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UL 428A

OUTLINE OF INVESTIGATION

FOR

ELECTRICALLY OPERATED VALVES FOR GASOLINE AND GASOLINE/  
ETHANOL BLENDS WITH NOMINAL ETHANOL CONCENTRATIONS UP TO  
85 PERCENT (E0 – E85)

Issue Number: 1

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*Summary of Topics*

*This is the first issue of the Outline of Investigation for Electrically  
Operated Valves for Gasoline and Gasoline/Ethanol Blends with Nominal  
Ethanol Concentrations Up To 85 Percent (E0 – E85).*

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**SUPPLEMENT SA - MARINE USE ELECTRICALLY OPERATED SHUT-OFF VALVES FOR GASOLINE AND GASOLINE/ETHANOL BLENDS WITH NOMINAL ETHANOL CONCENTRATIONS UP TO 85 PERCENT (E0 – E85)**

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**Superseded requirements for the Outline of Investigation for Electrically Operated Valves for Gasoline and Gasoline/Ethanol Blends with Nominal Ethanol Concentrations Up To 85 Percent (E0 – E85)UL 428A, First Issue**

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## INTRODUCTION

### 1 Scope

1.1 These requirements cover electrically operated general purpose and safety valves rated 600 volts or less and intended for the control of the fluids specified in 1.2. Electrically operated valves, other than automotive fuel valves, covered by these requirements are intended to be used in other than hazardous locations as defined in accordance with the National Electrical Code, NFPA 70.

1.2 Electrically operated valves for use in dispensing devices are intended for use with one or more of the following:

- a) Gasoline formulated in accordance with the Standard Specification for Automotive Spark Ignition Fuel, ANSI/ASTM D4814;
- b) Gasoline/ethanol blends with nominal ethanol concentrations up to 25 percent ethanol (E25), consisting of gasoline formulated in accordance with the Standard Specification for Automotive Spark Ignition Fuel, ANSI/ASTM D4814, when blended with denatured fuel ethanol formulated to be consistent with the Standard Specification for Denatured Fuel Ethanol for Blending With Gasoline For Use as Automotive Spark Ignition Engine Fuel, ANSI/ASTM D4806; or
- c) Gasoline/ethanol blends with nominal ethanol concentrations above 25 percent formulated in accordance with the Standard Specification in item (b) or formulated in accordance with the Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark Ignition Engines, ANSI/ASTM D5798, as applicable.

1.3 These requirements cover valves whose coils are powered by a Class 2 (low-voltage) source. Valves incorporating a high-voltage transformer with a low-voltage secondary as an integral part of the valve assembly, are also covered by these requirements.

1.4 These requirements do not cover valves for use with fluids other than as specified in 1.2.

1.5 These requirements do not cover valves employing electrical parts, including coils, switch contacts and resistance elements, located in the flammable gas containing compartment of a valve. Valves constructed as such shall comply with the requirements in the Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations, UL 913.

## 2 General

### 2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a valve covered by this outline 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 outline, or
- b) Is superseded by a requirement in this outline.

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.

2.2.2 Unless indicated otherwise all voltage and current values mentioned in this standard are root-mean-square (rms).

### 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.

### 2.4 Automotive-fuel valve

2.4.1 An automotive fuel valve shall comply with the requirements applicable to safety valves.

### 3 Glossary

3.1 For the purpose of this outline, the following definitions apply.

3.2 AUTOMOTIVE-FUEL VALVE – An electrically operated valve rated for use with a direct current (DC) circuit and intended for use as a fuel-line shutoff valve on mobile equipment.

3.3 BLENDING OPTION Dispensing devices may be provided with an option that blends two specific fuels into one fuel to be dispensed. This blending occurs at the dispenser level and can be in two forms:

- a) Fixed blending – Blending at the dispenser level that blends two specific fuels into one fuel to be dispensed, and that fuel to be dispensed is fixed. For example, fixed blending includes blend options where gasoline and denatured fuel ethanol can be blended to achieve E85, which is the actual dispensed fuel.
- b) Variable blending – Blending at the dispenser level that blends two specific fuels into the fuel to be dispensed, but the fuel to be dispensed can be any of a number of previously set points. For example, variable blending includes blend options where gasoline and E85 can be blended to achieve E40, E60, and E85 as the actual dispensed fuel.

### 3.4 ELECTRICAL CIRCUITS –

a) Class 2 Circuit – A circuit involving a potential of not more than 42.4 volts peak supplied by:

1) An isolating source that complies with the requirements in the Standard for Class 2 Power Units, UL 1310, or the requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3

2) A dry cell battery having output characteristics no greater than those of an inherently limited Class 2 transformer; or

3) A combination of a rechargeable battery and a fixed impedance or regulating network that complies with the applicable performance requirements for an inherently limited Class 2 transformer.

b) Low-Voltage Circuit – A circuit involving a potential of not more than 30 volts ac (42.4 volts peak or direct current) and supplied from transformer output windings which are electrically isolated (i.e. insulated from ground). A circuit derived from a source of supply classified as a high voltage circuit, by connecting resistance in series with the supply circuit as a means of limiting the voltage and current, is not considered to be a low voltage circuit. Unless the isolating transformer is provided as part of the valve or marked per 45.7, the circuit shall be considered a high voltage circuit.

c) High-Voltage Circuit – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage circuit.

d) Intrinsically Safe Circuit – A circuit in which any spark or thermal effect produced either normally or in specified fault conditions, is incapable of causing ignition of a mixture of flammable or combustible material in air in the mixtures most easily ignited concentration under the test conditions specified in the Standard for Intrinsically Safe Apparatus and Associated Apparatus, for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations, UL 913.

e) Safety-Control Circuit – A circuit involving one or more safety controls.

3.5 GASOLINE/ETHANOL BLENDS – Blended fuels composed of a gasoline component and an ethanol component. The numerical value corresponding to the ethanol component determines the blend rating (such as E85 for 85% ethanol, 15% gasoline).

