA[C]
		C	2.17	2.25	15 to <75[E]	50	NA[C]
	3	C	2.15	2.19	15 to <75[E]	15	200
		D	2.15	2.19	15 to <65[E]	15	100
		E	2.15	2.19	15 to <65[E]	50	200
	4	B	2.14	2.16	15 to <55[D]	15	50
II	1	A	2.14	2.25	5 to <15[B]	50	NA[C]

[A] The types, grades, and classes are not the same as those in previous editions of Specification D4895.
[B] Tested at a reduction ratio of 100:1 (reduction ratio is the ratio of the cross-sectional area of the preform to the cross-sectional area of the die).
[C] Not applicable.
[D] Tested at a reduction ratio of 400:1.
[E] Tested at a reduction ratio of 1600:1.

5. Mechanical Properties

5.1 The resins covered by this specification shall be in accordance with the requirements prescribed in Tables 1 and 2, when tested by the procedures specified herein.

6. Other Requirements

6.1 The resin shall be uniform and shall contain no additives or foreign material.

6.2 The color of the material as shipped by the supplier shall be natural white.

6.3 For purposes of determining conformance, all specified limits for this classification system are absolute limits, as defined in Practice E29.

6.3.1 With the absolute method, an observed value is not rounded, but is to be compared directly with the limiting value. Example: In Table 2 Type I, Grade 4, Class B, under Specific Gravity, 2.14 shall be considered as 2.140000 and 2.16 shall be considered 2.160000.

7. Sampling

7.1 Sampling shall be statistically adequate to satisfy the requirements in Section 11.

8. Number of Tests

8.1 Lot inspection shall include tests for bulk density, particle size, and extrusion pressure. Periodic tests shall consist of all the tests specified in Tables 1 and 2 and shall be made at least once per year.

8.2 The tests listed in Tables 1 and 2, as they apply, are sufficient to establish conformity of a material to this specification. One set of test specimens as prescribed in Section 9 shall be considered sufficient for testing each sample. The average of the results for the specimens tested shall conform to the requirements of this specification.

9. Specimen Preparation

9.1 *Test Disks for Tensile Properties:*

9.1.1 Use the die shown in Fig. 1 for the molding of test disks (see Note 2). Place flat aluminum disks, 0.1 to 0.4 mm (0.004 in. to 0.016 in.) thick and 76 mm (3 in.) in diameter, on both sides of the resin. The test resin shall be near ambient temperature prior to molding (see Note 3). **Warning—** PTFE resins can evolve small quantities of gaseous products when heated above 204°C (400°F). Some of these gases are harmful. Consequently, exhaust ventilation must be used whenever these resins are heated above this temperature, as they are during the sintering operations that are a part of this specification. Since the temperature of burning tobacco exceeds 204°C (400°F), those working with PTFE resins shall ensure that tobacco is not contaminated.

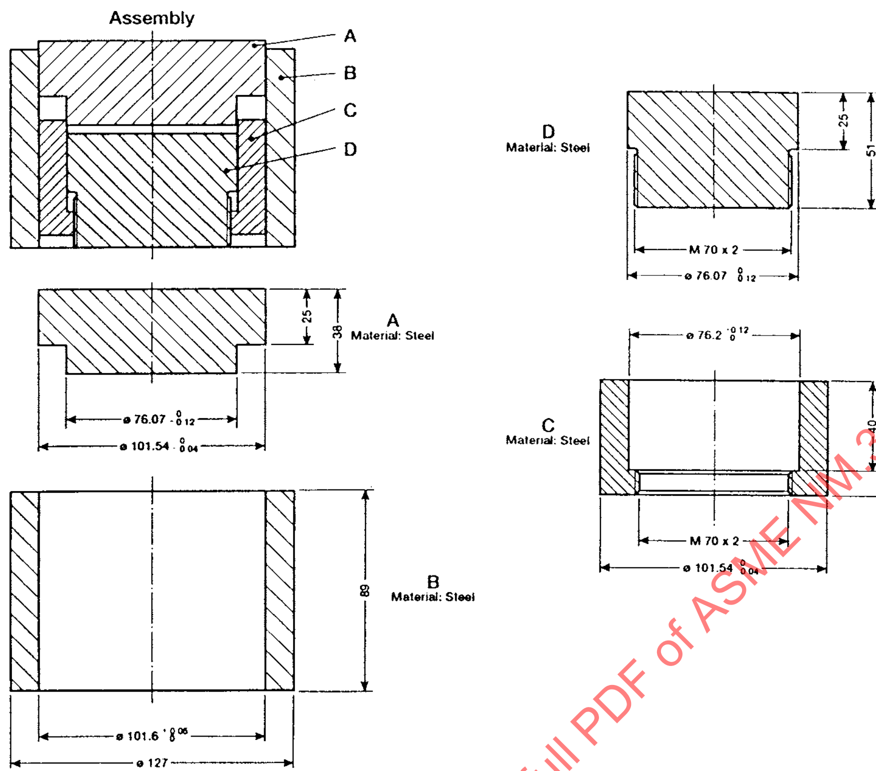
NOTE 3—For maximum precision, these weighing and preforming operations shall be carried out at 23 ± 2°C (73.4 ± 3.6°F) (the "near ambient" temperature referred to herein). These operations shall not be performed at temperatures below 21°C (70°F) due to the crystalline transition that occurs in PTFE in this temperature region which leads to possible cracks in sintered specimens and differences in specimen density (as well as changes in other physical properties). Problems caused by the effect of temperature on the specific gravity or density of PTFE shall be minimized when the measurement is made using immersion procedures if a sensitive thermometer (for example, one reading ± 0.1°C) is used in the liquid and the temperature is adjusted to be at least 22°C.

9.1.2 Screen 14.5 g of PTFE resin through a No. 10 sieve into the die. Adjust the lower plug height to allow the resin in the die can be leveled by drawing a straightedge in contact with the top of the die across the top of the die cavity. Insert the die in a suitable hydraulic press and apply pressure gradually (see Note 4) until a pressure of 14 MPa (2030 psi) is attained. Hold this pressure for 3 min. Remove the disk from the die. Write the sample identification number on the preform using an appropriate marker that will not effect the PTFE during sintering.

NOTE 4—As a guide, increasing the pressure at a rate of 3.5 MPa (500 psi)/min is suggested until the desired maximum pressure is attained.

9.1.3 Place the sintering oven in a laboratory hood (or equip it with an adequate exhaust system) and sinter the preforms in accordance with Table 3, Procedure A (see Note 5).

NOTE 5—Although the rate of heat application is not critical, the cooling cycle is most important and the conditions cited in this procedure



NOTE 1—All dimensions are in millimetres.

FIG. 1 Mold Assembly for the Preparation of Specimens for the Determination of Tensile Properties

TABLE 3 Sintering Procedures

	A	B
Initial temperature, °C (°F)	290 (554)	290 (554)
Rate of heating, °C/h (°F/h)	120 ± 10 (216 ± 18)	120 ± 10 (216 ± 18)
Hold temperature, °C (°F)	380 ± 6 (716 ± 10)	380 ± 6 (716 ± 10)
Hold time, min	30 + 2, −0	360 ± 5
Cooling rate, °C/h (°F/h)	60 ± 5 (108 ± 9)	60 ± 5 (108 ± 9)
Second hold temperature, °C (°F)	294 ± 6 (561 ± 10)	294 ± 6 (561 ± 10)
Second hold time, min	24 + 0.5, −0	24 + 0.5, −0
Period to room temperature, min	≥30	≥30

must be followed very closely. If they are not followed, the crystallinity of the disks and the resulting physical properties will be markedly changed. Therefore, the use of a programmed oven is recommended for the most precise sintering cycle control and the hood window shall be left down during the entire sintering procedure, the latter being an important safety consideration.

9.2 *Test Specimens for Standard Specific Gravity and Thermal Instability Index:*

9.2.1 A cylindrical preforming mold, 29-mm (1.14-in.) internal diameter by at least 76 mm (3 in.) deep, is used to prepare the preforms. Clearance shall be sufficient to ensure escape of air during pressing. Place flat aluminum foil disks, normally 0.13 mm (0.005 in.) thick and 29 mm (1.14 in.) in diameter on both sides of the resin. The test resin shall be near ambient temperature prior to molding (see Note 3).

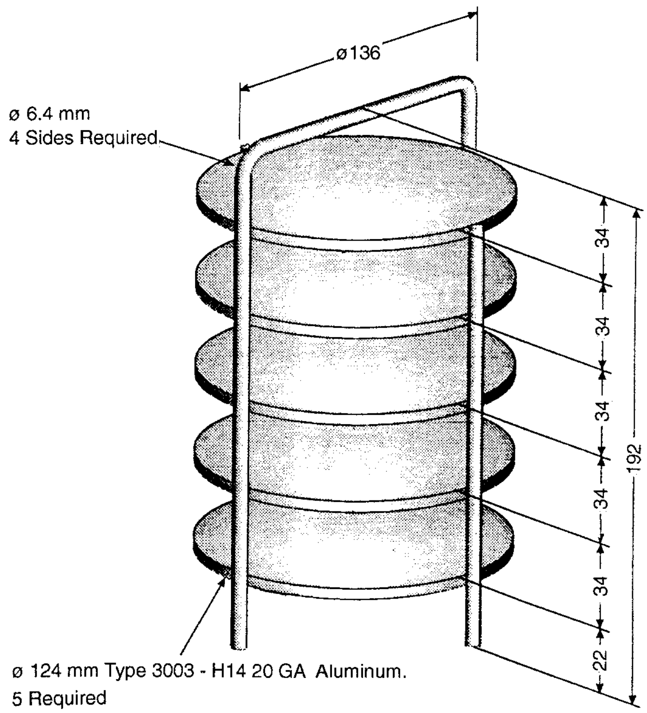
9.2.2 Weigh out 12.0 ± 0.1 g of resin and place it in the die. Screen non-freeflowing resins through a No. 10 sieve. Compacted resins shall be broken up by hand-shaking cold resin in a half-filled sealed glass container. Condition the resin in the sealed glass container in a freezer or dry-ice chest. After breaking up resin lumps, allow the sealed container to equilibrate to near ambient temperature. Then screen and weigh the 12.0 ± 0.1-g sample. Insert the die in a suitable hydraulic press and apply pressure gradually (see Note 4) until a pressure of 14 MPa (2030 psi) is attained. Hold this pressure for 2 min. Remove the preform from the die. Write the sample identification number on the preform using an appropriate marker that will not effect the PTFE during sintering.

9.2.3 Sinter the preforms in accordance with Table 3 (see Note 5).

9.2.3.1 For SSG specimens use Procedure A.

9.2.3.2 For ESG specimens use Procedure B.

NOTE 6—Improved precision in SSG and ESG test results has been obtained with the use of an upright, cylindrical oven and an aluminum sintering rack. The cylindrical oven has an inside diameter of 140 mm (5.5 in.) and an inside depth of 203 mm (8 in.) plus additional depth to accommodate a 51-mm (2-in.) thick cover, and is equipped with suitable heaters and controllers to sinter specimens in accordance with the procedures in Table 3. The rack, as shown in Fig. 2, allows preforms to be placed symmetrically in the center region of the oven. Place six preforms on each of the middle oven rack shelves (if six or fewer preforms are to be sintered, place them on the middle rack, filling in with "dummies" as needed). Place "dummies" on the top and bottom shelves. Specimens must be spaced evenly in a circle on each shelf, with none of them touching. An oven load must be no less than 18 pieces including "dummies." "Dummies" are defined as normal 12-g specimens that have previously been



NOTE 1—Aluminum plates tack welded to rods.

NOTE 2—All dimensions are in millimetres.

FIG. 2 Sintering Rack for SSG Specimens

through the sintering cycle. "Dummies" must only be used for an additional two or three thermal cycles, due to eventual loss of thermal stability and physical form.

9.2.4 Remove all flash from each specimen so that no air bubbles will cling to the edges when the specimen is immersed in the solution for weighing during the standard specific gravity and thermal instability index tests. It is recommended for this section and during testing that cotton gloves be worn while handling test specimens.

9.3 *Test Disks for Stretching Void Index (SVI):*

9.3.1 Mold the disk as in 9.1.1.

9.3.2 Screen 29 g of PTFE resin through a 2.00-mm (No. 10) sieve into the die. Adjust the lower plug to allow the resin to be leveled by drawing a straightedge in contact with the top of the die across the top of the die cavity. Insert the die in a suitable hydraulic press and apply pressure gradually (see Note 4) until a pressure of 7 MPa (1015 psi) is attained. Hold this pressure for 2 min, then increase the pressure to 14 MPa (2030 psi) and hold for an additional 2 min. Remove the disk from the die. Write the sample identification number on the preform using an appropriate marker that will not effect the PTFE during sintering.

9.3.3 Sinter the preforms in accordance with Table 3, Procedure A (see Note 5).

9.3.4 Remove all flash from those portions of these specimens that will be used for determination of specific gravities so that no air bubbles will cling to their edges when the specimens are immersed in liquid during these tests. It is recommended that cotton gloves be worn while handling test specimens.

9.4 *Conditioning Test Specimens:*

9.4.1 For tests of tensile properties and all tests requiring the measurement of specific gravities, condition the test specimens in general accordance with Procedure A of Practice D618, with the following deviations therefrom: (*1*) the aging period shall be a minimum of 4 h immediately prior to testing, (*2*) the laboratory temperature shall be 23 ± 2°C (73.4 ± 3.6°F), and (*3*) there shall be no requirement respecting humidity. The other tests require no conditioning of the molded test specimens.

9.5 *Test Conditions:*

9.5.1 Tests shall be conducted at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F), unless otherwise specified in the test methods or in this specification. This deviation from the standard laboratory temperature is made because of the necessity for maintaining test temperatures above approximately 21°C (70°F). See Note 3 for additional details. Since these resins do not absorb water, the maintenance of constant humidity during testing is not required.

10. Test Methods

10.1 *Melting Characteristics by Thermal Analysis:*

10.1.1 *Significance and Use*—For PTFE resins that have been melted prior to use, the melting peak temperature characteristics of a resin provide important information about the thermal history of the material. Melting peak temperatures (see Fig. 3) are used to determine conformance of a resin to the melting peak temperature requirements in Table 1 of this specification.

10.1.2 *Apparatus*—Use apparatus described in Test Method D4591.

10.1.3 *Procedure*—Measure melting peak temperatures in accordance with procedures given in Test Method D4591. An initial melting peak temperature above the melting peak temperature obtained on the second and subsequent melting (defined as the second melting peak temperature) indicates that the resin was not melted before the test. The second melting peak temperature occurs at about 327°C (621°F). The difference between the initial and second melting peak temperatures

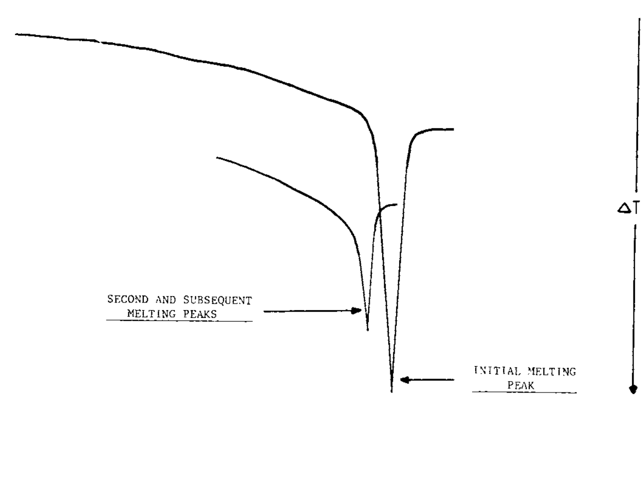


FIG. 3 Melting Characteristics by Thermal Analysis

is greater than 5°C (9°F). If peak temperatures are difficult to discern from the curves (that is, because the peaks are rounded rather than pointed) straight lines should be drawn tangent to the sides of the peak. These lines intersect at the peak temperature. Where more than one peak occurs during the initial melting test, the presence of any peak corresponding to the second melting peak temperature indicates the presence of some previously melted material.

10.2 *Bulk Density:*

10.2.1 *Significance and Use*—Bulk density gives an indication of how a resin performs during the filling of processing equipment. PTFE resins tend to compact during shipment and storage. Because of this tendency to pack under small amounts of compression or shear, Test Method D1895 is not applicable to these resins. The procedure given in 10.2.2 through 10.2.5 must be used to measure this property.

10.2.2 *Apparatus:*

10.2.2.1 *Funnel*—A funnel arrangement as shown in Fig. 4.

10.2.2.2 *Feeder* —A feeder with a No. 8 wire screen placed over approximately the top two thirds of the trough. The funnel shall be mounted permanently in the feeder outlet.

10.2.2.3 *Controller.*

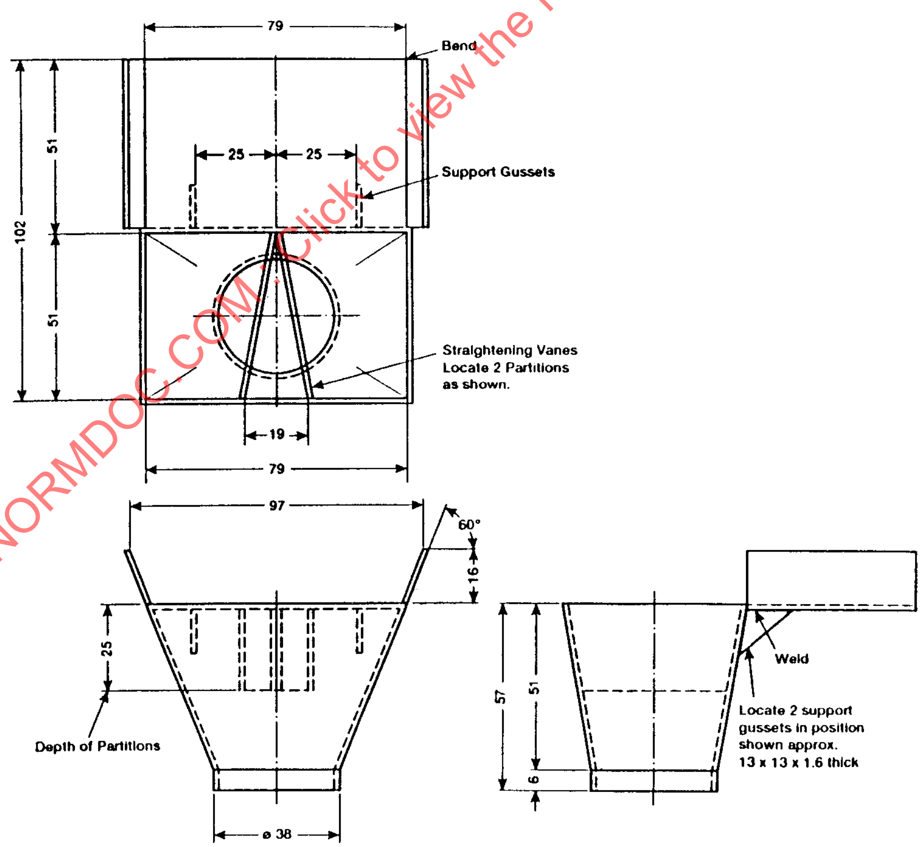
10.2.2.4 *Volumetric Cup and Cup Stand (see* Fig. 5*)*—The volumetric cup shall be calibrated initially to 250 mL by filling it with distilled water, placing a planar glass plate on top, drying the outside of the cup, and weighing. The net weight shall be 250 ± 0.5 g. The top and bottom faces of the volumetric cup and the cup stand shall be machined plane and parallel.

10.2.2.5 *Leveling Device*—The leveler (see Fig. 6) shall be affixed permanently to the table and adjusted so that the sawtooth edge of the leveler blade passes within 0.8 mm (0.031 in.) of the top of the volumetric cup.

10.2.2.6 *Work Surface*—The work surface for holding the volumetric cup and leveler shall be essentially free from vibration. The feeder, therefore, must be mounted on an adjoining table or wall bracket.

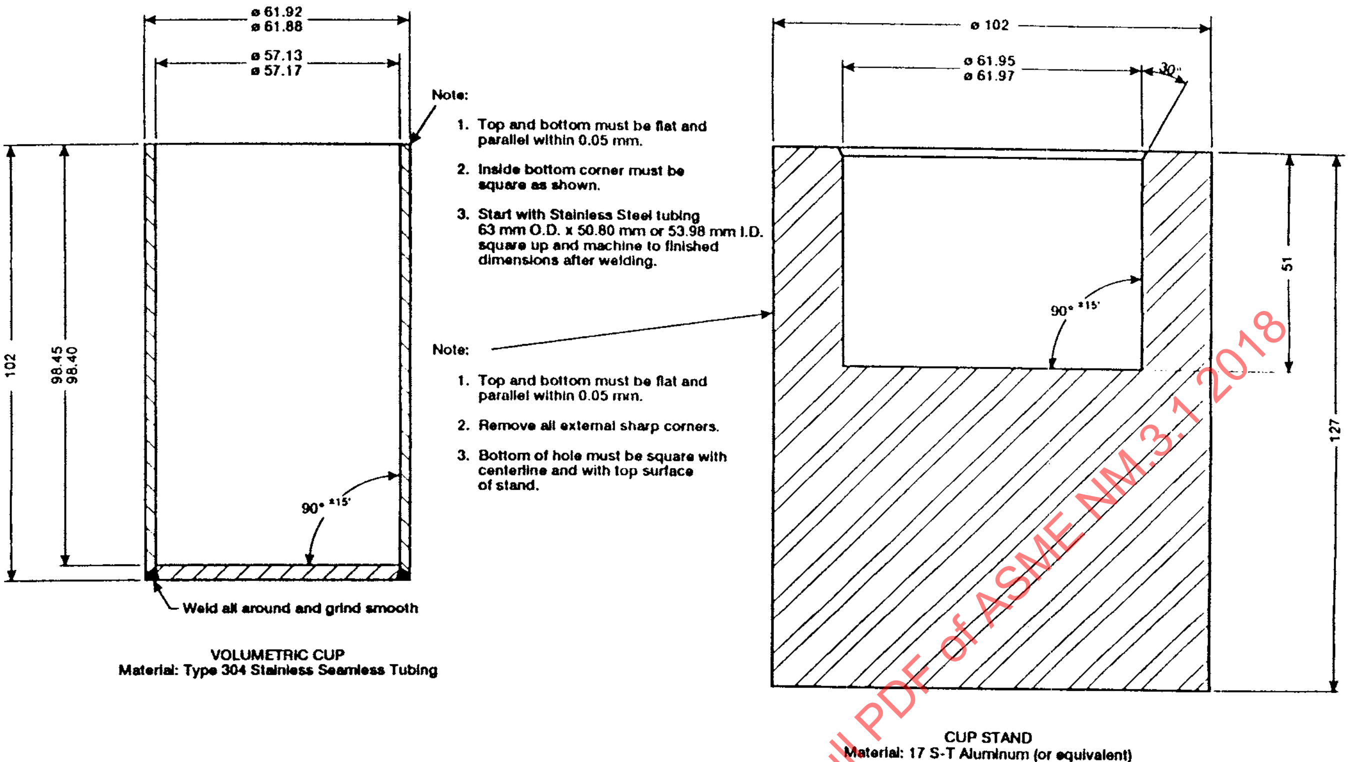
10.2.2.7 *Balance*—Balance, having an extended beam, with a capacity of 500 g and a sensitivity of 0.1 g, or equivalent.

10.2.3 *Procedure*—Place the clean, dry volumetric cup on the extended beam of the balance and adjust the tare to zero. Select about 500 mL of the resin to be tested and place it on the feeder screen. Put the cup in the cup stand and place the assembly such that the distance of free-polymer fall from the feeder outlet to the top rim of the cup shall be 39 ± 3 mm



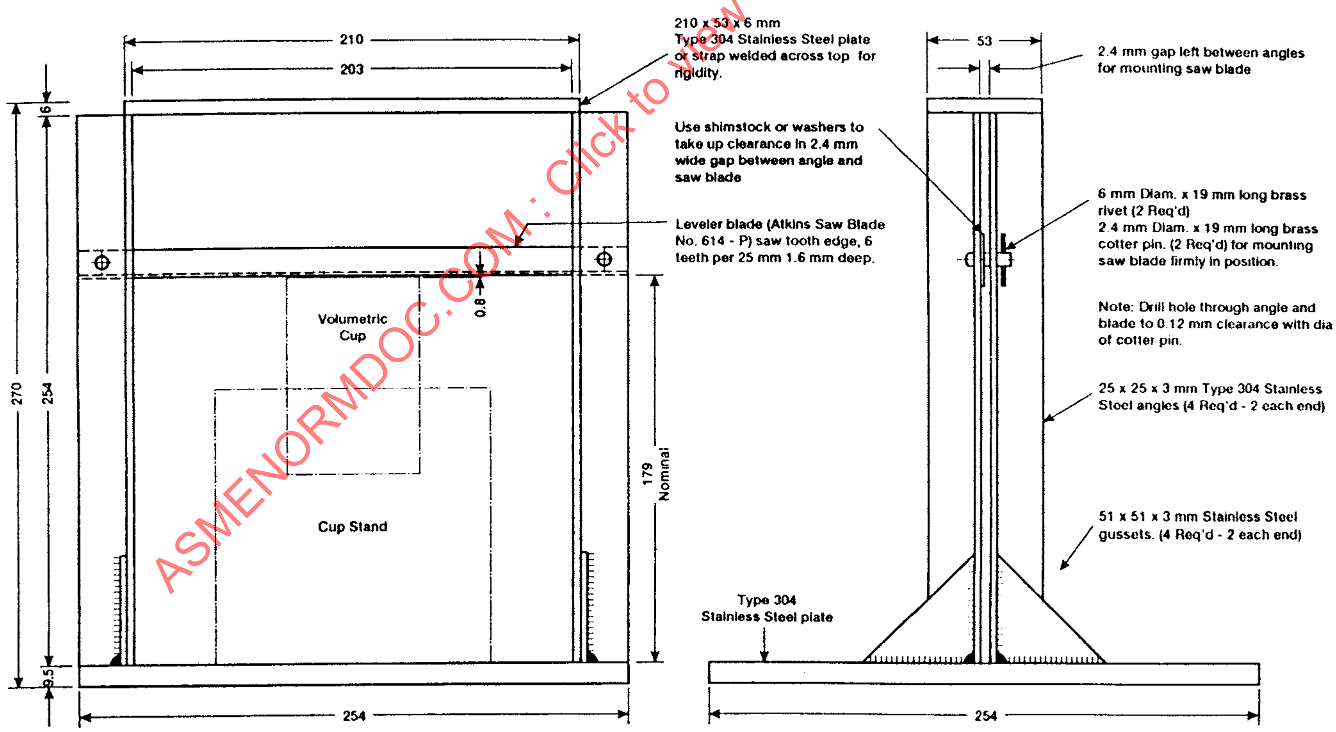
NOTE 1—Funnel Material: type 304 Stainless Steel 16 Gage (1.6-mm thickness).
NOTE 2—All dimensions are in millimetres.

FIG. 4 Details of the Funnel Used for the Determination of Bulk Density



NOTE 1—All dimensions are in millimetres.

FIG. 5 Volumetric Cup and Cup Stand for the Determination of Bulk Density



NOTE 1—Base plate must be flat and parallel. Saw blade, when mounted, must be square to and parallel with base plate within 0.13 mm from end to end. Height of saw blade must have 0.8 mm or less clearance between blade and assembled cup and cup stand (as indicated by phantom lines). Welded construction where indicated. Material: as noted.

NOTE 2—All dimensions are in millimetres.

FIG. 6 Leveler Stand for the Determination of Bulk Density

(1.5 ± 0.012 in.). Increased fall causes packing in the cup and higher bulk density values. Set the controller so that the cup is filled in 20 to 30 s. Pour the sample on the vibrating screen and fill the cup so that the resin forms a mound and overflows. Let the resin settle for about 15 s and then gently push the cup and its stand beneath the leveler. Exercise care to avoid agitation of the resin and cup before leveling. Weigh the resin to the nearest 0.1 g.

10.2.4 *Calculation*—Calculate the bulk density as follows:

$$\text{grams of resin} \times 4 = \text{bulk density(grams per litre)}$$

10.2.5 *Precision and Bias*—A precision statement for use with this procedure is under development. The procedure in this test method has no bias because the value of bulk density shall be defined only in terms of a test method.

10.3 *Particle Size:*

10.3.1 *Significance and Use*—The fabrication of PTFE resins is affected significantly by particle (or agglomerate) size and size distribution. The average particle size of PTFE resins is determined by fractionation of the material with a series of sieves. Fractionation is accomplished by mechanically shaking the material in the assembly of sieves for a specified period.

10.3.2 *Apparatus:*

10.3.2.1 *Balance,* capable of weighing to ±0.1 g.

10.3.2.2 *Sieves,* U.S. Standard Sieve Series, 203-mm (8-in.) diameter conforming to Specification E11. It is suggested that the following sieve numbers (openings) be used: 1.40 mm (14), 1.00 mm (18), 710 µm (25), 500 µm (35), 355 µm (45), 250 µm (60), and 180 µm (80). However, other configurations of sieves may be used to give equivalent results.

10.3.2.3 *Sieve Shaker*—A mechanical sieve shaking device capable of imparting uniform rotary and tapping action.

10.3.2.4 *Freezer*—Any commercial ice freezer. (A dry-ice chest may be used.)

10.3.3 *Procedure:*

10.3.3.1 Place 50 ± 0.1 g of the sample in an aluminum pan, and cool the pan and contents to less than 10°C (50°F).

10.3.3.2 Measure the tare weight of each of the sieves listed in 10.3.2.2. Place the conditioned sample on the top sieve of the assembly and shake in the sieve shaker for 10 ± 0.5 min. The dewpoint temperature of the sieving room must be less than the temperature of the conditioned sample so that water will not condense on the sample during this test. Determine the weight of resin retained on each sieve.

10.3.4 *Calculation:*

10.3.4.1 Calculate the net percentage of resin on each sieve as follows:

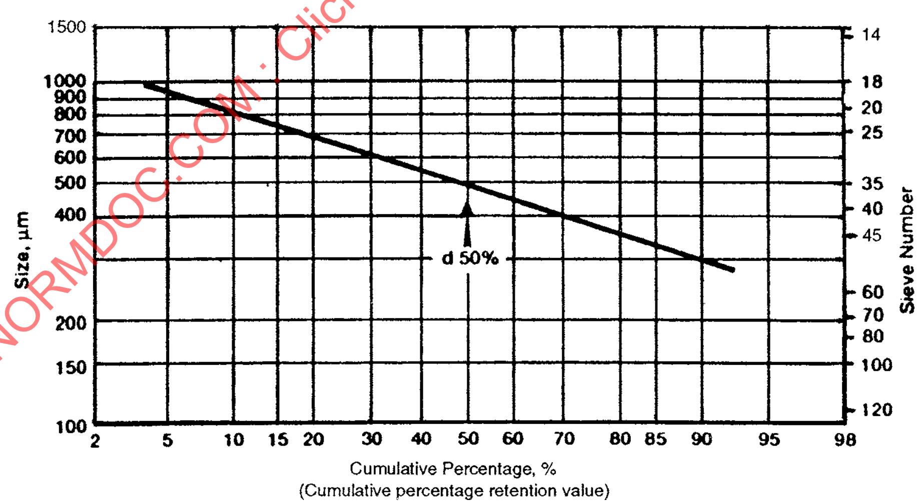
$$\text{net percentage on sieve } Y = 2 \times \text{weight of resin in grams on sieve } Y.$$

10.3.4.2 Calculate the cumulative percentage of resin on each sieve as follows:

$$\text{cumulative percentage on sieve } Y = \text{sum of net percentages on sieve } Y \text{ and sieves having numbers smaller than } Y.$$

NOTE 7—Cumulative percentage on 500-µm (No. 35) sieve = net percentage on 1.40-mm (No. 14) + net percentage on 1.00-mm (No. 18) + net percentage on 710-µm (No. 25) + net percentage on 500-µm (No. 35) sieves.

10.3.4.3 Plot the cumulative percentage versus the sieve opening size (or sieve number) on log-probability paper as shown in the sample plot (see Fig. 7). The sieve numbers and sieve opening sizes in micrometres are indicated below the figure. Draw the best straight line through the points and read the particle size at the 50 % cumulative percentage point (D_{50}).



Sieve No.	Sieve Opening, µm
14	1400
18	1000
25	710
35	500
45	355
60	250
80	180

FIG. 7 Log Probability Plot for Sieve Analysis

10.3.4.4 Calculate the particle size, average diameter, d_{50}, as follows:

$$d = d_{50}(\text{micrometres})$$

10.3.5 *Precision and Bias*—The test precision is ±3.2 % (two sigma limits) for the combination of 710 + 500 + 355-μm (25 + 35 + 45) sieve fractions for a resin where this combination of sieves retains, on the average, 78 % of the sample. Since there is no accepted reference material suitable for determining the bias for this test procedure, no statement on bias is being made.

10.3.6 Alternative methods for particle size are available. Light Scattering Instruments/Light Defraction Instruments (see ISO 12086-2, 8.6.4) and Electron Zone Sensing Instruments, which is a resistance-variation tester, (see ISO 12086-2, 8.6.3) are used as long as there is a direct correlation to the Particle Size Analysis in 10.3 of this specification.

10.3.6.1 This alternative method is very dependent on particle shape and is only recommended for processes that are stable and that have regular spherical type shape particles. Also, it is recommended that each manufacturing processor do an analysis to determine their own correlation.

10.4 *Water Content:*

10.4.1 *Significance and Use*—The presence of an excessive amount of water in PTFE resin has a significant adverse effect upon the processing characteristics of the resin and the quality of products made using the resin. A sample of PTFE resin of known weight is dried in a vacuum oven in a tared aluminum weighing dish. When the resin is dry, it is removed from the oven, placed in a desiccator, allowed to cool, and then reweighed. Water content is calculated from the weight lost during drying.

NOTE 8—If volatiles other than water are suspected, use the alternative method described in 10.4.6.

10.4.2 *Apparatus:*

10.4.2.1 *Balance,* capable of weighing to the nearest 0.0001 g.

10.4.2.2 *Oven.*

10.4.2.3 *Aluminum Weighing Dishes,* with lids.

10.4.3 *Procedure* (see Note 8)—Wash the aluminum weighing dishes with water and rinse with acetone. When the acetone has evaporated from the dishes, dry them thoroughly in an oven at 50 to 80°C (122 to 176°F), then store in a desiccator until ready for use. Obtain the tare weight, B, of an aluminum weighing dish, plus lid, to the nearest 0.0001 g. Place 35 to 40 g of PTFE resin in the tared aluminum weighing dish and record the weight (including lid), A, to the nearest 0.0001 g (see Note 9). Dry in an oven for two hours at 150°C (302°F), with the dish lid removed. Remove the dish from the oven, replace the lid on the weighing dish, and allow to cool in the desiccator for at least 30 min. Reweigh the dish (plus the resin and lid), C, and calculate the weight loss.

NOTE 9—Select one sample from each group of samples and run duplicate moisture determinations on it. If the difference between the duplicate results exceeds 0.01 percentage points, the entire group of samples must be run over.

NOTE 10—When a group of samples is run at the same time, it is good practice to place the lids from the weighing dishes directly under their corresponding dishes while the samples are drying in the oven. This eliminates the possibility of introducing errors in the tare weights. Also, overnight drying in a circulating air oven may be used if the data can be shown to be equivalent to those obtained with the above procedure.

10.4.4 *Calculation*—Calculate the water content as follows:

$$\text{water content, \%} = (A - C)/(A - B) \times 100$$

where:

A = weight of resin, dish, and lid, g
B = weight of dish and lid, g, and
C = weight of resin, dish, and lid after drying, g.

10.4.5 *Precision and Bias*—The precision of this test is ±0.0063 percentage points (two sigma limits). Since there is no accepted reference material suitable for determining the bias for this test, no statement on bias is being made.

10.4.6 *Alternative Method for Determination of Water Content by Karl Fischer Reagent:*

10.4.6.1 Weigh 35 ± 1 g of resin into a glass-stoppered flask containing about 50 mL of pretitrated methanol. Shake to mix with a swirling motion for a few minutes. Titrate with standardized Karl Fischer Reagent to a visual or electrometric end point.

10.5 *Standard Specific Gravity (SSG):*

10.5.1 *Significance and Use*—The specific gravity of an article made from a PTFE resin is affected both by the particular resin used and by the way the resin is processed. Therefore, a test method that measures the specific gravity of an article prepared in a precisely defined way provides valuable resin characterization data. The specific gravity of a specimen of PTFE resin prepared in accordance with all of the requirements of 9.2.3.1 defines the SSG for that resin specimen.

10.5.2 *Procedure:*

10.5.2.1 Determine, in accordance with 10.5.2.2, the specific gravity of specimens prepared in 9.2.3.1.

10.5.2.2 Make specific gravity determinations in accordance with the procedures described in Test Methods D792, Method A. Add two drops of a wetting agent to the water in order to reduce the surface tension and ensure complete wetting of the specimen.

10.6 *Thermal Instability Index (TII):*

10.6.1 *Significance and Use*—The TII gives an indication of how a resin resists degradation during extended periods of heating at sintering temperatures. This test method compares the SSG of a resin (determined in 10.5) to its extended specific gravity (determined here). Specimens used to determine ESG are identical to those used to determine SSG, except for the differences in thermal history described in 9.2.3. The specific gravity of a specimen of PTFE resin prepared in accordance with all of the requirements of 9.2.3.2 defines the ESG for that resin specimen.

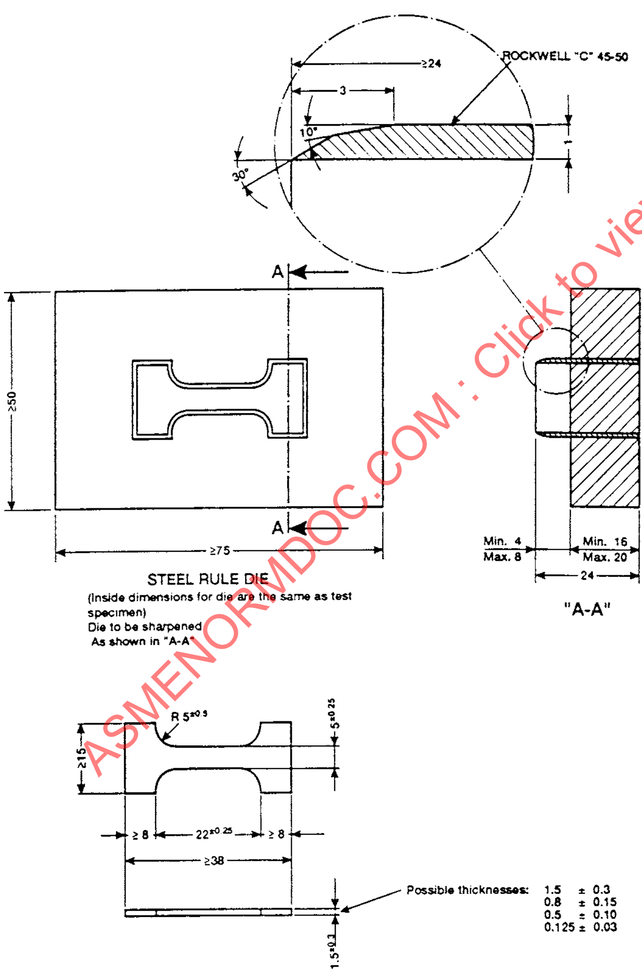
10.6.2 *Procedure*—Determine, in accordance with 10.5.2.2, the specific gravity of specimens prepared in 9.2.3.2.

10.6.3 *Calculation*—Calculate the thermal instability index (TII) as follows:

$$TII = (ESG - SSG) \times 1000$$

10.7 *Tensile Properties:*

10.7.1 *Procedure*—Cut five tensile specimens from the disk prepared in accordance with all of the requirements of 9.1, using the microtensile die described in Fig. 8. Determine the tensile strength in accordance with the procedures described in Test Method D638, except that the initial jaw separation shall be 22.0 ± 0.13 mm (0.875 ± 0.005 in.), and the speed of testing shall be 50 mm (2 in.)/min. Clamp the specimen with essentially equal lengths in each jaw. Determine elongation at break from the chart, expressed as a percentage of the initial jaw separation.



NOTE 1—All dimensions are in millimetres.

FIG. 8 Microtensile Die

10.7.2 *Precision and Bias*—A precision and bias statement for use with this procedure is under development and will be included when it has been approved by the balloting process.

10.8 *Extrusion Pressure:*

10.8.1 *Significance and Use*—Processing of the PTFE resins covered by this specification normally involves "paste extrusion" of a blend of the resin with a volatile liquid, as indicated in 1.1. The pressure that must be applied to such a blend to extrude it is affected by several processing conditions which include the nature and amount of deformation imparted to the blend during extrusion (usually characterized by the reduction ratio), the type and amount of liquid used, and the extrusion temperature. When such a blend is extruded under well-defined processing conditions, the pressure required to affect extrusion (extrusion pressure) provides significant characteristic information about the resin itself.

10.8.2 *Apparatus* Recommended apparatus:

10.8.2.1 *Paste Extruder* (Fig. 9)—One paste extruder that is used is a vertically disposed, breech-loading extruder with a 32-mm (1.26 in.) inside diameter extrusion cylinder. The barrel length is approximately 305 mm (12 in.), which is not critical so long as it will hold enough lubricated resin to extrude for about 5 min. The ram is 32 mm (1.26 in.) outside diameter, with a ring groove near its free end to hold an O-ring that makes a tight seal between the ram and extruder cylinder. The extruder is equipped with devices for sensing and recording pressure on the face of the ram. The range of the pressure sensing device shall be greater than 70 MPa (10 000 psi). Temperature-controlling equipment maintains the extruder at 30 ± 1°C. A system (hydraulic or screw) drives the ram at a speed of about 18 mm/min (0.7 in./min) to give an output rate of 19 g/min on a dry-resin basis (about 23.5 g/min of lubricated resin) during the extrusion pressure test. The extruder also has a fast-speed drive (speed not precisely controlled) to run the ram rapidly into the cylinder cavity prior to the extrusion pressure test. The extruder-die assembly slides on tracks from under the ram to allow easy access for loading and cleaning the cylinder. An alternative muzzle-loaded paste extruder shall be used which has a detachable die assembly. The die assembly is detached, a preformed charge of resin is inserted up into the cylinder and the die assembly is reattached.

10.8.2.2 *Extrusion Dies* (Fig. 10)—Interchangeable extrusion dies, each having 30° included angles, give the desired reduction ratios when dimensioned as follows:

Reduction Ratio	Die Orifice (Inside Diameter), mm (in.)	Land Length, mm (in.)	Die Length, mm (in.)
100 to 1	3.18 (0.125)	25.35 (0.998)	78.66 (3.0)
400 to 1	1.59 (0.0625)	4.78 (0.188)	61.06 (2.3)
1600 to 1	0.79 (0.0312)	0.38 (0.015)	58.15 (2.2)

NOTE 11—Reduction ratio in this specification is the ratio of the cross-sectional area of the extruder cylinder to the cross-sectional area of the die. This must not be confused with another definition wherein reduction ratio is the ratio of the cross-sectional area of the extruder cylinder to the cross-sectional area of the sintered extrudate.

10.8.2.3 *Miscellaneous Apparatus*—Equipment is needed for weighing, blending, conditioning (at 30°C) and preforming, as well as extruded cleaning.

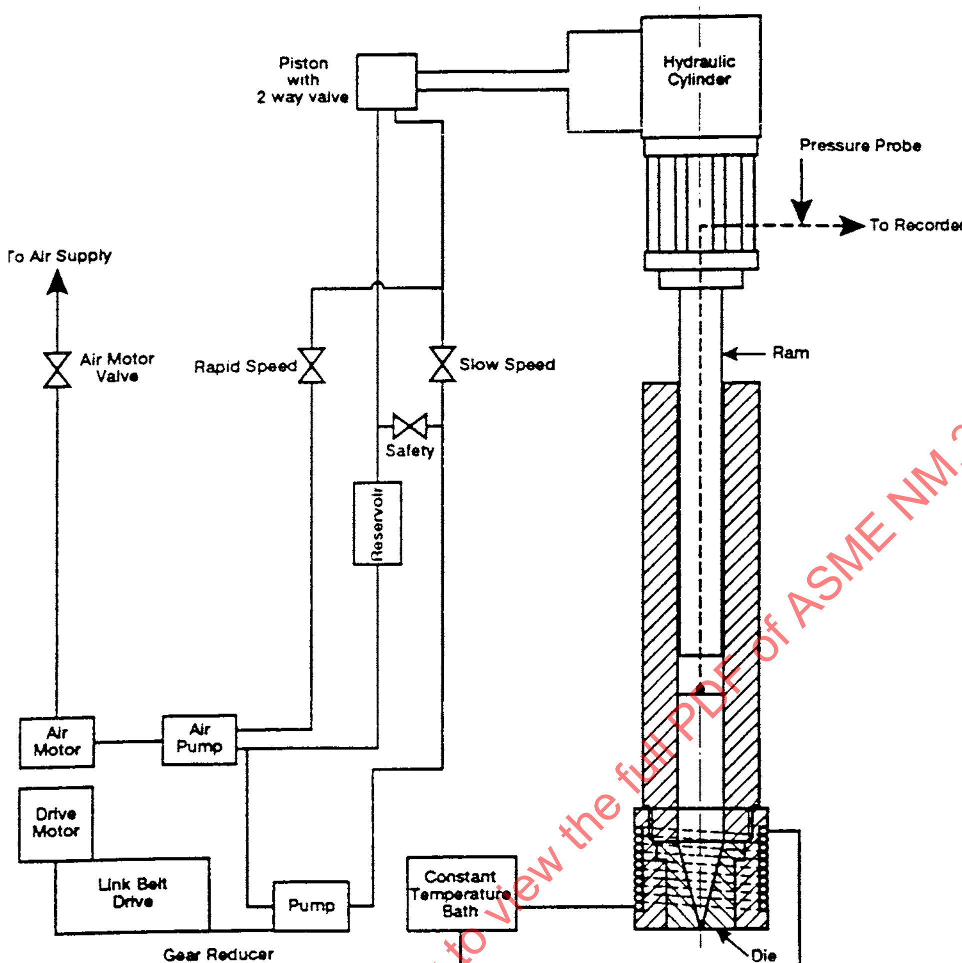


FIG. 9 Paste Extruder for Determining Extrusion Pressure

10.8.3 *Procedure:*

10.8.3.1 Screen the dry resin through a 4.75-mm (No. 4) sieve onto a clean, dry, lint-free sheet of paper.

10.8.3.2 Transfer 200 ± 0.5 g of the screened resin to a clean, dry glass jar about 92 mm (3.625 in.) in diameter (approximately 1-L capacity) having an airtight closure, or into a V-blender of laboratory size.

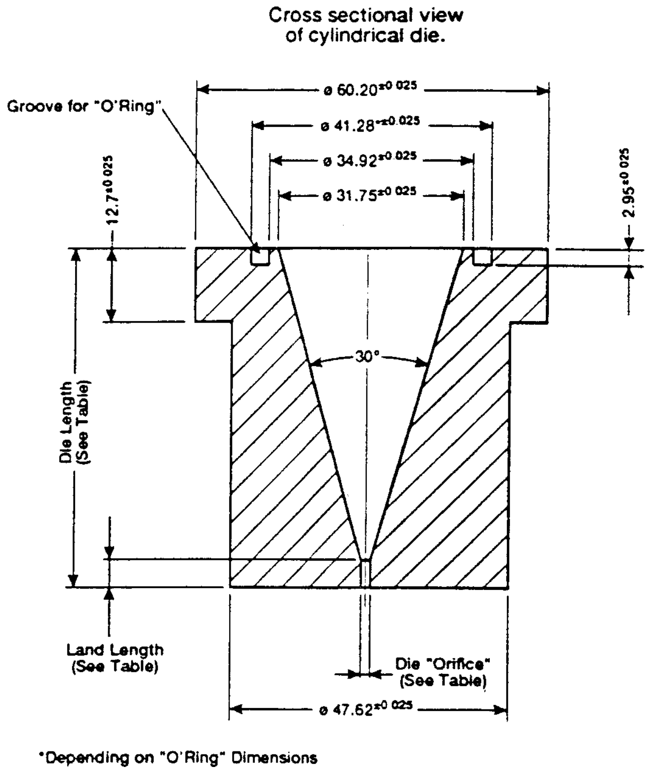
10.8.3.3 Determine the density of the lubricant, a kerosene-type hydrocarbon liquid. Determine the density at 25°C using Test Method D4052, a commercial density meter that will give four significant figures for the density, or a technically equivalent procedure. Calculate the mass of lubricant required by multiplying the density by 60.00 mL. Add the calculated mass ±0.01 g of the lubricant to the resin in the jar or blender. It is convenient to make this addition while the jar containing the powder is on a balance that has a sensitivity at least as good as the ±0.01 g required for the test. Avoid wetting the walls of the blending vessel with the liquid as this impairs mixing. When a jar is used the lid shall be taped in place to prevent loss of lubricant. Shake the jar briefly to minimize the wetting of the jar wall with liquid.

10.8.3.4 Blend the mixture by placing the jar on rubber-coated mill rolls and rolling it at 30 r/min for 25 ± 5 min, by fastening the jar to a windmill type blender and blending for 20 ± 1 min, or by blending the mixture in the V-blender for 15 ± 5 min. If a V-blender has been used, drop the resin from it into a jar of approximately 1-L capacity and seal the jar.

10.8.3.5 After blending, store the jar with its contents at 30 ± 1°C for a minimum of 2 h. A water bath has been found to be satisfactory. This enables the lubricant to diffuse to the interior of individual particles and surfaces not reached during the blending process.

10.8.3.6 Place the proper extrusion die for the desired reduction ratio (given in 10.8.2.2) in the paste extruder.

10.8.3.7 *Resin Preform*—To preform the resin for the breech-loading paste extruder of 10.8.2.1, slide the extruder-die assembly forward, mount a 32-mm (1.26-in.) inside diameter extension tube about 610 mm (24 in.) in length at the breech end of the extruder cylinder. Quickly pour the lubricated resin through a funnel into the extension and force the



Reduction Ratio	Die Orifice (Diameter)	Land Length	Die Length
100 to 1	3.18	25.35	78.66
400 to 1	1.59	4.78	61.06
1600 to 1	0.79	0.38	58.15

NOTE 1—All dimensions are in millimetres.

FIG. 10 Extruder Die Assembly for Extrusion Pressure Apparatus

resin into the extruder cylinder with a tamping rod. Apply the force with hand pressure and a very slow, even stroke. To preform the resin for the muzzle-loading paste extruder of 10.8.2.1, mount a 32-mm (1.26-in.) inside diameter preforming tube about 610 mm (24 in.) in length with its cross section resting against a flat, smooth surface. Quickly pour the lubricated resin through a funnel into the tube and force the resin down in the tube. The force may be applied with a hydraulically controlled tamping device to compact the resin with a slow, even stroke to a minimum of 690 kPa (100 psi) on the resin. Remove the preform from the preforming tube, insert the preform up into the cylinder of the extruder, and attach the die assembly.

10.8.3.8 Use the fast-speed drive to run the ram down into the cylinder cavity. When the first bit of beading emerges from the orifice, stop the descent of the ram.

10.8.3.9 Immediately change to slow-speed drive, start the pressure-recording system, and extrude the lubricated resin at a rate of 19.0 ± 1.0 g/min (dry-resin basis).

10.8.3.10 Record the pressure developed at the face of the ram in contact with the resin in the cylinder as a function of time. The extrusion pressure is the average pressure required to extrude the sample as measured between the third and fourth minutes of the extrusion.

10.8.4 *Precision and Bias*—The test precision and bias are to be determined by round-robin testing.

10.9 *Stretching Void Index:*

10.9.1 *Significance and Use*—This test method compares the unstrained specific gravity (USG) of a resin to its strained specific gravity (strained SG). The specific gravity of a specimen of PTFE resin prepared in accordance with all of the requirements of 9.3 defines the USG for that resin specimen. The SVI gives one indication of the potential for induced void content of a solid fabricated resin product in use. Such void content may contribute to a susceptibility to the formation of cracks and failures under conditions of extreme stretching and stress or in some environments when stressed. Similar failures have also been associated, at times, with improper processing techniques.

10.9.2 *Procedure:*

10.9.2.1 Determine, in accordance with 10.5.2.2, the specific gravity of specimens prepared in 9.3. This is the USG for the specimen.

10.9.2.2 Cut tensile specimens from the disk prepared in 9.3 using the microtensile die shown in Fig. 8. Clamp the specimen in a tensile testing machine with essentially equal lengths in each jaw. The initial jaw separation shall be 12.5 ± 0.1 mm (0.5 ± 0.005 in.). Strain the specimen at a constant rate of 5.0 mm (0.2 in.)/min until it breaks. This strain rate and initial jaw separation yield a strain rate of 40 %/min, based on the original gage length of the specimen. If elongation at break is less than 200 %, discard the result and repeat 10.9.2.2.

10.9.2.3 Cut off a portion of the stretched part of the specimen. Determine, in accordance with 10.5.2.2, the specific gravity of this strained specimen (strained SG).

10.9.3 *Calculation*—Calculate the stretching void index (*SVI*) as follows:

$$SVI = (USG - \text{strained}\, SG) \times 1000$$

11. Inspection

11.1 Inspection of the material supplied with reference to this specification shall be for conformance to the requirements specified herein.

11.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of the following:

11.2.1 Bulk density,

11.2.2 Particle size, and

11.2.3 Melting point.

11.3 Periodic check inspection with reference to a specification shall consist of the tests for all requirements of the material under the specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with Annex A1.

11.4 A report of test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

12. Certification

12.1 Certification shall be as required by Annex A1.

13. Packaging and Package Marking

13.1 *Packaging*—The resin shall be packaged in standard commercial containers so constructed as to ensure acceptance by common or other carriers for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

13.2 *Package Marking*—Shipping containers shall be marked with the name of the resin, type, and quantity contained therein.

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

14. Keywords

14.1 coagulated dispersion polytetrafluoroethylene; fluoropolymers; polytetrafluoroethylene; PTFE

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. *Ordering Information*—The purchase order should state this ASTM designation and year of issue, and which type, grade, and class is desired.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. EXPANSION TEST FOR EXTRUDED TUBING

X1.1 Significance and Use

X1.1.1 Processing of the PTFE resins covered by this specification almost always includes extrusion of a blend of the resin with a volatile liquid. The quality of the extrudate is affected by several processing conditions which include the nature and amount of deformation imparted during extrusion, the type of resin, the type and amount of liquid used, and the extrusion temperature. When the blend is extruded into a tube under well-defined processing conditions, characterization of the resultant tube using suitable test procedures provides significant characteristic information about the resin.

X1.2 Apparatus

X1.2.1 Use the extruder shown in Fig. 9 and described in 10.8.2.1 (or equivalent apparatus), except that a guide tube which extends through the center of the ram and into the die is attached to the hydraulic cylinder and a mandrel tip is screwed onto this guide tube. The guide tube has an outside diameter of 15 mm (0.59 in.), and the mandrel tip has an outside diameter of 0.4 mm (0.016 in.) over a land length of 0.4 mm. When used in combination with the 0.8-mm (0.031-in.) orifice given in 10.8.2.2, a reduction ratio of 1600 to 1 is produced. This setup will yield a sintered tube with an outside diameter of about 0.76 mm (0.03 in.), and an inside diameter of about 0.4 mm.

X1.2.2 Use the miscellaneous apparatus described in 10.8.2.3.

X1.3 Procedure

X1.3.1 The procedure is as given in 10.8.3, except that preforming is done in a separate mold shell having a 31.6-mm (1.245-in.) inside diameter, and fitted with a central die rod having the same diameter as the extruder guide tube and suitable end plugs. Pour the lubricated resin into one end of the vertical preform mold, and tap the side of the mold shell to level the resin. Place the top mold plug in the mold, and apply a minimum pressure of 690 kPa (100 psi) to the resin.

X1.3.2 Remove the preform from the mold and wrap in aluminum foil for 4 h. This is to provide uniform distribution of lubricant within the preform.

X1.3.3 When the extruder is ready for extrusion, unwrap the preform and quickly insert it into the extruder cylinder over the guide tube. Attach the mandrel tip to the guide tube, then close the extruder cylinder and attach the die assembly.

X1.3.4 Proceed in accordance with 10.8.3.8 and 10.8.3.9 Pass the extruded tubing vertically downward through an electrically heated air oven designed to produce a higher temperature in the lower half of the oven than in the upper half. The lubricant is vaporized in the upper half of the oven at about 120 to 150°C (248 to 302°F). Adjust the temperature in the lower half of the oven so that the tubing passing through it is in the gel (completely transparent) for about 100 mm (4 in.). As the tubing emerges from the oven it is allowed to cool in air, and is then coiled on a suitable spool.

X1.3.5 Connect one end of the extruded tubing to a source of nitrogen that shall apply at least 345-kPa (50-psi) internal pressure to the tubing. Make sure that there is at least 15 m (50 ft) of tubing. Clamp the free end of the tubing and push it through a heated glass tube having an inside diameter of 1.65 mm (0.065 in.). Apply 345-kPa pressure to the PTFE tubing, and move the PTFE tubing through the heated glass tube at a rate that allows the PTFE tubing to reach 340°C (644°F) in the last 75 to 100 mm (3 to 4 in.) of the glass tube (that is, the PTFE tubing becomes transparent). As the PTFE tubing becomes transparent it expands against the inner surface of the glass tube. If this does not occur, increase the nitrogen pressure slowly until expansion occurs.

X1.3.6 As the expanded tubing emerges from the glass tube allow it to cool in air and coil it up on a suitable spool. If a flaw appears and the expanded tubing loses nitrogen pressure, clamp off the tubing downstream of the flaw and continue.

X1.3.7 The expanded tubing is inspected visually for flaws and stretch marks.

NOTE X1.1—This test is not appropriate for all resins.

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SPECIFICATION FOR POLYETHYLENE PLASTICS MOLDING AND EXTRUSION MATERIALS

SD-4976

(Identical with ASTM D4976-12a except for revisions in paras. 3.2, 9.2, and section 13, additional requirements in section 14 and Annex A1, and renumbering of sections 15 and 16.)

Specification for Polyethylene Plastics Molding and Extrusion Materials

INTRODUCTION

This specification is not intended for the selection of materials, but only as a means to call out plastic materials to be used for the manufacture of parts. The selection of these materials is to be made by personnel with expertise in the plastics field where the environment, inherent properties of the materials, performance of the parts, part design, manufacturing process, and economics are considered. This specification does not specify the source of the resin to be used for the fabrication of any given article.

1. Scope

1.1 This specification provides for the identification of polyethylene plastics molding and extrusion materials in such a manner that the supplier and the user can agree on the acceptability of different commercial lots or shipments. The tests involved in this specification are intended to provide information for identifying materials in accordance with the groups, classes, and grades covered. It is not the function of this specification to provide specific engineering data for design purposes.

1.2 Other requirements necessary to identify particular characteristics important to specialized applications shall be agreed upon between the user and the supplier, by using the suffixes given in Section 1.3.

1.3 Ethylene plastic materials, being thermoplastic, are reprocessable and recyclable (see Note 1). This specification allows for the use of those ethylene plastic materials, provided that any specific requirements as governed by the producer and the end user are met.

NOTE 1—See Guide D7209 for information and definitions related to recycled plastics.

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

1.5 The following precautionary caveat pertains to the test method portion only, Section 12, 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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 For information regarding plastic pipe materials see Specification D3350. For information regarding wire and cable materials, see Specification D1248.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D568 Method of Test for Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position (Withdrawn 1991)
D618 Practice for Conditioning Plastics for Testing
D635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
D638 Test Method for Tensile Properties of Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
D1499 Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1531 Test Methods for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Fluid Displacement Procedures
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2839 Practice for Use of a Melt Index Strand for Determining Density of Polyethylene
D2951 Test Method for Resistance of Types III and IV Polyethylene Plastics to Thermal Stress-Cracking (Withdrawn 2006)
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
D3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position
D3892 Practice for Packaging/Packing of Plastics
D4000 Classification System for Specifying Plastic Materials
D4329 Practice for Fluorescent UV Exposure of Plastics
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D4804 Test Method for Determining the Flammability Characteristics of Nonrigid Solid Plastics
D4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D4986 Test Method for Horizontal Burning Characteristics of Cellular Polymeric Materials
D6360 Practice for Enclosed Carbon-Arc Exposures of Plastics
D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins

2.2 *Military Standard:*
MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

NOTE 3—According to the DOD, "MIL-STD-105E, dated 10 May 1989, is hereby canceled without replacement" (1995).

2.3 *DOT Standard:*
Federal Motor Vehicle Safety Standard 302, Flammability of Interior Materials

3. Terminology

3.1 *Definitions*—For definitions of technical terms pertaining to plastics used in this specification, see Terminology D883 and Terminology D1600.

3.2 Historical usage and user group conventions have resulted in inconsistent terminology used to categorize and describe polyethylene resins and compounds. The following terminology is in use in ASTM specifications pertaining to polyethylene:

3.2.1 *Specification D1248:*

3.2.1.1 Type (I, II, III, IV) = density ranges (same, respectively, as Classes 1, 2, 3, and 4 in Specification SD-4976).

3.2.1.2 Class (A, B, C, D) = composition and use.

3.2.1.3 Category (1, 2, 3, 4, 5) = melt index ranges (same as Grade in Specification SD-4976).

3.2.1.4 Grade (E, J, D, or W followed by one or two digits) = specific requirements from tables.

3.2.2 *Specification D3350:*

3.2.2.1 Type (I, II, III) = density ranges (same as Types I, II, and III in Specification D1248 and Classes 1, 2, and 3 in Specification SD-4976).

3.2.2.2 Class = a line callout system consisting of "PE" followed by six cell numbers from Table 1 plus a letter (A, B, C, D, E) denoting color and UV stabilizer.

3.2.2.3 Grade = simplified line callout system using "PE" followed by density and slow crack growth cell numbers from Table 1.

