7.29.4.3 The grounding conductors shall be connected to earth ground. The circuit conductors shall be connected to the power supply, as indicated in Figure 24.

7.29.4.4 The conductors shall be loaded to the maximum rated current based on conductor size and cord type. A voltage of 300 V shall be applied between the conductors. Current shall not be passed through the grounding conductor, which shall be connected to ground. The circuit shall be protected by a time-delay fuse. One or more series current relays shall be provided to shut down the machine if a conductor opens.

7.29.4.5 The six specimens shall be flexed at a rate of approximately 20 cycles per minute for 3,100 cycles or until open circuit or short circuit occurs. One cycle consists of 90-degree rotation of the test assembly in one direction, 180-degree rotation in the opposite direction, and then return to the starting point. The flex shall be in the direction of smallest cord cross-section.

7.29.5 Results and calculations

The following conditions shall be recorded for each specimen:

a) development of an open circuit;

b) development of a short circuit;

c) breakage of more than 10 percent of the strands of any circuit or grounding conductor;

d) broken strands piercing the insulation and becoming accessible;

e) cracking or degradation of the cord insulation; or

f) exposure of the shield on shielded constructions.

7.29.6 Report

The report shall include, as a minimum, the results in 7.29.5.

7.30 Armored cable bushing insertion

7.30.1 Scope

This test establishes the method to determine that the construction of an armored cable suitably accepts the proper insertion of a cable bushing.

7.30.2 Apparatus

The apparatus for this test shall include the following:

a) a sample of armored cable taken from a reel or from manufacture; and

b) cable bushing of a size appropriate for the cable to be tested.

7.30.3 Preparation of specimens

Approximately 50 mm (2 in) of armor shall be removed from one end of the cable. If it is intended that the fibrous covering be removed before a bushing is inserted, such covering shall be removed manually from the conductor assembly.

7.30.4 Procedure

The bushing shall be inserted between the conductors and the armor.

7.30.5 Results

It shall be observed whether or not the bushing can be readily inserted such that the flange on it comes into contact with the cut end of the armor, and that it remains in that position after pressure has been removed.

7.30.6 Report

The report shall include as a minimum, the following:

a) description of cable;

b) trade size of bushing; and

c) whether the bushing remains in position after insertion pressure is removed.

8 Environmental Tests for Finished Wire and Cable

8.1 Copper corrosion

8.1.1 Scope

This test establishes the method for determining the chemical compatibility of copper, copper alloy, or copper-clad aluminum conductors in contact with insulation material.

8.1.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i); and

b) a temperature-measuring device with an accuracy of ±1 °C.

8.1.3 Preparation of specimens

Two specimens of insulated conductor shall be cut to lengths not less than 300 mm (12 in) that allow for at least one specimen to be placed in the oven vertically.

8.1.4 Procedure

8.1.4.1 One specimen shall be conditioned at ROOM TEMPERATURE. The second specimen shall be conditioned in the oven at the specified temperature for the specified period of time. Oven temperatures shall be recorded throughout the period of conditioning. The specimen shall then be removed from the oven and allowed to cool to ROOM TEMPERATURE.

8.1.4.2 The insulation shall be stripped from the conductors of both specimens and the surface of the conductors examined with NORMAL VISION.

8.1.5 Results and calculations

Any evidence of corrosion of the copper (normal oxidation or discoloration not caused by the insulation or any separator shall be disregarded) shall be noted.

8.1.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) evidence of corrosion on conditioned and unconditioned specimens.

8.2 Ozone resistance

8.2.1 Scope

This test method is used to determine the resistance of insulated wire or cable to degradation when exposed to specified concentration of ozone in air or oxygen.

8.2.2 Materials and reactants

Materials and reactants shall consist of:

a) ambient air or compressed air supply with adequate filtration of particulate matter. The moisture content of the air source shall be minimized; and

b) a cooling water system for operating temperature below 49 °C.