3.6 GENERAL PURPOSE VALVE – Either a normally open or normally closed valve intended to control the flow of a fluid.

3.7 MAXIMUM OPERATING PRESSURE DIFFERENTIAL – The maximum difference between the pressure at an inlet port and the pressure at an outlet port against which an electrically operated valve is intended to operate.

3.8 MAXIMUM RATED PRESSURE – The maximum pressure to which the valve assembly may be subjected as specified by the manufacturer.

3.9 MINIMUM OPERATING PRESSURE DIFFERENTIAL – The minimum difference between the pressure at an inlet port and the pressure at an outlet port required for operation of the valve.

3.10 RAINPROOF ENCLOSURE – An enclosure that prevents rain from interfering with the intended operation of apparatus within the enclosure.

3.11 RAINTIGHT ENCLOSURE – An enclosure that, when exposed to a beating rain, does not permit water to enter the enclosure.

3.12 SAFETY VALVE – A normally closed valve intended to be actuated by a safety control or by an emergency device to prevent the delivery of a fluid that can result in risk of fire.

3.13 SEALS, DYNAMIC – A seal that is subject to mechanical movement or other applied forces that result in movement or flexing of the seal under normal use conditions.

3.14 SEALS, STATIC – A seal that is not subject to mechanical movement or other applied forces other than compression forces that are applied during installation and maintained during normal use conditions.

3.15 SWITCH – A contact device actuated by the valve mechanism and intended to control electrical loads that are internal or external to the valve.

a) Safety Switch – A switch that opens and closes a safety-control circuit, or one intended for use as an interlock in a safety-control circuit.

b) Nonsafety Switch – A switch not associated with a safety-control circuit.

3.16 WATERTIGHT ENCLOSURE – An enclosure that, when subjected to the application of a hose stream as described in the Hosedown Test, Section 37, does not permit water to enter the enclosure.

## CONSTRUCTION

### 4 General

4.1 Valves shall be constructed so that they comply with the rules for installation and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70.

4.2 Fluid confining parts, except gaskets and seals, shall be constructed of metallic materials.

### 5 Assembly

#### 5.1 All valves

5.1.1 A valve shall include all the components necessary for its intended function and installation. The components shall be constructed for assembly as a unit.

5.1.2 Two or more subassemblies intended to be assembled in the field as a unit shall be capable of being joined together without requiring any of the subassemblies to be cut, drilled, welded, or otherwise altered.

5.1.3 If two or more valves or actuating devices, or both, are intended to be used together as one unit, the entire assembly is to be considered and tested as one valve.

5.1.4 The construction of a valve shall be such that parts can be reassembled after being dismantled to the extent needed for servicing.

5.1.5 A screwed cap or cover that constitutes a fluid-confining part, and that is intended to be removed for servicing a valve, shall require the use of a tool for removal.

5.1.6 A seat disc shall be attached to its poppet or holder or be otherwise assembled to prevent it from becoming dislocated under service conditions. The disc may be secured by crimping, staking, or the equivalent, or by means of a chemical bond achieved by vulcanization in a controlled molding process. Cement or adhesive shall not be used as the sole means for securing a disc.

5.1.7 The valve assembly shall withstand the stresses and vibration of intended operation, as determined by compliance with the Endurance Test, Section 29.

## 5.2 Safety valves

5.2.1 A safety valve shall not depend on an outside source of energy, such as electricity, to function as a safety shutoff.

5.2.2 A safety valve shall close independently of the energy supplied by the medium flowing. However, the medium flowing may be used to exert supplementary closing forces on the valve seat.

5.2.3 A safety valve shall not be equipped with a bypass or with a means to prevent it from closing completely. This requirement does not apply to a feature provided to permit a takeoff to recirculate fluid or to supply a pilot or other individually controlled outlet.

5.2.4 An automatic shutoff mechanism shall be guarded to prevent unintended obstruction of moving parts.

5.2.5 A safety valve shall also function as a safety shutoff if intended to function as a safety shutoff, regardless of the position of any damper or external operating lever or any reset device. The manipulation of a manual-reset device shall not cause the valve to function as an automatic-reset valve.

5.2.6 A safety valve shall not be equipped with means for manually latching the valve in the open position if such latching may prevent the valve from functioning as a safety shutoff.

5.2.7 The appropriate positions or the direction of movement for a manual operating lever or reset handle included in a safety valve shall be clearly indicated.

5.2.8 If a mechanically actuated indicator is provided to indicate whether the main valve is open or shut, the indicator shall be visible from a distance of at least 5 feet (1.5 m).

## 5.3 Class 2 (low-voltage) valves

5.3.1 Valves whose coils are powered by a Class 2 (low-voltage) source shall comply with the construction and testing requirements defined in this outline.

## 6 Materials

### 6.1 Metallic materials

#### 6.1.1 General

6.1.1.1 A metallic part, in contact with the fuels anticipated by these requirements, shall be resistant to the action of the fuel if degradation of the material will result in leakage of the fuel or if it will impair the function of the device. For all fuel ratings, see Corrosion due to fluid, 6.1.2.1. For valves rated for gasoline/ethanol blends with nominal ethanol concentrations greater than 25%, see Metallic materials – system level, 6.1.3.

6.1.1.2 The exposed surfaces of metallic parts shall be resistant to atmospheric corrosion if this corrosion will lead to leakage of the fluid or if it will impair the function of the device. The material shall comply with the requirements in Atmospheric corrosion, 6.1.2.2.

6.1.1.3 Metallic parts in contact with the fuels anticipated by these requirements shall not be constructed of lead, or materials that are substantially lead. In addition, no coatings or platings containing lead shall be used, such as terne-plated steel.

## 6.1.2 Metallic materials – material level

### 6.1.2.1 Corrosion due to fluid

6.1.2.1.1 All metallic materials used for fluid confining parts shall be resistant to corrosion caused by the fuels anticipated by these requirements. In addition, metallic materials, used internally in fluid confining parts, that are required to operate in some manner to address safety (e.g. plunger on a valve) shall be resistant to corrosion caused by these fuels. Compliance is verified by the Long Term Exposure Test, Section 24.