3.2.3 *Specification SD-4976:*

3.2.3.1 Group (1, 2) = branched or linear polyethylene.

3.2.3.2 Class (1, 2, 3, 4) = density ranges (same, respectively, as Types I, II, III, and IV in Specification D1248).

3.2.3.3 Grade (1, 2, 3, 4, 5) = melt index ranges (same as Category in Specification D1248).

4. Classification

4.1 Unreinforced polyethylene plastic materials are classified into groups in accordance with molecular structure. These groups are subdivided into classes and grades as shown in Table PE (Basic Property Table).

TABLE PE Basic Requirement of Polyethylene Plastics

Group	Description	Class	Description	Grade	Flow Rate, D1238, g/10 min	Tensile Stress at Yield, D638, min, MPa	Nominal Strain at Break, D638, min, %	Flexural Modulus at 2 % Strain, D790, min, MPa
1	Branched	1	low density	1	>25	8	70	100
			. . .	2	>10 to 25	8	90	125
			0.910–0.925	3	>1 to 10	8.5	100	125

TABLE PE Basic Requirement of Polyethylene Plastics

Group	Description	Class	Description	Grade	Flow Rate, D1238, g/10 min	Tensile Stress at Yield, D638, min, MPa	Nominal Strain at Break, D638, min, %	Flexural Modulus at 2 % Strain, D790, min, MPa
			. . .	4	>0.4 to 1	9.5	300	125
			. . .	5	to 0.4	9.5	400	150
			. . .	0	. . .	. . .	. . .	. . .
		2	medium density	1	>25	8	40	200
			. . .	2	>10 to 25	11	50	200
			>0.925–0.940	3	>1 to 10	11	70	200
			. . .	4	>0.4 to 1	11	200	250
			. . .	5	to 0.4	12	400	300
			. . .	0	. . .	. . .	. . .	. . .
		0	. . .	0	. . .	. . .	. . .	. . .
2	Linear	1	low density	1	>25	10	300	300
			. . .	2	>10 to 25	10	300	325
			0.910–0.925	3	>1 to 10	10	300	350
			. . .	4	>0.4 to 1	10	400	350
			. . .	5	to 0.4	12	500	400
			. . .	0	. . .	. . .	. . .	. . .
		2	medium density	1	>25	14	90	500
			. . .	2	>10 to 25	14	100	500
			>0.925–0.940	3	>1 to 10	14	100	550
			. . .	4	>0.4 to 1	15	200	600
			. . .	5	to 0.4	19	400	600
			. . .	0	. . .	. . .	. . .	. . .
		3	high density	1	>25	17	10	400
			. . .	2	>10 to 25	17	50	400
			>0.a940–0.960	3	>1 to 10	18	200	450
			. . .	4	>0.4 to 1	19	400	500
			. . .	5	to 0.4	20	600	600
			. . .	0	. . .	. . .	. . .	. . .
		4	high density	1	>25	24	10	500
			. . .	2	>10 to 25	24	10	600
			>0.960	3	>1 to 10	25	30	800
			. . .	4	>0.4 to 1	28	300	900
			. . .	5	to 0.4	28	400	1000
			. . .	0	. . .	. . .	. . .	. . .
0		0	. . .	0	. . .	. . .	. . .	. . .

Cell Table A Detail Requirements for Polyethylene Plastics

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield, Test Method D638, MPa, min	unspecified	4	8	12	16	21	30	35	. . .	specify value
2	Nominal Strain at Break, Test Method D638, %, min	unspecified	25	50	200	400	600	800	1000	. . .	specify value
3	Secant Flexural Modulus at 2 % Strain, D790, MPa, min	unspecified	50	100	200	400	600	800	1000	. . .	specify value
4	Thermal stress-crack resistance, D2951, hours without cracking, min	unspecified	24	48	96	168	. . .	. . .	. . .	. . .	specify value
5	Environmental stress-crack resistance, D1693, min F_{50}, h	unspecified	24	48	96	168	336	672	1008	. . .	specify value

Cell Table B Detail Requirements for Polyethylene Plastics

Designation Order Number	Property	Cell Limits									
		0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield, D638, MPa, min	unspecified	4	8	12	16	21	30	35	. . .	specify value
2	Nominal Strain at Break, D638, %, min	unspecified	25	50	200	400	600	800	1000	. . .	specify value
3	Secant Flexural Modulus at 2 % Strain, D790, MPa, min	unspecified	50	100	200	400	600	800	1000	. . .	specify value
4	Thermal stress-crack resistance, D2951, hours without cracking, min	unspecified	24	48	96	168	. . .	. . .	. . .	. . .	specify value
5	Slow Crack Growth Resistance, PENT-Test Method F1473, h, min	unspecified	0.3	1	3	10	30	100	300	. . .	specify value

NOTE 4—An example of this classification system is as follows: The designation PE 112 would indicate PE, polyethylene as found in Terminology D1600, 1 (group) branched, 1 (class) low density, 2 (grade) >25 melt index.

4.2 Cell Tables A or B shall be used to specify the physical property requirements that shall be shown by a five-digit designation. The designation shall consist of the letter A and the five digits comprising the cell numbers for the property requirements in the order they appear in Cell Table A.

4.2.1 Although the values listed are necessary to include the range of properties available in the existing materials, users should not infer that every possible combination of the properties exist or can be obtained.

NOTE 5—It is recognized that some high-density polyethylene plastics of very high molecular weight have densities slightly less than 0.960, yet in all other respects they are characteristic of Class 4 materials. Similarly, there are other polyethylene plastics of very high molecular weight having densities slightly less than 0.941 that, in all other respects, are more characteristic of Class 2 than of Class 3 materials.

NOTE 6—Use the following terms in describing polyethylene plastics:

Class 1 (0.910 to 0.925) = low density,
Class 2 (>0.925 to 0.940) = medium density,
Class 3 (>0.940 to 0.960) = high density,
Class 4 (>0.960) = high density, and

Although Classes 3 and 4 cover two ranges of density, both are described by the term "high density."

5. Suffixes

5.1 When using the call-out for the materials covered by this specification, the following suffixes can be used for specific requirements of the material for the application intended. In general, the suffix letter indicates the requirement needed; the first number (digit) indicates the test condition, and the second number (digit) indicates the specimen requirement. The suffixes are as follows:

5.1.1 *E* = Electrical requirements as designated by the following digits:

First Digit
0 = To be specified by user.
1 = Specimens preconditioned 40 h at 23°C and 50 % relative humidity, then 14 days in distilled water at 23 ± 1°C.

Second Digit
0 = To be specified by user.
1 = Volume resistivity, permittivity, and dissipation factor meet property limits as shown as follows. These are electrical limits usually applied to unreinforced polyethylene plastics when control of their electrical properties is required.

Electrical Properties:

	Test Methods	
Permittivity, max	D1531	2.30
Dissipation factor, max	D1531	0.001
Volume resistivity, min Ω-cm	D257	1×10^{15}
Water immersion stability	D1531	shall meet the dielectric constant and dissipation factor requirements

5.1.2 Flammability requirements for polyethylene plastics shall be assessed by one or more of the following small scale flammability tests:

5.1.2.1 The rate of burning and/or extent and time of burning in a horizontal orientation for polyethylene plastics shall be assessed by Test Method D635. A plastic shall be classified HB if: (a) the rate of burning in the test does not exceed 40 mm per minute over a 75 mm span for specimens having a thickness of 3.0 – 13 mm, or b) the rate of burning does not exceed 75 mm per minute over a 75 mm for specimens having a thickness less than 3.0 mm, or c) the test specimen ceases to burn before the 100 mm reference mark.

5.1.2.2 The rate of burning and/or extent and time of burning in a horizontal orientation for foamed polyethylene plastics shall be assessed by Test Method D4986. A foamed plastic shall be classified HBF if: (a) the rate of burning in the test does not exceed 40 mm per minute over a 100 mm span b) the test specimen ceases to burn before flaming or glowing reaches the 125 mm gage mark.

5.1.2.3 The burning characteristics in a vertical orientation of polyethylene plastics shall be assessed by Test Method D3801. A plastic shall be classified V0, V1 or V2 as indicated in Appendix X1 of Test Method D3801.

5.1.2.4 The burning characteristics in a vertical orientation of nonrigid polyethylene plastics that, due to specimen thickness or lack of rigidity, would distort or shrink when tested using Test Method D3801shall be assessed by Test Method D4804. A plastic shall be classified VTM0, VTM1 or VTM2 as indicated in Appendix X1 of Test Method D4804.

5.1.2.5 *G* = Flammability requirements as designated by the following digits: as designated by the following digits:

First digit
0 = To be specified by user.
1 = Rigid
2 = Foam
3 = Non-rigid

Second Digit
0 = To be specified by user.
1 = Meets the classification requirements for HB when tested per D 635
2 = Meets the classification requirements for HBF when tested per D4986
3 = Meets the classification requirements for V0 when tested per D3801
4 = Meets the classification requirements for V1 when tested per D3801
5 = Meets the classification requirements for V2 when tested per D3801
6 = Meets the classification requirements for VTM0 when tested per D4804
7 = Meets the classification requirements for VTM1 when tested per D4804
8 = Meets the classification requirements for VTM2 when tested per D4804

5.1.2.6 The above call-out table reflects changes due to the withdrawal of D568 in 1991. For reference, the original call-out table can be be found in Appendix X1 of this document. The table in Appendix X1 is included only for reference and shall not be used for future specification of materials.

5.1.2.7 If requested, the heat release rate and ignitability in a horizontal orientation of polyethylene plastics shall be assessed when tested using Test Method E1354.

5.1.3 *W* = Weatherability requirements as designated by the following digits:

First Digit
0 = To be specified by user.
1 = Specimens exposed to xenon-arc type light source, in accordance with Practice D2565, Type BH. Specimens shall be Test Method D638, Type IV tensile bars.
2 = Specimens exposed to enclosed carbon-arc type light source, in accordance with Practice D6360. Specimens shall be Test Method D638, Type IV tensile bars.
3 = Specimens exposed to fluorescent-UV-condensation type light source, in accordance with Practice D4329. Specimens shall be Test Method D638, Type IV tensile bars.
4 = Specimens exposed to filtered open-flame carbon arc type light source in accordance with Practice D1499. Specimens shall be Test Method D638, Type IV tensile bars

Second Digit
0 = To be specified by user.
1 = 200-h exposure.
2 = 500-h exposure.
3 = 1000-h exposure.
4 = 2000-h exposure.

NOTE 7—The exposure duration shall be that necessary to produce a measurable change in the property evaluated for a product known to perform poorly in the application of interest. It will assure that the duration is of sufficient length to identify an unacceptable material.

5.1.3.1 The exposed specimens shall not exhibit surface changes (such as, dulling and chalking) or deep-seated changes (such as, checking, crazing, warping, and discoloration). The tensile strength after exposure must be no less than 50 % of the original.

5.1.4 *Z* = Other special requirements (for example, internal mold release agent) not covered by existing call-out capabilities can be assigned by the user. These shall be spelled out in detail and identified in sequence, that is, 01 UV-stabilized, 02 special color, and 03 etc.

5.2 Additional suffixes will be added to this specification as test methods and requirements are developed or requested, or both.

5.3 Additional suffixes are listed in Table 3 of Classification D4000. These use the two-letter, three-digit suffix system as established for the classification system for plastic materials.

6. Basic Requirements

6.1 Basic requirements from property or cell tables, as they apply, are always in effect unless these requirements are superseded by specific suffix requirements, that always take precedence.

7. Chemical Composition

7.1 The plastic composition shall be uniform and shall conform to the requirements specified herein. The color and form of the material shall be as agreed upon between the supplier and the user. Specification changes due to the effects of colorants should be noted by both parties and, when necessary, covered by suffixes.

8. Other Requirements

8.1 Test specimens for the various materials shall conform to the requirements prescribed in Table PE and Cell Tables A and B, and to suffix requirements as they apply.

8.2 Observed or calculated values obtained from analysis, measurement or test, shall be rounded in accordance with the rounding method in Practice E29 to the nearest unit in the last right-hand place of figures used in expressing the specified limiting value. The value obtained is compared directly with the specified limiting value. Conformance or nonconformance with the specification is based on this comparison.

9. Sampling

9.1 A batch or lot shall be considered as a unit of manufacture and can consist of a blend of two or more production runs of the same material.

9.2 Sampling shall be statistically adequate to satisfy the requirements of Annex A1.

10. Specimen Preparation

10.1 Unless otherwise specified, test specimens shall be compression molded in accordance with Annex A1, Procedure C of Practice D4703.

10.2 The specimen type and dimensions shall comply with those described in the test method section. Die-cut specimens are recommended; however, machine-cut specimens are acceptable.

11. Conditioning

11.1 *Conditioning*—Once specimens are molded, they shall be moved to a standard laboratory atmosphere or a controlled laboratory atmosphere. For natural unfilled polyethylene plastics the controlled laboratory atmosphere shall be 23 ± 2°C. Test specimens, 7 mm or under in thickness, shall be conditioned for a minimum of 40 h immediately prior to testing. For filled and reinforced polyethylene plastics or polyethylene plastic blends, which contain a hydrophilic co-monomer, pigment, or modifier the specimens shall be conditioned in a standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity (see Practice D618, Procedure A). For all materials to be conditioned for electrical testing, conditioning shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during the conditioning period.

11.2 *Test Conditions*—Natural unfilled polyethylene plastics shall be tested in a controlled laboratory atmosphere of 23 ± 2°C. For filled and reinforced polyethylene plastics and polyethylene plastic blends, which contain a hydrophilic co-monomer, pigment, or modifier the specimens shall be conditioned in a standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity. For all materials to be tested for electrical properties, the laboratory shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during testing.

11.3 *Dispute*—In cases of dispute, conditioning and testing shall be conducted in accordance with Procedure A of Practice D618.

12. Test Methods

12.1 Determine the properties enumerated in this specification in accordance with the ASTM methods as they apply, unless otherwise stated in this specification.

12.1.1 *Flow Rate*—Test Method D1238, using Condition 190°C/2.16 kg unless otherwise directed, (see Note 8). Make duplicate determinations on the material in the form of powder, granules, or pellets. No conditioning is required.

NOTE 8—Although the flow rate of polyethylene plastics can be measured under any of the conditions listed for it under 6.2 of Test Method D1238, only measurements made at Condition 190°C/2.16 kg are identified as "melt index."

This method of test serves to indicate the degree of uniformity of the flow rate of the polymer of a single manufacturer as made by an individual process and is not, by itself, indicative of the degree of uniformity of other properties. Additionally, uniformity of flow rate among various polymers of various manufacturers as made by various processes does not, in the absence of other tests, indicate uniformity or equivalency of other properties and vice versa.

The melt viscosity of polyethylene plastics, in common with that of most high polymers, is non Newtonian, that is, dependent on the rate of shear. The degree of departure from Newtonian behavior depends on the nature and molecular constitution of the individual sample. Additional characterization of the sample can be obtained if other conditions are used. Especially recommended as an adjunct to Condition 190°C/2.16 kg is Condition 190°C/10.0 kg or Condition 190°C/21.6 kg.

12.1.2 *Density*—Test Method D1505 or alternative methods referenced in 2.1 providing equivalent accuracy. Perform duplicate density determinations using two specimens taken from the same molding or one specimen taken from each of two moldings.

12.1.3 *Tensile Stress at Yield, Nominal Strain at Break, Test Method D638*—The speed of grip separation shall be 500 mm [20 in.]/min for specimens of densities of 0.925 g/cm^3 or less and 50 mm [2 in.]/min for densities greater than 0.925 g/cm^3. Specimens shall conform to the dimensions given for Type IV in Test Method D638 with thickness of 1.9 ± 0.2 mm [0.075 ± 0.008 in.]. Percentage elongation at break shall include the cold-drawing distance. Test results for specimens that break outside the gage marks after extensive cold drawing need not be discarded unless the break occurs between the contact surfaces of a grip.

12.1.4 *Secant Flexural Modulus at 2 % Strain*—Test Methods D790, using Procedure B, with a 51-mm [2-in.] span, and testing speed of 12.7 mm/min [0.5 in./min]. Test each 3.2 by 12.7-mm [0.125 by 0.5-in.] specimen flatwise and calculate the average value of the secant modulus at 2 % strain in the outer fibers.

12.1.5 *Environmental Stress-Crack Resistance, Test Method D1693*—The materials resistance shall meet the minimum requirement shown for the appropriate cell classification (in Cell Table A) when tested in accordance with Test Method D1693. Polyethylene materials with densities less than or equal to 0.925 shall be tested in accordance with Test Method D1693, Condition A. Polyethylenes with densities greater than 0.925 shall be tested in accordance to Test Method D1693, Condition B.

NOTE 9—The specimen dimensions and notch depths are different for these two conditions.

Igepal concentration for all testing is 100%. F_{50} shall be reported.

NOTE 10—F_{50} is the time required for failure of 50 % of the specimen tested in accordance with the graphical method described in Test Method D1693.

NOTE 11—There are environmental concerns regarding the disposal of Nonylphenoxy poly(ethyleneoxy) ethanol (CAS 68412-54-4), for example, Igepal CO-630. Users are advised to consult their supplier or local environmental office and follow the guidelines provided for the proper disposal of this chemical

12.1.6 *Slow Crack Growth Resistance, Test Method F1473*—The average failure time from two test specimens shall meet the minimum requirement shown (in Cell Table B) for the appropriate cell classification when tested in accordance with Test Method F1473 at 80°C and at 2.4 MPa stress. Specimen shall be prepared in accordance with the procedures described in Test Method F1473. A specimen with a nominal thickness of 10 mm shall be used. Test at least four specimens in case of a dispute.

12.1.7 *Thermal Stress Crack Resistance, Test Method D2951*—Specimen dimensions shall be in accordance with Test Method D2951. Each specimen being nominally 127 by 6.4 by 1.27 mm [5 by 0.25 by 0.05 in.]

12.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of:

12.2.1 Density

12.2.2 Flow Rate

12.2.3 Other tests (see Clauses 4 and 5) as required by end-use or contract requirements.

13. Inspection

13.1 Inspection of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

13.2 Lot acceptance shall be based on verification of the conformance of the lot to the requirements identified by the material designation and otherwise specified in the purchase order (see 5.1 and 5.2) and verified by tests made in accordance with the directions given in 12.1.

13.3 Periodic check inspection with reference to a specification based upon this classification system shall consist of the tests for all requirements of the material under the specification.

13.4 A report of the test results shall be furnished. The report shall consist of results of the lot acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

14. Certification

14.1 Certification shall be as required by Annex A1.

15. Packaging and Package Marking

15.1 For packing, packaging, and package marking, the provisions of Practice D3892 apply.

16. Keywords

16.1 molding and extrusion materials; polyethylene

SUPPLEMENTARY REQUIREMENTS

When applicable and as agreed upon between the user and the supplier, the following supplementary items are to be considered as part of this specification.

S1. Approval

S1.1 Material submitted by a new supplier must be approved by the user. Material or test specimens submitted by the supplier and intended for evaluation shall be accompanied by the supplier's laboratory test report.

S1.2 *New Sources*—The user has the option to temporarily accept shipment based on the supplier's certification.

S2. Infrared Spectrophotometry or Thermal Analysis, or Both

S2.1 At the option of the user, infrared or thermal analysis, or both can be conducted on material/parts supplied to this specification. The curves established for initial approval shall constitute the reference standard and shall be kept on file at the user's laboratory. All samples shall produce curves that correspond to the reference standard within agreed upon tolerances when tested under the same conditions as those specified on the master set of curves.

S2.2 In the event such tests are to be designated as requirements to be tested by the supplier, this must appear on the part drawing or purchase contract, or both.

S3. Quality Assurance Provisions for Government/Military Procurement

S3.1 In the absence of MIL-STD-105E, the following guidance shall be applied.

S3.2 Inspection and certification of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

S3.4 Lot acceptance shall be based on verification of the conformance of the lot to the requirements identified by the material designation and otherwise specified in the purchase order and verified by tests made in accordance with the directions given in clause 12.1 of this document.

S3.5 Periodic check inspection with reference to a specification based upon this classification system shall consist of the tests for all requirements of the material under the specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with S3.6.

S3.6 Certification shall be that the material was manufactured by a process in statistical control, sampled, tested, and inspected in accordance with this classification system, and that the average values for the lot meet the requirements of the specification (line callout).

S3.7 A report of the test results shall be furnished when requested. The report shall consist of results of the lot acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

X1. FLAMMABILITY REQUIREMENTS REFERENCING WITHDRAWN TEST METHODS

X1.1 The following table was extracted from the original subsection 5.1.2 and references D568, which was withdrawn in 1991 and is considered obsolete.

First digit

0 = To be specified by user.
1 = Product is 3.05-mm thickness, min.
2 = Product is 1.47-mm thickness, min.
3 = Product is 0.71-mm thickness, min.
4 = Product is 0.38-mm thickness, min.
5 = Motor Vehicle Safety Standard 302.

Second Digit

0 = To be specified by user.
1 = When burned horizontally in accordance with Test Method D635, a material:
(*a*)Does not have a burning rate exceeding 38.1 mm/min over a 76.2-mm span for specimens of 3.05 to 12.7-mm thickness; or
(*b*)Does not have a horizontal burning rate exceeding 76.2 mm/min over a 76.2-mm span for specimens of less than 3.05-mm thickness; or
(*c*) Ceases to burn, horizontally, before the 102-mm reference mark.
2 = When burned vertically in accordance with Test Method D568, the material:
(*a*)Does not have any specimens that burn with flaming combustion for more than 30 s after two applications of the test flame:
(*b*)Does not have a total flaming combustion time exceeding 250 s for 10 flame applications for each set of five specimens;
(*c*)Does not have any specimens that burn with flaming or glowing combustion up to the holder clamp;
(*d*)Has specimens that drip flaming particles that ignite the dry absorbent surgical cotton placed 305 mm [12 in.] below the test specimen;
(*e*)Does not have any specimens with glowing combustion that persists for more than 60 s after the second removal of the test flame.
3 = When burned vertically in accordance with Test Method D568, the material:
(*a*)Does not have any specimens that burn with flaming combustion for more than 30 s after either application of the test flame;
(*b*)Does not have a total flaming combustion time exceeding 250 s for the 10 flame applications for each set of five specimens;
(*c*)Does not have any specimens that burn with flaming or glowing combustion up to the holding clamp;
(*d*)Does not have any specimens that drip flaming particles that ignite the dry absorbent surgical cotton located 305 mm [12 in.] below the test specimen;
(*e*)Does not have any specimens with glowing combustion that persists for more than 60 s after the second removal of the test flame.
4 = When burned vertically as described in Test Method D568, the material:
(*a*)Does not have any specimens that burn with flaming combustion for more than 10 s after either application of the test flame;
(*b*)Does not have a total flaming combustion time exceeding 50 s for the 10 flame applications for each set of five specimens;
(*c*)Does not have any specimens that burn with flaming or glowing combustion up to the holding clamp;
(*d*)Does not have any specimens that drip flaming particles that ignite the dry absorbent surgical cotton located 305 mm [12 in.] below the test specimen;
(*e*)Does not have any specimens with glowing combustion that persists for more than 30 s after the second removal of the test flame.
5 = When burned vertically in accordance with Test Method D568, the material:
(*a*)Does not have any specimens that burn with flaming or glowing combustion for more than 60 s after the fifth flame;
(*b*)Does not have any specimens that drip particles.
6 = Has a burn rate less than 100 mm/min.

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CLASSIFICATION SYSTEM FOR COPOLYMERS OF VINYLIDENE FLUORIDE (VDF) WITH OTHER FLUORINATED MONOMERS

SD-5575

(Identical with ASTM D5575-07(R13) except for revisions in section 11, additional requirements in section 12 and Annex A1, and renumbering of sections 13, 14, and 15.)

Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers

1. Scope

1.1 This classification system covers both developing property designations and specifications for thermoplastic compositions consisting of vinylidene fluoride (VDF) polymers modified with other fluoromonomers and property-enhancing additives. The other fluoromonomers include one or more of the following: hexafluoropropylene (HFP), tetrafluoroethylene (TFE), and chlorotrifluoroethylene (CTFE). The additives are those that improve its flame resistance, processing, or physical properties. However, these additives are not normally considered to be reinforcing. This classification system covers thermoplastic compositions supplied in pellet or powder forms.

1.2 A designation or specification applies only to the virgin polymers prepared from vinylidene fluoride (>50 weight %) with one or more of the following comonomers: hexafluoropropylene, tetrafluoroethylene, and chlorotrifluoroethylene. Some polymers contain additives to enhance certain properties.

1.3 This system constitutes a line callout as a means of designating and specifying properties of VDF-based copolymers. At least four of the designated properties are used to define a polymer's specification. Specification criteria from international documents can be used if their criteria match designation properties currently used by this classification system. This classification system is not intended for the selection of materials.

1.4 The manufacturer of the virgin resin shall establish the designation of a resin based on the property value criteria in this classification system.

1.5 The minimum specification properties are established by this classification system. Additional specification properties, based on the designation properties cited, can be established by the resin supplier and customer.

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

1.7 The property tests are intended to provide information for specifications of modified VDF-copolymer compositions. It is not the purpose of this classification system to provide engineering data for design purposes.

NOTE 1—Although the values listed in Table 1, Table 2, Table 3, Table 4, and Table 5 are necessary to include the range of properties available in existing materials, they are not to be interpreted as implying that every possible combination of the properties exists or can be obtained. It is possible for a user or designer, using Tables 1-5, to call out property relationships that are physically impossible to occur in a copolymer made using current technology.

NOTE 2—Many of these polymers exhibit polymorphism. The type and extent of crystalline structure will vary with the thermomechanical history of the sample. Properties vary based on the technique used to prepare the specimens.

1.8 Test methods used in this classification system can result in the incidental production of hazardous materials. Modified VDF polymer fluoroplastics melt between 90 and 182°C (194 and 359°F) and are thermally stable up to about 350°C (662°F), or somewhat higher, depending on the composition. (**Warning—**Evolution of corrosive, colorless, and toxic hydrogen fluoride can occur under certain conditions.)

1.9 *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.* See Warning in 1.8 and Section 10 for specific hazards statements.

NOTE 3—Many, but not all of the codes and specifications found in this classification system are also in ISO 12086-1 and ISO 12086-2.

TABLE 1 Codes for the Information on Fluoropolymers Used in Data Block 1

Code	Meaning
A	modified
B	block copolymer
H	homopolymer
K	copolymer
L	graft polymer
R	random copolymer
Z	other

TABLE 2 Code-Letters Used in Data Block 2 (Intended Application or Method of Processing, Essential Properties, Additives, or Other Information

Code	Position 1	Code	Positions 2 to 8
A	adhesives	C	colored
B	blow molding	D	powder
B1	extrusion blow molding	D2	free-flowing
B2	injection blow molding	D3	not free-flowing
C	calendaring	E	expandable
E	extrusion	F	special burning characteristics
G	general use	F1	nonflammable
H	coating	F2	flame retarded
H1	powder coating	F4	reduced smoke emission
H2	dip coating	G	granules
K	cable and wire coating	G1	pellets
L	monofilament extrusion	L	light and weather stabilized
M	molding (injection/transfer)	M	nucleated
Q	compression molding	N	natural (no color added)
R	rotational molding	N1	suitable for food contact
V	thermoforming	N2	high purity
X	no indication	P	impact modified
Y	textile yarns, spinning	R	mold release agent
Z	other	S	lubricated
		T	transparent
		T1	translucent
		T2	opaque
		W1	improved chemical resistance
		Y	increased electrical conductivity
		Z	antistatic

TABLE 3 Designatory and Specification Properties for Data Block 3

Position Number[A]	Property
1	[B] melt temperature
2	[B] melt flow rate/melt viscosity
3	[B] tensile strength and modulus
4	tensile elongation
5	[B] density
6	electrical
7	flammability by oxygen index (OI)
8	specimen preparation method and type

[A] Property test information for Positions 1 to 7 are given in Section 8.
[B] Positions 1, 2, 3, and 5 are mandated as the minimum specification properties.

2. Referenced Documents

2.1 *ASTM Standards:*

NOTE 4—For ASTM and ISO documents, the equivalent or a comparable method is listed after each citation in parentheses.

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
D3222 Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer
D3892 Practice for Packaging/Packing of Plastics
D4591 Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D5740 Guide for Writing Material Standards in the Classification Format
IEEE/ASTM S1–10 Standard for Use of the International System of Units (SI)

2.2 *IEC and ISO Standards:*

IEC 60093 Recommended Methods of Test for Volume and Surface Resistivities of Electrical Insulating Materials
IEC 60250 Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulating Materials at Power, Audio and Radio Frequencies Including Metre Wavelengths
ISO 291 Plastics—Standard Atmospheres for Conditioning and Testing (Practice D618)
ISO 293 Plastics—Compression Molding Test Specimens of Thermoplastic Materials (Practice 4703)
ISO 472 Plastics—Vocabulary (Terminology D883)
ISO 527/1,2,3 Plastics—Determination of Tensile Properties (Test Method D638)
ISO 1043/1 Plastics—Symbols—Part 1: Symbols for Basic Polymers and Their Special Characteristics (Terminology D883)
ISO 1043/2 Plastics—Symbols—Part 2: Fillers and Reinforcing Materials (Terminology D883)
ISO 1133 Plastics—Determination of the Melt Mass-Flow Rate (MFR) and the Melt Volume-Flow Rate (MVR) of Thermoplastics (Test Method D1238)
ISO 1183 Plastics—Methods for Determining Density and

TABLE 4 Date Block 3

Position 1		Position 2					Position 3			Position 4		
		Melt Viscosity/Melt-Flow Rate					Tensile Strength			Tensile Elongation		
Code	Tm,° C	Code	Melt-Flow Rate, g/10 min	Load, kg	Melt Vis-cosity, Pa/s[A]	Temp-era-ture, °C	Code	Yield Strength, MPa	Modulus, MPa	Code	Yield, %	Break, %
a	<20	a	<0.1		<250		a	<15	<500	a	<5	<50
b	20 to <30	b	0.1 to< 0.2	0.325	>250		b	15 to <20	500 to< 800	b	5 to <10	50 to <100
c	30 to <40	c	0.2 to <0.5	1.20	>500		c	20 to <25	800 to< 1200	c	10 to <15	100 to <150
d	40 to< 50	d	0.5 to <1.0	2.16	>100		d	25 to< 30	1200 to <1600	d	15 to <20	150 to <200
e	50 to <60	e	1.0 to <2.0	3.80	>1500		e	30 to< 35	1600 to <2000	e	20 to <25	200 to <250
f	60 to <70	f	2.0 to <5.0	5.00	>2000	230	f	35 to< 40	2000 to <3000	f	25 to <30	250 to <300
g	70 to <80	g	5.0 to <10	10.00	>2500	125	g	40 to< 45	3000 to< 4000	g	>30	300 to <350
h	80 to< 90	h	10 to < 20	12.50	>3000		h	45 to< 50	4000 to <6000	h		350 to <400
i	90 to < 100	i	20 to <50	21.60	>3500		i	50 to< 55	>6000	i		400 to <500
j	100 to< 110	j	≥50	31.60			j	55 to< 60		j		500 to <600
k	110 to< 120	k					k	60 to <65		k		600 to< 800
l	120 to< 130	l					l	≥65		l		>800
m	130 to <140	m					m			m		
n	140 to <150	n					n			n		
o	150 to <160	o					o			o		
p	160 to <170	p					p			p		
q	170 to <180	q					q			q		
r	180 to <190	r					r			r		
s	190 to <200	s					s			s		
t	200 to <210	t					t			t		
u		u					u			u		
v		v					v			v		
w		w					w			w		
x		x					x			x		
y		y					y			y		
z	not specified	z	not specified				z	not specified		z	not specified	

[A] 1 Pa/s = 10 P.

TABLE 5 Codes for Filler and Physical Form of Materials for Use in Data Block 4

Code	Material	Code	Form/Structure
B	boron	B	beads, spheres, balls
C	carbon	C	chips, cuttings
CG	graphite	D	powder
E	clay	F	fiber
G	glass	G	ground
K	calcium carbonate	H	whisker
M	mineral, metal	K	knitted fabric
Ma	aluminum oxide	L	layer
Mb	bronze	M	mat (thick)
MC	calcium fluoride	N	nonwoven (fabric)
Md	molybdenum disulfide	P	paper
Me	stainless steel	S	roving
P	mica	T	scale, flake
Q	silica	V	cord
R	aramid	W	veneer
S	synthetic, organic	X	not specified
T	talcum	Y	yarn
X	not specified	Z	others
Z	none		

Relative Density of Non-Cellular Plastics (Test Methods D792)

ISO 4589 Plastics—Determination of Flammability By Oxygen Index

ISO 12086-1 Fluoropolymer Dispersion and Molding and Extrusion Materials—Part 1: Designation and Specification

ISO 12086-2 Fluoropolymer Dispersion and Molding and Extrusion Materials—Part 2: Preparation of Test Specimens and Determination of Properties

3. Terminology

3.1 *Definitions:*

3.1.1 *copolymer*—a polymer derived from more than one species of monomer.

3.1.2 *fluoroplastic*—a plastic based on polymers made with monomers containing one or more atoms of fluorine, or copolymers of such monomers with other monomers, the fluoro-monomer(s) being in the greatest amount by mass.

3.1.3 *monomer*—a low-molecular-weight substance consisting of molecules capable of reacting with like or unlike molecules to form a polymer.

3.1.4 *thermoplastic*—a plastic that repeatedly can be softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state can be shaped by flow into articles by molding or extrusion.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *amorphous*—noncrystalline or devoid of regular structure.

3.2.2 *contamination*—the presence of nonpolymer particulate and debris in the polymer, excluding any property-enhancing additives.

3.2.3 *fluoropolymer*—synonymous with fluoroplastic.

3.2.4 *melt-processible*—capable of being processed by, for example, injection molding, screw extrusion, and other operations typically used with thermoplastics.

Position 5		Position 6				Position 7		Position 8	
Code	Specific Gravity, g/cm^3	Code	Electrical a-c Dielectric Constant	Loss	d-c Electric Volume	Code	Limiting Oxygen Index	Code	Specimen Type
a	<1.6	a			>10E3	a	<40	a	D638 Type I
b	1.6 to <1.7	b			10E3 to 10E12	b	40 to <50	b	D638 Type II
c	1.7 to< 1.8	c			>10E12	c	50 to <60	c	D638 Type III
d	1.8 to <1.9	d				d	60 to< 70	d	D638 Type IV
e	1.9 to< 2.0	e				e	70 to <80	e	ISO 527 Type 1A
f	2.0 to <2.1	f				f	80 to <90	f	ISO 527 Type 1B
g	2.1 to< 2.2	g		<0.0012		g	>90	g	ISO 527 Type 6A
h	2.2 to< 2.3	h	<3.0	<0.0014		h		h	ISO 527 Type 7A
i	2.3 to <2.4	i	3.0 to< 3.1	<0.0016		i		i	ISO 12086/1 Fig. 1
j	2.4 to <2.5	j	3.1 to <3.2	<0.0018		j		j	D638 Type MI
k		k	3.2 to< 3.5	<0.0020		k		k	D638 Type MII
l		l	3.5 to <4.0	<0.0022		l		l	D638 Type MIII
m		m	4.0 to< 4.5	<0.0024		m		m	
n		n	4.5 to <5.0	<0.0026		n		n	
o		o	5.0 to< 5.5	<0.0028		o		o	
p		p	5.5 to <6.0	<0.0030		p		p	D1708
q		q	6.0 to <6.5	<0.0035		q		q	
r		r	6.5 to <7.0	<0.0040		r		r	
s		s	7.0 to <8.0	<0.0060		s		s	
t		t	8.0 to <9.0	<0.0080		t		t	
u		u	9.0 to <10	<0.0100		u		u	
v		v	10 to <11	<0.0300		v		v	
w		w	11 to <12	<0.1000		w		w	
x		x	12 to <14	>0.1000		x		x	
y		y	>14			y		y	
z	not specified	z	not specified		not specified	z	not specified	z	

3.2.5 *polymorphism*—the ability of a material to form two or more different but stable crystalline forms.

3.2.6 *thermomechanical history*—the mechanical and thermal exposure that a material experiences before testing.

3.3 *Abbreviations:*

3.3.1 *CTFE*—chlorotrifluoroethylene (1-chloro-1,2,2-trifluoroethylene).

3.3.2 *DMAC*—dimethylacetamide.

3.3.3 *DSC*—differential scanning calorimetry.

3.3.4 *HFP*—hexafluoropropylene (1,1,2,3,3,3-hexafluoropropylene).

3.3.5 *MFR*—melt-flow rate.

3.3.6 *MV*—melt viscosity.

3.3.7 *PVDF*—poly(vinylidene fluoride).

3.3.8 *TFE*—tetrafluoroethylene (1,1,2,2-tetrafluoroethylene).

3.3.9 *VDF*—vinylidene fluoride (1,1,-difluoroethylene).

3.3.10 *VDF/CTFE*—vinylidene fluoride/chlorotrifluoroethylene copolymer.

3.3.11 *VDF/HFP*—vinylidene fluoride/hexafluoropropenecopolymer.

3.3.12 *VDF/TFE*—vinylidene fluoride/tetrafluoroethylene copolymer.

3.3.13 *VDF/TFE/HFP*—vinylidene fluoride/tetrafluoroethylene/hexafluoropropene copolymer.

4. Classification and Designation

4.1 The classification and designation system of the polymers is based on the following standardized pattern taken from ISO 12086-1:

Designation and Classification System

Description Block

| Identity Block |

| Individual Item Block |

Data Block 1	Data Block 2	Data Block 3	Data Block 4	Data Block 5

4.1.1 The designation system consists of the following:

4.1.1.1 An optional description block, reading "Thermoplastics,"

4.1.1.2 An identity block comprising the ASTM standard number, and

4.1.1.3 An individual item block.

(1) The individual item block is subdivided into five data blocks that include the information in 4.2 – 4.6. Data Block 5 is used when a designation is converted to a specification. See Section 7 for more details.

(2) The blocks shall be separated from each other by commas. If a data block is not used, this shall be indicated by doubling the separation sign, that is, by two commas (,,).

4.2 *Data Block 1*—This data block identifies the fluoropolymer by its abbreviation from the list in 3.3 (additional terms are listed in ISO 12086-1, 2, or Terminology D1600). The abbreviation is followed by a hyphen and a one-letter code giving more information about the polymer, using the codes from Table 1.

4.3 *Data Block 2:*

4.3.1 This block can indicate up to eight items of information coded by letters as specified in Table 2. Position 1 gives information about intended application or method of processing. Positions 2 through 8 provide up to seven items that can use codes from Table 2 to indicate the polymer's form as well as specific special characteristics.

4.3.2 If only one letter is given (for example, E), it must apply to Position 1. Whenever there is an indication of properties, etc., in Positions 2 to 8, a code in Position 1 is required. The code "X" indicates that no other letter code is appropriate. An alphabetical order is recommended if more than one code letter is used in Positions 2 to 8.

NOTE 5—Selecting the application or processing method for Position 1 of Data Block 2 must be done carefully. Many polymers are capable of more than one application or method of processing (for example, extrusion (E) and molding (M) resins must be coded "general use" (G)). Coding for special methods of processing must be reserved for polymers only designed for the application.

4.4 *Data Block 3:*

4.4.1 Data Block 3 is used as the designation or general description of the fluoropolymer's properties. The property values are presented by code letters in seven of eight positions within Data Block 3. Each position represents a specific property listed in Table 3. Table 4 lists the code letters corresponding to the various property values. The values are determined by the methods cited in Section 8. At least four of the seven properties are specification properties. Position 8 cites specimen preparation methods when the designation is converted to a specification.

4.4.1.1 Each position shall contain one or more code letters, depending on the property cited. The positions are separated by a hyphen (-). Use of an asterisk (*) or question mark (?) before the code letters denotes that property as a specification property.

4.4.1.2 The resin manufacturer shall assign the codes in Data Block 3, based on test results from Table 4. If test values lie on, or on either side of, a cell limit because of manufacturing tolerances, the resin manufacturer shall state which cell will designate.

NOTE 6—Properties other than those in this classification system or do not have standard test methods are outside of the property focus of the document scope (for example, comonomer ratios).

4.4.2 *Melting Endotherm Peak Temperature (Position 1)*—Melting endotherm peak temperature shall be determined in accordance with the principles of Test Methods D3418 and D4591. Semicrystalline polymers shall use melting endotherm peak temperature as a designatory property. Cell codes and ranges are given in Table 4.

4.4.3 *Melt-Flow Rate or Melt Viscosity (Position 2)*—Melt viscosity (MV) shall be determined using Test Method D3835. Melt-flow rate (MFR) shall be determined in accordance with Test Method D1238 or ISO 1133, using test conditions selected from Table 4. The melt viscosity or the melt-flow rate is indicated in Data Block 3 by the cell code and ranges in accordance with Table 4, followed by the codes for temperature and load for MFR and shear rate for MV also included in Table 4. Order for Position 2 is as follows:

Position 2 Order

1st = MFR
2nd = MFR load
3rd = MV
4th = Temperature

4.4.4 *Tensile Strength Properties (Positions 3 and 4)*—Tensile-strength properties shall be determined in accordance with the principles of Test Method D638 or ISO 527 modified by details given in 8.9 or ISO 12086-2. Table 4 provides the codes to use for each range of tensile strength and modulus, and percentage elongation at yield and break. Order for Positions 3 and 4 are as follows:

Position 3 Order	Position 4 Order
1st = tensile yield	1st = tensile-yield elongation
2nd = tensile break	2nd = tensile-break elongation
3rd = tensile modulus	

4.4.5 *Density (Relative Density, Specific Gravity) (Position 5)*—Density shall be determined in accordance with the principles of Test Methods D150 or ISO 12086-2. The cell codes are listed in Table 4.

4.4.6 *Electrical Properties (Position 6)*— Electrical properties for d-c and a-c currents shall be determined by Test Methods D150, D257, or their ISO equivalents. The cell codes are listed in Table 4. Order for Position 6 is as follows:

Position 6 Order

Position 1 = resistivity
Position 2 = frequency (listed as the exponent of the power of ten)
Position 3 = dielectric constant
Position 4 = dissipation factor
Positions 5 to 7, 8 to 10, 11 to 13, ... (repeat of 2 to 4 for each frequency cited)

4.4.7 *Flammability Properties (Position 7)*—Flammability properties shall be determined by oxygen index (OI) values using Test Method D2863 or ISO 4583. The cell codes are listed in Table 4.

4.4.8 *Specimen Preparation and Type (Position 8)*—This position is used only when a designation is converted to a specification to describe the molded specimen type and its preparation. Section 9 provides information on preparing compression-molded specimens. Cell codes are listed in Table 2 and Table 4. Order for Position 8 is as follows:

Position 8 Order

1st = molding method (from Table 2, Position 1)
2nd = tensile bar type and method (Table 4)

NOTE 7—Using specimen preparation method and type cited in Position 8 allows the supplier and customer to monitor polymer properties while minimizing the effects of specimen preparation.

4.5 *Data Block 4*—Data Block 4 is used to site the type (Position 1) and form (Position 2) of fillers or other materials added to the fluoropolymer. Letter codes listed in Table 5 are used to indicate the type and form used (supplemental codes can be found in ISO 1043/2). The nominal content, by weight percent, is noted by arabic numerals after Position 2 to the nearest 1 %. Additive contents below 2 % need not be specified. For designation clarity, a hyphen (-) is used to separate material type codes. When a material is present in more than one form, a plus sign (+) is used to separate the form codes.

4.6 *Data Block 5:*

4.6.1 Data Block 5 is used to denote changes in the values of a property when the designation is converted to specification. The type of changes would be the following:

4.6.1.1 To cite the alternate property value range when a (?) is used in Data Block 3. Where more than one (?) is cited, the value ranges shall be listed in order of their occurrence.

NOTE 8—It is recommended that any ranges smaller than designated by

Table 4 codes be greater than the precision and bias for the test method that measures the property.

4.6.1.2 To cite a current ASTM or other standard specification for the polymer (see 4.7 for restrictions).

4.6.1.3 A combination of 4.6.1.1 and 4.6.1.2.

4.7 *Designation and Specification Restrictions:*

4.7.1 Data Block 5 of the specification call-out cannot cite properties beyond the scope of this classification system. In other words, specification criteria or properties from other specifications that conflict with this classification system's scope are not allowed.

NOTE 9—Some specifications cite properties that are either not detectable or use test methods not available to most customers. Therefore, specification property values or results shall be able to be determined by a user without *a priori* knowledge of the polymer's manufacturer, polymerization process, or any other unique finishing process.

4.7.2 A commercial grade of polymer shall not have multiple designations for Data Block 2. The application choice shall be broad enough for a variety of the applications to which it can be applied.

4.7.3 An alternate specification property range in Data Block 5 shall not be greater than the original designation-code range from Table 4 and either the preceding or following code. In other words, if a property code is normally "D," the new range could encompass values or ranges from Code "C and D" or "D and E." The new values cannot encompass a range cited by Codes "C to E" or greater.

4.7.4 At no time shall a designation for a commercial grade have more than one designation for Data Blocks 1, 2, 3, and 4. If the code values need to be modified from those cited in Table 4, the changes shall be done by use of a (?) and listed in Data Block 5.

5. General Requirements

5.1 The material shall be ordered by the manufacturer's trade name and corresponding copolymer line callout and the necessary suffix properties to define the material.

5.2 The material shall be of uniform composition and free of foreign matter to a contamination level agreed upon between the purchaser and the seller.

5.3 Adequate statistical sampling shall be considered an acceptable alternative.

6. Example of a Designation

6.1 The following example is for VDF/HFP fluoropolymer material for general-purpose molding with a designation of:

7. Specifications for Fluoropolymers

7.1 *Designation Conversion to Specification:*

7.1.1 A designation is converted into a specification by preceding 4 or more property codes in Data Block 3 with an asterisk and adding the specimen preparation codes in Data Block 3, Position 8, from Table 2 and Table 4.

7.1.1.1 Four property codes, cited by Data Block 3 positions, that must be included in a specification are as follows:

Data Block 3 Position	Property
1	melt temperature
2	melt-flow rate or melt viscosity, or both
3	tensile strength and modulus
5	density

7.1.2 *Specification Using Designation Ranges:*

7.1.2.1 *Example (see Appendix X2):*

A VDF/CTFE copolymer, a general-use grade, sold as granules, and having the following (specification properties are in boldface type):

(*1*) **A melting point of 165°C,**
(*2*) **An MV of 1500 Pa/s when tested at 230°C at 100 s^{-1},**
(*3*) **A tensile strength yield of 28 MPa; break strength not cited; modulus of 800 MPa,**
(*4*) Elongation yield of 9 %; break of 450 %,
(*5*) **Density between 1.78,**
(*6*) Electricals of:
Volume resistivity greater than 2.3 $E^{14}\Omega$,
Dielectric constant at 1 kHz at 10.1; at 10 kHz at 9.3; 1 MHz at 7.3,
Dissipation factor at 1 kHz at 0.021; at 10 kHz at 0.031; at 1 MHz at 0.15,
(*7*) OI at 53, and
(*8*) Tested using compression-molded specimens using ISO 527 Type-6A tensile bars.

Designation and specification where each designatory property is desired as part of the specification with the specification limits equal to the cell limits is as follows:

ASTM D5XXX, VDF/CTFE-K, GG,*P-*ZZE-*DZC-BI-*C-C3VU4UVSXY-C-*QG,Z,, ASTM D5XXX, VDF/CTFE-K, GG,*P-*ZZE-*DZC-BI-*C-C3VU4UVSXY-C-*QG, Z,,

7.1.3 *Specification Using Alternate Property Ranges:*

7.1.3.1 When the values given in the cell tables are not satisfactory for specification purposes, indicate this situation by inserting a question mark in Data Block 3 at the beginning of the destination cell code and the specification range given in Data Block 5.

7.1.3.2 *Example (see Appendix X3):*

A modified VDF/HFP copolymer that is processed by extrusion, with reduced-burning characteristics and smoke emissions. The resin is marketed as pellets, contains a lubricant, and is opaque. The additive level is less than 2 %. Its properties are as follows (specification properties are in boldface type):

(*1*) **A melting point of 143°C,**
(*2*) **An MV between 1300 and 1700 Pa/s when tested at 230°C at 100 s^{-1},**
(*3*) **A tensile strength yield of 24 MPa; break not cited; modulus of 1000 MPa,**
(*4*) Elongation yield of 12 %; break of 350 %,
(*5*) **Density of 1.79,**
(*6*) Electricals not cited.
(*7*) OI greater than 80,
(*8*) **Tensile specimens are compression-molded and Test Method D638, Type I,** and
(*9*) The melt-viscosity range encompasses two ranges.

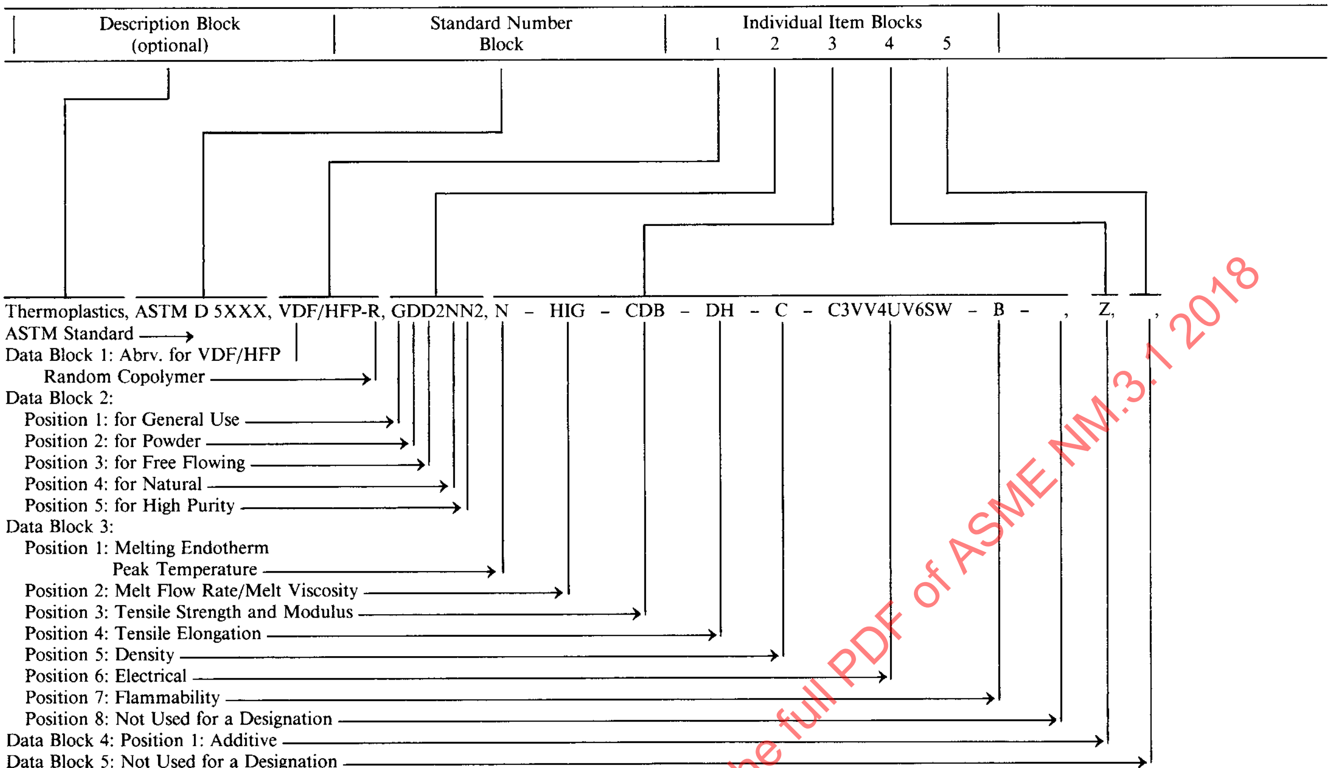
Designation and specification is as follows:

ASTM D5XXX, VDF/HFP-A, EFF4G1ST2, *N-*ZZ?E-*CZC-CH-*C-ZZ-*C-QA, Z, ?1300–1700,

8. Property Determination Methods

8.1 The following subsections of Section 8 cite test methods used to determine polymer-property values of code levels from Table 4 for Data Block 3 of a designation or specification line call-out. When a test value normally varies between two code levels, the manufacturer shall designate the code levels. Several properties are tested using molded specimens. Section 9 presents a procedure to prepare compression-molded specimens. Injection molded specimens are allowed, but due to stress effects on many properties, compression molding of specimens is preferred.

Thermoplastics, ASTM D 5XXX, VDF/HFP-R, GDO2MM2, M-MIG-CDB-DH-C-C3YY4UV6SW-B-, Z,,
Detailed Explanation of the Designation



8.2 *Melt Temperature*—The copolymers peak melting points are determined using Test Methods D4591 or D3418 using DSC. The sample size is 10 ± 1 mg. The sample is heated, cooled, and reheated over a temperature range from −20 to 220°C at a rate of 10°C/min. The sample is held at the upper temperature for 5 min before cooling. The second heating endotherm peak value shall be used. Occasionally multiple peaks are observed. The temperature of the tallest peak shall be reported as the melting point.

8.3 *Melt-Flow Rate and Melt Viscosity:*

8.3.1 *Melt-Flow Rate*—The melt-flow rate (MFR) shall be determined using Test Method D1238 or ISO 1133 at 230°C for all resins whose melt point is above 100°C. Lower melt-point resins shall use a test temperature of 125°C.

8.3.2 *Melt Viscosity*—The melt-viscosity value at 100 s^{-1} at 230°C shall be determined from a shear-rate viscosity curve of four or more points ranging from less than 50 s^{-1} to greater than 500 s^{-1} shear rate. For polymers with melt points greater than 110°C, a test temperature of 125°C shall be used. The rheometer die shall have an entrance angle of 60° (cone angle of 120°) and a capillary L/D ratio of 15. The sample shall be pellets or pieces cut from molded or extruded forms. Strips about 6 mm wide by 76 mm long are easily handled.

8.4 *Tensile Properties:*

8.4.1 Tensile properties, except modulus, shall be tested in accordance with Test Method D638 or ISO 527 at a strain rate of 25 mm/mm/min (1 in./in./min). The strain rate is the ratio of the cross-head speed divided by the specimen-gauge length. Tensile modulus shall use a strain rate of 2 % of the previous strain rate (0.5 mm/mm/min or 0.013 in./in./min). The property values of the resin shall be determined as the average of results from at least five specimens.

NOTE 10—When test equipment cannot test at a 2 % strain rate for the smaller test bars, a higher strain rate (less than 5 %) is allowed.

8.4.2 Elongation is determined as the percent change in specimen length during the test, based on the original gauge length. This value can be determined by either cross-head separation or by use of an extensometer.

8.4.3 Compression molded specimens are preferred (see Section 9), but injection-molded specimens or specimens cut from extruded sheet are allowed. Dies or mold cavity-dimensions to cut or mold specimens shall match the required specimen dimensions and tolerances.

NOTE 11—The different test bar shapes have three basic types with minor variations. Unfortunately, these differences can affect the test values. For this reason Position 8 in Data Block 3 is used when a designation is changed to a specification. Examples of the three basic shapes are as follows:

Large: D638 Type I or ISO 527 Type 1A	(50-mm gauge)
Medium: ISO 527 Type 6A or Test Method D638 Type IV	(25-mm gauge)
Small: ISO 12086-2 Figure 1	(22-mm gauge)

NOTE 12—Due to the molded-in stress and orientation, injection-molded or samples cut from extruded sheet are subject to breaking outside of the gauge region and show low (and possibly variable) elongation compared to compression-molded specimens. Some samples exhibit strain hardening. This effect can result in variable break properties.

8.5 *Specific Gravity*—The specific gravity shall be determined by Test Methods D792 using two test specimens cut from a compression-molded sample. With this test, care must be exercised to eliminate all air bubbles attached to the specimens upon immersion. Dipping the specimens in a very dilute solution (less than 0.1 weight %) of a surfactant will minimize the problem.

8.6 *Electrical Properties:*

8.6.1 *Specimen Type:*

8.6.1.1 The electrical tests are determined on three specimens, each 100 mm in diameter and 0.12 to 0.25 mm (0.005 to 0.010 in.) in accordance with IEC 250, Test Methods D150, and Test Method D257.

8.6.2 *Volume Resistivity*—The d-c volume resistivity shall be measured using Test Method D257 or IEC 93. Cell codes and ranges are listed in Table 4.

8.6.3 *Dielectric Constant and Dissipation Factor*—The a-c dielectric constant and dissipation factor shall be determined by Test Methods D150. The testing shall be done at the following frequencies: 1 kHz, 10 kHz, 0.1 MHz, and 1 MHz. Codes for dielectric constant and dissipation factor are listed in Table 4. The code used for each frequency shall be the first integer of the base 10 log of the frequency (for example, 1 kHz = 3; 1 MHz = 6).

8.7 *Limiting Oxygen Index (LOI)*—Limiting oxygen index is determined by Test Method D2863. For formulations that extinguish before the 3-min burn time that defines the LOI value at oxygen levels above 95 %. In this case, the LOI value is the highest oxygen level used.

NOTE 13—If a column with a restricted opening is used, the top of the specimen shall be positioned at least 40 mm below the opening.

9. Preparation of Compression-Molded Specimens

9.1 *Molding Conditions:*

9.1.1 Compression-molded sheets can be prepared by Practice D4703 using a "picture frame" mold. The resin form can be pellets, molded preforms, or powder. The temperature shall be 230°C for all resins with a melt point greater than 110°C. For resins with a lower melt point, use 125°C. Where possible, cooling shall be done under pressure either by slow cooling (Method A or B) or quench cooling (Method C). It is recommended that an inert mold-release sheet (less than 0.007 in.) of aluminum, polyimide, or PTFE be used.

9.1.2 The ram forces are used based on the size of the specimen area. The force adjustment exerts an approximate pressure of 0.25 kN/cm^2 (360 lb/in.^{2}) of specimen area.

NOTE 14—Powder samples tend to entrap air and cause bubbles in the specimen when compression molded. Such specimens are not suitable for any test in this classification system. Use molded preforms or densified powder to eliminate bubble formation.

9.2 *Specimen Preparation*—Test specimens can be molded directly by a shaped mold or cut from a molded sheet. The dimensions of shaped molds can vary due to mold-shrinkage effects. Cutting specimens from a molded sheet is preferred.

NOTE 15—The specimen edge will affect performance in mechanical tests. Die-cutting is the preferred method of preparing specimens. The cutting edges shall be sharp and free from any nicks or other defects that could cause a dimensional defect in the specimen.

10. Handling

10.1 As with any synthetic resin, it is advisable to wear a dust mask when handling large quantities of powder grades to prevent ingestion.

10.2 The Material Safety Data Sheets of the fluoropolymer grade must be reviewed to determine if there is any special-handling information.

11. Inspection

11.1 Inspection of the material supplied under this classification system or specification shall be for conformance to the requirements specified herein.

11.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of melt-flow rate, melt viscosity, tensile and elongation at break.

11.2.1 Those tests that ensure process control during manufacture as well as those necessary to ensure certifiability in accordance with Annex A1.

11.2.2 The four minimum lot-acceptance tests are melt temperature, melt flow rate/melt viscosity, tensile strength and modulus, and density as listed in Table 3.

11.3 A lot is defined as one production run or a uniform blend of two or more production runs.

11.4 Periodic check inspection shall consist of the tests specified for all requirements of the material under this classification system. Inspection frequency shall be adequate to ensure that the material is certifiable in accordance with Annex A1.

11.5 A report of the test results shall be furnished. The report shall consist of the results of the lot-acceptance inspection for the shipment and the results of the most recent periodic-check inspection.

12. Certification

12.1 Certification shall be as required by Annex A1.

13. Packaging, Packing, and Marking

13.1 Unless otherwise agreed upon between the purchaser and the seller, the packing, packaging, and marking provisions of Practice D3892 shall apply to this classification system.

14. Precision and Bias

14.1 The precision and bias statements of the ASTM test methods referenced herein apply to the specific tests required in this classification system.