8.2.3 Apparatus

The apparatus* shall consist of the following:

a) an ozone generator for generating a controlled amount of ozone, by means of either an ultraviolet light source, corona discharge or a combination of both. The ozone generator shall be equipped with a variable power controller to adjust the ozone generator output. The ozone generating source shall be isolated from the internal chamber but within the integral external structure;

b) an ozone test chamber with the following:

1) a chamber interior of stainless steel, with all seams sealed and the chamber door provided with a gasket to assure leakproof operation so as not to affect the ozone concentration during the duration of the test;

2) an automatic control system that regulates and maintains the set point ozone concentration and corrects for external barometric pressure, temperature and relative humidity;

3) a means for circulating ozonized air under controlled conditions of humidity and temperature through the chamber. The source of air may be ambient or from a compressed air supply. Adequate filtration of particulate matter from the source shall be minimized, either through filtration, a desiccant or by other means;

4) the door sealed to prevent loss of partial pressure that would affect the ozone concentration for the duration of the test. If equipped with an observation window, it shall be of tempered glass;

5) a volume of not less than 0.14 m^3 (5 ft^3);

6) installed in an environment free from dust, smoke or other volatiles which might affect the performance of the automatic measurement and control system;

7) a cooling water system provided for operating temperatures below 49 °C; and

8) the chamber exhaust properly routed to the atmosphere; and

c) an ozone measurement and control system.

The ozone concentration shall be determined using standard gas laws based upon the absorption of ultra-violet light in conjunction with the partial pressure of ozone in a controlled air-ozone mixture.

NOTE: There are other techniques used to measure gaseous ozone such as the wet chemical method, which is based on the absorption of ozone in a potassium iodide solution and titration of the released iodine with sodium thiosulfate. However, the UV absorption method has been found to be more accurate and precise and as such, is now commonly used and has been used as the method against which others are calibrated.

*There is currently only one known source of ozone test apparatus at this time – Ozone Research Equipment Co., a division of CCSi, Inc. 1145 Highbrook Avenue, #500, Akron, OH 44301. The OREC 0500-0900 Series Ozone test chambers and Model 03DM-100 ozone monitor have been found suitable. Equivalent apparatus are also acceptable.

8.2.4 Preparation of specimens

8.2.4.1 Two specimens shall be selected from a point beyond 1.5 m (4.9 feet) from the end of the reel or coil to be tested. If protective coverings have been applied, they shall be removed when non-adherent. Where tapes or sheaths are applied prior to curing, are left in place during curing, and are consequently adherent to the test specimen in the completed cable, such coverings shall not be removed. Specimens shall be examined to ensure they are free from mechanical defects, such as cuts, dents, tears, and loose threads.

8.2.4.2 The specimens shall be bent as follows:

a) One specimen, at a temperature not less than 20 °C, shall be bent in the direction of its existing curvature, without twisting, one turn around a brass, aluminum, or suitably treated wooden mandrel having a diameter as shown in Table 7.

b) The second specimen shall be bent in a similar manner, but in the direction opposite to the existing curvature.

c) Each of the bent specimens shall be tied with tape at the point where the ends cross. If the specimen is too rigid to permit crossing of the ends, it may be bent in the form of a “U” and tied so that at least a 180 degree bend of the appropriate diameter is obtained.

d) The specimen shall conform closely to the periphery of the mandrel.

e) The surface of each specimen shall be wiped with a clean cloth to remove dirt or moisture.

f) The bent specimen on its mandrel shall be placed in a desiccator for a minimum of 30 to 45 minutes to remove the surface moisture and then left in the desiccator until it is placed in the ozone test chamber.

8.2.5 Procedure

8.2.5.1 All equipment shall be calibrated in accordance with the equipment manufacturer's instructions.

8.2.5.2 Prior to bending of the specimen the atmosphere in the exposure chamber shall be conditioned as follows:

a) the exhaust system above the chamber shall be turned on.

b) the system parameter verification check shall be performed prior to start up.

c) the temperature of the air in the test chamber shall be adjusted to the specified oven temperature.

d) the desired ozone concentration shall be set on the control panel.

8.2.5.3 After the ozone chamber has been in equilibrium operation for at least 45 minutes at the specified ozone concentration and temperature, the test specimen on the mandrel shall be placed in the test chamber. Care shall be taken not to handle the material under test. The specimen shall be supported with the axis of the mandrel horizontal and midway between the top and bottom of the chamber, with the free ends of the specimen pointing down, but not touching the bottom of the chamber.

