



# Standard Specification for Polybutylene (PB) Plastic Hot- and Cold-Water Distribution Systems<sup>1</sup>

This standard is issued under the fixed designation D 3309; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers requirements, test methods, and methods of marking for polybutylene plastic system components made in one standard dimension ratio and intended for 0.69 MPa (100 psi) water service up to and including 82°C (180°F). These components comprise pipe and tubing, socket-fusion fittings, compression fittings, mechanical fittings, and plastic-to-metal transition fittings. Requirements and test methods are included for sustained, hydrostatic pressure strength, thermocycling resistance, joint strength, and dimensions and tolerances for pipe and socket fusion fittings. The components covered by this specification are intended for use in hot- and cold-water potable water service and distribution systems and such non-potable water applications as building services piping, water heating and cooling systems, fire sprinkler applications, and other miscellaneous applications involving the transport of water, ethylene glycol solutions, or other aqueous liquids shown not to adversely affect PB performance.

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 in SI units are the standard. The values stated in parentheses are for information only.

NOTE 1—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.

1.4 The following precautionary caveat pertains only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water. Current edition approved Sept. 10, 1996. Published November 1996. Originally published as D 3309 – 74. Last previous edition D 3309 – 96a.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 618 Practice for Conditioning Plastics for Testing<sup>2</sup>
- D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure<sup>3</sup>
- D 1599 Test Method for Resistance to Short-Time, Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings<sup>3</sup>
- D 1600 Terminology for Abbreviated Terms Relating to Plastics<sup>2</sup>
- D 1708 Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens<sup>2</sup>
- D 1784 Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds<sup>2</sup>
- D 1898 Practice for Sampling of Plastics<sup>2</sup>
- D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings<sup>3</sup>
- D 2581 Specification for Polybutylene (PB) Plastics Molding and Extrusion Materials<sup>4</sup>
- D 2749 Symbols for Dimensions of Plastic Pipe Fittings<sup>3</sup>
- D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials<sup>3</sup>
- D 3915 Specification for Rigid Poly (Vinyl Chloride) (PVC) and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds for Plastic Pipe and Fittings Used in Pressure Applications<sup>5</sup>
- D 4181 Specification for Acetal (POM) Molding and Extrusion Materials<sup>5</sup>
- F 412 Terminology Relating to Plastic Piping Systems<sup>3</sup>
- F 699 Practice for Accelerated Conditioning of Polybutylene Pipe and Tubing for Subsequent Quality Control Testing<sup>3</sup>
- F 948 Test Method for Time-to-Failure of Plastic Piping Systems and Components Under Constant Internal Pressure With Flow<sup>3</sup>

### 2.2 ANSI Standards:

<sup>2</sup> Annual Book of ASTM Standards, Vol 08.01.

<sup>3</sup> Annual Book of ASTM Standards, Vol 08.04.

<sup>4</sup> Annual Book of ASTM Standards, Vol 08.03.

<sup>5</sup> Annual Book of ASTM Standards, Vol 08.02.

ANSI B 36.10 Welded and Seamless Wrought Steel Pipe<sup>6</sup>  
ANSI Z 17.1 Preferred Numbers<sup>6</sup>

2.3 *AWWA Standard:*

Manual M-11 Steel Pipe Design and Insulation<sup>7</sup>

2.4 *Federal Standard:*

Fed Std. No. 123 Marking for Shipments (Civil Agencies)<sup>8</sup>

2.5 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage<sup>8</sup>

2.6 *NSF Standard:*

Standard No. 14 for Plastic Piping Components and Related Materials<sup>9</sup>

Standard No. 61 for Drinking Water System Components—Health Effects<sup>9</sup>

### 3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600 and Symbols D 2749, unless otherwise specified. The abbreviation for polybutylene is PB. 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 1/8 in. Plastic pipe outside diameter schedule conforms to ANSI B 36.10.

3.1.2 *polybutylene plastics*—plastics prepared by the polymerization of no less than 85 % butene-1 and no less than 95 weight % of total olefins.

3.1.3 *relation between standard dimension ratio, stress, and internal pressure*—The following expression, commonly known as the ISO equation, is used to relate standard dimension ratio, stress, and internal pressure for pipe and tubing:

$$2S/P = R - 1 \quad (1)$$

or

$$2S/P = (D_o/t) - 1 \quad (2)$$

where:

$S$  = stress in circumferential or hoop direction, psi (MPa),

$P$  = internal pressure, psi (MPa) gage,

$D_o$  = average outside diameter, in.,

$t$  = minimum wall thickness, in., and

$R$  = standard dimension ratio, SDR.

3.1.4 *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 Z 17.1 Preferred Number Series R 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.

3.1.5 *standard material designation code*—The polybutylene material designation code shall consist of the abbreviation PB followed by two digits indicating the ASTM type and grade in Arabic numerals. A third and fourth digit shall be added to indicate the hydrostatic design stress for water at 23°C (73°F) in units of 100 psi.

### 4. Classification

4.1 *Pipe, Tubing, and Socket-Fusion Fittings*—This specification classifies PB 2110 pipe, tubing, and socket-fusion fittings by a single standard dimension ratio that shall be SDR 11 and by a maximum continuous use temperature that shall be 82°C (180°F), and by nominal pipe or tubing diameters from 1/8 in. through 2 in.

4.2 *Plastic-to-Metal Transition Fittings*—This specification classifies plastic-to-metal transition fittings intended for use in systems with PB 2110 tubing and pipe by a maximum use temperature that shall be 82°C (180°F) and by nominal sizes from 1/8 in. through 2 in. on the basis of resistance to burst pressure and to failure by thermocycling.

4.3 *Compression and Mechanical Plastic Fittings*—This specification classifies compression-type plastic fittings intended for use in systems with PB 2110 tubing by a maximum continuous use temperature that shall be 82°C (180°F) and by nominal sizes from 1/8 in. through 1 in. on the basis of resistance to burst pressure and to failure by thermocycling.

### 5. Materials

5.1 *Basic Materials Description*—Polybutylene plastics used to make pipe, tubing, and fittings meeting the requirements of this specification are categorized by two criteria, basic short-term properties, and long-term hydrostatic strength. Paragraphs 5.1.1 and 5.1.2 respectively define these categories.

5.1.1 *Basic Short-Term Properties*—This specification covers pipe, tubing, and fittings made from plastic materials meeting the mechanical strength, melt characteristics, and density requirements of Type 2, Grade 1 material in Specification D 2581.

5.1.2 *Long-Term Hydrostatic PB Strength*—This specification covers pipe, tubing, and fittings that are made from polybutylene resins designated as PB 2110 and further have a long-term hydrostatic design stress of 500 psi (3.45 MPa) at 82°C (180°F). Pipe and tubing are also defined on the basis of long-term hydrostatic strength tests. Fittings are so defined by hydrostatic sustained pressure tests on fitting assemblies required by this specification (see 6.5) based on the hydrostatic strength of the corresponding pipe or tubing.

NOTE 2—No hydrostatic design stress, as such, exists for fittings until such time as long-term hydrostatic strength test methods for fittings are developed.

5.1.3 Plastic fittings and components shall be made from either polybutylene meeting the mechanical strength, melt characteristics, and chemical resistance requirements of PB 21 in Specification D 2581, or acetal plastic meeting the requirements of Class 1, Grade 1 in Table 1 of Specification D 4181 or chlorinated poly (vinyl chloride) (CPVC) meeting the

<sup>6</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>7</sup> Available from the American Water Works Association, 6666 W. Quincey Ave., Denver, CO 80235.

<sup>8</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>9</sup> Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140.

**TABLE 1 Outside Diameters, Wall Thicknesses, and Tolerances for PB 21 SDR 11, Plastic Pipe and Tubing<sup>A</sup>**

Nominal Size	Average	Outside Diameter		Wall Thickness <sup>B</sup>	
		Tolerance on Average	Max Out-of-Round <sup>C</sup>	SDR 11	
				Min	Tolerance
<i>Tubing</i>					
1/8	0.250	±0.003	±0.003	0.040 <sup>D</sup>	+0.007
3/16	0.312	±0.003	±0.004	0.062 <sup>D</sup>	+0.010
1/4	0.375	±0.003	±0.004	0.062 <sup>D</sup>	+0.010
3/8	0.500	±0.003	±0.006	0.062 <sup>D</sup>	+0.010
1/2	0.625	±0.004	±0.008	0.062 <sup>D</sup>	+0.010
3/4	0.875	±0.004	±0.008	0.080	+0.010
1	1.125	±0.005	±0.010	0.102	+0.010
1 1/4	1.375	±0.005	±0.010	0.125	+0.013
1 1/2	1.625	±0.006	±0.012	0.148	+0.015
2	2.125	±0.006	±0.015	0.193	+0.019
<i>Pipe</i>					
3/4	1.050	±0.004	±0.010	0.095	+0.021
1	1.315	±0.005	±0.010	0.119	+0.026
1 1/4	1.660	±0.005	±0.012	0.151	+0.026
1 1/2	1.900	±0.006	±0.012	0.173	+0.026
2	2.375	±0.006	±0.012	0.216	+0.026

<sup>A</sup>All dimensions are in inches (1 in. = 25.4 mm).

<sup>B</sup>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.

<sup>C</sup>The maximum out-of-roundness apply to pipe or tubing as extruded.

<sup>D</sup>For tubing sizes of 1/2 in. and below, wall thickness minimums are not a function of SDR.

requirements of cell classification 23447 in Specifications D 1784 and D 3915 with applicable cells.

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

## 6. Requirements for Pipe, Tubing, and Fittings

6.1 *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.

### 6.2 Dimensions and Tolerances:

6.2.1 *Pipe*—The outside diameters and wall thicknesses for pipe and tubing shall meet the requirements given in Table 1 when measured in accordance with Test Method D 2122. The maximum out-of-roundness requirements shown in Table 1 apply to the average measured diameter after rounding with a rounding tool approved by the manufacturer. Calculated SDR-11 tubing wall thicknesses that fall below 0.062 in. (1.6 mm) shall be arbitrarily increased to that value.

6.2.2 *Socket-Fusion Fittings*—Fitting sockets inside diameters (waterways) and laying lengths shall meet the requirements given in Table 2 and Table 3 when measured in accordance with Test Method D 2122. The out-of-roundness requirements shown in Table 2 apply to the average measured diameter. Calculated SDR 11 fitting wall thicknesses that fall below 0.102 in. (2.6 mm) for the fitting socket or 0.128 in. (3.2 mm) for the fitting body shall be arbitrarily increased to these values.

6.2.3 *Interference Fit*—The pipes and fitting dimensions and tolerances in Table 1 and Table 2 provide for socket fusion joints having an interference fit based on the major diameter of pipe and tubing after rounding with a rounding tool approved by the manufacturer.

6.3 *Plastic-to-Metal Transition Fittings, Mechanical Fittings and Compression Type Plastic Fittings*—Dimensions shall be compatible with the requirements of Table 1. Components shall be corrosion-resistant and assembled in accordance with the manufacturer's instructions.

### 6.4 Hydrostatic Burst:

6.4.1 Pipe, tubing, and fittings (tested as assemblies) shall meet the minimum hydrostatic burst requirements shown in Table 4 when tested in accordance with 7.6.

6.4.2 Socket-type joints heat fused according to the manufacturer's instructions and conditioned in accordance with 7.1 shall meet the minimum hydrostatic burst requirement shown in Table 4 when tested in accordance with 7.6.

6.4.3 Plastic-to-metal transition fittings and compression-type plastic fittings assembled using the manufacturer's instructions shall meet the minimum hydrostatic burst requirement shown in Table 4 when tested in accordance with 7.6.

### 6.5 Sustained, Hydrostatic Pressure Strength:

6.5.1 Pipe, tubing, and fittings (tested as assemblies) shall meet the minimum hydrostatic sustained pressure strength requirements shown in Table 5 when tested in accordance with 7.4.

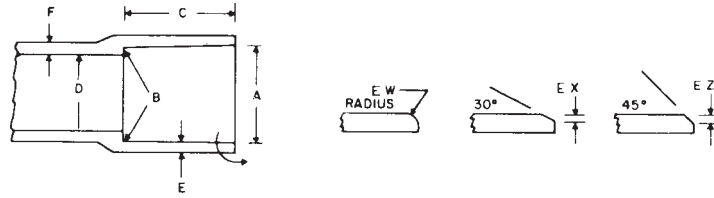
6.5.2 Socket-type joints heat fused according to the manufacturer's instructions and conditioned in accordance with 7.1 shall meet the requirements of 6.5.1 when tested in accordance with 7.4.

6.6 *Thermocycling*—Plastic-to-metal transition fittings and compression-type plastic fittings assembled using the manufacturers' instructions shall not separate or leak when thermocycled 1000 times between the temperatures of 16°C (60°F) and 82°C (180°F) when tested in accordance with 7.5.

NOTE 3—Tests applicable to assemblies (6.4-6.6) are intended to be performance qualification tests and not tests required of each joint.

6.7 *Excessive Temperature and Pressure Capability of Tubing and Pipe*—In the event of a heating system malfunction,

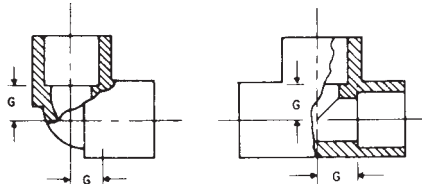
TABLE 2 Dimensions for Socket Fusion Fittings for PB 21, SDR 11.0 Pipe and Tubing<sup>A,B</sup>



Nominal Size	A Socket Entrance Diameter			B Socket Bottom Diameter			C Socket Length, min	D Inside Diameter, min	Wall Thickness min <sup>C</sup>		Entrance, min EW EX EZ
	Average Diameter	Tolerance on Diameter	Max Out-of-Round <sup>D</sup>	Average Diameter	Tolerance on Diameter	Max Out-of-Round <sup>D</sup>			E	F	
<i>Tubing</i>											
3/8	0.485	±0.005	±0.008	0.481	±0.005	±0.008	0.500	0.364	0.102	0.128	0.031
1/2	0.605	±0.005	±0.008	0.601	±0.005	±0.008	0.500	0.489	0.102	0.128	0.031
3/4	0.845	±0.005	±0.008	0.839	±0.005	±0.008	0.625	0.715	0.102	0.128	0.031
1	1.095	±0.008	±0.010	1.087	±0.008	±0.010	0.625	0.921	0.102	0.128	0.031
1 1/4	1.340	±0.008	±0.010	1.332	±0.008	±0.010	0.687	1.125	0.125	0.156	0.031
1 1/2	1.590	±0.008	±0.012	1.582	±0.008	±0.012	0.875	1.329	0.148	0.185	0.031
2	2.085	±0.010	±0.012	2.074	±0.010	±0.012	0.875	1.739	0.193	0.241	0.031
<i>Pipe</i>											
3/4	1.020	±0.008	±0.012	1.012	±0.008	±0.010	0.625	0.920	0.102	0.128	0.031
1	1.275	±0.008	±0.012	1.267	±0.008	±0.010	0.687	1.100	0.119	0.149	0.031
1 1/4	1.620	±0.008	±0.012	1.612	±0.008	±0.012	0.875	1.300	0.151	0.189	0.031
1 1/2	1.860	±0.010	±0.012	1.849	±0.010	±0.012	0.875	1.494	0.173	0.216	0.031
2	2.335	±0.010	±0.012	2.234	±0.010	±0.012	0.875	1.933	0.216	0.270	0.031

<sup>A</sup>All dimensions are in inches (1 in. = 25.4 mm).  
<sup>B</sup>All sketches and designs of fittings are illustrative only.  
<sup>C</sup>The minimum is the lowest wall thickness at any cross section.  
<sup>D</sup>Maximum out-of-roundness applies to the average measured inside diameter.

TABLE 3 Minimum Dimensions from Center to End of Sockets PB Socket Fusion Tees and 90° Elbows, SDR 11.0 PB Pipe and Tubing Fittings (Inches)



Nominal Size	G, min
<i>Tubing</i>	
3/8	0.359
1/2	0.382
3/4	0.507
1	0.633
1 1/4	0.758
1 1/2	0.884
2	1.134
<i>Pipe</i>	
3/4	0.750
1	0.875
1 1/4	1.000
1 1/2	1.250
2	1.500

TABLE 4 Minimum Hydrostatic Burst Strength Requirements for PB 21 Component Joints<sup>A</sup>

Temperature, °C (°F)	Burst Pressure, MPa (psi) <sup>B</sup>
23 (73)	3.03 (440)
82 (180)	1.73 (250)

<sup>A</sup>PB 21 joint components shall include: 1. Nominal 1 in. PB 21 Heat fused joints after conditioning according to 7.1. 2. Nominal 1/2-in. compression-type plastic fittings. 3. Nominal 1/2-in. plastic-to-metal transition fitting.

<sup>B</sup>The fiber stress used to derive this test pressure is: 15.18 MPa (2200 psi) at 23°C (73°F) and 8.63 MPa (1250 psi) at 82°C (180°F).

TABLE 5 Minimum Hydrostatic Sustained Pressure Requirements for PB 21 SDR 11 Pipe Tubing and Fitting Assemblies, and Heat-Fused Joints<sup>A</sup>

Test Duration, h	Hydrostatic Test Pressure Air Bath MPa (psi) <sup>B</sup>
1000	1.52 (220)

<sup>A</sup>Nominal 1-in. PB 21 heat-fused joints after conditioning according to 7.1.  
<sup>B</sup>The fiber stress used to derive this test pressure is 7.57 MPa (1100 psi) at 82°C (180°F).

accommodate short-term conditions, 48 h of 99°C (210°F) and 150 psi (1.04 MPa), until repairs can be made. Pipe and tubing shall be tested in accordance with 7.7.

6.7.1 *Hydrostatic Burst Strength*—None of the test specimens shall fail as defined in Test Method D 1599 at a pressure less than that specified in Table 6.

polybutylene pipe and tubing shall have adequate strength to

**TABLE 6 Minimum Requirements for PB 21 SDR 11 Pipe Tubing at 99°C (210°F)**

Pressure	(MPa)	psi
Hydrostatic burst strength <sup>A</sup>	(1.45)	210
Sustained hydrostatic internal pressure, <sup>B</sup> 1000 h	(1.04)	150

<sup>A</sup>The fiber stress used to derive this test pressure is 1050 psi (7.25 MPa) at 99°C (210°F).

<sup>B</sup>The fiber stress used to derive this test pressure is 750 psi (5.18 MPa) at 99°C (210°F).

6.7.2 *Sustained Hydrostatic Pressure*—None of the test specimens shall fail as defined in Test Method D 1598 in less than 1000 h at the pressure specified in Table 6.

6.8 *Elongation Value at Break*—The minimum pipe machine-direction elongation value at break shall exceed or equal an average of 125 % when samples are tested in accordance with 7.8.

## 7. Test Methods for Pipe, Tubing, and Fittings

7.1 *Conditioning*—Because of the crystalline transformation that takes place after polybutylene resins are cooled from the melt, it is necessary to delay physical testing until 10 days after pipe extrusion, molding of fittings, or socket fusion of joints. During this 10-day period, store the pipe fitting or assembly at temperatures between 4 and 38°C (40 and 100°F). Take the test specimens after 8 days and condition at 23 ± 2°C (70 to 77°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Practice D 618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct the tests in the Standard Laboratory Atmosphere of 23 ± 2°C (70 to 77°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods or in this specification.

7.3 *Sampling*—A sufficient quantity of pipe, tubing, or fittings, as agreed upon by the purchaser and the seller, shall be selected from each lot or shipment and tested to determine conformance with this specification (see Practice D 1898). In the case of no prior agreement, random samples selected by the testing laboratory shall be deemed adequate.

7.4 *Sustained Hydrostatic Pressure*—Determine in accordance with Test Method D 1598, except for the following sections:

7.4.1 Assemble test sections in accordance with manufacturer's instructions in Appendix X2. Select six specimens at random.

7.4.2 Condition socket fused joints in accordance with 7.1.

7.4.3 Test temperature shall be 82 ± 2°C (180 ± 4°F).

7.4.4 The external test environment shall be air at 82 ± 2°C (180 ± 4°F).

7.4.5 Fill the specimens with water at a temperature of at least 50°C (120°F). Condition the specimens filled with water in air at the test temperature 82 ± 2°C (180 ± 4°F) for at least 16 h.

7.4.6 Failure of any one of the six specimens constitutes failure in the test.

7.5 *Thermocycling*:

7.5.1 *Summary of Method*—This method describes a pass-fail test for thermally cycling PB plastic-to-metal transition

fitting assemblies and compression type plastic fittings 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 PB plastic-to-metal transition fittings, mechanical fittings, and compression plastic fittings intended for continuous use up to and including 82°C (180°F).

7.5.2 *Apparatus*—A nitrogen or air source capable of maintaining a nominal internal pressure of 0.69 ± 0.069 MPa (100 ± 10 psi) on the specimens is required. The immersion system shall consist of two water reservoirs controlled at 16 ± 2°C (60 ± 4°F) and 82 ± 2°C (180 ± 4°F). 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 reservoirs.

NOTE 4—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 specimen in the trough.

7.5.3 *Sampling and Specimen Preparation*—Select at random six specimens of the type and size of PB 21 plastic-to-metal transition of compression-type plastic 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 fitting manufacturer. 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.

7.5.4 *Procedure*—Pressurize the specimen assembly with nitrogen or air to 0.69 ± 0.069 MPa (100 ± 10 psi). Immerse in 16 ± 2°C (60 ± 4°F) 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 0.69 ± 0.069 MPa (100 ± 10 psi), alternately between 16 ± 2°C (60 ± 4°F) and 82 ± 2°C (180 ± 4°F) by means of immersion in water using the following test cycle:

Water immersion at 82°C (180°F)	2 minutes (min)
Air immersion at ambient	2 minutes (max)
Water immersion at 16°C (60°F)	2 minutes (min)
Air immersion at ambient	2 minutes (max)

Upon the completion of 1000 thermal cycles, immerse the specimen assembly again in 16 ± 2°C (60 ± 4°F) water and check for any sign of gas leakage. Any evidence of leakage at the fitting or separation of the fitting from the pipe or tubing constitutes a failure.

7.5.5 *Interpretation of Results*—Failure of any one of six specimens tested shall constitute failure of this test.

7.6 *Hydrostatic Burst Strength*—Determine the minimum hydrostatic strength for heat fusion joints, plastic-to-metal transition fittings, and compression-type plastic fittings at both 23°C (73°F) and 82°C (180°F) according to Test Method D 1599 except as herein specified.

7.6.1 *Assembly*:

7.6.1.1 *Heat-Fused Joints*—Assemble the joints in accordance with the manufacturer's instructions and condition in accordance with 7.1.

7.6.1.2 *Compression-Type Plastic Fittings and Plastic-to-Metal Transition Fittings*—Assemble the fittings in accordance with manufacturer's instructions.

7.6.2 *Procedure*—Test a single specimen assembly containing at least six joints prepared from PB 21 pipe or tubing, and fittings meeting the requirements of this specification. After assembly in accordance with 7.6.1, attach end closures, fill the specimen assembly with water and condition in water at the test temperature for 2 h minimum (or in air for 4 h minimum). In the case of testing at 82°C (180°F) the sample should be filled with water of at least 50°C (120°F) temperature prior to conditioning. Then test immediately.

7.6.2.1 Increase the internal pressure at a constant rate so as to reach the maximum burst requirement in 60 to 70 s. Leakage or separation at any of the joints tested at less than the minimum hydrostatic burst requirements for either temperature specified in Table 4 shall constitute failure in this test.

7.7 *Excessive Temperature and Pressure Capability of Tubing and Pipe:*

7.7.1 *Hydrostatic Burst Strength*—Determine the minimum hydrostatic burst strength for pipe and tubing at 99°C (210°F) according to Test Method D 1599.

7.7.2 *Hydrostatic Sustained Pressure*—Determine in accordance with Test Method D 1598, except for the following requirements:

7.7.2.1 Select six test specimens at random.

7.7.2.2 Condition pipe or tubing in accordance with 7.1.

7.7.2.3 Test temperature shall be  $99 \pm 2^\circ\text{C}$  ( $210 \pm 4^\circ\text{F}$ ).

7.7.2.4 The external test environment shall be air.

7.7.2.5 Fill specimens with water at a temperature of  $99 \pm 2^\circ\text{C}$  ( $210 \pm 4^\circ\text{F}$ ).

7.7.2.6 Pressurize test specimens to the required pressure and maintain for 1000 h.

7.8 *Elongation Value at Break:*

7.8.1 *Method*—The method, test equipment, and test report shall be as specified in Test Method D 1708, using Speed C, 10 to 13 mm/min (0.4 to 0.5 in./min). At least two microtensile specimens<sup>10</sup> taken 180° from each other from a 3-ft length of pipe shall be a minimum of 10 days old or pressure aged for 10 min at 2070 MPa (30 000 psi), according to Practice F 699. This method shall be the referee procedure. (An alternative test method is described in Appendix X4.) If a reading within 10 % of the minimum results, a retest over five specimens shall be taken from the original sample to confirm the reading.

NOTE 5—Pipe manufacturers have found that pipe tested within 2 h of extrusion give elongation at break values correlating within  $\pm 10\%$  of those for aged pipe. These conditions may be considered in developing elongation values. In the case of disagreement between seller and purchaser, naturally or pressure-aged samples shall be used.

## 8. Retest and Rejection

8.1 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.

## 9. Marking

9.1 The marking shall be applied in such a manner that it remains legible (easily read) after installation and inspection.

9.2 *Content of Marking:*

9.2.1 Manufacturer's name or trademark.

9.2.2 Certification mark or seal of the laboratory making the evaluation for this purpose (see 10.1).

9.2.3 ASTM D 3309 designation.

9.2.4 Material designation in accordance with 3.5 (PB 2110), for polybutylene pipe, tubing and fittings. A for acetal fittings, AC for acetal copolymer fittings and CPVC 41 for chlorinated poly (vinyl chloride) fittings.

9.2.5 Pressure rating (see Appendix X1) at 82°C (180°F),

9.2.6 Nominal size,

9.2.7 Standard dimension ratio (SDR 11), and

9.2.8 A code number identifying the compound and the date of manufacture.

9.3 *Pipe and Tubing*—Markings 9.2.1-9.2.8 shall be required on pipe and tubing at intervals of not more than 1.5 m (5 ft). Markings shall be applied without indentation in some permanent manner so as to remain legible under normal handling and installation practice. Pipe and tubing that is difficult to mark without indenting shall be so marked provided (1) the marking does not reduce the wall thickness to less than the minimum value for the pipe or tubing, and (2) it is demonstrated that these marks have no effect on the long-term strength of the pipe or tubing.

9.4 *Socket-Fusion Fittings*—Markings 9.2.1-9.2.3 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 that 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.

9.5 *Transition Fittings, Mechanical Fittings, and Compression Plastic Fittings*—Markings 9.2.1-9.2.3 shall be required on all fittings.

## 10. Quality Assurance

10.1 When the product is marked with this designation, D 3309, 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 cold and hot water distribution piping; polybutylene

<sup>10</sup> Dies are available from M.S. Instrument Co., Castle-on-Hudson, NY and Testing Machine Inc., Amityville, NY 11701.

**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. *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.

**APPENDIXES**

**(Nonmandatory Information)**

**X1. HYDROSTATIC DESIGN STRESS**

X1.1 Hydrostatic design stresses recommended by the Plastics Pipe Institute are used to pressure rate PB 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 D 2837. 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 6.4 for fittings tested as assembled systems are

based on stress rupture data for pipe and tubing.

X1.3 The hydrostatic design stresses and pressure ratings in Table X1.1 apply to systems assembled from PB 2110SDR 11 components meeting the requirements of this specification.

X1.4 These hydrostatic design stresses are not suitable for

**TABLE X1.1 Hydrostatic Design Stresses and Pressure Ratings for PB 21, SDR 11, Hot Water Distribution Systems**

Rated Temperature °C(°F)	Hydrostatic Design Stress, MPa (psi)	Pressure Rating for Water, MPa (psi)
23 (73.4)	6.89 (1000)	1.38 (200)
60 (140)	5.32 (800)	1.10 (160)
82 (180)	3.45 (500)	0.69 (100)
93 (200)	2.66 (400)	0.55 (80)

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 PB materials made in the United States and tested in the form of pipe tubing or fitting assemblies meet this requirement. Experience of the industry indicates that PB hot

and cold water distribution systems made from components meeting the requirements of this specification give satisfactory service under normal conditions at these temperature-pressure ratings.

**X2. DESIGN, ASSEMBLY, AND INSTALLATION CONSIDERATIONS**

**X2.1 Design**

**X2.1.1 Thermal Expansion**—The linear expansion rate for PB is approximately 1 in./10°F temperature change for each 100 ft of pipe or tubing, or 25 mm/5.6°C temperature change for each 30 m of pipe or tubing. When installing long runs of pipe allow 1/8 to 3/16 in./ft (10 to 14 mm longitudinal clearance per metre) of run to accommodate thermal expansion. Pipe should not be anchored rigidly to a support but allowed freedom of movement to expand and contract.

**X2.1.2 Water Heaters**—Components covered by this specification are intended for continuous use at 82°C (180°F). 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.

**X2.1.3 Sweating**—Even though the thermal conductivity of PB 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.

**X2.1.4 Water Hammer and Surge**—A PB 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 Chapter 7, AWWA Manual M-11, Steel Pipe Design and Installation.

**X2.1.5 Horizontal Support Spacing:**

**X2.1.5.1 One and Two Family Residential**—The maximum recommended spacing between horizontal supports is 32 in. (800 mm) for all sizes in this specification. Polybutylene piping should not be rigidly secured to a stud or joist but should be secured with smooth plastic strap hangers, which permit ease of movement during expansion/contraction cycles.

**X2.1.5.2 Multi Family, Commercial, Industrial, or Other Uses**—Support spacing shall be determined from Table X2.1 and Table X2.2.

**X2.2 Assembly**

**X2.2.1 Socket-Fused 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 fused joint it is advisable to check for an interference fit between both pipe or tubing and fitting and between heating tool and pipe or tubing and fitting respectively.

**X2.2.1.2 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** The heat-fusion recommendations of the material manufacturer, as well as the requirements of this standard, shall be observed in the performance of such work.

**X2.2.1.4** Trained construction personnel and special tools designed for the purpose shall be used to join PB components by the heat-fusion method.

**X2.2.1.5** The heating tool shall provide adequate heat, and it shall be capable of being adjusted to a closely controlled temperature over a range from 191 to 288°C (375 to 550°F). It may be heated with gas or electricity.

**TABLE X2.1 Horizontal Pipe Support Spacing<sup>A</sup>**

Nominal Pipe Size,	Long-Term Deflection (in.)				
	CTS	0.25	0.50	1	2
1	32	38	45	53	
1-1/4	35	42	50	70	
1-1/2	38	46	55	65	
2	43	51	60	72	
2-1/2	50	60	72	85	
3	55	66	78	93	
3-1/2	59	71	84	100	
4	63	75	90	107	
IPS					
3/4	31	37	44	52	
1	35	42	50	59	
1-1/4	39	47	56	66	
1-1/2	42	50	59	70	
2	47	56	66	79	
2-1/2	51	61	72	86	
3	57	68	80	96	
3-1/2	62	74	89	105	
4	63	75	89	106	

<sup>A</sup>Where aesthetics are a consideration, such as in multi-family residential potable hot water plumbing applications, it is desired that the 0.25 in. deflection spacing be used. Pipes installed with the higher deflections will perform acceptably.

**TABLE X2.2 Horizontal Pipe Support Spacing Temperature Adjustment<sup>A</sup>**

Temperature, °F	Adjustment Factor (%)
40	106
73	100
110	96
140	92
180	86

<sup>A</sup>Apply this temperature adjustment factor for systems designed to operate continuously at other than 73°F.



X2.2.1.6 The tool faces (heating surface) shall be made of suitable material such as aluminum, stainless steel, or bronze alloys. If they are made from copper or copper alloys, the surfaces shall be chromium plated. Polytetrafluoroethylene (PTFE) may be used as a coating on metal heating-surfaces to minimize sticking of heated PB material.

X2.2.1.7 The tool faces must be heated to the temperature recommended by the PB manufacturer for the specific pipe sizes to be joined. The heating tool may be equipped with a thermometer or other temperature-measuring device, or a crayon-temperature indicator may be used. When a crayon is used, it shall not be placed in contact with the tool at any place on its heating surface which will subsequently contact the PB material to be heated.

X2.2.1.8 The PB surfaces to be heat fused and the tool faces shall be clean and free of oil, dirt, and other foreign substances. PB surfaces and metal heating surfaces may be cleaned with oil-free steel wool or rags. Heating surfaces coated with PTFE shall be cleaned with rags or tissue paper. Residual PB material on tool faces shall be removed prior to reuse of the tool.

#### X2.2.1.9 *Step-by-Step Socket Fusion Assembly:*

1. The heating equipment shall be designed to accept various sizes of pipe and socket-fitting tool faces.

2. The tool faces for each size of pipe shall consist of one for the external surface of the pipe and one for the internal surface of the socket fitting. They shall be manufactured to proper tolerances for close fit with the pipe and fitting surfaces to be heated.

3. The pipe and fitting shall be of proper size to provide an interference fit during engagement and a sound heat fusion joint. (See Table 1 and Table 2).

4. Before heating, the pipe shall be marked at a distance back from its end equal to the depth of the fitting socket to indicate proper extent of pipe penetration during joint makeup. The pipe or fitting manufacturer's recommendations shall be observed in the use of marking devices.

5. For socket fusion of tubing below 0.080-in. wall a metal insert fitting (either stainless steel or brass) shall be placed in the tubing prior to fusion. The length of the metal insert shall be at least 3.2 mm ( $\frac{1}{8}$  in.) longer than the socket depth.

6. After the proper-size tool faces have been heated to the required temperature, they shall be placed in full contact with the pipe and fitting surfaces to be heated and then held against the PB surfaces until they have melted sufficiently to cause a small bead to form on the pipe around the edge of the tool face. The manufacturer should be consulted for recommended cycles and temperature for specific pipe sizes.

7. When the engaging surfaces of the joint have properly melted, the pipe and fitting shall be removed simultaneously from the heating tool and joined immediately. The fitting shall be placed in full contact with the molten surface of the pipe and held in position under light hand pressure without movement for about 30 s.

X2.2.2 *Plastic-to-Metal Transitions*—Assemble in accordance with the manufacturer's instructions. Compression-type transition fittings are likely to include plastic or metal inserts, and ferrules or O-rings which form an essential part of the fittings assembly and should not be omitted. Mechanical type

metal connectors are used to combine PB tubing with assembled cone flares to the initial transition fittings in one type of approved fitting.

#### X2.2.3 *Compression Type Fittings:*

X2.2.3.1 *Insert Fittings*—A number of techniques have been developed where a plastic or metal fitting is firmly secured to PB pipe or tubing. The fitting is placed inside the tube inside diameter and a tool is employed to crimp a metallic lock ring around the pipe outside diameter adjacent to the fitting. This provides a mechanical lock with the tubing being wedged securely between the ring and the insert fitting.

X2.2.3.2 *Mechanical Fittings*—A number of fitting systems have been developed which can be described as mechanical compression type joining. They are comprised of plastic or metal fittings that provide a seal on the outer surface of polybutylene tubing. The actual sealing is effected by the following methods:

(a) (a) Polybutylene cone with metal retainer ring and threaded plastic nut.

(b) (b) Elastomeric cone with threaded plastic or metal nut.

(c) (c) Plastic sleeve with metal retainer ring and threaded plastic nut.

(d) Metal or plastic ferrule with a threaded nut.

(e) Plastic fitting with internal elastomeric seal, plastic gasket, and metal retainer ring; or deformable plastic compression ring and nut.

The above compression type fittings should be assembled in accordance with the manufacturer's recommendations.

X2.2.3.3 *Cold Flaring*—Utilize a cold flaring tool wherein the pipe outside diameter is expanded mechanically. The expanded or flared end is then secured between a plastic or metal fitting. Flare configuration may vary depending on the particular tool employed. The flared surface generally serves as the sealing area between the pipe and fitting.

## X2.3 Installation

X2.3.1 *Storage and Handling*—PB pipe tubing and fittings should be stored under cover to avoid unnecessary dirt accumulation and long-term exposure to sunlight. Pipe and tubing can be stored in coils of number size and length recommended by the manufacturer. Care should be used in handling to ensure that unnecessary abuse such as abrasion on concrete or crushing is avoided.

X2.3.2 *Pressure Testing*—A socket-fused system is generally ready for pressure testing with cold potable water (not to exceed 38°C (100°F)) 15 min after the joint has cooled to room temperature. A short-term pressure test at 0.69 MPa (100 psi) on the system excluding the hot water heater is advisable to ensure that all joints have been fused, and to test for joint leakage.

X2.3.2.1 *Field pressure testing polybutylene systems* should be in accordance with manufacturer's instructions. The testing is not intended to assure long term performance. Manufacturers can only warrant systems installed according to their instructions.

NOTE X2.1—A socket-fused system should be allowed to age for 24 h prior to use of design pressure and temperature. Mechanical compression joints should be used for repairs in a system where it is desirable to repressurize immediately.

**X2.3.3 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 mechanical fitting should be installed using couplings and short lengths of pipe.

**X2.3.4 Soldering in the Area**—Soldered metal joints should not be made closer than 460 mm (18 in.) to an installed plastic-to-metal adapter in the same water line.

### **X3. OPTIONAL PERFORMANCE QUALIFICATION AND IN-PLANT QUALITY CONTROL PROGRAM FOR PB 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 PB hot-water distribution system components supplied under this specification shall consistently meet its requirements.

#### **X3.2 Performance Qualifications**

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 PB 2110 materials as defined in Section 4 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 by the purchaser and the manufacturer. The program outlined in Table X3.1 is recommended.

**TABLE X3.1 Suggested Quality Control Program**

Component	Property	Frequency	Method
Pipe and tubing	outside diameter	hourly	6.2.2.1
	wall thickness	hourly	6.2.2.2
	burst pressure	8 h	7.6
Socket-type fittings	socket diameter	hourly	6.2.3.1
	burst pressure	8 h	7.6
Compression-type plastic fittings	burst pressure	8 h	7.6
Plastic-to-metal transition fittings	burst pressure	8 h	7.6

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.

X3.3.3 *Marking*—A code number shall be included on the pipe and tubing that can be used to identify the manufacturer and the date of manufacture. Fittings shall be marked to identify the manufacturer and shall be coded or placed in dated containers to show the date of manufacture.

### **X4. OPTIONAL TEST METHOD FOR ELONGATION VALUE AT BREAK**

**X4.1 Introduction**—Because a tensiometer is costly and not readily available at most pipe extruder plants, a simplified quality control procedure has been established. A machinist vise modified as shown in Fig. X4.1 to allow clamping of die-cut microtensile specimen shall be used. The draw rate shall be uniform and approximately 10 to 13 mm (0.4 to 0.5 in.)/min. Microtensile specimens cut from pipe shall be a minimum of 10 days old or pressure aged for 10 min at 2070 MPa (30 000 psi), according to Practice F 699. (In view of the greater dependence on the operator in this optional method, in case of disagreement, Test Method D 1708 is the referee procedure.)

**X4.2 Procedure**—Die cut at least two microtensile specimens, as in Test Method D 1708, from a 3 ft length of 10 day old or pressure aged pipe, following the sampling procedure given in 7.8.1. Mount the specimen in the machinist vise as shown in Fig. X4.1. The shoulder of the tensile specimen shall be in line with the vise jaw faces. Tighten the grips evenly and

firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed. Before extending vise, measure the distance between jaw faces (gage length) with calipers or other measuring device to  $\pm 0.050$  mm ( $\pm 0.002$  in.). Extend the vise at approximately 13 mm (0.5 in.)/min jaw separation until rupture. Record the extension between jaws at rupture to  $\pm 0.050$  mm ( $\pm 0.002$  in.). Test remaining specimens in the same manner. Calculate the percentage elongation at break by dividing the change in gage length at rupture of specimen by the original distance between jaw faces (gage length) and multiply by 100. Report material identification, conditioning procedure, number of specimens tested, average value of percent elongation to three significant figures, standard deviation (if desired), and date of test.

**X4.3 Product Quality Control**—It is recommended that 2 samplings per 8 h be made per pipe per extrusion outlet. Test results shall be recorded and filed for inspection, on request.

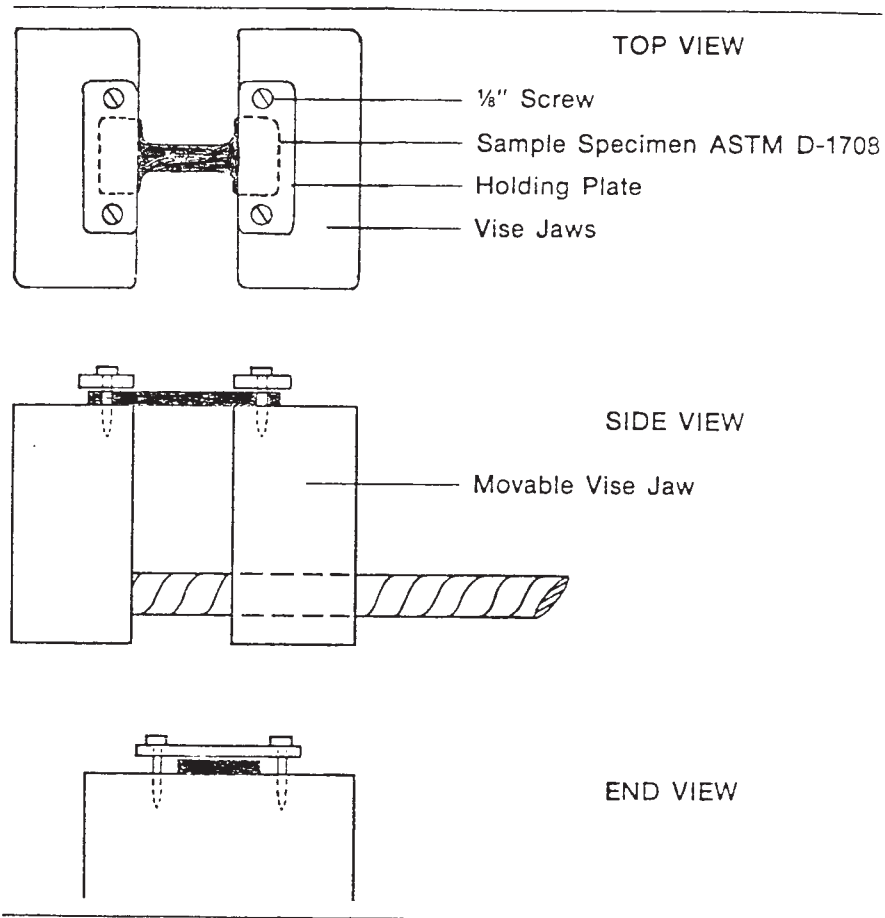


FIG. X4.1 Thin Wall Polybutylene Pipe Quality Control Use of Machinist Vise

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