15. Keywords

15.1 fluoropolymers; line callout; plastics; poly(vinylidene fluoride) copolymers

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. FORM TO DEVELOP DESIGNATION AND SPECIFICATION CODE

Test/Parameter	Actual Lot Data		Specification Y N	Data Block	Data Table	Code Used	Other Comments
Polymer abbreviation	____		Y-mandated	No. 1–2	Section 3.3	____	
Polymer type	____		Y-mandated	No. 1-2	Table 1	____	
Application/process and	____		Y-mandated	No. 2-1	Table 2-1	____	
special characteristics	____						
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
	____		Y N (optional)	No. 2-2	Table 2-2	____	
Properties	____					____	
Melt temperature	____	°C	Y-mandated	No. 3-1	Table 4-1	*____	Test Method D4591
MFR	____	g/10 min	Y-mandated	DB 3-2a	Table 4.1	*____	Test Method D1238
Load	____	kg	[or use]	DB 3-2b	Table 4.2	*____	Test Method D1238
Melt viscosity	____	Pa/s	Y-mandated	DB 3-2c	Table 4.3	*____	Test Method D3835
Temperature	____	°C	Y-mandated	DB 3-2d	Table 4.4	*____	
Tensile strength:	____					____	
Yield	____	MPa	Y-mandated	DB 3-3a	Table 4.3a	*____	Test Method D638/ISO 527
Break	____	MPa	Y N (optional)	DB 3-3a	Table 4.3b	____	Test Method D638/ISO 527
Modulus	____	MPa	Y-mandated	DB 3-3b	Table 4.3c	*____	Test Method D638/ISO 527
Tensile elongation:							
Yield	____	MPa	Y N (optional)	DB 3-4a	Table 4.4a	____	Test Method D638/ISO 527
Break	____	MPa	Y N (optional)	DB 3-4b	Table 4.4	____	Test Method D638/ISO 527
Density	____	g/cm^3	Y-mandated	DB 3-5	Table 4.5	*____	Test Method D1505
Electricals:							
d-c volume resistivity	____	Ω	Y N (optional)	DB 3-6	Table 4.6c	____	Test Methods D257
Frequency No. 1	____	Hz	Y N (optional)	DB 3-6	exponent	____	
Dielectric constant	____		Y N (optional)	DB 3-6	Table 4.6a	____	Test Methods D150/IEC 250
Loss	____		Y N (optional)	DB 3-6	Table 4.6	____	Test Methods D150/IEC 250
Frequency No. 2	____	Hz	Y N (optional)	DB 3-6	exponent	____	
Dielectric constant	____		Y N (optional)	DB 3-6	Table 4.6a	____	Test Methods D150/IEC 250
Loss	____		Y N (optional)	DB 3-6	Table 4.6b	____	Test Methods D150/IEC 250
Frequency No. 3	____	Hz	Y N (optional)	DB 3-6	exponent	____	
Dielectric constant	____		Y N (optional)	DB 3-6	Table 4.6a	____	Test Methods D150/IEC 250
Loss	____		Y N (optional)	DB 3-6	Table 4.6b	____	Test Methods D150/IEC 250
Frequency No. 4	____	Hz	Y N (optional)	DB 3-6	exponent	____	
Dielectric constant	____		Y N (optional)	DB 3-6	Table 4.6a	____	Test Methods D150/IEC 250
Loss	____		Y N (optional)	DB 3-6	Table 4.6b	____	Test Methods D150/IEC 250
Flammability (OI)	____		Y N (optional)	DB 3-7	Table 4.7	____	Test Method D2863/ISO 4583
Molding method	____		Y as specified	DB 3-8	Table 2-1	____	____
Specimen type (above 2 %)	____		Y as specified	DB 3-8	Table 4.8	____	____
Additives type	____		Y N (optional)	DB 4-1	Table 5.1	____	
Form	____		Y N (optional)	DB 4-2	Table 5.2	____	
Form	____		Y N (optional)	DB 4-2	Table 5.2	____	
Alternate:							
Property range No. 1	____		Y if used	____	____	____	____
Property range No. 2	____		Y if used	____	____	____	____
Method specification	____		Y If used	____	____	____	____
Designation code: ASTM D5 **XXX**	____						

X2. DEVELOPMENT OF DESIGNATION FOR 7.1.2.1

Test/Parameter	Actual Lot Data		Specification Y N	Data Block	Data Table	Code Used	Other Comments
Polymer abbreviation	VDF/CTFE		Y-mandated	No. 1-2	Section 3.3	VDF/CTFE	
Polymer type	copolymer		Y-mandated	No. 1-2	Table 1	K	
Application/process and	general		Y-mandated	No. 2-1	Table 2-1	Gn	
special characteristics	granules		Y N (optional)	No. 2-2	Table 2-2	G	
	natural		Y N (optional)	No. 2-2	Table 2-2	N	
			Y N (optional)	No. 2-2	Table 2-2		
			Y N (optional)	No. 2-2	Table 2-2		
			Y N (optional)	No. 2-2	Table 2-2		
			Y N (optional)	No. 2-2	Table 2-2		
			Y N (optional)	No. 2-2	Table 2-2		
Properties							
Melt temperature	168	°C	Y-mandated	No. 3-1	Table 4-1	*P	Test Method D4591
MFR	...	g/10 min	Y-mandated	DB 3-2a	Table 4.1	Z	Test Method D1238
Load	...	kg	[or use]	DB 3-2b	Table 4.2	Z	Test Method D1238
Melt Viscosity	1500	Pa/s	Y-mandated	DB 3-2c	Table 4.3	*E	Test Method D3835
Temperature	230	°C	Y-mandated	DB 3-2d	Table 4.4	*F	
Tensile strength:							
Yield	28	MPa	Y-mandated	DB 3-3a	Table 4.3a	*D	Test Method D638/ISO 527
Break	...	MPa	Y N (optional)	DB 3-3a	Table 4.3b	Z	Test Method D638/ISO 527
Modulus	800	MPa	Y-mandated	DB 3-3b	Table 4.3c	*C	Test Method D638/ISO 527
Tensile elongation:							
Yield	9	MPa	Y N (optional)	DB 3-4a	Table 4.4a	B	Test Method D638/ISO 527
Break	450	MPa	Y N (optional)	DB 3-4b	Table 4.4	I	Test Method D638/ISO 527
Density	1.78	g/cm^3	Y-mandated	DB 3-5	Table 4.5	C	Test Method D1505
Electricals:							
d-c volume resistivity	>2.4E14	Ω	Y N (optional)	DB 3-6	Table 4.6c	C	Test Methods D257
Frequency No. 1	1K	Hz	Y N (optional)	DB 3-6	exponent	3	
Dielectric constant	10.1		Y N (optional)	DB 3-6	Table 4.6a	V	Test Methods D150/IEC 250
Loss	0.021		Y N (optional)	DB 3-6	Table 4.6b	U	Test Methods D150/IEC 250
Frequency No. 2	10K	Hz	Y N (optional)	DB 3-6	exponent	4	
Dielectric constant	9.3		Y N (optional)	DB 3-6	Table 4.6a	U	Test Methods D150/IEC 250
Loss	0.031		Y N (optional)	DB 3-6	Table 4.6b	V	Test Methods D150/IEC 250
Frequency No. 3	1M	Hz	Y N (optional)	DB 3-6	exponent	6	
Dielectric constant	7.3		Y N (optional)	DB 3-6	Table 4.6a	S	Test Methods D150/IEC 250
Loss	0.15		Y N (optional)	DB 3-6	Table 4.6b	U	Test Methods D150/IEC 250
Frequency No. 4		Hz	Y N (optional)	DB 3-6	exponent		
Dielectric constant			Y N (optional)	DB 3-6	Table 4.6a		Test Methods D150/IEC 250
Loss			Y N (optional)	DB 3-6	Table 4.6b		Test Methods D150/IEC 250
Flammability (OI)	53		Y N (optional)	DB 3-7	Table 4.7	C	Test Method D2863/ISO 4583
Molding method	compression		Y as specified	DB 3-8	name	Q	
Specimen type (above 2 %)	527—Type 6a		Y as specified	DB 3-8	Table 4.	G	
Additives type	none		Y N (optional)	DB 4-1	Table 5.1	Z	
Form			Y N (optional)	DB 4-2	Table 5.2		
Form			Y N (optional)	DB 4-2	Table 5.2		
Alternate:							
Property range No. 1			Y if used				
Property range No. 2			Y if used				
Method specification			Y if used				
Designation code: ASTM D5**XXX**	VDF/CTFE-K, GGN, *P-*ZZEF-*DZC-BI-*C-C3VU4VU6SU-C-QG, Z, ,						

X3. DEVELOPMENT OF DESIGNATION AND SPECIFICATION FOR 7.1.3.2

Test/Parameter	Actual Lot	Data	Specification Y N	Data Block	Data Table	Code Used	Other Comments
Polymer abbreviation	VDF/HFP		Y-mandated	No. 1-2	Section 3.3	VDF/HFP	
Polymer type	modified		Y-mandated	No. 1-2	Table 1	A	
Application/process and	extrusion		Y-mandated	No. 2-1	Table 2-1	E	
special characteristics	specification		Y N (optional)	No. 2-2	Table 2-2	F	
	burn						
	low smoke		Y N (optional)	No. 2-2	Table 2-2	F4	
	pellets		Y N (optional)	No. 2-2	Table 2-2	G1	
	lubricated		Y N (optional)	No. 2-2	Table 2-2	S	
	opaque		Y N (optional)	No. 2-2	Table 2-2	T1	
			Y N (optional)	No. 2-2	Table 2-2		
			Y N (optional)	No. 2-2	Table 2-2		
Properties							
Melt temperature	143	°C	Y-mandated	No. 3-1	Table 4-1	*N	Test Method D4591
MFR	...	g/10 min	Y-mandated	DB 3-2a	Table 4.1	Z	Test Method D1238
Load	...	kg	[or use]	DB 3-2b	Table 4.2	Z	Test Method D1238
Melt Viscosity	1300–1400	Pa/s	Y-mandated	DB 3-2c	Table 4.3	*?	Test Method D3835
Temperature	230	°C	Y-mandated	DB 3-2d	Table 4.4	F	
Tensile strength:							
Yield	24	MPa	Y-mandated	DB 3-3a	Table 4.3a	*C	Test Method D638/ISO 527
Break	...	MPa	Y N (optional)	DB 3-3a	Table 4.3b	Z	Test Method D638/ISO 527
Modulus	1000	MPa	Y-mandated	DB 3-3b	Table 4.3c	*C	Test Method D638/ISO 527
Tensile elongation:							
Yield	12	MPa	Y N (optional)	DB 3-4a	Table 4.4a	C	Test Method D638/ISO 527
Break	350	MPa	Y N (optional)	DB 3-4b	Table 4.4	H	Test Method D638/ISO 527
Density	1.79	g/cm^3	Y-mandated	DB 3-5	Table 4.5	*C	Test Method D1505
Electricals:							
d-c volume resistivity	none	Ω	Y N (optional)	DB 3-6	Table 4.6c	Z	Test Methods D257
Frequency No. 1	none	Hz	Y N (optional)	DB 3-6	exponent	Z	
Dielectric constant			Y N (optional)	DB 3-6	Table 4.6a		Test Methods D150/IEC 250
Loss			Y N (optional)	DB 3-6	Table 4.6b		Test Methods D150/IEC 250
Frequency No. 2		Hz	Y N (optional)	DB 3-6	exponent		
Dielectric constant			Y N (optional)	DB 3-6	Table 4.6a		Test Methods D150/IEC 250
Loss			Y N (optional)	DB 3-6	Table 4.6b		Test Methods D150/IEC 250
Frequency No. 3		Hz	Y N (optional)	DB 3-6	exponent		
Dielectric constant			Y N (optional)	DB 3-6	Table 4.6a		Test Methods D150/IEC 250
Loss			Y N (optional)	DB 3-6	Table 4.6b		Test Methods D150/IEC 250
Frequency No. 4		Hz	Y N (optional)	DB 3-6	exponent		
Dielectric constant			Y N (optional)	DB 3-6	Table 4.6a		Test Methods D150/IEC 250
Loss			Y N (optional)	DB 3-6	Table 4.6b		Test Methods D150/IEC 250
Flammability (OI)	>80		Y N (optional)	DB 3-7	Table 4.7	*F	Test Method D2863/ISO 4583
Molding method	compression		Y as specified	DB 3-8	Table 2-1	*Q	
Specimen type (above 2 %)	D638 TYPE I		Y as specified	DB 3-8	Table 4.8	A	
Additives type	...		Y N (optional)	DB 4-1	Table 5.1	Z	
Form			Y N (optional)	DB 4-2	Table 5.2		
Form			Y N (optional)	DB 4-2	Table 5.2		
Alternate:							
Property range No. 1	1300–1700		Y if used			?1300–1700	
Property range No. 2			Y if used				
Method specification			Y if used				
Designation code: ASTM D5**XXX**	VDF/HFP-A, EFF4G1ST2, *N-*ZZ?F-*CZC-CH-*C-ZZ-*F-*QA, Z, ?1300–1700						

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CLASSIFICATION SYSTEM FOR AND BASIS OF SPECIFICATION FOR POLYAMIDE MOLDING AND EXTRUSION MATERIALS (PA)

SD-6779

(Identical with ASTM D6779-12a except for revisions in paras. 8.1, 11.1.1, and section 12, additional requirements in section 13 and Annex A1, and renumbering of sections 14 and 15.)

Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)

1. Scope

1.1 This classification system covers polyamide materials suitable for molding and extrusion. Some of these compositions are also suitable for application from solution.

1.2 The properties included in this classification system are those required to identify the compositions covered. Other requirements necessary to identify particular characteristics important to specialized applications are to be specified by using suffixes as given in Section 5.

1.3 This classification system and subsequent line callout (specification) are intended to provide a means of calling out plastic materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection can be made by those having expertise in the plastic field after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the costs involved, and the inherent properties of the material other than those covered by this classification system.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 11, of this classification system. *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 requirements prior to use.*

NOTE 1—This classification system is similar to ISO 1874-1/-2, although the technical content is significantly different.

2. Referenced Documents

2.1 *ASTM Standards:*

D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D789 Test Methods for Determination of Solution Viscosities of Polyamide (PA)
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D3892 Practice for Packaging/Packing of Plastics
D4000 Classification System for Specifying Plastic Materials
D5740 Guide for Writing Material Standards in the Classification Format
D6260 Test Method for Gravimetric Determination of Carbon Black in Nylon Materials (PA) (Withdrawn 2004)
D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *IEC/ISO Standards:*

IEC 60243-1 Electrical Strength of Insulating Materials—Test Methods—Part 1: Tests at Power Frequencies
IEC 60250 Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulating Materials at Power, Audio and Radio Frequencies Including Metre Wavelengths
ISO 75-1 Plastics—Determination of Temperature of Deflection Under Load—Part 1: General Test Methods

ISO 75-2 Plastics—Determination of Temperature of Deflection Under Load—Part 2: Plastic and Ebonite
ISO 179-1 Plastics—Determination of Charpy Impact Strength—Part 1: Non-instrumented Impact Test
ISO 294-1 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 1: General Principles, Multipurpose-Test Specimens and Bars
ISO 307 Determination of Viscosity Number of Polyamides In Dilute Solutions
ISO 527-1 Plastics—Determination of Tensile Properties—Part 1: General Principles
ISO 527-2 Plastics—Determination of Tensile Properties—Part 2: Testing Conditions
ISO 1183 Plastics—Methods for Determining the Density and Relative Density of Non-Cellular Plastics
ISO 1874-1 Plastics—Polyamide (PA) Homopolymers and Copolymers for Moulding and Extrusion—Part 1: Designation
ISO 1874-2.2 Plastics—Polyamide (PA) Homopolymers and Copolymers for Moulding and Extrusion—Part 2: Preparation of Test Specimens and Determination of Properties
ISO 3167 Plastics, Multipurpose Test Specimens
ISO 3451-4 Plastics—Determination of Ash—Part 4: Polyamides
ISO 11357-1 Plastics—Differential Scanning Calorimetry—Part 1: General Principles
ISO 11357-3 Plastics—Differential Scanning Calorimetry—Part 3: Determination of Temperature and Enthalpy of Melting and Crystallization
ISO 15512 Plastics—Determination of Water Content

3. Terminology

3.1 The terminology used in this classification system is in accordance with Terminologies D883 and D1600.

4. Classification

4.1 Polyamide materials are classified into groups in accordance with their composition. These groups are subdivided into classes and grades as shown in the Basic Property Table (Table PA).

NOTE 2—An example of this classification system for unreinforced polyamide is given as follows: The designation PA0123 indicates the following:

PA	=	polyamide as found in Terminology D1600,
01 (group)	=	polyamide 66,
2 (class)	=	heat stabilized, and
3 (grade)	=	with a minimum viscosity number of 210 and the requirements given in Table PA.

4.1.1 Grades of reinforced or filled versions, or both, of the basic materials are identified by a single letter that indicates the reinforcement or filler used and two digits, in multiples of 5, that indicate the nominal quantity in percent by weight. Thus, a letter designation G for glass reinforced and 35 for percent or reinforcement, G35, specifies a material with a nominal glass level of 35 %. The reinforcement letter designations and associated tolerance levels are shown as follows:

Symbol	Material	Tolerance (Based on the Total Mass)
C	carbon- and graphite-fiber-reinforced	±2 %
G	glass-reinforced	±2 %
L	lubricants (such as PTFE, graphite, silicone, and molybdenum disulfide)	Depends upon material and process—to be specified.
M	mineral-reinforced	±2 %
R	combinations of reinforcements or fillers, or both	±3 %

NOTE 3—An example of this classification system for reinforced polyamide is given as follows: The designation PA012G35 indicates the following:

PA	=	polyamide as found in Terminology D1600,
01 (group)	=	polyamide 66,
2 (class)	=	heat stabilized, and
G35 (grade)	=	nominal 35 % glass with the requirements given in Table PA.

NOTE 4—This part of the classification system uses percent of reinforcements or additives, or both, in the callout of the modified basic material. The types and percentages of reinforcements and additives are sometimes shown on the supplier's technical data sheet. If necessary, additional control of these reinforcements and additives can be accomplished by use of the suffix part of the system (see Section 5).

NOTE 5—Materials containing reinforcements or fillers, or both, at nominal levels not in multiples of 5 are included in the nearest PA grade designation. For example, a material with a nominal glass fiber level of 33 % is included with Grade G35 as shown in Note 4.

NOTE 6—Ash content of filled or reinforced materials is determined using Test Method ISO 3451-4.

4.2 Variations of polyamide materials that are not in Table PA are classified in accordance with Tables PA and A or B. Table PA is used to specify the group of polyamide and Table A or B is used to specify property requirements.

4.2.1 Specific requirements for variations of polyamide materials shall be shown by a six-character designator. The designation will consist of the letter "A" or "B" and the five digits comprising the cell numbers for the property requirements in the order as they appear in Tables A and B.

4.2.1.1 Although the values listed are necessary to include the range of properties available in existing materials, not every possible combination of the properties exists or can be obtained.

4.2.2 When the grade of the basic material is not known, is not important or does not meet the Table PA requirements, the use of "0" grade classification shall be used for reinforced materials in this classification system.

NOTE 7—An example of this classification system for a reinforced polyamide material is given as follows. The designation PA0110G30A42270 would indicate the following material requirements:

PA0110	=	Polyamide 66, from Table PA,
G30	=	Glass reinforced at 30 % nominal,
A	=	Table A property requirements,
4	=	Tensile strength, 140 MPa, min,
2	=	Tensile modulus, 4500 MPa, min,
2	=	Charpy impact, 5.0 kJ/m^2, min,
7	=	Deflection temperature at 1.8 MPa, 200°C, min, and
0	=	Unspecified.

If no properties are specified, the designation would be PA0110G30A00000.

NOTE 8—When a grade of polyamide is not fully identified by a standard callout, it is possible to specify all table properties by the use of an addition of Classification D4000 suffixes. Suffix values will override the PA table values. An example of an unreinforced polyamide material is given as follows: PA0212KN023. This example is a general purpose, low viscosity PA6 material where K denotes tensile properties, N denotes tensile modulus with ISO 527 as the test method, and 023 denotes a value of 2300 MPa. This value for tensile modulus overrides the normal table value. This example can be applied to replace all table values, that is, tensile stress, notched Charpy impact, and heat deflection temperature.

4.3 To facilitate the specification of special materials where the basic property table does not reflect the properties required, Table B has been incorporated into this classification system. This table will be used in a manner similar to Table A.

NOTE 9—Pigmented or colored polyamides can differ significantly from the natural polymers in mechanical properties depending on the choice of colorants and concentrations. The main property affected is ductility, as illustrated by a reduction in Charpy impact and elongation values. In a typical white pigmented polyamide, elongation losses of up to 50 % and Charpy impact losses of up to 30 % are common. To specify property requirements of pigmented materials, use Table B.

NOTE 10—An example of a special material using this classification system is as follows: The designation PA0220B54220 would indicate the following material requirements from Table B:

PA0220	=	Polyamide 6, heat stabilized, from Table PA,
B	=	Table B property requirements,
5	=	Tensile strength, 70 MPa, min,
4	=	Tensile modulus, 2400 MPa, min,
2	=	Charpy impact, 4.0 kJ/m^2, min,
2	=	Deflection temperature at 1.8 MPa, 55°C, min, and
0	=	unspecified.

TABLE PA Requirements for Polyamides Dry-as-Molded^{A,B}

Group	Description	Class	Description	Grade	Description^C	Viscosity Number, ISO 307, min, mL/g	Density,^{D} ISO 1183 g/cm^3	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,^{E} ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/ 1eA, kJ/m^2, min	Deflection Temperature,^{F} ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
01	PA66	1	General-purpose	1		135	1.13 to 1.15	70	2300	3.3	60
				2		165	1.13 to 1.15	70	2300	3.3	60
				3		210	1.13 to 1.15	70	2300	3.3	60
				4		270	1.13 to 1.15	70	2300	3.3	60
				5	recycled	115	1.13 to 1.15	70	2300	3.3	60
				6	recycled	135	1.13 to 1.15	70	2300	3.3	60
				7		115	1.13 to 1.15	70	2300	3.3	60
				G15	15 % glass	. . .	1.20 to 1.26	100	4000	3.0	215
				G20	20 % glass	. . .	1.25 to 1.33	115	5000	4.0	220
				G25	25 % glass	. . .	1.29 to 1.37	140	6000	5.0	225
				G35	35 % glass	. . .	1.35 to 1.45	170	8000	7.0	235
				G40	40 % glass	. . .	1.42 to 1.52	175	9000	8.0	235
				G45	45 % glass	. . .	1.45 to 1.55	180	10 000	9.0	240
				G50	50 % glass	. . .	1.51 to 1.61	190	11 000	10.0	245
				M40	40 % mineral	. . .	1.45 to 1.55	80	5000	2.0	100
				0	other						
		2	Heat-stabilized	1		135	1.13 to 1.15	70	2300	3.0	60
				2		165	1.13 to 1.15	70	2300	3.0	60
				3		210	1.13 to 1.15	70	2300	3.0	60
				4		270	1.13 to 1.15	70	2300	3.0	60
				5	recycled	115	1.13 to 1.15	70	2300	3.0	60
				6	recycled	135	1.13 to 1.15	70	2300	3.0	60
				G15	15 % glass	. . .	1.20 to 1.26	100	4000	3.0	220
				G25	25 % glass	. . .	1.29 to 1.37	140	6000	5.0	225
				G30	30 % glass	. . .	1.32 to 1.42	160	7000	6.0	230
				G35	35 % glass	. . .	1.35 to 1.45	170	8000	7.0	235
				G40	40 % glass	. . .	1.43 to 1.53	175	9000	8.0	235
				G45	45 % glass	. . .	1.45 to 1.55	180	10 000	9.0	240
				G50	50 % glass	. . .	1.51 to 1.61	190	11 000	10.0	245
				M40	40 % mineral	. . .	1.45 to 1.55	80	5000	2.0	100
				R20	20 % filler	. . .	1.23 to 1.31	70	3200	1.5	. . .
				R40	40 % filler	. . .	1.43 to 1.53	100	5500	2.5	200
				0	other						
		3	Nucleated	1		135	1.13 to 1.15	80	2500	2.8	60
				2		165	1.13 to 1.15	80	2500	2.8	60
				3		210	1.13 to 1.15	80	2500	2.8	60
				4		270	1.13 to 1.15	80	2500	2.8	60
				5	recycled	115	1.13 to 1.15	80	2500	2.8	60
				6	recycled	135	1.13 to 1.15	80	2500	2.8	60
				0	other						
		4	Nucleated, heat-stabilized	1		Requirements the same as corresponding grades under Group 01, Class 3					
				2							
				3							
				4							
				5							
				0	other						

TABLE PA Requirements for Polyamides Dry-as-Molded[A,B]

Group	Description	Class	Description	Grade	Description[C]	Viscosity Number, ISO 307, min, mL/g	Density,[D] ISO 1183 g/cm^3	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,[E] ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/ 1eA, kJ/m^2, min	Deflection Temperature,[F] ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
		5	Impact-	1		. . .	1.06 to 1.12	52	1700	9.0	50
			modified	2	recycled	. . .	1.06 to 1.12	50	1600	8.0	50
				G15	15 % glass	. . .	1.15 to 1.23	85	3000	6.0	210
				G35	35 % glass	. . .	1.31 to 1.41	110	5500	6.0	225
				0	other						
		6	Impact-	1		. . .	1.08 to 1.12	52	1700	9.0	50
			modified,	2	recycled	. . .	1.08 to 1.12	50	1600	8.0	50
			heat-	G15	15 % glass	. . .	1.15 to 1.23	85	3000	6.0	210
			stabilized	G35	35 % glass	. . .	1.31 to 1.41	110	5500	6.0	225
				M40	40 % mineral	. . .	1.45 to 1.55	75	4500	4.0	. . .
				R35	35 % filler	. . .	1.38 to 1.48	80	5500	3.0	200
				0	other						
		7	Toughened	1		. . .	1.06 to 1.10	42	1500	40	45
				2	recycled	. . .	1.05 to 1.11	40	1300	35	45
				G15	15 % glass	. . .	1.15 to 1.23	70	2800	9.0	180
				G35	35 % glass	. . .	1.28 to 1.38	110	5500	11	220
				0	other						
		8	Tough-	1		. . .	1.06 to 1.10	42	1500	40	45
			ened,	2	recycled	. . .	1.05 to 1.11	40	1300	35	45
			heat-	G15	15 % glass	. . .	1.15 to 1.23	70	2800	9.0	180
			stabilized	G35	35 % glass	. . .	1.28 to 1.38	110	5500	11	220
				G45	45 % glass	. . .	1.39 to 1.49	130	8000	10	230
				M35	35 % mineral	. . .	1.37 to 1.47	70	3800	6.0	. . .
				0	other						
		9	Weather-	1		135	1.13 to 1.17	80	2400	2.5	60
			stabil-	2	recycled	115	1.13 to 1.17	65	2200	2.0	60
			ized[G]	0	other						
		0	Other	0	other						
02	PA6	1	General-	1		100	1.12 to 1.14	75	2400	4.0	50
			purpose	2		135	1.12 to 1.14	70	2200	3.0	50
				3		150	1.12 to 1.15	70	2200	3.0	50
				4		200	1.12 to 1.15	70	2200	3.0	50
				G15	15 % glass		1.20 to 1.28	110	4200	4.0	170
				G25	25 % glass		1.28 to 1.36	135	5000	6.5	180
				G30	30 % glass		1.32 to 1.40	150	7000	7.5	180
				G35	35 % glass		1.38 to 1.44	155	7500	8.0	180
				G40	40 % glass		1.41 to 1.48	175	10 000	9.0	190
				M30	30 % mineral		1.30 to 1.40	70	3200	2.4	50
				M40	40 % mineral		1.44 to 1.52	75	4500	4.0	70
				R40	40 % glass/ mineral		1.42 to 1.50	100	6000	3.0	180
				0	other						
		2	Heat-	1		100	1.12 to 1.14	75	2400	4.0	50
			stabilized	2		135	1.12 to 1.14	70	2200	3.0	50
				3		150	1.12 to 1.15	70	2200	3.0	50
				4		200	1.12 to 1.15	70	2200	3.0	50
				5	recycled	135	1.12 to 1.14	70	2000	3.0	50
				G5	5 % glass		1.16 to 1.22	85	2500	2.5	110
				G15	15 % glass		1.20 to 1.28	110	4200	4.0	180
				G25	25 % glass		1.28 to 1.36	135	5000	6.5	190
				G30	30 % glass		1.32 to 1.40	150	7000	7.5	190
				G35	35 % glass		1.38 to 1.44	155	7500	8.0	190
				G40	40 % glass		1.41 to 1.48	175	10 000	9.0	190
				G45	45 % glass		1.46 to 1.54	175	10 000	10	190
				G50	50 % glass		1.52 to 1.60	175	10 000	10	190
				G65	65 % glass		1.70 to 1.78	175	13 000	10	200
				M30	30 % mineral		1.30 to 1.40	70	3200	2.4	50
				M35	35 % mineral		1.39 to 1.47	70	3500	3.0	60
				M40	40 % mineral		1.44 to 1.52	75	4500	4.0	70
				R20	20 % glass/ mineral		1.25 to 1.33	80	3200	2.5	120
				R40	40 % glass/ mineral		1.42 to 1.50	100	6000	3.0	180
				0	other						
		3	Nucleated	1		100	1.12 to 1.14	70	2300	2.5	50
			and	2		135	1.12 to 1.14	70	2300	2.5	50
			lubricated	3		150	1.12 to 1.15	75	2300	2.5	50
				4		200	1.12 to 1.15	80	2300	2.5	50
				0	other						

TABLE PA Requirements for Polyamides Dry-as-Molded[A,B]

Group	Description	Class	Description	Grade	Description[C]	Viscosity Number, ISO 307, min, mL/g	Density,[D] ISO 1183 g/cm^3	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,[E] ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/ 1eA, kJ/m^2, min	Deflection Temperature,[F] ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
		4	Nucleated and heat-stabilized	1		100	1.12 to 1.14	70	2300	2.5	50
				2		135	1.12 to 1.14	70	2300	2.5	50
				3		150	1.12 to 1.15	75	2300	2.5	50
				4		200	1.12 to 1.15	80	2300	2.5	50
				5	recycled	135	1.12 to 1.14	70	2100	2.5	50
				0	other						
		5	Impact-modified	1			1.05 to 1.12	45	1700	30	45
				2			1.05 to 1.18	55	2000	6.0	45
				3			1.05 to 1.18	40	1000	6.0	35
				G15	15 % glass		1.15 to 1.24	75	3300	9.0	130
				G30	30 % glass		1.30 to 1.40	135	6500	15	180
				G35	35 % glass		1.32 to 1.42	135	6800	15	190
				G40	40 % glass		1.39 to 1.47	135	8000	10	200
				0	other						
		6	Impact-modified, heat-stabilized	1			1.05 to 1.12	45	1700	30	45
				2			1.05 to 1.18	55	2000	6.0	45
				3			1.05 to 1.18	40	1000	6.0	35
				4			1.05 to 1.18	25	1000	30	30
				G15	15 % glass		1.15 to 1.24	75	3300	9.0	130
				G30	30 % glass		1.30 to 1.40	135	6500	15	180
				G35	35 % glass		1.32 to 1.42	135	6800	10	190
				G40	40 % glass		1.39 to 1.47	135	8000	10	200
				M35	35 % mineral		1.35 to 1.45	65	3200	3.0	50
				M40	40 % mineral		1.39 to 1.47	65	3200	3.0	50
				0	other						
		7	Flexural-modified, heat-stabilized	1	injection molding		1.05 to 1.16	55	2375 max	10	45
				2	extrusion		1.05 to 1.16	30	2000 max	7.0	25
				3	blends		1.05 to 1.10	35	1700 max	4.5	35
				0	other						
		0	Other	0	other						
03[H]	PA11	1	General purpose	1		115 to 140	1.01 to 1.06	35	900	4.0	36
				2		160 to 190	1.01 to 1.06	35	900	6.0	36
				0	other						
		2	Heat-stabilized	1		115 to 140	1.01 to 1.06	35	900	4.0	36
				2		160 to 190	1.01 to 1.06	35	900	6.0	36
				3	UV Stabilized	160 to 190	1.01 to 1.06	35	900	4.0	36
				4		210 to 255	1.01 to 1.06	35	900	6.0	36
				0	other						
		3	Plasticized	1		170 to 200	1.01 to 1.06	30	370	25	36
				0	other						
		4	Plasticized, Heat Stabilized	1		180 to 240	1.01 to 1.06	35	500	25	36
				2		170 to 200	1.01 to 1.06	35	400	25	36
				3		115 to 140	1.01 to 1.06	30	350	25	36
				4	UV Stabilized	175 to 240	1.01 to 1.06	35	400	25	36
				5		170 to 190	1.01 to 1.06	30	370	25	36
				6		200 to 230	1.01 to 1.06	35	370	25	36
				7	UV Stabilized	160 to 240	1.01 to 1.06	35	340	25	36
				0	other						
		0	Other	0	other						
04	PA12	1	General purpose	1		100 to 210	1.00 to 1.06	30	800	2.5	35
				2		100 to 210	1.00 to 1.06	35	1000	2.5	35
				3		211 to 270	1.00 to 1.06	35	1000	2.5	35
				4		271 to 340	1.00 to 1.06	35	1000	2.5	35
				0	other						
		2	Heat-stabilized	1		100 to 150	1.00 to 1.06	35	800	2.5	35
				2		151 to 210	1.00 to 1.06	35	800	2.5	35
				3		211 to 280	1.00 to 1.06	35	1000	2.5	35
				G15	15 % glass		1.10 to 1.20	75	3000	10	160
				G25	25 % glass		1.10 to 1.25	90	3000	15	160
				G30	30 % glass		1.15 to 1.30	95	4000	15	160
				G40	40 % glass		1.30 to 1.45	100	4500	15	160
				R30	30 % filler		1.18 to 1.32	55	3500	5.0	100
				0	other						
		3	Nucleated	1		100 to 180	1.00 to 1.06	35	800	1.0	35
				2		181 to 250	1.00 to 1.06	35	800	1.0	35
				0	other						

TABLE PA Requirements for Polyamides Dry-as-Molded[A,B]

Group	Description	Class	Description	Grade	Description[C]	Viscosity Number, ISO 307, min, mL/g	Density,[D] ISO 1183 g/cm³	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,[E] ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/1eA, kJ/m², min	Deflection Temperature,[F] ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
		4	Plasticized	1		100 to 280	1.00 to 1.06	30	300 to 550	15	
				2		100 to 280	1.00 to 1.06	30	450 to 750	10	
				0	other						
		5	Plasticized, heat-stabilized	1		100 to 280	1.00 to 1.06	20	200 to 350	20	
				2		100 to 280	1.00 to 1.06	30	300 to 550	15	
				3		100 to 280	1.00 to 1.06	30	450 to 750	10	
				4		100 to 280	1.00 to 1.06	35	550 to 950	5.0	
				0	other						
		0	Other	0	other						
05	PA612	1	General purpose	1		100 to 139	1.05 to 1.07	50	1800	2.0	45
				2		140 to 199	1.05 to 1.07	50	1800	2.5	45
				3		200	1.05 to 1.07	50	1800	3.0	45
				G35	35 % glass		1.28 to 1.38	140	7000	9.0	175
				G45	45 % glass		1.38 to 1.48	150	8500	11	180
				0	other						
		2	Heat-stabilized	1		140	1.05 to 1.07	50	1800	2.0	45
				G20	20 % glass		1.17 to 1.25	105	4500	5.0	170
				G30	30 % glass		1.25 to 1.33	120	5500	5.0	170
				G35	35 % glass		1.28 to 1.38	140	7000	9.0	175
				0	other						
		3	Weather-stabilized[G]	1		140	1.05 to 1.07	50	1800	1.5	45
				0	other						
06	PA46	1	General-purpose	1		170	1.16 to 1.20	85	2300	6.0	
				2		195	1.16 to 1.20	85	2300	6.0	140
				0	other						
		2	Heat-stabilized	1		165	1.16 to 1.20	85	2300	6.0	140
				2		195	1.16 to 1.20	85	2300	6.0	140
				G15	15 % glass		1.25 to 1.31	125	5000	3.6	240
				G30	30 % glass		1.38 to 1.42	175	8000	7.5	280
				G40	40 % glass		1.48 to 1.53	195	10 000	10.0	280
				G50	50 % glass		1.58 to 1.63	210	12 000	12.0	280
				R50	50 % filler		1.60 to 1.67	140	9000	4.0	280
				0	other						
		3	Flame-retardant[I], heat-stabilized	1			1.32 to 1.36	45	2250	4.0	140
				G15	15 % glass		1.55 to 1.59	115	6000	4.5	270
				G30	30 % glass		1.63 to 1.69	155	10 000	7.5	280
				G40	40 % glass		1.76 to 1.80	145	11 000	8.0	280
				G45	45 % glass		1.75 to 1.79	165	12 000	8.0	280
				0	other						
		4	Impact-modified, heat-stabilized	1			1.08 to 1.12	40	1500	50	70
				0	other						
		5	Wear-resistant, heat-stabilized	1			1.16 to 1.20	75	2200	3.0	140
				0	other						
		0	Other	0	other						
07	PA6T/MPMDT	1	Heat-stabilized	G35	35 % glass		1.42 to 1.52	200	10 000	8.0	250
				G45	45 % glass		1.53 to 1.63	210	12 000	8.0	250
				0	other						
		0	Other	0	other						
08	PA66 copolymers + blends	1	PA66/6 General purpose	G15	15 % glass		1.20 to 1.26	90	3500	3.0	180
				G35	35 % glass		1.35 to 1.45	160	7500	8.0	190
				G45	45 % glass		1.45 to 1.55	180	8500	10	200
				0	other						
		2	66/6 heat-stabilized	G15	15 % glass		1.20 to 1.26	90	3500	3.0	180
				G25	25 % glass		1.29 to 1.37	115	4500	6.5	190
				G35	35 % glass		1.35 to 1.45	160	7500	8.0	190
				G45	45 % glass		1.45 to 1.55	180	8500	10	200
				M20	20 % mineral		1.25 to 1.33	70	3000	4.0	
				M30	30 % mineral		1.35 to 1.45	75	4000	3.0	
				M40	40 % mineral		1.45 to 1.55	75	4000	3.0	
				0	other						

TABLE PA Requirements for Polyamides Dry-as-Molded[A,B]

Group	Description	Class	Description	Grade	Description[C]	Viscosity Number, ISO 307, min, mL/g	Density,[D] ISO 1183 g/cm³	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,[E] ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/1eA, kJ/m², min	Deflection Temperature,[F] ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
		3	66 + 6 general purpose	G15	15 % glass		1.20 to 1.26	100	4000	3.0	200
				G35	35 % glass		1.35 to 1.45	170	8000	9.0	210
				G45	45 % glass		1.45 to 1.55	190	10 000	10	220
				0	other						
		4	66 + 6 heat-stabilized	M20	20 % mineral		1.25 to 1.33	70	3000	3.0	
				M40	40 % mineral		1.45 to 1.55	75	4500	3.0	
		0	Other	0	other						
09	PA6 copolymer + blends	1	PA6 + polypropylene blend	1			1.00 to 1.05	50	2000	7.0	50
			Heat-stabilized	G35	35 % glass		1.23 to 1.33	150	8500	9.0	200
				R35	35 % filler		1.28 to 1.38	53	6000	2.0	135
				0	other						
		0	Other	0	other						
10	PA6T/66	1	Heat-stabilized	G35	35 % glass		1.41 to 1.51	175	9000	6.0	270
				G45	45 % glass		1.52 to 1.62	205	12 000	7.5	270
				G60	60 % glass		1.72 to 1.82	230	19 000	8.0	270
				0	other						
		2	High heat, heat stabilized	G35	35 % glass		1.39 to 1.49	180	9000	6.0	285
				G45	45 % glass		1.49 to 1.59	210	12 000	9.0	285
				G60	60 % glass		1.72 to 1.82	240	19 000	8.0	285
				0	other						
		3	Impact-modified	G15	15 % glass		1.17 to 1.27	90	4500	6.5	245
				G30	30 % glass		1.31 to 1.37	145	8000	10	270
				0	other						
		4	Flame-retardant	G35	35 % glass		1.63 to 1.73	150	9000	7.0	260
				G45	45 % glass		1.73 to 1.85	165	12 000	7.0	265
				0	other						
		5	Lubricated	G35	35 % glass		1.38 to 1.48	165	8500	6.0	285
				0	other						
		6	General Purpose	1	20 % glass, reflective		1.41 to 1.51	95	7000	5.5	285
				0	other						
		0	Other	0	other						
11	PAMXD6	1	General purpose	G30	30 % glass		1.43 to 1.47	170	10 000	4.5	225
				G50	50 % glass		1.63 to 1.67	245	17 500	6.5	225
				G60	60 % glass		1.75 to 1.79	240	21 000	8.0	225
				0	other						
		2	UV stability improved-exteriors	G50	50 % glass		1.59 to 1.63	210	16 500	7.0	210
				0	other						
		3	Heat stabilized	G50	50 % glass		1.62 to 1.66	220	17 500	7.0	225
				0	other						
		0	Other	0	other						
12	PA6T/6I/66	1	Heat stabilized	G35	35 % glass		1.41 to 1.51	195	9500	7.0	265
				G45	45 % glass		1.52 to 1.62	220	14 000	7.0	265
				G60	60 % glass		1.72 to 1.82	250	20000	7.0	265
				M40	40 % mineral		1.49 to 1.59	93	6000	2.5	140
				R40	40 % glass/mineral		1.49 to 1.59	130	8000	3.0	225
				R65	65 % glass/mineral		1.82 to 1.92	115	13 000	2.0	260
				0	other						
		2	Heat stabilized, high strength	R65	65 % glass/mineral		1.76 to 1.86	175	14 500	4.5	265
				0	other						
		3	Impact-modified	1			1.09 to 1.19	58	1800	12	110
				2			1.06 to 1.16	43	1700	25	105

TABLE PA Requirements for Polyamides Dry-as-Molded[A,B]

Group	Description	Class	Description	Grade	Description[C]	Viscosity Number, ISO 307, min, mL/g	Density,[D] ISO 1183 g/cm^3	Tensile Strength, ISO 527-1 and ISO 527-2, MPa, min	Tensile Modulus,[E] ISO 527-1 and ISO 527-2, MPa, min	Charpy Impact Resistance, ISO 179/1eA, kJ/m^2, min	Deflection Temperature,[F] ISO 75-1 and ISO 75-2, at 1.8 MPa, °C, min
				3			1.05 to 1.15	50	1700	5.0	80
				4			1.08 to 1.18	62	2000	12	115
				5			1.11 to 1.18	55	1800	40	100
				6			1.09 to 1.19	52	1800	2.0	100
				G15	15 % glass		1.23 to 1.33	125	5500	5.5	240
				G25	25 % glass		1.30 to 1.40	160	7500	6.5	255
				0	other						
		4	Plating	M40	40 % mineral		1.43 to 1.53	55	3000	2.0	115
				0	other						
		5	Flame-retardant	G35	35 % glass		1.64 to 1.74	160	12 000	5.5	250
				G45	45 % glass		1.74 to 1.84	170	14 000	5.5	250
				0	other						
		7	Lubricated	M30	30 % mineral		1.37 to 1.47	85	5700	2.0	170
				M40	40 % mineral		1.49 to 1.59	75	5500	2.5	150
				G45	45 % glass		1.53 to 1.63	220	14 000	7.0	260
				0	other						
		8	General Purpose	G35	35 % glass, reflective		1.50 to 1.60	145	8500	5.5	255
				0	other						
		0		0	other						
13	PA 6T/6I	1	Heat-stabilized	G30	30 % glass	100	1.42 to 1.46	170	10 000	5	270
				G35	35 % glass		1.46 to 1.52	170	10 500	6	275
				G40	40 % glass	100	1.51 to 1.55	200	12 500	6	275
				G45	45 % glass	100	1.57 to 1.61	215	15 000	7	275
				G50	50 % glass	100	1.63 to 1.67	225	16 500	7	280
				G60	60 % glass	100	1.76 to 1.80	235	21 000	8	280
				0	other						
		0	Other	0	Other						
14	PA6/6T	1	High heat, heat-stabilized	1		110	1.11 to 1.21	85	2700	6	85
				G25	25 % glass	110	1.30 to 1.40	140	7000	6	235
				G35	35 % glass	110	1.39 to 1.49	160	9000	8	235
				G50	50 % glass	110	1.57 to 1.67	200	14 000	10	235
				M5	5 % mineral	100	1.10 to 1.20	50	2400	10	220
				0	other						
		2	Impact-modified, high heat, heat-stabilized	G30	30 % glass	110	1.32 to 1.42	140	7000	10	220
				0	other						
		3	Flame retardant, high heat, heat-stabilized	G25	25 % glass	105	1.33 to 1.43	120	7000	4	180
				0	other						
		0	Other	0	other						
00	Other	0	Other	0	other						

[A] If data on 4-mm test specimens are limited, the minimum values will be changed in a later revision if a statistical database of sufficient size is generated, which justifies change.
[B] Refer to 9.1 for source of test pieces.
[C] No descriptions are listed unless needed to describe a special grade under the class. All other grades are listed by requirements.
[D] Test Methods D792 is an acceptable alternative method.
[E] Crosshead speed shall be 50 mm/min ± 10 % unless the specimen exhibits brittle failure (no yield point) and strain at break of <10 % in which case crosshead speed shall be 5 mm/min ± 25 %.
[F] Deflection temperature shall be determined with the specimen in the flatwise position (Method A_f).
[G] Weatherable nylon has typically contained about 2 % carbon black. Test Method D6260 - 98 (Withdrawn July 2004),D6260 Federal Specification L-P-419a, and other methods have been used to determine the amount of carbon black. It is possible that materials incorporating other pigments or soluble stabilizers, or both, may prove adequate for particular applications.

[H] Relative Viscosities for Group 03 were generated from a correlation with Test Methods D789, utilizing an Ubbelohde viscometer, and m-Cresol as the solvent. Viscosity for groups 03, 04, and 05 (PA11, PA12, and PA6,12) in this classification shall be measured using solvents other than formic acid. Relative viscosities for Groups 03 and 04 shall be measured using 0.5 g of polymer dissolved in 99.5 g of m-cresol at 25.0 ± 0.1°C in a Cannon-Fenske No. 200 viscometer. Inherent viscosity of Group 05 shall be measured using 0.5 g of polymer dissolved in 100 mL of m-cresol at 25.0 ± 0.1°C in a Cannon-Fenske No. 200 viscometer. The inherent viscosity is calculated as follows:

$$\text{Inherent viscosity} = \frac{\ln(t_s/t_c)}{C}$$

where:

t_s = average efflux time for sample solution,
t_c = average efflux time for solvent, and
C = concentration in g/100 mL.

[I] For specific flammability requirements, use the proper suffix from Classification D4000, for example, FL310 = V0 at 0.8 mm.

TABLE A Detail Requirements: Reinforced Polyamides[A,B]

Designation Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ISO 527, min, MPa[C]	unspecified	35	70	105	140	175	210	245	280	specify value[D]
2	Tensile modulus, ISO 527, min, MPa	unspecified	1500	4500	7500	10 500	13 500	16 500	19 500	22 500	specify value[D]
3	Charpy impact, ISO 179/1eA, min, kJ/m^2	unspecified	2.5	5.0	7.5	10.0	12.5	15.0	22.5	30.0	specify value[D]
4	Deflection temperature, ISO 75, Method A, 1.8 MPa, min, °C[E]	unspecified	50	85	110	135	160	185	200	235	specify value[D]
5	To be determined	unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] It is recognized that detailed test values, particularly Charpy impact, often do not predict nor even correlate with the performance of parts molded of these materials.
[B] Refer to 9.1 for source of test specimens.
[C] Crosshead speed shall be 50 mm/min ± 10 % unless the specimen exhibits brittle failure (no yield point) and a strain at break of <10 % in which case crosshead speed shall be 5 mm/min ± 25 %.
[D] If a specific value is required, it must appear on the drawing or contract, or both.
[E] Deflection temperature shall be determined with the specimen in the flatwise position (Method A_f).

TABLE B Detail Requirements: Unreinforced Polyamides[A,B]

Designation Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile strength, ISO 527, min, MPa[C]	unspecified	10	25	40	55	70	85	100	115	specify value[D]
2	Tensile modulus, ISO 527 min, MPa	unspecified	300	1000	1700	2400	3100	3800	4500	5200	specify value[D]
3	Charpy impact, ISO 179/1eA, min, kJ/m^2	unspecified	2.0	4.0	6.0	10.0	14.0	18.0	24.0	30.0	specify value[D]
4	Deflection temperature, ISO 75, Method A, 1.8 MPa, min, °C[E]	unspecified	40	55	70	85	100	115	130	145	specify value[D]
5	To be determined	unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] It is recognized that detailed test values, particularly Charpy impact, often do not predict nor even correlate with the performance of parts molded of these materials.
[B] Refer to 9.1 for source of test specimens.
[C] Crosshead speed shall be 50 mm/min ± 10 % unless the specimen exhibits brittle failure (no yield point) and a strain at break of <10 % in which case crosshead speed shall be 5 mm/min ± 25 %.
[D] If specific value is required, it must appear on the drawing or contract, or both.
[E] Deflection temperature shall be determined with the specimen in the flatwise position (Method A_f).

5. Suffixes

5.1 When additional requirements are needed that are not covered by the basic requirements or cell-table requirements, they shall be indicated through the use of suffixes.

5.2 A list of suffixes can be found in Classification D4000 (Table 3) and are to be used for additional requirements, as appropriate. Additional suffixes will be added to that classification system as test methods and requirements are developed and requested.

6. General Requirements

6.1 Basic requirements from the property tables or cell tables are always in effect unless superseded by specific suffix requirements, which always take precedence.

6.2 The plastics composition shall be uniform and shall conform to the requirements specified herein.

7. Detail Requirements

7.1 The material shall conform to the requirements prescribed in Tables PA, A, and B, and suffix requirements as they apply.

7.2 For purposes of determining conformance, all specified limits for a specification (line callout) based on this classification system are absolute limits, as defined in Practice E29.

7.2.1 With the absolute method, an observed value or a calculated value is not rounded, but is to be compared directly with the specified limiting value. Conformance or nonconformance is based on this comparison.

8. Sampling

8.1 Sampling shall be statistically adequate to satisfy the requirements of Annex A1.

8.2 A batch or lot shall be constituted as a unit of manufacture as prepared for shipment, and can consist of a blend of two or more "production runs."

9. Specimen Preparation

9.1 Test pieces for relevant test methods shall be based on the injection molded ISO 3167 type multipurpose test specimen. All tests shall be conducted on as-molded (not annealed) specimens conditioned dry-as-molded. The following pieces are to be used for the listed relevant test methods:

Test Piece	Relevant Test Method
ISO 3167 Type 1A bar	Tensile strength by ISO 527 Tensile modulus by ISO 527
80 ± 2 mm by 10 ± 0.2 mm by 4 ± 0.2 mm cut from the center portion of ISO 3167 Type 1A bar	Charpy impact resistance by ISO 179/1eA Deflection temperature by ISO 75/Method Ar
Specimen approximately 10 by 10 by 4 mm cut from center of ISO 3167 Type 1A bar	Density by ISO 1183

9.2 The test specimens shall be prepared by an injection molding process as specified in ISO 294. Recommended processing temperatures are shown in Table 1.

NOTE 11—Test specimens of PA 6 and PA 66 copolymers and blends prepared at the same process temperatures as specified for their homopolymers, usually show no significant property loss. Selection of process temperature is made based on the major polymer component.

NOTE 12—Consult ISO 1874-2, Table 1, for a more comprehensive listing of the Conditions for Injection Moulding of Test Specimens.

9.3 Molding material-granules of the molding material used in preparation of test specimens shall contain no more than 0.2 % moisture, with the exception of PA 46 which will contain no more than 0.05 % moisture.

NOTE 13—If the moisture content exceeds the limits stated above, the material can be dried by a variety of methods such as raising the temperature of the material to 80 to 100°C in a vacuum or in a stream of dry nitrogen using a desiccant-bed drier. Continue drying until the moisture content is within the stated limits.

TABLE 1 Process Temperatures for Injection Molding of Specimens

Polyamide	Viscosity Number		Plastic Melt Temperature, °C	Mold Surface Temperature, °C
PA 6	<200	unfilled	260	80
	>200	unfilled	270	80
		filled	290	80
PA 46		unfilled	305	80
		filled	305	80
PA 66		unfilled	290	80
		filled	290	80
PA11		unfilled	288	38
PA12	<210	unfilled	220	60
	>210	unfilled	240	60
		filled	240	80
PA612	<200	unfilled	250	80
	>200	unfilled	270	80
		filled	270	80
PA 6T/66		filled	335	130
PAMXD6		filled	280	125
PA6T/6I/66		filled	335	130
PA 6T/MPMDT		filled	325	140

10. Conditioning

10.1 *Conditioning*—Test data shall be obtained using dry-as-molded specimens, defined as those specimens that are sealed in containers that are impermeable to water vapor within one hour after removal from the mold. Maximum moisture content of specimens shall be 0.2 %. No moisture shall be intentionally added to reach this level. Condition specimens a minimum of 24 h in sealed containers at 23 ± 2°C.

NOTE 14—Physical properties of most nylon resins are highly dependent upon the moisture content of the molded item. The user is referred to the manufacturer's literature for details.

10.2 *Test Conditions*—Conduct tests, other than solution viscosity or those tests conducted at elevated temperature, in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity. Individual specimens shall not be removed from sealed containers until immediately before testing.

11. Test Methods

11.1 Determine the properties enumerated in this classification system by means of the test methods referenced in Section 2.

11.1.1 The number of tests shall be consistent with the requirements of Section 8 and Annex A1.

12. Inspection

12.1 Inspection of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

12.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of the tests listed as they apply:

12.2.1 Relative viscosity, or viscosity number, or both,

12.2.2 Moisture content per ISO 15512,

12.2.3 Reinforcement content,

12.2.4 Carbon black content (weather-stabilized materials), and

12.2.5 Heat stabilizer content (heat-stabilized materials, supplier's test showing positive presence).

12.3 Periodic-check inspection with reference to a specification based upon this classification system shall consist of the tests specified for all requirements of the material under this classification system.

NOTE 15—The ASTM publication, *Manual on Presentation of Data and Control Chart Analysis, 7th Edition*, stock number MNL7A, provides detailed information about statistical process control.

12.4 A report of the test results shall be furnished. The report shall consist of results of the lot-acceptance inspection for the shipment, the percent by weight of recycled plastic, as defined in 3.1.47 of Guide D7209, and the results of the most recent periodic-check inspection.

13. Certification

13.1 Certification shall be as required by Annex A1.

14. Packing, Packaging, and Marking

14.1 The provisions of Practice D3892 apply to packaging, packing, and marking of containers for plastic materials.

15. Keywords

15.1 classification; classification system; line callout; polyamide; recycle; specification

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the inquiry, contract, or order for agencies of the U. S. Government.

S1. Special End Uses

S1.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all testing and inspections. Except as otherwise specified, the supplier can utilize his own facilities or any commercial laboratory acceptable to the government. The government reserves the right to perform any testing or inspections set forth in the specification requirements. This testing ensures qualification on a one time basis unless the manufacturer makes a significant change in formulation, raw material, or process.

S2. Electrical Requirements

S2.1 The electrical property requirements for initial material qualification of electrical grade materials are given in Table S2.1 and the test methods in Table S2.2.

S3. Quality Assurance

S3.1 *Acceptance Criteria*—Failure to conform to requirements in Table S2.1 shall result in rejection of the material.

S3.2 *Sample Size*—The minimum number of test specimens to be tested shall be as specified in Table S2.2.

S3.3 *Test Method*—Testing shall be in accordance with the methods specified in Table S2.2.

S3.4 *Conditioning*—Standard test specimens shall be conditioned before testing as specified in Table S2.2 and described in Section S4.

S4. Conditioning

S4.1 *Nomenclature:*

S4.1.1 *Condition A*—Dry-as-molded. See Section 10.

S4.1.2 *Condition C*—Humidity conditioning.

S4.1.3 *Condition D*—Immersion conditioning in distilled water.

S4.2 *Designation*—Conditioning procedures shall be designated as follows:

S4.2.1 A capital letter indicating the general conditioning.

S4.2.2 A number indicating, in hours, the duration of conditioning.

S4.2.3 A number indicating, in °C, the conditioning temperature.

S4.2.4 A number indicating the relative humidity when it is controlled.

TABLE S2.1 Property Values for Initial Electrical Qualification Testing

Property	Units	Value Required for Each Type of Compound Unreinforced PA			Reinforced PA	
		Type III[A] Grade E	Type VI[A] Grade E	Type VIA[A] Grade E	Type I[A] Grade A	Type II[A] Grade A
Insulation resistance, min	ohms	5×10^{12}	5×10^{12}	5×10^{12}	...	...
Dielectric strength						
step-by-step test, min	kV/mm	14.8	14.8	14.8	...	...
short-time test, min	kV/mm	...	...	...	14.8	14.8
Dielectric constant @ 1 MHz, max		4.0	4.0	4.0	4.2	4.2
Dissipation factor @ 1 MHz, max		0.11	0.11	0.11	0.025	0.025

[A] Types as described in Appendix X3.

TABLE S2.2 Sampling and Conditioning for Initial Qualification

Property	Test Method	Test Method Modified per	Specimens	Number Tested	Conditioning	
					Unreinforced PA	Reinforced PA
Insulation resistance	ASTM D257	S5.1	60 × 60 × 2 mm plaque	3	C-96/23/50	. . .
Dielectric strength	IEC 60243		60 × 60 × 2 mm plaque			
step-by-step test				5	C-96/23/50	. . .
short-time test				5	. . .	A
Dielectric constant	IEC 60250		60 × 60 × 2 mm plaque	5	C-96/23/50 + D-48/50 + D-0.5/23	A
Dissipation factor	IEC 60250		60 × 60 × 2 mm plaque	5	C-96/23/50 + D-48/50 + D-0.5/23	A

S4.3 *Tolerances:*

S4.3.1 *Relative Humidity*—Standard tolerance shall be ±5 %.

S4.3.2 *Temperature*— Standard tolerance shall be ±2°C. For water immersion the standard tolerance shall be ±1°C.

NOTE 16—The numbers shall be separated from each other by slant (/) marks, and from the capital letter by a dash (-). A sequence of conditions shall be denoted by the use of a plus (+) sign between successive conditions.

Examples:

C-96/23/50—Humidity condition; 96 h at 23°C and 50 % R.H.

D-48/50—Immersion condition; 48 h at 50°C.

S5. Test Method Modification

S5.1 *Dielectric Strength:*

S5.1.1 The test shall be performed under oil at a frequency not exceeding 100 Hz.

S5.1.2 *Short-Time Test*—The voltage shall be increased uniformly at the rate of 500 V/s.

S5.1.3 *Step-by-Step Test*—Step-by-step testing shall be done after a short-time test. Voltage increments for the step-by-step test shall be determined from short-time results as follows:

Breakdown by short-time test, kV	Increment for step-by-step test, kV
≤12.5	0.5
>12.5 to ≤25	1.0
>25 to ≤50	2.5
>50 to ≤100	5.0
>100	10.0

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. VISCOSITY CONVERSION: ASTM TEST METHODS D789 and ISO 307

X1.1 The relation between relative viscosity in 90 % HCOOH (Test Methods D789) and viscosity number in 96 % H_2SO_4 (ISO 307) was developed in an interlaboratory round-robin study by ISO TC-61 Subcommittee 9/Work Group 8 (Plastic Materials/Polyamides). Seven laboratories, including 3 U.S. laboratories (Allied, DuPont, and Monsanto), participated in the work. A95 ± 9 % between-laboratory confidence interval was predicted for the measurements.

X1.2 For convenience, a conversion table and graph (Fig. X1.1) are provided using the following established relationship:

$$VN = A + B \times ln(RV) \tag{X1.1}$$

where:

VN = viscosity number (ISO 307),
RV = relative viscosity (Test Methods D789),
A = -206.52124, and
B = 90.23355.

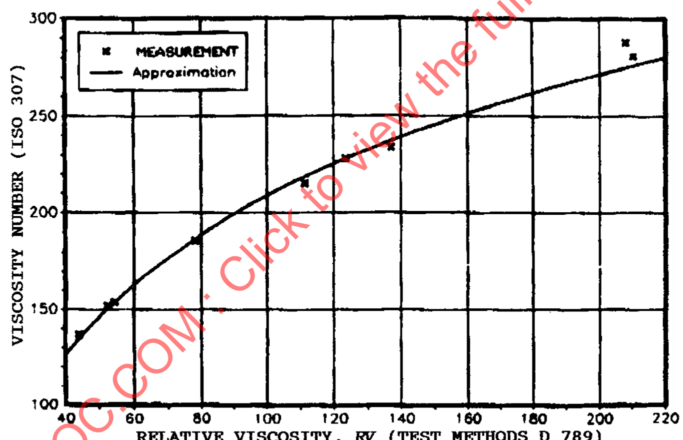

FIG. X1.1 Nylon 6 and Nylon 66 Viscosity Correlation Relative Viscosity in 90 % HCOOH (Test Methods D789) versus Viscosity Number in 96 % H_2SO_4 (ISO 307)

X2. MELTING POINT

X2.1 The nominal melting point of the various polyamide polymers shown in Table PA are listed below. The typical range for melting point determination is ±5°C.

X2.2 The melting point shall be determined using ISO 11357-3 except the heating rate shall be 10°C/min. The melting point, Tm, is obtained from the second melting curve.

Group	Description	Tm, °C
01	PA 66	262
02	PA 6	222
03	PA 11	190
04	PA 12	178
05	PA 612	212
06	PA 46	290
07	PA 6T/MPMDT	300
10	PA 6T/66	310

X3. CROSS-REFERENCES TO MIL-M-20693B AND L-P-395C

ASTM D6779	MIL-M-20693B
PA0111	Type I
PA0121	Type IA
PA0191	Type II
PA0511	Type III
PA0511	Type III, Grade E
PA0211	Type IV
PA0311	Type VI
PA0311	Type VI, Grade E
PA0321	Type VIA
PA0321	Type VIA, Grade E
ASTM D6779	L-P-395C
PA02G30	Type I, Grade A and Grade B
PA01G40	Type II, Grade A and Grade B

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SPECIFICATION FOR THREADED CHLORINATED POLY (VINYL CHLORIDE) (CPVC) PLASTIC PIPE FITTINGS, SCHEDULE 80

SF-437

(Identical with ASTM F437-09 except for additional requirements in section 12 and Annex A1, revised marking requirements in paras. 10.2.1.5 and 10.3, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) threaded Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The CPVC fittings covered by this specification were covered previously in Specification D2464.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 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.

1.4 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.

1.5 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers threaded Schedule 80 CPVC pipe fittings, intended for use with threaded Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, etc., shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by backwelding are not included in this specification.

NOTE 3—This specification does not include requirements for pipe and fittings intended to be used to vent combustion gases.

5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 as defined in Specification D1784.

NOTE 4—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 The dimensions and tolerances of the fittings shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D2122. Minimum dimensions have zero negative tolerances. Bushings shall have thread lengths applicable to the corresponding sizes. Counterbore, which is optional, is not shown in Table 1, and is not included in the center-to-end or end-to-end dimensions.

6.1.2 *Fittings Not Illustrated*—All fittings, whether illustrated in Table 1 and Table 2 or not, shall have wall thicknesses and thread dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

$$S = P(D_o - t)/2t \quad (1)$$

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_o = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

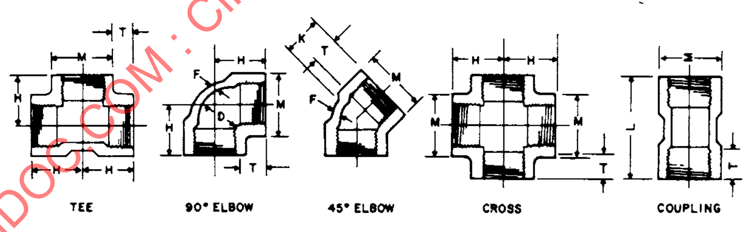
Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 3.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The

TABLE 1 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A,B]



Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses, *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[C] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
¼	0.812 (20.62)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.34)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.51)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.25)	1.500 (38.10)	1.500 (38.10)
1	1.500 (28.10)	0.81 (20.51)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (23.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.59)	1.438 (36.83)	1.446 (36.73)	0.270 (6.85)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.560 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.98)	2.820 (71.63)	0.405 (10.29)	4.300 (109.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B] Symbols for dimensions are per Symbols D2749.
[C] This dimension locates the end of the fitting.