8.2.5.4 After exposure for 3 hours to ozone at the specified concentration and temperature, the test specimen shall be removed from the chamber. Any covering on the specimen shall be removed.

8.2.6 Results and calculations

The insulation or jacket, whichever applicable, shall be examined by NORMAL VISION for cracks in the bent portion only.

8.2.7 Test report

The report shall include the following as a minimum:

a) temperature in the ozone chamber, °C;

b) exposure time, hours;

c) ozone concentration, percent by volume or ppm;

d) any evidence of cracks; and

e) mandrel diameter.

8.3 Copper sulfate test for zinc coatings on formed and unformed steel strip (Preece test)

8.3.1 Scope

This test establishes the method for determining the performance of zinc coatings for formed and unformed steel strip for finished armored cable.

8.3.2 Apparatus

The apparatus for the test shall consist of the following:

a) a vessel of glass or other chemically nonreactive material having a width of at least twice the widest dimension of the specimen;

b) a glass thermometer;

c) a timing device that indicates elapsed seconds;

d) a standard solution of copper sulfate;

e) paper towels or cheesecloth;

f) a solvent such as trichloroethylene or chloroform; and

g) a source of running tap water.

8.3.3 Materials and reactants

The requirements for the standard solution and wash water shall be as follows:

8.3.3.1 Preparation of solution

8.3.3.1.1 Copper sulfate solution shall be made by dissolving approximately 36 parts by weight of commercial reagent grade copper sulfate ($CuSO_4$) crystals in 100 parts by weight of distilled water.

NOTE: Chemically pure (cp) copper sulfate crystals are preferable to commercial grade, although not necessary, for the Preece test.

8.3.3.1.2 If heat is used to complete the solution of copper sulfate crystals, the solution shall be allowed to cool. The solution shall then be agitated with an excess of powdered cupric hydroxide [$Cu(OH)_2$], approximately 0.8 g/L of solution.

8.3.3.1.3 The neutralized solution shall be allowed to stand for 24 hours and then filtered or decanted.

NOTE 1: An excess of cupric hydroxide is present when the sediment of this reagent accumulates at the bottom of the vessel.

NOTE 2: Cupric oxide (CuO) of approximately 0.7 g/L of solution may be substituted for cupric hydroxide provided that the solution is allowed to stand not less than 48 hours after this addition and before filtering or decanting.

8.3.3.1.4 The test solution shall have a relative density of 1.186 at 18 °C. To adjust a solution of inappropriate relative density, distilled water shall be added if the relative density is high, and a copper sulfate solution of a higher relative density shall be added if the relative density is low.

8.3.3.2 Quantity of solution

The quantity of copper sulfate solution required for each test depends on the superficial area of the test specimen and the mass of coating. The quantity shall not be less than 40 ml/g of zinc coating on the specimen and shall be sufficient to cover the specimen so that the top surface of the solution is at least 10 mm (0.4 in) above the top of the section of the specimen under test.

NOTE: The theoretical minimum amount of copper sulfate solution required to dissolve 1 g of zinc is 13.3 ml. The quantity specified is three times this minimum to ensure an adequate rate of solution.

8.3.3.3 Wash water

Tap water shall be used for rinsing. If no running water is available, the rinse water shall be changed often enough, preferably after each dip, to ensure that it is reasonably free from copper sulfate. The temperature of the rinse water shall be 18 ±3 °C.

8.3.4 Preparation of specimens

8.3.4.1 The required quantity of specimens 150 mm (6 in) in length (axial measurement) shall be cut from partially uncoiled armor, free from abrasions from which the conductor assembly has been removed. The required quantity of additional straight specimens 150 mm (6 in) in length shall be cut from a sample length of the zinc-coated steel strip before forming.

8.3.4.2 All grease, etc., shall be removed by washing the specimen in trichloroethylene or chloroform. The specimen shall then be rinsed in water and dried with paper towels, and the zinc surface clean before immersion in the copper sulfate solution. Care shall be taken to avoid contact of the cleaned surface with foreign objects, particularly the hands.