6.1.2.1.2 A coating or plating, applied to a base metal, shall be resistant to the action of the fuels anticipated by these requirements as determined by the Long Term Exposure Test, Section 24.

### 6.1.2.2 Atmospheric corrosion

6.1.2.2.1 Metallic materials used for fluid confining parts shall be resistant to atmospheric corrosion. Ferrous materials of the thickness specified in the following items are acceptable for the preceding when uncoated:

a) A casting having a wall thickness of not less than 1/4 inch (6.4 mm) if shown by production test to be free of leakage, and

b) Fabricated sheet steel parts having a minimum wall thickness of 0.093 inch (2.36 mm).

6.1.2.2.2 A protective coating shall provide resistance against atmospheric corrosion to a degree not less than that provided by the protective coatings specified in 6.1.2.2.3.

6.1.2.2.3 Cadmium plating shall not be less than 0.0003 inch (0.008 mm) thick, and zinc plating shall not be less than 0.0005 inch (0.013 mm) thick, except on parts where threads constitute the major portion of the area in which case the cadmium or zinc plating shall not be less than 0.00015 inch (0.0038 mm) thick. Metallic parts are considered to comply with 6.1.2.2.1 when they are protected against atmospheric corrosion by:

a) Hot dipped, mill galvanized sheet steel complying with the coating designation G90 in Table I of the Specification for Sheet Steel, Zinc Coated (Galvanized) or Zinc-Iron-Alloy Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M; or

b) Coatings which have been determined to be equivalent to G90 under the requirements of the Standard for Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment, UL 1332.

6.1.2.2.4 A metallic material other than as described in 6.1.2.2.1 – 6.1.2.2.3 shall be painted or protected in a manner that has been determined to be equivalent.

### 6.1.3 Metallic materials – system level

6.1.3.1 Combinations of metallic materials in products rated for use with gasoline/ethanol blends with nominal ethanol concentrations greater than 25% shall be chosen to reduce degradation due to galvanic corrosion in accordance with 6.1.3.2 – 6.1.3.4.

6.1.3.2 Table 6.1 shows the galvanic series for metallic materials exposed to a conductive solution of sea water. The most active material in a given combination will experience increased levels of corrosion, while the most passive material in the combination will experience reduced levels of corrosion. The greater the separation of the materials are in the galvanic series of Table 6.1, the more pronounced the effects would be. Table 6.1 serves as a guide in selecting the appropriate test conditions based on manufacturer specified material combinations.

**Table 6.1**  
**Galvanic series of metal materials**

|              |                                        |
|--------------|----------------------------------------|
| Most passive | Platinum                               |
| –            | Gold                                   |
| –            | Graphite                               |
| –            | Silver                                 |
| –            | Stainless Steel Type 316 (Passive)     |
| –            | Stainless Steel Type 304 (Passive)     |
| –            | Titanium                               |
| –            | 13% Chromium Stainless Steel (Passive) |
| –            | 76 Ni – 16 Cr – 7 Fe Alloy (Passive)   |
| –            | Nickel (Passive)                       |
| –            | Silver Solder                          |
| –            | M-Bronze                               |
| –            | G-Bronze                               |
| –            | 70:30 Cupro Nickel                     |
| –            | Silicon Bronze                         |
| –            | Copper                                 |
| –            | Red Brass                              |
| –            | Aluminum Brass                         |
| –            | Admiralty Brass                        |
| –            | Yellow Brass                           |
| –            | 60 Ni – 30 Mo – 6 Fe – 1 Mn            |
| –            | 76 Ni – 16 Cr – 7 Fe Alloy (Active)    |
| –            | Nickel (Active)                        |
| –            | Manganese Bronze                       |
| –            | Tin                                    |
| –            | Stainless Steel Type 316 (Active)      |
| –            | Stainless Steel Type 304 (Active)      |
| –            | 13% Chromium Stainless Steel (Active)  |
| –            | Cast Iron                              |
| –            | Wrought Iron                           |
| –            | Mild Steel                             |
| –            | Aluminum 2024                          |
| –            | Cadmium                                |
| –            | Alclad                                 |
| –            | Aluminum 6053                          |
| –            | Aluminum 1100                          |

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**Table 6.1 Continued**

|                                                                                                                                                                                                                    |                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| –                                                                                                                                                                                                                  | Galvanized Steel |
| –                                                                                                                                                                                                                  | Zinc             |
| –                                                                                                                                                                                                                  | Magnesium Alloys |
| Most active                                                                                                                                                                                                        | Magnesium        |
| Note – Reprinted with permission from NACE. Based on table titled "Galvanic Series of Metals Exposed to Seawater" from NACE Corrosion Engineer's Reference Book, Third Edition ©NACE International 2002, page 127. |                  |

6.1.3.3 Platings, such as nickel plating, can be used to reduce or eliminate dissimilar metal contact areas, as long as the plating material complies with 6.1.3.2 as the contact metal. If used, the plating shall comply with the Long Term Exposure Test, Section 24.

6.1.3.4 Gaskets or nonmetallic spacers used to reduce or eliminate dissimilar metal contact areas, where permitted, shall be subjected to the applicable requirements for static seals in Nonmetallic materials, 6.2, when they are in contact with the fluid.

## **6.2 Nonmetallic materials**

### **6.2.1 General**

6.2.1.1 A nonmetallic part in contact with the fuels anticipated by these requirements, shall be resistant to the action of the fuel if degradation of the material will result in leakage of the fuel, or if it will impair the function of the device.

6.2.1.2 Gaskets or seals shall be designated as dynamic and/or static seals. See 3.9 and 3.10 respectively. If the type of seal cannot be determined, then the material shall be treated as both a static and a dynamic seal.