TABLE 2 Dimensions of Plugs and Caps, in.[A,B]

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head, *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.78)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (19.05)	0.144 (3.66)	0.188 (4.78)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.46)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.73)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.92)	0.65 (16.51)	1.125 (28.53)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.450 (35.03)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.85)	0.313 (7.95)	1.250 (31.75)	2.450 (62.23)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.95)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.25)	1.875 (47.63)	0.369 (8.00)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (49.45)	4.250 (107.98)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.60)	5.350 (125.87)
6	1.44 (36.58)	1.50 (35.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.10)	2.125 (53.98)	7.625 (193.68)

[A]The sketches and designs of fittings shown are illustrative only.
[B]Symbols for dimensions are per Symbols D2749.

[C]At the manufacturer's option the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 3 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Threaded Pipe Fittings, Schedule 80

Nominal Size, in.	Min Burst Strength[A] Class 23447 psi	(MPa)
¼	3620	(24.96)
⅜	2940	(20.27)
½	2720	(18.75)
¾	2200	(15.17)
1	2020	(13.93)
1¼	1600	(11.44)
1½	1510	(10.41)
2	1290	(8.89)
2½	1360	(9.38)
3	1200	(8.27)
4	1040	(7.17)
6	890	(6.14)

[A]This table was calculated for Schedule 80 pipe using the ISO formula and a stress level as follows:

	psi	MPa
Class 23447 (Type IV Grade 1 (CPVC))	6400	44.1

fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 5—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599. Join the fittings to the pipe sufficiently strong and in such a manner that no failures shall occur in the assembly at a pressure less than the pressure requirement given in Table 3. The time of testing each assembly shall be between 60 and 70 s.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, 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. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking:*

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation CPVC for CPVC 23447,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and
10.2.1.5 ASME SF-437 or both ASME SF-437 and ASTM F437.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

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

S1. *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 may 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 S1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR SOCKET-TYPE CHLORINATED POLY(VINYL CHLORIDE) (CPVC) PLASTIC PIPE FITTINGS, SCHEDULE 40

SF-438

(Identical with ASTM F438-09 except for additional requirements in section 12 and Annex A1, revised marking requirements in paras. 10.2.1.5 and 10.3, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) Schedule 40 socket-type pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The CPVC fittings covered by this standard were covered previously in Specification D2466.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases, some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 2—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy, which present serious safety hazards should a system fail for any reason.

1.3 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.

1.4 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.

1.5 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers Schedule 40 CPVC pipe fittings, socket-type, intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, and the like, shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by backwelding are not included in this specification.

NOTE 3—This specification does not include requirements for pipe and fittings intended to be used to vent combustion gases.

5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 as defined in Specification D1784.

NOTE 4—Mechanical strength, heat resistance, flammability, and chemical resistance requirements are covered in Specification D1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Fitting sockets, inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Tables 1-4 and when measured in accordance with Test Method D2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket in the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional.

6.1.3 The maximum angular variation of any opening shall be not more than ½ ° off the true centerline axis.

6.1.4 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 40 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 40 pipe. For any threaded transition fitting, the minimum wall thickness of the threaded portion shall be at least equal to the thickness of material under the thread root of threaded Schedule 80 pipe of the same size.

6.1.5 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 40 pipe. Any fitting having a male thread shall have an internal diameter not larger than Schedule 80 pipe of the same size.

6.1.6 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Table 1 and Table 3.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation:

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

where:

S = hoop stress, psi (or MPa),
P = internal pressure, psi (or MPa),
D_O = average outside diameter, in. (or mm), and
t = minimum wall thickness, in. (or mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 4.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

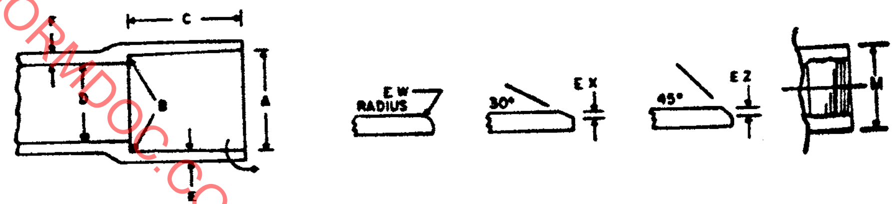
NOTE 5—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D1599. The time of testing each specimen shall be between 60 and 70 s.

8.5.1 *Apparatus*—Fittings shall be tested while held in a test jig constructed in such a manner as to seal the socket by means of O-rings, or gaskets, but not to reinforce or support the fittings, except where contact is necessary because of the shape of the fitting to keep the fitting in the test jig. Such contact shall be held to the minimum. The socket plug portion of the test

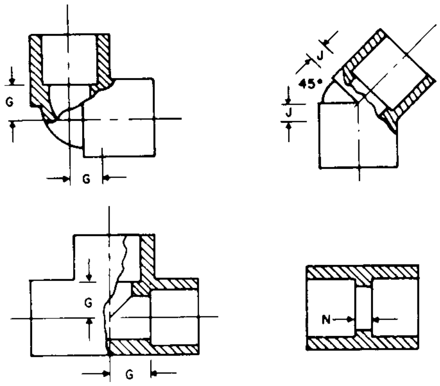
TABLE 1 Tapered Sockets for CPVC Pipe Fittings, Schedule 40, in. (mm)[A]



Nominal Pipe Size	*A* Socket Entrance Diameter: Diameter in. (mm)	*A*: Tolerance on Diameter in. (mm)	*A*: Maximum Out-of-Round in. (mm)	*B* Socket Bottom Diameter: Diameter in. (mm)	*B*: Tolerance on Diameter in. (mm)	*B*: Maximum Out-of-Round in. (mm)	C^B Socket min in. (mm)	D^C Inside Diameter, min in. (mm)	Wall Thickness, min: *E* in. (mm)	Wall Thickness, min: *F* in. (mm)	Outside Diameter of Hub, M, min	Entrance, min: *EW* in. (mm)	Entrance, min: *EX, EZ* in. (mm)
1/4	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.6)	±0.004 (0.10)	0.016 (0.41)	0.500 (12.70)	0.320 (8.13)	0.088 (2.23)	0.110 (2.79)	0.672	1/64 (0.40)	1/64 (0.40)
3/8	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.594 (15.08)	0.449 (11.40)	0.091 (2.31)	0.114 (2.90)	0.821	1/32 (0.79)	1/32 (0.79)
1/2	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.688 (17.48)	0.578 (14.68)	0.109 (2.76)	0.136 (3.45)	0.998	1/32 (0.79)	1/32 (0.79)
3/4	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	0.719 (18.26)	0.740 (18.80)	0.113 (2.87)	0.141 (3.58)	1.221	1/32 (0.79)	1/32 (0.79)
1	1.325 (33.66)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	0.875 (22.23)	0.990 (25.15)	0.133 (3.38)	0.166 (4.22)	1.504	1/16 (1.59)	1/16 (1.59)
1 1/4	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	0.938 (23.83)	1.335 (33.91)	0.140 (3.56)	0.175 (4.45)	1.871	1/16 (1.59)	1/16 (1.59)
1 1/2	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.10)	±0.006 (0.15)	0.024 (0.61)	1.094 (27.79)	1.564 (39.73)	0.145 (3.68)	0.181 (4.60)	2.127	1/16 (1.59)	1/16 (1.59)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.156 (29.36)	2.021 (51.33)	0.154 (3.91)	0.193 (4.90)	2.634	1/16 (1.59)	1/16 (1.59)
2 1/2	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.414 (61.32)	0.203 (5.16)	0.254 (6.45)	3.170	3/32 (2.38)	1/8 (3.18)
3	3.516 (89.31)	±0.008 (0.20)	0.030 (0.76)	3.492 (88.70)	±0.008 (0.20)	0.030 (0.76)	1.875 (47.63)	3.008 (76.40)	0.216 (5.49)	0.270 (6.86)	3.841	3/32 (2.38)	1/8 (3.18)
3 1/2	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.40)	±0.008 (0.20)	0.030 (0.76)	2.000 (50.80)	3.486 (88.54)	0.226 (5.74)	0.283 (7.19)	4.374	3/32 (2.38)	1/8 (3.18)
4	4.518 (114.76)	±0.009 (0.23)	0.030 (0.76)	4.491 (114.07)	±0.009 (0.23)	0.030 (0.76)	2.000 (50.80)	3.961 (100.61)	0.237 (6.02)	0.296 (7.52)	4.907	3/32 (2.38)	1/8 (3.18)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.05)	±0.010 (0.25)	0.060 (1.52)	3.000 (76.20)	4.975 (126.37)	0.258 (6.55)	0.323 (8.20)	6.039	3/32 (2.38)	1/8 (3.18)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.00)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.986 (152.04)	0.280 (7.11)	0.350 (8.89)	7.203	1/8 (3.18)	3/16 (4.76)

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.5.

TABLE 2 Minimum Dimension from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, CPVC Socket-Type Pipe Fittings, Schedule 40, in. (mm)[A]



Nominal Pipe Size	*G*, min in. (mm)	*J*, min in. (mm)	*N*, min in. (mm)
1/4	5/16 (7.94)	5/32 (3.97)	1/16 (1.59)
3/8	3/8 (9.53)	3/16 (4.76)	3/32 (2.38)
1/2	1/2 (12.70)	1/4 (6.35)	3/32 (2.38)
3/4	9/16 (14.29)	5/16 (7.94)	3/32 (2.38)
1	11/16 (17.46)	5/16 (7.94)	3/32 (2.38)
1 1/4	7/8 (22.22)	3/8 (9.53)	3/32 (2.38)
1 1/2	1 (25.40)	7/16 (11.11)	3/32 (2.38)
2	1 1/4 (31.75)	5/8 (15.88)	3/32 (2.38)
2 1/2	1 1/2 (38.10)	11/16 (17.46)	3/16 (4.76)
3	1 13/16 (46.04)	3/4 (19.05)	3/16 (4.76)
3 1/2	2 1/8 (53.98)	1 (25.40)	3/16 (4.76)
4	2 5/16 (58.74)	1 (25.40)	3/16 (4.76)
5	3 (76.20)	1 3/8 (34.92)	3/16 (4.76)
6	3 1/2 (88.90)	1 3/4 (44.45)	1/4 (6.35)

[A] The sketches and designs of fittings are illustrative only.

fixture must extend one third to two thirds of the socket depth. Failure of any part of the test apparatus does not constitute failure of the fittings.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the tests(s) shall be conducted again only by agreement between the purchaser and seller. Under such agreement, minimum requirements shall not be lowered, 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. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking:*

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

10.2.1.2 Material designation CPVC for CPVC 23447,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and

10.2.1.5 ASME SF-438 or both ASME SF-438 and ASTM F438.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case does marking cause cracks or reduce the wall thickness below the minimum specified.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

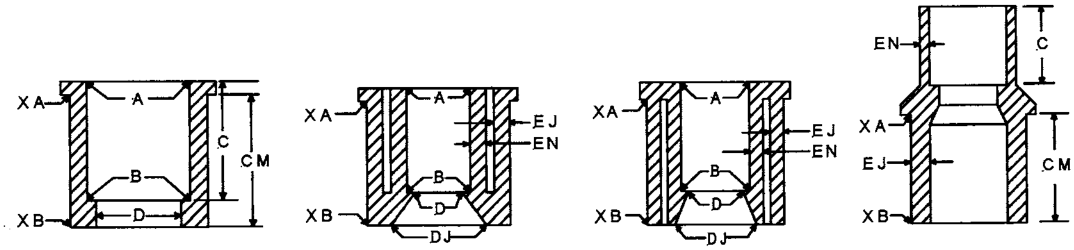
12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 CPVC; fittings; pressure; Sch 40; sockets; threads

TABLE 3 Dimensions of Reducer Bushings, CPVC Socket-Type Pipe Fittings, Schedule 40,[A] in.



Nominal Size	Outside Diameter XA	Tolerance on Outside Diameter	Outside Diameter XB	Tolerance on Outside Diameter	Maximum Out of Roundness (max. minus min.)
¼ by ⅛	0.540 (13.72)	+ 0.007 - 0.004 (0.18 - 0.10)	0.540 (13.72)	±0.004 (0.10)	0.016 (0.41)
⅜ by ¼, ⅛	0.675 (17.41)	+ 0.007 - 0.004 (0.18 - 0.10)	0.675 (17.41)	±0.004 (0.10)	0.016 (0.41)
½ by ⅜, ¼	0.840 (21.34)	+ 0.007 - 0.004 (0.18 - 0.10)	0.840 (21.34)	±0.004 (0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050 (26.67)	+ 0.007 - 0.004 (0.18 - 0.10)	1.050 (26.67)	±0.004 (0.10)	0.020 (0.51)
1 by ½,¾	1.315 (33.40)	+ 0.008 - 0.005 (0.20 - 0.13)	1.315 (33.40)	±0.005 (0.13)	0.020 (0.51)
1¼ by ½, ¾, 1	1.660 (42.16)	+ 0.008 - 0.005 (0.20 - 0.13)	1.660 (42.16)	±0.005 (0.13)	0.024 (0.61)
1½ by ½, ¾, 1, 1¼	1.900 (48.26)	+ 0.010 - 0.006 (0.25 - 0.15)	1.900 (48.26)	±0.006 (0.15)	0.024 (0.61)
2 by ½, ¾, 1, 1¼, 1½	2.375 (60.33)	+ 0.010 - 0.006 (0.25 - 0.15)	2.375 (60.33)	±0.006 (0.15)	0.024 (0.61)
2½ by 2	2.875 (73.03)	+ 0.012 - 0.007 (0.30 - 0.18)	2.875 (73.03)	±0.007 (0.18)	0.030 (0.76)
3 by 2½, 2	3.500 (88.90)	+ 0.013 - 0.008 (0.33 - 0.20)	3.500 (88.90)	±0.008 (0.20)	0.030 (0.76)
3½ by 2½, 2	4.000 (101.60)	+ 0.013 - 0.008 (0.33 - 0.20)	4.000 (101.60)	±0.008 (0.20)	0.030 (0.76)
4 by 3½, 3, 2½, 2	4.500 (114.30)	+ 0.015 - 0.009 (0.38 - 0.23)	4.500 (114.30)	±0.009 (0.23)	0.030 (0.76)
5 by 4	5.563 (141.30)	+ 0.017 - 0.010 (0.43 - 0.25)	5.563 (141.30)	±0.010 (0.25)	0.060 (1.52)
6 by 5	6.625 (168.28)	+ 0.018 - 0.011 (0.46 - 0.28)	6.625 (168.28)	±0.011 (0.28)	0.070 (1.78)

[A] The sketches and designs of fittings are illustrative only—per Symbols D2749.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Socket-Type Pipe Fittings, Schedule 40

Nominal Size, in.	Min Burst Strength,[A] Class 23447 psi	(MPa)
¼	2490	(17.17)
⅜	1990	(13.72)
½	1910	(13.17)
¾	1540	(10.62)
1	1440	(9.93)
1¼	1180	(8.14)
1½	1060	(7.31)
2	890	(6.14)
2½	970	(6.69)
3	840	(5.79)
3½	770	(5.31)
4	710	(4.90)
5	620	(4.27)
6	560	(3.86)

[A] This table was calculated for Schedule 40 pipe using the ISO formula and a stress level as follows:

	psi	(MPa)
Class 23447 (Type IV, Grade 1 (CPVC))	6400	(44.1)

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

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

S1. *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 may 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 S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR CHLORINATED POLY (VINYL CHLORIDE) (CPVC) PLASTIC PIPE FITTINGS, SCHEDULE 80

SF-439

(Identical with ASTM F439-13 except for additional requirements in section 12 and Annex A1, revised marking requirements in paras. 10.2.1.5 and 10.3, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) Schedule 80 pipe fittings. Included are requirements for materials, workmanship, dimensions, and burst pressure.

NOTE 1—The threaded CPVC fittings covered by this specification were covered previously in Specification F437.

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 this specification.

1.3 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.

1.4 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 and health 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

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

F412 Terminology Relating to Plastic Piping Systems

F437 Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water System Components—Health Effects

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

4. Classification

4.1 *General*—This specification covers Schedule 80 CPVC pipe fittings, intended for use with Iron Pipe Size (IPS) outside-diameter plastic pipe.

4.1.1 Fittings covered by this specification are normally molded. In-line fittings, such as couplings, unions, bushings, caps, nipples, and so forth, shall be molded or machined from extruded stock.

4.1.2 Fittings fabricated by back welding or butt fusion are not included in this specification.

NOTE 2—This specification does not include requirements for pipe and fittings intended to be used to vent combustion gases.

5. Materials and Manufacture

5.1 This specification covers CPVC pipe fittings made from compounds meeting the requirements of Class 23447 and Class 23448 as defined in Specification D1784.

NOTE 3—Mechanical strength, heat resistance and flammability requirements are covered in Specification D1784.

5.2 *Rework Material*—The manufacturers shall use only their own clean rework fitting material, and the fittings produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*

6.1.1 Fitting sockets, inside diameters (waterways), minimum wall thicknesses, and dimensions shall be as shown in Tables 1-6 when measured in accordance with Test Method D2122.

6.1.2 When multistep reducer bushings are cored out, the inner socket shall be reinforced from the outer wall by a minimum of three ribs extending from the top of the inner socket to the deepest extremity of the coring. The transition from D to DJ (Table 3) shall be straight, tapered as shown, or radiused. A positive taper in the same direction of the taper in the socket on the outside diameter of the bushing is optional (see XA/XB in Table 3). Any point measured along the outside diameter of the bushing (between XA and XB) shall not fall below minimum pipe OD.

6.1.3 The minimum wall thickness of fittings shall be 125 % of the minimum wall thickness of the corresponding size of Schedule 80 pipe for which they are designed to be used, except that for the socket, the wall thickness shall be at least equal to the minimum wall thickness of the corresponding size of Schedule 80 pipe.

6.1.4 The minimum inside diameter of the fittings shall be not less than the minimum specified inside diameter of the corresponding size of Schedule 80 pipe. This is calculated as follows:

$$(\text{minimum OD}) - 2 \times (\text{maximum wall}) = \text{minimum ID} \qquad (1)$$

6.1.5 Minimum dimensions have zero negative tolerance. Tolerances on other dimensions are shown in Tables 1 and 3.

6.1.6 *Fitting Not Illustrated*—All fittings, whether illustrated in Tables 1-5 or not, shall maintain the dimensions conforming to 6.1 and 6.2.

6.2 *Threads*—For all fittings having taper pipe threads, threads shall conform to Specification F1498 and be gaged in accordance with 8.4.

6.3 *Burst Pressure:*

6.3.1 The minimum burst strength of the fittings shall be not less than that calculated for the size and wall thickness of the pipe with which it is to be used, when calculated from the following equation and using a stress of 6400 psi for 8–in. and smaller fittings, and a stress of 5100 psi for fittings larger than 8–in.:

$$S = P(D_O - t)/2t \qquad (2)$$

where:

S = hoop stress, psi (MPa),
P = internal pressure, psi (MPa),
D_O = average outside diameter, in. (mm), and
t = minimum wall thickness, in. (mm).

Fittings tested in accordance with 8.5 shall withstand the minimum burst pressure shown in Table 6.

6.3.2 Pressures shown are minimum burst pressures and do not imply rated working pressures. The burst pressure shall be used only as an indication of quality.

7. Workmanship, Finish, and Appearance

7.1 The fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—Condition of test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—A sufficient quantity of fittings as agreed upon between the seller and the purchaser shall be selected at random from each lot or shipment and tested to determine that the basic design is in conformance with this specification.

NOTE 4—For individual orders or specifications where supplemental tests are required, only those tests and numbers of tests specifically agreed upon between the purchaser and the seller need be conducted.

8.4 *Threads*—All taper pipe threads shall be gaged in accordance with Specification F1498.

8.5 *Burst Pressure*—Determine the minimum burst pressure in accordance with Test Method D1599, Procedure B. The time of testing each specimen shall be between 60 and 70 s.

9. Retest and Rejection

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, 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. Marking

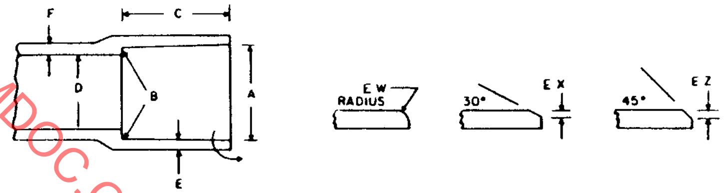
10.1 *Quality of Marking*—The markings shall be applied to the fitting in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking:*

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturer's name or trademark,

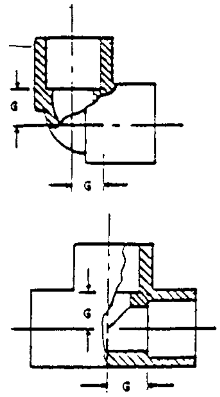
TABLE 1 Tapered Sockets for CPVC Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	A Socket Entrance Diameter: Diameter	A: Tolerance on Nominal Diameter	A: Maximum Out-of-Round	B Socket Bottom Diameter: Diameter	B: Tolerance on Nominal Diameter	B: Maximum Out-of-Round	C[B] Socket Length, min	D[C] Inside Diameter, min	Wall Thickness, min: E	Wall Thickness, min: F	Entrance, min: EW	Entrance, min: EX, EZ
¼	0.552 (14.02)	±0.004 (0.10)	0.016 (0.41)	0.536 (13.61)	±0.004 (0.10)	0.016 (0.41)	0.625 (15.88)	0.258 (6.55)	0.119 (3.02)	0.149 (3.78)	0.02 (0.5)	0.02 (0.5)
⅜	0.687 (17.45)	±0.004 (0.10)	0.016 (0.41)	0.671 (17.04)	±0.004 (0.10)	0.016 (0.41)	0.750 (19.05)	0.379 (9.63)	0.126 (3.20)	0.158 (4.01)	0.03 (0.8)	0.03 (0.8)
½	0.848 (21.54)	±0.004 (0.10)	0.016 (0.41)	0.836 (21.23)	±0.004 (0.10)	0.016 (0.41)	0.875 (22.22)	0.502 (12.75)	0.147 (3.73)	0.184 (4.67)	0.03 (0.8)	0.03 (0.8)
¾	1.058 (26.87)	±0.004 (0.10)	0.020 (0.51)	1.046 (26.57)	±0.004 (0.10)	0.020 (0.51)	1.000 (25.40)	0.698 (17.73)	0.154 (3.91)	0.193 (4.90)	0.03 (0.8)	0.03 (0.8)
1	1.325 (33.66)	±0.005 (0.13)	0.020 (0.51)	1.310 (33.27)	±0.005 (0.13)	0.020 (0.51)	1.125 (28.58)	0.910 (23.11)	0.179 (4.55)	0.224 (5.69)	0.06 (1.5)	0.06 (1.5)
1¼	1.670 (42.42)	±0.005 (0.13)	0.024 (0.61)	1.655 (42.04)	±0.005 (0.13)	0.024 (0.61)	1.250 (31.75)	1.227 (31.17)	0.191 (4.85)	0.239 (6.07)	0.06 (1.5)	0.06 (1.5)
1½	1.912 (48.56)	±0.006 (0.15)	0.024 (0.61)	1.894 (48.11)	±0.006 (0.15)	0.024 (0.61)	1.375 (34.93)	1.446 (36.73)	0.200 (5.08)	0.250 (6.35)	0.06 (1.5)	0.06 (1.5)
2	2.387 (60.63)	±0.006 (0.15)	0.024 (0.61)	2.369 (60.17)	±0.006 (0.15)	0.024 (0.61)	1.500 (38.10)	1.881 (47.78)	0.218 (5.54)	0.273 (6.93)	0.06 (1.5)	0.06 (1.5)
2½	2.889 (73.38)	±0.007 (0.18)	0.030 (0.76)	2.868 (72.85)	±0.007 (0.18)	0.030 (0.76)	1.750 (44.45)	2.250 (57.15)	0.276 (7.01)	0.345 (8.76)	0.09 (2.3)	0.13 (3.3)
3	3.515 (89.28)	±0.007 (0.18)	0.023 (0.58)	3.491 (88.67)	±0.007 (0.18)	0.023 (0.58)	1.875 (47.63)	2.820 (71.63)	0.300 (7.62)	0.375 (9.53)	0.09 (2.3)	0.13 (3.3)
3½	4.016 (102.01)	±0.008 (0.20)	0.030 (0.76)	3.992 (101.40)	±0.008 (0.20)	0.030 (0.76)	2.125 (53.98)	3.280 (83.31)	0.318 (8.08)	0.398 (10.11)	0.09 (2.3)	0.13 (3.3)
4	4.517 (114.73)	±0.008 (0.20)	0.023 (0.58)	4.490 (114.04)	±0.008 (0.20)	0.023 (0.58)	2.250 (57.15)	3.737 (94.92)	0.337 (8.56)	0.420 (10.67)	0.09 (2.3)	0.13 (3.3)
5	5.583 (141.81)	±0.010 (0.25)	0.060 (1.52)	5.553 (141.05)	±0.010 (0.25)	0.060 (1.52)	2.625 (66.68)	4.713 (119.71)	0.375 (9.53)	0.469 (11.91)	0.09 (2.3)	0.13 (3.3)
6	6.647 (168.83)	±0.011 (0.28)	0.060 (1.52)	6.614 (168.00)	±0.011 (0.28)	0.060 (1.52)	3.000 (76.20)	5.646 (143.41)	0.432 (10.97)	0.540 (13.72)	0.13 (3.3)	0.19 (4.8)
8	8.655 (219.84)	±0.015 (0.38)	0.090 (2.29)	8.610	±0.015 (0.38)	0.090 (2.29)	4.000 (101.60)	7.490 (190.25)	0.500 (12.70)	0.625 (15.88)	0.13 (3.3)	0.19 (4.8)
10	10.780 (273.81)	±0.015 (0.38)	0.100 (2.54)	10.735 (272.67)	±0.015 (0.38)	0.100 (2.54)	5.000 (127.00)	9.407 (238.94)	0.593 (15.06)	0.741 (18.82)	0.125 (3.18)	0.187 (4.76)
12	12.780 (324.61)	±0.015 (0.38)	0.120 (3.05)	12.735 (323.47)	±0.015 (0.38)	0.120 (3.05)	6.000 (152.40)	11.197 (284.40)	0.687 (17.45)	0.859 (21.82)	0.125 (3.18)	0.187 (4.76)

[A] The sketches and designs of fittings are illustrative only.
[B] Socket depth, measured from socket entrance face to socket bottom face.
[C] See 6.1.4.

TABLE 2 Minimum Dimensions from Center to End of Sockets (Laying Length) for Couplings, Tees, 90° and 45° Elbows, CPVC Socket-Type Pipe Fittings, Schedule 80, in. (mm)[A]



Nominal Pipe Size	*G*, min	*J*, min	*N*, min
¼	0.31 (7.9)	0.16 (4.1)	0.06 (1.5)
⅜	0.38 (9.7)	0.19 (4.8)	0.09 (2.3)
½	0.50 (12.7)	0.25 (6.4)	0.09 (2.3)
¾	0.56 (14.2)	0.31 (7.9)	0.09 (2.3)
1	0.69 (17.5)	0.31 (7.9)	0.09 (2.3)
1¼	0.88 (22.4)	0.38 (9.7)	0.09 (2.3)
1½	1.00 (25.4)	0.44 (11.2)	0.09 (2.3)
2	1.25 (31.8)	0.63 (16.0)	0.09 (2.3)
2½	1.50 (38.1)	0.69 (17.5)	0.19 (4.8)
3	1.81 (46.0)	0.75 (19.1)	0.19 (4.8)
3½	2.13 (54.1)	1.00 (25.4)	0.19 (4.8)
4	2.31 (58.7)	1.00 (25.4)	0.19 (4.8)
5	3.00 (76.2)	1.38 (35.1)	0.19 (4.8)
6	3.50 (88.9)	1.75 (44.5)	0.25 (6.4)
8	4.50 (114)	2.00 (50.8)	0.25 (6.4)
10	5.687 (144.45)	2.25 (57.15)	0.25 (6.35)
12	6.875 (174.63)	2.50 (63.50)	0.375 (9.53)

[A]The sketches and designs of fittings are illustrative only.

10.2.1.2 Material designation CPVC for CPVC 23447 and designation CPVC 42 for CPVC 23448,

10.2.1.3 The seal or mark of the laboratory making the evaluation for potable water contact,

10.2.1.4 Size, and

10.2.1.5 ASME SF-439 or both ASME SF-439 and ASTM F439.

10.3 Where the size of the fitting does not allow complete marking, omit identification marking in the following sequence: size, material designation, and the manufacturer's name or trademark.

10.4 Markings or symbols shall be molded, hot-stamped, or applied to fittings by any other suitable method, such as printing.

10.5 Where recessed marking is used, care shall be taken to see that in no case marking causes cracks or reduces the wall thickness below the minimum specified.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

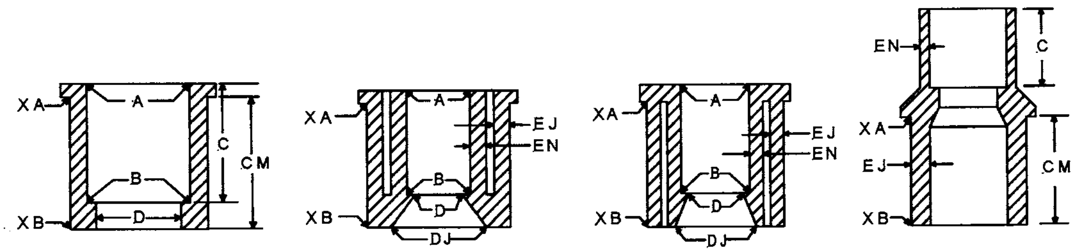
12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 CPVC; fittings; pressure; Schedule 80; sockets; threads

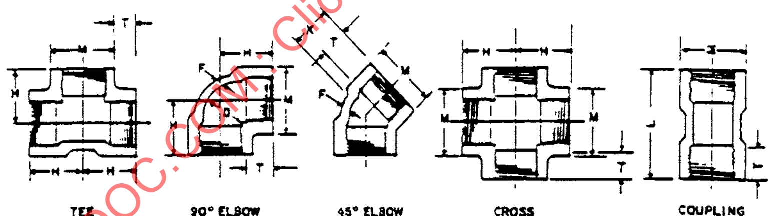
TABLE 3 Symbols for Dimensions of Reducer Blushings, CPVC Socket-type Pipe Fittings, Schedule 80[A], in. (mm)



Nominal Size	Outside Diameter XA	Tolerance on Outside Diameter	Outside Diameter XB	Tolerance on Outside Diameter	Maximum Out of Roundness (max. minus min.)
¼ by ⅛	0.540 (13.72)	+ 0.007 - 0.004 (0.18 - 0.10)	0.540 (13.72)	±0.004 (0.10)	0.016 (0.41)
⅜ by ¼,⅛	0.675 (17.41)	+ 0.007 - 0.004 (0.18 - 0.10)	0.675 (17.41)	±0.004 (0.10)	0.016 (0.41)
½ by ⅜,¼	0.840 (21.34)	+ 0.007 - 0.004 (0.18 - 0.10)	0.840 (21.34)	±0.004 (0.10)	0.016 (0.41)
¾ by ½, ⅜, ¼	1.050 (26.67)	+ 0.007 - 0.004 (0.18 - 0.10)	1.050 (26.67)	±0.004 (0.10)	0.020 (0.51)
1 by ½ , ¾	1.315 (33.40)	+ 0.008 - 0.005 (0.20 - 0.13)	1.315 (33.40)	±0.005 (0.13)	0.020 (0.51)
1¼ by ½, ¾,1	1.660 (42.16)	+ 0.008 - 0.005 (0.20 - 0.13)	1.660 (42.16)	±0.005 (0.13)	0.024 (0.61)
1½ by ½, ¾ 1, 1¼	1.900 (48.26)	+ 0.010 - 0.006 (0.25 - 0.15)	1.900 (48.26)	±0.006 (0.15)	0.024 (0.61)
2 by ½ , ¾, 1, 1¼, 1½	2.375 (60.33)	+ 0.010 - 0.006 (0.25 - 0.15)	2.375 (60.33)	±0.006 (0.15)	0.024 (0.61)
2½ by 2	2.875 (73.03)	+ 0.012 - 0.007 (0.30 - 0.18)	2.875 (73.03)	±0.007 (0.18)	0.030 (0.76)
3 by 2½ , 2	3.500 (88.90)	+ 0.012 - 0.007 (0.30 - 0.18)	3.500 (88.90)	±0.007 (0.18)	0.023 (0.58)
3½ by 2½, 2	4.000 (101.60)	+ 0.013 - 0.008 (0.33 - 0.20)	4.000 (101.60)	±0.008 (0.20)	0.030 (0.76)
4 by 3½ , 3, 2½, 2	4.500 (114.30)	+ 0.014 - 0.008 (0.35 - 0.20)	4.500 (114.30)	±0.008 (0.20)	0.023 (0.58)
5 by 4	5.563 (141.30)	+ 0.017 - 0.010 (0.43 - 0.25)	5.563 (141.30)	±0.010 (0.25)	0.060 (1.52)
6 by 5	6.625 (168.28)	+ 0.018 - 0.011 (0.46 - 0.28)	6.625 (168.28)	±0.011 (0.28)	0.070 (1.78)
8 by 6	8.625 (219.08)	+ 0.025 - 0.015 (0.64 - 0.38)	8.625 (219.08)	±0.015 (0.38)	0.090 (2.29)
10 by 6	10.750 (273.05)	+ 0.025 - 0.015 (0.64 - 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
10 by 8	10.750 (273.05)	+ 0.025 - 0.015 (0.64 - 0.38)	10.750 (273.05)	±0.015 (0.38)	0.100 (2.54)
12 by 6	12.750 (323.85)	+ 0.025 - 0.015 (0.64 - 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 8	12.750 (323.85)	+ 0.025 - 0.015 (0.64 - 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)
12 by 10	12.750 (323.85)	+ 0.025 - 0.015 (0.64 - 0.38)	12.750 (323.85)	±0.015 (0.38)	0.120 (3.05)

[A]The sketches and designs of fittings are illustrative only from symbols D2749.

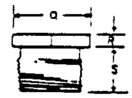
TABLE 4 Dimensions of 90° Ells, Tees, Crosses, 45° Elbows and Couplings (Straight Sizes), in. (mm)[A,B]



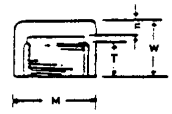
Nominal Pipe Size	Center to Thread End, 90° Elbows, Tees, Crosses, *H*, min	Length of Thread, *T*, min	Center to Thread End, 45° Elbow,[C] *K*, min	Inside Diameter of Fitting, *D*, min	Nominal Wall Thickness, *F*, min	Outside Diameter of Hub, *M*, min	Thread End to Thread End of Coupling, *L*, min
¼	0.812 (20.62)	0.50 (12.70)	0.688 (17.48)	0.258 (6.55)	0.135 (3.43)	0.840 (21.34)	1.063 (27.00)
⅜	0.938 (23.83)	0.50 (12.70)	0.750 (19.05)	0.379 (9.63)	0.144 (3.66)	1.000 (25.40)	1.063 (27.00)
½	1.125 (28.58)	0.64 (16.26)	0.750 (19.05)	0.502 (12.75)	0.198 (5.03)	1.280 (32.51)	1.344 (34.14)
¾	1.250 (31.75)	0.65 (16.51)	1.000 (25.40)	0.698 (17.73)	0.207 (5.25)	1.500 (38.10)	1.500 (38.10)
1	1.500 (28.10)	0.81 (20.51)	1.125 (28.58)	0.911 (23.14)	0.225 (5.72)	1.810 (45.97)	1.688 (42.88)
1¼	1.750 (44.45)	0.85 (21.59)	1.313 (23.35)	1.227 (31.17)	0.261 (6.63)	2.200 (55.88)	1.750 (44.45)
1½	1.938 (49.23)	0.85 (21.59)	1.438 (36.83)	1.446 (36.73)	0.270 (6.85)	2.500 (63.50)	2.000 (50.80)
2	2.250 (57.15)	0.90 (22.86)	1.625 (41.28)	1.881 (47.78)	0.297 (7.54)	3.000 (76.20)	2.063 (52.40)
2½	2.688 (68.28)	1.21 (30.73)	1.938 (49.23)	2.250 (57.15)	0.315 (8.00)	3.560 (90.42)	2.625 (66.68)
3	3.063 (77.80)	1.30 (33.02)	2.125 (53.98)	2.820 (71.63)	0.405 (10.29)	4.300 (109.22)	2.750 (69.85)
4	3.625 (92.08)	1.38 (35.05)	2.625 (66.68)	3.737 (94.92)	0.450 (11.43)	5.430 (137.92)	3.000 (76.20)
6	5.125 (130.18)	1.50 (38.10)	3.250 (82.55)	5.646 (143.41)	0.504 (12.80)	7.625 (193.68)	3.250 (82.55)

[A] The sketches and designs of fittings shown are illustrative only.
[B]Symbols for dimensions are in accordance with Symbols D2749.
[C]This dimension locates the end of the fitting.

TABLE 5 Dimensions of Threaded Plugs and Caps, in.[A,B]



PLUG



CAP

Nominal Pipe Size	Length of Male Thread, *S*, min	Length of Female Thread, *T*, min	Width of Flats,[B] *Q*, min	Nominal Wall Thickness, *F*, min	Height of Head,[C] *R*, min	Cap Height, *W*, min	Outside Diameter of Hub, *M*, min
¼	0.44 (11.18)	0.50 (12.70)	0.625 (15.88)	0.135 (3.43)	0.188 (4.78)	0.688 (17.48)	0.840 (21.34)
⅜	0.44 (11.18)	0.50 (12.70)	0.750 (19.05)	0.144 (3.66)	0.188 (4.78)	0.688 (17.48)	1.000 (25.40)
½	0.53 (13.46)	0.64 (16.26)	0.938 (23.83)	0.198 (5.03)	0.188 (4.73)	0.875 (22.23)	1.280 (32.51)
¾	0.55 (13.92)	0.65 (16.51)	1.125 (28.53)	0.207 (5.26)	0.219 (5.56)	1.000 (25.40)	1.500 (38.10)
1	0.68 (17.27)	0.81 (20.57)	1.375 (34.93)	0.225 (5.72)	0.219 (5.56)	1.188 (30.18)	1.810 (45.97)
1¼	0.71 (18.03)	0.85 (21.59)	1.750 (44.45)	0.261 (6.63)	0.281 (7.14)	1.250 (31.75)	2.200 (55.88)
1½	0.72 (18.29)	0.85 (21.59)	1.875 (47.63)	0.270 (6.85)	0.313 (7.95)	1.250 (31.75)	2.500 (63.50)
2	0.76 (19.30)	0.90 (22.86)	1.875 (47.63)	0.297 (7.54)	0.313 (7.95)	1.375 (34.93)	3.000 (76.20)
2½	1.14 (28.96)	1.21 (30.25)	1.875 (47.63)	0.369 (8.00)	0.375 (9.53)	1.625 (41.28)	3.560 (90.42)
3	1.20 (30.48)	1.30 (33.02)	2.000 (50.80)	0.405 (10.29)	0.375 (9.53)	1.750 (49.45)	4.300 (109.2)
4	1.30 (33.02)	1.38 (35.05)	2.000 (50.80)	0.450 (11.43)	0.375 (9.53)	2.000 (50.60)	5.430 (137.9)
6	1.44 (36.58)	1.50 (35.10)	2.000 (50.80)	0.504 (12.80)	0.500 (12.10)	2.125 (53.98)	7.625 (193.68)

[A] The sketches and designs of fittings shown are illustrative only.
[B] Symbols for dimensions are in accordance with Symbols D2749.
[C] At the manufacturer's option, the head of the plug shall be hexagonal, octagonal, square, or round.

TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC Pipe Fittings, Schedule 80

Nominal Size, in.	Minimum Burst Strength	
	Class 23447 and 23448	
	psi	MPa
¼	3620	24.96
⅜	2940	20.27
½	2720	18.75
¾	2200	15.17
1	2020	13.93
1¼	1660	11.44
1½	1510	10.41
2	1290	8.89
2½	1360	9.38
3	1200	8.27
3½	1110	7.65
4	1040	7.17
5	930	6.41
6	890	6.14
8	790	5.45
10	600	4.14
12	580	4.00

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

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

S1. *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 may 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 S1.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this document.

POTABLE WATER REQUIREMENT

This requirement applies whenever a regulatory authority or user calls for the product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR CHLORINATED POLY(VINYL CHLORIDE) (CPVC) PLASTIC PIPE, SCHEDULES 40 AND 80

SF-441/SF-441M

(Identical with ASTM F441/F441M-13e1 except for additional requirements in section 12 and Annex A1, revised marking requirements in para. 10.2.1.5, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) pipe made in Schedule 40 and 80 sizes and pressure-rated for water (see appendix). Included are criteria for classifying CPVC plastic pipe materials and CPVC plastic pipe, a system of nomenclature for CPVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

NOTE 1—The CPVC pipe covered by this specification was covered previously in Specification D1785.

NOTE 2—The sustained and burst pressure test requirements, and the pressure ratings in the appendix, are calculated from stress values obtained from tests made on pipe 2 in. [50 mm] and smaller. However, tests on larger pipe have shown these stress values to be valid.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 3—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 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.

1.4 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 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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 7.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

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

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

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

F412 Terminology Relating to Plastic Piping Systems

2.2 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
2.3 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage
2.4 *NSF Standards:*
Standard No. 14 for Plastic Piping Components and Related Materials
Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for chlorinated poly(vinyl chloride) is CPVC.

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *hydrostatic design stress*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.2.2 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.2.3 *relation between dimensions, design stress, and pressure rating*—The following expression, commonly known as the ISO equation, is used in this specification to relate dimensions, hydrostatic design stress, and pressure rating:

$$2\,S/P = (D_O/t) - 1$$

where:
S = hydrostatic design stress, psi [MPa],
P = pressure rating, psi [MPa],
D_O = average outside diameter, in. [mm], and
t = minimum wall thickness, in. [mm].

3.2.4 *standard thermoplastic pipe materials designation code*—The pipe materials designation code shall consist of the abbreviation CPVC for the type of plastic, followed by the ASTM type and grade in Arabic numerals and the design stress at 73°F [23°C] in units of 100 psi [0.7 MPa] with any decimal figures dropped, followed by the design stress at 180°F [82°C] in units of 100 psi [0.7MPa] with any decimal figures dropped. When the design stress code contains less than two figures, a cipher shall be used before the number. Thus a complete material code shall consist of four letters and six figures for CPVC plastic pipe materials (see Section 5).

4. Classification

4.1 *General*—This specification covers CPVC pipe made from one (see X1.2) CPVC plastic pipe material in Schedule 40 and 80 sizes.

4.2 *Hydrostatic Design Stresses*—This specification covers CPVC pipe made from CPVC plastic as defined by hydrostatic design stresses which have been developed on the basis of long-term tests (see appendix).

NOTE 4—This specification does not include requirements for pipe fittings intended to be used to vent combustion gases.

5. Materials

5.1 *General*—Chlorinated poly(vinyl chloride) plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, (*1*) short-term strength tests and (*2*) long-term hydrostatic strength tests at both 73 and 180°F [23 and 82°C].

5.2 *Basic Materials:*
5.2.1 *Basic Materials – Short-term Tests*—This specification covers pipe made from CPVC plastics having certain physical properties as described in Specification D1784.
5.2.1.1 *Compound*—The CPVC compounds used for this pipe shall equal or exceed the classification 23447 described in Specification D1784.
5.2.2 *Basic Materials – Long-term Test*—This specification convers pipe made from CPVC plastics having certain Hydrostatic Design Bases (HDB) and Hydrostatic Design Stresses (HDS) described in Test Method D2837
5.2.2.1 *Compound*—The CPVC compounds used for this pipe shall have a Hydrostatic Design Basis at 73ºF [23ºC] of 4000 psi [28 MPa], , and a Hydrostatic Design Basis at 180ºF [82ºC] of either 1000 psi [7.0 MPa] or 1250 psi [8.6 MPa] when evaluated in accordance with Test Method D2837
5.2.3 *Standard thermoplastic pipe materials designation*——The pipe materials designation shall consist of the material designation code CPVC 4120-05 or CPVC 4120-06 for the type of plastic.

NOTE 5—As per Terminology F412 (see, "code, thermoplastic pipe materials designation") the pipe materials designation code CPVC 4120 is as follows: CPVC is the abbreviation for chlorinated poly(vinyl chloride) as per Terminology D1600, 41 represents Cell Classification 23447 per Specification D1784, and 20 represents a HDS of 2000 psi [14 MPa] for water at 73ºF (23ºC) per Test Method D2837. In addition, the -05 or -06 suffix represents a HDS of 500 psi [3.4 MPa] or 625 psi [4.3 MPa] respectively for water at 180ºF [82ºC] per Test Method D2837.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework pipe material and the pipe produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances:*
6.1.1 Dimensions and tolerances shall be as shown in Table 1 and Table 2 when measured in accordance with Test Method D2122. The tolerances for out-of-roundness shall apply only to pipe prior to shipment.
6.1.2 *Wall Thickness Range*—The wall thickness range shall not exceed 12 % when measured in accordance with Test Method D2122.

6.2 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598, at the test pressures given in Table 3, when tested in accordance with 8.4.

TABLE 1 Outside Diameters and Tolerances for CPVC Plastic Pipe, Schedules 40 and 80, in. [mm]

Nominal Pipe Size	Outside Diameter	Tolerances		
			Maximum Out-of-Roundness (maximum minus minimum diameter)	
			Schedule 40 sizes 3½ in. and over; Schedule 80 sizes 8 in. and over	Schedule 40 sizes 3 in. and less; Schedule 80 sizes 6 in. and less
¼ [8]	0.540 [13.7]	±0.004 [0.10]	...	0.016 (0.41)
⅜ [10]	0.675 [17.1]	±0.004 [0.10]	...	0.016 (0.41)
½ [15]	0.840 [21.3]	±0.004 [0.10]	...	0.016 (0.41)
¾ [20]	1.050 [26.7]	±0.004 [0.10]	...	0.020 (0.51)
1 [25]	1.315 [33.4]	±0.005 [0.13]	...	0.020 (0.51)
1¼ [32]	1.660 [42.2]	±0.005 [0.13]	...	0.024 (0.61)
1½ [40]	1.900 [48.3]	±0.006 [0.15]	...	0.024 (0.61)
2 [50]	2.375 [60.3]	±0.006 [0.15]	...	0.024 (0.61)
2½ [65]	2.875 [73.0]	±0.007 [0.18]	...	0.030 (0.76)
3 [80]	3.500 [88.9]	±0.007 [0.18]	. . .	0.023 (0.58)
3½ [90]	4.000 [101.6]	±0.008 [0.20]	0.100 (2.54)	0.030 (0.76)
4 [100]	4.500 [114.3]	±0.008 [0.20]	0.100 (2.54)	0.023 (0.58)
5 [125]	5.563 [141.3]	±0.010 [0.25]	0.100 (2.54)	0.060 (1.52)
6 [150]	6.625 [168.3]	±0.011 [0.28]	0.100 (2.54)	0.070 (1.78)
8 [200]	8.625 [219.1]	±0.015 [0.38]	0.150 (3.81)	0.090 (2.29)
10 [250]	10.750 [273.1]	±0.015 [0.38]	0.150 (3.81)	0.100 (2.54)
12 [300]	12.750 [323.9]	±0.015 [0.38]	0.150 (3.81)	0.120 (3.05)
14 [350]	14.000 [355.6]	±0.015 [0.380]	0.200 (5.08)	...
16 [400]	16.000 [406.4]	±0.019 [0.480]	0.320 (8.13)	...

TABLE 2 Wall Thicknesses and Tolerances for CPVC Plastic Pipe, Schedules 40 and 80, in.[A,B] [mm]

Nominal Pipe Size	Wall Thickness[A]			
	Schedule 40		Schedule 80	
	Min	Tolerance	Min	Tolerance
¼ [8]	0.088 [2.24]	+0.020 [0.51]	0.119 [3.02]	+0.020 [0.51]
⅜ [10]	0.091 [2.31]	+0.020 [0.51]	0.126 [3.20]	+0.020 [0.51]
½ [15]	0.109 [2.77]	+0.020 [0.51]	0.147 [3.73]	+0.020 [0.51]
¾ [20]	0.113 [2.87]	+0.020 [0.51]	0.154 [3.91]	+0.020 [0.51]
1 [25]	0.133 [3.38]	+0.020 [0.51]	0.179 [4.55]	+0.021 [0.53]
1¼ [32]	0.140 [3.56]	+0.020 [0.51]	0.191 [4.85]	+0.023 [0.58]
1½ [40]	0.145 [3.68]	+0.020 [0.51]	0.200 [5.08]	+0.024 [0.61]
2 [50]	0.154 [3.91]	+0.020 [0.51]	0.218 [5.54]	+0.026 [0.66]
2½ [65]	0.203 [5.16]	+0.024 [0.61]	0.276 [7.01]	+0.033 [0.84]
3 [80]	0.216 [5.49]	+0.026 [0.66]	0.300 [7.62]	+0.036 [0.91]
3½ [90]	0.226 [5.74]	+0.027 [0.68]	0.318 [8.08]	+0.038 [0.96]
4 [100]	0.237 [6.02]	+0.028 [0.71]	0.337 [8.56]	+0.040 [1.02]
5 [125]	0.258 [6.55]	+0.031 [0.79]	0.375 [9.52]	+0.045 [1.14]
6 [150]	0.280 [7.11]	+0.034 [0.86]	0.432 [10.97]	+0.052 [1.32]
8 [200]	0.322 [8.18]	+0.039 [0.99]	0.500 [12.70]	+0.060 [1.52]
10 [250]	0.365 [9.27]	+0.044 [1.12]	0.593 [15.06]	+0.071 [1.80]
12 [300]	0.406 [10.31]	+0.049 [1.24]	0.687 [17.45]	+0.082 [2.08]
14 [350]	0.437 [11.10]	+0.053 [+1.35]	0.750 [19.05]	+0.090 [+2.29]
16 [400]	0.500 [12.70]	+0.060 [+1.52]	0.843 [21.14]	+0.101 [+2.57]

[A] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.
[B] These dimensions conform to nominal IPS dimensions.

6.2.1 *Accelerated Regression Test*—The accelerated regression test shall be used in place of both the sustained and burst pressure tests at the option of the manufacturer. The test shall be conducted in accordance with 8.4.1. The pipe shall demonstrate a hydrostatic design basis projection at the 100 000 h intercept that meets the hydrostatic design basis category requirement (see Table 1, Test Method D2837) for the CPVC material used in its manufacture. If the lower confidence value at 100 000 h differs from the extrapolated LTHS value by more than 15 % of the latter; or M in Appendix X2 (Test Method D2837) is zero or negative; or b in the equation $h = a + bf$ in Appendix X1 (Test Method D2837) is positive, consider the data unsuitable.

6.3 *Burst Pressure*—The minimum burst pressures for CPVC plastic pipe shall be as given in Table 4, when determined in accordance with Test Method D1599.

6.4 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 8.5.

7. Workmanship, Finish, and Appearance

7.1 The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

TABLE 3 Sustained Pressure Test Conditions for Water at 73°F [23°C] for CPVC 4120 Plastic Pipe, Schedules 40 and 80

Nominal Pipe Size	Pressure Required for Test[A]			
	Schedule 40		Schedule 80	
	psi	[kPa]	psi	[kPa]
¼ [8]	1640	[11 310]	2370	[16 340]
⅜ [10]	1310	[9 030]	1930	[13 310]
½ [15]	1250	[8 620]	1780	[12 270]
¾ [20]	1010	[6 960]	1440	[9 930]
1 [25]	950	[6 550]	1320	[9 100]
1¼ [32]	770	[5 310]	1090	[7 520]
1½ [40]	690	[4 760]	990	[6 830]
2 [50]	580	[4 000]	850	[5 860]
2½ [65]	640	[4 410]	890	[6 140]
3 [80]	590	[4 070]	790	[5 450]
3½ [90]	500	[3 450]	730	[5 030]
4 [100]	470	[3 240]	680	[4 690]
5 [125]	410	[2 830]	610	[4 210]
6 [150]	370	[2 550]	590	[4 070]
8 [200]	330	[2 280]	520	[3 590]
10 [250]	300	[2 070]	490	[3 380]
12 [300]	280	[1 930]	480	[3 310]
14 [350]	270	[1 890]	470	[3 290]
16 [400]	270	[1 890]	470	[3 290]

[A] The fiber stress used to derive these test pressures is 4200 psi [29.0 MPa].

TABLE 4 Burst Pressure Requirements for Water at 73°F [23°C] for CPVC 4120 Plastic Pipe, Schedules 40 and 80

Nominal Pipe Size	Minimum Burst Pressure[A]			
	Schedule 40		Schedule 80	
	psi	[kPa]	psi	[kPa]
¼ [8]	2490	[17 170]	3620	[24 960]
⅜ [10]	1990	[13 720]	2940	[20 270]
½ [15]	1910	[13 170]	2720	[18 760]
¾ [20]	1540	[10 620]	2200	[15 170]
1 [25]	1440	[9 930]	2020	[13 930]
1¼ [32]	1180	[8 140]	1660	[11 450]
1½ [40]	1060	[7 310]	1510	[10 410]
2 [50]	890	[6 140]	1290	[8 890]
2½ [65]	970	[6 690]	1360	[9 380]
3 [80]	840	[5 790]	1200	[8 270]
3½ [90]	770	[5 310]	1110	[7 650]
4 [100]	710	[4 900]	1040	[7 170]
5 [125]	620	[4 270]	930	[6 410]
6 [150]	560	[3 860]	890	[6 140]
8 [200]	500	[3 450]	790	[5 450]
10 [250]	450	[3 100]	750	[5 170]
12 [300]	420	[2 900]	730	[5 030]
14 [350]	410	[2 870]	720	[5 040]
16 [400]	410	[2 870]	710	[4 970]

[A] The fiber stress used to derive these test pressures is 6400 psi [44.1 MPa].

NOTE 6—Color and transparency or opacity should be specified in the contract or purchase order.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 73 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

8.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

8.4 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressures given in Table 3, six specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. [250 mm] or more than 3 ft [1000 mm] between end closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi [±69 kPa]. Condition the specimens at the test temperature of 73± 3.6°F [23 ± 2°C]. Test in accordance with Test Method D1598, except maintain the pressure at the values given in Table 3 for 1000 h. Evidence of failure of the pipe shall be as defined in Test Method D1598.

8.4.1 *Accelerated Regression Test*—Test in accordance with procedures in Test Method D1598, using either free end or restrained end fittings. A minimum of six specimens shall be tested. Test three specimens at a single pressure that will result in failures at or below 0.10 h. Test an additional three specimens at a single pressure that will result in failures at about 200 h. Additional data points may be generated if necessary to improve the LTHS or LCL, or both. No points shall be excluded unless an obvious defect is detected in the failure area of the test sample, or there was an obvious malfunction of the test equipment. Characterize the data using the least-squares regression described in Test Method D2837.

NOTE 7—**Caution:** Since the rupture of the test specimen is expected in quick burst and high stress regression testing, well shielded test equipment and protective personal equipment should be used when conducting the tests.

8.5 *Flattening*—Flatten three specimens of the pipe, 2 in. [50 mm] long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe or the walls of the pipe touch, whichever occurs first. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. On removal of the load examine the specimens for evidence of splitting, cracking, or breaking.

9. Retest and Rejection

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, 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. Marking

10.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

10.2 *Content of Marking:*

10.2.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft [1.5 m]:

10.2.1.1 Nominal pipe size (for example, 2 in. [50 mm]),

10.2.1.2 Type of plastic pipe material in accordance with the material designation code prescribed in 5.2.3, for example, CPVC 4120–05.

10.2.1.3 Schedule size (40 or 80 whichever is applicable).

10.2.1.4 The pressure rating in pounds-force per square inch for water at both 73°F [23°C] and 180°F [82°C], shown as the number followed by psi and the temperature (for example, "630 psi at 73°F, 155 psi at 180°F"). When the indicated pressure rating is lower than that calculated in accordance with 3.2.3 (see Appendix X1), this shall be indicated by placing a star after the pressure rating.

10.2.1.5 ASME SF-441/SF-441M or both ASME SF-441/SF-441M and ASTM F441/F441M.

10.2.1.6 Manufacturer's name (or trade mark) and code, and

10.2.1.7 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 8—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENT

This requirement applies whenever a regulatory authority or user calls for product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

GOVERNMENT / MILTARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales of transfers.

S2. *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 may 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 S2.1—In U.S. federal contracts, the contractor is responsible for inspection.

S3. *Packaging and Marking for U.S. Government Procurement:*

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL–STD–129 for military agencies.

NOTE S3.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 The hydrostatic design stress (HDS) at 73ºF [23ºC] and the hydrostatic design stress (HDS) at 180ºF [82ºC] recommended by the Plastics Pipe Institute and utilizing a service (design) factor for water of 0.5 are used to pressure rate CPVC plastic pipe for water service applications only. This hydrostatic design stress applies only to pipe meeting all the requirements of this specification.

X1.2 CPVC pipe materials are included based on the requirements of Specification D1784 and the PPI-recommended hydrostatic design stress for water at both 73ºF [23ºC] and 180ºF [82ºC], as follows:

X1.2.1 Type IV, Grade 1 (23447), with a hydrostatic design stress at 73ºF [23ºC], in water of 2000 psi [13.8 MPa], and a hydrostatic design stress at 180ºF [82ºC], in water of either 500 psi [3.4 MPa] or 625 psi [4.3 MPa] shall be designated as CPVC 4120-05 or CPVC 4120-06, respectively.

X1.3 The standard method for obtaining hydrostatic basis for thermoplastic pipe materials is Test Method D2837. Additional information regarding the test method and other criteria used in developing these hydrostatic design bases may be obtained from the Plastics Pipe Institute Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org. These hydrostatic design stresses may not be suitable for materials that show a wide departure from a straight-line plot of log stress versus log time to failure. All the data available to date on CPVC pipe materials made in the United States exhibit a straight-line plot under these plotting conditions.

TABLE X1.1 Water Pressure Ratings[A] (PR) in psi [kPa] at 73°F (23°C) for Schedule 40 Pipe Produced from CPVC Materials having an HDS[C] of 2000 psi [14 MPa] at 73°F [23°C]

Nominal Pipe Size	Pressure Ratings[B] psi	[kPa]
¼ [8]	780	[5 380]
⅜ [10]	620	[4 270]
½ [15]	600	[4 140]
¾ [20]	480	[3 310]
1 [25]	450	[3 100]
1¼ [32]	370	[2 550]
1½ [40]	330	[2 280]
2 [50]	280	[1 930]
2½ [65]	300	[2 070]
3 [80]	260	[1 790]
3½ [90]	240	[1 650]
4 [100]	220	[1 520]
5 [125]	190	[1 310]
6 [150]	180	[1 240]
8 [200]	160	[1 100]
10 [250]	140	[970]
12 [300]	130	[900]
14 [350]	130	[900]
16 [400]	130	[900]

[A] See appendix for code designation.
[B] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading CPVC plastic pipe in Schedule 40 dimensions in nominal pipe sizes 6 in. [150 mm] and smaller.
[C] HDB of 4000 psi [28 MPa].

TABLE X1.2 Water Pressure Ratings[A] (PR) in psi [kPa] at 73°F (23°C) for Schedule 80 Pipe Produced from CPVC 4120-05 and CPVC 4120-06 Materials having an HDS[B] of 2000 psi [14 MPa] at 73°F [23°C]

Nominal Pipe Size	Unthreaded psi	Unthreaded [kPa]	Threaded psi	Threaded [kPa]
¼ [8]	1130	[7 790]	570	[3 930]
⅜ [10]	920	[6 340]	460	[3 170]
½ [15]	850	[5 860]	420	[2 900]
¾ [20]	690	[4 760]	340	[2 340]
1 [25]	630	[4 340]	320	[2 210]
1¼ [32]	520	[3 590]	260	[1 790]
1½ [40]	470	[3 240]	240	[1 650]
2 [50]	400	[2 760]	200	[1 380]
2½ [65]	420	[2 900]	210	[1 450]
3 [80]	370	[2 550]	190	[1 310]
3½ [90]	350	[2 410]	170	[1 170]
4 [100]	320	[2 210]	160	[1 100]
5 [125]	290	[2 000]	140	[970]
6 [150]	280	[1 930]	140	[970]
8 [200]	250	[1 720]	120	[830]
10 [250]	230	[1 590]	120	[830]
12 [300]	230	[1 590]	110	[760]
14 [350]	220	[1 540]	...	...
16 [400]	220	[1 540]	...	...

[A] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading CPVC plastic pipe in Schedule 40 dimensions in normal pipe sizes 6 in. [150 mm] and smaller.
[B] HDB of 4000 psi [28 MPa].