8.3.4.3 At one end of a sample length of finished cable, the armor shall be unwound from the outside to expose to view, both edges and 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. In order to reduce the damage to the zinc coating, the strip shall not be straightened as it is unwound but shall remain in the helical form with a diameter not larger than approximately three times the cable diameter.

8.3.4.4 The specimens shall be cleaned with an organic solvent. Each specimen shall be examined for evidence of damage to the zinc coating occurring during specimen preparation, not during forming, and only specimens that are not damaged shall be selected for use in the test. One specimen of the unformed strip and one specimen of the armor shall be tested.

8.3.4.5 The two selected specimens shall be rinsed in water, and all of their surfaces dried with clean cheesecloth, removing as much of the water as possible in the drying operation as water slows the reaction between the zinc and the solution, thereby adversely affecting the test results.

8.3.4.6 The surface of the zinc shall be dry and clean before a specimen is immersed in the copper sulfate solution. The specimens shall not be touched by the hands or in any way that can contaminate or damage the surfaces.

8.3.5 Procedure

8.3.5.1 The vessel described in 8.3.2(a) shall be filled with the solution described in 8.3.3.1 – 8.3.3.2 to a depth sufficient to immerse not less than half the axial length of the specimen. The temperature of the solution shall be 18 ±1 °C. The specimen shall then be placed in a vertical position in the center of the vessel containing the standard solution. The specimen shall remain in the solution for 60 seconds, during which time it shall not be moved and the solution shall not be stirred.

8.3.5.2 After 60 seconds, the specimen shall be removed from the vessel, immediately rinsed in a stream of running water, and rubbed dry with a clean, wet, lint-free cloth until any loosely adhering deposits of copper are removed. The turns of the specimen of partially uncoiled armor shall not be further separated during this process, and hands and other damaging and contaminating objects and substances shall not be allowed to touch any surfaces that were immersed.

NOTE: A clean soft-bristle test-tube or bottle brush in good condition and of applicable size may be used to rub (only) the interior surfaces of the specimen of partially uncoiled armor.

8.3.5.3 The procedures in 8.3.5.1 – 8.3.5.2 shall be repeated until the specified total number of immersions has been made. Following completion of testing on each specimen, a fresh portion of the standard solution employed for each additional specimen.

NOTE: A fixed deposit of copper generally occurs first at the weakest points in the zinc coating and increases in area upon successive dips until the entire zinc coating disappears.

8.3.6 Results and calculations

8.3.6.1 The condition of the portion of the specimen that was immersed shall be examined for a bright deposit of closely adhering metallic copper on all or any part of that portion. Each edge and broad surface shall be considered separately. The portion of the specimen within 13 mm (0.5 in) of its immersed end shall be disregarded.

8.3.6.2 In the case of interlocked armor, if there is a deposit, an estimate shall be made of the ratio of the copper-covered surface to the total surface immersed, expressed as a percentage. The estimate shall be based on examination with NORMAL VISION. The surface within 10 mm (0.4 in) of the cut end shall be disregarded.

8.3.7 Report

The report shall include, as a minimum, the following:

a) presence of bright deposits, if any, on edges or on broad surfaces after each immersion; and

b) for interlocked armor, estimated ratio of copper-covered surface to total surface immersed, after each immersion.

9 Burning Characteristics Tests

9.1 FT2/FH/Horizontal flame

9.1.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the horizontal propagation of flame and the dropping of flaming particles.

9.1.2 Materials and reactants

Materials and reactants shall consist of the following:

a) methane, at 98 percent minimum purity, having a heat content of 37 ±1 MJ/m^3 (1000 ±30 Btu/ft^3) at 25 °C and 101 kPa (14.7 psi); or natural gas, with a heat content of 37 ±1 MJ/m^3 (1000 ±30 Btu/ft^3) at 25 °C and 101 kPa (14.7 psi); and

NOTE: Alternative gases, such as propane, at a 95 percent minimum purity, having a heat content of 94 ±2 MJ/m^3 (2540 ±50 Btu/ft^3) at 25 °C and 101 kPa (14.7 psi) or butane, at 99 percent minimum purity, having a heat content of 120 ±3 MJ/m^3 (3240 ±80 Btu/ft^3) at 25 °C and 101 kPa (14.7 psi), may be used if a stable flame is obtained and the heat evolution profile complies with ASTM D5207 or NMX-J-192-ANCE or IEC 60695-11-3.