6.2.1.3 Gaskets and seals shall comply with the requirements as outlined in Nonmetallic materials – material level, 6.2.2 and Nonmetallic materials – system level, 6.2.3.

6.2.1.4 Nonmetallic materials in contact with the fuels anticipated by these requirements shall not be constructed of the following:

- a) Polysulfide rubber;
- b) Ethylene propylene diene monomer (EPDM) rubber;
- c) Methyl-Methacrylate;
- d) Polyvinyl Chloride (PVC);
- e) Nylon 6/6; or
- f) Polyurethane.

## 6.2.2 Nonmetallic materials – fluid compatibility – material level

### 6.2.2.1 Static seals

6.2.2.1.1 Static seals shall be evaluated in accordance with the Standard for Gaskets and Seals, UL 157, modified as indicated in 6.2.2.1.2 – 6.2.2.1.4. If a specific material complies with these requirements, the material can be considered to be qualified for system testing.

6.2.2.1.2 A static seal shall be constructed of a material that is acceptable in accordance with the scope of Standard for Gaskets and Seals, UL 157.

6.2.2.1.3 Static seals shall be subjected to the Volume Change and Extraction Test in accordance with the Standard for Gaskets and Seals, UL 157, except for the following modifications:

- a) The test duration shall be 1000 hours;
- b) The applicable test fluids shall be as described in Supplement SA; and
- c) For all materials, the average volume change shall not exceed 40% swell (increase in volume) or 1% shrinkage (decrease in volume). In addition, the weight loss shall not exceed 10%. For coated fabrics, alternate limits can be used with the average volume change not exceeding 60% swell or 5% shrinkage, and the weight loss shall not exceed 20%. There shall be no visual evidence of cracking or other degradation as a result of the exposure for any material including coated fabrics.

6.2.2.1.4 Static seals shall be subjected to the Compression Set Test in accordance with the Standard for Gaskets and Seals, UL 157, except for the following modifications:

- a) The test duration shall be 1000 hours.
- b) The samples shall be immersed, at room temperature, in the test fluids (see item c) while compressed for the entire test duration. No oven conditioning is required.
- c) The applicable test fluids shall be as described in Supplement SA.
- d) The recovery period shall consist of removing the sample from the compression device and immersing it in the applicable test fluid for 30 minutes at room temperature. The sample shall not be allowed to dry out due to exposure to air. The 30-minute immersion should use the same fluid as the test fluid for each sample.
- e) For all materials, the average compressions set is calculated and shall not exceed 35 percent. For coated fabrics, alternate limits can be used with the average compression set not exceeding 70%.

*Exception: This requirement does not apply to composite gasket materials as defined in accordance with the Standard for Gaskets and Seals, UL 157.*

#### 6.2.2.2 Dynamic seals

6.2.2.2.1 Dynamic seals shall be evaluated in accordance with the Standard for Gaskets and Seals, UL 157 modified as indicated in 6.2.2.2.2 – 6.2.2.2.4. If a specific material complies with these requirements, the material can be considered to be qualified for system testing.

6.2.2.2.2 A dynamic seal shall be constructed of a material that is acceptable in accordance with the scope of the Standard for Gaskets and Seals, UL 157.

6.2.2.2.3 Dynamic seals shall be subjected to the Volume Change and Extraction Test in accordance with the Standard for Gaskets and Seals, UL 157, except for the following modifications:

- a) The test duration shall be 1000 hours;
- b) The applicable test fluids shall be as described in Supplement SA; and
- c) For all materials, the average volume change for a gasket or seal material shall not exceed 40% swell (increase in volume) or 1% shrinkage (decrease in volume). In addition, the weight loss shall not exceed 10%. For coated fabrics, alternate limits can be used with the average volume change not exceeding 60% swell or 5% shrinkage, and the weight loss shall not exceed 20%. There shall be no visual evidence of cracking or other degradation as a result of the exposure for any material including coated fabrics.

6.2.2.2.4 Dynamic seals shall be subjected to the Tensile Strength and Elongation Test in accordance with the Standard for Gaskets and Seals, UL 157, except for the following modifications:

- a) The test duration shall be 1000 hours;
- b) The applicable test fluids shall be as described in Supplement SA; and
- c) For all materials, the average tensile strength and the average elongation of materials shall not be less than 60 percent of the as-received values. For coated fabrics, alternate limits can be used with the average tensile strength and the average elongation not less than 30% of the as-received values.

### 6.2.3 Nonmetallic materials – fluid compatibility – system level

6.2.3.1 For all materials, gaskets and seals that have been shown to comply with the material level tests shall be subjected to the system level tests for the applicable component after the Long Term Exposure Test, Section 24.

## 6.3 Casting impregnation materials

### 6.3.1 Material level fluid compatibility

6.3.1.1 Casting impregnation materials shall be evaluated at the material level in accordance with the requirements in the Outline of Investigation for Power Operated Dispensing Devices for Gasoline and Gasoline/Ethanol Blends With Nominal Ethanol Concentrations Up To 85 Percent (E0 – E85), UL 87A.

### 6.3.2 System level fluid compatibility

6.3.2.1 The casting impregnation material, applied as intended to a casting, shall comply with the Long Term Exposure Test, Section 24. The casting shall not show indications of porosity leakage at any point during or after this test.

## 6.4 Internal parts – fluid compatibility

6.4.1 Nonmetallic parts located internally to a fluid confining part, degradation of which would not directly result in leakage, is not required to comply with Nonmetallic materials, 6.2. The part shall be tested in accordance with 6.4.2.

6.4.2 Internal nonmetallic parts shall be tested during the Long Term Exposure Test, Section 24. During this test, the part shall not degrade to the extent that visible particles can be observed in the fluid.

## 6.5 Nonmetallic materials for electrical insulation

6.5.1 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current-Arc Resistance to Ignition (HAI), Comparative Tracking Index (CTI) and Permanence/Water Absorption (Wa Abs) values indicated in Table 6.2. A material is in direct support of an uninsulated live part when:

- a) is in direct physical contact with the uninsulated live part; and
- b) It serves to physically support or maintain the relative position of the uninsulated live part with respect to spacing requirements.