TABLE X1.3 Water Pressure Ratings[A] (PR) in psi [kPa] at 180ºF (82ºC) for Schedule 40 and Schedule 80 Pipe Produced from CPVC 4120-05 Material having an HDS[B] of 500 psi 3.4 [MPa] at 180ºF [82ºC], psi [kPa]

Nominal Pipe Size	Schedule 40	Unthreaded Schedule 80	Threaded Schedule 80
¼ [8]	195 [1 340]	280 [1 930]	140 [970]
⅜ [10]	155 [1 070]	230 [1 590]	115 [790]
½ [15]	150 [1 030]	210 [1 450]	105 [720]
¾ [20]	120 [830]	170 [1 170]	85 [590]
1 [25]	110 [760]	155 [1 070]	80 [550]
1¼ [32]	90 [620]	130 [900]	65 [450]
1½ [40]	80 [550]	115 [790]	60 [410]
2 [50]	70 [480]	100 [690]	50 [340]
2½ [65]	75 [520]	105 [720]	50 [340]
3 [80]	65 [450]	90 [620]	45 [310]
3½ [90]	60 [410]	85 [590]	40 [280]
4 [100]	55 [380]	80 [550]	40 [280]
5 [125]	45 [310]	70 [480]	35 [240]
6 [150]	45 [310]	70 [480]	35 [240]
8 [200]	40 [280]	60 [410]	30 [210]
10 [250]	35 [240]	55 [380]	30 [210]
12 [300]	30 [210]	55 [380]	25 [170]
14 [350]	30 [210]	55 [380]	25 [170]
16 [400]	30 [210]	55 [380]	25 [170]

[A] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading CPVC plastic pipe in Schedule 40 dimensions in normal pipe sizes 6 in. [150 mm] and smaller.
[B] HDB of 1000 psi [6.9 MPa]

X1.4 The hydrostatic design stresses recommended by the Plastics Pipe Institute are based on tests made on pipe ranging in size from ½ to 2 in.

X1.5 The pipe is rated for use with water at 73°F [23°C] at the maximum internal pressures shown in Table X1.1 and Table X1.2. Lower pressure rating than those calculated in accordance with 8.4 may be recommended, at the option of the pipe manufacturer, in which case the pipe Schedule shall be included in the marking. Experience of the industry indicates that CPVC plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.6 The pipe is rated for use with water at 180ºF [82ºC] at the maximum internal pressures shown in Table X1.3 and Table X1.4 Lower pressure ratings than those calculated in accordance with 8.4 may be recommended at the option of the pipe manufacturer, in which case the pipe Schedule shall be included in the marking. Experience of the industry indicates that CPVC plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for long period at these pressure ratings. The sustained pressure requirements are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

TABLE X1.4 Water Pressure Ratings[A] (PR) in psi [kPa] at 180ºF (82ºC) for Schedule 40 and Schedule 80 Pipe Produced from CPVC 4120-06 Material having an HDS[B] of 625 psi [4.3 MPa] at 180ºF [82ºC]

Nominal Pipe Size	Schedule 40	Unthreaded Schedule 80	Threaded Schedule 80
¼ [8]	240 [1 660]	350 [2 410]	175 [1 210]
⅜ [10]	195 [1 340]	290 [2 000]	145 [1 000]
½ [15]	190 [1 310]	260 [1 790]	130 [900]
¾ [20]	150 [1 030]	210 [1 450]	105 [720]
1 [25]	140 [970]	195 [1 340]	100 [690]
1¼ [32]	110 [760]	160 [1 100]	80 [550]
1½ [40]	100 [690]	145 [1 000]	75[520]
2 [50]	90 [620]	125[860]	60 [410]
2½ [65]	95 [660]	130 [900]	60 [410]
3 [80]	80 [550]	110 [760]	55 [380]
3½ [90]	75 [520]	105 [720]	50 [340]
4 [100]	70 [480]	100 [690]	50 [340]
5 [125]	55 [380]	90 [620]	45 [310]
6 [150]	55 [380]	90 [620]	45 [310]
8 [200]	50 [340]	75 [520]	40 [280]
10 [250]	45 [310]	70 [480]	40 [280]
12 [300]	40 [280]	70[480]	30 [210]
14 [350]	40 [280]	70[480]	30 [210]
16 [400]	40 [280]	70[480]	30 [210]

[A] These pressure ratings apply only to unthreaded pipe. The industry does not recommend threading CPVC plastic pipe in Schedule 40 dimensions in normal pipe sizes 6 in. [150 mm] and smaller.
[B] HDB of 1250 psi [8.6 MPa.

X1.7 These derating factors are suitable for CPVC pipe conveying water at elevated temperatures. To determine elevated temperature rating, multiply 73°F [23°C] pressure rating by appropriate factor as follows (For pressure rating at 180°F, see Table X1.3.):

Temperature		Derating Factor with 180°F HDS of :	
°F	[°C]	500 psi	625 psi
73 to 80	[22.5 to 26.7]	1.00	1.00
90	[32.2]	0.91	0.91
100	[37.8]	0.82	0.83
120	[48.9]	0.65	0.70
140	[60.0]	0.50	0.57
160	[71.1]	0.40	0.44
180	[82.2]	0.25	0.31†
200	[93.3]	0.20	[A]

[A] Consult with specific product or component manufacturers for temperature derating factors above 180°F
†Editorially revised in September 2013.

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SPECIFICATION FOR CHLORINATED POLY(VINYL CHLORIDE) (CPVC) PLASTIC PIPE (SDR-PR)

SF-442/SF-442M

(Identical with ASTM F442/F442M-13e1 except for additional requirements in section 12 and Annex A1, revised marking requirements in para. 10.2.1.5, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe (SDR–PR)

1. Scope

1.1 This specification covers chlorinated poly(vinyl chloride) (CPVC) pipe made in standard thermoplastic pipe dimension ratios and pressure rated for water (see Appendix). Included are criteria for classifying CPVC plastic pipe materials and CPVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

NOTE 1—The CPVC pipe covered by this specification was covered previously in Specification D2241.

NOTE 2—The sustained and burst pressure test requirements and the pressure ratings in the Appendix are calculated from stress values obtained from tests made on pipe 2 in. (50 mm) and smaller. However, tests on larger pipe have shown these stress values to be valid.

1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 3—Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious saftey hazards should a system fail for any reason.

1.3 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.

1.4 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.Within the text, the SI units are shown in brackets.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 7.

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics for Testing

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

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)

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

F412 Terminology Relating to Plastic Piping Systems

2.2 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
2.3 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage
2.4 *NSF Standards:*
Standard No. 14 for Plastic Piping Components and Related Materials
Standard No. 61 for Drinking Water Systems Components—Health Effects

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600, unless otherwise specified. The abbreviation for chlorinated poly(vinyl chloride) plastic is CPVC.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hydrostatic design stress*— the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.2.2 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.2.3 *relation between standard dimension ratio, hydrostatic design stress, and pressure rating*—the following expression, commonly known as the ISO equation, is used in this specification to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

$$2\,S/P = R - 1 \text{ or } 2\,S/P = \left(D_o/t\right) - 1$$

where:

S = hydrostatic design stress, psi [MPa],
P = pressure rating, psi [kPa],
D_o = average outside diameter, in. [mm]
t = minimum wall thickness, in. [mm], and
R = standard thermoplastic pipe dimension ratio (D_o/t for CPVC pipe), also known as SDR.

3.2.4 *standard thermoplastic pipe dimension ratio (SDR)*—the standard thermoplastic pipe dimension ratio (SDR) is the ratio of pipe diameter to wall thickness. For CPVC pipe it is calculated by dividing the average outside diameter of the pipe in millimetres or in inches by the minimum wall thickness in millimetres or in inches. If the wall thickness calculated by this formula is less than 0.060 in. [1.52 mm], it shall be arbitrarily increased to 0.060 in. [1.52 mm]. The SDR values shall be rounded to the nearest 0.5.

3.2.5 *standard thermoplastic pipe materials designation code*—the pipe materials designation code shall consist of the abbreviation CPVC for the type of plastic, followed by the ASTM type and grade in Arabic numerals and the design stress at 73°F [23°C] in units of 100 psi [690 kPa] with any decimal figures dropped, followed by the design stress at 180°F [82°C] in units of 100 psi [0.7 MPa] with any decimal figures dropped. When the design stress code contains less than two figures, a cipher shall be used before the number. Thus a complete material code shall consist of four letters and six figures for CPVC plastic pipe materials (see Section 5, Note 5 and X1.2.1).

4. Classification

4.1 *General*—This specification covers CPVC pipe made from one CPVC plastic pipe material in six standard dimension ratios and water pressure ratings for nonthreaded pipe.

4.2 *Standard Thermoplastic Pipe Dimension Ratios (SDR)*—This specification covers CPVC pipe in six standard dimension ratios, namely, 11, 13.5, 17, 21, 26, and 32.5, which are uniform for all nominal pipe sizes for each material and pressure rating. These are referred to as SDR11, SDR13.5, SDR21, SDR17, SDR26, and SDR32.5, respectively. The pressure rating is uniform for all nominal pipe sizes for a given CPVC pipe material and SDR (see Table X1.1).

4.3 *Hydrostatic Design Stresses*—This specification covers CPVC pipe made from CPVC plastic as defined by hydrostatic design stresses developed on the basis of long-term tests (see Appendix).

NOTE 4—This standard specification does not include requirements for pipe and fittings intended to be used to vent combustion gases.

5. Materials

5.1 *General*—Chlorinated poly(vinyl chloride) plastics used to make pipe meeting the requirements of this specification are categorized by means of two criteria, namely, *(1)* short-term strength tests, and *(2)* long-term hydrostatic strength tests at both 73 and 180° F [23 and 82° C].

5.2 *Basic Materials:*

5.2.1 *Basic Materials – Short-term Tests*—This specification covers pipe made from CPVC plastics having certain physical properties as described in Specification D1784.

5.2.1.1 *Compound*—The CPVC compounds used for this pipe shall equal or exceed the classification 23447 described in Specification D1784.

5.2.2 *Basic Materials – Long-term Test*—This specification convers pipe made from CPVC plastics having certain Hydrostatic Design Bases (HDB) and Hydrostatic Design Stresses (HDS) described in Test Method D2837.

5.2.2.1 *Compound*—The CPVC compounds used for this pipe shall have a Hydrostatic Design Basis at 73ºF [23ºC] of 4000 psi [28 MPa], and a Hydrostatic Design Basis at 180ºF [82ºC] of either 1000 psi [7.0 MPa] or 1250 psi [8.6 MPa] when evaluated in accordance with Test Method D2837.

5.2.3 *Standard thermoplastic pipe materials designation*—The pipe materials designation shall consist of the material designation code CPVC 4120-05 or CPVC 4120-06 for the type of plastic.

NOTE 5—As per Terminology F412 (see, "code, thermoplastic pipe materials designation") the pipe materials designation code CPVC 4120 is as follows: CPVC is the abbreviation for chlorinated poly(vinyl chloride) as per Terminology D1600, 41 represents Cell Classification 23447 per Specification D1784, and 20 represents a HDS of 2000 psi [14 MPa] for water at 73ºF (23ºC) per Test Method D2837. In addition, the -05 or -06 suffix represents a HDS of 500 psi [3.4 MPa] or 625 psi [4.3 MPa] respectively for water at 180ºF [82ºC] per Test Method D2837.

5.3 *Rework Material*—The manufacturers shall use only their own clean rework pipe material and the pipe produced shall meet all the requirements of this specification.

6. Requirements

6.1 *Dimension and Tolerances:*

6.1.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 1 when measured in accordance with Test Method D2122. The tolerances on out-of-roundness shall apply only to pipe prior to shipment.

6.1.2 *Wall Thickness*—The wall thicknesses and tolerances shall be as shown in Table 2 when measured in accordance with Test Method D2122.

6.1.3 *Wall Thickness Range*—The wall thickness range shall be within 12 % when measured in accordance with Test Method D2122.

6.2 *Sustained Pressure*—The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598 at the test pressures given in Table 3 when tested in accordance with 8.4.

6.2.1 *Accelerated Regression Test*—At the option of the manufacturer, the accelerated regression test may be used as a substitute for both pressure tests—sustained and burst. The test shall be conducted in accordance with 8.4.1. The pipe shall demonstrate a hydrostatic design basis projection at the 100 000-h intercept that meets the hydrostatic design basis category requirement (see Table 1, Test Method D2837) for the CPVC material used in its manufacture. If the lower confidence value at 100 000 h differs from the extrapolated LTHS value by more than 15 % of the latter; or *M* in Appendix X2 (Test Method D2837) is zero or negative; or *b* in the equation $h = a + bf$ in Appendix X1 (Test Method D2837) is positive, consider the data unsuitable.

6.3 *Burst Pressure*—The minimum burst pressures for CPVC plastic pipe shall be as given in Table 4, when determined in accordance with 8.5.

6.4 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 8.6.

7. Workmanship, Finish, and Appearance

7.1 The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

NOTE 6—Color and transparency or opacity should be specified in the contract or purchase order.

8. Test Methods

8.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618 for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct the tests in the standard laboratory atmosphere of 73 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon by the purchaser and the seller. In case of no prior agreement, any sample selected by the testing laboratory shall be deemed adequate.

TABLE 1 Outside Diameters and Tolerances for CPVC Plastic Pipe

Nominal Pipe Size	Average Outside Diameter, in. [mm]	Tolerances, in. [mm]		
		For Average	Maximum Out-of-Roundness (maximum minus minimum diameter) SDR32.5 SDR26 SDR21	Maximum Out-of-Roundness (maximum minus minimum diameter) SDR17 SDR13.5 SDR11
¼ [8]	0.540 [13.7]	±0.004 [0.10]	0.030 (0.76)	0.016 (0.41)
⅜ [10]	0.675 [17.1]	±0.004 [0.10]	0.030 (0.76)	0.016 (0.41)
½ [15]	0.840 [21.3]	±0.004 [0.10]	0.030 (0.76)	0.016 (0.41)
¾ [20]	1.050 [26.7]	±0.004 [0.10]	0.030 (0.76)	0.020 (0.51)
1 [25]	1.315 [33.4]	±0.005 [0.13]	0.030 (0.76)	0.020 (0.51)
1¼ [32]	1.660 [42.2]	±0.005 [0.13]	0.030 (0.76)	0.024 (0.61)
1½ [40]	1.900 [48.2]	±0.006 [0.15]	0.060 (1.52)	0.024 (0.61)
2 [50]	2.375 [60.3]	±0.006 [0.15]	0.060 (1.52)	0.024 (0.61)
2½ [65]	2.875 [73.0]	±0.007 [0.18]	0.060 (1.52)	0.030 (0.76)
3 [80]	3.500 [88.9]	±0.007 [0.18]	0.060 (1.52)	0.023 (0.58)
3½ [90]	4.000 [101.6]	±0.008 [0.20]	0.100 (2.54)	0.030 (0.76)
4 [100]	4.500 [114.3]	±0.008 [0.20]	0.100 (2.54)	0.023 (0.58)
5 [125]	5.563 [141.3]	±0.010 [0.25]	0.100 (2.54)	0.060 (1.52)
6 [150]	6.625 [168.3]	±0.011 [0.28]	0.100 (2.54)	0.070 (1.78)
8 [200]	8.625 [219.1]	±0.015 [0.38]	0.150 (3.81)	0.090 (2.29)
10 [250]	10.750 [273.1]	±0.015 [0.38]	0.150 (3.81)	0.100 (2.54)
12 [300]	12.750 [323.9]	±0.015 [0.38]	0.150 (3.81)	0.120 (3.05)

TABLE 2 Wall Thicknesses and Tolerances for CPVC Plastic Pipe

Nominal Pipe Size,	Wall Thickness[A,B] in. [mm]											
	SDR32.5		SDS26		SDR21		SDR17		SDR13.5		SDR11	
	Min	Tolerance	Min	Tolerance	Min	Tolerance	Min	Tolerance	Min	Tolerance	Min	Tolerance
¼ [8]	. . .	. . .	. . .		. . .	. . .	. . .	. . .	0.060 [1.52]	+0.020 [0.51]	0.060 [1.52]	+0.020 [0.51]
⅜ [10]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.060 [1.52]	+0.020 [0.51]	0.061 [1.55]	+0.020 [0.51]
½ [15]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.062 [1.57]	+0.020 [0.51]	0.076 [1.93]	+0.020 [0.51]
¾ [20]	. . .	. . .	. . .	. . .	0.060 [1.52]	+0.020 [0.51]	0.062 [1.57]	+0.020 [0.51]	0.078 [1.98]	+0.020 [0.51]	0.095 [2.41]	+0.020 [0.51]
1 [25]	. . .	. . .	0.060 [1.52]	+0.020 [0.51]	0.063 [1.60]	+0.020 [0.51]	0.077 [1.96]	+0.020 [0.51]	0.097 [2.46]	+0.020 [0.51]	0.119 [3.02]	+0.020 [0.51]
1¼ [32]	. . .	. . .	0.064 [1.63]	+0.020 [0.51]	0.079 [2.01]	+0.020 [0.51]	0.098 [2.49]	+0.020 [0.51]	0.123 [3.12]	+0.020 [0.51]	0.151 [3.84]	+0.020 [0.51]
1½ [40]	. . .	. . .	0.073 [1.85]	+0.020 [0.51]	0.090 [2.29]	+0.020 [0.51]	0.112 [2.84]	+0.020 [0.51]	0.141 [3.58]	+0.020 [0.51]	0.173 [4.39]	+0.021 [0.53]
2 [50]	. . .	. . .	0.091 [2.31]	+0.020 [0.51]	0.113 [2.87]	+0.020 [0.51]	0.140 [3.56]	+0.020 [0.51]	0.176 [4.47]	+0.021 [0.53]	0.216 [5.49]	+0.026 [0.66]
2½ [65]	. . .	. . .	0.110 [2.79]	+0.020 [0.51]	0.137 [3.48]	+0.020 [0.51]	0.169 [4.29]	+0.020 [0.51]	0.213 [5.41]	+0.026 [0.66]	0.261 [6.63]	+0.031 [0.79]
3 [80]	0.108 [2.74]	+0.020 [0.51]	0.135 [3.43]	+0.020 [0.51]	0.167 [4.24]	+0.020 [0.51]	0.206 [5.23]	+0.025 [0.64]	0.259 [6.58]	+0.031 [0.79]	0.318 [8.08]	+0.039 [0.99]
3½ [90]	0.123 [3.12]	+0.020 [0.51]	0.154 [3.91]	+0.020 [0.51]	0.190 [4.83]	+0.023 [0.58]	0.235 [5.97]	+0.028 [0.71]	0.296 [7.52]	+0.036 [0.91]	0.363 [9.22]	+0.044 [1.12]
4 [100]	0.138 [3.50]	+0.020 [0.51]	0.173 [4.39]	+0.021 [0.53]	0.214 [5.44]	+0.026 [0.66]	0.265 [6.73]	+0.032 [0.81]	0.333 [8.46]	+0.040 [1.02]	0.409 [10.39]	+0.049 [1.24]
5 [125]	0.171 [4.34]	+0.021 [0.53]	0.214 [5.44]	+0.027 [0.69]	0.265 [6.73]	+0.032 [0.81]	0.327 [8.30]	+0.039 [0.99]	0.412 [10.46]	+0.049 [1.24]	0.506 [12.85]	+0.061 [1.55]
6 [150]	0.204 [5.18]	+0.024 [0.61]	0.255 [6.48]	+0.031 [0.79]	0.316 [8.03]	+0.038 [0.96]	0.390 [9.91]	+0.047 [1.19]	0.491 [12.47]	+0.059 [1.50]	0.602 [15.29]	+0.073 [1.85]
8 [200]	0.265 [6.73]	+0.032 [0.81]	0.332 [8.43]	+0.040 [1.02]	0.410 [10.41]	+0.049 [1.24]	0.508 [12.90]	+0.061 [1.55]	0.639 [16.23]	+ 0.077 [1.95]	0.785 [19.94]	+0.095 [2.41]
10 [250]	0.331 [8.41]	+0.040 [1.02]	0.413 [10.49]	+0.050 [1.27]	0.511 [12.98]	+0.061 [1.55]	0.632 [16.05]	+0.076 [1.93]	0.797 [20.24]	+ 0.096 [2.44]	0.978 [24.84]	+0.118 [2.99]
12 [300]	0.392 [9.96]	+0.047 [1.19]	0.490 [12.45]	+0.059 [1.50]	0.606 [15.39]	+0.073 [1.85]	0.750 [19.05]	+0.090 [2.29]	0.945 [24.00]	+ 0.114 [2.89]	1.160 [29.46]	+0.140 [3.56]

[A] The minimum is the lowest wall thickness of the pipe at any cross section. All tolerances are on the plus side of the minimum requirement.
[B] Where 0.060-in. [1.52 mm] wall thickness is shown, it may not be a true SDR value.

TABLE 3 Sustained Pressure Test Conditions for Water at 73°F (23°C) for CPVC 4120 Plastic Pipe

SDR	Pressure[A] Required for Test	
	psi	kPa
11	840	[5 790]
13.5	670	[4 620]
17	530	[3 650]
21	420	[2 900]
26	340	[2 340]
32.5	260	[1 790]

[A] The fiber stress used to derive these test pressures is 4200 psi [29.0 MPa]. Some minor adjustments have been made to keep the test pressures uniform to simply testing.

TABLE 4 Burst Pressure Requirements for Water at 73°F (23°C) for CPVC 4120 Plastic Pipe

SDR	Minimum Burst Pressure[A]	
	psi	kPa
11	1250	[8 620]
13.5	1000	[6 890]
17	800	[5 520]
21	630	[4 340]
26	500	[3 450]
32.5	400	[2 760]

[A] The fiber stress used to derive these test pressures is 6400 psi [44.1 MPa].

8.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

8.4 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressures given in Table 3, six specimens of pipe, each specimen at least ten times the nominal diameter in length, but not less than 10 in. [250 mm] or more than 3 ft [1000 mm] between end closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi [±70 kPa]. Condition the specimens at the test temperature of 73± 3.6°F [23 ± 2°C]. Maintain the test temperature at 73 ± 3.6°F [23 ± 2°C]. Test in accordance with Test Method D1598, except maintain the pressure at the values given in Table 3 for 1000 h. Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens tested in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

8.4.1 *Accelerated Regression Test*—Test in accordance with procedures in Test Method D1598, using either free end or restrained end fittings. A minimum of six specimens shall be tested. Test three specimens at a single pressure that will result in failures at or below 0.10 h. Test an additional three specimens at a single pressure that will result in failures at about 200 h. Additional data points may be generated if necessary to improve the LTHS or LCL, or both. No points shall be excluded unless an obvious defect is detected in the failure area of the test sample, or there was an obvious malfunction of the test equipment. Characterize the data using the least-squares regression described in Test Method D2837.

NOTE 7—**Caution:** Since the rupture of the test specimen is expected in quick burst and high stress regression testing, well shielded test equipment and protective personal equipment should be used when conducting the tests.

8.5 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599. The time of testing of each specimen shall be between 60 and 70 s.

8.6 *Flattening*—Flatten three specimens of the pipe, 2 in. [50 mm] long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. On removal of the load, examine the specimens for evidence of splitting, cracking, or breaking.

9. Retest and Rejection

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, 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. Marking

10.1 *Quality of Marking*—The marking shall be applied to the pipe in such a manner that it remains legible (easily read) after installation and inspection.

10.2 *Content of Marking:*

10.2.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft [1.5 m]:

10.2.1.1 Nominal pipe size (for example, 2 in. [50 mm]),

10.2.1.2 Type of plastic pipe material in accordance with the designation code given in 3.2.5 (for example, CPVC 4120–05),

10.2.1.3 Standard thermoplastic pipe dimension ratio in accordance with the designation code given in 3.2.5 (for example, SDR 13.5),

10.2.1.4 Pressure rating in pounds-force per square inch for water at both 73ºF [23ºC] and 180ºF [82ºC], shown as the number followed by psi and the temperature (for example, "400 psi at 73ºF, 100 psi at 180ºF").

10.2.1.5 ASME SF-442/SF-442M or both ASME SF-442/SF-442M and ASTM F442/F442M.

10.2.1.6 Manufacturer's name (or trademark) and code, and

10.2.1.7 Pipe intended for the transport of potable water shall also include the seal or mark of the laboratory making the evaluation for this purpose, spaced at intervals specified by the laboratory.

NOTE 8—Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

SUPPLEMENTARY REQUIREMENTS

POTABLE WATER REQUIREMENTS

This requirement applies whenever a regulatory authority or user calls for product to be used to convey or to be in contact with potable water.

S1. *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales of transfers.

S2. *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 may 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 S2.1—In U.S. Federal contracts, the contractor is responsible for inspection.

S3. *Packaging and Marking for U.S. Federal Government Procurement:*

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL–STD–129 for military agencies.

NOTE S3.1—The inclusion of U.S. Federal Government procurement requirements should not be construed as an indication that the U.S. Federal Government uses or endorses the products described in this specification

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIX

(Nonmandatory Information)

X1. SOURCE OF HYDROSTATIC DESIGN STRESSES

X1.1 The hydrostatic design stress (HDS) at 73ºF and the hydrostatic design stress (HDS) at 180ºF recommended by the Plastics Pipe Institute and utilizing a service (design) factor for water of 0.5 are used to pressure rate CPVC plastic pipe for water service applications only. This hydrostatic design stress applies only to pipe meeting all the requirements of this specification.

X1.2 CPVC pipe materials are included based on the requirements of Specification D1784 and the PPI-recommended hydrostatic design stress for water at both 73ºF [23ºC] and 180ºF [82ºC] as follows:

X1.2.1 Type IV, Grade 1 (23447), with a hydrostatic design stress at 73ºF [23ºC], in water of 2000 psi [13.80 MPa], and a hydrostatic design stress at 180ºF [82ºC] in water of either 500 psi [3.4 MPa] or 625 psi [4.3 MPa] shall be designated as CPVC 4120-05 or CPVC 4120-06, respectively.

X1.3 The standard method for obtaining hydrostatic basis for thermoplastic pipe materials is Test Method D2837. Additional information regarding the method of test and other criteria used in developing these hydrostatic design stresses may be obtained from the Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org. These hydrostatic design stresses may not be suitable for materials that show a wide departure from a straight-line plot of log stress versus log time to failure. All the data available to date on CPVC pipe materials made in the United States exhibit a straight-line plot under these plotting conditions.

X1.4 The hydrostatic design stresses recommended by the Plastics Pipe Institute are based on tests made on pipe ranging in size from ½ to 2½ in. [12 to 65 mm].

X1.5 The pipe is rated for use with water at 73°F [23°C] at the maximum internal pressures shown in Table X1.1. Lower pressure ratings than those calculated in accordance with 3.2.2 may be recommended, at the option of the pipe manufacturer, in which case the SDR shall be included in the marking. Experience of the industry indicates that CPVC plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for a long period at these pressure ratings. The sustained pressure requirements are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.6 The pipe is rated for use with water at 180ºF [82ºC] at the maximum internal pressures shown in Table X1.2 and Table X1.3 Lower pressure ratings than those calculated in accordance with 8.4 may be recommended at the option of the pipe manufacturer, in which case the SDR pipe shall be included in the marking. Experience of the industry indicates that CPVC plastic pipe meeting the requirements of this specification gives satisfactory service under normal conditions for long period at these pressure ratings. The sustained pressure requirements are related to these ratings through the slopes of the strength-time plots of these materials in pipe form.

X1.7 These derating factors are suitable for CPVC pipe conveying water at elevated temperatures. To determine elevated temperature rating, multiply 73°F [23°C] pressure rating by appropriate factor as follows:

Temperature		Derating Factor with 180°F HDS of:	
°F	°C	500 psi	625 psi
73 to 80°	[23 to 26.7°]	1.0	1.00
90	[32.2]	0.91	0.91
100	[37.8]	0.82	0.83
120	[48.9]	0.65	0.70
140	[60]	0.50	0.57
160	[71.1]	0.40	0.44
180	[82.2]	0.25	0.31
200	[93.3]	0.20	[A]

[A] Consult with specific product or component manufacturers for temperature

TABLE X1.1 Water Pressure Ratings (PR) in psi [kPa] at 73ºF (23ºC) for Nonthreaded[A] SDR Pipe Produced from CPVC Material having an HDS[B] of 2000 psi [14 MPa] at 73ºF [23ºC][C]

SDR	Pressure Rating	
	psi	kPa
11	400	[2 760]
13.5	320†	[2 170]
17	250	[1 720]
21	200	[1 380]
26	160	[1 100]
32.5[D]	125	[860]

[A] These pressure ratings do not apply for threaded pipe.
[B] HDB of 4000 psi [28 MPa]
[C] See 5.2.3 for material designation.
[D] Available only in nominal pipe size diameters of 3 to 12 in. [75 to 300 mm].
† Editorially corrected in September 2013.

TABLE X1.2 Water Pressure Ratings (PR) in psi [kPa] at 180ºF (82ºC) for Nonthreaded[A] SDR Pipe Produced from CPVC Material having an HDS[B] of 500 psi [3.4 MPa] at 180ºF [82ºC][C]

SDR	Pressure Rating	
	psi	kPa
11	100	[690]
13.5	80	[550]
17	63	[440]
21	50	[350]
26	40	[280]
32.5[D]	32	[220]

[A]These pressure ratings do not apply for threaded pipe.
[B] HDB of 4000 psi [28 MPa]
[C]See 5.1.3 for material designation.
[D]Available only in nominal pipe size diameters of 3 to 12 in. [75 to 300 mm]

TABLE X1.3 Water Pressure Ratings (PR) in psi [kPa] at 73ºF (23ºC) for Nonthreaded[A] SDR Pipe Produced from CPVC Material having an HDS[B] of 625 psi [4.3 MPa] at 180ºF [82ºC][C]

SDR	Pressure Rating	
	psi	kPa
11	125	[860]
13.5	100	[690]
17	80	[550]
21	63	[440]
26	50	[350]
32.5[D]	40	[280]

[A]These pressure ratings do not apply for threaded pipe.
[B] HDB of 4000 psi [28 MPa]
[C]See 5.1.3 for material designation.
[D]Available only in nominal pipe size diameters of 3 to 12 in. [75 to 300 mm]

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SPECIFICATION FOR POLYETHYLENE (PE) PLASTIC PIPE (DR-PR) BASED ON OUTSIDE DIAMETER

SF-714

(Identical with ASTM F714-13 except for additional requirements in section 8 and Annex A1, revised marking requirements in para. 9.1.2, changes from "ANSI" to "ASME" in paras. 1.7 and 2.2 and Tables 5 and 7, and quality assurance requirement in para. 10.1 has been made mandatory.)

Specification for
Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter

1. Scope

1.1 This specification covers polyethylene (PE) pipe made in dimensions based on outside diameters of 90 mm (3.500 in.) and larger.

1.2 Three standard outside diameter sizing systems are detailed: one known as the ISO metric system, one known as the IPS system, and the other known as the DIPS system. See 5.2.5 for guidelines for special sizes.

1.3 The piping is intended for new construction and insertion renewal of old piping systems used for the transport of water, municipal sewage, domestic sewage, industrial process liquids, effluents, slurries, etc., in both pressure and nonpressure systems.

NOTE 1—The user should consult the manufacturer to ensure that any damage to the polyethylene pipe caused by the material being transported will not affect the service life beyond limits acceptable to the user.

1.4 All pipes produced under this specification are pressure-rated. See Appendix X5 for information on pressure rating.

NOTE 2—References and material descriptions for PE2406, PE3406, PE3408 and materials having a HDB of 1450 psi have been removed from Specification F714 due to changes in Specification D3350 and PPI TR-3. For removed designations, refer to previous editions of Specification F714, Specification D3350, PPI TR-3 and PPI TR-4. The removal of these materials does not affect pipelines that are in service. See Notes 9 and 9.

1.5 This specification includes criteria for choice of raw material, together with performance requirements and test methods for determining conformance with the requirements.

1.6 Quality-control measures are to be taken by manufacturers. See Appendix X4 for general information on quality control.

1.7 In referee decisions, the SI units shall be used for metric-sized pipe and inch-pound units for pipe sized in the IPS system (ASME B36.10) and DIPS system. In all cases, the values given in parentheses are provided for information only.

1.8 The following safety hazards caveat pertains only to the test methods 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer

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

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2290 Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

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

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

D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials

F412 Terminology Relating to Plastic Piping Systems

F585 Guide for Insertion of Flexible Polyethylene Pipe Into Existing Sewers

2.2 *ASME Standard:*

B36.10 Standard Dimensions of Steel Pipe (IPS)

2.3 *ISO Standards:*

161 Thermoplastic Pipe for the Transport of Fluids - Nominal Outside Diameters and Nominal Pressures

3607 Polyethylene Pipe: Tolerances on Outside Diameters and Wall Thicknesses

4427 Polyethylene Pipes and Fittings for Water Supply Specification

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.6 *Canadian Standard:*

CGSB 41 GP-25M Pipe, Polyethylene for the Transport of Liquids

2.7 *NSF/ANSI Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials

Standard No. 61 for Drinking Water Systems Components—Health Effects

2.8 *Other Documents:*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

APWA Uniform Color Code

3. Terminology

3.1 Unless otherwise specified, definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dimension ratio, hydrostatic design stress, and pressure rating relationship:*

$$P = \frac{2S}{(D_O/t) - 1}$$

where:

S = hydrostatic design stress, HDS, for water at 73°F (23°C), psi (or kPa or MPa),

P = pressure rating, PR, psi (or kPa or MPa),

D_O = outside diameter, in. (or mm), per Tables 3, 4, or 5

t = minimum wall thickness, in. (or mm), per Tables 6, 7, or 8

D_O/t = dimension ratio (DR).

3.2.2 *hydrostatic design basis and hydrostatic design stress*—the hydrostatic design stress, S, is determined by multiplying the hydrostatic design basis (HDB) by a design factor, DF that has a value less than 1.0.

NOTE 3—Hydrostatic design stress (HDS) ratings for PE compounds are in accordance with this specification and are specified in Section 4.

4. Materials

4.1 *Polyethylene Compound*—Polyethylene compounds suitable for use in the manufacture of pipe under this specification shall meet thermoplastic materials designation codes PE2708 or PE3608 or PE4608 or PE4710, and shall meet Table 1 requirements for PE2708 or PE3608 or PE4608 or PE4710, and shall meet thermal stability, brittleness temperature and elongation at break requirements in accordance with Specification D3350.

4.1.1 Polyethylene compounds suitable for use in the manufacturer of DIPS pipe per Table 2 and Table 3 are identified by thermoplastic pipe material designation code, and shall be PE4710 or PE3608 in accordance with 4.1, 4.1.2 and 4.2.

4.1.2 *Color and Ultraviolet (UV) Stabilization*—Per Table 1, polyethylene compounds shall meet Specification D3350code C or E. In addition, Code C polyethylene compounds shall have 2 to 3 percent carbon black, and Code E polyethylene compounds shall have sufficient UV stabilizer to protect pipe from deleterious UV exposure effects during unprotected outdoor shipping and storage for at least eighteen (18) months.

4.2 *Potable Water Requirement*—When required by the regulatory authority having jurisdiction, products intended for contact with potable water shall be evaluated, tested, and certified for conformance with NSF/ANSI Standard No. 61 or the health effects portion of NSF/ANSI Standard No. 14 by an acceptable certifying organization.

4.3 *Rework Material*—Clean polyethylene compound from the manufacturer's own pipe production that met 4.1 through 4.1.2 as new compound is suitable for reextrusion into pipe, when blended with new compound of the same thermoplastic pipe material designation code. Pipe containing rework material shall meet the requirements of this specification.

5. Requirements

5.1 *Workmanship*—The pipe shall be homogeneous throughout and essentially uniform in color, opacity, density, and other properties. The inside and outside surfaces shall be semimatte or glossy in appearance (depending on the PE compound) and free of chalking, sticky, or tacky material. The surfaces shall be free of excessive bloom, that is, slight bloom is acceptable. The pipe walls shall be free of cracks, holes, blisters, voids, foreign inclusion, or other defects that are visible to the naked eye and that may affect the wall integrity. Holes deliberately placed in perforated pipe are acceptable. Bloom or chalking may develop in pipe exposed to direct rays

TABLE 1 Polyethylene Compound Requirements

Requirement	Material Designation			
	PE2708	PE3608	PE4608	PE4710
	Required Value			
Minimum HDB at 140ºF (60ºC), psi (MPa), per D2837and PPI TR-3	800 (5.5)[A]	800 (5.5)[A]	800 (5.5)[A]	800 (5.5)[A]
HDS for water at 73°F (23°C) psi (MPa), per D2837 and PPI TR-3[A]	800 (5.5)	800 (5.5)	800 (5.5)	1000 (6.9)
Melt flow rate per D1238	≤0.40 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6	≤0.15 g/10 min Cond. 190/2.16 or ≤20 g/10 min Cond. 190/21.6
Specification D3350 Cell Classification Property	Required Value			
Density (natural base resin)	2	3	4	4
SCG Resistance	7	6	6	7
Color and UV Stabilizer Code[B]	C or E	C or E	C or E	C or E

[A]Contact manufacturer or see PPI TR-4 for listed value.
[B]See 4.1.1.

TABLE 2 Outside Diameters and Tolerances-DIPS Sizing System

Nominal Size	Outside Diameter, in (mm)	Minimum Outside Diameter, in. (mm)	Maximum Outside Diameter, in. (mm)
3	3.960 (100.58)	3.942 (100.13)	3.976 (100.99)
4	4.800 (121.92)	4.778 (121.37)	4.822 (122.48)
6	6.900 (175.26)	6.869 (174.47)	6.931 (176.05)
8	9.050 (229.87)	9.009 (228.84)	9.091 (230.91)
10	11.100 (281.94)	11.050 (280.67)	11.150 (283.21)
12	13.200 (335.28)	13.141 (333.77)	13.259 (336.78)
14	15.300 (388.62)	15.231 (386.87)	15.369 (390.37)
16	17.400 (441.96)	17.322 (439.97)	17.478 (443.94)
18	19.500 (495.30)	19.412 (493.07)	19.588 (497.54)
20	21.600 (548.64)	21.503 (546.17)	21.697 (551.10)
24	25.800 (655.32)	25.684 (652.37)	25.916 (658.27)
30	32.000 (815.80)	31.856 (809.14)	32.144 (816.46)
36	38.300 (972.82)	38.128 (968.44)	38.472 (977.19)
42	44.500 (1130.30)	44.300 (1125.21)	44.700 (1135.38)
48	50.800 (1290.32)	50.571 (1284.51)	51.029 (1296.14)

of the sun (ultraviolet radiant energy) for extended periods and, consequently, these requirements do not apply to pipe after extended exposure to direct rays of the sun.

5.2 *Dimensions and Tolerances:*

5.2.1 *Outside Diameters*—These shall be in accordance with Table 2 (inch-pound units), Table 4 (SI units), Table 5 (inch-pound units) or when measured in accordance with Test Method D2122 at any point not closer than 300 mm (11.8 in.) to the cut end of a length of pipe. Conditioning to standard temperature without regard to relative humidity is required.

5.2.2 *Wall Thicknesses*—The minimum thicknesses shall be in accordance with Table 3, Table 6, or Table 7 when measured in accordance with Test Method D2122. Conditioning to standard temperature without regard to relative humidity is required.

5.2.3 *Eccentricity*—The wall thickness variability as measured and calculated in accordance with Test Method D2122 in any diametrical cross section of the pipe shall not exceed 12 %.

5.2.4 *Toe-In*—When measured in accordance with 5.2.1, the outside diameter at the cut end of the pipe shall not be more than 1.5 % smaller than the undistorted outside diameter. Measurement of the undistorted outside diameter shall be made no closer than 1.5 pipe diameters or 11.8 in. (300 mm), whichever distance is less, from the cut end of the pipe. Undistorted outside diameter shall meet specifications in Table 2, Table 4, or Table 5.

5.2.5 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the pipe is manufactured from plastic compounds meeting the material requirements of this specification, and the strength and design requirements are calculated on the same basis as those used in this specification. For diameters not shown in Table 2, Table 4, or Table 5, the tolerance shall be the same percentage as that used in the corresponding table for the next smaller listed size. Minimum wall thicknesses for DRs not shown in Table 3, Table 6, or Table 7 or shall be determined by dividing the average outside diameter by the DR and rounding to three decimal places for inch sized pipes or two decimal places for metric sized pipes, and the tolerance shall comply with 5.2.3.

5.3 *Pressure Test Performance*—All pipe shall meet the requirements of 5.3.2 and either 5.3.1 or 5.4.

NOTE 4—The requirements of 5.3.1 and 5.3.2 are for laboratory proof-testing only and should not be interpreted as applicable to in situ testing for acceptance of installed systems. See appropriate installation and leak testing standards or manufacturer's recommendations for field testing procedure.

5.3.1 *Short-Term Pressurization*—Quick burst or non-failure testing shall be conducted per 5.3.1.1 or 5.3.1.2. Test pressure shall be determined per 3.2.1 except that S shall be the prescribed hoop stress value, and P shall be test pressure.

TABLE 3 Minimum Wall Thickness DIPS Sizing System, in.

		PE4710[A]						PE3608[A]					
		PR350[B]	PR300[B]	PR250[B]	PR200[B]	PR150[B]	PR100[B]	PR350[B]	PR300[B]	PR250[B]	PR200[B]	PR150[B]	PR100[B]
Nominal Size	Outside Diameter in. (mm)[C]	350 psi (2415 kPa)[D]	300 psi (2070 kPa)[D]	250 psi (1725 kPa)[D]	200 psi (1380 kPa)[D]	150 psi (1035 kPa)[D]	100 psi (690 kPa)[D]	350 psi (2415 kPa)[D]	300 psi (2070 kPa)[D]	250 psi (1725 kPa)[D]	200 psi (1380 kPa)[D]	150 psi (1035 kPa)[D]	100 psi (690 kPa)[D]
		DR 6.7	DR 7.7	DR 9	DR 11	DR 14.3	DR 21	DR 5.6	DR 6.3	DR 7.4	DR 9	DR 11.7	DR 17
3	3.960 (100.58)	0.591 (15.01)	0.514 (13.06)	0.440 (11.18)	0.360 (9.14)	0.277 (7.04)	0.189 (4.80)	0.707 (17.96)	0.629 (15.97)	0.535 (13.59)	0.440 (11.18)	0.338 (8.59)	0.233 (5.92)
4	4.800 (121.92)	0.761 (18.20)	0.623 (15.83)	0.533 (13.54)	0.436 (11.07)	0.336 (8.53)	0.229 (5.82)	0.857 (21.77)	0.762 (19.35)	0.649 (16.48)	0.533 (13.54)	0.410 (10.41)	0.282 (7.16)
6	6.900 (175.26)	1.030 (26.16)	0.896 (22.76)	0.767 (19.48)	0.627 (15.93)	0.483 (12.27)	0.329 (8.36)	1.232 (31.30)	1.095 (27.82)	0.932 (23.67)	0.767 (19.48)	0.590 (14.99)	0.406 (10.31)
8	9.050 (229.87)	1.351 (34.31)	1.175 (29.85)	1.006 (25.55)	0.823 (20.90)	0.633 (16.08)	0.431 (10.95)	1.616 (41.05)	1.437 (36.49)	1.223 (31.06)	1.006 (25.55)	0.774 (19.66)	0.532 (13.51)
10	11.100 (281.94)	1.657 (42.08)	1.441 (36.62)	1.233 (31.32)	1.009 (25.63)	0.776 (19.71)	0.529 (13.44)	1.982 (50.35)	1.762 (44.75)	1.500 (38.10)	1.233 (31.32)	0.949 (24.10)	0.653 (16.59)
12	13.200 (335.28)	1.970 (50.04)	1.714 (43.54)	1.467 (37.26)	1.200 (30.48)	0.923 (23.44)	0.629 (15.98)	2.357 (59.87)	2.095 (53.22)	1.784 (45.31)	1.467 (37.26)	1.128 (28.65)	0.776 (19.71)
14	15.300 (388.62)	2.284 (58.00)	1.987 (50.47)	1.700 (43.18)	1.391 (35.33)	1.070 (27.18)	0.729 (18.52)	2.732 (69.40)	2.429 (61.69)	2.068 (52.53)	1.700 (43.18)	1.308 (33.22)	0.900 (22.86)
16	17.400 (441.96)	2.597 (65.96)	2.260 (57.40)	1.933 (49.10)	1.582 (39.67)	1.217 (30.91)	0.829 (21.06)	3.107 (78.92)	2.762 (70.15)	2.351 (59.72)	1.933 (49.10)	1.487 (37.77)	1.024 (26.01)
18	19.500 (495.30)	2.910 (73.93)	2.532 (64.32)	2.167 (55.04)	1.773 (45.03)	1.364 (34.65)	0.929 (23.60)	3.482 (88.45)	3.095 (78.62)	2.635 (66.93)	2.167 (55.04)	1.667 (42.34)	1.147 (29.13)
20	21.600 (548.64)	3.224 (81.89)	2.805 (71.25)	2.400 (60.96)	1.964 (49.89)	1.510 (38.35)	1.029 (26.14)	...	3.429 (87.09)	2.919 (74.14)	2.400 (60.96)	1.846 (46.89)	1.271 (32.28)
24	25.800 (655.32)	...	3.351 (85.11)	2.867 (72.82)	2.345 (59.56)	1.804 (45.82)	1.229 (31.22)	...	...	3.486 (88.54)	2.867 (72.82)	2.205 (56.01)	1.518 (38.56)
30	32.000 (815.80)	...	...	3.556 (90.32)	2.909 (73.89)	2.238 (56.85)	1.524 (38.71)	...	...	...	3.556 (90.32)	2.735 (69.47)	1.882 (47.80)
36	38.300 (972.82)	...	...	...	3.482 (88.44)	2.678 (68.02)	1.824 (46.33)	...	...	...	...	3.274 (83.16)	2.253 (57.23)
42	44.500 (1130.30)	...	...	...	...	3.112 (79.04)	2.119 (53.82)	...	...	...	...	...	2.618 (66.50)
48	50.800 (1290.32)	...	...	...	...	3.552 (90.22)	2.419 (61.44)	...	...	...	...	...	2.988 (75.90)

[A] Thermoplastic material designation code per 4.1.1.
[B] See 9.1.7.
[C] Per Table 2
[D] Per 3.2.1. Values rounded to the nearest 5 kPa.

TABLE 4 Outside Diameters and Tolerances

ISO Sizing System (ISO 161/1)			
NominalPipe Size	Equivalent	Outside Diameter, D_o, mm	
mm	in.	min	max[A]
90	3.543	90	90.8
110	4.331	110	111.0
160	6.299	160	161.4
200	7.874	200	201.8
250	9.843	250	252.3
280	11.024	280	282.5
315	12.402	315	317.8
355	13.976	355	358.2
400	15.748	400	403.6
450	17.717	450	454.1
500	19.685	500	504.5
560	22.047	560	565.0
630	24.803	630	635.7
710	27.953	710	716.4
800	31.496	800	807.2
900	35.433	900	908.1
1000	39.370	1000	1009.0
1200	47.244	1200	1210.8
1400	55.118	1400	1412.6
1600	62.992	1600	1614.4

[A] As specified in ISO 3607.

TABLE 5 Outside Diameters and Tolerances IPS Sizing System (ASME B36.10)

Nominal Pipe Size, in.	Equivalent, mm	Actual Outside Diameters, in.	
		Average	Tolerance ± in.
3	88.9	3.500	0.016
4	114.3	4.500	0.020
5[A]	136.5	5.375	0.025
5	141.3	5.563	0.025
6	168.3	6.625	0.030
7[A]	181.0	7.125	0.034
8	219.1	8.625	0.039
10	273.1	10.750	0.048
12	323.8	12.750	0.057
13[A]	339.7	13.375	0.060
14	355.6	14.000	0.063
16	406.4	16.000	0.072
18	457.2	18.000	0.081
20	508.0	20.000	0.090
21.5[A]	546.1	21.500	0.097
22	558.8	22.000	0.099
24	609.6	24.000	0.108
26	660.4	26.000	0.117
28	711.2	28.000	0.126
30	762.0	30.000	0.135
32	812.8	32.000	0.144
34	863.6	34.000	0.153
36	914.4	36.000	0.162
42	1066.8	42.000	0.189
48	1219.2	48.000	0.216
54	1371.6	54.000	0.243

[A] Irregular size.

5.3.1.1 *Quick Burst*—For pipe nominal 12-in. (315 mm) and smaller diameter, rupture shall be ductile when tested in accordance with 6.1. The minimum hoop stress shall be 2520 psi (17.4 MPa) for Table 1 density cell 2 materials and 2900 psi (20.0 MPa) for Table 1 density cell 3 and 4 materials.

5.3.1.2 *Non-Failure*—When raised to test pressure and held at test pressure for five (5) seconds, pipe shall not rupture, leak, nor exhibit localized deformation when tested in accordance with 6.1 at a test pressure determined using 2500 psi hoop stress for Table 1 density cell 2 materials, and 3200 psi hoop stress for Table 1 density cell 3 and 4 materials.

5.3.2 *Elevated Temperature Sustained Pressure*—Elevated-temperature sustained-pressure test for each Table 1 polyethylene pipe material (material designation) used in production at the facility shall be conducted twice annually per 6.2.

NOTE 5—Elevated temperature sustained pressure tests are intended to verify extrusion processing and are conducted in accordance with the manufacture's quality program.

5.3.2.1 Passing results are *(1)* non-failure for all three specimens at a time equal to or greater than the Table 8 "minimum average time before failure", or *(2)* not more than one ductile specimen failure and the average time before failure for all three specimens shall be greater than the specified "minimum average time before failure" for the selected Table 8 Condition. If more than one ductile failure occurs before the Table 8 "minimum average time before failure", it is permissible to conduct one retest at a Table 8 Condition of lower stress and longer minimum average time before failure for the material designation except that for Table 8 Condition 6 no retest is permissible. Brittle failure of any specimen in the test sample when tested at Table 8 Condition 1 through 6 constitutes failure to meet this requirement and no retest is allowed.

5.3.2.2 *Provision for retest (if needed)*—The retest sample shall be three specimens of the same pipe or tubing size and material designation from the same time frame as the test sample per 6.2. For the retest, any specimen failure before the "minimum average time before failure" at the retest condition of lower stress and longer minimum average time before failure constitutes failure to meet this requirement.

5.4 *Apparent Tensile Strength at Yield*—For pipe nominal 3-in. (90-mm) diameter and larger, Short-Term Pressurization requirement, 5.3.1, may be replaced by the apparent tensile strength at yield requirement, 5.4. The minimum apparent tensile strength at yield when determined in accordance with 6.3 shall be 2520 psi (17.4 MPa) for Table 1 density cell 2 materials and 2900 (20.0 MPa) for Table 1 density cell 3 and 4 materials.

5.5 *Quality Control*—To determine compliance with Section 5, the number of samples specified in the test method shall be tested. For quality control purposes, not for determining compliance with Section 5, Requirements, it is acceptable to test individual samples.

NOTE 6—Manufacturers conduct appropriate quality control tests at a frequency appropriate to their manufacturing operations. See Appendix X4.

6. Test Methods

6.1 *Short-Term Pressurization Tests*—When tested to rupture, this test is applicable to nominal 12-in. (315-mm) and smaller pipes and is conducted in accordance with Test Method D1599. When tested for non-failure, this test is applicable to all pipe sizes and is conducted in accordance with Test Method D1598 except that no failure will have occurred when tested at

TABLE 6 Minimum Wall Thickness ISO 161 Sizing System, mm

DR Nominal Pipe Size	41	32.5	26	21	17	11
90	. . .	. . .	3.5	4.3	5.3	8.2
110	. . .	3.4	4.2	5.2	6.5	10.0
160	. . .	4.9	6.2	7.6	9.4	14.5
200	. . .	6.2	7.7	9.5	11.8	18.2
250	. . .	7.7	9.6	11.9	14.7	22.7
280	. . .	8.6	10.8	13.3	16.5	25.5
315	. . .	9.7	12.1	15.0	18.5	28.6
355	. . .	10.9	13.7	16.9	20.9	32.3
400	. . .	12.3	15.4	19.0	23.5	36.4
450	. . .	13.8	17.3	21.4	26.5	. . .
500	. . .	15.4	19.2	23.8	29.4	. . .
560	. . .	17.2	21.5	26.7	32.9	. . .
630	. . .	19.4	24.2	30.0	37.1	. . .
710	. . .	21.8	27.3	33.8	41.8	. . .
800	. . .	24.6	30.8	38.1	47.1	. . .
900	. . .	27.7	34.6	42.9	. . .	. . .
1000	24.4	30.8	38.5	47.6	. . .	. . .
1200	29.3	36.9	46.2	. . .	. . .	. . .
1400	34.1	43.1	. . .	. . .	. . .	. . .
1600	39.0	49.2	. . .	. . .	. . .	. . .

TABLE 7 Minimum Wall Thickness IPS Sizing System, in. (ASME B36.10)

Nominal IPS Pipe Size	Actual Pipe Size	Dimension Ratio 41	32.5	26	21	17	15.5	13.5	11	9.3	9	8.3	7.3
3	3.500	0.085	0.108	0.135	0.167	0.206	0.226	0.259	0.318	0.376	0.389	0.422	0.479
4	4.500	0.110	0.138	0.173	0.214	0.265	0.290	0.333	0.409	0.484	0.500	0.542	0.616
5[A]	5.375	0.131	0.165	0.207	0.256	0.316	0.347	0.398	0.489	0.578	0.597	0.648	0.736
5	5.563	0.136	0.171	0.214	0.265	0.327	0.359	0.412	0.506	0.598	0.618	0.670	0.762
6	6.625	0.162	0.204	0.255	0.315	0.390	0.427	0.491	0.602	0.712	0.736	0.798	0.908
7[A]	7.125	0.174	0.219	0.274	0.340	0.420	0.460	0.528	0.648	0.766	0.792	0.858	0.976
8	8.625	0.210	0.265	0.332	0.411	0.507	0.556	0.639	0.784	0.927	0.958	1.039	1.182
10	10.750	0.262	0.331	0.413	0.512	0.632	0.694	0.796	0.977	1.156	1.194	1.295	1.473
12	12.750	0.310	0.392	0.490	0.607	0.750	0.823	0.944	1.159	1.371	1.417	1.536	1.747
13[A]	13.375	0.326	0.412	0.514	0.637	0.787	0.863	0.991	1.216	1.438	1.486	1.611	1.832
14	14.000	0.341	0.431	0.538	0.667	0.824	0.903	1.037	1.273	1.505	1.556	1.687	1.918
16	16.000	0.390	0.492	0.615	0.762	0.941	1.032	1.185	1.455	1.720	1.778	1.928	2.192
18	18.000	0.439	0.554	0.692	0.857	1.059	1.161	1.333	1.636	1.935	2.000	2.169	2.466
20	20.000	0.488	0.615	0.769	0.952	1.176	1.290	1.481	1.818	2.151	2.222	2.409	. . .
21.5[A]	21.500	0.524	0.662	0.827	1.024	1.265	1.387	1.593	. . .	. . .	. . .	. . .	. . .
22	22.000	0.537	0.677	0.846	1.048	1.294	1.419	1.630	2.000	2.366	2.444	. . .	. . .
24	24.000	0.585	0.738	0.923	1.143	1.412	1.548	1.778	2.182	2.581	2.667	. . .	. . .
26	26.000	0.634	0.800	1.000	1.238	1.529	1.677	1.926	2.364	2.796	. . .	. . .	. . .
28	28.000	0.683	0.862	1.077	1.333	1.647	1.806	2.074	2.545	3.011	. . .	. . .	. . .
30	30.000	0.732	0.923	1.154	1.429	1.765	1.935	2.222	2.727	3.226	. . .	. . .	. . .
32	32.000	0.780	0.985	1.231	1.524	1.882	2.065	2.370	2.909	. . .	. . .	. . .	. . .
34	34.000	0.829	1.046	1.308	1.619	2.000	2.194	2.519	3.091	. . .	. . .	. . .	. . .
36	36.000	0.878	1.108	1.385	1.714	2.118	2.323	2.667	3.273	. . .	. . .	. . .	. . .
42	42.000	1.024	1.292	1.615	2.000	2.471	2.710	. . .	. . .	. . .	. . .	. . .	. . .
48	48.000	1.171	1.477	1.846	2.286	2.824	3.097	. . .	. . .	. . .	. . .	. . .	. . .
54	54.000	1.317	1.662	2.077	2.571	3.176	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Irregular size.

the test pressure and duration per 5.3.1.2. The test shall be conducted at 73.4 ± 3.6°F (23 ± 2°C) without regard to relative humidity.

NOTE 7—**Warning:** Pressurization of specimens being tested under 6.1 should not commence until it is certain that all entrapped air has been bled from the water-filled specimens.

6.2 *Elevated Temperature Sustained Pressure Test*—The "test sample" shall be three specimens of a generally representative pipe or tubing size produced at the manufacturer's facility using the Table 1 polyethylene pipe material (material designation). Select one Table 8 Condition for the Table 1 polyethylene pipe material (material designation) and test the three specimen test sample in accordance with Test Method D1598 using water as the internal test medium.

6.3 *Apparent Tensile Properties*—The procedure and test equipment shall be as specified in Test Method D2290. Cut specimens from pipe. Test a minimum of five specimens at 73.4 ± 3.6°F (23 ± 2°C) without regard to relative humidity.

TABLE 8 Elevated Temperature Sustained Pressure Test Requirements

Condition	Test Temperature °F (°C)^{A}	PE2708, PE3608, PE4608 Test Pressure Hoop Stress^{B} psi (kPa)^{A}	PE2708, PE3608, PE4608 Minimum Average Time Before Failure Hours	PE4710 Test Pressure Hoop Stress^{B} psi (kPa)^{A}	PE4710 Minimum Average Time Before Failure Hours
1	176 (80)	670 (4620)	170	750 (5170)	200
2	176 (80)	650 (4480)	340	730 (5020)	400
3	176 (80)	630 (4345)	510	705 (4870)	600
4	176 (80)	610 (4210)	680	685 (4715)	800
5	176 (80)	590 (4070)	850	660 (4565)	1000
6	176 (80)	580 (4000)	1000	640 (4415)	1200

[A]Test temperature tolerance ± 3.6ºF (+/- 2ºC). Test pressure tolerance ± 5 psi (±35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa. Note: Table 1 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 test pressure hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Conditions 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE3710 and PE4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) · ((1200 – 200) / (750 – 640)) = 927).

[B]Calculate internal test pressure in accordance with:

$$P = \frac{2S}{\left(\frac{D_o}{t} - 1\right)}$$

Where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi. (kPa)
D_o = measured outside diameter, in. (mm)
t = measured minimum wall thickness, in (mm)

This test is applicable to all pipe of nominal 3-in. (90-mm) outside diameter and larger.

7. Retest and Rejection

7.1 Except as required in 5.3.2.1 or 5.3.2.2, if the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirement of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be met, and the test methods designated in the specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this specification.

8. Certification

8.1 Certification shall be as required by Annex A1.

9. Marking

9.1 Marking on the pipe shall include the following and shall be spaced at intervals of not more than 5 ft (1.5 m).

9.1.1 Markings placed at each end of each shipped length are acceptable by agreement between the manufacturer and the purchaser.

NOTE 8—End of pipe markings are intended for use only per a manufacturer-purchaser agreement where pipe is to be used as a subcomponent by the purchaser for the manufacture of another product such as fabricated fittings, transition fittings, coupling devices or other piping appurtenances where continuous markings along the pipe length may be undesirable. Where pipe is used as the fluid transporting conduit in a piping system, continuous marking per 9.1 is used.

9.1.2 ASME SF-714 or both ASME SF-714 and ASTM F714.

9.1.3 The thermoplastic pipe materials designation code, such as PE3608, in accordance with 4.1 and 4.1.1.

NOTE 9—Earlier editions of Specification F714 included PE material designations PE2406, PE3406, PE3407 and PE3408. Changes to Specification D3350 and PPI TR-3 led to changes in thermoplastic material designation codes, resulting in material designation PE2406 being superseded by material designations PE2606 and PE2708, material designation PE3406 being superseded by PE3606, material designation PE3407 being discontinued, and material designation PE3408 being superseded by material designations PE3608, PE3708, PE3710, PE4708 and PE4710. Recognizing that a period of time is necessary for the dissemination of information and to update specifications and literature, during the transitional period, product markings that include both older and newer materials designations, for example PE2406/PE2606, may occur.

9.1.4 Nominal pipe outside diameter in mm or inches in accordance with Table 4, Table 5, or Table 2, and the designated sizing system: "XX mm ISO," or" XX in IPS," or "XX in DIPS." For metric outside diameter pipe, the omission of "ISO" is acceptable, and for inch sized outside diameter pipe, omitting "in" or using a double-quotation mark (") are acceptable.

9.1.5 For ISO (metric) and IPS sizing system pipe, the dimension ratio, DR, as "DR YY" where "YY" is the numerical value of the dimension ratio.

9.1.6 For ISO (metric) and IPS sizing system pipe, a marking for pressure rating is optional. In kilopascals, the marking for pressure rating per 3.2.1is shown as "ZZZ kPa" where "ZZZ" is the numerical value of the pressure rating for water in kPa. In pounds-force per square inch, the marking for pressure rating per 3.2.1 is shown as "WWW psi" or "PRWWW" where "WWW" is the numerical value of the pressure rating for water in psi. (Appendix X5).

9.1.7 DIPS sizing system pipe shall be marked with the pressure rating for water expressed as "PRZZZ" where "PRZZZ" shall be in accordance with Table 8 for the applicable thermoplastic material designation code.

9.1.8 Name or trademark of the manufacturer.

9.1.9 Production code from which location and date of manufacturer can be identified.

9.1.10 Pipe intended for the transport of potable water shall also include the seal or mark of the accredited laboratory. (See 4.3.)

9.2 When color identifies piping service in accordance with the APWA Uniform Color Code, blue identifies potable water service; green identifies sewer (wastewater) service; and purple (violet, lavender) identifies reclaimed water service. Yellow that identifies gas service shall not be used.

9.3 Markings that identify gas, communications or electrical use are prohibited.

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Keywords

11.1 industrial pipe; non-pressure pipe; plastic pipe; polyethylene pipe; pressure pipe; sewer pipe; water pipe

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only*to federal/military procurement, not domestic sales or transfers.

S1. *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 may 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 S1.1—In federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Un iform Freight Classification rules on National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 It has been demonstrated that pipe stiffness is not a controlling factor in design of buried polyethylene piping systems installed in accordance with Practice D2321 or equivalent recommended practices **(1-15).**

X1.1.1 For those wishing to use deflection control in unpressurized polyethylene piping systems for construction specification purposes, the following information is provided.