CAUTION: Propane and butane gases are denser than air and can settle and become an explosion hazard. Consult the gas supplier for special precautions to be taken.

b) surgical cotton, dry and untreated.

9.1.3 Apparatus

The apparatus shall consist of the following:

a) a draft-free chamber having a means for access and viewing that can be sealed. Each linear interior dimension of the chamber shall be at least 610 mm (24 in). The interior volume of the chamber shall be at least 4 m^3 (140 ft^3), including the volume of an exhaust transition, if any. At least 2 m^3 (70 ft^3) of this volume shall be above the point of impingement of the flame on the specimen, as space for the heat and smoke to accumulate so as not to influence the test;

b) an angle block (see Figure 27) to place the burner at a 20 ±1 degree angle from the vertical position. The angle block shall be capable of moving the flame into position on the specimen. It shall also be capable of directing the flame away from the specimen beyond vertical, or withdrawing the flame a minimum distance of 150 mm (6 in) from the specimen;

c) laboratory stands or other supports used to secure the specimen. These shall not create updrafts or impede the air supply to the flame. Regardless of the method employed, the specimen supports shall be 200 to 230 mm (7 to 9 in) apart;

d) a laboratory burner conforming to ASTM D 5025 or NMX-J-192-ANCE or IEC 60695-11-3, suitable for the calorific value of the gas and having an inside diameter of 9.5 ±0.3 mm (0.375 ±0.01 in) and a length of 100 ±10 mm (4.0 ±0.4 in) above the primary-air inlets. The burner shall be calibrated in accordance with ASTM D 5207 or NMX-J-192-ANCE or IEC 60695-11-3 each time a cylinder of gas, when used, is changed or refilled, or any of the apparatus is changed;

NOTE: It is recommended that the burner flame be calibrated at least every 30 days and each time that a cylinder of gas is changed or if any of the apparatus is changed. It is also recommended that where the gas used is other than the grade of methane specified for referee purposes, the burner flame be calibrated each day immediately before testing is begun.

e) a length-measuring device accurate to 5 percent of char length requirement;

f) a flame height gauge capable of measuring the specified flame heights; and

g) a timing device capable of measuring the specified times in seconds, having a resolution of 1 second and an accuracy of ±0.5 second.

9.1.4 Preparation of specimens

A specimen shall be taken from a sample of wire, cable, or cord, finished or during manufacture, 250 to 300 mm (10 to 12 in) long, and shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours and then straightened and secured horizontally to the specimen supports. In the case of flat parallel constructions, the specimen shall be secured with its major axis in the vertical position.

9.1.5 Procedure

9.1.5.1 The height of the test flame, with the burner vertical, shall be adjusted to 125 ±10 mm (5.0 ±0.4 in), with an inner blue cone 40 ±2 mm (1.6 ±0.1 in) high. A gas-supply gauge pressure of 10 – 20 lbf/in^2 or 69 – 138 kPa or 690 – 1380 mbar or 700 – 1400 gf/cm^2 has been found to be adequate to maintain the required flame. A cylinder shall not be used when this range of pressure is no longer sustainable at room temperature. The burner shall be attached to the angle block to position the burner at an angle of 20 degrees from vertical.

9.1.5.2 A flat horizontal layer of cotton, 6 ±3 mm (0.25 ±0.12 in) thick and having dimensions of approximately 200 x 200 mm (8.0 x 8.0 in) shall cover the floor of the enclosure and be centered under the specimen. The upper surface of the cotton shall be 230 to 240 mm (9.0 to 9.5 in) below the point at which the tip of the inner blue cone touches the specimen.

9.1.5.3 The test chamber and exhaust system shall be sealed and the fan shall be off during the test. The burner shall be moved into position such that the tip of the inner blue cone of the test flame is applied to the center of the specimen (see Figure 28). After 30 seconds the flame shall be withdrawn and the specimen shall be allowed to burn until it self-extinguishes.

