UL 360

STANDARD FOR SAFETY

Liquid-Tight Flexible Metal Conduit

UL Standard for Safety for Liquid-Tight Flexible Metal Conduit, UL 360

Seventh Edition, Dated January 17, 2013

Summary of Topics:

This revision of ANSI/UL 360 dated January 16, 2024 includes the following:

> ***– Liquid tight flexible metal conduit with a core constructed of stainless steel shall be exempt from the Fault Current test; 3.2 and 9.1A***

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 December 15, 2023.

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UL 360

Standard for Liquid-Tight Flexible Metal Conduit

Prior to the seventh edition, this standard was entitled the Standard for Liquid-Tight Flexible Steel Conduit, UL 360.

First Edition – April, 1976
Second Edition – August, 1980
Third Edition – August, 1986
Fourth Edition – August, 1996
Fifth Edition – June, 2003
Sixth Edition – February, 2009

Seventh Edition

January 17, 2013

This ANSI/UL Standard for Safety consists of the Seventh Edition including revisions through January 16, 2024.

The most recent designation of ANSI/UL 360 as an American National Standard (ANSI) occurred on January 16, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 360 on January 20, 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 ULSE's Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

MARKINGS

No Text on This Page

INTRODUCTION

1 Scope

1.1 These requirements cover the 3/8 (12), 1/2 (16), 3/4 (21), 1 (27), 1-1/4 (35), 1-1/2 (41), 2 (53), 2-1/2 (63), 3 (78), 3–1/2 (91), and 4 (103) trade sizes (metric designators) of liquid-tight flexible steel, aluminum, brass, bronze, copper, and stainless steel conduit. The conduit covered is intended for installation in accordance with the National Electrical Code (NFPA 70) as raceway for wires and cables.

1.2 This conduit is for applications in which flexibility of the conduit is necessary during installation, operation, or maintenance and the contained conductors need protection from vapors, liquids or solids.

1.3 This conduit is circular in cross section, having an outer liquid-tight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core, and is for use in wet, dry, or oily locations in which the conduit is exposed but is not subject to physical damage. Conduit that is not marked with a temperature designation or is marked "60 C" is for use at temperatures not in excess of 60°C (140°F). Conduit that is for use in dry or oily locations at a temperature higher than 60°C (140°F) is marked "____C dry, 60 C wet, 70 C oil res" or "____C dry, 60 C wet, 70 C oil resistant" with "80 C" or "105 C" inserted as the dry-locations temperature.

1.4 Conduit that is marked "80 C dry, 60 C wet, 60 C oil res" or "80 C dry, 60 C wet, 60 C oil resistant" is for use at 80°C (176°F) and lower temperatures in air, and 60 °C (140°F) and lower temperatures where exposed to water, oil or coolants – that is, to cutting oils and the like in machine-tool and other industrial applications.

1.5 Conduit marked in accordance with 24.4(g) is limited to use in oil free environments.

1.6 Fittings for conduit are covered in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

1.7 These requirements do not cover liquid-tight flexible nonmetallic conduit. Flexible nonmetallic conduit is covered in the Standard for Liquid-Tight Flexible Nonmetallic Conduit, UL 1660, and the fittings for this conduit are covered in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

1.8 These requirements do not cover flexible metallic tubing.

1.9 These requirements do not cover electrical nonmetallic tubing (ENT).

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this standard shall comply with the requirements for that component.

2.1.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.1.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.1.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.2 Units of measurement

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

2.3 Undated references

2.3.1 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.

CONSTRUCTION

3 General

3.1 Liquid-tight flexible metal conduit shall be fabricated from metal that will provide the mechanical and electrical properties to comply with the performance requirements of this standard.

3.2 Steel conduit in trade sizes 3/8 – 1-1/4 (12 – 35) shall be provided with a bonding strip wound enclosed by the conduit convolutions throughout the entire length of the conduit. Conduit made from aluminum, brass, bronze, and copper in these trade sizes shall be tested according to the Resistance Test, Section 8 and the Fault Current Test, Section 9 to determine the need for a bonding strip. The material and dimensions of the bonding strip shall result in the finished conduit having the resistance values shown in Table 8.1 before high-current testing and shall not adversely affect the flexibility and minimum bending radii of the finished conduit.

3.3 A metallic braiding material with a minimum wire diameter (O.D.) of 0.005 inches (0.13 mm) may be optionally provided between the metal conduit and the outer jacket. When the conduit core material is aluminum, the metallic braiding material, if present, shall be aluminum or tinned metal.

4 Thermoplastic Jacket

4.1 The thickness of the finished jacket shall not be less than indicated in Table 4.1 when determined as described in 4.2.

4.2 The minimum average thickness of the jacket is to be determined by measuring a specimen of the jacket removed from the finished conduit and buffed to remove any ridges or other irregularities on the inside surface of the jacket. The specimen is to be selected to include the thinnest portion of the jacket as determined visually. Measurements are to be made with a dead-weight dial micrometer having a presser foot 0.250 ±0.010 inch (6.4 ±0.2 mm) in diameter and exerting a total of 3.0 ±0.1 ozf (0.84 ±0.02 N or 85 ±3 gf) on the specimen – the load being applied by means of a weight. Five readings are to be taken at different points on the specimen and the average taken as the minimum acceptable average thickness, or by means of an optical device accurate to at least 0.001 inch (0.01 mm).

Table 4.1
Jacket thickness

Trade size of conduit	(Metric designator)	Minimum average thickness of jacket, inch	(mm)
3/8	(12)	0.030	0.76
1/2	(16)	0.030	0.76
3/4	(21)	0.035	0.89
1	(27)	0.035	0.89
1-1/4	(35)	0.035	0.89
1-1/2	(41)	0.040	1.02
2	(53)	0.040	1.02
2-1/2	(63)	0.050	1.27
3	(78)	0.050	1.27
3-1/2	(91)	0.060	1.52
4	(103)	0.060	1.52

4.3 Liquid-tight Flexible Metallic Conduit sampling for testing of thermoplastic jacket materials shall be in accordance with Table 4.2.

Table 4.2
Sample requirements for testing of thermoplastic jacket

		Sample requirements for alternate jacket with no changes to inner metal core				Sample requirements for color, using jacket material in accordance with this standard with no changes to the inner metal core			
Test	Cl.	Qty	Trade size[a]	Length	Color	Qty	Trade size[a]	Length	Color
Detailed examination	4		N/A				N/A		
Fault current	9	3 each 3 each	3/8 or 1/2 3/4 or 1 or 1-1/4	6 ft. (1.83 m) 6 ft.			N/A		
Flexibility	14	2 each	3/8 or 1/2 and largest up to 2	6 ft.			N/A		
Vertical flame	16	2 Each	3/8 or 1/2 and largest up to 2	18 in. (457 mm)	L & D[b]	2 Each	3/8 or 1/2 and largest up to 2	18 in.	L & D[b] or individual colors
Physical properties of thermoplastic jacket	17	3 1	Largest up to 2	20 in. (508 mm) 4 in. (101.6 mm)			N/A		
Mechanical water absorption	19	3	Largest up to 2	4 in.			N/A		
Sunlight resistance	21	6	Largest up to 2	3 ft. (0.9 m)	L & D[b]	6	Largest up to 2	3 ft.	L & D[b] or individual colors

Table 4.2 Continued on Next Page

Table 4.2 Continued

		Sample requirements for alternate jacket with no changes to inner metal core				Sample requirements for color, using jacket material in accordance with this standard with no changes to the inner metal core			
Test	Cl.	Qty	Trade size[a]	Length	Color	Qty	Trade size[a]	Length	Color
Test for Durability of ink printing	23	24	3/8 or 1/2	6 in. (152.4 mm)			N/A		

[a] See Table 4.1 for corresponding metric designators

[b] L & D: Lightest and darkest color

5 Conduit Diameters

5.1 Finished metal conduit shall not be larger or smaller in internal and external diameter than indicated in Table 5.1 when determined as described in 5.2.

5.2 Compliance of all trade sizes of conduit with the minimum and maximum internal diameters in Table 5.1 is to be determined by means of a vernier caliper accurate to at least 0.001 inch (0.01 mm).

Table 5.1
Internal and external diameters

Trade size of conduit	(Metric desig.)	Internal diameter				External diameter, over jacket			
		Minimum,		Maximum,[a]		Minimum,		Maximum,[a]	
		inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
3/8	(12)	0.484	12.29	0.504	12.80	0.690	17.5	0.710	18.0
1/2	(16)	0.622	15.80	0.642	16.31	0.820	20.8	0.840	21.3
3/4	(21)	0.820	20.83	0.840	21.34	1.030	25.2	1.050	26.7
1	(27)	1.041	26.44	1.066	27.08	1.290	32.8	1.315	33.4
1-1/4	(35)	1.380	35.05	1.410	35.81	1.630	41.4	1.660	42.2
1-1/2	(41)	1.575	40.01	1.600	40.64	1.865	47.4	1.900	48.3
2	(53)	2.020	51.31	2.045	51.94	2.340	59.4	2.375	60.3
2-1/2	(63)	2.480	62.99	2.505	63.63	2.840	72.1	2.875	73.0
3	(78)	3.070	77.98	3.100	78.74	3.460	87.9	3.500	88.9
3-1/2	(91)	3.500	88.90	3.540	89.92	3.960	100.6	4.000	101.6
4	(103)	4.000	101.60	4.040	102.62	4.460	113.3	4.500	114.3

[a] Other values are acceptable if the finished conduit is accommodated as intended by all acceptable fittings as determined by investigation.

6 Corrosion Protection

6.1 The corrosion protection of the steel strip from which the steel conduit is formed shall comply with the requirements of the Zinc-Coating Test, Section 15. A coating of zinc is not required on the cut edges.

7 Strip Material

7.1 The strip material used in liquid-tight flexible stainless steel conduit shall be stainless steel having a chromium content of not less than 16 percent.

PERFORMANCE

8 Resistance Test

8.1 The electrical resistance of specimens of previously untested finished conduit shall not exceed the values shown in Table 8.1.

Exception: A Stainless Steel flexible metal core need not be subjected to this test.

8.2 The jacket is to be stripped from 4 inches (102 mm) at each end of a 10-1/2 feet (3.2-m) length of previously untested finished conduit and the conduit is to be laid out straight on a flat, horizontal, noncombustible, electrically nonconductive surface. Low-resistance connectors are to be secured to each end of the metal conduit and to a low-voltage alternating-current supply circuit.

8.3 No specimen is to be moved or otherwise manipulated during any part of this test.

Table 8.1
Resistance testing

Trade size of conduit	(Metric designator)	Maximum resistance in ohms per 100 feet or in ohms per 30.5 meters
3/8	(12)	5.0
1/2	(16)	2.5
3/4	(21)	2.5
1	(27)	1.5
1-1/4	(35)	1.5

8.4 A current of 10 A is to be passed through the metal conduit and, while the current is flowing, the voltage drop is to be measured between points on the metal conduit that are 10 feet (3.05 m) apart. This voltage is numerically equal to the resistance of the conduit in ohms per 100 feet (ohms per 30.5 m).

9 Fault-Current Test

9.1 The equipment-ground path provided by steel, aluminum, brass, bronze, copper conduit and the bonding strip in the conduit, if provided, shall not open when previously untested specimens of the finished conduit are subjected to a current of 470 A for 4 seconds for trade sizes 3/8 (12) and 1/2 (16), and 750 A for 4 seconds for trade sizes 3/4 – 1-1/4 (21 – 35). The thermoplastic jacket on the conduit shall not flame. After the test specimens have cooled to room temperature, the integrity of the jacket shall be such that both of the following are complied with:

a) The total area(s) of the metal conduit exposed due to openings in the jacket shall not be more than 5 percent of the specimen exterior surface area and

b) The largest dimension of any single opening in the jacket shall not exceed 7.5 inches (190 mm).

9.1A Stainless Steel flexible metal core need not be subjected to this test.

9.2 The test specimens of finished conduit are each to be 6 feet (1.83 m) in length. A liquid-tight flexible metal conduit fitting that is acceptable for the size of conduit being tested and for connecting a test specimen to a solid copper bus bar is to be installed on each end of each test specimen.

9.3 The end of each of the bus bars, opposite that to which the conduit connection is made, is to be connected by means of connectors intended for the purpose to two 36-inch (914-mm) lengths of 3/0 AWG copper conductors in parallel. The ends of the copper bus bars at which the connection to the conduit is to be made are to be connected together. The free ends of each pair of copper conductors are to be connected together and then each of the two parallel pairs is to be connected so that one pair is connected to each side of an adjustable nominal 600-V a-c supply circuit. This supply is to be adjusted to deliver the test current. Without disturbing this adjustment the supply is to be turned off and the bus bars are to be separated.

9.4 The bus bars are then to be attached to the conduit connectors that have been assembled to each end of the test specimen. The specimen is to be laid out (essentially straight) on a wide, flat, horizontal surface of a fire-resistant, chemically inert, and electrically nonconductive material. After this connection is made, the supply is to be energized and the test current is to be passed through the specimen for 4 seconds.

9.5 The conduit and the bonding strip in it are not acceptable if they melt or otherwise open the circuit during the 4 seconds of current flow, if they ignite the thermoplastic jacket, or if they open the thermoplastic jacket to the degree that, after the specimen temperature returns to room ambient, more of the metal conduit is visible than specified in 9.1 (a) and (b).

10 Impact Test

10.1 Ten specimens of the finished conduit are to be subjected to the impact force indicated in Table 10.1. At least seven of the specimens shall withstand the impact to the extent that the original outside diameter is not reduced more than 50 percent.

Table 10.1
Impact force

Trade size of conduit	(Metric designator)	Force, Ft-lbf	(J)
3/8	(12)	25	34
1/2	(16)	35	47
3/4	(21)	40	54
1	(27)	70	95
1-1/4	(35)	90	122
1-1/2	(41)	125	170
2	(53)	150	203
2-1/2	(63)	150	203
3	(78)	200	271
3-1/2	(91)	200	271
4	(103)	250	339

10.2 A solid steel block measuring 3 by 4 by 6 inches (76 by 102 by 152 mm) and having the 4- by 6-inch (102- by 152-mm) faces flat and parallel to one another is to be placed on a nonimpact-absorbing surface with the 4- by 6-inch (102- by 152-mm) faces horizontal. A straight specimen of the finished conduit approximately 15 inches (381 mm) long is to be laid on the steel block with the longitudinal axis of the specimen perpendicular to the 6-inch (152-mm) dimension of the block and the center of the specimen above the center of the upper face of the block.

10.3 A weight having a flat rectangular impact surface measuring 2 by 6 inches (50 by 152 mm) for trade sizes 3/8 – 1-1/4 (12 – 35) or 3 by 6 inches (76 by 152 mm) for trade sizes 1-1/2 – 4 (41 – 103) is to be used to impact the specimen. All four edges of the impact surface are to be rounded. Means are to be provided for supporting each weight with the center of its impact surface above the center of the uppermost surface of the specimen, for releasing the weight, for guiding but not impeding the weight as it falls, and for keeping the weight from striking the specimen more than once.

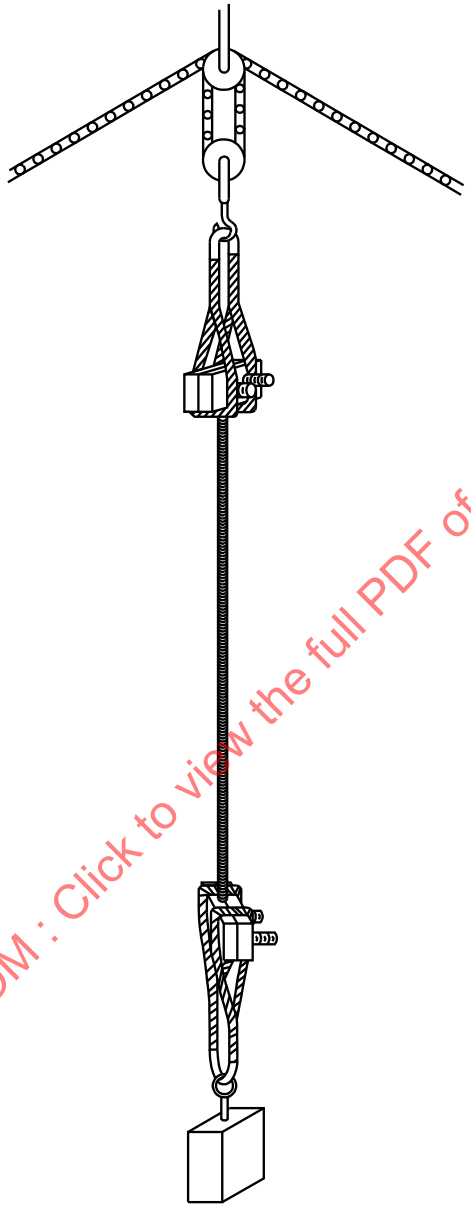
11 Tension Test

11.1 Finished conduit shall be capable of withstanding an axial tension of 300 lbf (1334 N or 136 kgf) for 60 seconds without opening up at any point when tested as indicated in 11.2 – 11.6.

11.2 The apparatus is to consist of a pair of clamps and a weight or tensile testing machine for exerting 300 lbf (1334 N or 136 kgf). If a weight is used, a block and tackle or a differential pulley is to be provided to lift the specimen, clamps, and weight (see Figure 11.1).

Figure 11.1

Tension test using block and tackle



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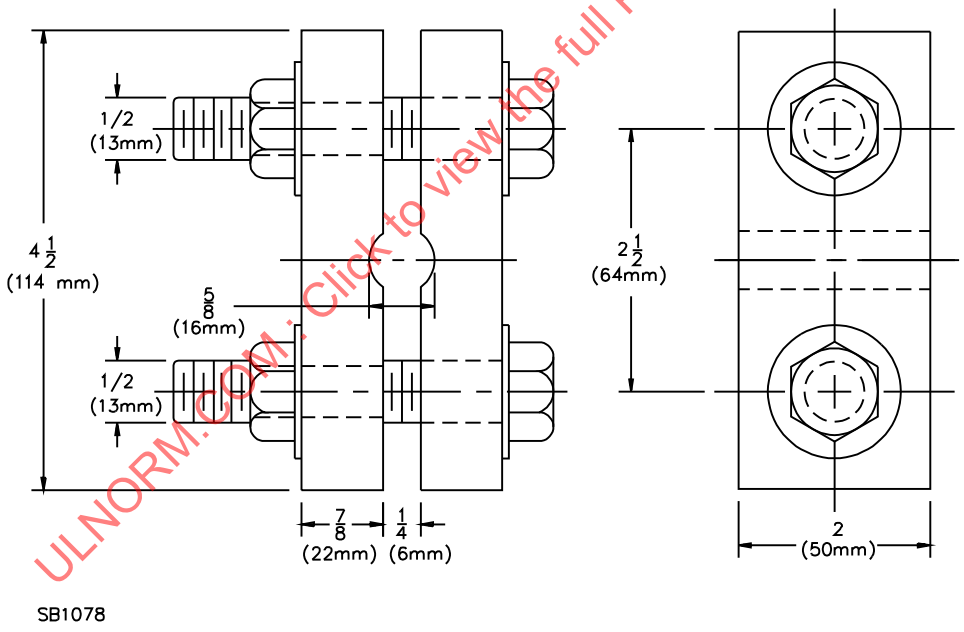
11.3 For a test using a weight and either a block and tackle or a differential pulley, the clamps are to be made of hard wood, and the two pieces comprising each clamp are to be fastened together by two bolts, enabling the conduit to be clamped tightly between the jaws without being crushed (see Figure 11.2). Two such clamps are to be provided.

11.4 For a test using a weight and either a block and tackle or a differential pulley, a 44-inch (1115-mm) specimen of the conduit is to be fastened in the clamps so that its ends project about 2 inches (50 mm) beyond the edges of each clamp, thus providing a specimen 36 inches (915 mm) long between the clamps, which are then to be tightened to keep the specimen from slipping but not any further.

11.5 For a test using a testing machine, an 18-inch (457-mm) specimen is to be gripped in the jaws of the machine. If necessary to keep the jaws from crushing the specimen, round metal plugs are to be inserted into the ends of the specimen. The jaws are then to be separated at the rate of 2.0 ±0.2 inch/minute (50 ±5 mm/minute) until the specimen is under a tension of 300 lbf (1334 N or 136 kgf). This level of tension is to be maintained for 60 seconds and is then to be released at the same rate at which it was applied. For any adjustment necessary for maintaining the tension during the 60 seconds the jaws are to be separated at the rate of 1/2 ±1/8 inch/minute (10.0 ±2.5 mm/minute).

Figure 11.2

Clamp for tension test



Dimensions are shown in inches (millimeters)

11.6 For a test using a weight and either a block and tackle or a differential pulley, the specimen is to be suspended by the upper clamp with a loop of rope passing over the hook of the block and tackle or differential pulley assembly, and a weight exerting 300 lbf (1334 N or 136 kgf) is to be attached to the lower clamp. Care is to be taken to have the specimen hang vertically for its full length and at right angles to the face of the clamps. The specimen, clamps, and weight are then to be raised gently so that tension is applied to the specimen as evenly as possible. The total weight is to be applied within 30 seconds so that the weight just clears the floor and hangs freely in the air. The weight is to be kept by hand from rotating. The weight is to be supported by the specimen for 60 seconds, and then is to be lowered to the floor, and the weight and clamps are to be removed.

11.7 After removal of the tension, observation is to be made to determine whether or not the edges of adjacent convolutions of the conduit have separated. The jacket may be stripped to make this determination.

12 Crushing Test

12.1 The center section of five specimens of finished conduit, each approximately 15 inches (380 mm) long, are to be crushed between two flat, square steel plates having rounded edges and measuring 6 inches (150 mm) on each side moving toward one another at the rate of 1/2 ±1/8 inch/minute (10.0 ±2.5 mm/minute) until the overall diameter of the conduit is reduced to one-half its original value. The load required to crush any specimen of the conduit to half of its original overall diameter shall be at least as great as the value indicated in Table 12.1.

Table 12.1
Minimum crushing load for any specimen

Trade size of conduit	(Metric designator)	lbf	N	kgf
3/8	(12)	2500	11121	1134
1/2	(16)	2000	8896	907
3/4	(21)	1800	8007	816
1	(27)	1800	8007	816
1-1/4	(35)	1800	8007	816
1-1/2	(41)	1500	6672	681
2	(53)	1500	6672	681
2-1/2	(63)	1500	6672	681
3	(78)	1500	6672	681
3-1/2	(91)	1500	6672	681
4	(103)	1500	6672	681

13 Pipe Stiffness for Conduit Intended for Direct-Burial

13.1 Conduit which is intended for direct burial use shall have a minimum pipe stiffness of 120 lbs./in/in at 10 percent deflection when determined in accordance with the Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading, ASTM D2412.

14 Flexibility Test

14.1 The outer thermoplastic jacket shall not show evidence of cracking, nor shall the conduit open at any point when wrapped around an appropriate mandrel having diameters as specified in Table 14.1. Specimens of the finished conduit are to be tested:

a) At room temperature in all trade sizes and

b) For 3/8 – 1-1/4 (12 – 35) trade sizes at

1) Minus 10.0 ±2.0°C (14.0±3.6°F), or

2) The marked temperature ±2.0°C (±3.6°F) if less than minus 10°C.

Table 14.1
Flexibility-test mandrels

Trade size of conduit in inches	(Metric designator)	Conduit Length		Mandrel diameter,	
		feet	(m)	inches	(mm)
3/8	(12)	6	(1.8)	4.0	(101.6)
1/2	(16)	6	(1.8)	6.5	(165.1)
3/4	(21)	6	(1.8)	8.5	(215.9)
1	(27)	6	(1.8)	13.0	(330.2)
1-1/4	(35)	6	(1.8)	16.0	(406.4)
1-1/2	(41)	6	(1.8)	18.0	(457.2)
2	(53)	8	(2.4)	22.25	(565.2)
2-1/2	(63)	10	(3.0)	29.25	(749.3)
3	(78)	11	(3.4)	35.0	(889.0)
3-1/2	(91)	12	(3.7)	40.0	(1016.0)
4	(103)	14	(4.3)	48.0	(1219.2)

14.2 The cold specimens are to be exposed to air at the low temperature indicated for 60 minutes before being tested. Each specimen is to be wrapped for one full turn around the applicable mandrel with the tension applied to the specimen, causing the specimen to conform closely to the curved surface of the mandrel.

15 Zinc-Coating Test

15.1 The coating of zinc on steel conduit shall be such that all of the following requirements are met:

a) A specimen of the zinc-coating strip tested before forming shall not show a bright, adherent deposit of copper on any surface, except edges, after two 60-second immersions in a solution of copper sulfate.

b) A specimen of partially uncoiled conduit from finished conduit:

1) Shall not show a bright, adherent deposit of copper, except edges, after one 60-second immersion in a solution of copper sulfate and

2) Shall not show a bright, adherent deposit of copper on more than 25 percent of any surface, except edges, after two 60-second immersions in a solution of copper sulfate.

15.2 The solution of copper sulfate is to be made from distilled water and the American Chemical Society (ACS) reagent grade of cupric sulfate ($CuSO_4$). In a copper container or in a glass, polyethylene, or other chemically nonreactive container to which a bright piece of copper is added, a quantity of the cupric sulfate is to be dissolved in hot distilled water to obtain a solution that has a specific gravity within the range of 1.183 to 1.189 after the solution is cooled to a temperature of 18.3°C (65.0°F). As necessary, any free acid that might be present is to be neutralized by the addition of approximately 1 gram of cupric oxide (CuO) or

1 gram of cupric hydroxide [$Cu(OH)_2$] per liter of solution. The solution is to be diluted with distilled water to obtain a specific gravity within the range of 1.183 to 1.189 at a temperature of 18.3°C (65.0°F). The solution is then to be filtered.

15.3 At one end of a sample length of finished conduit, the conduit is to be carefully unwound from the outside to expose to view the inner surface of the formed strip, and to facilitate working cheesecloth between the turns onto the inner surface to dry that surface during the test. To reduce the damage to the zinc coating, the strip is not to be straightened as it is unwound but is to remain in the helical form with a diameter that is not larger than about three times the diameter measured over the jacket on the finished conduit. Three 6-inch (150-mm) (axial measurement) specimens are to be cut from the partially uncoiled conduit.

15.4 Additionally, three straight 6-inch (150-mm) specimens are to be cut from a sample length of the zinc-coated steel before forming.

15.5 With prudent attention to the risks to health and to the risk of fire, the six specimens are to be cleaned with an organic solvent. Each specimen is to be examined for evidence of damage to the zinc coating, and only specimens that are not damaged are to be selected for use in the test. One specimen of the unformed strip and one specimen of the conduit are to be tested.

15.6 The two selected specimens are to be rinsed in water, and all of their surfaces are to be dried with clean cheesecloth. As much of the water as possible is to be removed in the drying operation because water slows the reaction between the zinc and the solution, thereby adversely affecting the test results. The surface of the zinc is to be dry and clean before a specimen is immersed in the copper sulfate solution. The specimens are not to be touched by the hands or anything else that can contaminate or damage the surfaces.

15.7 A glass, polyethylene, or other chemically nonreactive beaker having a diameter equal to twice the diameter measured over the specimen of partially uncoiled conduit is to be filled with the solution of copper sulfate to a depth of not less than 3 inches (76 mm). The temperature of the solution is to be maintained at 18.3 ±1.1°C (65.0 ±2.0°F).

15.8 One of the selected specimens is to be immersed in the solution and supported on end in the center of the beaker so that no less than half of its axial length is immersed. The specimen is to remain in the solution for 60 seconds during which time it is not to be moved nor is the solution to be stirred.

15.9 At the end of the 60-second period, the specimen is to be removed from the beaker, rinsed immediately in running tap water, rubbed with clean cheesecloth (a clean soft-bristle test-tube or bottle brush in good condition and of applicable size may be used to rub the interior surfaces of the specimen of partially uncoiled conduit, but cheesecloth is to be used on the other surfaces of this specimen and on the unformed strip) until any loosely adhering deposits of copper are removed, and is then to be dried with clean cheesecloth. The turns of the specimen of partially uncoiled conduit are not to be further separated during this process. Again, the hands and other damaging and contaminating objects and substances are not to touch the surfaces that were immersed. The part of the specimen that was immersed is to be examined, considering each broad surface separately and disregarding the portion of the specimen within 1/2 inch (13 mm) of its immersed end.

15.10 If the part of the specimen that was immersed has any bright deposit of firmly adhering metallic copper outside the 1/2-inch (13-mm) end portion, an estimate is to be made and recorded of the percentage of each broad surface that is covered with copper.

15.11 Regardless of whether the first dip results in a bright, adherent deposit of copper, the immersion, washing, rubbing, drying, examining, estimating, and recording operations are to be repeated once using

the same specimen and beaker of solution. After the second dip, the solution in the beaker is to be discarded.

15.12 The remaining specimen is to be subjected to the 2-dip procedure described in 15.7 – 15.11.

15.13 The results of this test are not acceptable if

a) There is any bright, adherent deposit of copper showing outside the 1/2-inch (13-mm) end portion of the immersed part of the specimen (except edges) of unformed strip after the first or second dip, or

b) The specimen of partially uncoiled conduit shows any bright, adherent deposit of copper (except edges) after the first dip or more than 25 percent coverage after the second dip.

16 Vertical Flame Test

16.1 A vertical specimen of the finished conduit with the jacket in place shall not flame longer than 60 seconds following any of three 60-second applications of a flame, the period between applications being 30 seconds if the specimen flaming ceases within 30 seconds, or the duration of the specimen flaming if the specimen flame persists longer than 30 seconds. The conduit shall not ignite combustible materials in its vicinity or damage more than 25 percent of the indicator flag during, between, or after the three applications of the test flame. The test is to be conducted as described in 16.2 – 16.10.

16.2 The test is to be performed on unaged specimens and on specimens conditioned in a full-draft circulating-air oven for 168 hours at 100.0 ±1.0°C (212.0 ±1.8°F). The oven is to be operating at full draft at the indicated temperature at the time that the specimens that are to be conditioned are placed in the oven (see 16.6). Specimens having widely different properties or composition are to be conditioned in separate ovens. Unaged and conditioned specimens are to be tested in close succession and at a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unaged specimens are to be maintained at this room temperature for 30 minutes or longer before being tested. Conditioned specimens are to have a 16 – 96-hour rest period at this room temperature following their removal from the oven and prior to their being tested.

16.3 The test is to be conducted in a three-sided metal enclosure in an exhaust hood or cabinet. The metal enclosure is to be 12 inches (305 mm) wide, 14 inches (355 mm) deep, 24 inches (610 mm) high, and the top and front are to be open. An 18-inch (457-mm) specimen cut from a sample length of the finished conduit is to be secured with its longitudinal axis vertical in the center of the enclosure (see Figure 16.1). A flat, horizontal layer of untreated surgical cotton 1/4 – 1 inch (6 – 25 mm) thick is to cover the floor of the enclosure. The upper surface of the cotton is to be 9 – 9-1/2 inches (229 – 241 mm) below point B, which is the point at which the tip of the blue inner cone of the test flame touches the specimen (this is shown in Figure 16.1).

16.4 A Tirrill gas burner (such a burner differs from a Bunsen burner in that the air flow as well as the flow of gas is adjustable) with or without a gas pilot light attached is to supply the flame. The barrel of the burner is to extend 4 inches (102 mm) above the air inlets, and its inside diameter is to be 3/8 inch (9.5 mm). While the barrel is vertical and the burner is well away from the specimen, the overall height of the flame is to be adjusted to approximately 4 – 5 inches (100 – 125 mm). The blue inner cone is to be 1-1/2 inches (38 mm) high and the temperature at its tip is to be 816°C (1500°F) or higher as measured by a potentiometer equipped with a chromel-alumel (nickel-chromium and nickel-manganese-aluminum) thermocouple before and after the test but not during the test. Without disturbing the adjustments for the height of the flame, the valve supplying gas to the burner flame and the separate valve supplying gas to any pilot flame are to be closed.

16.5 A wedge (dimensions are shown in Figure 16.2) to which the base of the burner can be secured is to be provided for tilting the barrel 20 degrees from the vertical while the longitudinal axis of the barrel

remains in a vertical plane. The burner is to be secured to the wedge and the assembly is to be placed in an adjustable support jig. A layer of untreated surgical cotton 1/4 – 1 inch (6 – 25 mm) thick is to be placed on the wedge around the base of the burner. The jig is to be adjusted toward one side or the other of the enclosure to place the longitudinal axis of the barrel in the vertical plane that contains the longitudinal axis of the specimen. The plane is to be parallel to the sides of the enclosure. The jig is also to be adjusted toward the rear or front of the enclosure to position the point A, which is the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel, 1-1/2 inches (38 mm) from the point B at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone is to touch the center of the front of the specimen.

Figure 16.1

Essential dimensions for vertical flame test

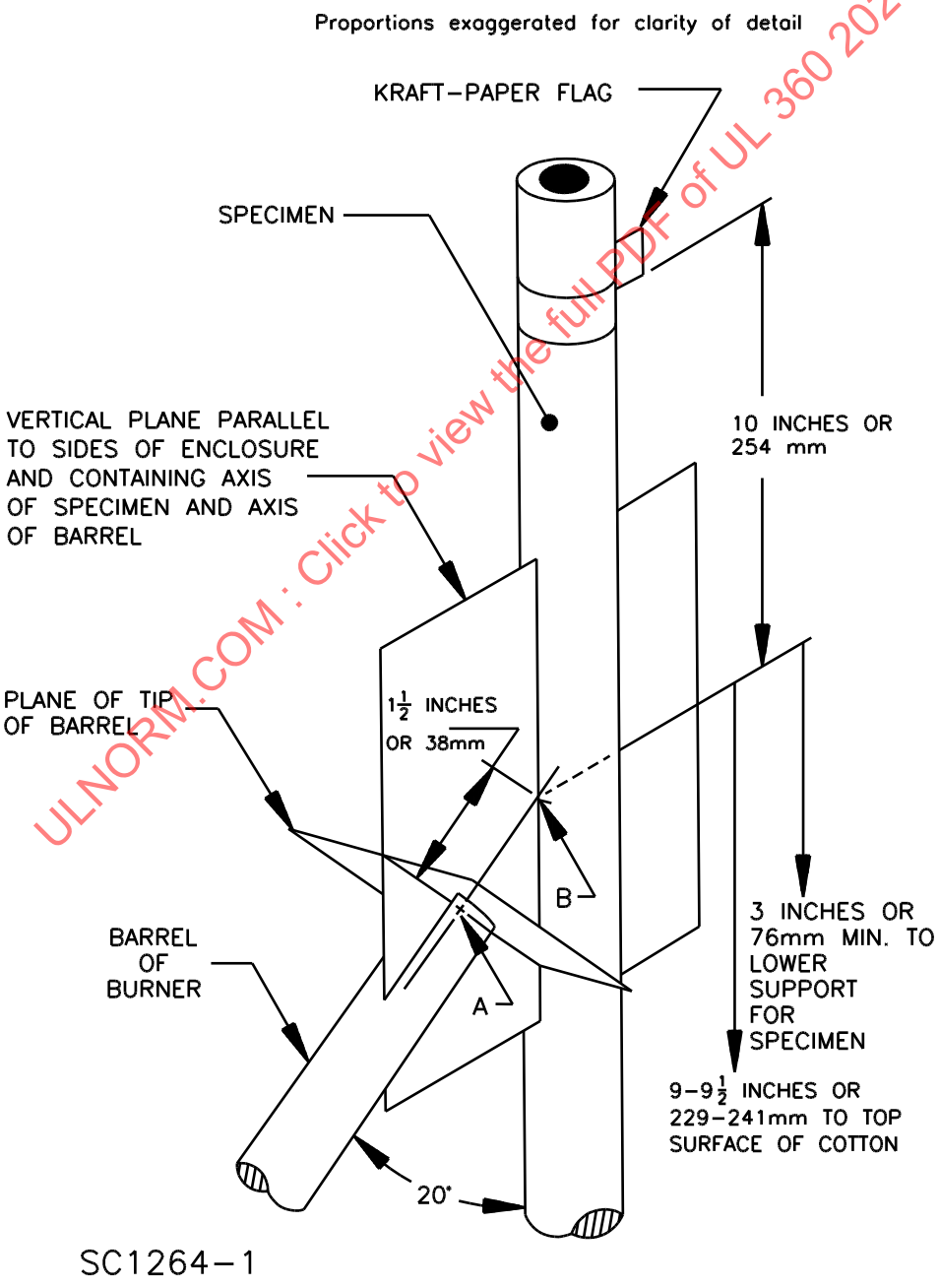
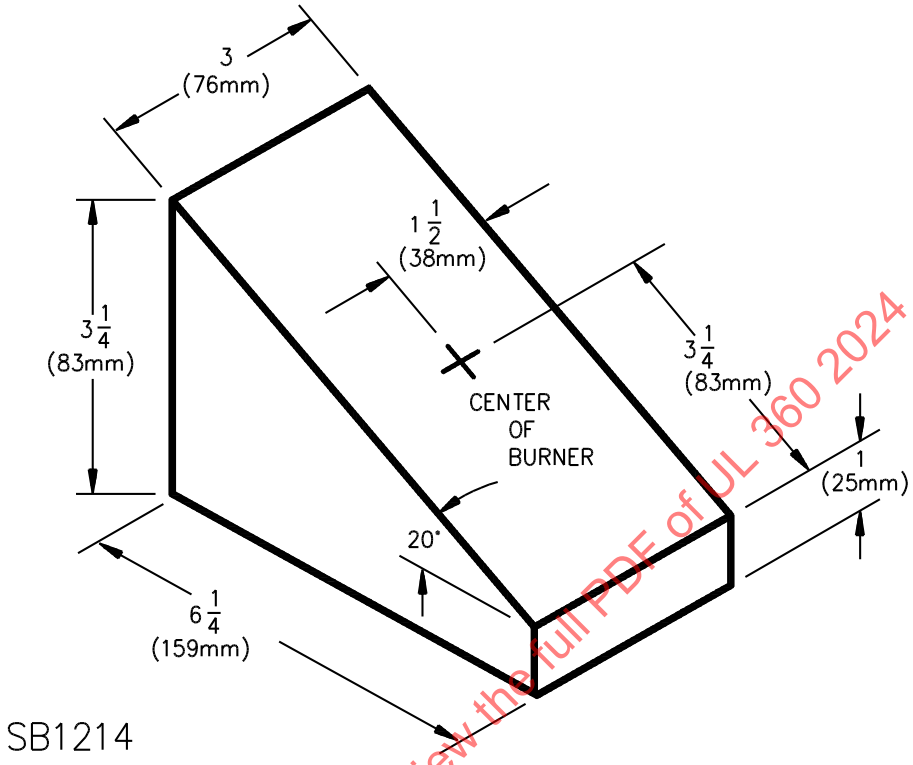


Figure 16.2

Dimensions of wedge in inches (millimeters)



16.6 In the absence of a gas pilot light on the burner, the support for the burner and wedge is to be arranged to enable the burner to be quickly removed from and precisely returned to the position described in 16.5 without disturbing the layer of cotton on the floor of the enclosure or the cotton on the wedge and around the base of the burner.

16.7 A strip of unreinforced 60-lb (94-g/m^2) kraft paper that is 1/2 inch (13 mm) wide, approximately 5 mils (0.1 mm) thick, and is gummed on one side is to be used to make an indicator flag. The gumming is to be moistened just to facilitate adhesion. With the gum toward the specimen, the strip is to be wrapped around the specimen once with its lower edge 10 inches (254 mm) above B, the point at which the blue inner cone is to touch the specimen. The ends of the strip are to be pasted together evenly and trimmed to provide a flag that projects 3/4 inch (19 mm) from the specimen toward the rear of the enclosure with the flag parallel to the sides of the enclosure (see Figure 16.1). The lower clamp or other support for the specimen is to be adjusted vertically to keep it from being any closer than 3 inches (76 mm) to point B.

16.8 If the burner has a gas pilot light, the valve supplying gas to the pilot is to be opened and the pilot lit. If the burner does not have a gas pilot light, it is to be supported as indicated in 16.6 in a position away from the specimen and then lit. This operation and the remainder of the test are to be conducted under a forced-draft exhaust hood or cabinet operating to provide removal of smoke and fumes but not having drafts that affect the flame.

16.9 If the burner has a gas pilot light, the valve supplying gas to the burner is to be opened to apply the flame to the specimen automatically. This valve is to be held open for 60 seconds, closed for 30 seconds (longer if flaming of the specimen persists – see the last two sentences of this paragraph), opened for 60 seconds and so forth for the total of three 60-second applications of the gas flame to the specimen with 30 seconds (longer if flaming of the specimen persists – see the last two sentences of this paragraph) between applications. If the burner does not have a gas pilot light, the burner is to be moved into position

to apply the gas flame to the specimen, kept there for 60 seconds, removed for 30 seconds (longer if flaming of the specimen persists – see the last two sentences of this paragraph), and so forth for a total of three 60-second applications of the gas flame to the specimen with 30 seconds (longer if flaming of the specimen persists – see the last two sentences of this paragraph) between applications. The gas flame is to be reapplied to the specimen 30 seconds after the previous application if flaming of the specimen ceases of its own accord within 30 seconds of the previous application. If flaming of the specimen persists longer than 30 seconds after the previous application of the gas flame, the gas flame is not to be reapplied until flaming of the specimen ceases of its own accord. In the latter case, the gas flame is to be reapplied as soon as flaming of the specimen ceases.

16.10 If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching are to be ignored) after any of the three applications of flame, the conduit is to be judged capable of conveying flame along its length.If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton is to be ignored), the conduit is to be judged capable of conveying flame to combustible materials in its vicinity. If any specimen continues to flame longer than 60 seconds after any application of the gas flame, the conduit is to be judged capable of conveying flame to combustible materials in its vicinity.

17 Physical Properties of Thermoplastic Jacket

17.1 General

17.1.1 The physical properties of the thermoplastic jacket shall make unaged and aged specimens, tested with the apparatus and according to the methods described in 17.2.1.1 – 17.4.4.3, perform in accordance with Table 17.1.

17.2 Apparatus for making physical tests

17.2.1 Power-driven testing machine

17.2.1.1 Elongation and tensile-strength measurements are to be made on a power-driven machine provided with a device that indicates the actual maximum load applied to the specimen. If a machine of the spring-balance type is used, provision is to be made to prevent recoil of the spring. The machine is to be adjusted to make the speed of the power-actuated grip 20 ±1 inch/minute (500 ±25 mm/minute). The applied tension as indicated by a dial or scale is to be accurate to 2 percent or less of the value read, and a set of weights is to be provided for calibrating the machine. A method for calibrating the machine is given in the Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension, ASTM D 412.

17.2.2 Die for cutting specimens

17.2.2.1 The die (ASTM die C) for cutting specimens is to have the form and dimensions shown in Figure 17.1. The dimensions of a resulting die-cut specimen are expected to be only approximately those shown for the die. If the dimensions of the sample make use of this shape impractical, a die having a constricted portion 0.125, plus 0.002, minus 0.000 inch (3.00, plus 0.05, minus 0.00 mm) wide (ASTM die D) is to be used.

Table 17.1
Physical properties of thermoplastic jacket

Condition of specimens at time of measurement	Minimum average ultimate elongation (1-inch or 25-mm bench marks)[a]	Minimum average tensile strength
Unaged	100 percent [1 inch (25 mm)]	1600 lbf/in^2 (11.0 MN/m^2 or 1103 N/cm^2 or 1.12 kgf/mm^2)
Jacket marked for 105 C dry use:		
Aged in a full-draft circulating- air oven for 168 hours at 136.0 ±1.0°C (276.8 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Jacket marked for 80 C dry use:		
Aged in a full-draft circulating-air oven for 168 hours at 113.0 ±1.0°C (235.4 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Jacket marked for 60 C dry or wet use:		
Aged in a full-draft circulating-air oven for 168 hours at 100.0 ±1.0°C (212.0 ±1.8°F)	45 percent of the result with unaged specimens	85 percent of the result with unaged specimens
Jacket marked for 80 or 105 C dry, 60 C wet, 70 C oil use:		
IRM 902 oil[b] for 168 hours at 70.0 ±1.0°C (158 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Jacket for 60 C oil use:		
IRM 902 oil[b] for 168 hours at 60.0 ±1.0°C (140.0 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] The methods of preparation of samples, of selection and conditioning of specimens and of making the measurements and calculations for ultimate elongation and tensile strength are indicated in 17.2.1.1 – 17.4.4.3.

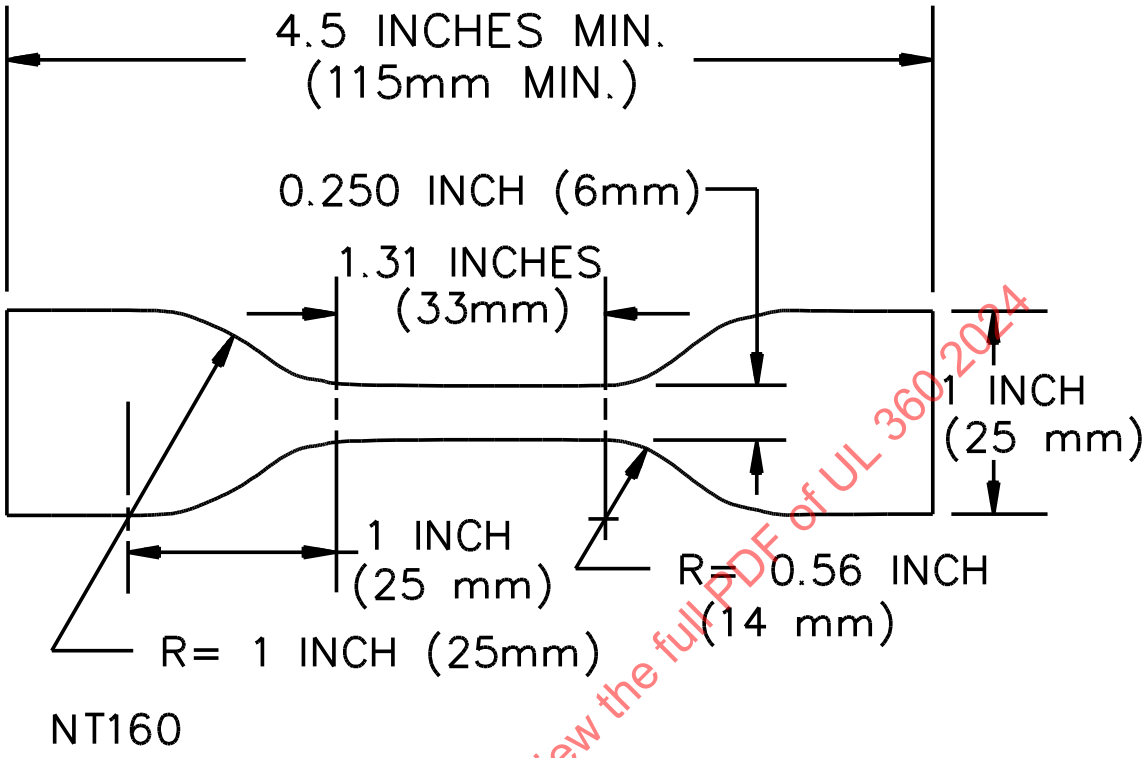
[b] IRM 902 oil is medium swelling and of a petroleum base. Measured at 210.0°F (98.9°C), its Saybolt Universal viscosity is 100 ±5 seconds (443 – 490 m^2 seconds at 310 K). Its aniline point is 93.0 ±3.0°C (199.4 ±5.4°F). Its open-cup flash point is 475.0 ±10.0°F (246.1 ±5.6°C).

17.2.3 Specimen marker

17.2.3.1 The specimen marker is to consist of a stamp with parallel metal blades capable of marking fine lines with ink on a specimen without damaging the jacket. The lines (bench marks) are to be 1 inch (25 mm) apart, are to be applied at right angles to the axis of the specimen, and are to be centrally located on the constricted portion of the specimen. Because the width of a mark increases while a specimen is being stretched, measurement of elongation is to be made with reference to the center of each mark – that is, with reference to a point halfway between the edges of each mark.

Figure 17.1

Die for cutting specimens



17.2.4 Buffing machine

17.2.4.1 A power-driven buffing machine (grinding wheel) is necessary for buffing irregularities from the samples from which die-cut specimens are prepared. The abrasive wheel is to be of about No. 36 grit [particle size of 0.019 inch (0.486 mm)], and the diameter and rotary velocity of the wheel are to give the wheel a peripheral speed of 4000 – 5000 feet/minute (20 – 25 m/second). The machine is to be provided with a slow feed that removes very little compound at each cut, thereby not overheating the specimen.

17.2.5 Apparatus for aging

17.2.5.1 The apparatus for the air-oven aging of specimens is to be essentially as indicated in the Standard Specifications for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423 (Type II ovens) and Standard Test Method for Rubber-Deterioration in an Air Oven, D 573 and is to circulate the air within the aging chamber at high velocity. A portion of the air may be recirculated, but a substantial amount of fresh air is to be admitted continuously to maintain an essentially normal oxygen content in the air surrounding the specimens. The exhaust ports of the oven are to be adjusted to achieve 200 – 250 complete fresh-air changes per hour. The blower or other means for circulating the air is to be located entirely outside the aging chamber. The oven is to maintain the specified temperature within ±1.0°C (1.8°F). Provision is to be made for suspending each specimen vertically within the chamber without touching the sides of the chamber or any other specimen.

17.3 Preparation of specimens for physical tests

17.3.1 Samples for the physical tests are to be taken from finished conduit or from the conduit during manufacture, and the tests are to be conducted at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F).

17.3.2 A test specimen of the jacket is to be die-cut from a sample that has been cut longitudinally, removed from the metal conduit, and buffed in accordance with 17.3.3. The test specimen is not to have any surface incisions or imperfections.

17.3.3 If required, buffing is to be done by means of a suitable grinding machine (see 17.2.4.1) and without excessive heating of the jacket. When removing the impressions or other unevenness, buffing is not to be carried beyond the point at which the unevenness just disappears. If it is necessary to reduce the thickness of the sample for the preparation of test specimens, it is acceptable to slice the insulation nearly to the required thickness and then finish by buffing. In any case, the final buffed surface is to be smooth. The buffing is to be done at least 30 minutes prior to testing of the specimens.

17.3.4 A sample of the jacket is to be cut into approximately 7-inch (180-mm) sections. Each such section is to be buffed to remove any irregularities, a test specimen is then to be cut from it with a die as described in 17.2.2.1, and the specimen is to be marked with two lines 1 inch (25 mm) apart as shown in Figure 17.1. The width of each specimen between the two marks is to be checked carefully.

17.3.5 The use of a press for operating the die is recommended. If the die is struck with a mallet, care is to be taken to see that all points of the cutting edges of the die are in contact with the compound. The cutting is to be done on a smooth surface of material that cannot damage the cutting edges of the die.

17.3.6 The thickness of the specimen is to be taken as smallest of four measurements to 0.001 inch (0.01 mm), two of which are to be made at 1/2-inch (13-mm) intervals between the bench marks on one edge beginning 1/4 inch (6 mm) from either mark. The other two measurements are to be made at corresponding points on the opposite edge. These measurements are to be made with a dead-weight dial micrometer having a presser foot 0.250 ±0.010 inch (6.4 ±0.1 mm) in diameter and exerting a total 3.0 ±0.1 ozf (85 ±3 gf or 0.84 ±0.02 N) on the specimen – the load being applied by means of a weight. If the results of measurements by this method are in doubt, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch (0.001 mm).

17.4 Elongation and tensile strength

17.4.1 General

17.4.1.1 Elongation and tensile-strength tests are to be conducted simultaneously, using specimens that have not been subjected previously to any test. Each specimen is to be clamped in position with both 1-inch (25-mm) bench marks outside of and between the grips. The movable grip is to be adjusted to make the specimen taut but not under tension. The grips are then to be separated at a rate of 20 ±1 inch/minute (500 ±25 mm/minute) until the specimen ruptures. During separation, the distance between the marks is to be observed continuously to facilitate observing the distance at the instant of rupture with an accuracy of at least 0.1 inch (2 mm). The distance at rupture is to be recorded. The elongation is to be taken as the increase in distance between the bench marks, which originally were 1 inch (25 mm) apart. The temperature of the ambient air is to be recorded.

17.4.1.2 After rupture of the specimen, the maximum load in pounds, meganewtons, newtons, or kilograms force is to be noted from the dial or scale and recorded together with the original dimensions of the specimen for use in calculating the tensile strength. If a specimen breaks within one of the jaws at a value below that specified as the minimum that is acceptable, the test results for that specimen are to be disregarded and another specimen is to be tested, the results from which are to be considered final. The overall results are to be expressed as the average for three specimens.

17.4.2 Calculation of area

17.4.2.1 The cross-sectional area of the test specimen of a jacket is to be computed by means of the formula:

$$A = WT$$

in which:

A is the cross-sectional area of the narrow center portion of the specimen in square inches, square centimeters, or square millimeters;

W is the width of the narrow center portion of the specimen in inches, meters, centimeters, or millimeters; and

T is the thickness of the specimen in inches, meters, centimeters, or millimeters.

17.4.3 Test results

17.4.3.1 The tensile strength of a specimen is to be computed by means of the formula:

$$S = \frac{P}{A}$$

in which:

S is the tensile strength in pounds force per square inch, meganewtons per square meter, newtons per square centimeter, or kilograms force per square millimeter;

P is the maximum load in pounds force, meganewtons, newtons, or kilograms force; and

A is the cross-sectional area as indicated in 17.4.2.1.

17.4.4 Accelerated aging

17.4.4.1 All buffing and die-cutting operations are to be completed at least 30 minutes before the specimens are placed in the air oven for aging or are immersed in oil. Measurements for determining the cross-sectional area are to be made before the specimens are aged or immersed in oil. The bench marks (see 17.2.3.1) for the determination of elongation are to be placed on the specimens after the specimens are removed from the air oven in which they were aged. For oil immersion, the marks are to be placed on the specimens before they are immersed in oil.

17.4.4.2 Physical tests are to be made on both aged and unaged specimens at the same time and at a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unaged specimens are to be maintained at this room temperature for not less than 30 minutes prior to being subjected to physical tests, and specimens subjected to air-oven aging are to have a rest period of 16 – 96 hours at this room temperature following their removal from the oven and prior to their being subjected to the physical tests. Specimens subjected to oil immersion are to be blotted lightly to remove any excess oil, and are then to be suspended in air at the above-mentioned room temperature for 3.5 – 4.5 hours before being subjected to the physical tests. Specimens that are aged in the air oven are to be suspended vertically in such a manner that they cannot touch one another or the sides of the chamber. Specimens having widely different properties or composition are to be aged in separate ovens.

17.4.4.3 The oil-immersion vessel is to be of stainless-steel or glass of dimensions that make it possible to suspend the die-cut specimens vertically in the oil. The vessel is to be filled with the specified oil (see Note b to Table 17.1) and placed in a liquid bath having an automatic temperature control that maintains the specimens at the specified temperature. The oil in the immersion vessel is to be heated to the specified temperature before the specimens are immersed. The die-cut specimens are to be suspended vertically in the oil and the vessel is to be covered.

18 Deformation Test

18.1 Specimens of the jacket removed from finished conduit shall not decrease more than 50 percent in thickness when subjected to 2000 gf exerted by a flat surface 3/8 inch (9.5 mm) in diameter while at a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) for 60 minutes.

18.2 A sample of jacket 8 inches (203 mm) long is to be removed from finished conduit and buffed to remove any impressions on the surface and to achieve a uniform thickness. From the buffed sample, a rectangular specimen 1 inch (25 mm) long and 9/16 inch (14 mm) wide is to be cut. The thickness T_1 of the specimen is to be measured to the nearest 0.001 inch (0.01 mm) by means of a dead-weight dial micrometer whose presser foot exerts 85 ±3 gf (0.84 ±0.02 N or 3.0 ±0.1 ozf) on the specimen. The presser foot is to have a flat face 0.250 ±0.010 inch (6.4 ±0.2 mm) in diameter. The anvil of the instrument is to be at least 1.5 inches (38 mm) in diameter and is to be parallel to the face of the presser foot.

18.3 The thickness T_2 at elevated temperature is to be determined from measurements made by a dead-weight dial micrometer with a presser foot 0.375 ±0.010 inch (9.5 ±0.2 mm) in diameter and having graduations of 0.001 inch (0.01 mm). The micrometer is to be actuated by a weight of magnitude that causes the foot of the micrometer to press on a specimen positioned between the foot and the anvil with 2000 gf.

18.4 With the weight in place on its spindle, the dial micrometer is to be placed beside the test specimen in a full-draft circulating-air oven preheated to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F). The specimen and dial micrometer are to remain side by side in the oven for 60 minutes of preliminary heating at full draft. At the end of the 60 minutes, the specimen is to be placed on the anvil of the dial micrometer. The loaded presser foot is to be gently brought to bear on the specimen and is to continue to bear on the specimen while the dial micrometer and specimen remain in the oven for an additional 60 minutes at full draft at a temperature of 121.0 ±1.0°C (249.8 ±1.8°F).

18.5 At the end of the second 60 minutes, the thickness T_2 of the specimen is to be read directly from the dial on the loaded micrometer and is to be recorded to the nearest 0.001 inch (0.01 mm).

18.6 The jacket is not acceptable if T_2 is less than half of T_1.

19 Mechanical Water Absorption Test

19.1 Specimens of the thermoplastic jacket prepared from finished conduit shall not absorb any more than 25.0 milligrams mass of water per square inch of immersed surface or shall not absorb any more than 3.9 milligrams mass of water per square centimeter of immersed surface during immersion in tap water for 168 hours at a temperature of 70.0 ±1.0°C (158.0 ±1.8°F).

Exception: A PVC or other material known to be non-hygroscopic need not be subjected to this test.

19.2 The specimens are to be segments of the jacket that are approximately 4 inches (102 mm) long by 1 inch (25 mm) wide. The segments are to be buffed to remove all corrugations and are then to be cleaned, dried, cooled, and weighed as described in 19.3, after which they are to be placed in the water bath at the temperature specified in 19.1 for 168 hours. They are then to be transferred to distilled water at room temperature, removed one at a time, shaken, blotted, and reweighed as described in 19.6. The specimens are then to be dried, cooled, and weighed again as outlined in 19.7. The immersed surface area in square inches or square centimeters is to be determined by means of the following formula in which T is the thickness buffed specimen and with all dimensions expressed in inches or in centimeters

$$S = 2(length \times width) + 2T(length + width).$$