X2. DEFLECTION CONTROL IN UNPRESSURIZED POLYETHYLENE PIPING SYSTEMS

X2.1 Control of deflection is achieved primarily through control of the earthwork surrounding buried systems. Practice D2321 should be followed to achieve this control. All dimensions of pipe specified in this specification may be successfully installed if this practice is followed.

X2.2 When polyethylene pipe is to be installed by insertion into older existing pipes or is to be laid where no support from the surrounding environment is possible, Practice F585 should be followed in making a selection of appropriate dimension ratio pipe from this specification.

X2.3 The appropriate degree of deflection in buried piping may be calculated using the modified Spangler formula.

$$X = \frac{D_e\, K\, W_c}{0.149\ \mathrm{PS} + 0.061\ \mathrm{E}^{\ 1}}$$

where:

X = deflection (horizontal or vertical), in. (or mm),
K = bedding constant, dependent on the support the pipe receives from the bottom of the trench (dimensionless),
D_e = deflection lag factor (dimensionless),
W_c = vertical load per unit of pipe length, lbf/in. (or N/m) of pipe,
PS = pipe stiffness = $4.472E/(\mathrm{SDR}\text{-}1)^3$ where E is the flexural modulus of its pipe material (see Section 4 of this specification), psi (or kPa), and
E^1 = modulus of soil reaction, depending on soil strength and degree of compaction, psi (or kPa).

NOTE X2.1—Pipe stiffness (PS) may also be determined by measurement for datum at a constant 5 % deflection by Test Method D2412. See appendix to Test Method D2412 for correction of this test value to other deflection levels.

X2.4 For purposes of this calculation, the pipe stiffness values given in Table X2.1 may be used. For specific data on particular products, consult the manufacturer's literature.

TABLE X2.1 Pipe Stiffness Ranges for Specified Materials and DR's, psi

DR Modulus, Cell Classification	41	32.5	26	21	17	11
3	2–6	6–11	11–23	22–45	71–87	179–358
4	6–8	11–16	23–31	45–61	87–120	358–492
5	8–11	16–23	31–46	61–89	120–175	492–716

X3. ALLOWABLE DEFLECTION LIMITS

X3.1 Research reports, including case histories supporting the following information, are on file at ASTM Headquarters.

X3.2 When said support is achieved, polyethylene pipes made to this specification may deflect or otherwise distort without kinking or buckling, and remain structurally stable up to 20 % or more of the vertical diameter. However, the lower the DR, the lower is the amount of deflection which should be permitted to ensure that long-term structural integrity is maintained. The pipe manufacturer should be consulted for the safe value for the particular pipe material involved. In the absence of specific data on a particular pipe material, Table X3.1 provides safe values for conventional polyethylene pipe materials. These values provide a safety factor of at least two against loss of structural integrity.

X3.3 If there is *no*external support around the pipe, structural integrity of the pipe is likely to be lost due to buckling if deflection exceeds 10 %. For selection of proper DR, see Practice F585.

TABLE X3.1 Allowable Deflection of Buried Polyethylene Pipe, Short Term, %

DR	Allowable Deflection
41	10.9
32.5	8.6
26	6.5
21	5.0
17	4.0
11	3.3

X3.4 When polyethylene piping is subject to live external loading at buried depths of less than 4 ft (1200 mm), special precautions to ensure strong supporting soil conditions should be taken.

X3.5 Polyethylene pipes having high DR's will require more careful handling in storage, transport, and installation to avoid inducing pre-installation deflection. Kinking of pipe should be considered destructive damage and sections which have been kinked should not be installed, even though no leakage is observed.

X4. QUALITY CONTROL

X4.1 Visual inspection of every length of pipe for workmanship defects shall be carried out at the manufacturer's plant. Measurements of outside diameter and wall thickness shall be made for each hour's production or each length of pipe, whichever is less frequent. Tests for apparent tensile properties shall be carried out as agreed upon between the manufacturer and the purchaser.

X4.2 Lengths of pipe that are shorter than standard shipping lengths may be butt-fused to produce standard lengths. Such built-up lengths must otherwise meet all of the product requirements of Section 5 of this specification.

X4.3 Manufacturers of pipe shall conduct such other quality control tests as are appropriate to their manufacturing operations and which will provide assurance that the product requirements of 5.3 will be met instead of the actual performance of the specified tests.

NOTE X4.1—The pressure tests required under product requirements are tests for performance. These tests are not adaptable to inplant quality control. Quality control tests have not been standardized because the requirements for such tests vary substantially from one manufacturing plant to another.

X5. PIPE PRESSURE RATING

X5.1 Pipe meeting the requirements of this specification is pressure rated for water in accordance with 3.2.1 at the maximum internal pressures in Table X5.1. Pressure ratings lower than those in Table X5.1 may be recommended by the pipe manufacturer or may be determined by the system designer for special or unusual application conditions such as those described in X5.2. Industry experience indicates that PE plastic pipe meeting the requirements of this specification that is handled with reasonable care, installed in accordance with applicable standards, and operated under normal service conditions gives satisfactory long-term service at the pressure ratings in Table X5.1.

X5.2 Pressure ratings for a particular application can vary from standard ratings for water service depending on actual application conditions. Pressure rating should be reduced for systems operating under special or unusual conditions or where the pipe transports fluids that are known to have some degrading effect on the properties of polyethylene or where specified in Codes or Regulations or by the authority having jurisdiction. When used at elevated temperatures (temperatures above 80°F (27°C)), elevated temperature stress ratings for the material are used to determine pressure rating. The actual choice of pressure rating for a particular application rests with the system designer, taking into account applicable Codes and Regulations, transportation and on-site handling conditions, the quality of installation, the fluid being transported, the external environment, and the possibility of deviation from design operating conditions of internal pressure or external load. A reduced pressure rating should be applied at the designing engineer's discretion where warranted by consideration of these or other conditions for the particular application. Users should consult the pipe manufacturer for elevated temperature and other information relating to pipe performance in various applications and application conditions. Information is also available from the Plastics Pipe Institute, PPI.

TABLE X5.1 PE Plastic Pipe Pressure Ratings (PR) for Water

	Thermoplastic Pipe Material Designation Code			
PE Pipe Material	PE4710		PE2708 PE3608 PE4608	
	HDS,[A] psi (kPa)		HDS,[A] psi (kPa)	
	1000 psi	(6890 kPa)	800 psi	(5520 kPa)
Pipe DR	Pressure Rating, psi (kPa)			
7.3	317	(2190)	254	(1750)
8.3	274	(1890)	219	(1510)
9	250	(1720)	200	(1380)
9.3	241	(1660)	193	(1330)
11	200	(1380)	160	(1100)
13.5	160	(1100)	128	(880)
15.5	138	(950)	110	(760)
17	125	(860)	100	(690)
21	100	(690)	80	(550)
26	80	(550)	64	(440)
32.5	63	(430)	51	(350)
41	50	(340)	40	(280)

[A] HDS for water at 73°F (23°C) per 3.2.1 and 4.1.1.

SPECIFICATION FOR ELECTROFUSION TYPE POLYETHYLENE FITTINGS FOR OUTSIDE DIAMETER CONTROLLED POLYETHYLENE AND CROSSLINKED POLYETHYLENE (PEX) PIPE AND TUBING

SF-1055

(Identical with ASTM F1055-13 except for additional requirements in section 12 and Annex A2, revised marking requirements in para. 10.1.5, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing

1. Scope

1.1 This specification covers electrofusion polyethylene fittings for use with outside diameter-controlled polyethylene pipe, covered by Specifications D2513, D2737, D3035, and F714 and crosslinked polyethylene (PEX), covered by Specification F2788. Requirements for materials, workmanship, and testing performance are included. All requirements for joining PE electrofusion fittings to PE pipe shall also apply to joining PE electrofusion fittings to PEX pipe. Where applicable in this specification "pipe" shall mean "pipe" or "tubing."

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

2. Referenced Documents

2.1 *ASTM Standards:*

D638 Test Method for Tensile Properties of 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
D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings
D2737 Specification for Polyethylene (PE) Plastic Tubing
D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
D3350 Specification for Polyethylene Plastics Pipe and Fittings Materials
F412 Terminology Relating to Plastic Piping Systems
F714 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter
F905 Practice for Qualification of Polyethylene Saddle-Fused Joints
F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F2788 Specification for Metric-sized Crosslinked Polyethylene (PEX) Pipe

2.2 *PPI Standards:*

PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Rating for Thermoplastic Piping Materials or Pipe
PPI TR-4 HDB/SDB/PDB/MRS Listed Materials, PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Rating for Thermoplastic Piping Materials or Pipe

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *electrofusion*—a heat fusion joining process where the heat source is an integral part of the fitting, such that when electric current is applied, heat is produced that melts and joins the plastics.

TABLE 1 Specification D3350 Classification Requirements of Polyethylene Electrofusion Fitting Materials

Physical Properties	Cell Classification and Properties for Polyethylene Materials	
	PE2708	PE4710
Density	2	4
Melt Index	3 or 4	4
Flexural Modulus	≥4	≥5
Tensile Strength	≥3	≥4
Slow Crack Growth Resistance (F1473)	7	7
Hydrostatic Strength Classification	3	4
Color and UV Stabilizer	C or E	C or E
HDB at 73°F (23°C), psi (MPa)	1250 (8.62)	1600 (11.03)

3.2.2 *fusion interface*—surface in the heat fusion process where the plastic materials of the products being joined bond together.

3.2.3 *fusion zone length*—total length of the melted material in the fitting cross-section under evaluation.

4. Materials and Manufacture

4.1 This specification covers fittings made from polyethylene compounds as defined in Specification D3350.

4.1.1 Polyethylene material compounds suitable for use in the manufacture of electrofusion fittings under this specification shall meet Specification D3350 and shall meet Specification D3350 classification and property requirements shown in Table 1 and shall have PPI TR-4 HDB and HDS listings at 73°F (23°C) and HDB listings at 140°F (60°C).

4.2 *Rework Material*—Clean rework polyethylene material of the same resin, free of any wire or contaminants generated from the fitting manufacturer's own production, may be used by the same manufacturer, as long as the fittings produced conform to the requirements of this specification.

4.3 *Heating Mechanism*—The heat mechanism shall be of materials and design not detrimental to the performance of the fitting or the pipe to which it is intended to be joined. Heating mechanisms, such as wires or materials other than polyethylene, shall not exit the fitting in an area exposed to internal pressure. Heat mechanisms shall be of a design that ensures that wire terminations are toward the outer edges of the fusion zone length and away from the pressure containing area. Examples of acceptable and unacceptable wire terminations are shown in Figs. 1-5.

5. Performance Requirements

5.1 The following requirements are for electrofusion joints that have been joined using the manufacturer's recommended joining procedures. These requirements must be met by each electrofusion joint design, on each size and type of pipe material for which the manufacturer recommends use of his fitting. Any revisions to the electrofusion joint design or processing by the manufacturer after the initial testing requires retesting to ensure these requirements can still be met. Fittings intended for use in the distribution of natural gas or liquid petroleum gas shall also meet the requirements of Specification D2513.

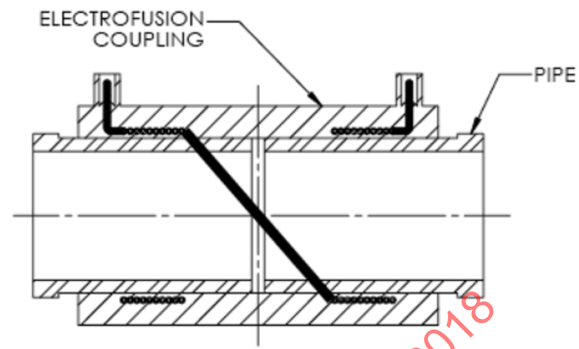

FIG. 1 Correct Wire Termination Coupling–Single Coil

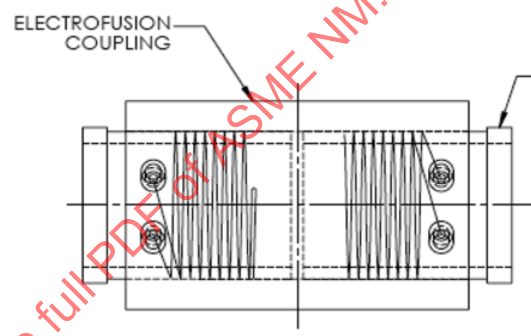

FIG. 2 Correct Wire Termination Coupling–Dual Coil

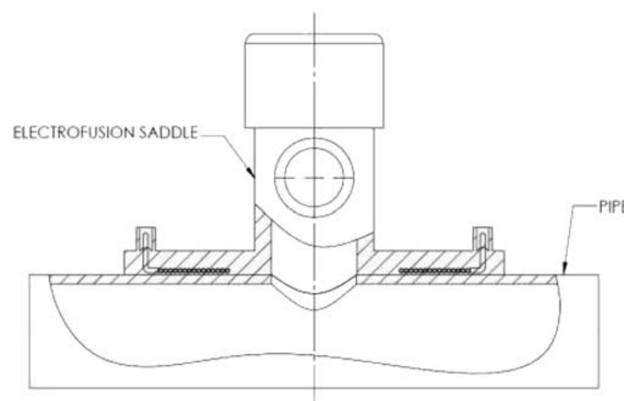

FIG. 3 Correct Wire Termination–Saddle Fitting

5.1.1 It is not required that each configuration of a fitting be tested to meet all of these qualifications (that is, 2 in. main saddle joint with multiple outlet configurations offered) as long as the electrofusion joint design is not altered in the configuration differences.

NOTE 1—It is permissible when accomplishing these tests, to do so on the highest and lowest dimension ratio of the same pipe material. If in those tests all performance requirements are met, all dimension ratios between those tested may be considered as having met the requirements.

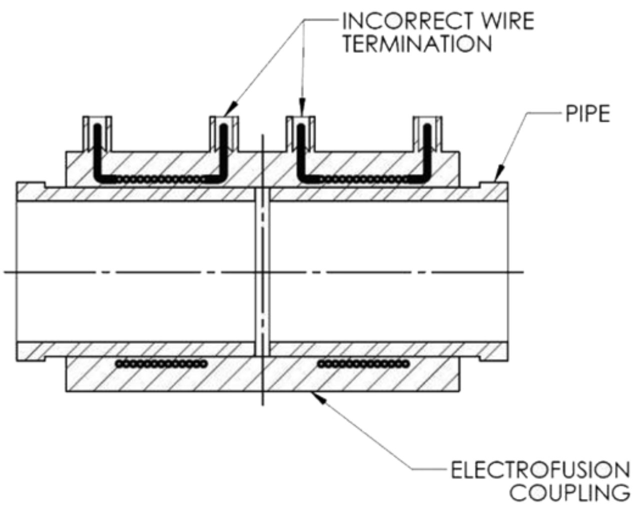

FIG. 4 Incorrect Wire Termination Coupling–Dual Coil

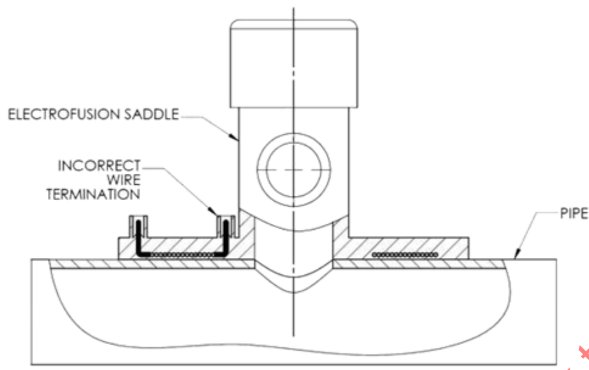

FIG. 5 Incorrect Wire Termination Saddle–Single Coil

These tests do not have to cover the full range of dimension ratios available, only the dimension ratio range on which the manufacturer recommends his fitting be used.

5.2 *Pressure Requirements:*

5.2.1 *Minimum Hydraulic Burst Pressure*—The fitting and fused joint shall not fail when tested in accordance with 9.1. The minimum hydraulic burst pressure of the test specimen shall not be less than that required to produce the minimum fiber stress in the pipe as required by the controlling pipe standard for the type of pipe used in the test. In no case shall the minimum hydraulic burst pressure be less than that required to produce 2520 psi (17.4 MPa) fiber stress in the pipe for medium density PE (density cell 2) and 2900 psi (20 MPa) fiber stress in the pipe for high density PE (density cell 3 or 4) test specimens when tested in accordance with 9.1. The test equipment, procedures, and failures definitions shall be as specified in Test Method D1599.

5.2.2 *Sustained Pressure*—The fitting and fused joint shall not fail when tested in accordance with 9.2. The test pressure, minimum time-to-failure, and test temperature shall be as required by the controlling pipe standard for the type of pipe used in the test. If a pipe standard is not specified, or does not contain test requirements, the test pressure, minimum time-to-failure and test temperature shall be as shown in Table 2.

5.3 *Tensile Strength Requirements (Coupling Type Joints Only)*—The fitting or the pipe to fitting joint made on pipe shall not fail when tested in accordance with 9.3. Specimens shall be subjected to a tensile stress that causes the pipe to yield to an elongation no less than 25 % or causes the pipe to break outside the joint area. Tensile tests must be made on specimens as joined, not on straps cut from the specimen. Yielding must be measured only in the pipe, independent of the fitting or joint.

5.4 *Impact Resistance (Saddle Type Joints Only)*—The joint made on the specimen shall not fail when impacted with a force sufficient to break the body or other portion of the specimen. Tests of 500 ft·lbf or higher impact with no failures noted shall be considered as a "pass" impact test. The device for testing and the methods shall be as defined in Practice F905.

5.5 *Joint Integrity Tests*—(*Couplings and Saddle Type Joints*)—The joint made on the specimen shall meet the requirements in 9.4 and 9.5 of this specification, when tested in accordance with 9.4.

6. Dimensions, Mass, and Permissible Variations

6.1 Dimension and tolerances of electrofusion fittings must be such that heat fusion is possible to outside diameter (OD) controlled PE pipes such as those listed in Specifications D2513, D2737, D3035, and F714 and PEX pipes listed in Specification F2788, such that the joints will satisfy the performance requirements in Section 5.

6.2 Because of the varying designs for electrofusion fittings, the actual spread of dimensions may be quite different from manufacturer to manufacturer. A table of dimensions and tolerances encompassing these differences would be meaningless and without value and, therefore, is omitted from this specification.

6.3 The manufacturer shall furnish to the user the electrical resistance, critical dimensions, and tolerances of his fittings. This information must include at least the following dimensions and tolerances:

6.3.1 Coupling inside diameter,

6.3.2 Temperature joining limits, and

6.3.3 Operating pressure of the fitting.

NOTE 2—There are other items that fall beyond the scope of this specification which would be of interest to the user for proper application of the fittings and is recommended as additional information to be furnished. A few of these are: (*1*) maximum pipe out of round allowed at joint area; (*2*) minimum/maximum pipe SDR capability of the fitting, and (*3*) for saddles intended for use on a live main, the maximum allowable line pressure when making the joint.

7. Workmanship, Finish, and Appearance

7.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification.

7.2 The fittings shall be homogeneous throughout, except where a heating coil or electrical connectors are incorporated, and free of cracks, holes, foreign inclusions, or injurious defects such as gouges, dents, cuts, etc. The fittings shall be as

TABLE 2 Supplemental Sustained Pressure Test Requirements for the Pipe Material Being Tested

Condition	Test Temperature °C (°F)^A	PE2408, PE2706, PE2708		PE3408, PE3608, PE3708, PE3710, PE4708, PE4710	
		Test Pressure Hoop Stress psi^B (kPa)^A	Minimum Average Time Before Failure Hours	Test Pressure Hoop Stress psi^B (kPa)^A	Minimum Average Time Before Failure Hours
1	80 (176)	670 (4620)	170	750 (5170)	200
2	80 (176)	650 (4480)	340	730 (5020)	400
3	80 (176)	630 (4345)	510	705 (4870)	600
4	80 (176)	610 (4210)	680	685 (4715)	800
5	80 (176)	590 (4070)	850	660 (4565)	1000
6	80 (176)	580 (4000)	1000	640 (4415)	1200

^{A}Test temperature tolerance ± 2 °C (± 3.6°F). Test pressure tolerance ± 5 psi (± 35 kPa); test pressure hoop stress values are rounded to the nearest 5 psi or 5 kPa. Table 2 conditions are based on PE validation requirements per PPI TR-3 with Condition 6 being 85% of Condition 1 hoop stress and six times greater minimum average time before failure. Conditions 2 through 5 are linear stress and time interpolations between Condition 1 and 6. The intent of multiple conditions is to maintain equivalent performance criteria, but provide for retest in the event of a ductile failure. The test pressure hoop stress levels for Conditions 2-5 are linear interpolations for arbitrarily chosen time increments. An equivalent performance requirement, however, may be determined by arbitrarily choosing a test pressure hoop stress between Conditions 1 and 6 and linearly interpolating the minimum average time before failure. For example for PE4710 material, at 670 psi test pressure hoop stress, the minimum average time before failure would be 927 hours (200 + (750 – 670) · ((1200 – 200) / (750 – 640)) = 927.

^{B}Calculate internal test pressure in accordance with:

$$P = \frac{2S}{\left(\frac{Do}{t-1}\right)}$$

where:

P = test pressure, psig (kPa)
S = test pressure hoop stress, psi (kPa)
Do = measured outside pipe diameter, in. (mm)
t = measured minimum pipe wall thickness, in (mm)

uniform as commercially practicable in opacity, density, and other physical properties. Any heating coils, connecting cables, connectors, and related electrical power source shall be designed to prevent electrical shock to the user.

8. Specimen Preparation

8.1 *Conditioning:*

8.1.1 Unless otherwise specified, condition the specimens (pipe and fittings) prior to joining at the minimum pipe temperature allowable for fusion as recommended by the manufacturer, for not less than 16 h and make the fusion joint at that temperature for those tests where conditioning is required.

8.1.2 Unless otherwise specified, condition the specimens (pipe and fittings) prior to joining at the maximum pipe temperature allowable for fusion as recommended by the manufacturer, for not less than 16 h and make the fusion joint at that temperature for those tests where conditioning is required.

8.2 *Test Conditions*—Conduct the tests at the Standard Laboratory Temperature of 23 ± 2°C (73.4 ± 3.6°F) unless otherwise specified.

8.3 *Preparation of Specimens for Testing:*

8.3.1 Prepare test specimens so that the minimum length of unreinforced pipe on one side of any fitting is equal to three times the diameter of the pipe, but in no case less than 12 in. (304 mm). It is permissible to test multiple fittings together provided they are separated by a minimum distance equal to three times the diameter of the pipe, but in no case less than 12 in. (304 mm).

8.3.2 Fuse all fitting outlets with the appropriate size pipe in accordance with the manufacturer's recommended procedures.

8.3.3 All saddle fusion joint specimens conditioned as in 8.1.2 and destined for quick burst testing as in 9.1 and sustained pressure testing as in 9.2, are to be joined with the pipe at no less than maximum allowable operating pressure of the pipe system or fitting, whichever is lowest, when being prepared for those tests. The pipe should be left under pressure for a time period not less than recommended by the manufacturer for cooling in the field prior to disturbing the joint. Saddle joint specimens destined for mechanical/destructive type tests such as impact as in 5.4 or crush tests as in 9.4, or specimens conditioned for cold temperature joining as in 8.1.1, may be made on unpressured pipe specimens.

9. Test Methods

9.1 *Minimum Hydraulic Burst Pressure Test:*

9.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.1.2 Test the specimens in accordance with Test Method D1599.

9.1.3 Failure of the fitting or joint shall constitute specimen failure.

9.1.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.2 *Sustained Pressure Test:*

9.2.1 Select four fittings at random and prepare specimens in accordance with Section 8 of this specification. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.2.2 Test the specimens in accordance with Test Method D1598. All tests shall be conducted at 80 ± 2°C. The assemblies are to be subjected to pipe fiber stresses and minimum test periods in accordance with the controlling pipe standards requirements for sustained pressure test. Joint specimens shall not fail within these time periods. Any failures within these time periods must be of the pipe, independent of the fitting or joint and must be of a“ brittle” type pipe failure, not “ductile.” If ductile pipe failures occur, reduce the pressure of the test and repeat until the required results or pipe brittle failures are achieved. If test conditions are not specified by the controlling pipe standard, the requirements of Table 2 shall be used for the pipe material type being tested with the electrofusion fitting.

9.2.3 Failure of the fitting or joint shall constitute specimen failure.

9.2.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed-specimens-joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.3 *Tensile Strength Test:*

9.3.1 Select four fittings at random and prepare specimens in accordance with Section 8 with the exception that it is permissible, on pipe sizes above 4 in. (102 mm) IPS, if limits of tensile machine will not allow 25 % elongation with pipe specimens of three-pipe diameters, to test with free pipe lengths of 20 in. (304-mm) minimum. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.3.2 Test the specimens using the apparatus of Test Method D638. Test at a pull rate of 0.20 in. (5.0 mm) per min, ±25 %.

9.3.3 Failure of the fitting or joint as defined in 5.3, shall constitute specimen failure.

9.3.4 Failure of any one of the four specimens shall constitute failure of the test. Failure of one of the four specimens tested is cause for retest of four additional specimens, joined at the failed specimens joining temperature. Failure of any of these four additional specimens constitutes a failure of the test.

9.4 *Joint Integrity Tests*—Illustrations of joint crush tests for socket type joints and saddles are offered in 9.4.1 and 9.4.2 as test methods that are useful as an evaluation of bonding strength between the pipe and fitting. Alternately, the fusion evaluation test (FET) offered in 9.4.3 and 9.4.4 may be used in lieu of the crush test. Similar test evaluations as specified in the contract or purchase order and as agreed upon by the purchaser and manufacturer are of equal value in performing such evaluations and may be substituted with such agreement.

9.4.1 *Joint Crush Test:*

9.4.1.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (Note 3).

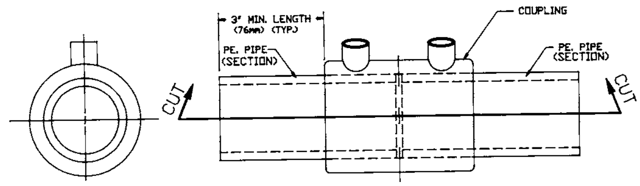

FIG. 6 Preparation of Coupling Specimen for Crush Test

NOTE 3—It is permissible to utilize in joint integrity testing, specimens from the quick-burst tests conducted in 9.1 after visually determining that neither the joint area nor the pipe segment to be crushed was a part of the failure mode in the quick-burst test.

9.4.1.2 Slit socket joints longitudinally as illustrated in Fig. 6 as near the centerline of the pipe as practical. Pipe lengths extending out of the socket may be cut back to a minimum of 3 in. (76 mm) for ease of placing in a vise.

9.4.1.3 Place each specimen half in a vise such that the outermost wire of coil is within 1.250 ± 0.125 in. (32 ± 3 mm) of vise jaws, with the jaws closing only on the pipe portion of the specimen (Fig. 7).

9.4.1.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 8). Repeat crush test on both halves and each end of specimen, at all ends, where a joint exists.

9.4.1.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.1.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.4.2 *Saddle Type Joint Crush Test (Not Full-Wrap Design):*

9.4.2.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2 (see 9.4).

9.4.2.2 Pipe lengths extending from saddle joint may be cut back clear up to the outer edges of the saddle for convenience of handling, if desired, however, it is not necessary. The length of the pipe extending beyond the saddle is not important to this test (Fig. 9).

9.4.2.3 Place the specimen in vise jaws as shown in Fig. 10, such that vise jaws are within ½ in. of saddle bottom and the jaws will close only on the pipe portion of the specimen. Saddle designs incorporating a bottom half saddle will need the bottom half removed for this test. Saddle designs incorporating a full-wrap single piece saddle are to be tested as in 9.4 socket type joints (Fig. 7 and Fig. 8).

9.4.2.4 Tighten the jaws of the vise on the pipe until the inner walls of the pipe meet (Fig. 11).

9.4.2.5 Separation of the fitting from the pipe at the fusion interface constitutes a failure of the test. Some minor separation at the outer limits of the fusion heat source up to 15 % of

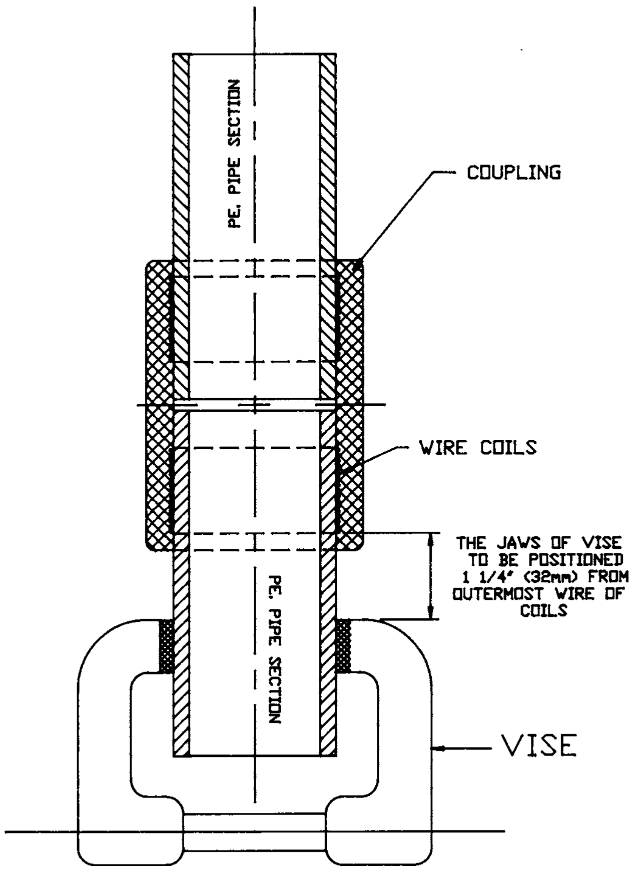

FIG. 7 Coupling Crush Test Arrangement

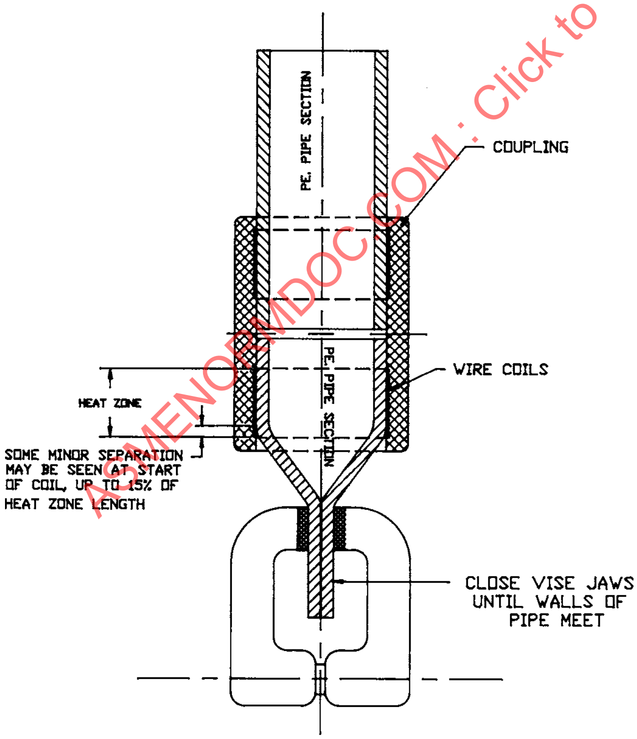

FIG. 8 Coupling Crush Test

the fusion length may be seen. This does not constitute a failure. Ductile failure in the pipe, fitting, or the wire insulation material, is acceptable as long as the bond interface remains intact.

9.4.2.6 Failure of any one of the four specimens shall constitute failure of the test and is cause for retest of four additional fittings, joined at the same temperature as the failed specimens. Failure of any of these four additional specimens constitutes a failure of the test.

9.4.3 *Fusion Evaluation Test (FET) of Sockets:*

9.4.3.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.4.3.2 A band saw with a locking guide and a blade restricted to cutting plastic is recommended for obtaining the FET samples. Slit the socket in the order of cuts as illustrated in Fig. 12. First, radially cut the socket in half along the centerline of the joint. Pipe extending from the fittings may be cut back to about 1 in. from the fitting edge. Cut FET specimens approximately 1/16 in. wide from each joint half. A minimum of four FET strips shall be cut from one half of the socket and spaced approximately 90° apart.

9.4.3.3 Grip an FET specimen in a vise or clamping device as shown in Fig. 13 so that the bond line between the pipe and fitting is at least 1/16 in. from the edges of the clamping device. Flex the specimen four times 90° in both directions. Pliers may be used in lieu of a vise as long as the entire length of the fusion is flexed.

9.4.3.4 Separation of the specimen along the bond line constitutes failure of the specimen. Some minor separation at the outer limits of the fusion heat source may be seen or there may be voids between wires. This does not constitute failure as long as the voids do not exceed the limits of 9.5. Ductile failure in the pipe, fitting, or the wire insulation material is acceptable as long as the bond interface remains intact.

9.4.3.5 Failure of any one of the four joints shall constitute failure of the test and is cause for retest using four additional fittings joined at the same conditions as the failed joint specimens. Failure of any of these four additional joint specimens constitutes a failure in the test.

9.4.4 *Fusion Evaluation Test of Saddle Type Joints (Not Full-Wrap Design):*

9.4.4.1 Select four fittings at random and prepare specimens in accordance with Section 8. From the four specimens, condition two specimens each in accordance with 8.1.1 and 8.1.2.

9.4.4.2 A band saw with a locking guide and a blade restricted to cutting plastic is recommended for obtaining the FET samples. Remove the stack from the fitting and cut the bottom portion of the pipe from the test piece. Cut the saddle in half in the transverse direction and then cut each half again in the longitudinal direction as shown in Fig. 14. Cut FET specimens approximately 1/16 in. wide through the fusion base of the saddle fitting. These cuts must be both longitudinal and transverse using two diagonal quarters for transverse direction and the two remaining quarters for the longitudinal direction.

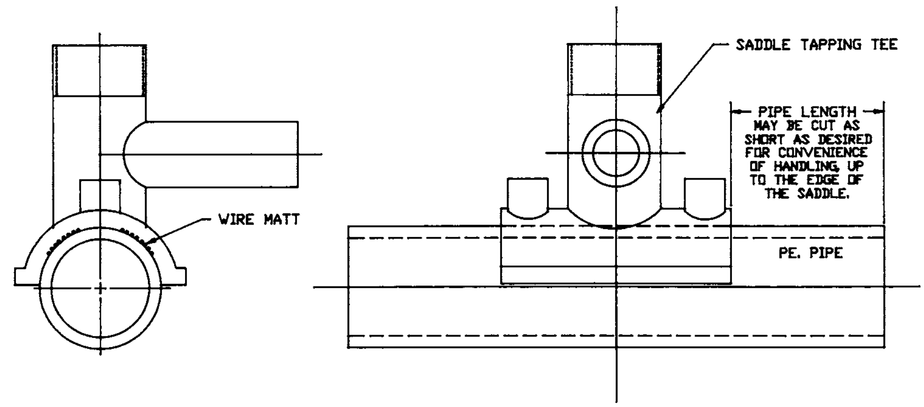

FIG. 9 Preparation of Saddle Specimen for Crush Test

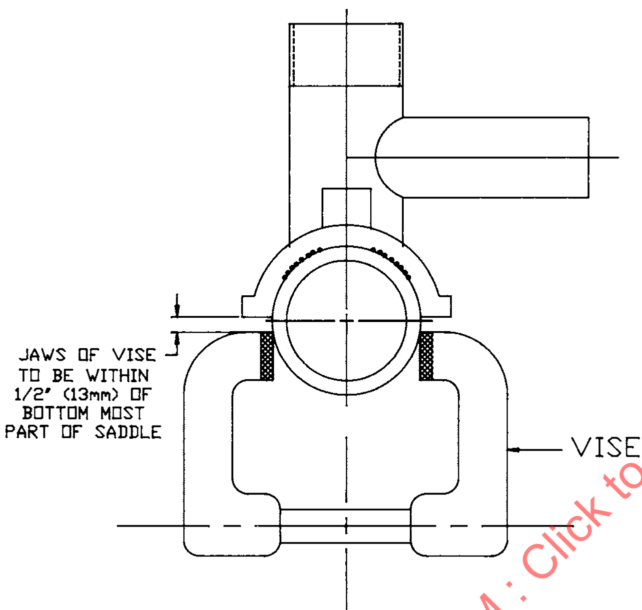

FIG. 10 Saddle Fitting Crush Test Before Crush

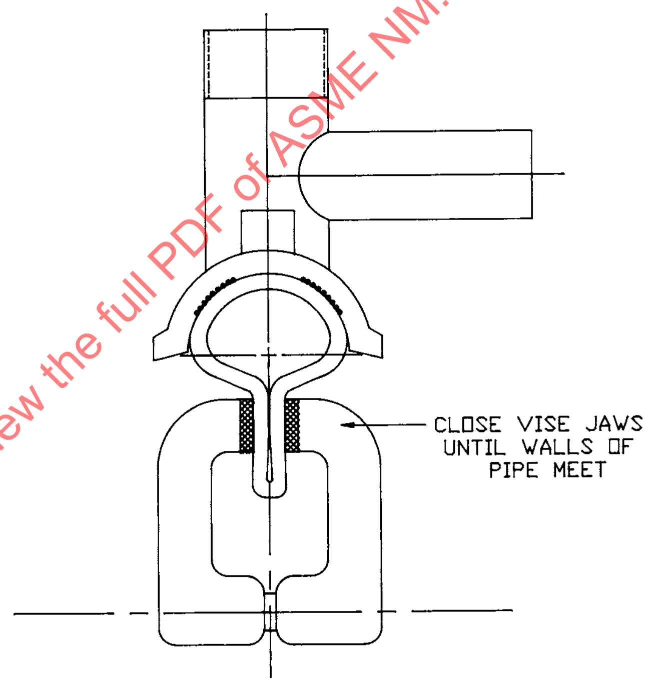

FIG. 11 Saddle Fitting Crush Test After Crush

9.4.4.3 Inspect the fusion area for any discontinuities. Follow the instructions in 9.4.3.3 to test the FET samples.

9.4.4.4 Separation of the specimen along the bond line constitutes failure of the specimen. Some minor separation at the outer limits of the fusion heat source may be seen or there may be voids between wires. This does not constitute failure as long as the voids do not exceed the limits of 9.5. Ductile failure in the pipe, fitting, or the wire insulation material is acceptable as long as the bond interface remains intact.

9.4.4.5 Failure of any one of the four joints shall constitute failure of the test and is cause for retest using four additional fittings, joined at the same conditions as the failed joint specimens. Failure of any of these four additional joint specimens constitutes a failure in the test.

9.5 *Evaluation for Voids*—When dissecting electrofusion joints for the integrity tests in 9.4, or any reason, voids at or near the fusion interface may be exposed. The voids, should they be present, are a phenomenon of the electrofusion process, due to trapped air and shrinking during the cooling process after the joint is made. If detected, such voids are considered acceptable only if round or elliptical in shape, with no sharp corners allowed and if they meet the limitations of 9.5.1 through 9.5.3.

9.5.1 Voids that do not exceed 10 % of the fusion zone length in size are acceptable. (See Fig. 15.)

9.5.2 Multiple voids, if present, are acceptable if the combined void sizes do not exceed 20 % of the fusion zone length. (See Fig. 15.)

9.5.3 If voids are exposed, additional longitudinal cuts should be made to ensure that the void does not follow a diametric path which connects to the pressure-containing area of the joint. (See Fig. 16.)

NOTE 4—Some voids in electrofusion fitting joints may be due to the natural phenomenon described in 9.5. It is also possible the voids can be produced by not following proper fusion procedures. If voids are detected, one should ensure that all procedures were followed in making the joint.

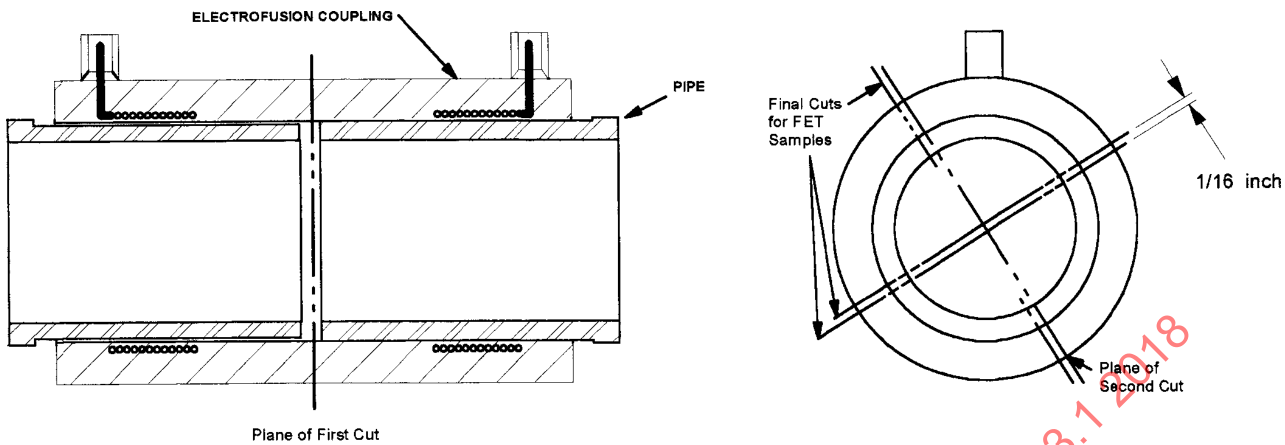

FIG. 12 Recommended Procedure for Cutting FET Strip From Coupling

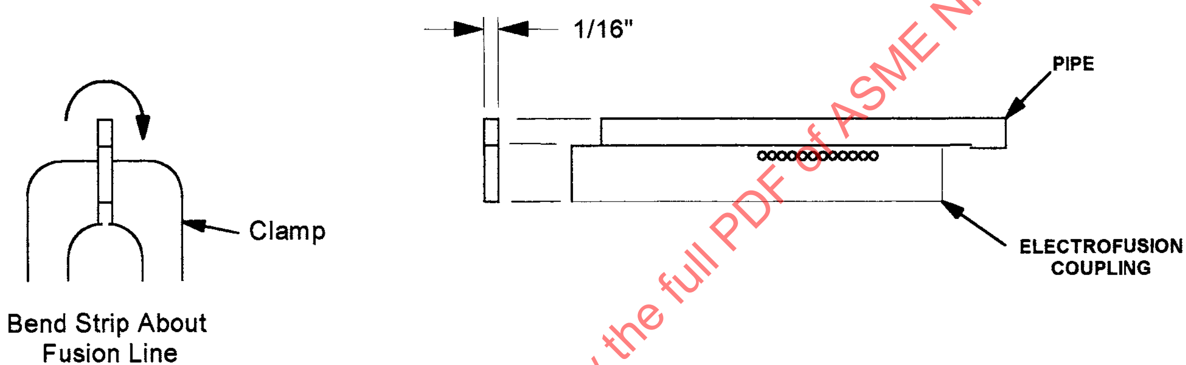

FIG. 13 Strip for FET Bend Test

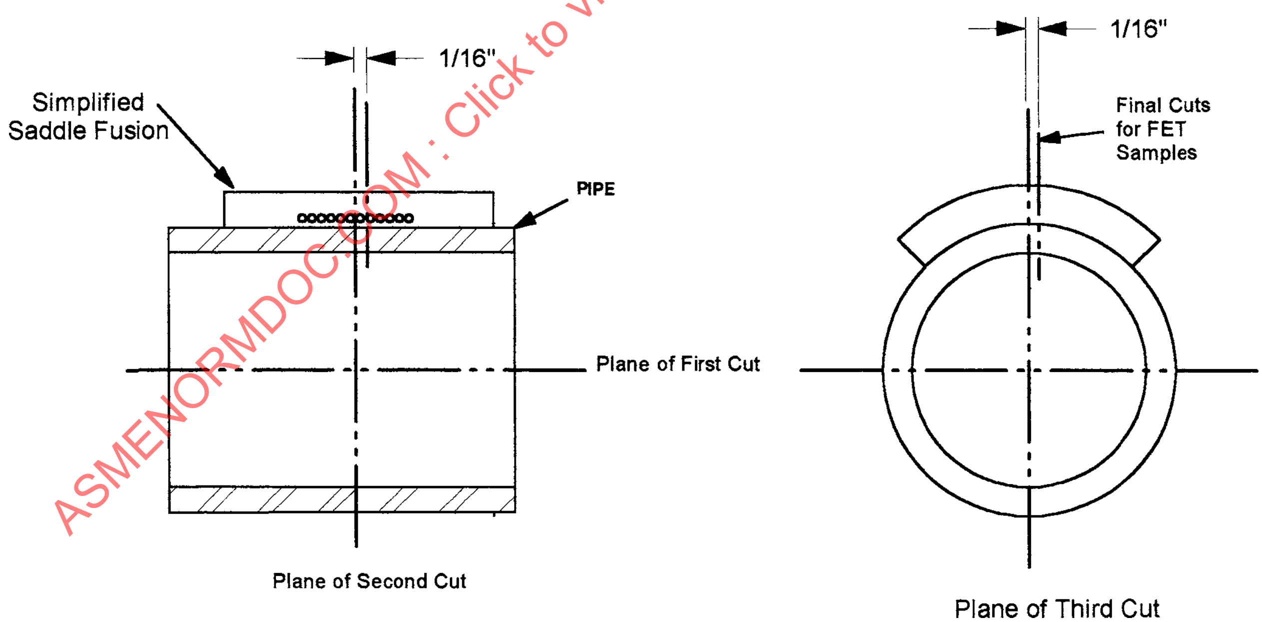

FIG. 14 Procedure for Cutting FET Strips from a Saddle

10. Product Marking

10.1 Fittings shall be marked with the following:

10.1.1 Manufacturer's name or trademark,

10.1.2 Material designation (for example, PE2708, PE4710, etc.),

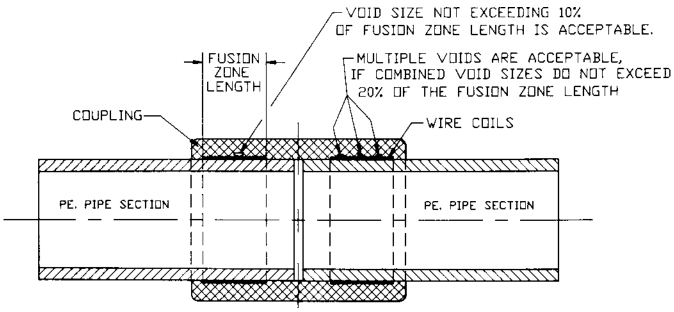

FIG. 15 Coupling Fusion Assembly With Possible Void Characteristics

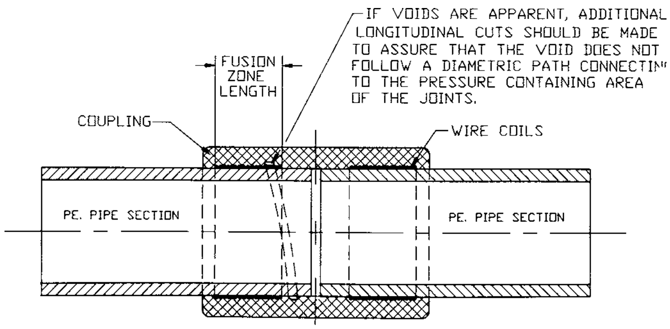

FIG. 16 Coupling Fusion Assembly—Further Examination Guidance

NOTE 5—Earlier editions of ASTM F1055, as well as related piping standards, included PE material designations PE2306, PE2406, PE3406, and PE3408. Changes to Specification D3350 and PPI TR-3 led to changes in thermoplastic material designation codes, resulting in material designation PE2406 being superseded by material designation PE2708. Similarly, PE3408 was superseded by material designations PE3708, PE3710, PE4708, and PE4710. Recognizing that a period of time is necessary for the dissemination of information and to update specifications and literature, during the transitional period, product markings that include both older and newer material designations, for example PE3408/PE4710, may occur.

10.1.3 For fittings intended for transporting potable water, the seal of approval of an accredited laboratory, for fittings complying with Specification D2513 and intended for gas distribution, the word "gas" or if space does not permit, the letter "G,"

10.1.4 Size, followed by "IPS" or "CTS" designation,

10.1.5 ASME SF-1055 or both ASME SF-1055 and ASTM F1055,

10.1.6 The fittings shall bear an appropriate code number that will assure identification on the fittings as to date of production and resin formulas used in the production of said fittings. The manufacturer shall maintain such additional records as are necessary to confirm identification of all coded fittings, and

10.1.7 Where the size of the fitting does not allow complete marking, identification marking may be omitted in the following sequence: ASTM designation number, and material designation.

10.2 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices. If indentation is used, it shall be demonstrated that these marks have no effect on the long term strength of the fitting.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A2.

13. Keywords

13.1 electrofusion; fittings; joining; polyethylene

ANNEXES

(Mandatory Information)

A1. IN-PLANT QUALITY CONTROL PROGRAM FOR ELECTROFUSION FITTINGS

A1.1 *Introduction:*

A1.1.1 Use the following in-plant quality control program, covering material and performance requirements in manufacture to provide reasonable assurance that the product meets the requirements of this specification and normally anticipated field performance requirements.

A1.2 *Fittings Tests:*

A1.2.1 Conduct the fittings tests at the frequencies indicated as follows:

NOTE A1.1—When any failure to meet the requirements of this specification occurs, make additional tests to ascertain those fittings that are acceptable, back to the last acceptable ones. Those that do not meet the requirements must be rejected.

A1.2.2 Dimensions of fusion area with heating element in place:

A1.2.2.1 *Socket Diameters*—Immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.2.2 *Saddle Sizes*—Main sizes and branching outlet sizes, immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.2.3 *Heating Element Resistance* —Immediately proceeding production start up, then once per h, or one out of ten fittings, whichever is less frequent.

A1.2.3 *Molding or Extrusion Quality*—Make the following tests on each cavity in the mold or each extrusion line being used. Test at the start of each production run, whenever production conditions have changed or when the resin lot has changed, but not less than once per 500 fittings thereafter.

A1.2.3.1 *Voids in Part*—Inspect for voids in the fitting by means of X-ray or dissection of the fitting in 0.25-in. (6-mm) wide strips.

A1.2.3.2 *Molding Knit Line Strength*—Test by one of the following tests, or other suitable tests:

(1) By crushing a fitting or a portion of a fitting in a manner that applies load in a direction normal to the knit line.

(2) By performing an apparent tensile strength test of a ring cut from a fitting with the load oriented normal to the knit line.

(3) By performing a burst test of the fitting in accordance with Test Method D1599.

NOTE A1.2—Separation in the knit line of any of these tests constitutes a failure of the test.

A2. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

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SPECIFICATION FOR ORIENTED POLY(VINYL CHLORIDE), PVCO, PRESSURE PIPE

SF-1483

(Identical with ASTM F1483-12 except for additional requirements in section 11 and Annex A1, revised marking requirements in para. 9.1.6, quality assurance requirement in para. 10.1 has been made mandatory, and renumbering of section 12.)

Specification for Oriented Poly(Vinyl Chloride), PVCO, Pressure Pipe

1. Scope

1.1 This specification covers requirements for materials, dimensions, sustained pressure, accelerated regression testing, burst pressure, flattening, impact resistance, workmanship, and methods of marking for oriented poly(vinyl chloride) (PVCO) pipe for pressure applications.

1.2 The PVCO pipe shall be joined using elastomeric seals (gaskets). The joint shall meet the requirements of Specification D3139 and the elastomeric seal shall meet the requirements of Specification F477. The PVCO shall not be joined by solvent cementing.

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

1.4 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 and health 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
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
D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2152 Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion
D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
F412 Terminology Relating to Plastic Piping Systems
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

2.2 *Other Standards:*

NSF Standard No. 14 for Plastic Piping Components and Related Materials
ANSI/NSF Standard No. 61 for Drinking Water System Components—Health Effects
PPI-TR 3 Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe

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 poly(vinyl chloride) plastics is PVC.

3.1.2 *PVCO pipe*—abbreviation for oriented poly(vinyl chloride) plastics. PVCO pipe is PVC pressure pipe which attains a relatively high strength by reorienting the molecules. Conventionally extruded PVC pipe is expanded circumferentially (for example, 2-in. diameter is expanded to 4-in. diameter) through the application of pressure and temperature. The expansion reorients the PVC molecular structure in the hoop direction, thereby increasing the material strength.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *expansion ratio (ER)*—the ratio of the finished PVCO pipe outside diameter to the outside diameter of the original starting stock.

3.2.2 *standard thermoplastic pipe material designation code*—the molecularly oriented poly(vinyl chloride) materials designation code shall consist of the abbreviation PVCO for the type of plastics, followed by the ASTM type and grade in arabic numerals and the hydrostatic design stress in units of 100 psi (0.69 MPa) with any decimal figures dropped. The ASTM type and grade shall be that of the starting stock material. The hydrostatic design stress shall be that of the finished PVCO pipe.

3.2.3 DISCUSSION—A complete material designation code shall consist of four letters and four figures (for example; a PVCO pipe manufactured from 12454 (Type 1, Grade 1) material starting stock and having an HDB of 7100 psi (48.92 MPa) [HDS of 3550 psi) (24.46 MPa)] will have a material designation code of PVCO 1135).

3.2.4 *starting stock*—the conventionally extruded PVC pipe of uniform wall thickness which will be expanded to a larger diameter, molecularly oriented pipe.

3.2.5 *wall-thickness-ratio (WTR)*—the ratio of the finished product wall thickness to the wall thickness of the starting stock.

4. Classification

4.1 *General*—This specification covers PVCO made from PVC plastic pipe, starting stock, having a hydrostatic design stress of 2000 psi (13.78 MPa) determined in accordance with Test Method D2837. Finished PVCO pipe shall have a hydrostatic design stress of 3550 psi (24.46 MPa) determined by testing in accordance with Test Methods D1598, with data evaluated in accordance with Test Methods D2837, as in 6.3.2.

5. Materials

5.1 *General*—Poly(vinyl chloride) plastics used to make PVCO pipe meeting the requirements of this specification are categorized by means of two criteria, namely (*1*) short-term strength tests; and (*2*) long-term strength tests.

5.1.1 *Supplementary Requirement*—This applies whenever a regulatory authority or user calls for the product to be used to convey or to be in contact with potable water. Potable water applications products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 or the health effects portion of NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

5.2 *Basic Materials*—This specification covers PVCO pipe made from PVC compounds having certain physical and chemical properties as described in Specification D1784.

5.3 The PVC compound used for the starting stock of this pipe shall equal or exceed the following cell classification described in Specification D1784: PVC 12454 (Type 1, Grade 1). Recycled materials shall not be used in the compound.

5.4 *Rework Materials*—Clean, rework material, generated from the manufacturer's own pipe production, shall be permitted to be used by the same manufacturer, as long as the pipe produced meets all the requirements of this specification.

6. Requirements

6.1 *General*—These requirements are for finished PVCO pipe, unless otherwise noted.

6.2 *Dimensions and Tolerances:*

6.2.1 *Outside Diameters*—The outside diameters and tolerances shall be shown in Table 1 and Table 2 when measured in accordance with Test Method D2122. The tolerances for out-of-roundness shall apply only on pipe prior to shipment.

6.2.2 *Wall Thicknesses*—The wall thicknesses and tolerances shall be as shown in Table 3 and Table 4 when measured in accordance with Test Method D2122.

6.3 *Qualification Tests*—These tests are for qualification of the compound and extrusion process, not for quality control.

6.3.1 *Sustained Pressure*—The sustained pressure test shall be completed for each diameter at initial start-up. Thereafter, it shall be completed whenever there is a change in the ER (3.2.1), or the WTR (3.2.5), or whenever a change is made to the compound which is outside the allowable limits of the Plastics Pipe Institute PVC compound range formula (see PPI TR-3). The pipe shall not fail, balloon, burst, or weep as defined in Test Method D1598 at the test pressures given in Table 5 when tested in accordance with 7.4.

6.3.2 *Accelerated Regression Test*—This test shall be completed on a representative diameter at initial start-up. A representative diameter is one which has an ER, a WTR, and a compound which is the same as the other diameters manufactured. Thereafter, it shall be completed on a representative diameter whenever there is a change in the ER or the WTR, or whenever a change is made to the compound which is outside the allowable limits of the Plastics Pipe Institute PVC compound range formula (see PPI TR-3). The test shall be conducted in accordance with 7.5.

6.3.2.1 The pipe shall demonstrate a minimum hydrostatic design basis projection, at the 100 000-h intercept, of 6810 psi (46.92 MPa) (for Hydrostatic Design Basis Categories, see Table 1 of Test Method D2837). At the option of the manufacturer, the accelerated regression test may be used as a substitute for both pressure tests, sustained and burst (6.4.1).

6.4 *Quality Control Tests*—These tests are intended to ensure the quality of the finished pipe product.

6.4.1 *Burst Pressure*—The minimum burst pressure for PVCO pipe shall be as given in Table 6, when determined in accordance with 7.6.

TABLE 1 IPS PVCO Pipe—Outside Diameters and Tolerances

Nominal Pipe Size, in.	Average Outside Diameter, in. (mm)	Tolerance, ±in. (mm)
4	4.500 (114.30)	0.009 (0.23)
6	6.625 (168.28)	0.011 (0.28)
8	8.625 (219.08)	0.015 (0.38)
10	10.750 (273.05)	0.016 (0.41)
12	12.750 (323.85)	0.017 (0.43)
14	14.000 (355.60)	0.018 (0.46)
16	16.000 (406.40)	0.019 (0.48)

TABLE 2 CIOD PVCO Pipe—Outside Diameters and Tolerances

Nominal Pipe Size, in.	Average Outside Diameter, in. (mm)	Tolerance, ±in. (mm)
4	4.800 (121.92)	0.009 (0.23)
6	6.900 (175.26)	0.010 (0.25)
8	9.050 (229.87)	0.015 (0.38)
10	11.100 (281.94)	0.016 (0.41)
12	13.200 (335.28)	0.017 (0.43)
14	15.300 (388.62)	0.018 (0.46)
16	17.400 (441.96)	0.019 (0.48)

6.4.2 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 7.7.

6.4.3 *Extrusion Quality*—The starting stock pipe shall not flake, crack, or disintegrate when tested in accordance with Test Method D2152.

6.4.4 *Impact Resistance*—The minimum impact resistance for PVCO shall be as given in Table 7, when determined in accordance with 7.8.

NOTE 1—The impact resistance test is intended for use only as a quality-control test, not as a simulated service test. This test has been found to have no quality-control significance in sizes over 12 in. (300 mm).

6.4.5 *Workmanship, Finish, and Appearance*—The pipe shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other defects. The pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

NOTE 2—Color and transparency or opacity should be specified in the contract or purchase order.

7. Test Methods

7.1 *Conditioning*—Condition the test specimen at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618 for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct the tests in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

7.3 *Sampling*—The selection of the sample or samples of pipe shall be as agreed upon between the purchaser and the seller. In case of no prior agreement, the sample selection of the manufacturer shall be deemed adequate.

7.3.1 *Test Specimens*—Not less than 50 % of the test specimens required for any pressure test shall have at least a part of the marking in their central sections. The central section is that portion of pipe which is at least one pipe diameter away from an end closure.

7.4 *Sustained Pressure Test*—Select the test specimens at random. Test individually with water at the internal pressure given in Table 5, six specimens of pipe, each specimen shall be 3 ft long (1000 mm) between end closures and bearing the permanent marking on the pipe. Maintain the specimens at the pressure indicated for a period of 1000 h. Hold the pressure as closely as possible, but within ±10 psi (±70 kPa). Condition the specimens at the test temperature of 73.4± 3.6°F (23 ± 2°C).

7.4.1 Maintain the test temperature at 73.4 ± 3.6°F (23 ± 2°C). Test in accordance with Test Methods D1598, except maintain the pressure at the values given in Table 5 for 1000 h. Failure of two of six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens tested in retest shall constitute failure in the test. Evidence of failure of the pipe shall be as defined in Test Methods D1598.

7.5 *Accelerated Regression Test*—Test in accordance with procedures in Test Methods D1598, except that restrained end fittings shall be permitted to be employed. A minimum of six samples will be tested at pressures selected to yield data points as follows:

0.010 to 0.099 h (36 s to 6 min)
0.10 to 0.999 h (6 min to 1 h)
1.00 to 9.999 h
10.0 to 99.999 h
100.0 to 100+ h
0 to 100+ h (random point)

Additional points may be added if necessary to improve projection or LCL, or both. No points shall be excluded unless an obvious defect is detected in the failure area of the test sample. Characterize the results using the least squares extrapolation described in Test Method D2837.

NOTE 3—**Caution:** Since rupture of the test specimen is expected in quick-burst and high-strength regression testing, well-shielded test equipment and protective personal equipment should be used when conducting the tests.

7.6 *Burst Pressure*—Determine the minimum burst pressure with at least five specimens in accordance with Test Method D1599, having the lengths specified in 7.4. The time of testing of each specimen shall be not less than 60 s.

NOTE 4—Times greater than 60 s may be needed to bring the larger-sized specimens to the burst pressure. The test is more difficult to pass using greater pressuring times.

7.7 *Flattening*—Flatten three specimens of the pipe, 2 in. (50 mm) long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. Upon removal of the load, examine the specimens for evidence of splitting, cracking, or breaking.

7.8 *Impact Resistance*—Determine the impact resistance in accordance with the specification requirement section of Test Method D2444. Test at 73.4 ± 3.6°F (23± 2°C) using a Tup B and flat plate support. Use a 20-lb (9-kg) tup.

7.8.1 *Test Specimens*—Specimens of pipe for impact testing shall be cut to lengths required in Test Method D2444.

7.8.2 *Test Requirements*—For pipe sizes 4 through 12 in. (100 through 300 mm), test ten specimens. If nine or more pass, the lot passes. If two or more fail, the lot fails.

