UL 651A

STANDARD FOR SAFETY

High Density Polyethylene (HDPE) Conduit

UL Standard for Safety for High Density Polyethylene (HDPE) Conduit, UL 651A

Sixth Edition, Dated May 10, 2023

Summary of Topics

This revision of ANSI/UL 651A dated January 3, 2024 includes the following changes:

– Referenced Publication Corrections; Section 3 and Section 3A

– IGEPAL Trademark Statement; 4.1

– Move Tensile Strength Section; Table 7.1, Section 8 and Section 7.5

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated November 3, 2023.

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UL 651A

Standard for High Density Polyethylene (HDPE) Conduit

Prior to the first edition, the requirements for the products covered by this standard were included in the Standard for Rigid Nonmetallic Conduit, UL 651.

Prior to the fifth edition, the requirements for continuous length HDPE conduit covered by this standard were included in the Standard for Continuous Length HDPE Conduit, UL 651B.

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Second Edition – August, 1989
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Sixth Edition

May 10, 2023

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through January 3, 2024.

The most recent designation of ANSI/UL 651A as an American National Standard (ANSI) occurred on January 3, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

TThe Department of Defense (DoD) has adopted UL 651A on November 30, 1984. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover smooth-wall straight length and coiled continuous length conduit with a circular cross section, including elbows. Included are Schedule 40, Schedule 80, EPEC-A, EPEC-9, EPEC-11, and EPEC-13.5 high density PE electrical conduit.

1.2 The conduit mentioned in 1.1 are intended for use at 50 °C (122 °F) and lower ambient temperatures. HDPE conduit, where directly buried or encased in concrete in trenches outside of buildings, may be used with 90 °C (194 °F) wiring.

1.3 The conduit covered in these requirements are intended for use as rigid nonmetallic raceway for wires and cables in accordance with the National Electrical Code, NFPA 70.

1.4 HDPE conduit is for aboveground use where encased in not less than 2 inches (50 mm) of concrete and for underground use by direct burial or encasement in concrete.

2 Units of Masurement

2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

3 Undated References

3.1 Deleted

3A Referenced Publications

3A.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

3A.2 The following publications are referenced in this Standard:

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D1693, *Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics*

ASTM D2122, *Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings*

ASTM D2412, *Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading*

ASTM D3350, *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*

NFPA 70, *National Electrical Code*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

CONSTRUCTION

4 General

4.1 All conduit shall be made and furnished with the degree of uniformity and quality of workmanship that are practicable in a well-equipped factory. The following materials shall be used as specified in the Standard Specification for Polyethylene Plastics Pipe and Fittings Materials, ASTM D3350 and shall equal or exceed the cell classification PE334480C or E. The¬ material property evaluation shall be conducted on the final compound and include the evaluation of the Density, Melt Index, Flexural Modulus, Tensile Strength, Slow Crack Growth Resistance, Color and Ultraviolet (UV) Stabilizer (the carbon black content shall be in the range of 2 to 4 % for black conduit), Thermal Stability, and Brittleness Temperature properties as per ASTM D3350, with the exception that the minimum specified slow crack growth cell class 8 requirements is F10 > 96 hr per Test Method D1693, condition B, 10 % IGEPAL.

NOTE: IGEPAL is a Registered Trademark of Rhodia Operations.

4.2 Conduit shall be essentially circular in cross section. The inside surface of conduit shall be without indentations (normal convolutions are not to be considered as indentations), projections, roughness, or other features that could damage or impede wires and cables being pulled into the conduit.

4.3 Conduit shall provide a smooth raceway for field installation of wires and cables. They shall not have any features that can abrade or otherwise damage wires and cables. The outside surfaces of conduit shall be smooth and without any chips, blister, cracks, or other defects. There shall not be any tendency for conduit to peel, scale, flake chalk, or crumble.

4.4 Both ends of each length of conduit shall be perpendicular to the longitudinal axis of the conduit.

4.5 Friction reduction, in the form of lubrication or interior ribbing, or both, shall be permitted. Ribbing shall not be sharp or severe. Lubricants shall be chemically compatible with both conduit and cable jacket materials.