*Exception: A generic material provided in the thickness indicated in Table 6.3 shall comply with this requirement without additional evaluation.*

6.5.1 effective November 11, 2014

**Table 6.2**  
**Minimum material characteristics for the direct support of uninsulated live parts**

Table 6.2 effective November 11, 2014

| Flame Class | RTI Electrical | Maximum Performance Level Category (PLC) |                    |                    |
|-------------|----------------|------------------------------------------|--------------------|--------------------|
|             |                | HWI <sup>b,c</sup>                       | HAI <sup>d,e</sup> | CTI <sup>f,g</sup> |
| HB          | a              | 2                                        | 1                  | 3                  |
| V-2, VTM-2  | a              | 2                                        | 2                  | 3                  |
| V-1, VTM-1  | a              | 3                                        | 2                  | 3                  |
| V-0, VTM-0  | a              | 4                                        | 3                  | 3                  |

<sup>a</sup> The electrical Relative Thermal Index (RTI) value of a material is to be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used. The RTI shall not be exceeded during the Temperature Test, Section 23.

<sup>b</sup> The Hot Wire Ignition (HWI) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

<sup>c</sup> A material without an HWI Performance Level Category (PLC) value or with a HWI PLC value greater (worse) than the value required by this table shall be subjected to the end-product Abnormal Overload Test or the Glow-Wire End-Product Test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C or for AC coil constructions to the Burn Out Test in the Outline of Investigation for Solenoids, UL 906.

<sup>d</sup> The High Current Arc Resistance to Ignition (HAI) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e. For constructions where there are no arcing parts or no mechanically secured electrical connections subjected to movement, HAI is not applicable.

<sup>e</sup> A material without an HAI PLC value or with an HAI PLC value greater (worse) than the value required by this table shall be subjected to the End-Product Arc Resistance Test specified in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C.

<sup>f</sup> The Comparative Tracking Index (CTI) PLC value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness. The CTI value applies to insulating materials used in pollution degree 3 environments for voltages of 600 V or less. For equipment where pollution degree 1 or 2 is maintained, an insulating material shall have a CTI PLC of 4 or less. For constructions where creepage distances between uninsulated live parts of opposite polarity or between uninsulated live parts and grounded or dead metal parts are greater than 12.7 mm, CTI is not applicable.

<sup>g</sup> A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 6.2 shall have a proof tracking index of 175 when used in pollution degree 3 environment or a proof tracking index of 100 when used in pollution degree 1 or 2 environment as determined by the end-product Proof Tracking Test specified in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C.

**Table 6.3**  
**Generic materials for direct support of uninsulated live parts**

Table 6.3 effective November 11, 2014

| Generic Material                                                                                                                                                          | Thickness, |        | RTI, °C  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|--------|----------|
|                                                                                                                                                                           | Inch       | (mm)   |          |
| Diallyl Phthalate                                                                                                                                                         | 0.028      | (0.71) | 105      |
| Epoxy                                                                                                                                                                     | 0.028      | (0.71) | 105      |
| Melamine                                                                                                                                                                  | 0.028      | (0.71) | 130      |
| Melamine-Phenolic                                                                                                                                                         | 0.028      | (0.71) | 130      |
| Phenolic                                                                                                                                                                  | 0.028      | (0.71) | 150      |
| Unfilled Nylon                                                                                                                                                            | 0.028      | (0.71) | 105      |
| Unfilled Polycarbonate                                                                                                                                                    | 0.028      | (0.71) | 105      |
| Urea Formaldehyde                                                                                                                                                         | 0.028      | (0.71) | 100      |
| Ceramic, Porcelain, and Slate                                                                                                                                             | No limit   |        | No limit |
| Beryllium Oxide                                                                                                                                                           | No limit   |        | No limit |
| NOTE – Each material shall be used within its minimum thickness and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature Test, Section 23. |            |        |          |

6.5.2 Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as the sole support for uninsulated current-carrying parts of other than low-voltage nonsafety circuits.

6.5.3 A polymeric electrical enclosure or a polymeric part (such as a plug or other closure) that is relied upon to complete and maintain the integrity of an electrical enclosure shall comply with the Flammability – 127 mm (5 Inch) Flame Test, Crushing Resistance Test, Resistance to Impact Test (both normal and cold), and the Mold Stress-Relief Distortion Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and also with the additional requirements specified in this standard. Polymeric parts may be tested separately or may be tested as part of the overall electrical enclosure.

*Exception No. 1: Polymeric enclosures enclosing Class 2 circuits only, need not comply with the flammability – HB flame rating, Crush Resistance Test, Resistance to Impact Test, maximum use temperature properties and the Mold Stress-Relief Distortion Test.*

*Exception No. 2: A polymeric plug or other closure made of a material classed in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and that serves to complete and maintain the integrity of an electrical enclosure is acceptable if the closure is:*

*a) Not more than 1.2 square inches (775 mm<sup>2</sup>) in area and is:*

*1) Rated 5VA, 5VB, V-0, V-1, or V-2; or*

*2) Rated HB and complies with the Flammability – 127 mm (5 Inch) Flame Test requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.*

*b) More than 1.2 square inches (775 mm<sup>2</sup>) in area and is:*

*1) Rated 5VA and complies with the Resistance to Impact Test requirements (both normal and cold) in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; or*

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*2) Rated 5VB, V-0, V-1, V-2 or HB and complies with the Flammability – 127 mm (5 Inch) Flame Test, the Resistance to Impact Test (both normal and cold) and the Crushing Resistance Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.*

6.5.3 effective November 11, 2014

## 6.6 Blending options

6.6.1 Valves intended for use with dispensing equipment that provides for a variable blending option, at gasoline/ethanol blends with nominal ethanol concentrations above 25 percent, shall be subjected to the Blend Cycling Test, Section 36.

6.6.2 Valves intended for use with dispensing equipment that provides for a fixed blending option, as gasoline/ethanol blends with nominal ethanol concentrations above 25 percent, shall be evaluated in accordance with (a) or (b):

a) If intended to be located after the blending option such that the valve is only subjected to the final blended fuel, then the Blending Cycling Test is not required.

b) If intended to be located at or before the blending option such that it is subjected to a different gasoline/ethanol blend levels, the valve shall be subjected to the Blending Cycling Test, Section 36.

6.6.3 Valves intended for use with dispensing equipment that provides for a variable or fixed blending of gasoline/ethanol blends with nominal ethanol concentrations below 25 percent are considered acceptable without further evaluation for the blending option.

## 7 Fluid Connections

7.1 An opening threaded for connection of pipe shall be in accordance with the Standard for Pipe Threads General Purpose (Inch), ANSI/ASME B1.20.1.

7.2 An opening threaded for attachment to pipe shall be constructed so that a pipe threaded two threads beyond standard (for the size in question) may be run into the opening without distorting any part of the fitting.

7.3 A male thread for attachment to pipe fittings shall have no shoulder within the distance specified in Table 7.1, from the beginning of the thread, including any chamfer, nor shall any shoulder prevent an additional turn being made within this distance as determined by assembling the part into a fitting within a tolerance of plus or minus one thread.

**Table 7.1**  
**Shoulder distance from beginning of thread**

| Pipe size, ANSI B36.10 nominal inches | Shoulder distance, |        |
|---------------------------------------|--------------------|--------|
|                                       | inches             | (mm)   |
| 1/8                                   | 3/8                | (9.5)  |
| 1/4, 3/8                              | 9/16               | (14.3) |
| 1/2, 3/4                              | 3/4                | (19.1) |
| 1                                     | 15/16              | (23.8) |
| 1-1/4                                 | 31/32              | (24.6) |
| 1-1/2                                 | 1                  | (25.4) |
| 2                                     | 1-1/32             | (26.2) |
| 2-1/2                                 | 1-33/64            | (38.5) |
| 3                                     | 1-37/64            | (40.1) |

7.4 threaded pipe connection shall be made with litharge and glycerine cement, shellac, shellac and inert powder filler, or a suitable pipe joint sealing compound that is not alcohol based.

7.5 ASTM Schedule 40 metallic pipe shall be used, and the metallic materials shall comply with Materials, Section 6. A union, if used, shall be the ground joint type or a part that has been determined to be equivalent.

*Exception: A fitting need not comply with these requirements if it complies with the requirements specified in Torque Test, Section 26.*

7.6 Tube fittings shall be metallic, and all metallic materials shall comply with Materials, Section 6.

7.7 Tubing shall have a minimum wall thickness in accordance with Table 7.2 in any configuration that is used.

**Table 7.2**  
**Wall thickness for tubing**

| Outside diameter, |         | Minimum wall thickness, |        |
|-------------------|---------|-------------------------|--------|
| inches            | (mm)    | inch                    | (mm)   |
| 1/8               | (3.17)  | 0.028                   | (0.71) |
| 1/4               | (6.35)  | 0.028                   | (0.71) |
| 5/16              | (7.94)  | 0.028                   | (0.71) |
| 3/8               | (9.53)  | 0.028                   | (0.71) |
| 1/2               | (12.70) | 0.0315                  | (0.80) |
| 5/8               | (15.88) | 0.0365                  | (0.93) |
| 3/4               | (19.05) | 0.0385                  | (0.98) |
| 7/8               | (22.23) | 0.049                   | (1.24) |
| 1                 | (25.40) | 0.049                   | (1.24) |
| 1-1/8             | (28.58) | 0.049                   | (1.24) |
| 1-1/4             | (31.75) | 0.0505                  | (1.28) |
| 1-3/8             | (34.93) | 0.0505                  | (1.28) |
| 1-1/2             | (38.10) | 0.065                   | (1.65) |

## 8 Seals and Stuff Boxes

8.1 A manually operated stem shall not back out of the valve nor shall threads of a stem enter a stuffing box recess when the stem is rotated or reciprocated, even though an adjustable packing nut or other takeup is disengaged.

8.2 If packing is used to reduce the risk of leakage around a valve stem, and if it is necessary for the user to adjust or renew the packing during intended usage or as wear occurs, a stuffing box conforming to the following shall be used:

- a) The stuffing box shall be provided with a removable gland or follower, and shall be provided with a packing nut or other means for adjustment.
- b) The stuffing box gland shall be made of corrosion-resistant material.
- c) The stuffing box shall be fully packed prior to shipment of the valve.

8.3 A stuffing box for an automatically operated valve shall be constructed to reduce the risk of binding of the valve stem.

8.4 An adjustable stuffing box used to seal an automatically actuated stem of a safety valve shall be constructed so that any adjustment of the packing takeup will not bind the stem sufficiently to interfere with automatic functioning of the valve. A gland shall be spring-loaded.

8.5 The physical characteristics of a takeup spring shall be such that it will advance the gland through not less than one-half its possible travel from its initial setting with the spring compressed. At the advanced position of the gland, a takeup spring shall not require further adjustment to prevent leakage from the stuffing box when tested in accordance with these requirements.

## 9 Springs

9.1 A spring employed in a dispensing device assembly to reduce the risk of leakage, or in a safety mechanism, such as is employed in an operating handle, shall:

- a) Be protected against abrasion and corrosion; and
- b) Demonstrate no loss in strength following subjection to a compression force of three times that exerted by the spring in any position of its intended function.

9.2 In reference to 9.1(a), springs that are exposed to the fuels anticipated by these requirements shall comply with the applicable material requirements from Section 6. Springs not exposed to fuels, but exposed to the environment, shall comply with the atmospheric corrosion requirements of Section 6.

## 10 Diaphragms

10.1 The assembly of a diaphragm type valve shall be such that positive motion of the valve will follow as a result of diaphragm movement.

10.2 A metal part coming in contact with a diaphragm shall have no sharp edges, burrs, projections, and the like, that may chafe or abrade the diaphragm.

10.3 A valve in which a flexible diaphragm, bellows, or similar construction constitutes the only fluid seal, shall have the atmospheric side of the diaphragm or bellows enclosed in a casing constructed to limit external leakage in the event of a diaphragm or bellows rupture, or shall have provisions for connection of a vent pipe or tubing intended to be routed to the outdoors or other acceptable location.

## 11 Operating Mechanisms

11.1 If threaded fasteners secure moving parts, they shall be upset, locked, or otherwise prevented from loosening when tested in accordance with these requirements.

11.2 Operation of a manually actuated mechanism of a valve shall not subject parts to distortion or damage to the extent that their intended function is impaired.

11.3 Moving parts shall be separated from conductors by barriers or by its physical location so that such an operating part is not obstructed by stowed wiring.

11.4 A valve using an electronic control circuit shall be investigated under conditions of actual service to determine compliance with applicable requirements.

## 12 Current-Carrying Parts

12.1 A current-carrying part shall be silver, copper, copper alloy, or other metal that has been determined to be acceptable for such use.

12.2 An uninsulated live part, including a terminal or contact assembly, shall be secured to its supporting surface by methods other than friction between surfaces so that it will be prevented from turning or shifting in position.

12.3 A lock washer may be used to prevent turning of a terminal or connection stud.

## 13 Enclosures

### 13.1 General

13.1.1 The mechanism of a valve shall be protected by an enclosure to reduce the risk of damage to or interference with operating parts. Electrical parts, other than low-voltage terminals in nonsafety circuits, shall be located or enclosed so that protection against unintentional contact or shorting of live parts will be provided if such contact or shorting may result in a risk of fire, electric shock, or injury to persons.

13.1.2 Low-voltage terminals for a safety-control circuit shall comply with the requirements in 13.1.1 if shorting or grounding of the terminals may result in a risk of fire, electric shock, or injury to persons, or cause improper operation of a safety control.

13.1.3 The enclosure shall provide room for the distribution of wires and cables required for the intended wiring of the valve.

13.1.4 The enclosure and any part of the enclosure such as a cover, or the like, shall be provided with means for securing it in place.

13.1.5 The thickness of a metal enclosure shall not be less than that specified in Tables 13.1, 13.2, and 13.3.

13.1.6 A part such as a dial or nameplate that constitutes part of the enclosure, shall be of metal or other material as specified for the basic enclosure.

13.1.7 Glass covering an observation opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 4 inches (101.6 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick. Glass for a larger opening, but not more than 144 square inches (929 cm<sup>2</sup>) in area and having no dimension greater than 12 inches (304.8 mm), shall not be less than 1/8 inch (3.2 mm) thick.

13.1.8 A nonmetallic enclosure or enclosure part shall comply with Materials, Section 6.

13.1.8 effective November 11, 2014

**Table 13.1**  
**Thickness of sheet metal for enclosures – carbon steel or stainless steel**

| Without supporting frame <sup>a</sup>      |                                             | With supporting frame or equivalent reinforcing <sup>a</sup> |                                             | Minimum thickness           |                             |
|--------------------------------------------|---------------------------------------------|--------------------------------------------------------------|---------------------------------------------|-----------------------------|-----------------------------|
| Maximum width, <sup>b</sup><br>inches (cm) | Maximum length, <sup>c</sup><br>inches (cm) | Maximum width, <sup>b</sup><br>inches (cm)                   | Maximum length, <sup>c</sup><br>inches (cm) | Uncoated,<br>inch (mm)      | Metal coated,<br>inch (mm)  |
| 4.0 (10.2)                                 | Not limited                                 | 6.25 (15.9)                                                  | Not limited                                 | 0.020 <sup>d,e</sup> (0.51) | 0.023 <sup>d,e</sup> (0.58) |
| 4.75 (12.1)                                | 5.75 (14.6)                                 | 6.75 (17.1)                                                  | 8.25 (21.0)                                 |                             |                             |
| 6.0 (15.2)                                 | Not limited                                 | 9.5 (24.1)                                                   | Not limited                                 | 0.026 <sup>d,e</sup> (0.66) | 0.029 <sup>d,e</sup> (0.74) |
| 7.0 (17.8)                                 | 8.75 (22.2)                                 | 10.0 (25.4)                                                  | 12.5 (31.8)                                 |                             |                             |
| 8.0 (20.4)                                 | Not limited                                 | 12.0 (30.5)                                                  | Not limited                                 | 0.032 (0.81)                | 0.034 (0.86)                |
| 9.0 (22.9)                                 | 11.5 (29.2)                                 | 13.0 (33.0)                                                  | 16.0 (40.6)                                 |                             |                             |
| 12.5 (31.8)                                | Not limited                                 | 19.5 (49.5)                                                  | Not limited                                 | 0.042 (1.07)                | 0.045 (1.14)                |
| 14.0 (35.6)                                | 18.0 (45.7)                                 | 21.0 (53.3)                                                  | 25.0 (63.5)                                 |                             |                             |

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Table 13.1 Continued

| Without supporting frame <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                             | With supporting frame or equivalent reinforcing <sup>a</sup> |                                             | Minimum thickness      |                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------------|---------------------------------------------|------------------------|----------------------------|
| Maximum width, <sup>b</sup><br>inches (cm)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Maximum length, <sup>c</sup><br>inches (cm) | Maximum width, <sup>b</sup><br>inches (cm)                   | Maximum length, <sup>c</sup><br>inches (cm) | Uncoated,<br>inch (mm) | Metal coated,<br>inch (mm) |
| <sup>a</sup> A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which is capable of being applied via the enclosure surface when it is deflected. Construction that is determined to have equivalent reinforcing is allowed to be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Constructions determined to be without supporting frame include: <ol style="list-style-type: none"> <li>1) Single sheet with single formed flanges (formed edges),</li> <li>2) A single sheet which is corrugated or ribbed, and</li> <li>3) An enclosure surface loosely attached to a frame, for example, with spring clips.</li> </ol> <sup>b</sup> The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure are allowed to have supports in common and be made of a single sheet. <sup>c</sup> For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide. <sup>d</sup> Sheet metal for an enclosure intended for outdoor use shall comply with 13.3.1 – 13.3.5. <sup>e</sup> At points where a wiring system is to be connected, the thickness shall not be less than 0.032 inch (0.81 mm) if uncoated and not less than 0.034 inch (0.86 mm) if zinc coated. |                                             |                                                              |                                             |                        |                            |

13.1.9 If threads for the connection of a conduit are not tapped all the way through a hole in an enclosure wall, or if a construction that has been investigated and determined to be equivalent is used, there shall not be less than three threads in the metal and the construction of the control shall be such that a conduit bushing can be attached as intended.

13.1.9 effective November 11, 2014

**Table 13.2**  
**Minimum thickness of sheet metal for enclosures aluminum, copper, or brass**

| Without supporting frame <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                             | With supporting frame or equivalent reinforcing <sup>a</sup> |                                             | Minimum thickness,   |        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------------|---------------------------------------------|----------------------|--------|
| Maximum width, <sup>b</sup><br>inches (cm)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Maximum length, <sup>c</sup><br>inches (cm) | Maximum width, <sup>b</sup><br>inches (cm)                   | Maximum length, <sup>c</sup><br>inches (cm) | inch                 | (mm)   |
| 3.0 (7.6)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Not limited                                 | 7.0 (17.8)                                                   | Not limited                                 | 0.023 <sup>d,e</sup> | (0.58) |
| 3.5 (8.9)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4.0 (10.2)                                  | 8.5 (21.7)                                                   | 9.5 (24.1)                                  |                      |        |
| 4.0 (10.2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Not limited                                 | 10.0 (25.4)                                                  | Not limited                                 | 0.029 <sup>e</sup>   | (0.74) |
| 5.0 (12.7)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 6.0 (15.2)                                  | 10.5 (26.7)                                                  | 13.5 (34.2)                                 |                      |        |
| 6.0 (15.2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Not limited                                 | 14.0 (35.6)                                                  | Not limited                                 | 0.036 <sup>e</sup>   | (0.91) |
| 6.5 (16.5)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 8.0 (20.3)                                  | 15.0 (38.1)                                                  | 18.0 (45.7)                                 |                      |        |
| 8.0 (20.3)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Not limited                                 | 19.0 (48.3)                                                  | Not limited                                 | 0.045                | (1.14) |
| 9.5 (24.1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 11.5 (29.2)                                 | 21.0 (53.3)                                                  | 25.0 (63.5)                                 |                      |        |
| 12.0 (30.5)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Not limited                                 | 28.0 (71.1)                                                  | Not limited                                 | 0.058                | (1.47) |
| 14.0 (35.6)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 16.0 (40.6)                                 | 30.0 (76.2)                                                  | 37.0 (94.0)                                 |                      |        |
| <sup>a</sup> A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which are capable of being applied via the enclosure surface when it is deflected. Construction that is determined to have equivalent reinforcing is allowed to be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Constructions considered to be without supporting frame include: |                                             |                                                              |                                             |                      |        |

Table 13.2 Continued

| Without supporting frame <sup>a</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                             | With supporting frame or equivalent reinforcing <sup>a</sup> |                                | Minimum thickness,<br><br>inch (mm) |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------------|--------------------------------|-------------------------------------|
| Maximum width, <sup>b</sup><br>inches (cm)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Maximum length, <sup>c</sup><br>inches (cm) | Maximum width, <sup>b</sup><br>inches (cm)                   | Maximum length,<br>inches (cm) |                                     |
| 1) Single sheet with single formed flanges (formed edges),<br>2) A single sheet which is corrugated or ribbed, and<br>3) An enclosure surface loosely attached to a frame (for example, with spring clips).<br><br><sup>b</sup> The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.<br><br><sup>c</sup> For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.<br><br><sup>d</sup> Sheet copper, brass, or aluminum for an enclosure intended for outdoor use (rainproof or raintight) shall not be less than 0.029 inch (0.74 mm) thick.<br><br><sup>e</sup> At points where a wiring system is to be connected, the thickness shall not be less than 0.045 inch (1.14 mm). |                                             |                                                              |                                |                                     |

Table 13.3

**Cast-metal enclosures of malleable iron and die-cast or permanent mold cast aluminum, brass, bronze, or zinc**

| Use or dimensions of area involved                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Minimum thickness |       |                                             |       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------|---------------------------------------------|-------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Die-cast metal,   |       | Cast metal of other than the die-cast type, |       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | inch              | (mm)  | inch                                        | (mm)  |
| Area of 24 square inches (155 cm <sup>2</sup> ) or less and having no dimension greater than 6 inches (152 mm) <sup>a,b,c</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1/16              | (1.6) | 1/8                                         | (3.2) |
| Area greater than 24 square inches or having any dimension greater than 6 inches                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 3/32              | (2.4) | 1/8                                         | (3.2) |
| At a conduit hole                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1/4               | (6.4) | 1/4                                         | (6.4) |
| <sup>a</sup> The area limitation for metal 1/16 inch thick may be obtained by the provision of reinforcing ribs subdividing a larger area.<br><sup>b</sup> Die-cast metal may be minimum 0.035 inch (0.89 mm) thick if:<br>1) The enclosure is not intended to be used as a splice box and<br>2) The voltage rating of the complete device is such that the potential between any two conductors does not exceed 250 volts AC or DC.<br><sup>c</sup> Die-cast metal may be minimum 0.028 inch (0.71 mm) thick for an enclosure housing only low-voltage circuits. |                   |       |                                             |       |

13.1.10 If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors that affords protection to the conductors equivalent to that provided by a standard conduit bushing and that has an internal diameter as indicated in Table 13.4.