8. Retest and Rejection

8.1 If the results of any test(s) do not meet the requirements of this specification, the test(s) may be conducted again in

TABLE 3 Minimum Wall Thickness for PVCO Plastic Pipes with IPS Outside Diameter

Nominal Pipe Size, in.	Wall Thickness, in. (mm)		
	PVCO 1135		
	Pressure Rated, 160 psi, min	Pressure Rated, 200 psi, min	Pressure Rated, 250 psi, min
4	0.099 (2.52)	0.123 (3.12)	0.153 (3.89)
6	0.146 (3.71)	0.182 (4.62)	0.225 (5.72)
8	0.190 (4.83)	0.236 (5.99)	0.293 (7.44)
10	0.237 (6.02)	0.295 (7.49)	0.366 (9.30)
12	0.281 (7.14)	0.349 (8.86)	0.434 (11.02)
14	0.309 (7.85)	0.384 (9.75)	0.476 (12.09)
16	0.353 (8.97)	0.438 (11.13)	0.544 (13.82)

TABLE 4 Minimum Wall Thickness for PVCO Plastic Pipes with Cast Iron Outside Diameter (CIOD)

Nominal Pipe Size, in.	Wall Thickness, in. (mm)		
	PVCO 1135		
	Pressure Rated, 150 psi, min	Pressure Rated, 200 psi, min	Pressure Rated, 250 psi, min
4	0.099 (2.51)	0.132 (3.35)	0.163 (4.14)
6	0.143 (3.63)	0.189 (4.80)	0.235 (5.97)
8	0.187 (4.75)	0.248 (6.30)	0.308 (7.82)
10	0.229 (5.82)	0.304 (7.72)	0.378 (9.60)
12	0.273 (6.93)	0.362 (9.19)	0.449 (11.40)
14	0.317 (8.05)	0.419 (10.64)	0.520 (13.21)
16	0.360 (9.14)	0.477 (12.12)	0.592 (15.04)

TABLE 5 Sustained Pressure Test Conditions for Water at 73°F (23°C) for PVCO Plastic Pipes with IPS and CIOD Outside Diameters

Pressure Rating	Test Pressures[A]	
	psi	MPa
150	320	(2.21)
160	335	(2.31)
200	420	(2.89)
250	525	(3.48)

[A]The fiber stress used to derive these test pressures is as follows:
PVCO 1135 7400 psi (50.99 MPa)

TABLE 6 Burst Pressure Requirements for Water at 73°F (23°C) for PVCO Plastic Pipe with IPS and CIOD Outside Diameters

Pressure Rating	Test Pressures[A]	
	psi	MPa
150	475	(3.27)
160	505	(3.48)
200	630	(4.35)
250	790	(5.44)

[A]The fiber stress used to derive these test pressures is as follows:
PVCO 1135 11 100 psi (76.48 MPa)

accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirements of the specification by such means as omitting tests that are a part of the specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirement of this specification shall be met and the test method designated in the specification shall be followed. If, upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirement of this specification.

TABLE 7 Impact Resistance at 73°F (23°C) for PVCO Pipe

Size, in.	Impact Resistance, ft·lbf (J)—All Series
4	100 (136)
6	150 (203)
8	200 (271)
10	200 (271)
12	200 (271)

9. Product Marking

9.1 Marking on the pipe shall include the following, spaced at intervals of not more than 5 ft (1.5 m).

9.1.1 Nominal pipe size.

9.1.2 The outside diameter system (IPS or CIOD).

9.1.3 The letters PVCO.

9.1.4 The type of plastic pipe material in accordance with the designation code given in 3.2.5 (for example, PVCO 1135).

9.1.5 Maximum operating pressure rating, psi.

9.1.6 ASME SF-1483 or both ASME SF-1483 and ASTM F1483.

9.1.7 Manufacturer's name (or trademark) and code. The manufacturer's code shall include year, month, day, shift, plant, and extruder of manufacture.

9.1.8 Pipe intended for the transport of potable water shall also include the standard to which it was evaluated and the mark of the laboratory making the evaluation for that purpose. Manufacturers using the seal or mark of a laboratory must obtain prior authorization from the laboratory concerned.

9.1.9 Mark on the pipe "DO NOT SOLVENT CEMENT".

10. Quality Assurance

10.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

12. Keywords

12.1 PVCO oriented polyvinyl chloride; pipe pressure

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection* —S1.1 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 may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. 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 S1.1—In U.S. Federal Government contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the material shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in a satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packaging shall comply with Uniform Freight Classification rules of National Motors Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Federal Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirements designated in the purchase order or contract, and the results met the requirements of that Specification, the Supplementary Requirements and the other requirements. A signature or notarizations is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the Report. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR POLYVINYLIDENE FLUORIDE (PVDF) CORROSIVE WASTE DRAINAGE SYSTEMS

SF-1673

(Identical with ASTM F1673-10 except for additional requirements in section 12 and Annex A2, revised marking requirements in para. 10.2.2.5, quality assurance requirement in para. 11.1 has been made mandatory, and renumbering of section 13.)

Specification for Polyvinylidene Fluoride (PVDF) Corrosive Waste Drainage Systems

1. Scope

1.1 This specification covers requirements for polyvinylidene fluoride drainage systems for corrosive applications. Requirements for material, pipe and fittings are included. Polyvinylidene fluoride includes emulsion/suspension polymerization and copolymers of vinylidene fluoride/hexafluoropropylene produced by either method.

1.2 These requirements apply to Schedule 40 and 80 IPS, SDR 32.5, and SDR 21 pipe sizes. Pipe and fittings are to be joined by heat fusion or mechanical methods using the equipment supplied by the manufacturers.

1.3 This specification is not intended to provide for interchangeability between plastic pipe and fittings from different manufacturers, but it does allow for transition fittings for joining one manufacturer's product to another's product, provided the joining technique used is other than heat fusion.

1.4 This specification is not for polyvinylidene pressure systems.

1.5 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.

1.6 Notes and appendixes are not a mandatory part of this specification.

1.7 The following safety hazard 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D570 Test Method for Water Absorption of Plastics

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

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

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

D3222 Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials

D3311 Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns

D5575 Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers

F412 Terminology Relating to Plastic Piping Systems

F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment

2.3 *Military Standard:*

MIL-STD 129 Marking for Shipment and Storage

2.4 *Other Standard:*
Uniform Plumbing Code

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions used in this specification are in accordance with the definitions given in Terminologies D883 and F412 and abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.1.2 The plumbing terminology used in this specification is in accordance with the definitions given in the *Uniform Plumbing Code*, unless otherwise indicated.

4. Classification

4.1 *General*—This specification covers PVDF pipe and fittings made from PVDF or VF/HFP copolymers in Schedule 40 and 80 IPS sizes and in SDR 32.5 and SDR 21.

4.2 This specification also includes molded fittings and the larger sizes (8, 10, 12 in.) of fabricated fittings.

5. Materials and Manufacture

5.1 Polyvinylidene fluoride (PVDF) material for pipe or fittings shall conform to the requirements of Type I Grade 1, Type I Grade 2, or Type II PVDF as defined in Specification D3222 or copolymers as defined in Specification D5575.

5.2 The PVDF material may contain pigment and fillers not detrimental to the pipe and fittings, provided the pipe and fittings produced meet the requirements of this specification.

5.3 *Rework Material*—Clean rework material, generated from the manufacturer's pipe and fittings products may be used by the same manufacturer, provided that the pipe or fittings produced meet the requirements of this specification.

6. Requirements

6.1 *Dimensions and Tolerances—Pipe and Fittings:*

6.1.1 *Pipe:*

6.1.1.1 Dimensions and tolerances for pipe shown in Table 1 and Table 2 shall be measured in accordance with Method D2122. The tolerance for out-of-roundness shall apply only to pipe prior to shipment.

TABLE 1 Outside Diameters and Tolerances for PVDF Pipe Schedules 40 and 80 and SDR 21, in. (mm)

Nominal Pipe Size	Average Outside Diameter	Tolerance	Out-of-Roundness (Maximum Diameter Minus Minimum Diameter)
1¼	1.660 (42.16)	±0.005 (±0.13)	0.050 (1.28)
1½	1.900 (48.26)	±0.006 (±0.15)	0.060 (1.52)
2	2.375 (60.32)	±0.006 (±0.15)	0.070 (1.78)
3	3.500 (88.90)	±0.008 (±0.20)	0.080 (2.04)
4	4.500 (114.30)	±0.009 (±0.23)	0.100 (2.54)
6	6.625 (168.28)	±0.011 (±0.28)	0.100 (2.54)
8	8.625 (219.08)	±0.015 (±0.38)	0.150 (3.80)
10	10.750 (273.05)	±0.015 (±0.38)	0.150 (3.80)
12	12.750 (323.85)	±0.015 (±0.38)	0.150 (3.80)

6.1.1.2 *Toe-In*—The outside diameter, when measured in accordance with Method D2122, shall meet the requirements of Table 1 and Table 2 at any point within 1.5 pipe diameters or 11.8 in. (300 mm), whichever is less, to the cut end of the pipe length.

6.1.2 *Fittings:*

6.1.2.1 The minimum wall thickness of the body all fittings shall not be less than the corresponding Schedule 40 pipe size and shall be measured in accordance with Method D2122.

6.1.2.2 Spigot ends of fittings shall conform to the diameter and out-of-roundness requirements for pipe.

6.1.2.3 Socket ends of fittings shall conform to the dimensional requirements for size and tolerances as provided by the manufacturer.

6.1.2.4 The average minimum diameters of waterways of fittings, excluding adapters, shall be as specified in Table 3.

6.1.2.5 Taper pipe threads in any fittings shall be as specified in Specification F1498. The tolerance shall be 1½ large or small turns from the basic thread dimension and gaged in accordance with 8.7.

6.1.2.6 The patterns, dimensions, and laying lengths of molded fittings, including adaptors, shall meet the requirements of Specification D3311, or shall be of a proven design and allow a smooth transition of fluid flow from one direction to another.

6.1.2.7 Cleanouts, cleanout plugs, and caps as commonly used in the manufacturer's laboratory drainage system, shall have a thread size and depth sufficient to ensure that the minimum waterway sizes are maintained.

6.1.2.8 *Traps*—All traps shall have a minimum water seal of 2 in.

6.2 *Chemical Resistance*—Pipe and fittings material shall be evaluated in accordance with Practice D543, Procedures I and II, using the chemicals listed in 8.3. The weight change shall not exceed 2 %, nor shall the apparent tensile strength change by more than 10 %. In cases where there is a change in the apparent tensile strength greater than 10 %, a further evaluation shall be made after removal from the chemical and conditioning for 72 h. If there is a minimum of 50 % recovery of tensile strength after 72 h, and that figure is within ±10 % of the original tensile strength, the specimen shall be considered acceptable.

6.3 *Water Absorption*—Pipe and fitting materials shall not change in weight more than 0.50 % when tested in accordance with 8.4.

6.4 *System Integrity:*

6.4.1 Fused joints and associated pipe shall withstand a pressure of 50 psi (345 kPa) without leaking when tested in accordance with 8.5.1.

6.4.2 Mechanical joints shall withstand a pressure of 14.5 psi (100 kPa) without leaking when tested in accordance with 8.5.2.

NOTE 1—Mechanical joints include transition, compression, threaded, and other type mechanical joints.

6.4.3 Mechanical joints shall incorporate a positive mechanical system for axial restraint in addition to any restraint provided by friction.

TABLE 2 Wall Thicknesses and Tolerances for PVDF Pipe Schedules 40 and 80 and SDR 21, in. (mm)

NOTE 1— For fittings, the wall thickness is a minimum value, except that a 10 % variation resulting from core shift is allowable. In such a case, the average of the two opposite wall thickness' shall equal or exceed the value shown in the Schedule 40 table.

Nominal Pipe Sizes	Schedule 40		Schedule 80		SDR 21		SDR 32.5	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.079 (2.01)	+0.020 (+0.51)	0.062 (1.57)	+0.020 (0.51)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.090 (2.28)	+0.020 (+0.51)	0.062 (1.57)	+0.020 (0.51)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.113 (2.87)	+0.020 (+0.51)	0.073 (1.85)	+0.020 (0.51)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.167 (4.22)	+0.020 (+0.51)	0.108 (2.74)	+0.020 (0.51)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	0.214 (5.44)	+0.026 (+0.66)	0.138 (3.51)	+0.020 (0.51)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	0.315 (8.00)	+0.038 (+0.97)	0.204 (5.18)	+0.0241 (0.61)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	0.411 (10.44)	+0.049 (+1.24)	0.265 (6.73)	+0.032 (0.81)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	0.512 (13.00)	+0.061 (+1.55)	0.331 (8.41)	+0.040 (1.02)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	0.607 (15.42)	+0.073 (+1.85)	0.392 (9.96)	+0.047 (+1.19)

TABLE 3 Average Waterway Diameter, in. (mm)

Nominal Pipe Size	Unthreaded Fittings	Under Half Thread of Male Adapters	
	Minimum	Minimum	Maximum
1¼	1.227 (31.17)	1.220 (30.99)	1.280 (32.51)
1½	1.446 (36.73)	1.458 (37.03)	1.501 (38.13)
2	1.881 (47.78)	1.915 (48.64)	1.946 (49.43)
3	2.820 (71.63)	2.849 (72.36)	2.983 (75.77)
4	3.737 (94.92)	3.806 (96.67)	3.972 (100.89)
6	5.646 (143.41)	5.851 (148.62)	6.008 (152.53)
8	7.490 (190.25)	. . .	. . .
10	9.407 (238.94)	. . .	. . .
12	11.197 (284.40)	. . .	. . .

6.4.4 Mechanical joints shall show no evidence of separation at the joint under Force *P* when tested in accordance with 8.6.1, nor shall they leak or show any other damage when tested in accordance with 8.6.2. Two fittings shall be tested and both shall pass.

6.5 All stainless steel parts shall be made of corrosion-resistant steel, containing not less than 16 % chromium and not less than 6 % nickel by weight.

6.6 *Sealing Rings*—Sealing rings shall be made from a material with a chemical resistance similar to PVDF.

6.7 *Flattening*—There shall be no evidence of splitting, cracking, or breaking when the pipe is tested in accordance with 8.8.1.

6.8 *Impact Resistance*—The impact resistance testing shall be in accordance with 8.9.

7. Workmanship, Finish, and Appearance

7.1 The manufacture of pipe and fittings shall be in accordance with good commercial practice, so as to produce fittings meeting the requirements of this specification. Fittings and pipe shall be homogenous throughout and free from visible cracks, holes, foreign inclusions, or injurious defects. The fittings and pipe shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8. Test Methods

8.1 *Conditioning*—When required, condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, for not less than 40 h prior to the test in accordance with Procedure A of Practice D618.

8.2 *Test Conditions*—Conduct the test in a standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

8.3 *Chemical Resistance*—Determine the resistance to the following chemicals using the material quantification method in Practice D543.

Chemical	Percent in Water
Acetic acid	5 by volume
Acetone	5 by volume
Methyl alcohol	100
Ammonia hydroxide	10 by volume
Nitric acid	40 by volume
Sodium hydroxide	10 by weight
Sulfuric acid	20 by volume
Hydrochloric acid	20 by volume

8.4 *Water Absorption*—Three cleanly cut specimens measuring approximately 2 by 3 in. (50 by 75 mm) and having smooth edges shall be weighed to the nearest 0.001 g and immersed in distilled water at 73.4 ± 1.8°F (23 ± 1°C) for 24 h + ½ −0 h, in accordance with Test Method D570. The specimens shall be removed, wiped dry with a clean, dry cloth, and reweighed immediately. The average percent gain in weight shall be calculated to the nearest 0.01 % on the basis of the initial mass. Weight change shall be less than 0.50 % (material qualification only).

8.5 *Joint Tests—Hydrostatic Pressure Tests:*

8.5.1 *Fused Joint Pressure Test*—Six specimens of pipe, each five times the nominal diameter or a maximum of 18 in. (450 mm) in length, shall be selected at random for each size of piping and each type of system being considered. Three suitable couplings shall also be selected at random. Three joined specimens shall be prepared by joining two pipe specimens with one coupling, using the equipment and instructions supplied by the manufacturer of the system. Fill each specimen with water at 73.4 ± 3.6°F (23 ± 2°C) and cap, taking care to exclude all air from the system. Fix one end of the specimen to a pressurizing apparatus, and support the free end if necessary. Pressurize each specimen to 50 psi (345 kPa) for a minimum of 5 min and inspect for leaks. None of the three specimens shall leak.

8.5.1.1 This is a laboratory performance test only and is not for field use.

8.5.2 *Mechanical Joint Pressure Test*—The pressure test on mechanical joints shall be carried out on test specimens prepared in a manner similar to that described in 8.5.1, except use appropriate pipe specimens where the joint is intended to join pipes of similar or dissimilar material and sizes. Pressurize the assembly to 14.5 psi (100 kPa) for a period of 24 h +15, −0.0 min and inspect for signs of leakage. Apply this test to each size and type of joint being considered.

8.5.2.1 This is a laboratory performance test only and is not for field use.

8.6 *Mechanical Joint Pullout Test:*

8.6.1 Join two sections of pipe by a coupling, with the positive mechanical axial restraint system removed or deactivated. Mount the assembly with the outer ends of the pipe sections fastened in the clamps of a tensile testing machine. Pull the two pipe sections apart at a rate of approximately 1 in./min (25 mm/min) until at least one pipe section has separated from the coupling. Record the maximum force, *F*, applied.

8.6.2 Using the setup described in 8.6.1, subject a complete joint assembled in accordance with the manufacturer's instructions to an axial pullout force, *P*, of 25 lbf (110 N) greater than Force *F*. In no case shall this force *P* be less than 50 lbf (220 N). Apply Force *P* within 5 to 30 s and maintain for at least 60 s.

8.6.3 Remove the axial force and pressurize the complete joint assembly to 14.5-psi (100-kPa) hydrostatic pressure for a period of 1 h and inspect for leaks.

8.7 *Threads*—All molded taper threads shall have a blunt start with a pilot equal to ½ to ¾ turns. Include the pilot in the thread length measurement. Schedule 80 PVDF pipe may be threaded. Measure threads using taper pipe thread gages conforming to Specification F1498 dimensions and follow the method of gaging outlined:

8.7.1 *Gaging External Taper Threads*—In gaging external taper threads, screw the ring gage tight by hand on the external thread. The thread is within the permissible tolerance when the gaging face of the working ring gage is not more than 1½ large or small turns from being flush with the face of the fitting, after correction has been made for any variation in the gage from basic dimensions.

8.7.2 *Gaging Internal Taper Threads*—In gaging internal taper threads, screw the plug gage tight by hand into the fitting. The thread is within the permissible tolerance when the gaging notch of the working plug gage is not more than 1½ large or small turns from being flush with the face of the fitting, after correction has been made for any variation in the gage from basic dimensions.

8.8 *Flattening*—Using Test Method D2412, flatten three specimens of pipe 6 in. (152 mm) long between parallel plates in a suitable press until the distance between the plates is 40 % of the original outside diameter of the pipe. The rate of vertical displacement shall be uniform and such that the flattening is completed within 2 to 5 min. Upon removal of the load, examine the specimens for evidence of splitting, cracking, or breaking.

8.9 *Impact Resistance for PVDF Pipe and Fittings*—Determine and test PVDF pipe and fitting impact values in accordance with Test Method D2444, using Tup A and Holder A. The level of impact shall be in accordance with data provided by the manufacturer which shall show impact values for each size at 73°F (23°C) that specifies adequate quality consistent with the PVDF compound used by that manufacturer. Test 10 specimens. When 9 or 10 specimens pass, accept the lot. When 4 or more specimens fail, reject the lot. When 2 or 3 specimens of 10 fail, test 10 additional specimens. When 17 of 20 specimens tested pass, accept the lot. When 7 or more of 20 fail, reject the lot. When 4, 5, or 6 of 20 fail, test 20 additional specimens. When 32 of 40 specimens pass, accept the lot. When 9 or more of 40 specimens fail, reject the lot. Failure in the test specimens shall be shattering or any crack or break extending entirely through the pipe wall visible to the unaided eye.

8.9.1 This test is intended only for use as a quality control test not as a simulated service test.

9. Retest and Rejection

9.1 If the results of any test(s) do not meet the requirements of this specification, the test(s), may be conducted again in accordance with an agreement between the purchaser and the seller. There shall be no agreement to lower the minimum requirements of this specification by such means as omitting tests that are a part of this specification, substituting or modifying a test method, or by changing the specification limits. In retesting, the product requirements of this specification shall be followed. If upon retest, failure occurs, the quantity of product represented by the test(s) does not meet the requirements of this test.

10. Product Marking

10.1 *Quality of Marking*—The markings shall be applied to the fittings and pipe in such a manner that they remain legible under normal handling and installation practices.

10.2 *Content of Marking:*

10.2.1 Fittings shall be marked with the following:

10.2.1.1 Manufacturers name or trademark,

10.2.1.2 Raw material designation and type in accordance with 5.1,

10.2.1.3 If listed, the seal or mark of the laboratory making the evaluation or corrosive waste application, and

10.2.1.4 Size.

10.2.2 Marking on the pipe shall include the following spaced at intervals of not more than 5 ft (1.5 m):

10.2.2.1 Manufacturer's name or trademark,

10.2.2.2 Raw material designation and type in accordance with 5.1,

10.2.2.3 If listed, the seal or mark of the laboratory making the evaluation for corrosive waste application,

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

10.2.2.5 ASME SF-1673 or both ASME SF-1673 and ASTM F1673, and

10.2.2.6 Schedule size (40, 80, or SDR 21), whichever is applicable.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A2.

13. Keywords

13.1 acid waste; corrosion resistance; corrosive waste drainage; drain pipes; installation; joints; laboratory piped services; pipe fittings; pipes; plastic pipes; PVDF (polyvinylidene); traps (drainage); waste disposal (building)

SUPPLEMENTARY REQUIREMENTS

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the producer is responsible for all inspection and test requirements specified herein. The producer may 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of the U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

ANNEXES

(Mandatory Information)

A1. INSTRUCTIONS

A1.1 The manufacturer shall ensure that the equipment and instructions needed for joining the pipe and fittings are readily obtainable by the installer.

A1.2 The PVDF drainage systems shall be installed and supported in accordance with the manufacturer's recommendations.

A2. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

APPENDIXES

(Nonmandatory Information)

X1. STORAGE

X1.1 *Outside Storage*—Plastic pipe should be stored on a flat surface or supported in a manner that will prevent sagging or bending. Do not store pipe in direct sunlight for extended periods of time.

X1.2 Inventories of plastic pipe should be used on a first-in, first-out basis.

X2. JOINING

X2.1 *Field Inspection*—Prior to use, all pipes should be carefully inspected for cuts, gouges, deep scratches, damaged ends, or other major imperfections. Defective pipe should be rejected or the damaged section should be cut out.

X2.2 *Pipe Fit*—Pipe is manufactured to close tolerances to ensure satisfactory fit between the pipe and the fittings socket during assembly. Use only combinations of pipe and fittings that yield manufacturers' recommended fits.

X2.3 Caution must be taken if there is an excess amount of toe-in. This could result in excess clearance and, if not cut off, result in a poor joint.

X2.4 *Cutting*—Pipe may be easily cut with ordinary saws. The pipe shall be cut square and the burrs should be removed with a sharp knife fine-tooth file or other suitable tool, such as a chamfering tool or reamer. If cut with a saw, a miter box should be used to ensure square-cut ends. The use of specially designed plastic pipe cutters with extra-wide rollers and thin-cutting wheels is recommended.

X2.5 *Cleaning*—Remove burrs from inside and outside pipe edges. Wipe off all dust, dirt, and moisture from the surfaces to be joined with a clean dry rag or a paper towel. Pipe and fittings shall be dry before assembly to obtain good pipe joints.

X3. INSTALLATION

X3.1 *Underground Installation*—Underground installation of pipe shall be in accordance with Practice D2321, except aggregate size shall be limited to ½ in. (13 mm) for angular and ¾ in. (19 mm) for rounded particles.

X3.2 *Above-Ground Installation*—The PVDF pipe and fittings are used in applications where the surface flame spread and the smoke density are an important consideration and in applications where high temperatures are required.

X3.3 *DWV Installation*—Pipe shall be installed in conformance with governing building codes. In areas not governed by codes, pipe shall be installed in accordance with accepted engineering practices.

X3.4 *Installation Under Freezing Conditions* —Plastic pipe has decreased resistance to impact under freezing conditions. Increased care shall be exercised if installation is likely to occur under these conditions, particularly during handling, transportation, installation, and backfilling. When possible, installation should be avoided during freezing conditions. Allowance shall be made for expansion that will occur when the temperature of the pipe is raised.

X3.5 *Alignment and Grade*—Align all piping system components properly without strain. Do not bend or pull pipe into position after being joined. The grade of the horizontal drainage and vent piping shall be as specified in the application code.

X3.6 *Supports and Spacing*—Hangers and straps shall not compress, distort, cut, or abrade the piping and shall allow free movement of the piping system. Support horizontal piping in accordance with the manufacturer's recommendations. Supports must allow for free movement of the pipe. Maintain vertical piping in straight alignment, with supports at each floor level or at 10-ft (3.1-m) intervals, whichever is less. Vertical supports shall allow the pipe to move freely.

X3.7 *Threaded Connections*—Do not cut threads on Schedule 40 or SDR 21 pipe. Schedule 80 pipe may be threaded with dies specifically designed for plastic pipe. Molded threads on adapter fittings for transition to threaded connections are necessary, except in the case of cleanout plugs. Only approved thread tape or thread lubricant specifically intended for use with plastic pipe shall be used.

X3.8 *Thread Tightness*—Maximum thread tightness is hand tight plus one full turn.

X3.9 *Connection to Nonplastic Pipe*—When connecting plastic pipe to other types of piping, use only approved type fittings and adapters designed for the specific transition.

X3.10 *Building Drains Under Floor Slabs*—Trench bottoms shall be smooth and of uniform grade with either undisturbed soil or a layer of selected and compacted backfill so that no settlement will occur. The bottom of the pipe shall rest on this material throughout the entire length.

X3.11 *Thermal Expansion*—Allow for thermal expansion and movement in all piping installations by the use of approved methods. Support, but do not rigidly restrain, piping at branches or changes of direction. Do not anchor pipe rigidly in walls or floors. For thermal expansion, consult the manufacturer.

X3.12 *Chemical Resistance*—Before installing a PVDF (polyvinylidene fluoride) corrosive waste piping system, chemical resistance data for the piping material shall be consulted. Take caution when mixing chemicals, as properties can change. If there is a chemical resistance question, consult the manufacturer.

SPECIFICATION FOR BUTT HEAT FUSION POLYAMIDE (PA) PLASTIC FITTING FOR POLYAMIDE (PA) PLASTIC PIPE AND TUBING

SF-1733

(Identical with ASTM F1733-13 except for additional requirements in section 13 and Annex A1, revised marking requirements in para. 11.1.1, and quality assurance requirement in para. 12.1 has been made mandatory.)

Specification for Butt Heat Fusion Polyamide(PA) Plastic Fitting for Polyamide(PA) Plastic Pipe and Tubing

1. Scope

1.1 This specification covers polyamide (PA) butt fusion fittings for use with polyamide pipe (IPS and ISO) and tubing (CTS). Included are requirements for materials, workmanship, dimensions, marking, sustained pressure, and burst pressure.

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 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

NOTE 1—For over 40 years D2513 was the singular US CFR Title 49 Part 192 referenced Standard Specification codifying the installation and use of thermoplastic gas piping in jurisdictional installations. Initially all materials (PE, PVC, ABS, CAB) were contained within the body of the standard D2513. In later years D2513 was completely reformatted to make it more user friendly by moving material-specific requirements from the standard's body to mandatory annexes. The next major change occurred late in 2009 at which time all thermoplastic materials, except polyethylene, were removed from D2513 changing its Title and Scope from a thermoplastic gas piping standard to a polyethylene-only gas piping standard. This recent change required that new standards be developed for those materials that were removed from D2513 including PA11. This causes problems for PA11 piping because it has been referenced and permitted for jurisdictional use and installation under US CFR Title 49 Part 192 as complying with D2513 and D2513 no longer has the A5 polyamide annex and Part 192 still references D2513-99 which makes for potential confusion. This puts PA11 gas piping standards into somewhat of a limbo since D2513 is now a PE-only specification is referenced in all of these standards. Therefore until Part 192 is revised to reference the new PA11 specification, F2945, PA11 has to fall back to citing the US Code referenced 1999 edition of D2513 in related standard such as this one. Until CFR Title 49 Part 192 references the newly developed thermoplastic gas piping standards for those materials removed from D2513, there will be dual references, both D2513–99 and F2945 for PA11, as seen in this standard. At which time Part 192 references F2945, the PA11 gas piping standard, all references to D2513 and this note will be removed from these standards.

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
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2513 Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings
D4066 Classification System for Nylon Injection and Extrusion Materials (PA) (Withdrawn 2012)
D6779 Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)
F412 Terminology Relating to Plastic Piping Systems
F2785 Specification for Polyamide 12 Gas Pressure Pipe, Tubing, and Fittings
F2945 Specification for Polyamide 11 Gas Pressure Pipe, Tubing, and Fittings

2.2 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
CFR Title 49 Part 192 Transportation of Natural and Other Gas By Pipeline: Minimum Federal Safety Standards

2.3 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage

2.4 *National Sanitation Foundation Standard:*
Standard No. 14 for Plastic Piping Components and Related Materials

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *dimension ratio (DR) for thermoplastic pipe*—the ratio of diameter to wall thickness. For this specification it is calculated by dividing the specified outside diameter by the specified wall thickness of the fitting at its area of fusion. DRs are rounded and do not calculate exactly.

4. Classification

4.1 *General*—This specification covers butt fusion fittings intended for use with polyamide pipe and tubing.

4.1.1 Fittings covered by this specification are normally molded. Fittings may be machined from extruded or molded stock.

4.1.2 Fittings fabricated by thermal welding are not included in this specification.

4.1.3 Fittings intended for use in the distribution of natural gas or petroleum fuels shall also meet the requirements of Specification D2513–99 and Specification F2945 for PA11 materials or Specification F2785 for PA12 materials.

5. Ordering Information

5.1 When ordering fittings under this specification, the following should be specified:

5.1.1 Polyamide compound (material designation or trade name)

5.1.2 Style of fitting (tee, 90° ell, and the like)

5.1.3 Size:

5.1.3.1 Nominal diameter.

5.1.3.2 CTS, IPS, or schedule.

5.1.3.3 Dimension ratio number or schedule number.

6. Materials

6.1 *Basic Materials*—This specification covers fittings made from polyamide plastics as defined in Specifications D4066 or D6779.

NOTE 2—The PA plastic fittings 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 National Sanitation Foundation (NSF) Standard No. 14. The seal or mark of the laboratory making the evaluation should be included on the pipe and tubing.

6.2 *Compounds*—The polyamide fittings compounds shall meet the requirements for Group 3, Class 2, and Grade 3, or Group 4, Class 2 and Grade 3 as prescribed in Specifications D4066 or D6779.

NOTE 3—Fittings produced from compounds meeting the requirements of Group 3, Class 2, and Grade 3 (PA 323) are intended for use with pipe manufactured from compounds meeting the requirements of Group 3, Class 2, and Grade 3. Fittings produced from compounds meeting the requirements of Group 4, Class 2, and Grade 3 (PA 423) are intended for use with pipe manufactured from compounds meeting the requirements of Group 4, Class 2, and Grade 3. As per the recommendations of respective resin manufacturers, no cross fusion between PA 323 pipe and fittings and PA 423 pipe and fittings is permitted.

6.3 *Rework Material*—Clean rework material generated from the manufacturer's own production may be used by the same manufacturer as long as the fittings produced conform to the requirements of this specification.

7. Requirements

7.1 *Dimensions and Tolerances:*

7.1.1 *Outside Diameter*—Nominal outside diameters of butt fusion fittings shall conform to the nominal iron pipe size (IPS) or copper tubing size (CTS) dimensions at area of fusion. These dimensions and tolerances shall be as shown in Table 1, Table 2, and Table 3 of this specification.

7.1.2 *Inside Diameter (CTS Fittings Only)*—Inside diameters of butt fusion fittings for tubing at area of fusion shall conform to the dimensions of the tubing being joined. The dimensions and tolerances for the fittings are shown in Table 3.

7.1.3 *Wall Thickness*—The wall thicknesses of butt fusion fittings shall not be less than the minimum specified for the pipe or tubing. The wall thicknesses and tolerances at the area of fusion shall be as shown in Table 3, Table 4, and Table 5 of this specification.

7.1.4 *Measurements*—These shall be made in accordance with Test Method D2122 for roundable pipe.

7.1.5 *Design Dimensions*—Overall fitting dimensions may be as preferred from a design standpoint by the manufacturer and accepted by the purchaser consistent with 7.1.3.

7.2 *Pressure Test Requirements :*

7.2.1 *Short-Term Rupture Strength for Fittings ½ to 12 in. and 90 to 315 mm, Nominal Diameter*—The minimum short-term rupture strength of the fitting and fused pipe or tubing shall not be less than the minimum short-term rupture strength of the pipe or tubing in the system when tested in accordance

TABLE 1 IPS Sizing System Outside Diameters and Tolerances for Fittings for Use with Polyamide Pipe, in.

Nominal Pipe Size	Average Outside Diameter at Area of Fusion[A]	Tolerance
½	0.840	±0.008
¾	1.050	±0.008
1	1.315	±0.010
1¼	1.660	±0.010
1½	1.900	±0.010
2	2.375	±0.010
3	3.500	±0.012
4	4.500	±0.015
6	6.625	±0.018
8	8.625	±0.025
10	10.750	±0.027
12	12.750	±0.036
14	14.000	±0.063
16	16.000	±0.072
18	18.000	±0.081
20	20.000	±0.090
21.5	21.500	±0.097
22	22.000	±0.099
24	24.000	±0.108
28	28.000	±0.126
32	32.000	±0.144
36	36.000	±0.162
42	42.000	±0.189
48	48.000	±0.216

[A] Defined as measured ¼ in. (6.4 mm) from fitting outlet extremity.

TABLE 2 ISO Sizing System (ISO 161/1) Outside Diameters and Tolerances for Fit for Use with Polyamide Pipe, (mm)

Nominal Pipe Size	Average Outside Diameter at Area of Fusion	
	Min	Max[A]
90	90.0	90.8
110	110.0	111.0
160	160.0	161.4
200	200.0	201.8
250	250.0	252.3
280	280.0	282.5
315	315.0	317.8
355	355.0	358.2
400	400.0	403.6
450	450.0	454.1
500	500.0	504.5
560	560.0	565.0
630	630.0	635.7
710	710.0	716.4
800	800.0	807.2
900	900.0	908.1
1000	1000.0	1009.0
1200	1200.0	1210.8
1400	1400.0	1412.6
1600	1600.0	1614.4

[A] Specified in ISO 3607.

with 10.5.3. These minimum pressures shall be as shown in Table 6 of this specification. Test specimens shall be prepared for testing in the manner described in 10.5.1 of this specification. The test equipment, procedures, and failures definitions shall be as specified in Test Method D1599.

7.2.2 *Short-Term Strength for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—Fittings shall not fail when tested in accordance with 10.5.3. The minimum pressure shall be as shown in Table 6 of this specification. Test specimens shall be prepared for testing in the manner described in 10.2 of this specification. The test equipment and procedures shall be as specified in Test Method D1599.

7.2.3 *Sustained Pressure*—The fitting and fused pipe or tubing shall not fail, as defined in Test Method D1598, when tested at the time, pressures, and test temperatures selected from test options offered in Table 7. The test specimens shall be prepared for testing in the manner prescribed in 10.5.1.

8. Workmanship, Finish, and Appearance

8.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions, or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

9. Sampling

9.1 Parts made for sale under this specification should be sampled at a frequency appropriate for the end use intended. When the fittings are to be installed under a system specification the minimum requirements of that specification must be satisfied.

10. Test Methods

10.1 *General*—The test methods in this specification cover fittings to be used with pipe and tubing for gas, water, and other engineered piping systems. Test methods that are applicable from other specifications will be referenced in the paragraph pertaining to the particular test. Certain special test methods applicable to this specification only are explained in the appropriate paragraph.

10.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) for not less than 6 h in air, or 1 h in water, for those tests where conditioning is required and in all cases of disagreement. Newly molded fittings shall be conditioned 40 h prior to test.

10.3 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified.

10.4 *Dimensions and Tolerances:*

10.4.1 *Outside Diameter*—Measure the outside diameter of the fittings at the area of fusion in accordance with the Wall Thickness section of Test Method D2122 by use of a circumferential tape readable to the nearest 0.001 in. (0.02 mm).

10.4.2 *Inside Diameter (CTS Fittings Only)*—Use a stepped plug gage to determine the inside diameter of the CTS end of the fitting. The plug gage shall be of the go/no go type and shall have ½-in. (12.7-mm) land lengths cut to the minimum inside diameter and maximum inside diameter. A fitting is unacceptable (no go) if it fits snugly on the minimum inside diameter land of the gage or if it fits loosely on the maximum diameter land of the gage.

10.4.3 *Wall Thickness*—Make a series of measurements using a cylindrical anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thicknesses to the nearest 0.001 in. (0.02 mm) have been determined. Make a minimum of six measurements at each cross section.

10.5 *Pressure Testing:*

10.5.1 *Preparation of Specimens for Pressure Testing*—Prepare test specimens in such a manner that each, whether individual fittings or groups of fittings, is a system incorporating at least one length of pipe or tubing. Fuse all fitting outlets with the appropriate size pipe or tubing. At least one piece of pipe or tubing in the system shall have a minimum length equal to five pipe diameters.

10.5.2 *Sustained Pressure Test:*

10.5.2.1 Select the test temperature and pressures from one of the options offered in Table 7.

10.5.2.2 Select the test specimens at random and condition at the selected option test temperature. Test the fitting specimens with water, in accordance with Test Method D1598 at the selected option, stress, and hours of testing.

NOTE 4—Other test mediums and test conditions than offered in Table 7 may be used as agreed upon between the manufacturer and the purchaser.

10.5.2.3 Test six specimens at the selected option conditions and time.

TABLE 3 Diameter, Wall Thickness, and Tolerances for Fittings for Use with Polyamide Tubing

Tubing Type, in. (mm)	Nominal Tubing Size, in.	Diameter at Area of Fusion[A]				Minimum Wall Thickness, in. (mm)
		Outside, in. (mm)		Inside, in. (mm)		
		Average	Tolerance	Average	Tolerance	
0.062 (1.57)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.495 (12.58)	±0.004 (±0.10)	0.062 (1.58)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.745 (18.92)	. . .	. . .
0.090 (2.29)	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.437 (11.10)	±0.004 (±0.10)	0.090 (2.28)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.687 (17.44)	±0.004 (±0.10)	0.090 (2.28)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.937 (23.80)	±0.005 (±0.12)	0.090 (2.28)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.187 (30.14)	±0.005 (±0.12)	0.090 (2.28)
DR 11	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.715 (18.16)	±0.004 (±0.10)	0.077 (1.96)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.915 (23.24)	±0.005 (±0.12)	0.101 (2.56)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.125 (28.58)	±0.005 (±0.12)	0.121 (3.08)
DR 9.3	½ CTS	0.625 (15.88)	±0.010 (±0.26)	0.483 (12.26)	±0.004 (±0.10)	0.067 (1.70)
	¾ CTS	0.875 (22.22)	±0.010 (±0.26)	0.679 (17.24)	±0.004 (±0.10)	0.094 (2.38)
	1 CTS	1.125 (28.58)	±0.013 (±0.34)	0.873 (22.18)	±0.005 (±0.12)	0.121 (3.08)
	1¼ CTS	1.375 (34.92)	±0.013 (±0.34)	1.069 (27.16)	±0.005 (±0.12)	0.148 (3.76)

[A] Defined as measured ¼ in. (6.4 mm) from fitting outlet extremity.

TABLE 4 IPS Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyamide Pipe, in.[A,B,C]

Nominal Pipe Size	Minimum Wall Thickness									
	SCH 40	SCH 80	SDR 21	SDR 17	SDR 13.5	DR 10	DR 11.5	SDR 11	DR 9.3	SDR 9
½	0.109	0.147	. . .	. . .	. . .	. . .	. . .	0.076	0.090	. . .
¾	0.113	0.154	. . .	. . .	. . .	. . .	. . .	0.095	0.113	0.117
1	0.133	0.179	. . .	. . .	. . .	. . .	. . .	0.119	0.142	0.146
1¼	0.140	0.191	. . .	. . .	. . .	0.166	. . .	0.151	0.179	0.184
1½	0.145	0.200	. . .	. . .	. . .	. . .	. . .	0.173	0.204	0.211
2	0.154	0.218	. . .	. . .	. . .	. . .	. . .	0.216	0.256	0.264
3	0.216	0.300	. . .	. . .	0.259	. . .	0.305	0.318	0.377	0.389
4	0.237	0.337	. . .	0.264	0.333	. . .	0.392	0.409	0.484	0.500
6	0.280	0.432	0.316	0.390	0.491	. . .	0.576	0.603	0.713	0.736
8	0.322	. . .	0.410	0.508	0.639	. . .	0.750	0.785	0.928	0.958
10	0.365	. . .	0.511	0.633	0.797	. . .	0.935	0.978	1.156	1.194
12	0.406	. . .	0.608	0.750	0.945	. . .	1.109	1.160	1.371	1.417
14	. . .	. . .	0.667	0.824	. . .	. . .	. . .	1.273	1.505	1.556
16	. . .	. . .	0.762	0.941	. . .	. . .	. . .	1.455	1.720	1.778
18	. . .	. . .	0.857	1.059	. . .	. . .	. . .	1.636	1.935	2.000
20	. . .	. . .	0.952	1.176	. . .	. . .	. . .	1.818	2.151	2.222
21.5	. . .	. . .	1.024	1.265	. . .	. . .	. . .	. . .	. . .	. . .
22	. . .	. . .	1.048	1.294	. . .	. . .	. . .	2.000	2.366	2.444
24	. . .	. . .	1.143	1.412	. . .	. . .	. . .	2.182	2.581	. . .
28	. . .	. . .	1.333	1.647	. . .	. . .	. . .	2.545	. . .	. . .
32	. . .	. . .	1.524	1.882	. . .	. . .	. . .	2.909	. . .	. . .
36	. . .	. . .	1.714	2.118	. . .	. . .	. . .	. . .	. . .	. . .
42	. . .	. . .	2.000	2.471	. . .	. . .	. . .	. . .	. . .	. . .
48	. . .	. . .	2.286	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapping thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001 in.

10.5.2.4 Failure of two of the six specimens tested shall constitute failure of the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure of the test.

10.5.3 *Minimum Hydrostatic Burst Pressure for Fittings ½ to 12 in. and 90 to 315 mm, Nominal Diameter*—The test equipment, procedures, and failure definitions shall be as specified in Test Method D1599. The hydrostatic pressure shall be increased at a uniform rate such that the specimen fails between 60 and 70 s from start of the test. Minimum failure pressures are shown in Table 6.

10.5.4 *Minimum Hydrostatic Pressure for Fittings 14 to 48 in. and 355 to 1600 mm, Nominal Diameter*—The test equipment and procedures shall be as specified in Test Method D1599. The hydrostatic pressure shall be increased at a uniform rate such that the test pressure is reached within 60 to 70 s from the start of the test. No failure should occur in the sample during the test period.

11. Product Marking

11.1 Fittings shall be marked with the following:

11.1.1 ASME SF-1733 or both ASME SF-1733 and ASTM F1733,

11.1.2 Manufacturer's name or trademark,

11.1.3 Material designations (such as PA32312)

TABLE 5 ISO Sizing System Wall Thickness and Tolerance at the Area of Fusion for Fittings for Use with Polyamide Pipe, (mm)[A,B,C]

Nominal Pipe Size	Minimal Wall Thickness					
	DR 41	DR 32.5	DR 26	DR 21	DR 17	DR 11
90	. . .	. . .	3.5	4.3	5.3	8.2
110	. . .	3.4	4.2	5.2	6.5	10.0
160	. . .	4.9	6.2	7.6	9.4	14.5
200	. . .	6.2	7.7	9.5	11.8	18.2
250	. . .	7.7	9.6	11.9	14.7	22.7
280	. . .	8.6	10.8	13.3	16.5	25.5
315	. . .	9.7	12.1	15.0	18.5	28.6
355	. . .	10.9	13.7	16.9	20.9	32.3
400	. . .	12.3	15.4	19.0	23.5	36.4
450	. . .	13.8	17.3	21.4	26.5	. . .
500	. . .	15.4	19.2	23.8	29.4	. . .
560	. . .	17.2	21.5	26.7	32.9	. . .
630	. . .	19.4	24.2	30.0	37.1	. . .
710	. . .	21.8	27.3	33.8	41.8	. . .
800	. . .	24.6	30.8	38.1	47.1	. . .
900	. . .	27.7	34.6	42.9	. . .	. . .
1000	24.4	30.8	38.5	47.6	. . .	. . .
1200	29.3	36.9	46.2	. . .	. . .	. . .
1400	34.1	43.1	. . .	. . .	. . .	. . .
1600	39.0	49.2	. . .	. . .	. . .	. . .

[A] Tolerance +20 %, −0 %.
[B] For those SDR groups having overlapped thickness requirements, a manufacturer may represent their product as applying to the combination (for example, 11.0/11.5) so long as their product falls within the dimensional requirements of both DR's.
[C] For wall thicknesses not listed the minimum wall thickness may be calculated by the average outside diameter/SDR rounded up to the nearest 0.001.

11.1.4 Date of manufacture or manufacturing code,

11.1.5 Size, and

11.1.6 For PA 32312 fittings:
"for fusion to PA 32312 (PA11) pipe only"
For PA 42316 fittings:
"for fusion to PA 42316 (PA12) pipe only."

11.2 Where the physical size of the fitting does not allow complete marking, marking may be omitted in the following sequence: size, date of manufacture, material designation, manufacturer's name or trademark.

11.3 Where recessed marking is used, take care not to reduce the wall thickness below the minimum specified.

12. Quality Assurance

12.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

13. Certification

13.1 Certification shall be as required by Annex A1.

TABLE 6 Minimum Burst Pressure Requirements at 73.4°F for Common Fitting Sizes[A]

Wall Thickness, DR, or Schedule	Nominal Diameter	Minimum Pressure, psi
DR 7	ALL[B]	1300
SDR 9	ALL[B]	975
DR 9.3	ALL[B]	945
SDR 11	ALL[B]	775
DR 11.5	ALL[B]	745
DR 15.5	ALL[B]	540
SDR 17	ALL[B]	495
SDR 21	ALL[B]	385
DR 32.5	ALL[B]	250
0.062 in. (1.575 mm)	½ CTS	860
0.062 in. (1.575 mm)	¾ CTS	590
0.062 in. (1.575 mm)	1 CTS	450
0.090 in. (2.286 mm)	½ CTS	1315
0.090 in. (2.286 mm)	¾ CTS	700
0.090 in. (2.286 mm)	1 CTS	650
0.090 in. (2.286 mm)	1¼ CTS	540
SCH 40	½ IPS	1160
SCH 40	¾ IPS	930
SCH 40	1 IPS	880
SCH 40	1¼ IPS	710
SCH 40	1½ IPS	650
SCH 40	2 IPS	590
SCH 40	3 IPS	510
SCH 40	4 IPS	435
SCH 40	6 IPS	340
SCH 40	8 IPS	310
SCH 40	10 IPS	280
SCH 40	12 IPS	265
SCH 40	16 IPS	255
SCH 40	20 IPS	240

[A] Fiber stress of 3900 psi (27 MPa) for PA32312 and PA42316.
[B] Refers to IPS and ISO diameters shown in Table 1 and Table 2.

TABLE 7 Sustained Pressure Test Options, psig (MPa)

SDR/DR	Option 1[A, B] 73°F (23°C)/1000 h	Option 2[C, B] 176°F (80°C)/170 h
DR 7	935 (6.5)	485 (3.3)
SDR 9	700 (4.8)	360 (2.5)
SDR 11	560 (3.9)	290 (2.0)
DR 15.5	385 (2.7)	200 (1.4)
SDR 17	350 (2.4)	180 (1.2)
SDR 21	280 (1.9)	145 (1.0)
DR 32.5	180 (1.2)	90 (0.6)

[A] Sustained pressure is based on stress of 2800 psi (19 MPa).
[B] All psig values were rounded to nearest 5 psig.
[C] Sustained pressure is based on stress of 1450 psi (10 MPa).

SUPPLEMENTARY REQUIREMENTS

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply *only* to federal/military procurement, not domestic sales or transfers.

S1. *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 may 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 S1.1—In U.S. federal contracts, the contractor is responsible for inspection.

S2. *Packaging and Marking for U.S. Government Procurement:*

S2.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S2.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE S2.1—The inclusion of U.S. Government procurement requirements should not be construed as an indication that the U.S. Government uses or endorses the products described in this specification.

POTABLE WATER REQUIREMENT

This requirement applies whenever a Regulatory Authority or user calls for the product to be used to convey or to be in contact with potable water.

S3. Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 or the health effects portion of NSF Standard 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR PLASTIC MECHANICAL FITTINGS FOR USE ON OUTSIDE DIAMETER CONTROLLED POLYETHYLENE GAS DISTRIBUTION PIPE AND TUBING

SF-1924

(Identical with ASTM F1924-12 except for additional requirements in section 11 and Annex A1, revised marking requirements in para. 9.1.1, renumbering of section 12, and quality assurance requirement in para 10.1 has been made mandatory.)

Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing

1. Scope

1.1 This specification describes requirements and test methods for the qualification of plastic bodied mechanical fittings for use with outside diameter controlled polyethylene (PE) gas distribution pipe, nominal 2 pipe size (IPS) and smaller complying with Specification D2513. In addition, it specifies general requirements of the material from which these fittings are made.

1.2 The test methods described in this specification are not intended to be used as routine quality control tests.

1.3 This specification covers the types of mechanical fittings described in 3.2.

1.4 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.

1.5 The following safety hazards 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*

D638 Test Method for Tensile Properties of Plastics

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

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

F412 Terminology Relating to Plastic Piping Systems

F1588 Test Method for Constant Tensile Load Joint Test (CTLJT)

F2897 Specification for Tracking and Traceability Encoding System of Natural Gas Distribution Components (Pipe, Tubing, Fittings, Valves, and Appurtenances)

2.2 *ASME Standard:*

ASME B31.8 Gas Transmission and Distribution Piping Systems

2.3 *Federal Standard:*

CFR, Title 49, Part 192 Pipeline Safety Regulations

2.4 *Plastics Pipe Institute Standard:*

PPI TR-4 Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Pipe and Fittings Compounds

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification are in accordance with Terminology F412 unless otherwise specified. Abbreviations are in accordance with Terminology D1600 unless otherwise specified.

3.1.1 The Gas Industry terminology used in this specification is in accordance with ASME B31.8 or CFR, Title 49, Part 192 unless otherwise indicated.

3.1.2 The term "pipe" used herein refers to both "pipe" and "tubing" unless specifically stated otherwise. The term "fitting" refers to a mechanical connecting device as described in 3.1.4 and 3.1.6.

3.1.3 *joint, n*—the location at which two pieces of pipe, or a pipe and a fitting are connected together, for example, an installed coupling has two joints.

3.1.4 *joint, mechanical, n*—a connection between piping components employing physical force to develop a seal or produce alignment.

3.1.5 *long-term strength (LTS), n*—the estimated tensile stress that when applied continuously will cause failure at 100 000 h. This is the intercept of the stress regression line with the 100 000 h coordinate.

3.1.6 *mechanical fitting, n*—fitting for making a mechanical joint to provide for pressure integrity, leak tightness, and depending on category, as defined in this specification, resistance to end loads.

3.1.6.1 *category 1 mechanical fitting, n*—fitting for assembling pipes, which includes a compression zone(s) to provide for pressure integrity, leak tightness, and resistance to end loads sufficient to cause no less than 25 % elongation of the PE piping as described in this specification.

3.1.6.2 *category 2 mechanical fitting, n*—fitting for assembling pipes, which includes a compression zone(s) to provide for pressure integrity and leak tightness only. Category 2 fittings do not provide for resistance to end loads.

3.1.7 *MAOP, n*—the Maximum Allowable Operating Pressure of the fuel gas piping system, in psig, as determined in accordance with CFR, Title 49, Part 192.121 and as represented in the following:

$$MAOP = P = 2 \times S/(R - 1) \times f_D \tag{1}$$

where:

S = the PE material's HDB as published in PPI TR-4,
R = the pipe's dimension ratio determined by dividing the pipe's specified nominal outside diameter by the pipes specified nominal wall thickness; and,
f_D = the design (derating) factor for thermoplastic fuel gas piping as set by the authority having jurisdiction. In the United States the design factor is cited in CFR, Title 49 Part 192.121.

3.2 *Types of Mechanical Fittings:*

3.2.1 *in-line fitting, n*—mechanical fitting used to make a mechanical joint where the bore axis of the compression and sealing zones of the fitting is essentially the same as the connected piping, for example, couplings, ells, and tees.

3.2.2 *mechanical saddle fitting, n*—mechanical fitting used to make a mechanical joint that allows a lateral connection to an existing main in which a portion of the fitting is contoured to match the O.D. of the pipe to which it is attached. Herein referred to as the *saddle fitting mating pipe*.

4. Materials and Manufacture Requirements

4.1 Plastic pressure containing materials subject to continuous stress, either hoop or axial, shall have an ASTM material specification, and the materials long-term strength, such as the long-term hydrostatic strength, determined in accordance with Test Method D2837, excepting that failure data can be obtained from specimens such as the following: tensile bars, plane strain, or actual fitting samples. A material listing in PPI TR-4 document is evidence of compliance with this paragraph for third party certifying and listing agencies.

4.2 The physical properties of each material used to produce the fitting shall be available from the fitting manufacturer upon request.

4.3 Specifications outlining all the physical properties and effects of environmental conditions for materials of manufacture shall be available from the fitting manufacturer upon request.

NOTE 1—Materials in long-term contact with natural gas of line quality and LP gas vapor should be demonstrated not to adversely affect the performance of the fitting.

NOTE 2—Materials should have a demonstrated resistance to environmental stress cracking when exposed, under stress, to chemical compounds encountered in, or external to gas piping systems, and a demonstrated resistance to bacteriological decomposition. Such compounds include, but are not limited to, ice thawing chemicals, fertilizers, insecticides, herbicides, leak detection fluids, acids, bases and antifreeze solutions used to thaw frozen lines. The effects of liquid environments, such as antifreeze agents, odorants, and hydrocarbons are known to be deleterious to some plastics, particularly when under service conditions.

5. Dimensions

5.1 The dimensions and tolerances shall be determined by the manufacturer.

6. Qualification Requirements

6.1 *General*—Unless otherwise specified, each nominal size of fitting shall be tested. Testing of the thickest wall pipe that the fitting is designed to be used with qualifies the use of that fitting with pipe of lesser wall thickness.

6.1.1 Mechanical joint qualifications shall be performed on assembled joints using the fitting manufacturer's joining procedure. All mechanical fittings offered by the manufacturer shall be capable of meeting the requirements of this standard when connecting polyethylene gas piping complying with Specification D2513. To verify the structural integrity of the fitting body, representative samples shall be subjected to the requirements of 6.2.1. It is not the intent of this specification to require testing of all fitting configurations, that is, tees, ells, etc., but each mechanical joint design in each size.

6.1.2 All mechanical fittings described in 3.2 shall have an internal pipe reinforcing tubular insert stiffener that extends at least under the seal and gripping device, where used. The saddle portion of saddle-type fittings do not require an internal tubular stiffener due to the nature of the connection.

6.2 *Performance Requirements:*

6.2.1 *Elevated Temperature Sustained Pressure*—The fitting, joint or pipe in the area affected by the fitting shall not fail as defined in Test Method D1598, when tested in accordance with 7.2. The fitting or joint meets this requirement when tested in accordance with any one of the three conditions (A, B, or C) listed in 7.2.

6.2.2 *Tensile Strength*—The pipe joint shall accommodate the tensile loadings when tested in accordance with 7.3.

6.2.2.1 *In-Line Fittings, Category 1*—The joint shall provide resistance to a force on the pipe joint equal to or greater than that which will cause no less than 25 % elongation of pipe, or the pipe fails outside the joint area when tested in accordance with 7.3.

6.2.2.2 *In-Line Fittings, Category 2*—A joint design that provides a seal only. A mechanical joint designed for this category excludes any provisions in the design of the joint to resist any axial pullout forces; therefore, tensile tests are not required.

6.2.2.3 *Mechanical Saddle Fittings*—The joint between the saddle and mating pipe shall not fail by rotation or leakage when tested in accordance with 7.6.

6.2.2.4 Joint restraint capabilities less than as defined above shall constitute failure of the test.

6.2.3 *Temperature Cycling Test*—The mechanical joint shall provide a pressure seal after 10 cycles of the temperature cycling test when tested in accordance with 7.4.

6.2.4 *Constant Tensile Load Joint Test*— The joint shall not fail by leakage or pullout when loaded to an axial tensile stress of 1320 psi (9.1 MPa) and tested in accordance with 7.5.

7. Test Methods

7.1 *General*—The test methods in this specification cover mechanical joint designs. Test methods that are applicable from other specifications will be referenced in the section pertaining to that particular test.

7.1.1 *Conditioning*—Unless otherwise specified, condition the specimens (pipe and fittings) prior to joining at 73.4 ± 3.6° F (23 ± 2° C) for not less than 16 h.

7.1.2 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6° F (23 ± 2° C) unless otherwise specified.

7.1.3 *Test Specimens*—Test joints shall be prepared with the appropriate size PE pipe, complying with the dimensional requirements of Specification D2513, in accordance with the manufacturer's joining procedures.

7.2 *Elevated Temperature Sustained Pressure Test:*

7.2.1 The apparatus and report shall be as specified in Test Method D1598. Test six joints assembled in accordance with 6.1.1.

7.2.2 The assembled joints shall be tested in accordance with Test Method D1598 with the exception that it is not required that 12 in. or five times the nominal outside diameter of the pipe used in conducting the test be placed on each side of the fitting being tested. The test shall be conducted at one of the time/temperature/hoop stress combinations shown in Table 1 with the test pressure calculated using Eq 2. If ductile failure occurs in the pipe at 176°F (80°C)/670 psi (4.6 MPa) hoop stress, retest at 176°F (80°C)/580 psi (4.0 MPa) hoop stress.

TABLE 1 Elevated Temperature Sustained Pressure Test Conditions

Condition	Minimum Time	Temperature	Pipe Hoop Stress, S
A	3 000 h	140±3.6°F (60± 2°C)	1 000 psi (6.8 MPa)
B	1 000 h	176±3.6°F (80± 2°C)	580 psi (4.0 MPa)
C	170 h	176±3.6°F (80± 2°C)	670 psi (4.6 MPa)

$$P = \frac{2S}{DR - 1} \tag{2}$$

where:

P = test pressure, psig,
S = hoop stress from Table 1, and
DR = dimension ratio (OD/wall).

7.2.3 Failure of two of the six specimens tested shall constitute failure in the test. Failure of one of the six specimens tested is cause for retest of six additional specimens. Failure of one of the six specimens in retest shall constitute failure of the test. Evidence of failure of the pipe shall be as defined in Test Method D1598.

7.3 *Tensile Strength Test:*

7.3.1 Test specimens shall be prepared so that the minimum length of unreinforced pipe is equal to five times the nominal outside diameter of the pipe being tested. It is permissible to test multiple joints together provided the minimum length of unreinforced pipe (as stated above) exists on at least one joint.

7.3.2 In-line fittings shall be tested with the apparatus and reported as specified in Test Method D638. Test six joints.

7.3.3 The test shall be conducted at 73.4 ± 3.6°F (23 ± 2°C).

7.3.4 The speed of the testing shall be 0.2 in. (5 mm)/min± 25 %.

7.3.5 Failure of any sample shall constitute failure of the test.

7.4 *Temperature Cycling Test:*

7.4.1 Tests shall be conducted on six of the smallest and six of the largest nominal pipe sizes of each mechanical joint design and assembled in accordance with 6.1.1.

7.4.2 Leak test specimens at ambient at 7 ± 3 psig and a minimum of 1.5 × MAOP.

7.4.3 Cool specimens to a temperature of −20 ± 3.6°F (−29 ± 2°C) and maintain for a minimum of 2.5 h.

7.4.4 Condition specimens to a temperature of 140 ± 3.6°F (60 ± 2°C) and maintain for a minimum of 2.5 h.

7.4.5 Repeat 7.4.3 and 7.4.4 for a total of 10 cycles.

7.4.6 Pressurize 50 % of the speciments of each size at 7 ± 3 psig and the remaining 50 % of each size at 1.5× MAOP of the piping material and SDR that the fittings are designed to be used with. Leak test first at 140 ± 3.6°F (60 ± 2°C) and then at −20 ± 3.6°F (−29 ± 2°C).

NOTE 3—If immersion is used for leak testing, and the design of the joint is such that air can be trapped within the joint assembly, allow adequate time for all air trapped within the joint to escape prior to observing for leaks.

7.5 *Constant Tensile Load Joint Test (In-Line Joints Only):*

7.5.1 One specimen of each nominal pipe size shall be tested in accordance with Test Method F1588 for a minimum of 1000 h at an internal pressure between 4 psig (27.6 kPa) and the pipe MAOP.

7.5.2 Failure of the specimen shall constitute failure of the test.

7.6 *Rotation Test (Mechanical Saddle Fittings Only):*

7.6.1 Test shall be conducted on six of the smallest and six of the largest nominal pipe sizes of each mechanical joint design and assembly assembled in accordance with 6.1.1.

7.6.2 The test shall be conducted at 73.4 ± 3.6°F (23 ± 2°C).

7.6.3 Saddle fittings shall be assembled onto the mating pipe so that the minimum length of unreinforced pipe is equal to five times the nominal diameter of the pipe to which the saddle is being installed.

7.6.4 Following the manufacturer's recommended procedure for installing saddle fittings, tap the mating pipe and remove the saddle fitting cutter.

7.6.5 Alignment marks shall be placed on both the saddle fitting and the mating pipe to identify the original position of the assembly.

7.6.6 Either the saddle fitting, or the mating pipe, shall be restrained in a manner that does not affect the saddle fitting joint.