5 Dimensions

5.1 Limits on the outside diameter shall be as specified in Table 5.1. Limits on the wall thicknesses shall be as specified in Table 5.2 through Table 5.4 for the appropriate wall type.

Table 5.1
Conduit Outside Diameter

Trade size	(Metric designator)	Average outside diameter					
		Average,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)
1/2	(16)	0.84 ±0.004	(21.34 ±0.10)	0.855	(21.72)	0.825	(20.96)
3/4	(21)	1.050 ±0.004	(26.67 ±0.10)	1.070	(27.18)	1.030	(26.16)
1	(27)	1.315 ±0.005	(33.40 ±0.13)	1.340	(34.04)	1.290	(32.77)
1-1/4	(35)	1.660 ±0.005	(42.16 ±0.13)	1.685	(42.80)	1.635	(41.53)
1-1/2	(41)	1.900 ±0.006	(48.26 ±0.15)	1.930	(49.02)	1.870	(47.50)
2	(53)	2.375 ±0.006	(60.32 ±0.15)	2.410	(61.21)	2.340	(59.44)
2-1/2	(63)	2.875 ±0.007	(73.02 ±0.18)	2.910	(73.91)	2.840	(72.14)

Table 5.1 Continued on Next Page

Table 5.1 Continued

Trade size	(Metric designator)	Average outside diameter					
		Average,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)
3	(78)	3.500 ±0.008	(88.90 ±0.20)	3.540	(89.92)	3.460	(87.88)
3-1/2	(91)	4.000 ±0.008	(101.60 ±0.20)	4.045	(102.74)	3.955	(100.46)
4	(103)	4.500 ±0.009	(114.30 ±0.23)	4.550	(115.57)	4.450	(113.03)
5	(129)	5.563 ±0.010	(141.30 ±0.25)	5.618	(142.70)	5.508	(139.90)
6	(155)	6.625 ±0.011	(168.28 ±0.28)	6.690	(169.93)	6.560	(166.62)

Table 5.2
Conduit Wall Thickness, Types Schedule 40 and Schedule 80

Trade size	(Metric designator)	Wall thickness							
		Schedule-40				Schedule-80			
		Maximum,		Minimum,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
1/2	(16)	0.129	(3.28)	0.109	(2.77)	0.167	(4.24)	0.147	(3.73)
3/4	(21)	0.133	(3.38)	0.113	(2.87)	0.174	(4.42)	0.154	(3.91)
1	(27)	0.153	(3.89)	0.133	(3.38)	0.200	(5.08)	0.179	(4.55)
1-1/4	(35)	0.160	(4.06)	0.140	(3.56)	0.214	(5.44)	0.191	(4.85)
1-1/2	(41)	0.165	(4.20)	0.145	(3.68)	0.224	(5.69)	0.200	(5.08)
2	(53)	0.174	(4.42)	0.154	(3.91)	0.244	(6.20)	0.218	(5.54)
2-1/2	(63)	0.227	(5.77)	0.203	(5.16)	0.309	(7.85)	0.276	(7.01)
3	(78)	0.242	(6.15)	0.216	(5.49)	0.336	(8.53)	0.300	(7.62)
3-1/2	(91)	0.253	(6.43)	0.226	(5.74)	0.356	(9.04)	0.318	(8.08)
4	(103)	0.265	(6.73)	0.237	(6.02)	0.377	(9.58)	0.337	(8.56)
5	(129)	0.289	(7.34)	0.258	(6.55)	0.420	(10.67)	0.375	(9.53)
6	(155)	0.314	(7.98)	0.280	(7.11)	0.484	(12.29)	0.432	(10.97)

Table 5.3
Conduit Wall Thickness, Types EPEC-A and EPEC-13.5

Trade size	(Metric designator)	Wall thickness							
		EPEC-A				EPEC-13.5			
		Maximum,		Minimum,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
1/2	(16)	0.080	(2.03)	0.060	(1.52)	0.082	(2.08)	0.062	(1.57)
3/4	(21)	0.080	(2.03)	0.060	(1.52)	0.098	(2.49)	0.078	(1.98)
1	(27)	0.095	(2.41)	0.075	(1.91)	0.117	(2.97)	0.097	(2.46)
1-1/4	(35)	0.120	(3.05)	0.100	(2.54)	0.143	(3.63)	0.123	(3.12)
1-1/2	(41)	0.135	(3.43)	0.115	(2.92)	0.161	(4.09)	0.141	(3.58)

Table 5.3 Continued on Next Page

Table 5.3 Continued

Trade size	(Metric designator)	Wall thickness							
		EPEC-A				EPEC-13.5			
		Maximum,		Minimum,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
2	(53)	0.165	(4.19)	0.145	(3.68)	0.197	(5.00)	0.176	(4.47)
2-1/2	(63)	0.223	(5.66)	0.203	(5.16)	0.238	(6.05)	0.213	(5.41)
3	(78)	0.236	(5.99)	0.216	(5.49)	0.290	(7.37)	0.259	(6.58)
3-1/2	(91)	a	a	a	a	a	a	a	a
4	(103)	0.265	(6.73)	0.237	(6.02)	0.373	(9.47)	0.333	(8.46)
5	(129)	0.289	(7.34)	0.258	(6.55)	0.463	(11.76)	0.413	(10.49)
6	(155)	0.314	(7.98)	0.280	(7.11)	0.550	(13.97)	0.491	(12.47)

[a] To be developed

Table 5.4
Conduit Wall Thickness, Types EPEC-9 and EPEC-11

Trade size	(Metric designator)	Wall thickness							
		EPEC-9				EPEC-11			
		Maximum,		Minimum,		Maximum,		Minimum,	
		inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
1/2	(16)	0.123	(3.12)	0.093	(2.36)	0.096	(2.44)	0.076	(1.93)
3/4	(21)	0.137	(3.48)	0.117	(2.97)	0.115	(2.92)	0.095	(2.41)
1	(27)	0.166	(4.22)	0.146	(3.71)	0.140	(3.56)	0.120	(3.05)
1-1/4	(35)	0.206	(5.23)	0.184	(4.67)	0.171	(4.34)	0.151	(3.84)
1-1/2	(41)	0.236	(5.99)	0.211	(5.36)	0.194	(4.93)	0.173	(4.39)
2	(53)	0.296	(7.52)	0.264	(6.71)	0.242	(6.15)	0.216	(5.49)
2-1/2	(63)	0.357	(9.07)	0.319	(8.1)	0.292	(7.42)	0.261	(6.63)
3	(78)	0.436	(11.07)	0.389	(9.88)	0.356	(9.04)	0.318	(8.08)
3-1/2	(91)	a	a	a	a	a	a	a	a
4	(103)	0.560	(14.22)	0.500	(12.7)	0.458	(11.63)	0.409	(10.39)
5	(129)	0.692	(17.58)	0.618	(15.7)	0.567	(14.4)	0.506	(12.85)
6	(155)	0.824	(20.93)	0.736	(18.69)	0.674	(17.12)	0.602	(15.29)

[a] To be developed

5.2 Each length of conduit on which measurements are made is to be finished, smooth and clean wherever it is to touch any part of a measuring device or tool. All of the average and individual outside diameter measurements are to be performed at the center for straight conduit and at least at a distance greater than 5 ft (1.52 m) from the end of the coil or reel of conduit.

5.3 Measurements to establish dimensional conformance shall be done in accordance with ASTM Test Method D2122 and shall meet all the required dimensions and tolerances for the conduit type being manufactured. Instruments shall be calibrated to read directly at least ±0.001 inch or ±0.02 mm. All measurements and tests shall be conducted at 73 ±3.6 °F or 23 ±2.0 °C. In case of dispute, specimens shall be preconditioned for at least 24 hours in still air at a temperature of 73 ±3.6 °F or 23 ±2.0 °C. Humidity control is not required.

5.4 In disputes that may arise between measuring techniques, the vernier wrap tape is to act as the referee in determining compliance with the requirements for average outside diameters and the vernier caliper is to act as the referee in determining compliance with the requirements for minimum and maximum outside diameters.

5.5 The ovality for straight conduit shall not exceed 5 %. The ovality of nominal size 2 and smaller coiled conduit shall not exceed 7 % after removal from the coil. Coiled conduit larger than nominal size 2 through 3 shall not exceed 10 %. Kinks in a coil shall not be acceptable.

