



UL 1561

STANDARD FOR SAFETY

Dry-Type General Purpose and Power Transformers

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UL Standard for Safety for Dry-Type General Purpose and Power Transformers, UL 1561

Fourth Edition, Dated March 2, 2011

Summary of Topics

This revision of ANSI/UL 1561 dated August 31, 2023 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated June 16, 2023.

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MARCH 2, 2011
(Title Page Reprinted: August 31, 2023)



ANSI/UL 1561-2019 (R2023)

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UL 1561

Standard for Dry-Type General Purpose and Power Transformers

Prior to the first edition, the requirements for the products covered by this standard were included in a supplement to the Standard for Specialty Transformers, UL 506.

Prior to March 27, 1987, the first edition was titled the Standard for Large General Purpose Transformers.

First Edition – January, 1986

Second Edition – April, 1994

Third Edition – March, 1999

Fourth Edition

March 2, 2011

This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through August 31, 2023.

The most recent designation of ANSI/UL 1561 as a Reaffirmed American National Standard (ANS) occurred on August 31, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover:

- a) General purpose and power transformers of the air-cooled, dry, ventilated, and nonventilated types to be used in accordance with the National Electrical Code, ANSI/NFPA 70. Constructions include step up, step down, insulating, and autotransformer type transformers as well as air-cooled and dry-type reactors or
- b) General purpose and power transformers of the exposed core, air-cooled, dry, and compound-filled types rated more than 10 kVA to be used in accordance with the National Electrical Code, ANSI/NFPA 70. Constructions include step up, step down, insulating, and autotransformer type transformers as well as air-cooled, dry, and compound-filled type reactors.

1.2 These requirements do not cover ballasts for high intensity discharge (HID) lamps (metal halide, mercury vapor, and sodium types) or fluorescent lamps, exposed core transformers, compound-filled transformers, liquid-filled transformers, voltage regulators, general use or special types of transformers covered in requirements for other electrical equipment, autotransformers forming part of industrial control equipment, motor-starting autotransformers, variable voltage autotransformers, transformers having a nominal primary or secondary rating of more than 600 volts, or overvoltage taps rated greater than 660 volts.

1.3 These requirements do not cover transformers provided with waveshaping or rectifying circuitry. Waveshaping or rectifying circuits may include components such as diodes and transistors. Components such as capacitors, transient voltage surge suppressors, and surge arresters are not considered to be waveshaping or rectifying devices.

2 Components

2.1 Except as indicated in [2.2](#), a component of a product covered by this standard shall comply with the requirements for that component. See Appendix [A](#) for a list of standards covering components used in the products covered by this standard.

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

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

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

2.4 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.

3 Units of Measurement

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

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

4 Undated References

4.1 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.

5 Glossary

5.1 For the purpose of this standard the following definitions apply.

5.2 COMPOUND-FILLED TRANSFORMER – A transformer in which the windings are enclosed with an insulating fluid which becomes solid, or remains plastic, at intended operating temperatures.

5.3 ENCAPSULATED COIL – A coil that

- a) Is enclosed with an insulating fluid that becomes solid and
- b) Can be used in either a ventilated or nonventilated transformer.

5.4 EXPOSED CORE TRANSFORMER – A transformer with exposed core laminations.

5.5 K-FACTOR – A rating optionally applied to a transformer indicating its suitability for use with loads that draw nonsinusoidal currents. The K-factor equals:

$$\sum_{h=1}^{\infty} I_h (pu)^2 h^2$$

in which:

$I_h(pu)$ is the rms current at harmonic "h" (per unit of rated rms load current) and

h is the harmonic order.

K-factor rated transformers have not been evaluated for use with harmonic loads where the rms current of any singular harmonic greater than the tenth harmonic is greater than 1/h of the fundamental rms current.

5.6 NONVENTILATED DRY-TYPE TRANSFORMER – A dry-type transformer other than of the compound-filled or exposed core type that is constructed so as to provide no intentional circulation of ambient air through the transformer and is intended to operate at normal ambient air pressure.

5.7 VENTILATED DRY-TYPE TRANSFORMER – A dry-type transformer that is constructed so that ambient air may circulate through the enclosure to cool the transformer core and windings.

CONSTRUCTION

6 Mechanical Assembly

6.1 A transformer shall be complete when it is shipped from the factory.

Exception No. 1: A transformer that is complete for indoor use may have provision for a field-added rainproof hood if the transformer is marked in accordance with [38.9.2](#) and [38.9.3](#).

Exception No. 2: A transformer that is complete for intended use may have provision for a field-added extension to the enclosure to provide for additional wiring space.

Exception No. 3: Wire connectors may be field supplied.

6.2 A transformer that weighs more than 100 pounds (45 kg) shall be provided with a means for lifting by a fork lift, a cable, a sling, or the equivalent. The lifting means may be provided on the transformer core or frame or the equivalent if the transformer has a removable top cover. The lifting means shall be subjected to the Lifting or Mounting Means Test, Section [27](#).

Exception: The lifting means test does not apply to a transformer that is intended to be lifted from underneath by a fork lift or other means.

6.3 A transformer shall be marked in accordance with [38.11.1](#). The weight of the transformer shall not exceed 110 percent of the weight marked on the transformer.

6.4 A solid rivet, screw, bolt, or similar fastener in a sheet metal enclosure shall have a diameter at least 50 percent greater than the sum total thickness of all the sheet metal items secured by the fastener. Screws securing covers shall comply with [7.5.2](#). Screws threaded directly into a metal component of the enclosure shall meet or exceed the torque requirements in [6.5\(b\)](#).

Exception No. 1: A fastening device as described in [6.5](#) may be used.

Exception No. 2: A machine screw fully engaging two complete threads need not be tested.

6.5 With respect to [6.4](#), a different type of fastening device may be used if employed with a conventional screw. Other types of fastening devices may be used if investigated for the particular application. A single-threaded nut intended to slip over the edge of sheet metal to receive a retaining screw may be used to secure a cover to an enclosure if:

- a) The nut is protected against corrosion by painting, galvanizing, sherardizing, plating, or other equivalent means and
- b) The threads do not strip when a torque of 30 pound-force-inches (3.4 N·m) is applied.

7 Enclosure

7.1 General

7.1.1 A transformer shall have an enclosure of moisture-resistant material. An iron or steel enclosure shall be protected against corrosion as described in [7.8.1](#) – [7.8.3](#). The enclosure shall house all uninsulated live parts.

Exception: A bottom for the enclosure need not be provided for a transformer intended to be pad mounted if the walls will be flush or within 3/8 inch (9.5 mm) of the pad and if the transformer is marked in accordance with [38.10.3](#).

7.1.2 If a transformer is intended to be mounted on a concrete pad, aluminum parts of an enclosure shall be located at least 1/4 inch (6.4 mm) above the mounting pad.

Exception: Aluminum parts of an enclosure coated with a metallic or nonmetallic coating may be in contact with a concrete pad if the coating is protected against corrosion by one of the means described in [8.9](#) (a), (b), (c), (d), or (e).

7.1.3 An edge, projection, or corner of an enclosure, opening, frame, guard, knob, handle, or the like of a transformer shall be smooth and not sufficiently sharp to cause a cut-type injury when contacted during intended use or maintenance.

7.2 Sheet metal

7.2.1 The thickness of a sheet metal enclosure shall comply with:

- a) [Table 7.1](#) for an enclosure without a supporting frame,
- b) [7.2.2](#) and [Table 7.1](#) for an enclosure with a supporting frame, or
- c) [28.2.1](#) for an enclosure with equivalent reinforcement.

7.2.2 With reference to [Table 7.1](#), a supporting frame is a structure of angle or channel or folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments that may be applied by the enclosure surface when it is deflected. Constructions considered to be without supporting frame include:

- a) A single sheet with single formed flanges (formed edges);
- b) A single sheet that is corrugated or ribbed;
- c) An enclosure surface loosely attached to a frame, for example, with spring clips; and
- d) An enclosure surface having an unsupported edge.

7.2.3 The upper edge of a vertical sheet of an enclosure that is under the overhang of the hood and not secured to the hood shall comply with the deflection test in [28.1.1](#) and [28.1.2](#).

Table 7.1
Minimum thickness of sheet metal for enclosures

Maximum dimensions of enclosure				Minimum average thickness of sheet metal							
				Steel ^a				Copper, brass, or aluminum			
Length or width, inches (cm)		Area, inches ² (cm ²)		Without supporting frame, inch (mm)		With supporting ^b frame or equivalent reinforcement ^c , inch (mm)		Without supporting frame, inch (mm)		With supporting frame ^b or equivalent reinforcement ^c , inch (mm)	
3	(7.6)	6	(38.7)	0.020	(0.51)	0.020	(0.51)	0.023	(0.58)	0.023	(0.58)
8	(20.3)	30	(194)	0.026	(0.66)	0.020	(0.51)	0.036	(0.91)	0.029	(0.74)
12	(30.5)	90	(581)	0.032	(0.81)	0.020	(0.51)	0.045	(1.14)	0.045	(0.74)
18	(45.7)	135	(871)	0.042	(1.07)	0.032	(0.81)	0.058	(1.47)	0.058	(1.14)
24	(61)	360	(2323)	0.053	(1.35)	0.042	(1.07)	0.075	(1.91)	0.075	(1.47)
46	(122)	1200	(7742)	0.067	(1.70)	0.053	(1.35)	0.095	(2.41)	0.075	(1.91)
60	(152)	1500	(9677)	0.093	(2.36)	0.053	(1.35)	0.122	(3.10)	0.075	(1.91)
Over 60	(Over 152)	Over 1500	(Over 9677)	0.123	(3.12)	0.053	(1.35)	0.153	(3.89)	0.075	(1.91)

^a Other metals may be used if they are tested in accordance with [28.2.1](#).

^b A supporting frame is described in [7.2.2](#).

^c As referenced in [7.2.1](#), thinner metals may be used if they are tested in accordance with [28.2.1](#).

7.3 Nonmetallic enclosures

7.3.1 Among the factors that shall be taken into consideration when judging the acceptability of a nonmetallic material are resistance to:

- a) Mechanical damage,
- b) Impact,
- c) Moisture absorption,
- d) Combustion, and
- e) Distortion at temperatures to which the material may be subjected under conditions of use.

Additional considerations are specified in [8.5](#).

7.3.2 A polymeric material shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.4 Mounting

7.4.1 A transformer shall be provided with means of mounting or securing it to a surface.

7.4.2 For a transformer intended to be wall mounted, the construction shall be such that, if the enclosure is mounted on a plane surface, it will make contact at points of support only and shall maintain a clearance of not less than 1/4 inch (6.4 mm) at other points.

7.4.3 A means of securing a transformer to a wall shall be subjected to the Lifting or Mounting Means Test, Section [27](#).

7.5 Covers

7.5.1 A cover shall have means for securing it to the enclosure. A flat unflanged cover shall be secured within 6 inches (152 mm) of each corner.

7.5.2 Fastening screws shall be not less than 5/32 inch (4.0 mm) in major diameter for a cover 360 square inches (2323 cm²) or less in area, and not less than 3/16 inch (4.8 mm) in major diameter for a larger cover.

7.5.3 A cover intended to be removed for inspection purposes that exceeds either 12 square feet (1.1 m²) in area or 60 pounds (27.2 kg) in weight shall be equipped with a lifting means or with hinges.

7.5.4 A removable cover shall be constructed such that it will not fall onto or damage any live part inside the enclosure when all of the fastenings and supports of the cover are removed.

7.6 Ventilation

7.6.1 Any opening in an enclosure shall have such size or shape that a test rod having the diameter specified in [7.6.2](#) will be prevented from entering.

Exception: An opening is investigated and found acceptable if, by means of its size, location, baffling, or the like, it will prevent a straight rod 33/64 inch (13.1 mm) in diameter from passing within 4 inches (102 mm) of any uninsulated live part inside the enclosure.

7.6.2 The test rod specified in [7.6.1](#) shall be 33/64 inch (13.1 mm) in diameter if the plane of the opening is less than 4 inches (102 mm) from an uninsulated live part or 49/64 inch (19.4 mm) in diameter if the plane of the opening is 4 inches or more from such a part.

7.6.3 The wires of a screen of a ventilating opening shall have a minimum diameter of:

- a) 0.054 inch (1.37 mm) for a screen opening 1/2 square inch (3.2 cm²) or less in area or
- b) 0.080 inch (2.03 mm) for a screen opening larger than 1/2 square inch in area.

7.6.4 The minimum thickness of perforated sheet steel or sheet steel used for expanded metal mesh shall be in accordance with [Table 7.2](#).

Exception: The thickness of expanded metal mesh may be less than as specified in [Table 7.2](#) if the enclosure complies with [28.2.1](#).

Table 7.2
Minimum thickness of perforated sheet steel or sheet steel used for expanded metal mesh

Area of perforation or mesh openings, inch ² (cm ²)		Minimum thickness of metal	
		Uncoated, inch (mm)	Zinc coated, inch (mm)
1/2 or less (3.2 or less)		0.042 (1.07)	0.045 (1.14)
More than 1/2 (More than 3.2)		0.080 (2.03)	0.084 (2.13)

7.6.5 The total area of enclosure material removed from a top or vertical wall for providing an opening or for the insertion of a panel or screen, together with the total area of openings as a result of forming the parent material, shall not exceed 25 percent of the area of the entire surface of any wall in which such openings are located.

Exception: The total area of enclosure material removed from a wall may exceed 25 percent of the area of the entire wall surface if the enclosure complies with [28.2.1](#).

7.6.6 The area of any opening in a top or vertical wall, as defined by the opening in the parent metal, shall not exceed 200 square inches (1.29 m²) if the closing panel is formed from material having a thickness less than that of the parent metal. A closing panel of maximum 0.053 inch (1.35 mm) thick sheet steel or 0.064 inch (1.63 mm) diameter or thinner screen wire shall not be used to close an opening of more than 80 square inches (516 cm²).

7.6.7 A ventilated closing panel of less than 0.06 inch (1.52 mm) thick uncoated steel; 0.063 inch (1.60 mm) thick zinc-coated steel; 0.075 inch (1.91 mm) thick aluminum, copper, or brass; or steel wire mesh less than 0.063 inch (1.6 mm) in diameter shall not be used to close an opening larger than 80 square inches (516 cm²).

7.7 Specific environmental conditions

7.7.1 An enclosure intended for a specific environmental condition and found acceptable by investigation for such use, as specified in [Table 7.3](#), shall be marked in accordance with [38.9.1](#). An enclosure that complies with the requirements for more than one type of enclosure may be marked accordingly with multiple type designations.

7.7.2 An enclosure shall be subjected to the tests specified in [Table 7.3](#), and shall comply with the construction requirements applicable to an enclosure of the type number or numbers with which it is marked.

7.7.3 A watertight connection at a conduit entrance shall be a conduit hub or the equivalent (such as a knockout or fitting) located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure is found to be acceptable by investigation, as specified in [Table 7.3](#).

Table 7.3
Enclosure types

Number	Environmental condition	Required tests	Openings
1	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt .	Rust Resistance Test ^a , Section 33	Rod Entry, 7.6.1
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt .	Drip Test, Section 31 ; Rust Resistance Test ^a , Section 33	Rod Entry, 7.6.1
3R	Outdoor use to provide a degree of protection against rain; undamaged by the formation of ice on the enclosure.	Water Spray Test, Section 30 ; Icing Test ^b , Section 32 ; and Metallic Coating Thickness Test ^c , Section 35	Rod Entry, 7.6.1
3RX	Outdoor use to provide a degree of protection against rain or corrosion; undamaged by the formation of ice on the enclosure.	Water Spray Test, Section 30 ; Icing Test ^b , Section 32 ; Metallic Coating Thickness Test ^c , Section 35 ; and Corrosion Resistance Test, Section 34	Rod Entry, 7.6.1
^a The rust resistance test is not required if the enclosure is constructed as specified in 7.8.2 or Corrosion Resistance, Section 8 . ^b The transformer need not be subjected to the icing test if the enclosure has no external cavities that can trap water. ^c The metallic coating thickness test is not required if the enclosure is constructed as specified in 8.1 – 8.8 ; 8.9 (a) or (c); 8.10 (a), (c), or (d); and 8.11 – 8.14 .			

7.7.4 An enclosure marked "Type 2" shall have provision for drainage. Provision for the entrance of conduit at the top or side walls shall be a conduit hub or the equivalent.

7.7.5 An enclosure marked "Type 3R or "Type 3RX" shall have:

- a) A conduit hub or the equivalent for a watertight connection when the conduit entrances are at a level higher than the lowest insulated live part in compliance with [7.7.3](#);
- b) Provision for drainage; and
- c) Provision for locking the door, if a door is provided.

7.7.6 An enclosure of a transformer that complies with the requirements for a rainproof Type 3R or Type 3RX enclosure, if used with a field-added rainproof hood, may be shipped without the hood if the transformer and hood are marked as described in [38.9.2](#) and [38.9.3](#).

7.7.7 In an enclosure marked "Type 3R or "Type 3RX and intended for mounting on a horizontal supporting surface, any live part (including a winding) shall be located at least 4 inches (102 mm) above that surface.

7.8 Corrosion protection

7.8.1 An enclosure marked "Type 3R" or Type 3RX" (as described in [7.7.1](#) and [38.9.1](#)) and fabricated of iron or sheet steel shall be protected against corrosion as specified in Corrosion Resistance, Section [8](#).

7.8.2 For other than a rainproof type, an enclosure of iron or steel shall be protected against corrosion by galvanizing, plating, painting, or the equivalent.

Exception: An interior surface that is covered by a compound need not be additionally protected against corrosion.

7.8.3 Iron or steel parts other than the enclosure shall be plated, painted, or otherwise protected against corrosion.

8 Corrosion Resistance

8.1 Metal shall be used in combinations that are galvanically compatible.

8.2 Hinges and other attachments shall be resistant to corrosion.

8.3 The requirements in [8.5](#) – [8.14](#) do not contemplate corrosion that might be caused by exposure to the earth or to other corrosive agents.

8.4 The requirements in [8.5](#) – [8.14](#) do not apply to a part that is not required to form a part of the enclosure.

8.5 A nonmetallic enclosure shall be judged on the basis of the effect of exposure to ultraviolet light and water. Additional considerations are specified in [7.3.1](#).

8.6 A metallic enclosure shall be protected against corrosion as specified in [8.7](#) – [8.14](#).

8.7 Copper, bronze, brass containing not less than 80 percent copper, or stainless steel may be used without additional protection against corrosion. Sheet, extruded, or cast aluminum; die-cast zinc; and other metals shall be of a grade or alloy known to be resistant to atmospheric corrosion, shall be subjected to appropriate tests, or shall be additionally protected against corrosion.

8.8 An enclosure of cast iron or malleable iron shall be at least 1/8 inch (3.2 mm) thick and shall be protected against corrosion by:

- a) A 0.00015-inch (0.0038-mm) thick coating of zinc, cadmium, or the equivalent on the outside surface, and a visible coating of such metal on the inside surface or
- b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface.

8.9 An enclosure of sheet steel less than 0.126 inch (3.20 mm) thick if zinc coated or 0.123 inch (3.12 mm) thick if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in [8.12](#).

- a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G90 in Table I of the Standard Specifications for Sheet Steel, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirements in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of

question, the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90-A90M.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.015 mm) on each surface with a minimum thickness of 0.00054 inch (0.014 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section [35](#). An annealed coating shall also comply with [8.14](#).

c) A zinc coating conforming with [8.10](#) (a) or (b) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface applied after forming.

d) A cadmium coating not less than 0.001 inch (0.025 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the Metallic Coating Thickness Test, Section [35](#).

e) A cadmium coating not less than 0.00075 inch (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the Metallic Coating Thickness Test, Section [35](#), and the paint shall be as specified in (c).

8.10 An enclosure of sheet steel 0.126 inch (3.20 mm) thick or thicker if zinc-coated or 0.123 inch (3.12 mm) thick or thicker if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in [8.12](#).

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Table I of the Standard Specifications for Sheet Steel, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90-A90M.

b) A zinc coating, other than that at provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.010 mm) on each surface with a minimum thickness of 0.00034 inch (0.009 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section [35](#).

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface.

d) Any one of the means specified in [8.9](#).

8.11 The requirements in [8.10](#) also apply to an enclosure of zinc-coated sheet steel 0.056 inch (1.42 mm) thick or thicker and an enclosure of uncoated sheet steel 0.053 inch (1.35 mm) thick or thicker if the enclosure is intended to be mounted within and protected from direct exposure to weather by the enclosure of other equipment, such as an air conditioner. Such an enclosure shall not be marked rainproof.

8.12 With reference to [8.9](#) – [8.11](#), other finishes (including paints, metallic finishes, and combinations of the two) may be used if comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – conforming with [8.9](#)(a) or [8.10](#)(a), as applicable, indicate that they provide equivalent protection. Among the factors that are to be taken into consideration when judging the suitability of such

coating systems are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water.

8.13 If tests are required, test specimens of a finish as described in [8.8](#), [8.9\(c\)](#), [8.10\(c\)](#), and [8.12](#) are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, or the like.

8.14 A hot-dipped, mill-galvanized A60 (alloyed) coating or an annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process has damaged the zinc coating. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

Exception: If the damaged zinc coating on the bent or formed area is on the inside surface of the enclosure and is not exposed to water during the water spray test, that area need not be painted.

9 Supply and Load Connections

9.1 The enclosure shall provide for connection of the supply and load wiring. An enclosure intended to be penetrated as a field modification to provide for the passage of wiring shall be marked as specified in [38.9.4](#) and [38.12.6](#).

9.2 If threads for the connection of conduit are tapped completely through a hole in an enclosure, or if an equivalent construction is used, there shall be no less than three full threads in the metal and the construction shall be such that a conduit bushing can be attached.

9.3 If the threads for connection of conduit are not tapped all the way through a hole in an enclosure, there shall be no less than five full threads in the metal and there shall be a smooth rounded hole for the conductors.

9.4 With respect to the requirements in [9.3](#), if the enclosure is intended for outdoor use, the threaded hole shall be provided with a conduit end stop.

Exception: The end stop may be omitted if the threads are tapered.

9.5 A knockout shall completely close the opening in which it is located.

Exception: There may be a displacement clearance between the knockout and the edge of the opening of no more than 0.010 inch (0.25 mm).

9.6 The diameter of a knockout to accommodate conduit of the size for which the knockout is intended and the width of the flat surrounding surface shall be as specified in [Table 16.3](#).

9.7 A knockout in a sheet metal enclosure shall be rigidly secured but shall be capable of being removed without resulting in deformation of the enclosure.

10 Field Wiring Connections

10.1 General

10.1.1 A transformer shall be provided with pressure terminal connectors or terminal pads to which pressure terminal connectors may be secured for connection of supply and load conductors. The pressure terminal connectors may be either factory installed or field installed.

Exception No. 1: Wire-binding screws or studs may be used for field connections if the full load current of the terminal is 24 amperes or less and the transformer is marked for use with copper field wiring in compliance with [38.12.7](#).

Exception No. 2: A copper, brass, or bronze stud may be used for securing a field-installed pressure wire connector.

Exception No. 3: Leads may be used in accordance with [10.2.1](#).

Exception No. 4: A transformer having an opening in the enclosure adjacent to the ends of main busbars is considered to be specifically intended for the connection of a busway when the transformer is marked in accordance with [38.12.9](#).

10.1.2 Access to field wiring connections shall not necessitate moving any other wiring.

10.2 Leads

10.2.1 A transformer lead or parallel leads for connection to field wiring shall:

- a) Be of stranded copper or aluminum wire at least 6 inches (152 mm) long.
- b) Be no smaller than 14 AWG (2.1 mm²) copper or 12 AWG (3.3 mm²) aluminum.
- c) Have insulation rated for at least the voltage involved including the elevated voltage if marked as specified in [38.7.3](#).
- d) Have insulation with a minimum temperature rating of:
 - 1) 90°C (194°F), but sized for 75°C (167°F) ampacity if the transformer is marked for 90°C field wiring, as covered in [38.12.3](#) or
 - 2) 75°C in all other cases.

Exception: For factory-installed internal wiring, greater ampacities may be used on the basis of a temperature test.

- e) Comply with [13.1](#).

10.3 Pressure terminal connectors

10.3.1 If pressure terminal connectors for field wiring are factory installed, they shall be able to accommodate conductors sized for at least 125 percent of the current based on the transformer full load rating and [Table 23.2](#).

10.3.2 If a pressure terminal connector for field wiring of the neutral conductor on a transformer marked with a K-factor rating in accordance with [38.2.1](#) is factory-installed, the connector shall accommodate a

conductor sized for at least 200 percent of the line current based on the transformer full load rating and [Table 23.2](#).

10.3.3 A factory-installed pressure terminal connector shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B.

10.3.4 Terminal pads provided for securing field-installed pressure terminal connectors shall be located so that, after such connectors are installed, spacings comply with the requirements in Electrical Spacings, Section [16](#).

10.3.5 The installation of a field-installed pressure terminal connector shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means of securing the pressure terminal connector shall be readily accessible (for tightening) before and after installation of conductors.

10.3.6 If a pressure terminal connector is provided and requires the use of a special tool for securing the conductor, any necessary instructions shall be included with the transformer.

10.3.7 A wire-binding screw or stud shall be not smaller than 10 (4.8 mm major diameter) with no more than 32 threads per inch. The terminal shall be provided with upturned lugs, a cupped washer, or the equivalent, capable of retaining a 14 AWG (3.3 mm²) solid conductor even though the screw or nut becomes slightly loose.

Exception: A cupped washer or the equivalent is not required for conductors larger than 10 AWG (5.3 mm²).

10.3.8 A wire-binding screw terminal construction is one in which the conductor is intended to encircle the terminal screw at least 3/4 of one full turn around the screw without overlapping.

10.3.9 A No. 10 (4.8 mm major diameter) or larger wire-binding screw may be of iron or steel if plated. Copper and brass shall not be used for plating of a steel wire-binding screw, but a plating of tin, nickel, zinc, or cadmium may be used.

10.3.10 A wire-binding screw shall thread into metal.

10.3.11 A terminal plate tapped for a wire-binding screw shall be of nonferrous metal not less than 0.030 inch (0.76 mm) thick. There shall be two or more full threads in the metal, which may be extruded if necessary to provide the threads.

11 Current-Carrying Parts

11.1 An uninsulated live part shall be secured so that it will be prevented from turning or shifting in position if such motion can result in the reduction of spacings below minimum required values.

11.2 Friction between surfaces shall not be used as means to prevent shifting or turning of a live part.

11.3 Iron or steel shall not be used for a part that is depended upon to carry current. A wire-binding screw is not considered to be a current carrying part.

11.4 A current carrying part shall be of silver, copper, aluminum, alloys of these metals, or the equivalent.

11.5 Aluminum current carrying parts shall be plated at each bolted joint (including tap terminals) with tin, silver, nickel, or cadmium.

Exception No. 1: Plating is not necessary when internal connections are welded to an aluminum pad to which pressure terminal connectors are bolted in the factory if a corrosion-inhibiting compound is provided at each bolted joint.

Exception No. 2: Plating is not necessary when internal connections are welded to an aluminum pad to which pressure terminal connectors are to be bolted in the field if instructions as specified in [38.12.10](#) are provided indicating that a corrosion-inhibiting compound is to be used when pressure terminal connectors are installed.

11.6 A spring washer of a type intended for use with an aluminum bus shall be used at one end of a bolt that secures current carrying parts together if an aluminum part is included in the joint.

Exception No. 1: A spring washer may be replaced with a split-ring lock washer and flat washer if each aluminum bus in the joint has a tensile yield strength of at least 20,000 pounds per square inch (137,895 kPa).

Exception No. 2: A flat washer, a split-ring lock washer, or a bolt head that complies with [11.8\(b\)](#) may be used in place of a spring washer if aluminum bolts are used with aluminum bus bars.

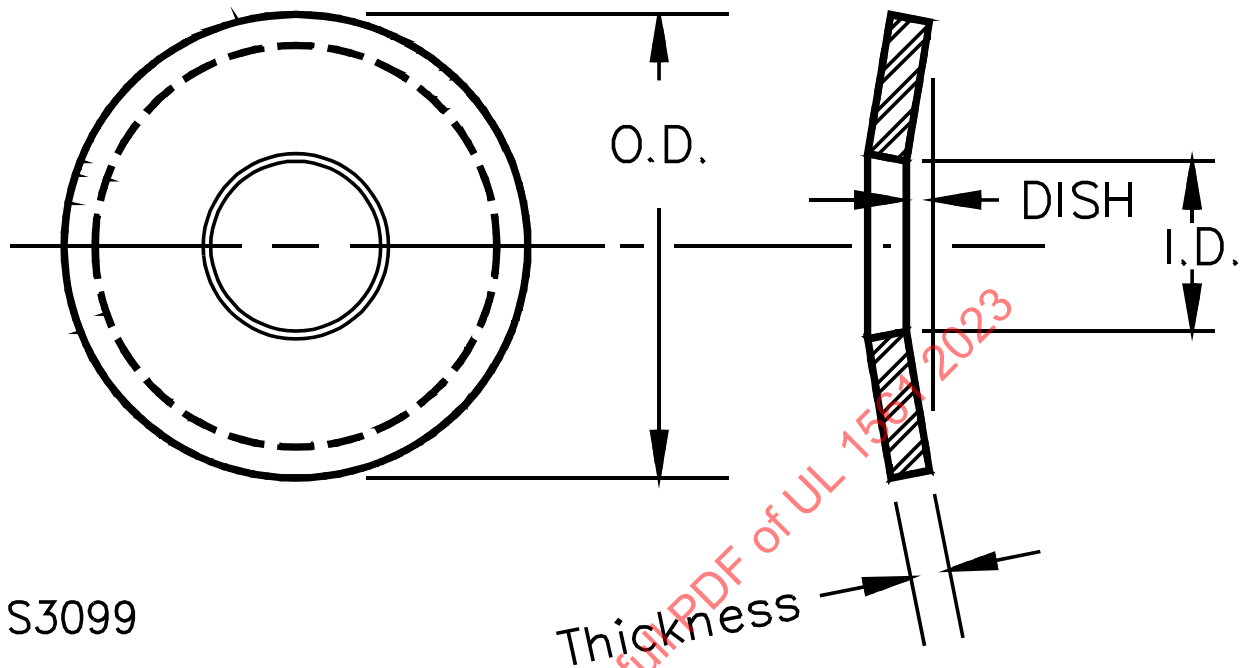
Exception No. 3: A spring washer is not required for a type of fastening equivalent to that used for investigating a component wire connector in accordance with the requirements in the Standard for Wire Connectors, UL 486A-486B.

Exception No. 4: A spring washer is not required at a bolted contact of an aluminum alloy conductor used in the grounding circuit for an application such as the service grounding electrode, a neutral bonding conductor, or an equipment grounding conductor.

Exception No. 5: A spring washer is not required in a construction that has been tested in accordance with [23.4.1](#) and [23.4.2](#).

11.7 A spring washer as mentioned in [11.6](#) (such as a Belleville washer or the equivalent) and illustrated in [Figure 11.1](#) is a dished washer of stainless or hardened and tempered steel, having an outer diameter not less than 150 percent of the bolt diameter, a thickness not less than one eighth of the bolt diameter, and dished not less than 3-1/2 percent of the bolt diameter.

Figure 11.1
Spring washer



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11.8 A flat washer as mentioned in Exception No. 2 to [11.6](#) shall have:

- a) A thickness at least one sixth the diameter of the rivet shank or bolt and
- b) An outer diameter at least 150 percent of that of the rivet shank or bolt but not less than the outer diameter of the spring washer.

11.9 Unless investigated for such use, a bolted connection between two bus bars or between a bus bar and another current carrying part shall not depend on any polymeric insulation material to maintain the clamping force.

11.10 The neutral bus bar and a terminal pad provided for securing the neutral pressure terminal connector on a transformer marked with a K-factor rating in accordance with [38.2.1](#) shall be sized based on the transformer full load current determined in accordance with [21.4](#) and the following maximum current densities:

- a) Five hundred amperes per square inch (77.5 A/cm^2) of cross section for solid copper;
- b) Three hundred and seventy five amperes per square inch (58 A/cm^2) of cross section for solid aluminum having a conductivity of at least 55 percent of that of the International Annealed Copper Standard;
- c) One hundred amperes per square inch (15.5 A/cm^2) of contact area at bolted contacts between copper bus bars and connecting straps or connectors. In determining the contact area of a bolted or riveted connection, no additions or subtractions shall be made for the area of screws, bolts, or rivets; and

d) Seventy five amperes per square inch (11.6 A/cm²) of contact area at bolted contacts between aluminum bus bars and connecting straps or connectors. In determining the contact area of a bolted or riveted connection, no additions or subtractions shall be made for the area of screws, bolts, or rivets.

Exception No. 1: The current densities of the neutral bus bar and terminal pad may be greater than the specified values if the transformer is found to comply with the Temperature Test, Section 23, while the neutral bus bar and terminal pad are carrying 200 percent of the transformer full load current.

Exception No. 2: The current densities of the neutral bus bar and terminal pad may be greater than the specified values if the cross sectional areas of the neutral bus bar and terminal pad are no less than 200 percent of the cross sectional area of the phase bus bar and terminal pad, respectively.

11.11 The cross section of a bus bar as specified in 11.10 may be reduced by no more than 5 percent due to rounding, shaping, or dimensional tolerances. Bus bar ampacity is determined by compliance with the temperature test requirements of Section 23.

12 Electrical Insulation

12.1 An insulation material used for direct or indirect support of live parts shall provide the levels of performance specified for direct and indirect support of live parts in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

12.2 Ordinary vulcanized fiber may be used for insulation bushings, washers, separators, and barriers but not as the sole support of uninsulated live parts.

13 Internal Wiring

13.1 The internal wiring of a transformer shall be rated for the temperature, voltage, and other conditions of use to which it will be subjected. In a Class 130 or higher insulation system, a lead entering a coil shall be additionally investigated in accordance with the Standard for Systems of Insulating Materials – General, UL 1446. See 10.2.1 for requirements for leads for connection to field wiring.

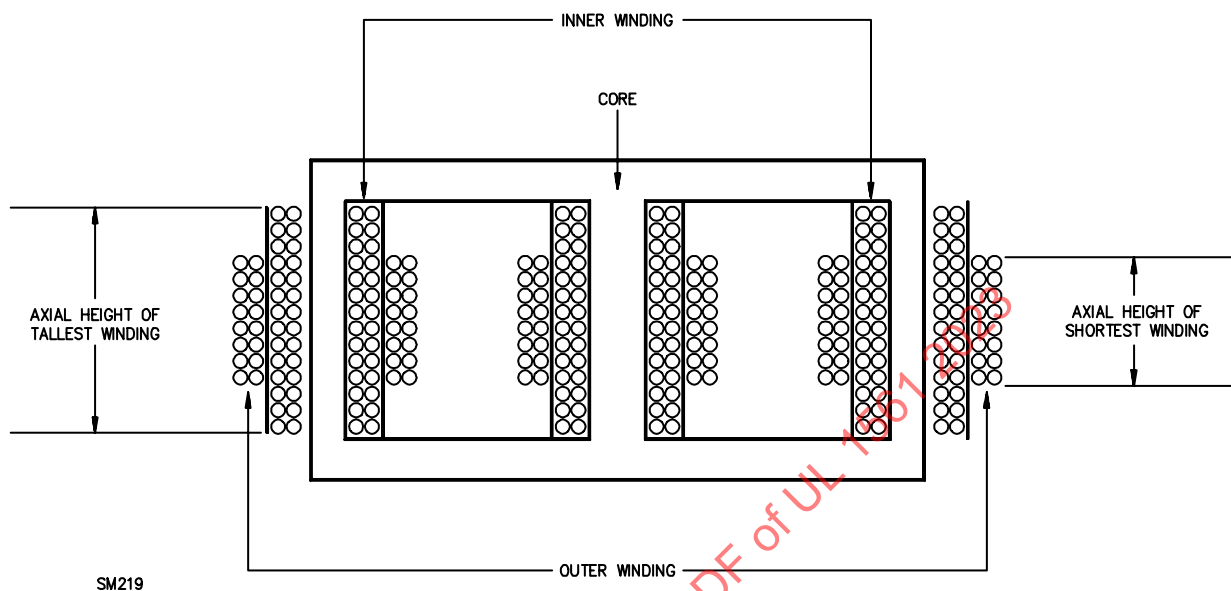
14 Coil Insulation

14.1 The coil insulation of a transformer rated Class 130 or more shall comply with the requirements in the Standard for Systems of Insulating Materials – General, UL 1446, for the temperature rating involved.

15 Coil Details

15.1 An isolation transformer marked with a K-factor rating in accordance with 38.2.1 shall be constructed such that the axial height of the tallest of the input and output windings does not exceed the height of the shortest winding by more than 15 percent. Figure 15.1 shows a typical transformer construction.

Figure 15.1
Typical transformer construction



The shortest winding is X inches and the tallest winding is no more than 1.15 times X inches.

16 Electrical Spacings

16.1 The minimum spacings at field wiring terminals shall be as indicated in [Table 16.1](#).

Table 16.1
Minimum spacings at field wiring terminal

Voltage involved	Minimum spacings between uninsulated live parts of opposite polarity and between an uninsulated live part and a grounded part of conductive materials ^a			
	Through air, ^b		Over surface, ^b	
	inch	(mm)	inch	(mm)
0 – 50	1/8	(3.2)	1/4	(6.4)
51 – 250	1/2	(12.7)	1/2	(12.7)
251 – 600	1	(25.4)	1	(25.4)

^a An isolated part of conductive material (such as a screw head or washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

^b A minimum spacing of 1 inch (25.4 mm) is required between a live part and a metal enclosure.

16.2 The minimum spacing at a point other than a field wiring terminal shall be as indicated in [Table 16.2](#).

Exception: These spacing requirements do not apply between turns of the same high-voltage coil and between turns of the same low-voltage coil.

Table 16.2
Minimum spacings at points other than field wiring terminals

Voltage involved	Minimum spacings between uninsulated live parts of opposite polarity and between an uninsulated live part and a grounded part of conductive material ^a			
	Through air,		Over surface,	
	inch	(mm)	inch	(mm)
0 – 50	1/16	(1.6)	1/16	(1.6)
51 – 125	1/8	(3.2)	1/4	(6.4)
126 – 250	1/4	(6.4)	3/8	(9.5)
250 – 600	3/8	(9.5)	1/2	(12.7)

^a An isolated part of conductive material (such as a screw head or washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

16.3 A film-coated wire is considered insulated with regard to other turns of the same coil, but is otherwise considered uninsulated for these requirements.

16.4 In measuring an over surface spacing:

- a) Any slot, groove, or the like, 0.013 inch (0.33 mm) or less wide in the contour of insulation material is to be disregarded and
- b) An air space of 0.013 inch or less between a live part and an insulation surface is to be disregarded and the live part considered in contact with the insulation material.

16.5 Spacings are to be measured through cracks between insulators, unless a clamped joint complies with the requirements in the Clamped Insulating Joint and Insulating Barrier Tests, Section 29. A clamped joint is a joint between two pieces of insulation material that are under pressure as shown in Figure 16.1. Adhesives, cements, and the like, if used to effect a seal in lieu of a tightly mated joint, shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

16.6 With respect to 16.1 and 16.2, spacings are to be judged with bushings installed as intended. The dimensions of such bushings are as shown in Table 16.3.

Table 16.3
Dimensions of conduit bushings and diameter of knockouts and widths of flat surrounding surfaces

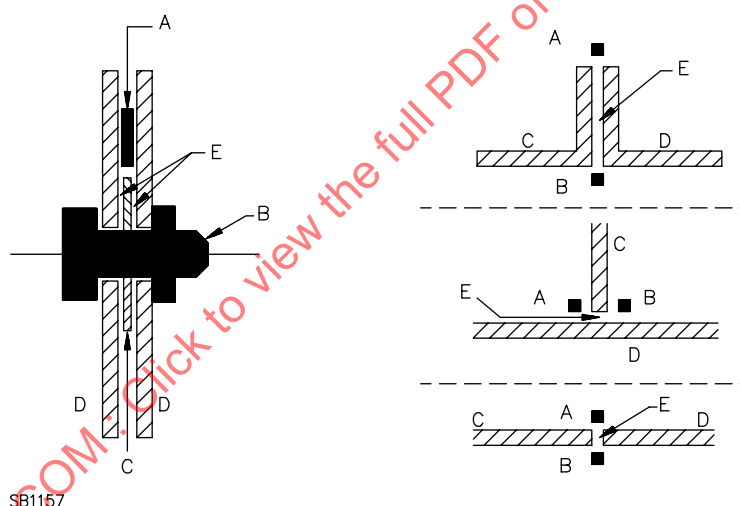
Trade size of conduit, inches	Bushings				Knockout diameter				Minimum width of flat surrounding surfaces, inch (mm)	
	Overall diameter, inches (mm)		Height, inches (mm)		Minimum, inches (mm)		Maximum, inches (mm)			
	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)	inch	(mm)
1/2	1	(25.4)	3/8	(9.5)	0.859	(21.82)	0.906	(23.01)	0.13	(3.4)
3/4	1-15/64	(31.4)	27/64	(10.7)	1.094	(27.79)	1.141	(29.98)	0.16	(4.1)
1	1-19/32	(40.5)	33/64	(13.1)	1.359	(34.52)	1.406	(35.71)	0.20	(5.0)
1-1/4	1-15/16	(49)	9/16	(14.3)	1.719	(43.66)	1.766	(44.86)	0.27	(7.0)
1-1/2	2-13/64	(56)	19/32	(15.1)	1.969	(50.01)	2.016	(51.21)	0.31	(7.8)

Table 16.3 Continued on Next Page

Table 16.3 Continued

Trade size of conduit, inches	Bushings				Knockout diameter				Minimum width of flat surrounding surfaces, inch (mm)	
	Overall diameter, inches (mm)		Height, inches (mm)		Minimum, inches (mm)		Maximum, inches (mm)			
2	2-45/64	(68.7)	5/8	(15.9)	2.453	(62.31)	2.50	(63.50)	0.36	(9.2)
2-1/2	3-7/32	(81.8)	3/4	(19.1)	2.953	(75.01)	3.00	(76.20)	0.30	(7.8)
3	3-7/8	(98.4)	13/16	(20.6)	3.578	(90.88)	3.625	(92.08)	0.33	(8.3)
3-1/2	4-7/16	(113)	15/16	(23.8)	4.094	(103.99)	4.156	(105.56)	0.34	(8.6)
4	4-31/32	(126)	1	(25.4)	4.609	(117.07)	4.672	(118.67)	0.38	(9.7)
5	6-7/32	(158)	1-3/16	(30.2)	5.688	(144.48)	5.750	(146.05)	0.48	(12.2)
6	7-7/32	(183)	1-1/4	(31.8)	6.781	(172.24)	6.844	(173.84)	0.56	(14.2)

Figure 16.1
Clamped joint



Parts A, B – Live parts of opposite polarity, or a live part and a grounded metal part with spacing through the crack between C and D less than required in [Table 16.2](#).

Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E – The clamped joint.

17 Insulating Barriers

17.1 In [17.2](#) and [17.3](#), the liner or barrier referred to is insulation material (other than that used within the winding insulation system) that separates uninsulated live parts of opposite polarity or separates an uninsulated live part from a grounded dead part of conductive material (including the enclosure), if the through air spacing between the parts would otherwise be less than the minimum value, specified in [Table 16.1](#) or [Table 16.2](#).

17.2 A barrier or liner that comprises the sole separation or that is used with an air space of less than one-half the required through air spacing shall comply with the following items. The barrier or liner shall:

a) Be of material investigated and determined to be acceptable for supporting an uninsulated live part, as covered in Electrical Insulation, Section [12](#), for the thickness involved.

Exception No. 1: A barrier between a grounded part and an uninsulated part electrically connected to a grounded circuit conductor (neutral) may be of fiber.

Exception No. 2: An insulation barrier may be used if there is a minimum air space of 1/32 inch (0.8 mm).

b) Have a thickness of 0.028 inch (0.71 mm) or more.

Exception: Insulation material less than 0.028 inch thick may be used if tested and determined to be acceptable in accordance with [29.4](#).

17.3 A barrier or liner used in conjunction with an air space of one-half or more of the required through air spacing shall have a thickness of no less than 0.013 inch (0.33 mm) if it is:

a) Of material investigated and determined to be acceptable for supporting uninsulated live parts, as covered in Electrical Insulation, Section [12](#), for the thickness involved,

b) Of such strength to withstand exposure to mechanical damage,

c) Secured in place, and

d) Located so that it will not be adversely affected by operation of the equipment in service.

Exception: Insulation material less than 0.013 inch thick may be used if it complies with (a) – (d) and has been tested and determined to be acceptable in accordance with [29.4](#).

18 Transient Voltage Surge Suppressors

18.1 A transient voltage surge suppressor provided with the transformer shall comply with the Standard for Surge Protective Devices, UL 1449.

19 Capacitors

19.1 A protected oil-filled capacitor or a dry metallized-film dielectric capacitor provided with the transformer shall comply with the Standard for Capacitors, UL 810.

20 Surge Arresters

20.1 A metal-oxide surge arrester provided with the transformer shall comply with the Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1kV), ANSI/IEEE C62.11. All other surge arresters provided with the transformer shall comply with the Standard for Surge Arresters for AC Power Circuits, ANSI/IEEE C62.1.

PERFORMANCE

21 General

21.1 A transformer shall be subjected to the tests shown in [Table 21.1](#) and, for those tests in Sections [22](#) – [26](#), in the order presented. The same sample shall be used for the tests specified in Sections [22](#) – [26](#). Other samples may be used for the tests specified in [21.5](#) and Sections [27](#) – [35](#).

21.2 Unless indicated otherwise, all tests are to be conducted at 60 hertz.

21.3 For test purposes the energized winding shall be considered the primary winding.

Table 21.1
Transformer tests

Reference	Test
21.5	Weight
22	Impedance ^a
23	Temperature
24	Dielectric voltage-withstand
25	Overload
26	Dielectric voltage-withstand repeated
27	Lifting or mounting means ^b
28	Enclosure strength ^b
29	Clamped insulating joint and insulating barrier ^b
30	Water spray ^b
31	Drip ^b
32	Icing ^b
33	Rust resistance ^b
34	Corrosion resistance ^b
35	Metallic coating thickness ^b

^a Applicable only to transformers rated 25 kVA or more.

^b If applicable.

21.4 If a transformer has its output rated in volt-amperes, the full load current is to be determined by one of the following formulas. (When a range of tap voltages is involved, the lowest voltage in the range is to be used.) The following formulas apply only to transformers having one primary winding and one secondary winding or one kVA rating.

a) For a single-phase transformer:

$$\text{Full Load Secondary Amperes} = \frac{\text{rated volt-amperes}}{\text{rated secondary volts}}$$

b) For a three-phase transformer:

$$\text{Full Load Secondary Line Amperes} = \frac{\text{rated volt-amperes}}{\sqrt{3} \times \text{rated secondary line-to-line volts}}$$

c) For a single-phase transformer:

$$\text{Rated Single-Phase Primary Amperes} = \frac{\text{rated volt-amperes}}{\text{rated primary volts}}$$

d) For a three-phase transformer:

$$\text{Rated Three-Phase Primary Line Amperes} = \frac{\text{rated three-phase volt-amperes}}{\sqrt{3} \times \text{rated primary}}$$

Exception No. 1: When a transformer rating indicates that the taps are of reduced capacity, the rated voltage is to be used.

Exception No. 2: When a transformer has more than one output voltage, the amperes for each output voltage (winding) are to be determined using the volt-ampere rating of the winding and the appropriate single-phase or three-phase formula.

21.5 The weight of a transformer shall be determined, and the transformer shall be marked in accordance with [38.11.1](#).

22 Impedance Test

22.1 The percent impedance of a transformer rated 25 kVA or more shall be determined in accordance with the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C-57.12.91. The marked value is acceptable if it is within ± 10 percent of the determined value. The determined value shall be corrected to be the required insulation system temperature rise plus 20°C (36°F) as shown in [Table 23.1\(f\)](#).

23 Temperature Test

23.1 General

23.1.1 A transformer shall be subjected to a temperature test. The results are acceptable if:

- a) The temperature at any point is not sufficiently high to constitute a risk of fire or to damage any material used in the transformer and
- b) No temperature rise at specific points is greater than that specified in [Table 23.1](#).

23.1.2 The temperature test shall be conducted in accordance with the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12.91.

23.1.3 A transformer marked with a K-factor rating in accordance with [38.2.1](#) shall be loaded with a nonsinusoidal load having a K-factor of no less than the K-factor rating of the transformer.

Exception: The transformer may be tested by the loading-back method, the impedance kVA method, the actual (resistance) method, or the short circuit (separate load loss and excitation test) method in accordance with the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C-57.12.91 provided the load is adjusted to compensate for harmonic losses in accordance with [23.1.4](#).

23.1.4 With regard to the exception of [23.1.3](#) the transformer load losses (P_{LL}) are to be determined as follows:

$$P_{LL} = P_{DC} [1 + K(P_{EC})] [T_C]$$

in which:

K is the K-factor rating at the transformer (4, 9, 13, 20, 30, 40, or 50) and

P_{EC} is the assumed eddy-current losses under rated conditions (per unit of rated load I^2R loss) calculated as follows:

$$P_{EC} = \frac{(P_{AC} - P_{DC})}{(P_{DC}) T_C^2}$$

for transformers rated 300 kVA or less and

$$P_{EC} = \frac{C(P_{AC} - P_{DC})}{(P_{DC-I}) T_C^2}$$

for transformers rated more than 300 kVA,

in which:

P_{AC} is the measured impedance losses with the windings at ambient temperature;

P_{DC} is the total I^2R losses with the windings at ambient temperature;

C is 0.7 for transformers having a turns ratio greater than 4:1 and having one or more windings with a current rating greater than 1000 amperes, or 0.6 for all other transformers;

P_{DC-I} is the I^2R losses for the inner winding with the winding at ambient temperature; and

$$T_C = \frac{T_s + T_k}{T_m + T_k}$$

in which:

T_s is the maximum insulation system temperature rise as shown in [Table 23.1\(f\)](#) plus 20°C (36°F);

T_m is the ambient temperature at which the impedance losses and the I^2R losses were determined; and

T_k is 234.5 for copper windings or 225.0 for aluminum windings.

The impedance losses and the I^2R losses shall be determined in accordance with the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12.91. The load on the transformer may be adjusted during the conduction of the temperature test in order to maintain the proper transformer load losses.

23.1.5 With regard to the transformer load losses (P_{LL}) determined in [23.1.4](#), during the conduction of the temperature test, the load losses are to be monitored as indicated below (reference the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12.91):

- If the loading-back method is used, the load losses are to be monitored at the loading source of the loading transformer.
- If the impedance kVA method is used, the load losses are to be monitored at the source for the impedance loss.
- If the short-circuit method is used, the load losses are to be monitored at the excited windings during the conduction of the short circuit portion of the test.
- If the actual (resistance) method is used, the load losses are to be monitored as the difference between the measured input power and the measured output power.

23.1.6 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm²) and not smaller than 30 AWG (0.05 mm²). The junction of a thermocouple is to be secured in contact with the point on the surface at which the temperature is to be measured.

Exception No. 1: Where the thermocouple is used to measure temperatures of live electrical points, electrical insulation having a maximum thickness of 0.028 inch (0.71 mm) is acceptable between the thermocouple and the live points.

Exception No. 2: The coil temperature is to be determined by the change of resistance method.

Exception No. 3: The ambient temperature may be determined by a thermometer.

Table 23.1
Maximum temperature rises

Material or component			°C
a) Fiber used as electrical insulation			50
b) Any point on a surface adjacent to a transformer, including the surface on which the transformer is mounted			50
c) Insulated wire			40°C less than its recognized temperature rating
d) Any point within a terminal or wiring compartment that a field-installed conductor might contact, including such a conductor itself, unless the transformer is marked in accordance with 38.12.3			
1) Field-wiring conductor current rating of 100 amperes or less			20 ^{a,b}
2) Field-wiring conductor current rating of greater than 100 amperes			35 ^{a,b}
e) Any point on the exterior of the transformer enclosure, except as indicated in 23.2.1 and 23.3.1			50
f) Transformer winding insulation systems (resistance method)			
<u>Insulation System</u>	<u>Ambient</u>	<u>Hot Spot Differential</u>	
Class 105	40	10	55
Class 130	40	15	75
Class 155	40	20	95
Class 180	40	25	115
Class 200	40	25	135
Class 220	40	30	150
Class 240	40	35	165
g) Polymeric insulation materials			40°C less than its recognized temperature rating
h) Bolted joints involving aluminum or copper except where lower limit is specified in (d)			65
^a The temperature on a wiring terminal or lug is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service.			
^b If the rise is 35°C or less and an aluminum bodied connector is used or aluminum wire is intended, the connector shall be marked AL7CU or AL9CU. If the terminal temperature rise exceeds 35°C but does not exceed 50°C, the connector shall be marked AL9CU. See 38.12.3 and 38.12.4 for additional markings.			

23.1.7 Thermocouples are to comply with the requirements specified in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

23.1.8 A minimum of 4 feet (1.2 m) of copper wire is to be attached to field-wiring terminals. The size of wire to be used is to be the smallest size having an ampacity in compliance with [21.4](#) and [Table 23.2](#) of at least 100 percent of rated current for the circuit involved.

Table 23.2
Ampacity of insulated conductors

Wire size		75°C Cu	(167°F) Al
AWG, kcmil	(mm ²)		
14	(2.1)	15	—
12	(3.3)	20	(15)
10	(5.3)	30	(25)
8	(8.4)	50	(40)
6	(13.3)	65	(50)
4	(21.2)	85	(65)
3	(26.7)	100	(75)
2	(33.6)	115	(90)
1	(42.4)	130	(100)
1/0	(53.5)	150	(120)
2/0	(67.4)	175	(135)
3/0	(85.0)	200	(155)
4/0	(107.2)	230	(180)
250	(126.7)	255	(205)
300	(152.0)	285	(230)
350	(177.3)	310	(250)
400	(202.7)	335	(270)
500	(253.7)	380	(310)

NOTES

1 For factory-installed internal wiring, greater ampacities may be considered acceptable on the basis of a temperature test.

2 These values of ampacity apply only where a maximum of three current-carrying conductors will be field installed in a single conduit. If more than three conductors are to be installed, it is assumed that multiple conduits will be used. For ampacities exceeding those shown in this Table, it is assumed that multiple conductors within the range of 1/0 AWG to 500 kcmil will be used. For multiple conductors, the ampacity value of each conductor is to be multiplied by the number of conductors.

23.1.9 If a transformer is provided with one or more primary voltage winding taps, the lowest rated full capacity tap shall be used. The test voltage applied to this tap shall be the rated tap voltage. If the voltage is expressed as a range, the highest voltage of the range shall be used.

23.1.10 When the transformer is rated for a range of frequencies (such as 50 – 400 Hz), the test shall be conducted with the supply circuit at the lowest frequency.

Exception: Transformers rated 50/60 Hz shall be tested at either 50 Hz or at 60 Hz plus 120 percent of the rated input voltage of the transformer.

23.1.11 During the temperature test, the transformer is to be mounted in its intended manner. If marked with a specific clearance to an adjacent wall or ceiling as indicated in [38.10.1](#), the transformer is to be mounted in an alcove as described in [23.2.2](#) for a transformer intended for wall mounting or as described in [23.3.2](#) for a transformer intended for floor mounting.

Exception: If a transformer is marked with a clearance of 6 inches (152 mm) or more, the transformer need not be tested in an alcove as described in [23.3.2](#).

23.2 Units for wall mounting

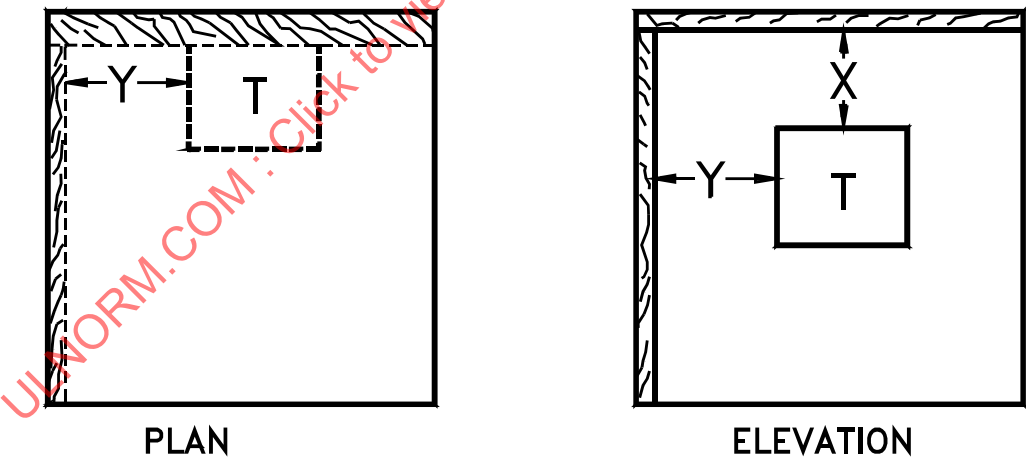
23.2.1 With respect to [Table 23.1](#)(e), the temperature rise on the enclosure of a transformer intended for wall mounting may be more than 50°C (90°F) but not more than 65°C (117°F) during the temperature test if:

- a) The temperature test is conducted with the transformer mounted in an alcove as described in [23.2.2](#) and shown in [Figure 23.1](#);
- b) The temperature rise at any point on the inner surfaces of the alcove is no more than 50°C (90°F); and
- c) The transformer is marked in accordance with [38.10.1](#) and [38.10.2](#).

23.2.2 The side wall and the top of the test alcove represented in [Figure 23.1](#) are of minimum 3/8 inch (9.5 mm) thick fir plywood, and the rear wall (on which the transformer is mounted) is of minimum 3/4 inch (19.1 mm) thick fir plywood. The inner surfaces of the test alcove are to be painted dull black, and the transformer is to be mounted in the intended manner. The horizontal dimensions of the walls and the top are to extend beyond the transformer at least 12 inches (305 mm). The dimensions X and Y are to be the minimum specified by the manufacturer, as provided by the marking specified in [38.10.1](#).

Figure 23.1

Test alcove for wall-mounted transformers



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T – Transformer.

X – Minimum spacing between top of transformer enclosure and surface above transformer.

Y – Minimum spacing between hotter end of transformer and adjacent side wall. If the temperature of the right end of the transformer is higher than that of the left end, the side wall is to be to the right instead of to the left as shown.

23.3 Units for floor mounting

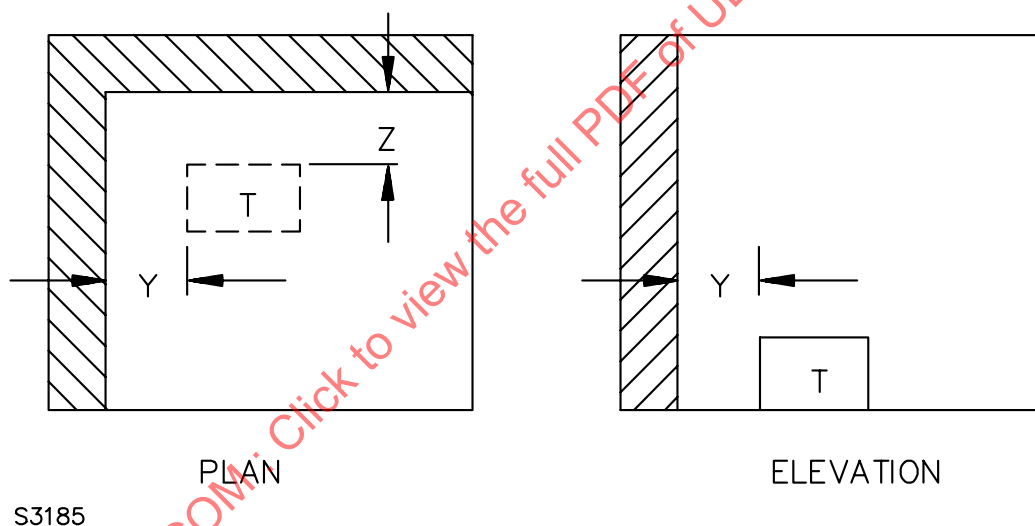
23.3.1 With respect to [Table 23.1](#)(e), the temperature rise on the enclosure of a transformer intended for floor mounting may be more than 50°C (90°F) but not more than 65°C (117°F) during the temperature test if:

- a) The temperature test is conducted with the transformer mounted in an alcove as described in [23.3.2](#) and shown in [Figure 23.2](#).
- b) The temperature rise at any point on the inner surfaces of the alcove is not more than 50°C (90°F); and
- c) The transformer is marked in accordance with [38.10.2](#).

23.3.2 The side wall of the test alcove represented in [Figure 23.2](#) is of minimum 3/8 inch (9.5 mm) thick fir plywood, the rear wall is of minimum 3/4 inch (19.1 mm) thick fir plywood, and the floor is of minimum 3/4 inch thick fir plywood. The inner surfaces of the test alcove are to be painted dull black, and the transformer is to be mounted in the intended manner. The horizontal and vertical dimensions of the walls are to extend beyond the transformer at least 12 inches (305 mm). The dimensions Y and Z are to be the minimum specified by the manufacturer, as provided by the marking specified in [38.10.1](#).

Figure 23.2

Test alcove for floor-mounted transformers



T – Transformer.

Y – Minimum spacing between hotter end of transformer and adjacent side wall. If the temperature of the right end of the transformer is higher than that of the left end, the side wall is to be to the right instead of to the left as shown.

Z – Minimum spacing between rear of transformer and adjacent wall.

23.4 Clamped bus joint

23.4.1 A clamped bus joint construction as referenced in Exception No. 5 to [11.6](#) shall be subjected to the test described in [23.4.2](#). The temperature rise at the joint during the five-hundredth cycle shall be not more than 15°C (27°F) higher than the temperature rise at the twenty-fifth cycle.

23.4.2 The test sample is to consist of an assembly of bus bars connected together to form a series circuit. The bus bars are to be clamped together with the joint construction used in actual production. The number and sizes of the bus bars are to represent the maximum ampere rating and the maximum current density in which the joint construction is used. This may necessitate more than one test. The minimum length of each bus bar is to be 2 feet (610 mm). The bus bar is to be connected to a power supply by any convenient means that will not affect the joint temperature. The power supply is to be adjusted to deliver a value of current that will result in a temperature of 75°C (135°F) above room temperature at the joint. The assembly is then to be subjected to a 500 cycle test. At the end of the twenty-fourth cycle, the current is to

be readjusted to bring the temperature of the joint to 75°C above room temperature. At the end of the twenty-fifth and five-hundredth cycles, the temperatures are to be recorded. The temperatures are to be measured on both sides of the joint as close as possible to the bolt or rivet. The cycling rate is to be 3 hours on and 1 hour off. The on period, during which temperatures are recorded, may be extended to more than 3 hours if necessary for the joint to attain thermal equilibrium.

Exception: The length of the bus bar may be less than 2 feet with the concurrence of those involved.

24 Dielectric Voltage-Withstand Test

24.1 Applied potential

24.1.1 Within 1 hour after conclusion of the temperature test, a transformer other than an autotransformer or a transformer marked for elevated voltage use, as specified in [38.7.3](#), shall be subjected for 1 minute to an applied potential between each winding and every other winding of the transformer to which it is not conductively connected and between each winding and shield or metal of the core or enclosure. The applied potential is to be in accordance with [Table 24.1](#). The terminal ends and taps of the winding under test are to be electrically joined together and to one output terminal of the testing transformer. All other terminals and parts (including the core and enclosure) are to be connected to the other terminal of the testing transformer. The results are acceptable if there is no dielectric breakdown.

Exception: A separate test of a shield is not necessary if there is no provision for field connection of the shield to ground or to a live part.

Table 24.1
Dielectric test potential

Maximum rated voltage of winding or windings involved in test	Applied test potential volts
250 or less	2500
251 – 600	4000

24.1.2 For a transformer provided with the marking described in [38.7.3](#), the applied potential between each winding and metal of the core and enclosure and between each winding and every other winding that may not be involved in the connection shall be based on the voltage attained when connected as so marked.

24.1.3 Within 1 hour after conclusion of the temperature test, an autotransformer shall be subjected for 1 minute to an applied potential between the windings and the core or enclosure. The applied potential is to be in accordance with [Table 24.1](#). The terminal ends and taps of the winding under test are to be electrically joined together and to one output terminal of the testing transformer. All other terminals and parts (including the core and enclosure) are to be connected to the other terminal of the testing transformer. The results are acceptable if there is no dielectric breakdown.

24.1.4 For the tests described in [24.1.1](#) and [24.1.3](#), the test potential is to be supplied from a testing transformer, the output voltage of which can be varied, and the wave form of which is essentially sinusoidal. The capacity of the testing transformer shall be sufficient to maintain the test voltage with respect to capacitive and resistive leakage currents, as determined by direct measurement of the output voltage. The applied potential is to be increased gradually from zero until the required test value is reached, and is to be held at that value for 1 minute, then gradually reduced back to zero.

24.1.5 Dielectric breakdown is considered to exist when the test voltage applied to the sample cannot be maintained at the specified value.

24.2 Induced potential

24.2.1 A winding of a transformer shall be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential shall be applied for 7200 cycles at any frequency not less than twice the rated frequency.

24.2.2 The test voltage required in [24.2.1](#) is to be initiated at one-fourth less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to one-fourth of the maximum value or less, and the circuit is to be opened.

25 Overload Test

25.1 The transformer is to be operated using one of the methods in the Temperature Test, Section [23](#), except that the initial load is to be 50 percent until the core temperature becomes stabilized. Then the overload is to be adjusted to 200 percent of rated load; no further adjustment of the overload current is to be made. The duration of the overload is to be as specified in [Table 25.1](#). The short-circuit method may be used to obtain the 200 percent of rated load.

Exception: The overload test is not required for a transformer rated more than 500 kVA if:

- a) The test has been performed with acceptable results on a smaller transformer rated not less than 500 kVA,*
- b) The smaller transformer has the same insulation system and same general construction as the larger transformer, and*
- c) The temperature rises recorded during the temperature test are not greater for the larger transformer than those recorded during the temperature test for the smaller transformer.*

Table 25.1
Overload test times

Class	Temperature rise, °C	Overload time, minutes
105	55	30
130	60	30
155	85	30
180	110	26
200	130	23
220	150	20
240	165	17

26 Dielectric Voltage-Withstand Test Repeated

26.1 Within 1 hour after the overload test, the transformer shall be subjected to applied potential and induced potential dielectric tests conducted with a test voltage of 65 percent of the value specified in the Dielectric Voltage-Withstand Test, Section [24](#). The results are acceptable if there is no dielectric breakdown.

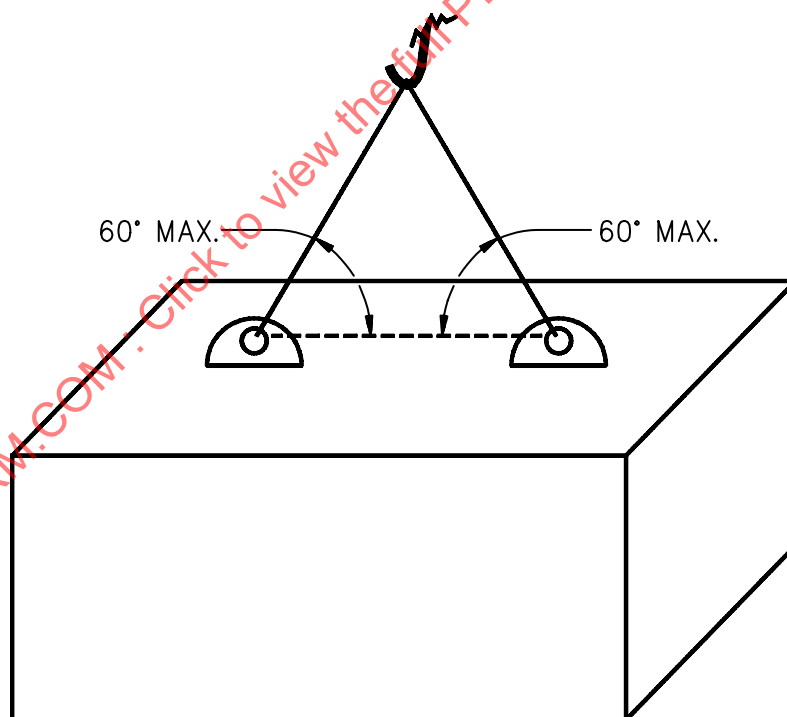
27 Lifting or Mounting Means Test

27.1 The lifting means mentioned in [6.2](#) or the mounting means mentioned in [7.4.3](#) and the mounting means of each to the transformer shall be subjected to the direct application of a force (as specified in [27.3](#)) equal to a minimum of four times the weight of the transformer (a force equal to the weight of the transformer plus a force of three times the weight of the transformer).

27.2 If there is more than one hook, bracket, or hole of a type intended for use with a lifting cable, the test is to be conducted with the cable arranged so that the load will be equally divided and so that the cable under load will be at an angle of 60 degrees maximum from the horizontal plane. A spreader bar shall not be used with the cable. A typical test set-up is shown in [Figure 27.1](#).

27.3 The force is to be gradually applied between the hole, hook, or bracket and that part of the transformer to which it is secured (by any convenient means) and is to be maintained for 5 minutes. For convenience in testing, the sample used for this test may consist of only the portion of the enclosure containing the lifting or mounting means and that part of the transformer to which it is secured. The results are acceptable if there is no breakage of the lifting or mounting means.

Figure 27.1
Lifting or mounting means test configuration



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28 Enclosure Strength Tests

28.1 Deflection test

28.1.1 A drawn, embossed, flanged, or similarly strengthened metal sheet with an opening at the upper edge (as covered in [7.2.3](#)) shall be subjected to a force of 100 pounds (445 N) as described in [28.1.2](#).

28.1.2 The force is to be applied gradually and held for 1 minute with a steel rod having a 1/2 inch (12.7 mm) square flat face, at any point 1 inch (25.4 mm) below the top of the vertical portion of the sheet in an inward direction perpendicular to the sheet. The result is acceptable if there is no inward deflection greater than 1/2 inch (12.7 mm) during the application of the force.

28.2 Compression test

28.2.1 With respect to [7.2.1](#), an enclosure shall comply with the compression test described in [28.2.2](#).

28.2.2 An outside force of 100 pounds (444 N) is to be directed toward the inside of the transformer on each of the five surfaces of the assembled transformer enclosure. (The transformer core and coil need not be installed in the enclosure during this test unless the core and coil are a part of the structural strength of the finished transformer.) The force is to be applied gradually at 90 degrees ± 5 degrees to each of the thinner metal surfaces in any area that is most likely to cause the greatest deflection. The force is to be transmitted through a rod, having a flat, steel face with a 1/2 inch (12.7 mm) square contact area at the transformer surface. The results are acceptable if there is no inward deflection greater than 1/2 inch.

29 Clamped Insulating Joint and Insulating Barrier Tests

29.1 A clamped joint, as described in [16.5](#), between two insulators shall be tested using two samples.

29.2 The first sample is to have the clamped joint opened to produce a space 1/8 inch (3.2 mm) wide. This may be accomplished by loosening the clamping means or by drilling a 1/8 inch diameter hole at the joint between the insulators at a point of minimum spacing between the opposite polarity parts as measured through the crack between the insulators. The dielectric breakdown voltage through this hole is then determined by applying a gradually increasing 60 hertz voltage (500 volts per second) until breakdown occurs.

29.3 The second sample with the clamped joint intact is to be subjected to a gradually increasing 60 hertz voltage until 110 percent of the breakdown voltage in [29.2](#) is reached. If the breakdown voltage in [29.2](#) is less than 4600 volts, the voltage applied to the second sample is to be further increased to 5000 volts and held for 1 second. The clamped joint is acceptable if there is no dielectric breakdown of the second sample.

29.4 A barrier less than 0.028 inch (0.71 mm) thick [as described in the Exception to [17.2\(b\)](#)] or less than 0.013 inch (0.33 mm) thick (as described in the Exception to [17.3](#)) shall be placed between two flat metal electrodes. A barrier less than 0.028 inch shall be subjected to a 5000 volt, 60 hertz potential for 1 second. A barrier less than 0.013 inch shall be subjected to a 2500 volt, 60 hertz potential for 1 second. The results are acceptable if there is no dielectric breakdown.

30 Water Spray Test

30.1 With reference to [7.7.1](#) and [Table 7.3](#), to determine if an enclosure is rainproof, a complete enclosure with conduit connections (without pipe thread compounds) shall be mounted as in actual service and subjected to a water spray as described in [30.2](#) and [30.3](#).

30.2 An enclosure marked "Type 3R" or "Type 3RX" may be used if, at the conclusion of the test:

- a) No water is visible on insulation or on any electrical component.

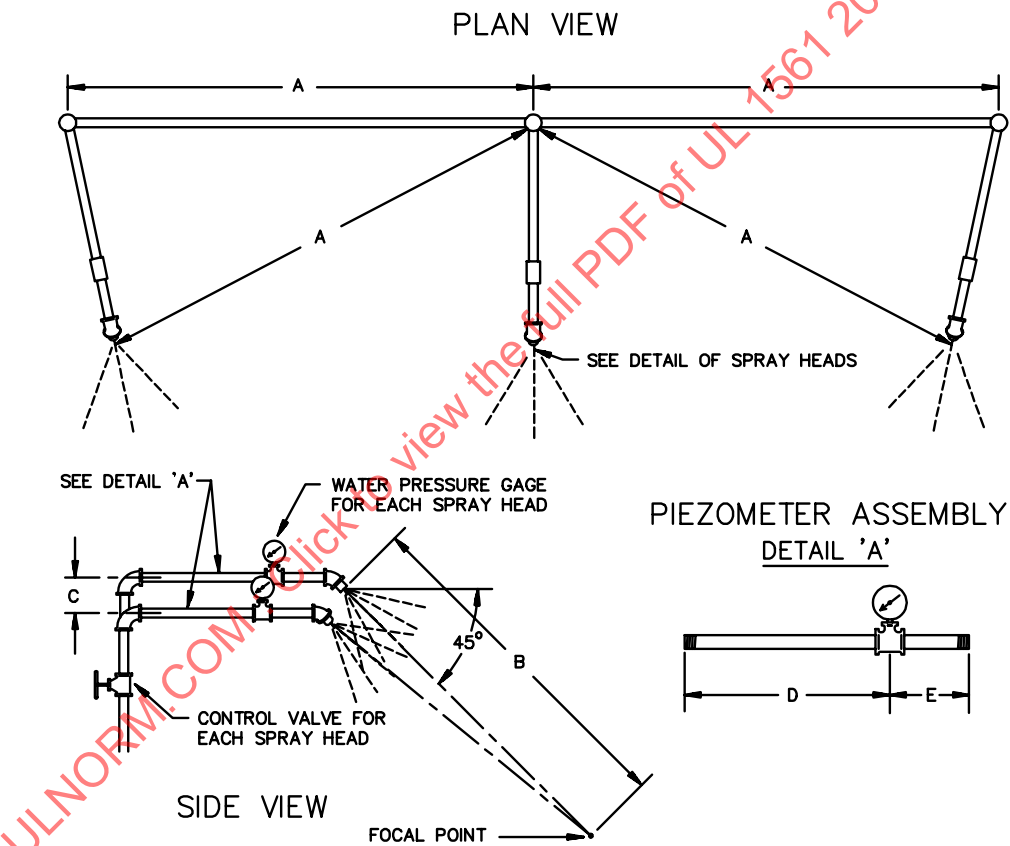
Exception: Water may be visible on encapsulating or filling compounds.

- b) No significant accumulation of water is retained on the transformer structure or other noninsulating parts.

c) No water has entered any area of the enclosure that may enclose wiring installed as intended and located above any uninsulated live part.

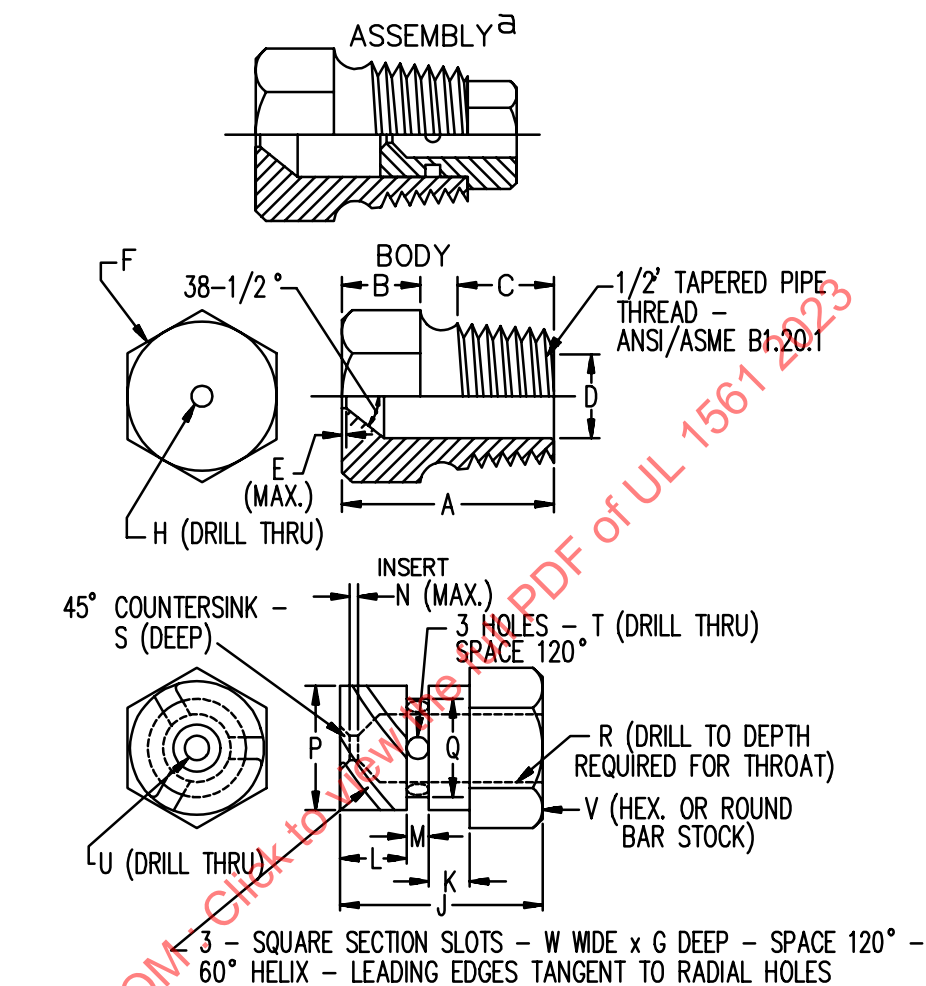
30.3 The water-spray-test apparatus is to consist of three spray heads mounted in a water supply pipe rack as shown in [Figure 30.1](#). Spray heads are to be constructed in accordance with [Figure 30.2](#). The enclosure is to be set up as in an intended installation with conduit connections, without pipe compound if so intended. The enclosure is to be positioned in the focal area of the spray heads so that the greatest quantity of water is likely to enter the enclosure. The water pressure is to be maintained at 5 pounds per square inch (34.5 kPa) at each spray head. The enclosure is to be exposed to the water spray for 1 hour.

Figure 30.1
Water-spray-head piping



Item	inch	mm
A	28	710
B	55	1400
C	2-1/4	55
D	9	230
E	3	75

Figure 30.2
Water spray head



Item	inch	mm	Item	inch	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0		.576	14.63
D	.578	14.68	Q	.453	11.51
	.580	14.73		.454	11.53
E	1/64	0.40	R	1/4	6.35
F	c	c	S	1/32	0.80
G	.06	1.52	T	(No. 35) ^b	2.80
H	(No.9) ^b	5.0	U	(No. 40) ^b	2.50
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

^a Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

^b ANSI B94.11M Drill Size

^c Optional - To serve as a wrench grip.

31 Drip Test

31.1 An enclosure marked "Type 2" shall be tested as described in [31.2](#). The results are acceptable if, at the conclusion of the test:

a) No water is visible on the insulation, on any electrical component.

Exception: Water may be visible on encapsulating or filling compounds.

b) No significant accumulation of water is retained on the transformer structure or on other noninsulating parts.

c) No water has entered any area of the enclosure that may enclose wiring installed as intended and located above any live part.

31.2 The enclosure is to be mounted beneath a drip pan that produces both splashing and dripping and extends beyond all exposed sides of the enclosure. The bottom of the drip pan is to be equipped with uniformly distributed spouts, one spout for each 20 square inches (129 cm²) of pan area. Each spout is to drip water at a rate of approximately 20 drops per minute. The enclosure is to be subjected to continuous dripping water for 30 minutes.

32 Icing Test

32.1 An enclosure marked "Type 3R" or "Type 3RX" and its external mechanisms shall be tested as described in [32.2](#). The results are acceptable if, at the conclusion of the test, the enclosure is undamaged after the ice has melted.

Exception: An enclosure that has no external cavities that can trap water is acceptable for a Type 3R designation without undergoing the test in [32.2](#).

32.2 The enclosure is to be mounted in a room that can be cooled to 20°F (minus 6.7°C). A metal test bar, 1 inch (25.4 mm) in diameter and 2 feet (610 mm) long, is to be mounted in a horizontal position in a location where it will receive the same water spray as the enclosure being tested. Provision is to be made for spraying the entire enclosure from above with water at an angle of approximately 45 degrees from the vertical. The water is to be 32 – 37°F (0 – 2.8°C). Spraying facilities that provide 1 – 2 gallons (3.8 – 7.6 L) per hour per square foot (928 cm²) of area to be sprayed are sufficient. The room temperature is to be lowered to 35°F (1.7°C). The water spray is to be started and continued for at least 1 hour, maintaining the room temperature at 33 – 37°F (0.56 – 2.8°C). The room temperature is then to be lowered to 20 – 27°F (minus 6.7 – 2.8°C) while continuing the water spray. The rate of change in the room temperature is not critical and is to be whatever is obtainable with the cooling method used. The water spray is to be controlled to cause ice to build up on the bar at a rate of approximately 1/4 inch (6.4 mm) per hour and is to be continued until 3/4 inch (19 mm) of ice has formed on the top surface of the bar. The spray is then to be discontinued, but the room temperature is to be maintained at 20 – 27°F for 3 hours so that all parts of the enclosure and the ice coating have reached the same temperature.

33 Rust Resistance Test

33.1 An enclosure marked "Type 1" or "Type 2" shall be tested as described in [33.2](#). The results are acceptable if there is no visible rust or visible damage to the finish at the conclusion of the test.

33.2 The enclosure or representative parts of the enclosure are to be subjected to a salt spray (fog) using the test method in Salt Spray (Fog) Testing, ASTM B117-1973, and using a 5 percent (by weight) salt solution for 24 hours. At the end of the test, the specimens are to be removed from the chamber, are to be washed in clean running water not warmer than 100°F (37.8°C) to remove salt deposits from the

surface, and are to be dried immediately. Corrosion products may be removed by light brushing if required to observe corrosion of the under-lying surface.

34 Corrosion Resistance Test

34.1 An enclosure marked "Type 3RX" is acceptable when, upon completion of the test specified in [34.2](#), it does not show pitting, cracking, or other deterioration more severe than that resulting from a similar test on passivated American Iron and Steel Institute Type 304 stainless steel.

Exception: An enclosure constructed of American Iron and Steel Institute Type 304 or Type 316 stainless steel is not required to be subjected to the test specified in [34.2](#).

34.2 The enclosure is to be subjected to the test described in [33.2](#), except that the exposure time is to be 200 hours.

35 Metallic Coating Thickness Test

35.1 The method of determining the thickness of a zinc or cadmium coating is described in [35.2](#) – [35.9](#).

35.2 The solution used for the test is to be made from distilled water and is to contain 200 grams per liter of American Chemical Society (ACS) reagent grade chromic acid (CrO_3) and 50 grams per liter of ACS reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of ACS reagent grade concentrated sulfuric acid, specific gravity 1.84, containing 96 percent H_2SO_4 .

35.3 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.025 inch (0.64 mm) and a length of 5.5 inches (139.7 mm). The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.025 milliliter each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper, and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ± 5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

35.4 The sample and the test solution are to be kept in the test room sufficiently long to attain the temperature of the room, which is to be noted and recorded. The test is to be conducted at an ambient temperature of $70 - 90^\circ\text{F}$ ($21 - 32^\circ\text{C}$).

35.5 Each sample is to be cleaned before testing. All grease, lacquer, paint, and other nonmetallic coatings are to be removed using solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care is to be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

35.6 The sample to be tested is to be supported 0.7 – 1.0 inch (17.8 – 25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 degrees from horizontal.

35.7 The stopcock is to be opened, and the time (in seconds) until the dropping solution dissolves the protective metal coating exposing the base metal is to be measured. The endpoint is the first appearance of the base metal recognizable by a change in color.

35.8 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at the equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. On an enclosure made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

35.9 To calculate the thickness of the coating being tested, the thickness factor appropriate for the temperature at which the test was conducted is to be selected from [Table 35.1](#) and multiplied by the time in seconds required to expose base metal as described in [35.7](#).

Table 35.1
Coating thickness factors

Temperature,		Thickness 0.00001 inch (0.00025 mm) per second	
°F	(°C)	Cadmium plating	Zinc plating
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

36 Production-Line Dielectric Voltage-Withstand Test

36.1 Each transformer shall withstand without dielectric breakdown, as a routine production-line test, the application of a potential at a frequency within the range of 40 – 70 hertz. The potential shall be applied:

- Between each winding and every other winding of the transformer to which it is not conductively connected and
- Between each winding and metal of the core and the enclosure.

The applied potential is to be increased gradually from zero until the required test value is reached, and is to be held at that value for 1 minute, then gradually reduced back to zero.

36.2 The production-line test shall be in accordance with either Condition A or Condition B of [Table 36.1](#).