7.6.7 A torque shall be applied to the unrestrained component of the assembly and a torsion load applied about the centerline of the mating pipe.

7.6.8 The saddle fitting assembly shall be capable of withstanding the torsion loads indicated in Table 2 without the saddle fitting rotating relative to the mating pipe or adversely affecting the integrity of the joint.

7.6.9 Following rotation testing, leak test in accordance with the following. Pressurize each saddle tee joint at 7 ± 3 psig (48.3 ± 20.7 kPa) and at a minimum of 1.5 × MAOP of the pipe on which they are being tested.

7.6.10 Observe the joint for leakage for 2 to 3 min at each pressure.

7.6.11 The joint shall be bubble tight when tested with leak detection soap, liquid immersion, or other equivalent methods.

7.6.12 Failure of any of the six samples tested shall constitute failure of the test.

NOTE 4—The rotation test is intended to qualify only the joint between the saddle fitting and the mating pipe, not the lateral connection coming from the saddle fitting. It is the intent of this specification that the lateral connection joint design will be qualified by virtue of utilizing a design similar to an in-line fitting and capable of meeting the requirements for in-line fittings contained within this specification.

8. Product Instructions

8.1 Qualified installation instructions shall be available from the manufacturer and supplied with the fitting.

TABLE 2 Rotation Test Torsion Load Requirements

Main Pipe Size	Minimum Torsion Load
NPS 1¼	30 ft-lbf (40.7 N · m)
NPS 2 and larger	50 ft-lbf (67.8 N · m)

9. Product Marking

9.1 Fittings shall be marked with the following:

9.1.1 ASME SF-1924 or both ASME SF-1924 and ASTM F1924.

9.1.2 Two or three letter coded plastic material identification, in accordance with PPI TR-4 or the equivalent.

9.1.3 Date or lot code identification.

9.1.4 Manufacturer's name or trademark.

9.1.5 Size, followed by "IPS" or "CTS" designation, and SDR or wall thickness range.

9.1.6 The word "gas", or if space does not permit, the letter "G".

9.1.7 Category 1 or Category 2 abbreviation is permitted as CAT1 or CAT2.

9.1.8 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices. If indentation is used, it shall be demonstrated that these marks have no affect on the long term strength of the fitting.

9.1.9 Fittings manufactured from materials listed in Specification D2513 and intended for use with natural gas at elevated temperatures greater than 73°F (23°C) shall be marked with additional code letters from Table 4 of Specification D2513 the first code letter to identify the temperature of the pressure rating, and a second code letter to identify HDB at the highest recommended temperature.

9.2 Fittings intended for transport of natural gas and meeting the requirements of this specification shall be marked with the 16- character gas distribution component tracking and traceability identifier in accordance with F2897. The 16-character code shall be expressed in alpha-numeric format and Code 128 bar code format with a minimum bar thickness value of 0.005 in. or an alternative **1D** or **2D** bar code symbology, as agreed upon between manufacturer and end user. All fittings shall have the 16-character codes marked or affixed to the product, product packaging, or any manner agreed upon between manufacturer and end user.

10. Quality Assurance

10.1 The manufacturer affirms that the product is manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

11. Certification

11.1 Certification shall be as required by Annex A1.

12. Keywords

12.1 gas; mechanical saddle fitting ; plastic mechanical fitting; polyethylene pipe; rotation test; temperature cycling test

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR SPECIAL ENGINEERED FITTINGS, APPURTENANCES OR VALVES FOR USE IN POLY (VINYL CHLORIDE) (PVC) OR CHLORINATED POLY (VINYL CHLORIDE) (CPVC) SYSTEMS

SF-1970

(Identical with ASTM F1970-12e1 except for additional requirements in section 13 and Annex A1, revised marking requirements in para. 11.1.7, renumbering of section 14, and quality assurance requirement in para. 12.1 has been made mandatory.)

Specification for
Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Systems

1. Scope

1.1 This specification covers fittings, appurtenances and valves which are to be used with pipe and tubing complying with Specifications D1785, D2241, D2846/D2846M, F441/F441M or F442/F442M, or other piping as specified by the fittings manufacturer. These products, such as unions, flanges or valves, are not included in the scope of existing ASTM specifications. This specification includes minimum requirements for testing, materials, dimensions, workmanship, marking, and in-plant quality control.

1.2 Fittings or appurtenances covered by this specification are generally either molded, fabricated, or assembled from molded or machined components. The materials used in components include rigid thermoplastics, thermoplastic elastomers, elastomerics, and metals. The body or main portion of the fitting, appurtenance or valve is typically PVC, CPVC, PE or PA (nylon). All products covered by this standard are intended to be used in PVC or CPVC plastic piping systems, or as a transition from these to metal systems.

1.3 The application of these products to gas service is beyond the scope of this specification.

1.4 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing.

NOTE 1—**Warning:** Pressurized (compressed) air or other compressed gases contain large amounts of stored energy which present serious safety which present serious safety hazards should a system fail for any reason.

1.5 Fittings which rely on heat fusion welding for connection to the piping system are outside the scope of this specification.

1.6 Check valves (including foot valves) covered by this specification shall not be considered backflow prevention devices and shall not be used for the protection of a potable water supply. For definitions and requirements of backflow prevention devices, consult model plumbing codes and ASSE.

1.7 Due to the complex and installation-specific concerns surrounding chemical resistance and corrosion, this specification does not address the compatibility of the products with all possible end-use environments. Additional testing specific to the end-use environment is recommended if the system is conveying liquids other than potable water.

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

1.9 The following safety caveat applies only to the test methods and in-plant quality control portions, section 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

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
D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
D1898 Practice for Sampling of Plastics (Withdrawn 1998)
D2000 Classification System for Rubber Products in Automotive Applications
D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
D2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
D2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
D2467 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D2846/D2846M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems
F412 Terminology Relating to Plastic Piping Systems
F438 Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40
F439 Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
F441/F441M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
F442/F442M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe (SDR–PR)
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings

2.2 *ASME Standards:*
B1.20.1 Pipe Threads, General Purpose (Inch)
B16.5 Pipe Flanges and Flanged Fittings

2.3 *NSF Standards:*
NSF 14 Plastics Piping Components and Related Materials
NSF 61 Drinking Water System Components - Health Effects

2.4 *ISA Standard:*
ISA S75.02 Control Valve Capacity Test Procedure

2.5 *ASQ Standard:*
ANSI/ASQ Z1.4 Sampling Procedures and Tables for Inspection by Attributes

3. Terminology

3.1 *General*—Definitions are in accordance with the Definitions in F412 and abbreviations are in accordance with D1600 unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *activation pressure*—the activation pressure of a check valve is that inlet pressure, exceeding the outlet pressure, required to open the check valve and allow water to flow.

3.2.2 *appurtenances*—accessories of a plastic piping system designed for special applications or end-uses. Appurtenances may include, but are not limited to pipes, fittings, valves, storage tanks, mechanical devices and expansion tanks.

3.2.3 *connections*—the portion of the fitting intended to join the fitting with the rest of the piping system (see 5.1).

3.2.4 *CTS*—abbreviation for "copper tube size", indicating an outside-diameter controlled tubing with outside diameter dimensions meeting the tube specifications given in Specification D2846/D2846M.

3.2.5 *IPS*—abbreviation for "iron pipe size", indicating an outside-diameter controlled tubing with outside diameter dimensions meeting the requirements of schedule 40 pipe (see Specification D1785 for dimensions of schedule 40 pipe).

3.2.6 *lot size*—the total number of completely finished fittings or appurtenances that are manufactured under conditions of production that are considered uniform.

3.2.7 *referee test*—testing conducted to compare performance of the product against all requirements of this specification. In-plant QC testing is not considered referee testing.

4. Materials and Manufacture

4.1 The elastomeric seals designed for push-on joints, which require no internal or external pressure to effect the initial seal, shall comply with the requirements of Specification F477, Table 1 for thermoset, Table 2 for thermoplastic.

4.2 All other elastomeric seals shall be designed to meet the product performance requirements stated within this document and be specified in accordance with Classification D2000.

4.3 Materials used in components which provide structural integrity of the fitting or appurtenance shall meet the requirements of 4.3.1, 4.3.2, or 4.4.

NOTE 2—Components which provide structural integrity include the body; connections such as sockets, compression joint components, saddles, and flanges.

4.3.1 PVC materials shall meet the minimum requirements for a cell-classification of 12454, 13354, 11443 or 14333 as defined by Specification D1784.

4.3.2 CPVC materials shall meet the minimum requirements for a cell-classification of 23447 or 23448 as defined in Specification D1784.

4.4 *Rework Material*— The manufacturers shall use only their own clean rework fitting material and the fittings produced shall meet the requirements of this specification. Materials containing contaminants from other base materials or elastomerics shall not be used in the manufacture of fittings or appurtenances under this specification.

5. Requirements

5.1 *Dimensions:*

5.1.1 *Seal Dimensions*— Seal dimensions shall be in accordance with the manufacturer's standard design dimensions and tolerances. The seal shall be designed to provide an adequate compressive force against the mating parts after assembly to effect a positive seal under all combinations of permitted fitting and seal tolerances.

5.1.2 *Solvent-Weld Connections*—Sockets shall comply with the fittings dimensions applicable to the size of pipe being joined. Dimensioning of sockets shall be conducted in accordance with 8.2.

5.1.2.1 Socket connections for solvent-weld to IPS pipe shall comply with the socket dimensions given in Specification D2467 for Sch 80 PVC, Specification D2466 for Sch 40 PVC, Specification F439 for Sch 80 CPVC or Specification F438 for Sch 40 CPVC.

5.1.2.2 Socket connections for solvent-weld to CTS pipe shall comply with the socket dimensions given in D2846/D2846M.

5.1.3 *Threaded Connections*—For all thermoplastic components having taper pipe threads, thermoplastic threads shall conform to Specification F1498 and be gaged in accordance with 8.2.2. The tolerance on thermoplastic threads, when measured using gages, shall be ±1.5 turns. For all metallic components having taper pipe threads, threads shall conform to ASME B1.20.1. The tolerance on metallic threads when measured using gages shall be ±1 turn.

5.1.4 *Flange Connections*—Flanges and flange-connections on assemblies shall meet the bolt-pattern requirements of ASME B16.5.

5.1.5 *Spigot Connections*—Spigot ends of fittings shall meet the requirements for average outside diameter, out-of-roundness and minimum wall thickness of the corresponding pipe.

5.1.6 Other dimensions shall be in accordance with the manufacturer's standard dimensions and tolerances.

5.2 *Internal Pressure Tests*—Fittings shall meet the minimum requirements for resistance to hydrostatic pressure when tested in accordance with 8.2.

5.2.1 *Valves*—Valves shall be tested in both the open (shell test) and shut-off (seat test) configurations for compliance with this section. Valves without a specified flow direction shall be tested in shut-off position from each possible flow direction. For operating (test) temperatures above 145°F (63°C), the 1000-h test on the valves shall be conducted only in the open (shell test) configuration.

5.2.2 *Blind Flanges*— Blind flanges shall be tested in addition to any other flange configurations for compliance with this section.

5.3 *Valves and Check Valves:*

5.3.1 *Pressure Drop Across Valves and Check Valves*—When tested in accordance with 8.4, the pressure drop across the valve shall not exceed the manufacturer's published values at 25, 50, 75 and 100 % of maximum flow. The maximum flow rate shall be either as specified by the manufacturer, or the flow achieved with 80 psig (550 kPa) inlet (at no flow condition) pressure and pipe of the same nominal size as the valve. For valves with more than one flow direction, testing shall be conducted in each flow configuration.

5.3.2 *Leakage Through Reverse Direction of Valves*—This requirement is applicable to valves with a specified flow direction, and check valves. The reverse flow rate (leakage, L) through the valve shall not exceed 0.01 % of the flow that would exist if the valve were not installed (F), when tested in accordance with 8.5. That is, L shall be less than or equal to 0.0001(F), or alternatively, the leakage percentage, P, shall be less than or equal to 0.01 %.

5.3.3 *Activation Pressure of Check Valves*—The activation pressure of check valves shall be within± 5 % or ±2 in. (mm) water column of the manufacturer's published value, whichever is greater, when tested in accordance with 8.6.

5.4 *Joint Tightness*— Fittings utilizing push-on joints with elastomeric seals shall not leak or fail when tested in accordance with 8.3.

6. Workmanship, Finish, and Appearance

6.1 The requirements of this section are verified by visual (non-magnified) inspection of the components and surfaces.

6.2 All surfaces of the fitting or assembly against which a seal may rest shall be free of imperfections that could adversely affect the performance of the fitting or assembly.

6.3 The surfaces of all thermoplastic and metallic components shall be free from defects which will adversely affect the performance and service of the fitting or assembly.

6.4 The thermoplastic materials, after molding or fabrication, shall be as uniform as commercially practical in color and opacity.

7. Sample Conditioning

7.1 For referee testing, all samples shall be conditioned at 73 ± 3.6°F (23 ± 2°C) for not less than 40 hours immediately preceding testing.

7.2 For in-plant quality control testing purposes, samples shall be conditioned at ambient temperature.

8. Test Methods

8.1 *Dimensioning:*

8.1.1 Measure dimensions in accordance with D2122. For those part dimensions that are not covered by Test Method D2122, note the method of determining dimensions on the test report.

8.1.2 *Threads*—Gage all thermoplastic taper pipe threads in accordance with Specification F1498.

8.1.3 *Threads*—Gage all metal taper pipe threads in accordance with ASME B1.20.1.

8.2 *Resistance to Hydrostatic Pressure :*

8.2.1 Test specimens shall consist of assemblies of fittings and pipe, using pipe sufficient to withstand the internal hydrostatic pressure until completion of the test. The assemblies used for each test shall contain the same fittings in the same configuration. Each individual assembly shall contain at least two of each fitting being tested.

8.2.2 The test temperature, with a tolerance of ± 3.6°F (2°C), shall be the maximum operating temperature for which the piping system component's recommended maximum operating pressure is being verified.

8.2.3 Conduct hydrostatic pressure testing in accordance with the method and at the times and pressures given in Table 1. Specimens which include an elastomeric seal shall be conditioned for one h at 50% of the test pressure immediately prior to conducting th 1-h and 1000-h tests.

8.2.4 For the 1-h and 1000-h tests, failure is defined as any loss of pressure in the assembly, due to failure of any component of the fittings under test. For the burst test, some loss of pressure due to seepage in a valve stem area is acceptable, provided no failure or leakage occurs in the body or connections areas of the fitting.

NOTE 3—Loss of pressure which can be corrected by tightening of threads or valve seals without removal of the fitting from the assembly, is not considered failure of a component, as specified in 8.2.4.

8.2.5 Consider all fittings used to construct the assemblies as evaluated upon completion of this test. All fittings from which this representative sample was drawn will also be considered as evaluated upon completion of this test.

8.3 *Joint Tightness:*

8.3.1 Conduct testing on two specimens of the same fitting size/configuration.

8.3.2 Use water as the internal pressurizing fluid. The external fluid shall be either air or water. The internal and external fluid temperatures shall be the maximum temperature for which the fittings nominal pressure was verified with a tolerance of ± 3.6°F (2°C).

8.3.3 Subject the joint to 20 psig (140 kPa) for 1 h, and then raised to 2.5 times the nominal pressure of the fitting and maintained for 1 h. For those products requiring joint tightness testing, this test replaces the 1-h hydrostatic test shown in Table 1.

8.3.4 Any leakage or failure of the fitting during the full test duration constitutes failure of this test.

8.4 *Pressure Drop Across Valves:*

8.4.1 Conduct testing on a single specimen of the configuration/size being evaluated.

8.4.2 Water shall be used as the internal pressurizing fluid. The water temperature shall be 73 ± 4°F (23 ± 2°C).

8.4.3 The test systems shall be in accordance with ANSI/ISA S75.02 (see Fig. 1). The test procedure shall be in accordance with the C_v Procedure of ANSI/ISA S75.02.

8.4.4 Conduct testing at 25, 50, 75, and 100 % of maximum flow as defined in 5.3.1. The internal cross-sectional area of the pipe shall be no less than the smallest cross-section in the flow path through the valve. This will ensure that the greatest restriction to flow is the valve under test, rather than the pipe portion of the test assembly.

TABLE 1 Hydrostatic Testing

Test Pressure, psi	Time	Test Method
3.2×(P[A]) minimum burst pressure	60 s	D1599[B]
2.5×(P[A]) ± 10 psi	1 h	D1598
2.1×(P[A]) ± 10 psi	1000 h	D1598

[A]P is the manufacturer's recommended pressure as marked on the fitting. It is the responsibility of the manufacturer to establish a recommended maximum operating pressure.

[B]Testing may be stopped upon reaching the minimum required pressure, rather than taking the sample to failure.

8.5 *Leakage In Reverse Direction for Valves:*

8.5.1 Conduct testing on a single specimen of the configuration/size being evaluated. Connect the fitting to the test system as shown in Fig. 2.

8.5.2 The water temperature shall be 73 ± 4°F (23 ± 2°C).

8.5.3 With the upstream test valve connection open to atmosphere, apply pressure to the downstream test valve connection equal to the 1.5 times the nominal pressure of the valve and begin the timer.

8.5.4 Collect any water leaking through the valve over a 60 min period, in a graduated cylinder or other container capable of measuring accurately to 0.0003 gal (1 mL).

8.5.5 Calculate the leakage rate in gal/min (gpm) or litres per min (Lpm). Record this as "L".

8.5.6 Remove the test valve from the system and determine the flow rate (gpm or Lpm) with the piping open to atmosphere as shown in Fig. 3, with a flow velocity of 5 ft/s. Alternatively, the inside diameter of the pipe, and the density of the water shall be determined, and the flow rate calculated based on a 5 ft/s flow velocity. Record this open flow value as "F".

8.5.7 Calculate the leakage rate as a percentage of the flow rate determined in 8.5.6, using the equation $P = (L/F) \times 100$ %.

8.6 *Activation Pressure of Check Valves:*

8.6.1 Conduct testing on a single specimen of the configuration/size being evaluated. Install the valve as shown in Fig. 1. For valves which can be installed either horizontally or vertically, this test must be conducted with the valve in three configurations; vertical flow up, vertical flow down, and horizontal. For vertical flow testing, the pressure differential must be corrected for the relative difference in height of the pressure sensors.

8.6.2 The water temperature shall be 73 ± 4°F (23 ± 2°C).

8.6.3 Increase the pressure differential across the valve at a rate not exceeding 6 psi/min (690 Pa/s) until the check opens and flow is detected at the outlet. Record this differential as the activation pressure.

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 seller. Under such agreement, minimum requirements shall not be lowered, 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. In-Plant Quality Control

10.1 *Sampling*—A sufficient quantity of fittings or appurtenances, as agreed upon between the purchaser and seller, shall be selected from each lot or shipment and tested to determine conformance with this specification (see Practice D1898). In the case of no prior agreement, the quantity of samples shown in Table 2 shall be selected randomly and

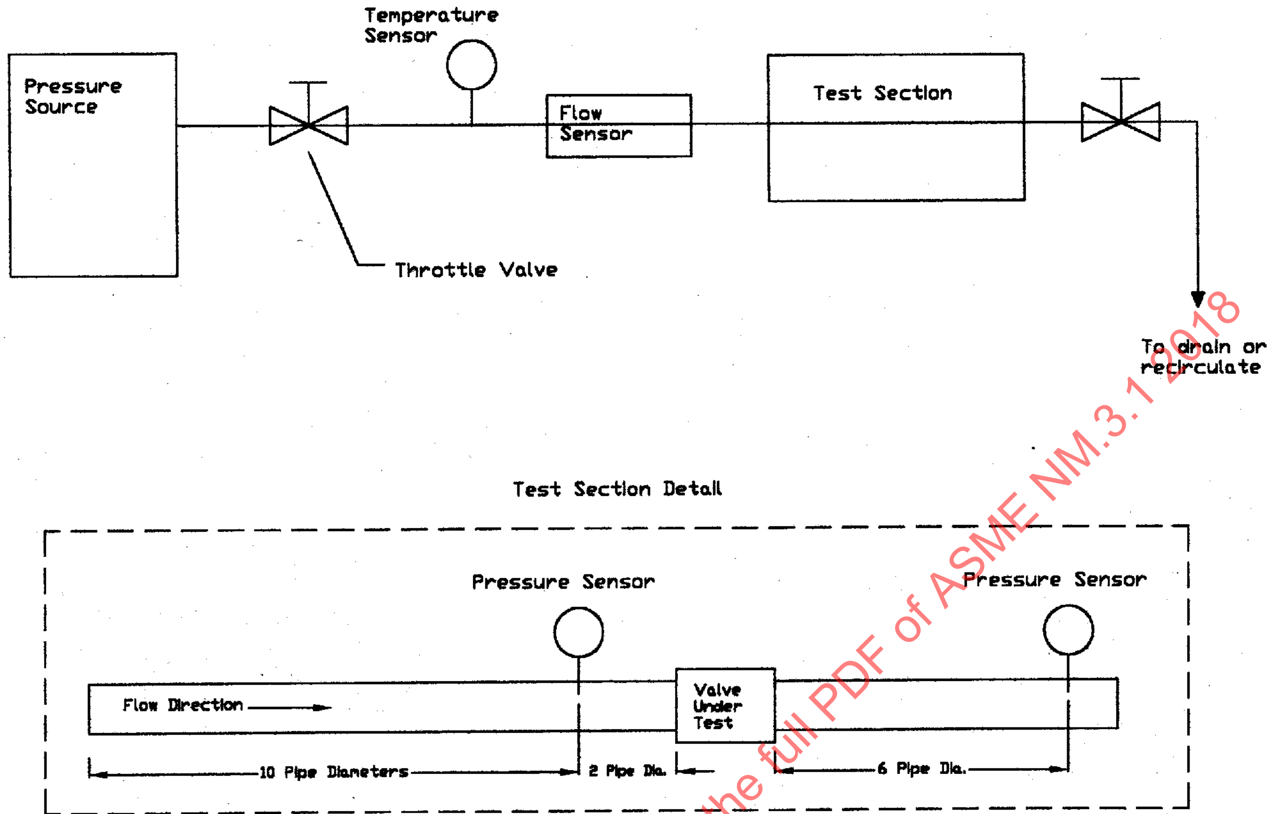

FIG. 1 Pressure LossTest System

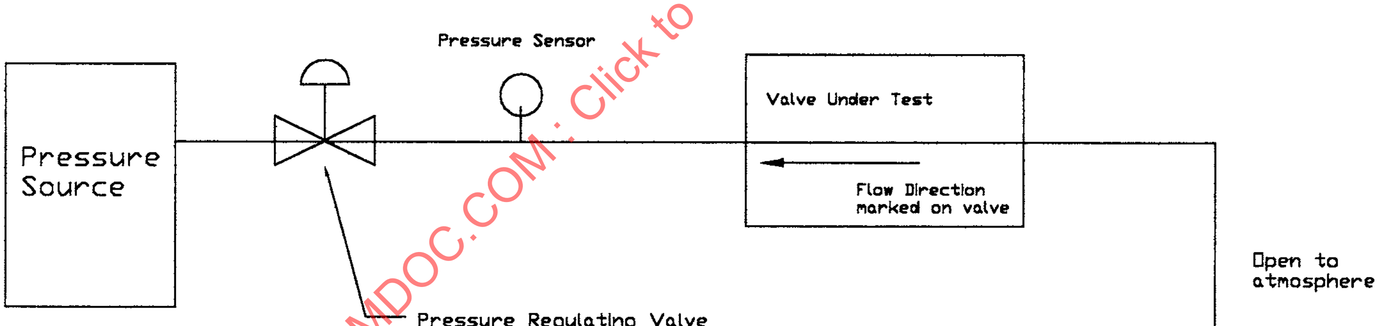

FIG. 2 Reverse Direction Leakage Test

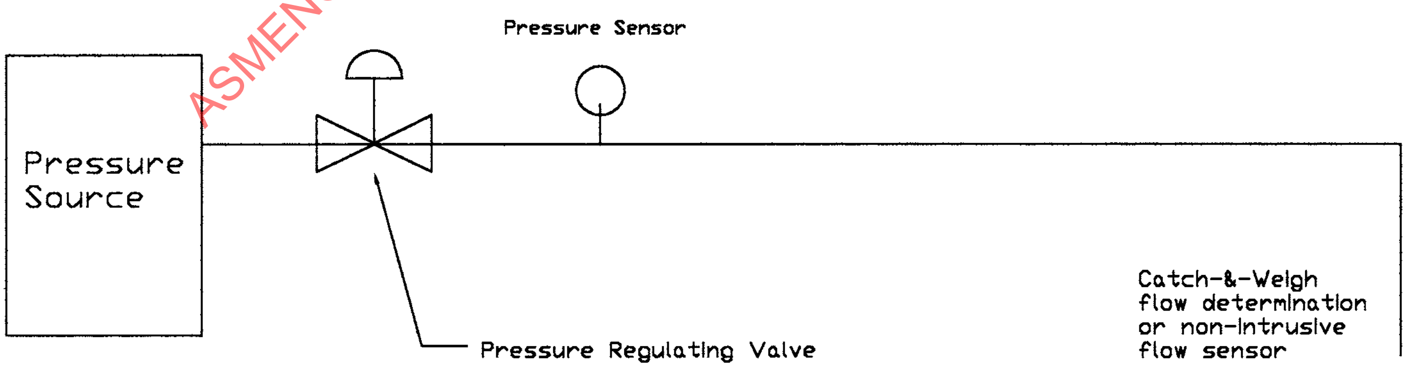

FIG. 3 Flow Without Test Valve

TABLE 2 Sample Size for In-Plant QC Testing

Lot Size[A]	Number of Dimensions Specimens	Number of Burst Specimens
16 to 25	3	1
26 to 90	5	1
91 to 150	8	2
151 to 280	13	3
281 to 500	20	5
501 to 1200	32	8

[A]For products manufactured under a single continuous process without further assembly or fabrication required, dimensions shall be conducted at start-up and once per 24 h, and burst testing shall be conducted at start-up and once per week.

tested. The values shown in Table 2 for dimensions are based on Practice D1898, sampling for attributes, random sampling, and the sample size based on the lot size of finished products using General Inspection Level I. Larger lot sizes and sampling plans are given in D1898. Additionally, based on historical testing data, allowance shall be made for tightening or reducing the Inspection Level, as described in Practice D1898 and ANSI/ASQC Z1.4.

10.2 Dimensions shall comply with 5.1, when determined in accordance with 8.1.

10.3 Hydrostatic burst testing shall be conducted using Test Method D1599, with the exception that the test can be stopped upon reaching the burst pressure given in Table 1, rather than taking the fitting or appurtenance to failure. The minimum required burst pressure is as given in Table 1.

11. Product Marking

11.1 Fittings shall be marked with the following:

11.1.1 Manufacturer's name or trademark,

11.1.2 Material designation,

11.1.3 Fittings intended for the transport of potable water shall include the seal or mark of the laboratory making the evaluation for this purpose,

11.1.4 Manufacturer's recommended pressure, and the temperature for which the pressure is applicable. For fittings intended to be used at 100 psi/180°F (hot water supply) the word HOT is acceptable rather than the pressure and temperature,

11.1.5 Nominal size, and

11.1.6 If the fitting is intended to be used only with certain SDR, Schedule, or pressure-class pipe within one of the standards given in 1.1, marking shall indicate this.

NOTE 4—Fittings need only be marked with the schedule or SDR of the pipe with the highest pressure rating for which they are intended. All thinner-wall schedules and SDR's need not be marked on the fitting.

11.1.7 ASME SF-1970 or both ASME SF-1970 and ASTM F1970.

11.2 The manufacturer's literature shall include assembly instructions which provide adequate information to achieve a connection which will meet the nominal pressure given in 5.1.

12. Quality Assurance

12.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

13. Certification

13.1 Certification shall be as required by Annex A1.

14. Keywords

14.1 appurtenances; check valves; CPVC; elastomeric joints; elastomers; fittings; flanges; PVC; SE; special-engineered; unions; valves

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a Regulatory Authority or user calls for product to be used to convey or to be in contact with potable water.

S1. Potable Water Requirement

S1.1 *Potable Water Requirement*—Products intended for contact with potable water shall be evaluated, tested and certified for conformance with ANSI/NSF Standard No. 61 or the health effects portion of ANSI/NSF Standard No. 14 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR FABRICATED FITTINGS OF BUTT-FUSED POLYETHYLENE (PE)

SF-2206

(Identical with ASTM F2206-14 except for additional requirements in section 13 and Annex A1, revised marking requirements in para. 10.1.1, renumbering of section 13, and quality assurance requirement in para. 11.1 has been made mandatory.)

Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE)

1. Scope

1.1 This specification establishes requirements for fabricated fittings intended for use with outside-diameter controlled polyethylene pipe and tubing. These fittings are manufactured by heat-fusion joining shape-modified polyethylene components prepared from pipe, molded fittings, sheet, billet, or block. Included are requirements for materials, design, workmanship, minimum dimensions, marking, test methods, and quality control.

1.2 Pressure rating of the fabricated-fitting design is beyond the scope of this standard and shall be established by the fitting manufacturer. This specification includes requirements for both elevated temperature pressure-tests and short-term pressurization tests to demonstrate a reasonable level of performance of the fabricated-fitting design at the pressure rating established by the fitting manufacturer.

1.3 The pressure-tests requirements are specified by the fittings' equivalent (E) DR. The EDR specified is the DR of the piping system for which the fabricated fitting is intended to be butt-fused.

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

1.5 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units which are provided for information only and are not considered standard.

1.6 The following safety hazards 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2513 Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter

D3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

F412 Terminology Relating to Plastic Piping Systems

F714 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter

F2619/F2619M Specification for High-Density Polyethylene (PE) Line Pipe

F2880 Specification For Lap-Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes 3/4 in. to 65 in.

F3034 Specification for Billets made by Winding Molten Extruded Stress-Rated High Density Polyethylene (HDPE)

2.2 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

OPS Part 192 Title 49, Code of Federal Regulations

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.4 *ANSI/NSF Standard:*

ANSI/NSF 61 for Drinking Water System Components—Health Effects

2.5 *Plastic Pipe Institute:*

TR-4 Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) for Thermoplastic Materials or Pipe.

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *Definitions:*

3.2.1 *butt-fusion end(s), n*—the butt end(s) of the fabricated fitting intended for field fusion by the installer.

3.2.2 *billet, n*—a mass formed from a single stress-rated polyethylene compound in the approximate shape of a thick-walled cylindrical shell. (See Specification F3034.)

3.2.3 *fabricated fitting, n*—a fitting constructed from manufactured polyethylene components or materials.

3.3 *Abbreviations:*

3.3.1 *DIPS*—ductile iron pipe size.

3.3.2 *DR*—dimension ratio.

3.3.3 *EDR*—equivalent dimension ratio. The DR of the pipe to which the fitting is to be joined.

3.3.4 *IPS*—iron pipe size.

3.3.5 *OD*—outside diameter.

4. Classification

4.1 *General*—This specification establishes requirements for fabricated fittings intended for butt-fusion joining to polyethylene pipe.

4.1.1 Fabricated fittings intended for use in the distribution of natural gas or other fuel gases shall also meet the requirements of Specification D2513.

5. Ordering Information

5.1 When ordering fittings under this specification include the following information:

5.1.1 Polyethylene compound (material designation or trade name).

5.1.2 Style of fitting (3 piece tee, 5 segment 90° ell, etc.).

5.1.3 Size:

5.1.3.1 Nominal size of end connections.

5.1.3.2 End configurations (for example, IPS or DIPS).

5.1.3.3 System DR.

6. Material

6.1 Polyethylene materials allowed for use in fittings produced in accordance with this specification shall be in accordance with the manufacturer's fabricated-fitting design specifications. In addition:

6.1.1 Polyethylene pipe used in the production of fittings in accordance with this specification shall meet the requirements of Specification F714, D3035, F2619/F2619M or D2513.

6.1.2 Molded PE fittings used in the production of fabricated fittings in accordance with this specification shall meet the requirements of Specification D3261.

6.1.3 Flange adaptors used in the production of fabricated fittings in accordance with this specification shall meet the requirements of Specification F2880.

6.1.4 Billet used in the production of fabricated fittings in accordance with this specification shall meet the requirements of Specification F3034.

6.1.5 Sheet, block or plate stock used in the production of fabricated fittings shall be produced from stress-rated polyethylene compounds listed in PPI's TR-4.

NOTE 1—Manufacturers should use appropriate quality assurance procedures to ensure that sheet, block and plate are free from voids, laminations, foreign inclusions, cracks, and other injurious defects.

7. Requirements

7.1 *Dimension and Tolerances*—Butt-fusion ends shall be produced from fittings or pipe conforming to Specification D3261, or by machining billet, block, sheet, plate, or pipe to the required dimensions.

7.1.1 *Diameter*—Nominal outside-diameter of the butt-fusion end shall conform to the IPS or DIPS dimension at area of fusion. Outer-diameter dimensions and tolerances at the area of fusion shall be as shown in Table 1 or Table 2.

7.1.2 *Wall Thickness*—The minimum wall thickness of the butt-fusion end shall be in accordance with Table 1 or Table 2 when measured in accordance with Test Method D2122. Conditioning to standard temperature but not to standard humidity is required.

7.1.3 *Eccentricity*—The wall thickness variability of the butt-fusion end as measured and calculated in accordance with Test Method D2122, in any diametrical cross-section of the pipe shall not exceed 12 %.

7.1.4 *Measurements*—These shall be made in accordance with Test Method D2122 for roundable pipe.

7.1.5 *Laying Lengths*—Laying length dimensions shall be defined by the manufacturer.

7.1.6 *Special Sizes*—Where existing system conditions or special local requirements make other diameters or dimension ratios necessary, other sizes or dimension ratios, or both, shall be acceptable for engineered applications when mutually agreed upon by the customer and the manufacturer, if the fitting is manufactured from plastic compounds meeting the material requirements of this specification, and the fitting performs in accordance with the requirements in this specification. For diameters not shown in Table 1 or Table 2, the tolerance shall be the same percentage as that shown in the corresponding tables for the next smaller listed size. Minimum wall thickness at the butt-fusion end for these special sizes shall not be less than the minimum wall thickness specified for the pipe the fitting is designed to be used with.

7.2 *Physical Requirements*—Fabricated fittings using miter cut pipe stock shall be manufactured from pipe stock with a wall thickness that is at least 22% greater than that of the pipe to which the fitting is to be joined. (For example: An EDR11 fitting shall be made using DR9 pipe stock.)

7.3 *Pressure Test Requirements*—Design validation tests per 7.3.1 and 7.3.2 shall be conducted on "test samples" that are representative of:

–Each of three (3) size groupings - 12 in. (300 mm) and smaller, greater than 12 to less than 24 in. (300 to less than 600 mm), and 24 in. (600 mm) and larger.

–Each style of fitting (for example, 4 segment 90 Elbow, Straight Tee, etc.).

TABLE 1 IPS Sizing System: Butt-Fusion End Dimensions, in.

Size IPS	Average OD[A]	Minimum Wall Thickness[B] versus DR									
		7.3	9	9.3	11	13.5	15.5	17	21	26	32.5
2	2.38	. . .	0.26	. . .	0.22	0.18	. . .	0.14	. . .	. . .	. . .
3	3.500	0.479	0.389	0.376	0.318	0.259	0.226	0.206	0.167	0.135	0.108
4	4.500	0.616	0.500	0.484	0.409	0.333	0.290	0.265	0.214	0.173	0.138
5	5.563	0.762	0.618	0.598	0.506	0.412	0.359	0.327	0.265	0.214	0.171
6	6.625	0.908	0.736	0.712	0.602	0.491	0.427	0.390	0.315	0.255	0.204
8	8.625	1.182	0.958	0.927	0.784	0.639	0.556	0.507	0.411	0.332	0.265
10	10.750	1.473	1.194	1.156	0.977	0.796	0.694	0.632	0.512	0.413	0.331
12	12.750	1.747	1.417	1.371	1.159	0.944	0.823	0.750	0.607	0.490	0.392
14	14.000	1.918	1.556	1.505	1.273	1.037	0.903	0.824	0.667	0.538	0.431
16	16.000	2.192	1.778	1.720	1.455	1.185	1.032	0.941	0.762	0.615	0.492
18	18.000	2.466	2.000	1.935	1.636	1.333	1.161	1.059	0.857	0.692	0.554
20	20.000	. . .	2.222	2.151	1.818	1.481	1.290	1.176	0.952	0.769	0.615
22	22.000	. . .	2.444	2.366	2.000	1.630	1.419	1.294	1.048	0.846	0.677
24	24.000	. . .	2.667	2.581	2.182	1.778	1.548	1.412	1.143	0.923	0.738
26	26.000	. . .	. . .	2.796	2.364	1.926	1.677	1.529	1.238	1.000	0.800
28	28.000	. . .	. . .	3.011	2.545	2.074	1.806	1.647	1.333	1.077	0.862
30	30.000	. . .	. . .	3.226	2.727	2.222	1.935	1.765	1.429	1.154	0.923
32	32.000	. . .	. . .	. . .	2.909	2.370	2.065	1.882	1.524	1.231	0.985
34	34.000	. . .	. . .	. . .	3.091	2.519	2.194	2.000	1.619	1.308	1.046
36	36.000	. . .	. . .	. . .	3.273	2.667	2.323	2.118	1.714	1.385	1.108
42	42.000	. . .	. . .	. . .	. . .	. . .	2.710	2.471	2.000	1.615	1.292
48	48.000	. . .	. . .	. . .	. . .	. . .	3.097	2.824	2.286	1.846	1.477
54	54.000	. . .	. . .	. . .	. . .	. . .	. . .	3.176	2.571	2.077	1.662

[A] Tolerance on OD is ± 0.45 %.
[B] Eccentricity of wall shall not exceed 12 %.

TABLE 2 DIPS Sizing System: Butt-Fusion End Dimensions, in.

Size DIPS	Average OD[A]	Minimum Wall Thickness[B] versus DR						
		9	11	13.5	17	21	26	32.5
3	3.96	0.389	0.360	0.294	0.233	0.189	0.153	0.122
4	4.80	0.500	0.437	0.356	0.283	0.229	0.185	0.148
6	6.90	0.736	0.628	0.512	0.406	0.329	0.266	0.213
8	9.05	0.958	0.823	0.670	0.533	0.431	0.348	0.279
10	11.10	1.194	1.009	0.823	0.653	0.529	0.427	0.342
12	13.20	1.417	1.200	0.978	0.777	0.629	0.508	0.407
14	15.30	1.556	1.391	1.134	0.900	0.729	0.589	0.471
16	17.40	1.778	1.582	1.289	1.024	0.829	0.670	0.536
18	19.50	2.000	1.773	1.445	1.147	0.929	0.750	0.600
20	21.60	2.222	1.964	1.600	1.271	1.029	0.831	0.665
24	25.80	2.667	2.346	1.912	1.518	1.229	0.993	0.794
30	32.00	. . .	2.909	2.371	1.883	1.524	1.231	0.985
36	38.30	. . .	3.482	2.837	2.253	1.824	1.473	1.179
42	44.50	. . .	4.046	3.297	2.618	2.119	1.712	1.370
48	50.80	. . .	4.619	3.763	2.989	2.419	1.954	1.563

[A] Tolerance on OD is ± 0.45 %.
[B] Eccentricity of wall shall not exceed 12 %.

A single EDR sample shall be considered as representative of all of the wall thickness' produced in that size and style grouping. The EDR of the test fitting(s) shall be in the mid range of the wall thickness' typically produced for that size grouping. Fitting styles are characterized as elbows, tees, wyes, crosses, reducing tees, reducing laterals, branch saddles, mechanical joint adapters, and end caps.

7.3.1 *Elevated Temperature Sustained Pressure Test*—The "test sample" shall be three specimens. Each specimen shall have a minimum distance of three pipe diameters between end closure(s) and any miter joints in the fitting(s).

7.3.2 *Short-term Pressurization Testing*—Quick Burst of Non-Failure testing shall be conducted. The "test sample" shall be five specimens. Each specimen shall have a minimum distance of three pipe diameters between end closure(s) and any miter joints in the fittings(s).

8. Workmanship, Finish, and Appearance

8.1 The manufacture of these fittings shall be in accordance with good commercial practice so as to produce fittings meeting the requirements of this specification. Fittings shall be homogeneous throughout and free of cracks, holes, foreign inclusions or other injurious defects. The fittings shall be as uniform as commercially practicable in color, opacity, density, and other physical properties.

8.2 The procedure used for the heat fusion in the fabrication process shall be written and qualified in accordance with the requirements of OPS 49 CFR Part 192.283 "Plastic Pipe: Qualifying Joining Procedures."

8.3 All personnel engaged in the heat fusion process shall be qualified in accordance with the requirements of OPS 49 CFR Part 192.285 "Plastic Pipe: Qualifying Persons to Make Joints."

9. Test Methods

9.1 *General*—The test methods in this specification apply to fittings for use with pipe and tubing for gas, water, and other engineered piping systems.

9.2 *Conditioning*—Unless otherwise specified, condition the specimens prior to test at 73.4 ± 3.6°F (23 ± 2°C) for not less than 6 h in air or 1 h in water.

9.3 *Test Conditions*—Conduct the tests at the standard laboratory temperature of 73.4 ± 3.6°F (23 ± 2°C) unless otherwise specified.

9.4 *Dimensions and Tolerances:*

9.4.1 *Outside Diameter*—Measure the outside diameter of the fittings at the butt-fusion end in accordance with the Wall Thickness section of Test Method D2122 by use of circumferential tape readable to the nearest 0.001 in. (0.02 mm). Other methods may be used if proven to be equivalent.

9.4.2 *Wall Thickness*—Make a series of measurements using a cylindrical-anvil tubular micrometer or other accurate device at closely spaced intervals to ensure that minimum and maximum wall thickness to the nearest 0.01 in. (0.2 mm) have been determined. Make a minimum of six measurements at each butt-fusion end.

9.5 *Pressure Testing:*

9.5.1 *Preparation of Specimens for Pressure Testing*—Test samples may be individual fittings or groups of fittings. The distance between end closures and the nearest miter joint in the fitting or in adjacent fittings shall be equal to three pipe diameters, measured on the OD.

9.5.2 *Elevated Temperature Sustained Pressure Test:*

9.5.2.1 The "test sample" specimens shall be tested and evaluated in accordance with the procedures in 6.2 of Specification F714.

9.5.2.2 Failure of one of the three specimens shall constitute failure of the test.

9.5.3 *Short Term Pressurization Test:*

9.5.3.1 The "test sample" specimens shall be tested and evaluated in accordance with the procedures in 6.1 of Specification F714.

9.5.3.2 Failure of one of the five specimens shall constitute failure of the test.

10. Product Marking

10.1 Fittings shall be marked with the following:

10.1.1 ASME SF-2206 or both ASME SF-2206 and ASTM F2206,

10.1.2 Manufacturer's name or trademark,

10.1.3 Material designations (such as PE2606, PE3608, or PE4710),

10.1.4 Date of manufacture or manufacturing code, and

10.1.5 Nominal size and fitting EDR.

10.2 Where recessed marking is used, such marking shall have no injurious effect on the product's performance.

11. Quality Assurance

11.1 The manufacturer affirms that the product was manufactured, inspected, sampled, and tested in accordance with this specification and has been found to meet the requirements of this specification.

12. Certification

12.1 Certification shall be as required by Annex A1.

13. Keywords

13.1 fabricated fittings; polyethylene

SUPPLEMENTARY REQUIREMENTS

This requirement applies whenever a Regulatory Authority or user calls for the product to be used to convey or to be in contact with potable water.

S1. Potable Water Requirement

S1.1 Products intended for contact with potable water shall be evaluated, tested, and certified for conformance with ANSI/NSF Standard 61 by an acceptable certifying organization when required by the regulatory authority having jurisdiction.

GOVERNMENT/MILITARY PROCUREMENT

These requirements apply only to federal/military procurement, not domestic sales or transfers.

S2. Responsibility for Inspection

S2.1 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 may 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 federal contracts, the contractor is responsible for inspection.

S3. Packaging and Marking for U.S. Government Procurement

S3.1 *Packaging*—Unless otherwise specified in the contract, the materials shall be packaged in accordance with the supplier's standard practice in a manner ensuring arrival at destination in satisfactory condition and which will be acceptable to the carrier at lowest rates. Containers and packing shall comply with Uniform Freight Classification rules or National Motor Freight Classification rules.

S3.2 *Marking*—Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

NOTE 3—The inclusion of U.S. government procurement requirements should not be construed as an indication that the U.S. government uses or endorses the products described in this specification.

ANNEX

(Mandatory Information)

A1. CERTIFICATION

The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirement designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the certificate. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

SPECIFICATION FOR PRESSURE-RATED POLYPROPYLENE (PP) PIPING SYSTEMS

SF-2389

(Identical with ASTM F2389-10 except for revisions to section 11, additional requirements in Annex A1, revised marking requirements in para. 12.1.7, and quality assurance requirement in para. 13.1 has been made mandatory.)

Specification for Pressure-rated Polypropylene (PP) Piping Systems

1. Scope

1.1 This specification establishes requirements for polypropylene (PP) piping system components made to metric sizes and IPS schedule 80 sizes, and pressure rated for water service and distribution supply (see Appendix X1). Included are criteria for materials, workmanship, dimensions and tolerances, product tests, and marking for polypropylene (PP) piping system components such as pipe, fittings, valves, and manifolds.

1.2 The components governed by this specification shall be permitted for use in water service lines, hot-and-cold water distribution, hydronic heating, and irrigation systems.

1.3 The pipe and fittings produced under this specification shall be permitted to be used to transport industrial process fluids, effluents, slurries, municipal sewage, etc. The user shall consult the manufacturer to determine whether the material being transported is compatible with the polypropylene piping system and will not affect the service life beyond limits acceptable to the user.

1.4 *Units*—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.

1.5 *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 requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D1505 Test Method for Density of Plastics by the Density-Gradient Technique

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

D1600 Terminology for Abbreviated Terms Relating to Plastics

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2749 Symbols for Dimensions of Plastic Pipe Fittings

D3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry

D4101 Specification for Polypropylene Injection and Extrusion Materials

F412 Terminology Relating to Plastic Piping Systems

F2023 Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water

2.2 *International Organization for Standardization (ISO) Standards:*

ISO 3127 Thermoplastic Pipes—Determination of Resistance to External Blows—Round the Clock Method

ISO 4065 Thermoplastics Pipes—Universal Wall Thickness Table

ISO 9080 Plastics Piping and Ducting Systems—Determination of the Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation

ISO 15874-2:2002 Plastics Piping Systems for Hot and Cold Water Installations—Polypropylene (PP)—Part 2: Pipes

ISO 15874-3:2002 Plastics Piping Systems for Hot and Cold Water Installations—Polypropylene (PP)—Part 3: Fittings

ISO/TS 15874-7 Plastics Piping Systems for Hot and Cold Water Installations—Polypropylene (PP)—Part 7: Guidance for the Assessment of Conformity

2.3 *NSF International Standards:*

NSF/ANSI 14 Plastics Piping System Components and Related Materials

NSF/ANSI 61 Drinking Water System Components—Health Effects

2.4 *European Norm:*

EN 10226-1 Pipe Threads Where Pressure Tight Joints are Made on the Threads—Part 1: Designation, Dimensions and Tolerances

2.5 *American Society of Mechanical Engineers (ASME) Standard:*

B1.20.1 Pipe Threads, General Purpose, Inch

2.6 *Plastic Pipe Institute (PPI) Technical Report:*

TR-4 PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *polypropylene random copolymer (PP-R), n*—a propylene plastic containing not more than 50 % of another olefinic monomer (or monomers), having no functional group other than the olefinic group, copolymerized with the propylene.

3.2.1.1 *Discussion*—This term is also used for finished compound which comprises the PP-R resin and additives such as colorants, UV inhibitors, and stabilizers. Polypropylene random copolymers containing more than one additional monomer are often referred to as "terpolymers."

3.2.2 *plastic-to-metal transition fittings, n*—a fitting designed to provide a means of connection between the PP piping system and metal piping systems such as steel pipe and copper tubing. The fittings include a means of taking into account the differences in thermal expansion of the materials and maintaining a pressure-tight seal over the intended use temperature range.

4. Classification

4.1 *General*—This specification covers PP piping systems made from PP materials (PP-R) in various dimension ratios and pressure ratings.

4.2 *Thermoplastic Pipe Series and Schedule*—This specification covers PP pipe made in schedule 80 IPS sizes and metric sizes in accordance with ISO 4065.

5. Materials and Manufacture

5.1 The pipe and fittings shall be polypropylene material of type PP-R. Clean rework material, of the same PP-R resin generated from the manufacturer's own pipe or fitting production, shall be permitted to be used provided the pipe or fittings produced meet all requirements of this specification.

5.2 For pipe compound, the melt flow rate (MFR) shall not exceed 10.8 grain/10 min (0.7 g/10 min), when tested in accordance with D1238 using conditions of 4.76 lbm (2.16 kg) at 446°F (230°C).

5.3 The density of the unreinforced, natural color PP material shall not exceed 56.9 lbm/ft^3 (912 kg/m^3), when tested in accordance with Test Method D1505 or Test Method D792.

5.4 *Minimum Required Strength (MRS)*—The PP material used in the pipe and fittings shall have an MRS value of 1160 psi (8.0 MPa) or 1450 psi (10.0 MPa) based on testing in accordance with ISO 9080 and classification of the lower confidence limit (σ_{LCL}) at 50 years in accordance with ISO 12162.

5.5 *Categorized Required Strength ($CRS_{\theta,t}$)*—The PP material used in the pipe and fittings shall have a $CRS_{\theta,t}$ value of 280 psi (1.93 MPa) based on testing in accordance with ISO 9080 and classification of the lower confidence limit (σ_{LCL}) at 180°F (82°C) and 50 years.

5.6 *Minimum Pressure Rating*—The minimum pressure rating of the pipe shall be 160 psi (1.1 MPa) at 73°F (23°C) and 100 psi (0.69 MPa) at 180°F (82°C) for hot-and-cold distribution and 160 psi (1.1 MPa) at 73°F (23°C) for cold water service.

5.7 *Threads*—Fittings shall be permitted to be threaded by use of metal inserts molded into the fitting.

5.7.1 Metal threads shall be constructed of brass or stainless steel inserts molded into the fitting.

5.7.2 Threads shall not be molded or fabricated directly into the polypropylene plastic.

5.8 The piping compound shall be permitted to include colorants, antioxidants, reinforcing materials and additives necessary for the finished product. The modified material and finished product shall meet all requirements of this specification.

NOTE 1—The Plastics Pipe Institute (PPI) publishes listings of minimum required strength (MRS) and categorized required strength ($CRS_{\theta,t}$) ratings for thermoplastic piping materials in Technical Report No. 4 (TR-4). ISO/TS 15874-7 provides guidance on evaluating the effect of additives on long-term strength of the pipe and fittings material.

6. Workmanship, Finish, and Appearance

6.1 The pipe and fittings shall be free of visible cracks, holes, foreign inclusions, blisters and other known injurious defects. The pipe and fittings shall be uniform in color, opacity, density and other physical properties.

7. Dimensions and Tolerances

7.1 *Pipe Dimensions*—Pipe dimensions shall meet the requirements in 7.1.1 and 7.1.2.

7.1.1 *Outside Diameters*—The outside diameters and tolerances shall be as shown in Table 1 (IPS Sch. 80), or Tables 2 and 3 (metric series), when measured in accordance with Test Method D2122. For diameters not shown in these tables, the tolerance shall be the same percentage of outside diameter as those for the closest listed diameter.

7.1.2 *Wall Thicknesses*—The wall thicknesses and tolerances shall be as shown in Table 1, or Tables 2 and 3, when

TABLE 1 IPS Schedule 80 OD and Wall Thickness

Nominal Pipe Size	Average Outside Diameter, OD, in.		Tolerance on OD, in.		Out-of-roundness (max–min)		Minimum Wall Thickness, in.		Tolerance on Wall Thickness, in.	
½	0.840	(21.34)	±0.004	(±0.10)	0.015	(0.38)	0.147	(3.73)	+0.020	(+0.51)
¾	1.050	(26.67)	±0.004	(±0.10)	0.020	(0.51)	0.154	(3.91)	+0.020	(+0.51)
1	1.315	(33.40)	±0.005	(±0.13)	0.025	(0.64)	0.179	(4.55)	+0.021	(+0.53)
1-½	1.900	(48.26)	±0.006	(±0.15)	0.030	(0.76)	0.200	(5.08)	+0.024	(+0.61)
2	2.375	(60.33)	±0.006	(±0.15)	0.035	(0.89)	0.218	(5.54)	+0.026	(+0.66)
3	3.500	(88.90)	±0.008	(±0.20)	0.040	(1.02)	0.300	(7.62)	+0.036	(+0.91)
4	4.500	(114.30)	±0.009	(±0.23)	0.050	(1.27)	0.337	(8.56)	+0.040	(+1.02)
6	6.625	(168.28)	±0.011	(±0.28)	0.050	(1.27)	0.432	(10.97)	+0.052	(+1.32)

TABLE 2 Metric Sizes OD

Nominal Size	Outside Diameter, OD					
	Minimum Average OD, in.		Maximum Average OD, in.		Maximum Out-of-roundness, in.	
16	0.630	(16.0)	0.642	(16.3)	0.016	(0.4)
20	0.787	(20.0)	0.799	(20.3)	0.016	(0.4)
25	0.984	(25.0)	0.996	(25.3)	0.016	(0.4)
32	1.260	(32.0)	1.272	(32.3)	0.020	(0.5)
40	1.575	(40.0)	1.591	(40.4)	0.020	(0.5)
50	1.969	(50.0)	1.988	(50.5)	0.024	(0.6)
63	2.480	(63.0)	2.504	(63.6)	0.024	(0.6)
75	2.953	(75.0)	2.980	(75.7)	0.039	(1.0)
90	3.543	(90.0)	3.579	(90.9)	0.039	(1.0)
110	4.331	(110.0)	4.370	(111.0)	0.039	(1.0)
125	4.921	(125.0)	4.969	(126.2)	0.051	(1.3)
140	5.512	(140.0)	5.563	(141.3)	...	...
160	6.299	(160.0)	6.358	(161.5)	...	...
200	7.874	(200.0)	7.953	(202.0)	...	...
250	9.842	(250.0)	9.941	(252.5)	...	...
280	11.023	(280.0)	11.142	(283.0)	...	...
315	12.401	(315.0)	12.528	(318.2)	...	...
355	13.976	(355.0)	14.118	(358.6)	...	...

measured in accordance with Test Method D2122. For wall thicknesses (DR's) not shown in these tables, the minimum wall thickness shall be as calculated using the DR and outside diameter, and the tolerance on the wall thickness shall be the same percentage of the calculated minimum wall thickness as for the closest listed minimum wall thickness.

7.1.3 *Threaded Pipe*—Pipe covered by this specification shall not be threaded.

7.2 *Fittings Dimensions*—Fittings dimensions shall meet the requirements in 7.2.1 through 7.2.4.

7.2.1 *Threads*—Taper threads for joining fittings shall comply with the requirements of ASME B1.20.1 for NPT metal thread inserts or EN 10226-1 for metric threads. Threads used by the manufacturer to join component parts of a fitting together shall meet the manufacturer's specifications.

7.2.2 *Laying Lengths*—Laying lengths shall be in accordance with the manufacturer's specifications.

7.2.3 *Socket-fused Fittings*—Dimensions for socket-fused fittings shall be in accordance with Tables 4 and 5 (IPS Sch 80) or Tables 6 and 7 (metric series). Socket depth shall be measured from the face of the socket entrance to the face of the pipe stop at the socket bottom.

7.2.4 *Electrofusion Fittings*—Dimensions for electrofusion fittings shall be in accordance with manufacturer's specifications.

7.2.5 *Valves and Flanges*—Dimensions for valves and flanges shall be in accordance with the manufacturer's specifications.

8. Requirements

8.1 *Longitudinal Reversion*—When tested in accordance with ISO 15874-2, at the conditions given in Table 8, the mean relative change in pipe length shall not exceed 2 %.

8.2 *Melt Flow Rate (MFR) of Pipe and Fittings*—When tested in accordance with D1238, the MFR of specimens taken from the finished pipe or fittings shall be within 30 % of the MFR of the compound used to produce the pipe or fitting. Two specimens shall be tested, and both shall pass.

8.3 *Impact Strength*—When tested in accordance with ISO 3127, 9 of 10 specimens shall pass at the impact level specified in Table 9 at a test temperature of 32 ± 2°F (0 ± 1°C).

8.4 *Thermal Stability and Oxidative Induction Time (OIT)*—Pipe and fittings shall meet the requirements of 8.4.1–thermal stability by hydrostatic testing, and 8.4.2–oxidative induction time.

8.4.1 When tested in accordance with Test Method D1598, pipe and fittings shall not fail at the pressure corresponding to the pipe circumferential stresses and times given in Table 10. If an assembly fails at a joint, the fitting material shall be permitted to be retested in pipe form.

8.4.2 The oxidative induction time (OIT) shall be determined on pipe and fittings in accordance with Test Method D3895. Two specimens shall be tested and the average OIT of the two shall be at least 80 % of the OIT of the virgin material compound. For those materials which require final blending at

TABLE 3 Metric Sizes Wall Thickness

Nominal Size	Minimum Wall Thickness											
	DR = 17.6		DR = 17		DR = 11		DR = 7.3		DR = 6		DR = 5	
	Min Wall, in.	Tolerance, in.	Min Wall, in.	Tolerance, in.	Min Wall, in.	Tolerance, in.	Min Wall, in.	Tolerance, in.	Min Wall, in.	Tolerance, in.	Min Wall, in.	Tolerance, in.
16	... ...	... ...	... ...	... ...	0.071 (1.8)	+0.020 (+0.50)	0.087 (2.2)	+0.020 (+0.50)	0.106 (2.7)	+0.020 (+0.50)	0.130 (3.3)	+0.020 (+0.50)
20	... ...	... ...	... ...	... ...	0.075 (1.9)	+0.009 (+0.23)	0.110 (2.8)	+0.013 (+0.34)	0.134 (3.4)	+0.016 (+0.41)	0.161 (4.1)	+0.019 (+0.49)
25	... ...	... ...	... ...	... ...	0.091 (2.3)	+0.011 (+0.28)	0.138 (3.5)	+0.017 (+0.42)	0.165 (4.2)	+0.020 (+0.50)	0.201 (5.1)	+0.024 (+0.61)
32	... ...	... ...	... ...	... ...	0.114 (2.9)	+0.014 (+0.35)	0.173 (4.4)	+0.021 (+0.53)	0.213 (5.4)	+0.026 (+0.65)	0.256 (6.5)	+0.031 (+0.78)
40	... ...	... ...	... ...	... ...	0.146 (3.7)	+0.017 (+0.44)	0.217 (5.5)	+0.026 (+0.66)	0.264 (6.7)	+0.032 (+0.80)	0.319 (8.1)	+0.038 (+0.97)
50	... ...	... ...	... ...	... ...	0.181 (4.6)	+0.022 (+0.55)	0.272 (6.9)	+0.033 (+0.83)	0.327 (8.3)	+0.039 (+1.00)	0.398 (10.1)	+0.048 (+1.21)
63	... ...	... ...	... ...	... ...	0.228 (5.8)	+0.027 (+0.70)	0.339 (8.6)	+0.041 (+1.03)	0.413 (10.5)	+0.050 (+1.26)	0.500 (12.7)	+0.060 (+1.52)
75	... ...	... ...	... ...	... ...	0.268 (6.8)	+0.032 (+0.82)	0.406 (10.3)	+0.049 (+1.24)	0.492 (12.5)	+0.059 (+1.50)	0.594 (15.1)	+0.071 (+1.81)
90	... ...	... ...	... ...	... ...	0.323 (8.2)	+0.039 (+0.98)	0.484 (12.3)	+0.058 (+1.48)	0.591 (15.0)	+0.071 (+1.80)	0.713 (18.1)	+0.086 (+2.17)
110	... ...	... ...	... ...	... ...	0.394 (10.0)	+0.047 (+1.20)	0.594 (15.1)	+0.071 (+1.81)	0.720 (18.3)	+0.086 (+2.20)	0.870 (22.1)	+0.104 (+2.65)
125	... ...	... ...	... ...	... ...	0.449 (11.4)	+0.054 (+1.37)	0.673 (17.1)	+0.081 (+2.05)	0.819 (20.8)	+0.098 (+2.50)	0.988 (25.1)	+0.119 (+3.01)
140	... ...	... ...	... ...	... ...	0.500 (12.7)	+0.060 (+1.52)	0.756 (19.2)	+0.091 (+2.30)	0.917 (23.3)	+0.110 (+2.80)	1.106 (28.1)	+0.133 (+3.37)
160	... ...	... ...	... ...	... ...	0.575 (14.6)	+0.069 (+1.75)	0.862 (21.9)	+0.103 (+2.63)	1.047 (26.6)	+0.126 (+3.19)	1.264 (32.1)	+0.152 (+3.85)
200	... ...	... ...	... ...	... ...	0.716 (18.2)	+0.083 (+2.1)	1.079 (27.4)	+0.122 (+3.1)	1.311 (33.3)	+0.154 (+3.9)	1.575 (40.0)	+0.181 (+4.6)
250	... ...	... ...	... ...	... ...	0.894 (22.7)	+0.102 (+2.6)	1.346 (34.2)	+0.157 (+4.0)	1.642 (41.7)	+0.189 (+4.8)	1.968 (50.0)	+0.220 (+5.6)
280	0.626 (15.9)	+0.071 (+1.8)	0.653 (16.6)	+0.075 (+1.9)	1.000 (25.4)	+0.110 (+2.8)	... ...	... ...	... ...	... ...	... ...	... ...
315	0.705 (17.9)	+0.079 (+2.0)	0.736 (18.7)	+0.083 (+2.1)	1.126 (28.6)	+0.122 (+3.1)	... ...	... ...	... ...	... ...	... ...	... ...
355	0.791 (20.1)	+0.091 (+2.3)	0.831 (21.1)	+0.094 (+2.4)	1.268 (32.2)	+0.138 (+3.5)	... ...	... ...	... ...	... ...	... ...	... ...