Note 1: Deformations within 5 ft of the ends of coiled products are due to packaging requirements and should not be considered. Conduit with deformation as noted above should not be utilized.

Note 2: Ovality is a packaging condition that occurs when roundable conduit is wound into a coil. Conduit flattens out as it is coiled. Larger diameter conduit may have significant ovality. For example, the ovality of the inner coil layers of nominal sizes 4 – 6 coiled conduit may be 20 % or greater. Ovality is corrected when joining equipment is applied to roundable conduit, or by field processing roundable conduit through re-rounding and straightening equipment during installation.

6 Elbows Made from Conduit

6.1 Elbows shall be formed from lengths of conduit that are of any convenient length (see 6.2) but otherwise comply with the requirements in this standard. The axial length of a finished elbow shall not exceed 10 feet (3.05 m). Each finished elbow shall not have any kinks or creases. A coupling need not be attached to an elbow before the elbow is shipped from the factory.

6.2 If the lengths of conduit from which elbows are formed are longer or shorter than 10 feet (3.05 m), and are shipped to another of the conduit manufacturer's factories, or to a second manufacturer, each length or bundle of lengths shall be tagged or otherwise marked to indicate that the conduit is intended for further processing.

6.3 Examples of elbows are illustrated in Figure 6.1. No bend other than at the end curve of a gooseneck shall be sharper than 90°. The sharpest end curve shall not be more than 135°. No elbow shall be shallower than 15°. The length L_s of the straight portions at the ends of an elbow and the radius R of an elbow shall not be smaller than indicated in Table 6.1 for each size of conduit. The straight end portions of elbows shall comply with the dimensions specified in Table 6.1.

Table 6.1
Minimum Dimensions of Elbows

Trade size	(Metric designator)	Radius R of elbow to center line of conduit, inch	(mm)	Length L_s of straight end portion, inch	(mm)
1/2	(16)	4	(100)	1-1/2	(38)
3/4	(21)	4-1/2	(114)	1-1/2	(38)
1	(27)	5-3/4	(146)	1-7/8	(48)
1-1/4	(35)	7-1/4	(184)	2	(50)
1-1/2	(41)	8-1/4	(210)	2	(50)
2	(53)	9-1/2	(241)	2	(50)
2-1/2	(63)	10-1/2	(267)	3	(76)
3	(78)	13	(330)	3-1/8	(79)
3-1/2	(91)	15	(380)	3-1/4	(83)

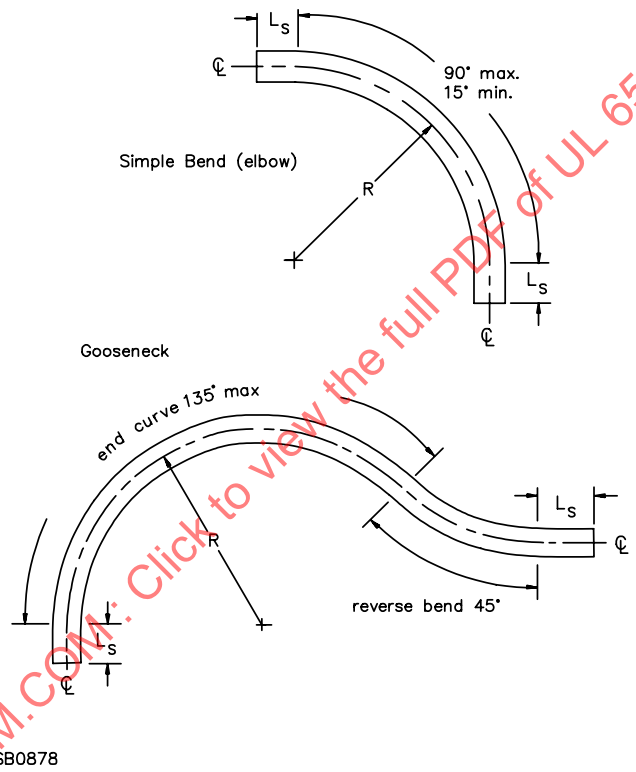
Table 6.1 Continued on Next Page

Table 6.1 Continued

Trade size	(Metric designator)	Radius R of elbow to center line of conduit, inch	(mm)	Length L_s of straight end portion, inch	(mm)
4	(103)	16	(400)	3-3/8	(86)
5	(129)	24	(600)	3-5/8	(92)
6	(155)	30	(760)	3-3/4	(95)

Figure 6.1

Elbows



PERFORMANCE

7 All Conduit Types

7.1 General

7.1.1 Specimens of conduit shall be subjected to the tests specified in Table 7.1. Modified tests, or additional tests other than those specified in Table 7.1, may be determined necessary. Other test requirements to be considered include the installation of wires, resistance to arcing, and dimensional stability.

Table 7.1
Tests for Conduit

Conduit type	Test	Location
All conduit	Identification of conduit compound	7.3
	Resistance to impact	7.2
	Resistance to deflection	7.4
	Tensile Strength	7.5

7.1.2 Unless specified otherwise in the description of the test, all specimens for each of the performance tests in this standard shall be preconditioned for at least 24 hours in still air at a temperature of 23.0 ±2.0 °C (73.4 ±3.6 °F). Humidity control is not required.

7.2 Resistance to impact

7.2.1 Conduit shall not fail when three specimen are tested at the low-temperature condition of -4 °F (-20 °C), in accordance with 7.2.2 or if one out of three specimen fails, then a retest of three additional specimen shall result in no failures. Failure is determined by a crack or tear longer than 0.031 in. (0.8 mm) appearing on the inner or outer surface of the conduit.

7.2.2 Test three specimens of conduit. Each specimen shall be cut from finished lengths of each trade size of conduit and shall exhibiting no cracks, tears, or other imperfections. The specimens shall be equal in length to the nominal outside diameter but not less than 6 in (152 mm) in length. Condition the specimens at a temperature of -4 ± 3.6 °F (-20 ±2 °C) for a minimum of 5 h. Conduct the test within 30 seconds after removal from the cold chamber. In a case of disagreement, conduct the tests in a room maintained at 73.4 ±3.6 °F (23 ±2 °C).

Note: To facilitate testing, it has been found that using an insulated box packed with freezer packs and conditioned at the conditioning temperature, can be used to transport specimens to the test equipment.

7.2.3 The specimens are to be tested separately while resting on a solid, flat, steel plate that is at least 1/2 inch (13 mm) thick and is firmly anchored with its upper surface horizontal. A protective cage is to surround the plates and specimen to reduce the risk of injury from pieces of broken conduit in the event that the conduit flies apart. A steel weight of 20 lb (9.1 kg) in the form of a solid right-circular cylinder, with a diameter of 2 inches (51 mm) and a flat impact face having rounded edges, is to fall freely through a vertical guide from the height indicated in Table 7.2. The flat face of the weight is to strike the center of the specimen across the diameter and along the longitudinal axis once (provision is to be made for keeping the weight from striking the specimen more than once).

Table 7.2
Impact Height

Trade size	(Metric designator)	Height of the face of the weight above the specimen before the weight is released,	
		feet	(meters)
1/2	(16)	2-1/2	(0.762)
3/4	(21)	4	(1.22)
1	(27)	5	(1.52)
1-1/4	(35)	6	(1.83)

Table 7.2 Continued on Next Page

Table 7.2 Continued

Trade size	(Metric designator)	Height of the face of the weight above the specimen before the weight is released,	
		feet	(meters)
1-1/2	(41)	7-1/2	(2.29)
2	(53)	9-1/2	(2.90)
2-1/2	(63)	10-1/2	(3.20)
3 – 6	(78 – 155)	11	(3.35)

7.3 Identification of conduit compound

7.3.1 A material used in conduit shall be subjected to the Infrared Spectroscopy (IR), Thermogravimetry (TGA), and Differential Scanning Calorimetry (DSC) Tests specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

7.4 Resistance to deflection

7.4.1 Six-inch (150-mm) specimens of finished straight conduit shall not flatten under the load indicated in Table 7.3 to the point that they buckle. The minor axis measured inside each loaded specimen shall not be less than the Table 7.3 percentage of the inside diameter of the specimen measured before loading. The test shall be performed as indicated in 7.4.2 (similar to the procedure described in the Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading, ASTM D2412).

Table 7.3
Minimum Deflection Load for HDPE Specimens

Trade size	(Metric designator)	Minimum deflection load for HDPE specimens			
		Deflection percentage[a]	lbf	N	kgf
1/2	(16)	70	665	2958	302
3/4	(21)	70	510	2268	231
1	(27)	70	405	1801	184
1-1/4	(35)	75	395	1757	179
1-1/2	(41)	75	345	1535	157
2	(53)	75	275	1223	125
2-1/2	(63)	75	230	1023	104
3	(78)	75	185	823	84
3-1/2	(91)	75	160	712	73
4	(103)	75	140	623	64
5	(129)	75	110	489	50
6	(155)	75	95	423	43

[a] The figure in this column is the percentage of its original length to which the minor axis of the loaded specimen can be reduced by the load.

7.4.2 Three 6-inch (150-mm) specimens are to be cut from finished lengths of each size of high density PE conduit. The specimens, the testing machine, and the surrounding air are to be in the thermal equilibrium with one another at a temperature of 23.0 ±2.0 °C (73.4 ±3.6 °F) during the test. The inside

diameter of each specimen is to be measured. The specimens are then to be tested separately between a pair of rigid, flat, steel plates that are at least 6 inches (150 mm) long and are horizontal and parallel to one another. One plate is to be moved toward the other at the rate of 1/2 ±1/8 inch per minute or 10.0 ±2.5 mm per minute until the load specified in Table 7.3 is applied as indicated on the dial on the machine. All specimens shall comply with the following:

a) The surface shall not pull away from contact with either plate during or after application of the load (buckle) and

b) The minor axis measured inside any flattened specimen shall not be less than the Table 7.3 percentage of the inside diameter of that specimen measured before loading.

7.5 Tensile strength

7.5.1 General

7.5.1.1 The average tensile strength of three aged specimens of finished conduit shall equal or exceed 95 % of the average tensile strength of three unaged specimens of conduit. The average tensile strength of the unaged specimens shall comply with the limit established for the compound used, but in any case, shall not be less than 2700 lbf/in^2 (18.6 MPa).

7.5.1.2 The procedures (similar to those described in the Standard Test Method for Tensile Properties of Plastics, ASTM D638) for preparing and conditioning the specimens, for making the measurements, and for calculating the average tensile strengths are indicated in 7.5.2 – 7.5.4.

7.5.2 Preparation of specimens

7.5.2.1 Six complete tubes are to be cut from sample lengths of each size of finished conduit. Each tube is to be 15 inches (380 mm) long. Each cut is to be made in a plane perpendicular to the longitudinal axis of the conduit. Each trade size is to be tested on the available power-driven machine.

7.5.2.2 Measurements are to be made by means of two machinist's micrometer calipers, each with a ratchet and a flat-ended spindle. The anvil is to be hemispherical on the caliper used for measurements of thickness on each tube and is to be flat on the caliper used for measurements of diameter on each tube. The calibration of the scale on each caliper is to facilitate estimation of each measurement to 0.0001 inch or 0.001 mm.

7.5.2.3 Each tube is to be smooth and clean wherever it is touched by a spindle or anvil. While measurements are being made, each tube and the air around it are to be in thermal equilibrium with one another at a temperature of 23.0 ±2.0 °C (73.4 ±3.6 °F).

7.5.2.4 The wall thickness is to be measured at each end of each tube by means of the caliper with the hemispherical anvil. At least four measurements are necessary at each end to make certain that the thickest and thinnest parts of the wall are found. Each measurement is to be estimated to the nearest 0.0001 inch or 0.002 mm and recorded. The average of all of the recorded thicknesses is to be determined to the nearest 0.001 inch or 0.02 mm for each tube and recorded as T.

7.5.2.5 The outside diameter is to be measured at the center and each end of each tube by means of the caliper with the flat anvil. At least four measurements (every 45°) are necessary at each location to make certain that the largest and smallest diameters are found. Each measurement is to be estimated to the nearest 0.0001 inch or 0.002 mm and recorded. The average of all of the recorded diameters is to be determined to the nearest 0.001 inch or 0.02 mm for each tube and recorded as D.