9.1.5.4 After the specimen has extinguished, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.1.6 Results and calculations

9.1.6.1 The length of damage to the specimen shall be measured and recorded. Damage is defined as charring, burning, or melting.

9.1.6.2 Ignition of the cotton, if any, shall be recorded. Flameless charring of the cotton shall be ignored.

9.1.7 Report

The test report shall include, as a minimum, the following:

a) length of damage to the specimen; and

b) indication of ignition of cotton.

9.2 Burning particles (dropping)

9.2.1 Scope

This test establishes the method for determining the resistance to dropping of burning particles of wire or cable insulation during and after the application of a test flame.

9.2.2 Materials and reactants

Materials and reactants shall consist of

a) methane as described in 9.1.2(a); and

b) standard newsprint having a mass of 46.4 to 57.0 g/m^2 (0.086 to 0.105 lb/yd^2), a maximum thickness of 0.11 mm (0.043 in), and a maximum ash content of 6.5 percent.

9.2.3 Apparatus

The apparatus shall consist of the following:

a) the apparatus as described in 9.1.3 (a), (b), and (d), and a means for supporting the test specimen in a vertical position;

b) a test shield of sheet metal 300 ±50 mm (12 ±2 in) wide, 350 ±50 mm (14 ±2 in) deep, and 600 ±50 mm (24 ±2 in) high open at the top and front and provided with means for supporting the test specimen in the vertical position; and

c) a steel plate with a minimum thickness of 3 mm (0.1 in) with approximate dimensions of 200 x 300 mm (8 x 12 in).

9.2.4 Preparation of specimens

9.2.4.1 A specimen 450 to 600 mm (18 to 24 in) in length shall be taken from a sample of wire, cable, or cord, finished or taken from manufacture. The specimen shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours and then straightened and secured vertically with the specimen supports.

9.2.4.2 The bottom support shall be at least 50 mm (2 in) below the point of impingement of the test flame. The top support shall be at least 300 mm (12 in) above of the point of impingement of the test flame.

9.2.5 Procedure

9.2.5.1 The specimen, apparatus, and surrounding air shall be at ROOM TEMPERATURE.

9.2.5.2 The steel plate shall be placed on the floor of the chamber under the specimen. A sheet of newsprint with approximate dimensions of 200 x 300 mm (8 x 12 in) shall be laid flat on the steel plate.

9.2.5.3 The height of the test flame, with the burner vertical, shall be adjusted to 125 ±10 mm (4.9 ±0.4 in), with an inner blue cone 40 ±2 mm 1.6 ±0.1 in) high. A gas-supply gauge pressure of 10 – 20 lbf/in^2 or 69 – 138 kPa or 690 – 1380 mbar or 700 – 1400 gf/cm^2 has been found to be adequate to maintain the required flame. A cylinder shall not be used when this range of pressure is no longer sustainable at room temperature. The burner shall be attached to the angle block to position the burner at an angle of 20 degrees from vertical.

9.2.5.4 The test chamber and exhaust system shall be sealed and the fan shall be off during the test. The tip of the inner blue cone of the test flame shall be applied to the specimen for 15 seconds, and then removed for 15 seconds. The tip of the blue cone shall impinge the specimen at a distance not greater than 238 mm (9.375 in) above the newsprint (see Figure 29).

9.2.5.5 The application of the flame in 9.2.5.4 shall be repeated until 5 applications of the flame have been made. During the test and up to 60 seconds following the fifth flame application, the newsprint shall be monitored for evidence of ignition caused by dropping of burning particles.

9.2.5.6 After the specimen has extinguished, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.2.6 Results and calculations

Combustion of the newsprint, or the presence of holes in the newsprint, shall be recorded.

9.2.7 Report

The test report shall include, as a minimum, evidence of combustion or holes in the newsprint.

9.3 FT1

9.3.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the vertical propagation of flame.

9.3.2 Materials and reactants

Materials and reactants shall consist of the following:

a) methane as described in 9.1.2(a); and

b) 94 g/m^2 (60 lb) kraft paper with a nominal thickness of 0.13 mm (0.005 in), gummed on one side.

9.3.3 Apparatus

The apparatus shall consist of the following: