UL 1996

STANDARD FOR SAFETY

Electric Duct Heaters

UL Standard for Safety for Electric Duct Heaters, UL 1996

Fourth Edition, Dated August 31, 2009

SUMMARY OF TOPICS

This revision of ANSI/UL 1996 dated August 30, 2022 includes alternate compliance paths for UL 873 and UL 353: 3.8.2.1, 3.8.3.1, 21.1, 22.5 and 23.3.2.

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated July 22, 2022.

No Text on This Page

AUGUST 31, 2009
(Title Page Reprinted: August 30, 2022)

ANSI/UL 1996-2022

UL 1996

Standard for Electric Duct Heaters

The First edition was titled the Standard for Duct Heaters.

First Edition – December, 1992
Second Edition – December, 1996
Third Edition – November, 2004

Fourth Edition

August 31, 2009

This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through August 30, 2022.

The most recent designation of ANSI/UL 1996 as an American National Standard (ANSI) occurred on August 30, 2022. 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 UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

MANUFACTURING AND PRODUCTION TESTS

MARKING

INSTRUCTIONS

APPENDIX A (informative)

No Text on This Page

INTRODUCTION

1 Scope

1.1 These requirements cover fixed electric duct heaters, and remote control assemblies for such equipment, rated at 600 volts or less to be employed in ordinary locations in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 These requirements do not cover fan-coil units, central heating furnaces, panel or cable type radiant heating equipment, electric boilers, baseboard heaters, air heaters, nor any other electric heating equipment or appliances which are covered in or as a part of separate, individual requirements.

1.3 Duct heaters intended for use in a hazardous location are judged on the basis of its compliance with the requirements in this standard, together with the requirements for hazardous location equipment included in other applicable standards.

1.4 Duct heaters designed to be connected to air-duct systems are intended for installation in accordance with the Standard for the Installation of Air Conditioning and Ventilating Systems, NFPA 90A, and the Standard for the Installation of Warm Air Heating and Air Conditioning Systems, NFPA 90B.

1.5 These requirements apply to relays and other auxiliary control devices that may be provided as part of a duct heater to make it usable with other heating or cooling equipment, and are intended to take into account the effects of operating the duct heater in conjunction with or in proximity to such equipment.

1.6 A duct heater is a self-contained heater designed to be installed in the field in the air stream of a ducted system, external to the air-moving unit. It is designed to be installed in a duct where an adequate flow of air from a separate, interlocked fan or blower system is provided. Such a heater may be located in the main supply duct of an air heating system, or in one of the branch ducts. Two or more duct heaters may be installed in a group (in proximity to one another in the duct) if tests indicate acceptable results when the heaters are installed in accordance with the manufacturer's instructions.

1.7 A duct heater intended to be employed in conjunction with another source of heat is judged on the basis of its compliance with the requirements in this standard, and further examination and tests to determine whether or not the combination is acceptable.

2 General

2.1 General

2.1.1 A low voltage circuit is one that has an ac potential of not more than 30 volts alternating current (42.4 peak), and power of 100 VA or less; or 30 V dc supplied by a primary battery; or supplied by a Class 2 transformer; or supplied by a combination of a transformer and fixed impedance that, as a unit, complies with all the performance requirements for a Class 2 transformer. A circuit that is derived from a circuit that exceeds 30 V by connecting resistance or impedance, or both, in series with the supply circuit to limit the voltage and current is not considered to be a low voltage circuit.

2.1.2 A high-voltage circuit is one having characteristics in excess of those of an low-voltage circuit.

2.1.3 Duct heaters intended for installation within 1.22 m (4 ft) of heating or cooling equipment shall be evaluated for the combination use in accordance with the requirements in the standard. See 45.1.8.

2.2 Terminology

2.2.1 Unless otherwise indicated, all voltage and current values mentioned in this standard are rms.

2.3 Units of measurement

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

2.4 Undated references

2.4.1 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.

2A Glossary

2A.1 For the purpose of this standard, the following definitions apply.

2A.2 CAPACITOR, CLASS X – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor or RC unit would not lead to danger of electrical shock but could result in a risk of fire. Examples would be units connected phase to phase or phase to neutral.

Notes:

1) X1 capacitors are generally used in circuits of permanently connected appliances. However, if the appliance is provided with a separate surge protective device that limits the impulse voltage to £ 2.5KV, an X2 capacitor is permitted.

2) X2 capacitors are generally used in circuits of cord-connected appliances.

2A.3 CAPACITOR, CLASS Y – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock. Examples would be capacitors connected across the primary and secondary circuits where electrical isolation is required to prevent an electric shock or between hazardous live parts and accessible parts.

Notes:

1) Y1 capacitors are used in circuits where the prevention of electric shock is afforded solely by the isolation provided by the capacitor. Two Y2 capacitors connected in series is considered to provide the same level of protection as one Y1 capacitor.

2) Y2 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≥ 150V and ≤ 300V.

3) Y4 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≤ 150V.

2A.4 SAFETY CRITICAL FUNCTION – Control, protection and monitoring functions which are being relied upon to reduce the risk of fire, electric shock or casualty hazards.

3 Components

3.1 *Deleted*

3.2 *Deleted*

3.3 *Deleted*

3.4 *Deleted*

3.1 General

3.1.1 A component of a product covered by this standard shall:

a) Comply with the requirements for that component as indicated in 3.2 – 3.8 or the individual component section;

b) Be used in accordance with its rating(s) established for the intended conditions of use;

c) Be used within its established use limitations or conditions of acceptability;

d) Additionally comply with the applicable requirements of this end product standard; and

e) Not contain mercury.

Note – 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.

Exception No. 1: A component of a product covered by this standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product; or

b) Is superseded by a requirement in this standard; or

c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

Exception No. 2: A component complying with a UL component standard other than those cited in 3.2 – 3.8 or the individual component section is acceptable if:

a) The component also complies with the applicable component standard of 3.2 – 3.8 or the individual component section; or

b) The component standard:

1) Is compatible with the ampacity and overcurrent protection requirements of the National Electrical Code, ANSI/NFPA 70, where appropriate;

2) Considers long-term thermal properties of polymeric insulating materials in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and

3) Any use limitations of the other component standard is identified and appropriately accommodated in the end use application. For example, a component used in a household application, but intended for industrial use and complying with the relevant component standard may assume user expertise not common in household applications.

3.1.2 A component that is also intended to perform other functions, such as over current protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable UL standard(s) that cover devices that provide those functions.

Exception: Where these other functions are not required for the application and not identified as part of markings, instructions, or packaging for the duct heater, the additional component standard(s) need not be applied.

3.1.3 A component not anticipated by the requirements of this standard, not specifically covered by the component standards of 3.2 – 3.8 or individual component sections and that involves a potential risk of electric shock, fire, or personal injury, shall be additionally investigated in accordance with the applicable UL standard, and shall comply with 3.1.1 (b) – (d).

3.1.4 With regard to a component being additionally investigated, reference to construction and performance requirements in another UL end product standard is appropriate where that standard anticipates normal and abnormal use conditions consistent with the application of this standard.

3.2 Attachment plugs, receptacles, connectors, and terminals

3.2.1 Attachment plugs, receptacles, appliance couplers, appliance inlets (motor attachment plugs), and appliance (flatiron) plugs, shall comply with the Standard for Attachment Plugs and Receptacles, UL 498. See 3.2.9.

Exception: Attachment plugs and appliance couplers integral to cord sets or power supply cords are covered under the requirements of the Standard for Cord Sets and Power-Supply Cords, UL 817, and need not comply with UL 498.

3.2.2 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 3.5, 3.2, 4.8, 5.2, and 6.3 mm (0.110, 0.125, 0.187, 0.205, and 0.250 in), intended for internal wiring connections in duct heaters, or for the field termination of conductors to the appliance, shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310.

Exception: Other sizes of quick-connect terminals shall be investigated with respect to crimp pull out, insertion-withdrawal, temperature rise, and all tests shall be conducted in accordance with UL 310.

3.2.3 Single and multipole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory connection and for factory assembly to copper or copper alloy conductors, or for factory assembly to printed wiring boards, shall comply with the Standard for Component Connectors for Data, Signal, Control and Power Applications, UL 1977. See 3.2.9.

3.2.4 Wire connectors shall comply with the Standard for Wiring Connectors, UL 486A-486B.

3.2.5 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

3.2.6 Multi-pole splicing wire connectors that are intended to facilitate the connection of hard-wired utilization equipment to the branch-circuit conductors of buildings or that are intended for consumer connection within and between parts of electrical equipment, shall comply with the Standard for Multi-Pole Splicing Wire Connectors, UL 2459. See 3.2.9.

3.2.7 Equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors, shall comply with the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

3.2.8 Terminal blocks shall comply with the Standard for Terminal Blocks, UL 1059, and, if applicable, be suitably rated for field wiring.

3.2.9 Female devices (such as receptacles, appliance couplers, and connectors) that are intended, or that may be used, to interrupt current in the end product, shall be suitably rated for current interruption of the specific type of load, when evaluated with its mating plug or connector. For example, an appliance coupler that can be used to interrupt the current of a motor load shall have a suitable horsepower rating when tested with its mating plug.

3.3 Electrical enclosures and raceways

3.3.1 Electrical enclosures and the associated bushings and fittings, and raceways, of the types specified in Chapter 3 of the National Electrical Code, ANSI/NFPA 70 and that comply with the following standards and 3.1 are considered to fulfill the requirements of this standard:

a) Standard for Metallic Outlet Boxes, UL 514A;

b) Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C; or

c) Standard for Cover Plates for Flush-Mounted Wiring Devices, UL 514D.

3.4 Cords, cables, and internal wiring

3.4.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817.

3.4.2 Flexible cords and cables shall comply with the Standard for Flexible Cords and Cables, UL 62. Flexible cord and cables are considered to fulfill this requirement when preassembled in a cord set or power supply cord complying with the Standard for Cord Sets and Power Supply Cords, UL 817.

3.4.3 Internal wiring composed of insulated conductors shall comply with the Standard for Appliance Wiring Material, UL 758.

Exception No. 1: Insulated conductors need not comply with UL 758 if they comply with one of the following:

a) Standard for Thermoset-Insulated Wires and Cables, UL 44;

b) Standard for Thermoplastic-Insulated Wires and Cables, UL 83; or

c) Standard for Fixture Wire, UL 66.

Exception No. 2: Insulated conductors for specialty applications (e.g. data processing or communications) and located in a low-voltage circuit not involving the risk of fire or personal injury need not comply with UL 758.

3.5 Lampholders

3.5.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

Exception: Lampholders forming part of a luminaire that complies with the Standard for Luminaires, UL 1598 is considered to fulfill this requirement.

3.6 Power supplies

3.6.1 A Class 2 power supply shall comply with one of the following:

a) Standard for Class 2 Power Units, UL 1310; or

b) Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1, with an output marked “Class 2”, or that complies with the limited power source (LPS) requirements and is marked “LPS”.

3.6.2 A non-Class 2 power supply shall comply with one of the following:

a) Standard for Power Units Other Than Class 2, UL 1012; or

b) Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1; or

c) The circuits requirements in Section 24B.

3.7 Printed wiring boards

3.7.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, including direct support criteria, and shall be classed V-0, V-1, or V-2 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A printed-wiring board in a Class 2 nonsafety circuit is not required to comply with the bonding requirements in UL 796 if the board is separated from parts of other circuits such that loosening of the bond between the foil conductor and the base material will not result in the foil conductors or components coming in contact with parts of other circuits of the control or of the end-use product.

3.8 Controls

3.8.1 General

3.8.1.1 Auxiliary controls shall be evaluated using the applicable requirements of this end product standard and the parameters in Section 24A.

Exception: A circuit meeting the parameters of Section 24A and evaluated to the alternate circuit requirements of Section 24B.

3.8.1.2 Operating (regulating) controls shall be evaluated using the applicable component standard requirements specified in 3.8.2 – 3.8.4, and if applicable, the parameters in Section 24A, unless otherwise specified in this end product standard.

Exception: A circuit meeting the parameters of Section 24A and evaluated to the alternate circuit requirements of Section 24B.

3.8.1.2.1 Operating controls that rely upon software for the normal operation of the end product where deviation or drift of the control may result in a risk of safety, such as a speed control unexpectedly changing its output, shall comply with the:

a) Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and Standard for Software in Programmable Components, UL 1998; or

b) Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; or

c) Parameters of Section 24A and the alternate circuit requirements of Section 24B.

3.8.1.3 Controls that perform safety critical functions shall be evaluated using the applicable component standard requirements specified in 3.8.2 – 3.8.4, and if applicable, the parameters in Section 24A, unless otherwise specified in this end product standard.

Exception: A circuit meeting the parameters of Section 24A and evaluated to the alternate circuit requirements of Section 24B.

3.8.1.3.1 Solid-state controls that perform safety critical functions (protective controls) that do not rely upon software as a protective component shall comply with:

a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991;

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1, except Clause H 11.12 (Controls using software); or

c) A circuit meeting the parameters of Section 24A and the alternate circuit requirements of Section 24B.

3.8.1.3.2 Controls that perform safety critical functions (protective controls) that rely upon software as a protective component shall comply with:

a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991; and Standard for Software in Programmable Components, UL 1998;

b) Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; or

c) A circuit meeting the parameters of Section 24A and the alternate circuit requirements of Section 24B.

3.8.1.4 An electronic, non-protective control that is simple in design need only be subjected to the applicable requirements of this end-product standard. A control that does not include an integrated circuit or microprocessor, but does consist of a discrete switching device, capacitors, transistors, and resistors, is considered simple in design.

3.8.2 Electromechanical and electronic controls

3.8.2.1 A control, other than as specified in 3.8.3 – 3.8.4, shall comply with:

a) *Deleted*

aa) The Standard for Temperature Indicating and Regulating Equipment, UL 873; or

b) The Standard for Automatic Electrical Controls; Part 1: General Requirements, UL 60730-1; or

c) A circuit meeting the parameters of Section 24A and the alternate circuit requirements of Section 24B.

3.8.3 Temperature controls

3.8.3.1 A temperature control shall comply with the:

a) *Deleted*

aa) The Standard for Temperature Indicating and Regulating Equipment, UL 873; or

b) Standard for Industrial Control Equipment, UL 508; or

c) Standard for Automatic Electrical Controls; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls; Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9; or

d) Parameters of Section 24A and the alternate circuit requirements of Section 24B.

3.8.3.2 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control shall comply with the Standard for Thermistor-Type Devices, UL 1434.

3.8.3.3 A thermal cutoff shall comply with the Standard for Thermal-Links (Thermal Cutoffs) for Use in Electrical Appliances and Components, UL 60691.

3.8.4 Timer controls

3.8.4.1 A timer control shall comply with the Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

Exception: A circuit meeting the parameters of Section 24A and evaluated to the alternate circuit requirements of Section 24B.

CONSTRUCTION

4 Enclosures

4.1 Enclosures for duct heaters shall be so formed and assembled that, they have the strength and rigidity to resist abuse during shipment, installation, or use without increasing their fire and accident hazards due to a total or partial collapse that could result in a reduction of spacings, a loosening or displacement of parts, or any other defect.

4.2 Enclosures for individual electrical components and wiring, outer enclosures, and combinations of the two, shall be considered in determining compliance with the requirements of 4.1.

4.3 Among the factors to be used in determining the acceptability of an enclosure are:

a) Physical strength,

b) Resistance to impact,

c) Moisture-absorptive properties,

d) Flammability,

e) Resistance to corrosion, and

f) Resistance to distortion or melting caused by the temperatures that is possible under conditions of anticipated use or by electrical disturbances within.

g) Intended installation within ducts and plenums.

4.4 Nonmetallic enclosures or parts thereof shall be considered to comply with 4.3 (d) and (f), when:

a) They comply with the flammability test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C; and

b) They have temperature ratings not less than the maximum temperatures to which exposure during normal operation is possible.

4.5 A sheet metal enclosure shall be evaluated with respect to its size, shape, metal thickness, and use in a particular application. Sheet steel having a thickness of less than 0.66 mm (0.026 inch) when uncoated or 0.74 mm (0.029 inch) when galvanized, or nonferrous sheet metal having a thickness of less than 0.91 mm (0.036 inch) is not acceptable, except for relatively small areas or for surfaces that are curved or corrugated, or otherwise reinforced such as by angles, channels, flanges, or ribs.

4.6 The enclosure of a unit shall be provided with means for mounting in the intended manner. Any special fittings necessary for intended mounting shall be shipped with the unit.

4.7 An electrical part within the outer cabinet need not be individually enclosed when the assembly complies with all of the following:

a) The construction and location of the part do not permit the emission of flame or molten metal through openings in the outer cabinet, or it can be shown that malfunction of the component does not result in a risk of fire.

b) There are no openings in the bottom of the compartment in which the part is located that permit molten metal or the equivalent to drop onto flammable material. See 16.8 for units for outdoor installation.

c) The part is not near flammable material other than electrical insulation.

d) Sheet metal thickness of the outer cabinet is in compliance with Section 5.

e) The part is not located in an air-handling compartment.

f) The part is not subject to unintended contact by persons, as specified in Section 6.

g) There are no openings in the top surface of the outer cabinet that permit objects to fall on or near uninsulated live parts.

Exception: Electric resistance heating elements and other similar components that does not emit smoke or components protected to prevent emission of smoke into the air-handling compartment need not be individually enclosed.

4.8 To determine when a product complies with 4.7, all of its intended mounting positions are to be considered.

5 Thickness of Sheet Metal Enclosures for Uninsulated Live Parts

5.1 Sheet metal used in making enclosures shall have a thickness of not less than that specified in Table 5.1 and Table 5.2, except as permitted by 5.4.

Table 5.1
Minimum thickness of sheet metal for electrical enclosures carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness in mm (inches)			
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,		Uncoated		Metal coated	
cm	(Inches)	cm	(Inches)	cm	(Inches)	cm	(Inches)	MSG		GSG	
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited		0.51	(0.020)	0.58	(0.023)
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)	24		24	
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited		0.66	(0.026)	0.74	(0.029)
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5)	22		22	
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited		0.81	(0.032)	0.86	(0.034)
22.9	(9.0)	29.2	(11.5)	33.0	(13.0)	40.6	(16.0)	20		20	
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited		1.07	(0.042)	1.14	(0.045)
35.6	(14.0)	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)	18		18	
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited		1.35	(0.053)	1.42	(0.056)
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)	16		16	
55.9	(22.0)	Not limited		83.8	(33.0)	Not limited		1.52	(0.060)	1.60	(0.063)
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)	15		15	
63.5	(25.0)	Not limited		99.1	(39.0)	Not limited		1.70	(0.067)	1.78	(0.070)
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)	14		14	
83.8	(33.0)	Not limited		129.5	(51.0)	Not limited		2.03	(0.080)	2.13	(0.084)
96.5	(38.0)	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)	13		13	
106.7	(42.0)	Not limited		162.6	(64.0)	Not limited		2.36	(0.093)	2.46	(0.097)
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)	12		12	
132.1	(52.0)	Not limited		203.2	(80.0)	Not limited		2.74	(0.108)	2.82	(0.111)
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)	11		11	
160.0	(63.0)	Not limited		246.4	(97.0)	Not limited		3.12	(0.123)	3.20	(0.126)
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)	10		10	

[a] A supporting frame is a structure of angle or channel of a 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 which are applied via the enclosure surface when it is deflected. Construction considered to have equivalent reinforcing shall be accomplished by designs that produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) Single sheet with single-formed flanges (formed edges);

2) A single sheet that is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame with, for example, spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] For panels that 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 12.7 mm (1/2 inch) wide.

Table 5.2
Minimum thickness of sheet metal for electrical enclosures aluminum, copper, or brass

Without supporting Frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness	
Maximum width[b],		Maximum length[c],		Maximum width[b],		Maximum length,			
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm (inches)	AWG
7.6	(3.0)	Not limited		17.8	(7.0)	Not limited		0.58	22
8.9	(3.5)	10.2	(4.0)	21.6	(8.5)	24.1	(9.5)	(0.023)	
10.2	(4.0)	Not limited		25.4	(10.0)	Not limited		0.74	20
12.7	(5.0)	15.2	(6.0)	26.7	(10.5)	34.3	(13.5)	(0.029)	
15.2	(6.0)	Not limited		35.6	(14.0)	Not limited		0.91	18
16.5	(6.5)	20.3	(8.0)	38.1	(15.0)	45.7	(18.0)	(0.036)	
20.3	(8.0)	Not limited		48.3	(19.0)	Not limited		1.14	16
24.1	(9.5)	29.2	(11.5)	53.3	(21.0)	63.5	(25.0)	(0.045)	
30.5	(12.0)	Not limited		71.1	(28.0)	Not limited		1.47	14
35.6	(14.0)	40.6	(16.0)	76.2	(30.0)	94.0	(37.0)	(0.058)	
45.7	(18.0)	Not limited		106.7	(42.0)	Not limited		1.91	12
50.8	(20.0)	63.4	(25.0)	114.3	(45.0)	139.7	(55.0)	(0.075)	
63.4	(25.0)	Not limited		152.4	(60.0)	Not limited		2.41	10
73.7	(29.0)	91.4	(36.0)	162.6	(64.0)	198.1	(78.0)	(0.095)	
94.0	(37.0)	Not limited		221.0	(87.0)	Not limited		3.10	8
106.7	(42.0)	134.6	(53.0)	236.2	(93.0)	289.6	(114.0)	(0.122)	
132.1	(52.0)	Not limited		312.4	(123.0)	Not limited		3.89	6
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)	(0.153)	

[a] A support frame is a structure of angle or channel or a 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 which are applied via the enclosure surface when it is deflected. Construction considered to have equivalent reinforcing shall be accomplished by designs that produce a structure as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) Single sheet with single-formed flanges (formed edges);

2) A single sheet that is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame with, for example, spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] For panels that 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 12.7 mm (1/2 inch) wide.

5.2 The minimum thickness of metal for cast enclosures shall comply with Table 5.3.

Table 5.3
Minimum thickness of cast metal enclosures for live parts

Method of fabrication	Minimum thickness, mm (inch)					
	Plain walls					
	Maximum area[a] 154.9 cm^2 (24 inch^2) maximum length 152.4 mm (6 inch)		Area over 154.9 cm^2 (24 inch^2) maximum length 152.4 mm (6 inch)		Around conduit holes	
Die-Cast	1.6	(1/16)[b,c]	2.4	(3/32)	6.3	(1/4)
Other	3.2	(1/8)	3.2	(1/8)	6.3	(1/4)

[a] Area and length limitations may be complied with by subdividing larger areas by means of suitable reinforcing ribs.

[b] Is reduced to 0.8 mm (1/32 inch) when:

1) The enclosure will not be used as a splice box; and

2) The voltage rating of the complete device is such that the voltage between any two conductors is not more than 250 volts dc or single-phase ac.

[c] Is reduced to 0.7 mm (0.028 inch) minimum thickness for enclosures housing only low-voltage circuits.

5.3 A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

a) 0.35 mm (0.014 inch) when steel, or 0.48 mm (0.019 inch) when nonferrous metal, for a hole having a 6.4 mm (1/4 inch) maximum dimension; and

b) 0.68 mm (0.027 inch) when steel, or 0.81 mm (0.032 inch) when nonferrous metal, for a hole having a 34.9 mm (1-3/8 inch) maximum dimension. A closure for a larger hole shall have a thickness no less than that required for the enclosure of the device, or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

5.4 With reference to 5.1, the thickness of an enclosure shall be two gauge sizes less than indicated in Table 5.1 and Table 5.2, if the electrical components are located at least 64 mm (2-1/2 inch) from the surface, and 4 gauge sizes less when the components are located at least 128 mm (5 inches) from the surface. The thickness shall be not less than No. 24 MSG or GSG (steel), or 18 AWG (aluminum, copper, or brass), unless a lesser thickness is in accordance with Table 5.1 and Table 5.2. An example of 2 gauge sizes less is No. 18 MSG instead of No. 16 MSG; an example of 4 gauge sizes less is No. 20 MSG instead of No. 16 MSG.

6 Openings in Enclosures

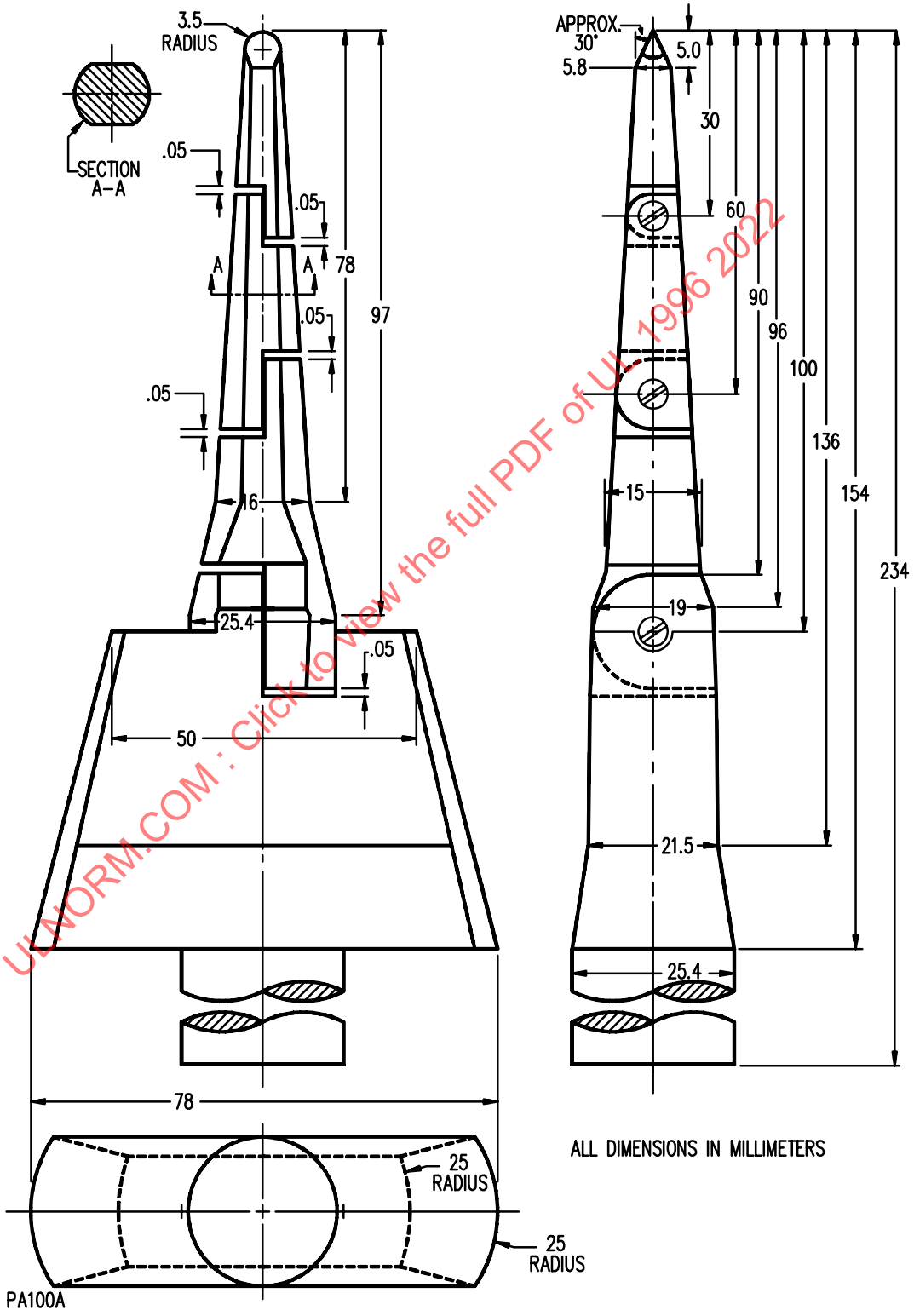
6.1 Uninsulated live parts excluding film-coated wire, of high-voltage circuits, shall be located, guarded, or enclosed so as to prevent unintended contact by persons reaching through openings in the enclosure, or by persons adjusting controls, or performing other intended service and maintenance operations.

6.2 Openings in enclosures, including perforations, louvers, and openings protected by means of screening, expanded metal, or perforated covers, shall be of such size or shape as to prevent the passage of a probe, illustrated in Figure 6.1, from contacting uninsulated live parts. The configuration of the probe shall be changed (articulated) after insertion. See 6.4 for film-coated wire.

Figure 6.1

Probe

(Other than moving parts)



Note: All dimensions given are in millimeters.

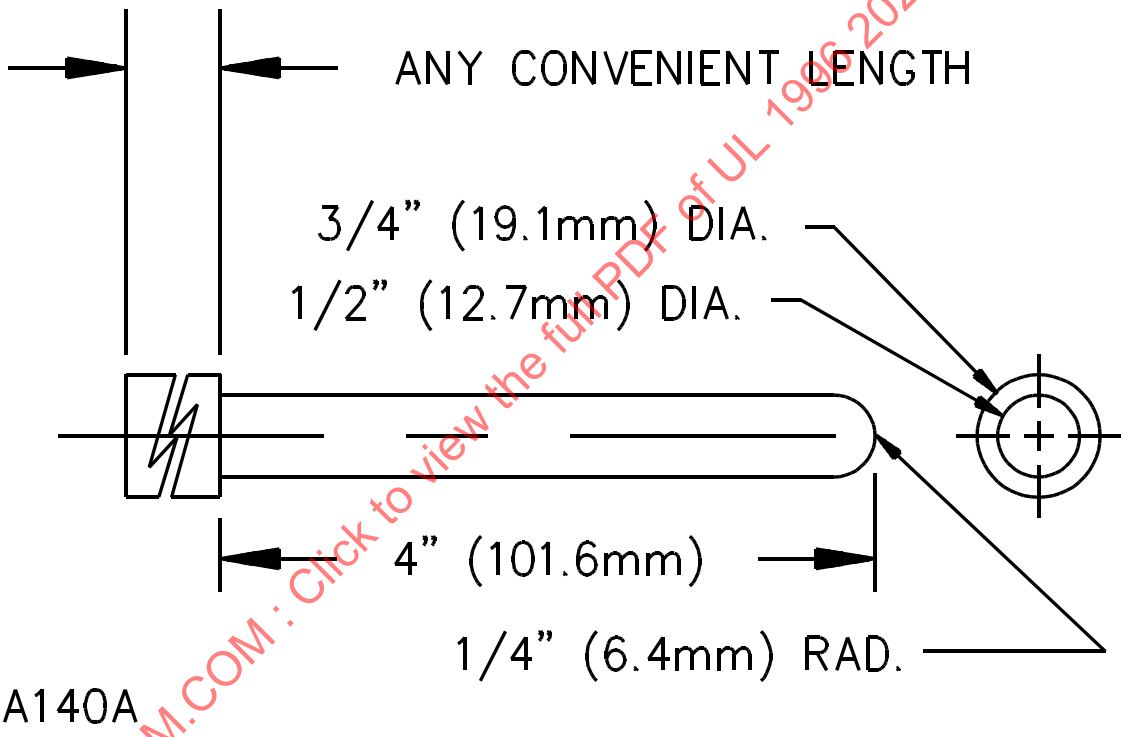
6.3 During the examination of a unit or part thereof, in connection with the requirements in 6.1, parts of the enclosure, such as covers, panels, and grilles are to be removed unless tools are required for their removal. A warning marking, such as specified in 45.1.3 (i) is disregarded in establishing compliance with these requirements.

6.4 A probe as illustrated in Figure 6.2 shall not touch film-coated wire when inserted through the opening.

Figure 6.2

Probe

(For film-coated wire)



7 Enclosures, Doors, and Covers

7.1 Doors and covers that give access to uninsulated live high-voltage parts shall be secured firmly in place, and shall require the use of a tool or key to open them or shall be provided with an interlocking mechanism; except that components having covers that comply with their respective standards do not require additional enclosures.

7.2 An interlocking mechanism complies with the requirements of 7.1 when it:

a) Secures the cover in the closed position when engaged; and

b) Is engaged before parts in a high-voltage circuit are energized.

8 Accessibility of Parts

8.1 Sufficient and reasonable accessibility shall be afforded to all parts that require normal servicing or adjustment (adjustment of controls) when the equipment is installed as intended. Covers or access panels

giving access to such parts that are required to be removed for routine maintenance shall not expose uninsulated live parts.

8.2 The assembly shall be arranged so that any overcurrent protective device that is replaced or reset as required is accessible without removal of parts other than the service covers or panels.

8.3 Except as specified in 8.4, the door or cover of an enclosure shall be hinged, sliding type, pivoted, or the equivalent, and not intended for removal, when it gives access to fuses.

Exception: When more than one door or cover is opened to provide access, only one of these needs to comply with this requirement.

8.3.1 Where the enclosure is located in a space above a ceiling, all doors or hinged panels shall open to at least 90 degrees.

8.4 A cover as specified in 8.3 is not required when fuses only of the following types are enclosed:

a) Fuses connected in low-voltage circuits;

b) Extractor type fuses that have their own enclosures;

c) Control circuit fuses provided that the control circuit loads (other than fixed loads, such as pilot lamps) are housed in the same enclosure as the fuses; or

d) Supplementary type fuses rated 2 amperes or less used in small, auxiliary resistance heater circuits having a maximum rating of 100 watts.

8.5 The reset button or lever of manual resettable devices (for example, the operating handle of a circuit breaker, the adjusting screw or knob of an adjustable temperature control) may be accessible without the use of a tool, providing that the resetting of the device does not result in exposure to uninsulated live high-voltage parts.

8.6 A cover as specified in 8.3 shall not depend solely upon screws or other similar means to hold it closed, but shall be provided with an automatic latch or the equivalent. A spring latch, a magnetic latch, a dimple, or any other mechanical arrangement that holds the door in place and requires some effort on the user's part to open complies for holding the door closed. A cover interlocking mechanism, as described in 7.2, and provided as the sole means for securing the cover or panel, complies.

9 Assembly

9.1 A duct heater shall have provision for the intended connection of ducts, either in the form of duct flanges, openings without flanges, or locations marked for openings, providing that drilling or cutting into the cabinet, or the use of screws, will not damage electrical components and wiring. A distance of 6 inch (152 mm) separating the opening from all components and wiring is considered to prevent damage due to drilling or cutting. Protection shall be provided by equivalent means.

10 Outdoor Use Equipment

10.1 General

10.1.1 Sheet steel cabinets and enclosures of units intended for outdoor use shall be protected against corrosion as specified in Table 10.1, or by other metallic or nonmetallic coatings that have been shown to give equivalent protection. Nonferrous cabinets and enclosures are not required to employ special corrosion protection. The thickness of the material is to be judged on the basis of its strength and rigidity.

Table 10.1
Corrosion protection

Type of cabinet and enclosure	1.35 mm (0.053 in) uncoated and 1.42 mm (0.056 in) coated and greater as specified by	Less than 1.35 mm (0.053 in) uncoated and 1.42 mm (0.056 in) coated as specified by
Outer cabinets that protect motors, wiring, or enclosed current-carrying parts	10.1.2	10.1.3
Inside enclosures that protect current-carrying parts other than motors	10.1.2	10.1.3
Outer cabinets that are the sole enclosure of current-carrying parts	10.1.3	10.1.3

10.1.2 Where Table 10.1 references 10.1.2, a cabinet or enclosure intended for outdoor use shall be provided with one of the following coatings:

a) Hot dipped mill galvanized sheet steel conforming with the coating designation G60 or A60 in Table 1 of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) for Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653 or in Table 1 of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) for Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process (Metric), ASTM A653M, with not less than 40% of the zinc on any side, as determined by the minimum single spot test requirement in this ASTM designation. The weight of zinc coating shall be determined by any recognized method; however, where results are in question, the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90.

b) A zinc coating, other than that provided on hot dipped mill galvanized sheet steel, uniformly applied on each surface to an average thickness of not less than 0.01041 mm (0.00041 in), and to a minimum thickness of 0.00864 mm (0.00034 in).

c) Two coats of outdoor paint on both surfaces. The suitability of the paint shall be determined by consideration of its composition.

10.1.3 Where Table 10.1 references 10.1.3, a cabinet or enclosure intended for outdoor use shall be provided with one of the following coatings:

a) Hot dipped mill galvanized sheet steel having the coating designation G90 in Table 1 of ASTM designation A653 or A653M, with not less than 40 percent of the zinc on any side as determined by the minimum single spot test requirement in these ASTM designations. The weight of zinc coating shall be determined by any recognized method; however, where results are in question, the weight of coating shall be established in accordance with the test method of ASTM designation A90.

b) A zinc coating, other than that provided on hot dipped mill galvanized sheet steel, uniformly applied on each surface to an average thickness of not less than 0.01549 mm (0.00061 in), and to a minimum thickness of 0.01372 mm (0.00054 in).

c) A zinc coating complying with 10.1.2 (a) or (b), plus one coat of outdoor paint as specified in 10.1.2 (c) on each surface.

10.1.4 With reference to 10.1.1, other finishes, including paints, special metallic finishes, and combinations of the two is accepted when comparisons with galvanized sheet steel (without annealing, wiping, or other surface treatment) that complies with 10.1.2 (a) or 10.1.3 (a), as applicable, indicate they provide equivalent protection.

10.1.5 Metals shall not be used in combinations such as to cause galvanic action that adversely affects cabinets or enclosures.

10.2 Enclosures

10.2.1 The outer cabinet of the equipment intended for outdoor use shall be so constructed as to prevent the wetting of uninsulated live parts (hazardous voltage or extra-low-voltage safety circuits), and shall protect the system against risk of shock due to exposure to rain (see Rain Test, Section 40). When of steel, it shall be not less than 0.78 mm (0.0307 in) thick, and shall be protected against corrosion as required by Section 10. Enclosures made of other metal shall have mechanical strength and rigidity at least equivalent to that of steel, 0.78 mm (0.0307 in) thick.

10.2.2 An enclosure that is formed of metal which is thinner than specified in 10.2.1, and which complies with Table 5.1 and Table 5.2, whichever applies, is acceptable when it is protected by an outer cabinet. A sheet steel cabinet or enclosures employing panels consisting of more than one sheet, each sheet thinner than specified in 10.2.1, shall be used when equivalent in all respects, including mechanical strength and corrosion resistance, to a single sheet of steel of the thickness specified in 10.2.1.

10.2.3 Service covers and access panels that are not secured by screws or other fasteners requiring the use of tools to remove them shall be left open or removed during the Rain Test described in Section 40.

10.2.4 An enclosure for electrical components shall have provision for drainage when the enclosure employs knockouts or unthreaded openings. The drainage holes shall be not less than 3.2 mm (1/8 in) in diameter, or drainage openings of at least equivalent size shall be included.

10.2.5 The effects of exposure to ultra-violet light and water are to be considered, in an evaluation of nonmetallic cabinets and enclosures.

10.2.6 Gaskets required to seal enclosures of electrical components shall comply with the requirements of Section 41, Gaskets – Accelerated Aging Test.

10.3 Field wiring connections

10.3.1 Conduit openings or knockouts shall be provided for all field wiring connections, and shall be at least 22.2 mm (7/8 in) in diameter. Threaded openings shall be provided unless:

a) The opening prevents drainage into the enclosure along the outside surface of a field supplied wireway; or

b) The opening is wholly below or not in proximity to a component, other than insulated wire or a component intended for exposure to water, or an uninsulated live part that is high voltage or low voltage safety; or

c) The routing of the factory- or field-supplied wiring is required such that a drip-loop is formed, which physically prevents entering water from contacting a component, other than insulated wire or a component intended for exposure to water, or an uninsulated live part that is high voltage or low voltage safety.

10.3.2 With reference to 10.3.1, threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or when an equivalent construction is employed, there shall be not less than three nor more than five threads in the metal. Construction of the device shall be such that a conduit bushing is properly attachable when 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 be not less than 3-1/2 threads in the metal. There shall be a smooth, rounded inlet hole for the conductors which shall afford protection to

the conductors equivalent to that provided by a standard conduit bushing and which shall have an internal diameter the same as that of the corresponding trade size of rigid conduit.

10.3.3 An enclosure threaded for support by rigid conduit shall provide at least five full threads for engaging with the conduit.

11 Mechanical Assembly

11.1 Parts used in the construction of the complete assembly shall have adequate strength, and shall be assembled and secured in position to ensure proper functioning under both normal and abnormal conditions that are met in service.

11.2 Duct heaters that are designed to be shipped in separable sections (for example, heating section, control section) shall be marked in accordance with the requirements of 45.1.3, and the following shall be complied with:

a) Each section shall be constructed and packaged so as to prevent damage to the parts during shipment and assembly;

b) Each section and the contents shall be identified as required by 45.1.3 (a) and (b); additionally the unit shall be marked to identify each section;

c) Electrical connections between the separable sections shall be capable of being made without additional parts being required, such as internal wiring, connectors, receptacles, terminal blocks;

d) Electrical bonding shall be maintained between sections after assembly;

e) All connections shall be properly marked for assembly;

f) Safety controls shall be an integral part of the sections requiring them; and

g) Each package shall contain that part of the installation instructions intended to assemble it into the other sections.

12 Auxiliary Devices

12.1 A unit having provisions for the use of additional auxiliary devices intended to be attached in the field shall be constructed so that their use will not cause a risk of fire, electric shock, or injury.

12.2 The unit shall comply with the requirements of this standard, both with and without the auxiliary device installed.

12.3 The installation of auxiliary devices by service personnel shall be by means of receptacles, plug-in connectors, wiring terminals, insulated wire connectors, or by connection to existing wire terminals.

12.4 Any installation of an auxiliary device shall not require the cutting of wiring or the soldering of connections by the installer, and shall not require cutting, drilling, or welding in electrical enclosures and in other areas where such operations damage electrical components and wiring.

12.5 Field rearrangement of components shall not comply.

12.6 As part of the investigation, a trial installation of auxiliary devices shall be made, to determine that its installation is feasible, that the instructions are detailed and correct, and that its use does not cause a risk of fire, electric shock, or injury.

12.7 A strain relief means shall be provided for the wiring in the auxiliary device, when there is any possibility of transmitting stress to the terminal connections during installation.

12.8 All terminals and wiring intended to be field-connected shall be identified on the auxiliary device, the unit (when connections are made between the device and the unit), and the wiring diagram.

12.9 The mounting location of the auxiliary device shall be indicated on the unit. However, when the mounting location is predetermined by the function of the device and arrangement of the unit, and when instructions are provided covering the installation and location for the device, the mounting location of the device need not be indicated.

13 Connection to Power Supply

13.1 A duct heater shall have provision for the connection of conduit (or conduits) of a size (see Table 13.1) suitable for the supply circuit conductors (see Table 13.2) needed to connect the unit in accordance with Tables 310-16 and 310-17 in the National Electrical Code, ANSI/NFPA 70. Provisions shall be made for field cutting the openings necessary for field wiring system connections, when their intended locations are indicated by one of the following methods:

a) Use of pilot holes intended for use with a hole punch; or

b) An attached marking showing the exact center of each opening; or

c) An attached marking showing the area in which the openings can be located.

Table 13.1
Knockout or hole sizes and dimensions of bushings

Trade size of conduit		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
Inches	mm	Inches	mm	Inches	mm	Inches	mm
1/2	21.3	7/8	22.2	1	25.4	3/8	9.5
3/4	26.7	1-3/32	27.8	1-15/64	31.4	27/64	10.7
1	33.4	1-23/64	34.5	1-19/32	40.5	33/64	13.1
1-1/4	42.3	1-23/32	43.7	1-15/16	49.2	9/16	14.3
1-1/2	48.3	1-31/32	50.0	2-13/64	56.0	19/32	15.1
2	60.3	2-15/32	62.7	2-45/64	68.7	5/8	15.9
2-1/2	73.0	3	76.2	3-7/32	81.8	3/4	19.1
3	88.9	3-5/8	92.1	3-7/8	98.4	13/16	20.6
3-1/2	101.6	4-1/8	104.8	4-7/16	112.7	15/16	23.8
4	114.0	4-5/8	117.5	4-31/32	126.2	1	25.4
4-1/2	127.0	5-1/8	130.2	5-35/64	140.9	1-1/16	27.0
5	141.3	5-5/8	142.9	6-7/32	158.0	1-3/16	30.2
6	168.3	6-3/4	171.5	7-7/32	183.4	1-1/4	31.8

Table 13.2
Trade size of conduit

Wire size		Number of wire				
		2	3	4	5	6
AWG (mm^2)						
14	(2.1)	1/2	1/2	1/2	1/2	1/2
12	(3.3)	1/2	1/2	1/2	3/4	3/4
10	(5.3)	1/2	1/2	1/2	3/4	3/4
8	(8.4)	3/4	3/4	1	1	1-1/4
6	(13.3)	3/4	1	1	1-1/4	1-1/4
4	(21.2)	1	1	1-1/4	1-1/4	1-1/2
3	(26.7)	1	1-1/4	1-1/4	1-1/2	1-1/2
2	(33.6)	1	1-1/4	1-1/4	1-1/2	2
1	(42.4)	1-1/4	1-1/4	1-1/2	2	2
0	(53.5)	1-1/4	1-1/2	2	2	2-1/2
2/0	(67.4)	1-1/2	1-1/2	2	2	2-1/2
3/0	(85.0)	1-1/2	2	2	2-1/2	2-1/2
4/0	(107.2)	2	2	2-1/2	2-1/2	3
kcmil						
250	(127)	2	2-1/2	2-1/2	3	3
300	(152)	2	2-1/2	3	3	3-1/2
350	(177)	2-1/2	2-1/2	3	3-1/2	3-1/2
400	(203)	2-1/2	3	3	3-1/2	4
500	(253)	3	3	3-1/2	4	4

Note – This table is based on the assumption that all conductors are of the same size and there are no more than six conductors in the conduit. When more than six conductors are involved or when all of them are not of the same size, the internal cross-sectional area of the smallest conduit used is determined by multiplying by 2.5 the total cross-sectional area of the wires, based on the cross-sectional area of Type THW specified in the National Electrical Code.

13.2 Field-provided openings for field wiring system connections shall be so located that the required cutting, drilling, or punching operation does not damage components or wiring within the enclosure. Separation shall be maintained as specified in 9.1.

13.3 A metal plate to which conduit is to be attached in the field shall be not less than 0.78 mm (0.0307 inch) thick when uncoated steel, not less than 0.88 mm (0.0346 inch) thick if galvanized steel, and not less than 1.14 mm (0.045 inch) thick when nonferrous metal.

13.4 A knockout shall be provided with a flat surrounding surface for seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout used during installation does not result in spacings between uninsulated live parts and the bushing of less than those required by Section 26, Spacings.

13.5 The construction of the equipment at the point where the conduit of the supply is attached shall be such that supply conductors can be installed in compliance with the requirements of Section 17, Separation of Circuits.

13.6 The space provided at terminals or leads intended for the connection of supply conductors, or other conductors to be connected at the time of installation, shall be sufficient for intended installation (see 13.7) including the accommodation of the required splices.

13.7 An installation shall:

a) Be possible using ordinary tools required for the installation; and

b) Not require installed conductors to be forced into contact with uninsulated live parts, or with noncurrent-carrying parts that are grounded.

A trial installation may be performed to determine compliance with these requirements.

13.8 Equipment which incorporates more than one independent internal circuit, and is designed for connection to more than one source of electrical power supply shall have each internal circuit provided with means for connection to the supply, in accordance with Section 13.

13.9 High-voltage circuit connections shall be made within required enclosures or outlet boxes. The location of an outlet box or compartment in which supply connections are made shall be such that the connections will be readily accessible for inspection after the equipment is installed as intended.

14 Thermal Insulation and Air Filters

14.1 Thermal insulation such as mineral wool, which contain conductive impurities, shall not contact uninsulated live parts. Exposed unimpregnated asbestos material shall not be used in an air handling compartment. The unprotected edge of a gasket sandwiched between two parts is determined as exposed.

14.2 Materials in a compartment handling conditioned air for circulation through a duct system shall have a flame spread rating of not more than 25, and a smoke developed rating of not more than 50, when tested as specified in the requirements for Standard Method of Test for Surface Burning Characteristics of Building Materials, UL 723. This requirement does not apply to the following:

a) Wire insulation, paint applied for corrosion protection, or tubing of material equivalent to one of the types of wire insulation intended by this standard;

b) Gaskets forming air seals between metal parts;

c) Miscellaneous small parts such as insulating bushings, resilient or vibration mounts, wire ties, clamps, or labels having a total exposed surface area not exceeding 161.29 cm^2 (25 $inch^2$);

d) An adhesive that, when tested in combination with the specific insulating material, complies with the requirement;

e) Molded or formed components (not liners) of polymeric materials in such quantities that their total exposed surface area within the compartment does not exceed 0.93 square m (10 square feet).

14.3 Polymeric materials exempted by 14.2 (e) shall have a flame spread rating of not more than 25, or shall comply with the requirements of the vertical burning test for classifying materials 5V in accordance with the Standard Tests for Flammability of Plastic Materials in Devices and Appliances, UL 94.

14.4 Thermal insulating material shall be securely positioned when loosening reduces or blocks airflow so as to cause temperatures in excess of those complying with the requirements in the temperature tests, or when loosening results in reduction of electrical spacings below the required values, short circuiting, or grounding. Leading edges of insulation shall be protected against damage from the effects of moving air.

14.5 A mechanical fastener for each 0.1 m^2 (1 ft^2) of exposed surface is considered to securely position insulating liners to meet the requirement of 14.4. Mechanical fasteners are bolts, metal clamps, wire rods,

or the equivalent. Butting edges of insulation against bulkheads normally provide protection for leading edges against damage from the effects of moving air. Rigid or semirigid sheets of insulating material shall not require fastening to the extent needed for less rigid material, nor is protection of leading edges, for such material, required.

14.6 An adhesive provided to secure insulating material, to comply with 14.4, shall retain its adhesive qualities at any temperature attained by the adhesive when the unit is tested under the requirements of this standard, and at minus 18°C (0°F).

15 Terminal Parts and Leads for Field Wiring Connections

15.1 General

15.1.1 A duct heater shall have provision for connection of one or more of the power supply wiring systems that, in accordance with the National Electrical Code, ANSI/NFPA 70, is applicable to the unit.

15.1.2 Where leads are provided for making connection to the power supply, they shall be not less than 18 AWG. These leads shall be provided with means for strain relief when stress on the leads are transmitted to terminals, splices, or internal wiring that cause the leads to separate from their terminations, or subject them to damage by sharp edges.

15.1.3 Field wiring terminals shall have means other than friction to prevent them from turning, which might results in unacceptable electrical spacings.

15.1.4 Line terminals of an intended control or fuseholder shall be used as field wiring terminals when they comply with the requirements of 15.2.3 and 15.2.4.

15.1.5 The location of an outlet box or compartment in which field wiring connections are to be made shall allow these connections to be inspected after the unit is installed as intended.

15.1.6 The connections shall be accessible without removal of parts other than service covers or panels and the cover of the outlet box or compartment in which the connections are made.

15.1.7 The free end of any lead that is not used in every installation shall be insulated, when that end reduces spacings below the minimum acceptable values.

15.1.8 Equipment (including auxiliary devices) that is not part of the duct heater, but that is supplied for field installation, shall have provision for field wiring connections as specified above, except that special connectors are used when both mating parts are provided and factory-attached to the equipment.

15.1.9 The surface of an insulated lead intended solely for the connection of an equipment grounding conductor shall be finished a continuous green, or a green with one or more yellow stripes. No other leads visible to the installer, other than grounding conductors, shall be so identified.

Exception No. 1: This requirement does not apply to leads or wiring that are intended to be field-connected to low-voltage circuits, and that are separated or segregated by barriers from field wiring connections in circuits exceeding 30 volts.

Exception No. 2: This requirement does not apply to internal wiring that is not visible in a field wiring compartment.

15.1.10 Control equipment, including an auxiliary device that is not part of the duct heater but is supplied with the product for field installation, shall have provision for field wiring connections as required by

Section 13, Connection to Power Supply, except that special connectors are used when both mating parts are provided, and factory-attached to the product or the auxiliary device.

15.2 High-voltage circuits

15.2.1 Duct heaters or remote control assemblies shall be equipped with wiring terminals or leads not less than 152 mm (6 inches) long for connection of field wiring conductors. The terminals or leads shall be intended for connection to a conductor having an ampacity of 125 percent of the rated current. When a single conductor larger than 500 kcmil would be required, the unit shall have provision for the connection of conductors in parallel. When a product is marked to indicate that it is intended for use with either copper, copper clad aluminum, or aluminum power supply conductors, a field wiring terminal shall comply with the requirement in 15.1.1 for a wire of each metal.

Exception: The rated current of the heater load is multiplied by 100 percent, rather than 125 percent, when:

a) The rated heater load at a field wiring terminal is 50 kilowatt or more;

b) The minimum conductor size that is field-connected to such terminal is marked; and

c) The heater element circuits connected to the field wiring terminals are subdivided as specified in 23.2.1 and are arranged to be controlled by one or more temperature-actuated devices to reduce the likelihood of continuous simultaneous operation of all of the element circuits.

Exception: Duct heaters with a rated heater load of less than 24 amperes shall have terminals or leads intended for connection to a 30 ampere branch circuit or shall be marked to indicate that the duct heaters are for use only on a 15 or 20 ampere branch circuit, whichever is appropriate.

15.2.2 A field wiring terminal or lead for the connection of a grounded conductor (identified conductor) shall be finished a white or gray. No other leads other than grounded conductors shall be so identified.

Exception: This requirement does not apply to:

a) Internal wiring that is not visible in a field wiring compartment; or

b) Terminals that are identified by a marking on the unit "WHITE" or equivalent.

15.2.3 When a wire binding screw is employed at a field wiring terminal intended for the connection of supply circuit conductors, it shall be not smaller than No. 8 screw size when the supply circuit conductors are 14 AWG, and not smaller than No. 10 screw size when the supply circuit conductors are 12 AWG or 10 AWG.

15.2.4 When conductors of the field wiring to be connected will be larger than 10 AWG, a field wiring terminal part shall either include a connector suitable for clamping the required conductors, or shall be suitable for use with such a connector or an appropriate soldering lug.

15.2.5 In determining the size of the power supply terminals or conductors required, unless the equipment is otherwise marked, supply conductors rated 75°C (167°F) are to be used.

15.2.6 Terminal parts for factory-installed conductors that are larger than 8 AWG shall include solderless connectors or soldering lugs, unless the suitability of the combination of terminal and conductor termination has been investigated.

15.2.7 For equipment intended for connection with two or more supply conductors in parallel per terminal, the terminals shall be of a size suitable for securing connectors that are intended for the termination of the conductors.

15.2.8 A field wiring terminal or lead shall be provided for connection of an equipment grounding conductor.

Exception: The equipment grounding terminal or lead may be omitted when all the following conditions are satisfied:

a) The rating of the product is such that the power supply conductors are likely to be larger than 2 AWG;

b) The construction is such that an acceptable terminal can be installed in the field, for example, the terminal can be secured as intended without a drilling or cutting operation upon installation, and sufficient space for the equipment grounding conductor is provided; and

c) The product is marked: "When this product is supplied by a wiring system that, in accordance with the National Electrical Code, ANSI/NFPA 70, requires the installation of an equipment grounding conductor or conductors, a terminal or terminals for connection thereof must be installed", or with an equivalent statement. This marking shall be located in the wiring compartment where the power supply conductors will be connected, and shall give adequate pertinent information, such as where the terminal or terminals should be mounted, how they should be mounted, and the like.

15.2.9 Each equipment grounding terminal or lead shall be located in the field wiring compartment, and shall be identified as specified in 15.1.9 or 15.2.13, as applicable.

15.2.10 When more than one circuit is intended to be connected to the unit, the terminals or leads provided for field connection of the equipment grounding conductor shall comply with the applicable requirements for connection of a separate grounding conductor for each circuit.

15.2.11 When provision is made for connection of two or more power supply conductors in parallel at each terminal, as mentioned in 15.2.1, provision shall be made for connection of an equal number of equipment grounding conductors.

15.2.12 The size of each grounding conductor shall comply with the applicable requirements for connection of an equipment grounding conductor as specified in Table 250-122 of the National Electrical Code, ANSI/NFPA 70, except that such a conductor need be no larger than one of the power supply conductors.

15.2.13 A wire binding screw intended for the connection of an equipment grounding conductor shall have a green colored head that is hexagonal shaped, slotted, or both. A pressure wire connector intended for connection of this conductor shall be identified by being marked "G", "GR", or the equivalent, or by being represented on a wiring diagram provided on the unit. The wire binding screw or pressure wire connector shall be located so that it does not need to be removed during servicing of the equipment. (Upturned lugs or the equivalent shall be provided at a wire binding screw to retain the conductor.) When a pressure connector is used adjacent to the connectors intended for the supply conductors involving the neutral of a grounded supply, a marking shall also be provided indicating "equipment ground" or the connector shall be identified by a green color.

15.2.14 The wiring compartment intended for connection of the power supply conduit or raceway shall be attached to the unit so that it is prevented from turning. This does not preclude the application of an outlet box, control box, or equivalent enclosure (to which the power supply connections are to be made) connected to the unit by factory wiring enclosed within a length of flexible metal conduit, providing conduit

fittings are applied. Unless the conduit is terminated in an outlet box no larger than 102 × 102 × 51 mm (4 × 4 × 2 inches) for the splice connections, locknuts on the fittings are not an acceptable means of preventing loosening of the conduit fittings. A grounding conductor of the size specified in 15.2.12 shall be included.

15.2.15 Except as indicated in 15.2.16, a field wiring lead shall be no more than two standard wire sizes smaller than the conductor to which it is connected.

15.2.16 The leads specified in 15.2.15 shall be more than two wire sizes smaller than the field when conductors to which they are connected (but not smaller than 18 AWG), when more than one factory-provided lead is intended for connection to the same field-provided lead wire, when:

a) The wire connector for the splice connection to the field-provided wire is provided as part of the unit, and the wire connector is acceptable for the combination of wires that are spliced;

b) A marking is included indicating that the provided wire connector is to be used for the field wiring splice connection; and

c) The factory-provided leads are grouped in a manner to prevent stress on an individual lead.

15.2.17 A lead provided for connection to an external circuit shall not be connected to a wire binding screw or pressure terminal connector located in the same compartment as the splice, unless:

a) The screw or connector is rendered unusable for field wiring connections; or

b) The lead is insulated at the unconnected end, and its intended use is clearly indicated (for example, on the applied wiring diagram).

15.2.18 A terminal plate for a wire binding screw shall be of metal not less than 0.76 mm (0.030 inch) thick for a conductor sized 14 AWG or smaller, and not less than 1.27 mm (0.050 inch) thick for a conductor larger than 14 AWG. In either case there shall be not less than two full threads engaging. (The terminal plate is extruded at the tapped hole to provide the two full threads.)

15.3 Low-voltage circuits

15.3.1 Leads for making connection to the low-voltage supply circuit shall be of adequate length.

15.3.2 Openings for the entry of conductors of an low-voltage circuit shall be provided with insulating bushings. The bushing shall be either mounted in place in the opening, or shall be packed within the enclosure for mounting when the unit is installed.

Exception: An insulating bushing need not be provided when:

a) A wiring assembly for Class 2 control is furnished with the equipment;

b) The edges of the opening will not abrade the insulation on the wiring assembly; and

c) The insulation between any conductor of the wiring assembly and edges of the opening is at least 1.2 mm (3/64 inch) thick.

15.3.3 In a Class 2 low-voltage safety circuit, when operation at the duct heater with a short circuit or a grounded circuit results in unsafe operation of the equipment, the terminals or leads provided for connection of field wired conductors shall comply with the applicable requirements for high-voltage circuit conductors.

Exception: Other means, such as quick-connect terminals or mating connectors, are utilized for field wiring connections of conductors of Class 2 low-voltage circuits when:

a) The connection means are part of a wiring assembly furnished with the equipment, or more than one type of identified wiring assembly is available from the equipment manufacturer and the equipment is marked at or near the connection point to specify the wiring assemblies to be used; and

b) The wiring assemblies do not require cutting, splicing, or similar alterations for field connection on the equipment; and

c) Installation instructions furnished with the equipment clearly indicate the use of the wiring assembly.

16 Internal Wiring

16.1 This section shall apply to both high-voltage circuits and low-voltage safety circuits, unless stated otherwise. Low-voltage nonsafety circuit wiring requirements are not specified.

16.2 Wireways shall be smooth and entirely free from sharp edges and burrs.

16.3 Only conductors having oil-resistant insulation shall be used where the conductors are exposed to oil, grease, oily vapor, or other substances having a deleterious effect.

16.4 Wiring shall have insulation rated for the potential involved and the temperatures to which it is subjected. Temperatures are to be judged on the basis of the temperatures measured during the applicable temperature tests specified in 28.1.

Exception: When it is determined that the wiring is not exposed to heat from radiating sources or heated components, and when the ampacity of the conductors is in accordance with Table 16.1, the temperature tests on the wiring is waived.

Table 16.1
Wiring materials ampacities

Wire size		Ampacity
AWG	mm^2	
22	0.41	4
20	0.66	7
18	0.82	10
16	1.3	13
14	2.1	18
12	3.3	25
10	5.3	30
8	8.4	40
6	13.3	55
4	21.2	70
2	33.6	95
1	42.4	110

Note – The ampacities shown apply to appliance wiring materials with insulation rated not less than 90°C (194°F). For types of wires other than appliance wiring materials, the ampacity shall be determined from Tables 310-16 and 310-17 in the National Electrical Code, ANSI/NFPA 70, for the type of wire employed. The correction factors of the referenced tables need not be applied.

16.5 Conductors shall be selected from Table 16.2 in accordance with the circuit requirements for conductor size, voltage, and temperature rating.

Table 16.2
Typical wiring material

Group	Type of wire, cord, or cable[a,b]	Wire size		Insulation thickness	
		AWG	mm^2	Inch	mm
A	Thermoplastic appliance wiring material, with insulation thicknesses shown at the right corresponding to wire sizes indicated; or Type AC, ACL, ACT, FFH-2, TF, TFF, TFN, TFFN, SF-2, SFF-2, RH, RHH, RHW, THW, XHHW, MTW, THW-MTW, THWN, PF, PGF, PFF, PGFF, TW	10 to 22	5.3 to 0.41	2/64	0.08
		8	8.4	3/64	1.2
		6	13.3	4/64	1.6
		4	21.2	4/64	1.6
		3	26.7	4/64	1.6
		2	33.6	4/64	1.6
		1	42.4	5/64	2.0
		1/0	54.0	5/64	2.0
		2/0	67.0	5/64	2.0
		3/0	85.0	5/64	2.0
		4/0	107.2	5/64	2.0
B	Appliance wiring material having thermoplastic or neoprene insulation, with insulation thicknesses shown at right corresponding to the wire sizes indicated; or cord Types S, SE, SO, SOO, ST, STO, STOO, SJ, SJE, SJO, SJOO, SJT, SJTO, SJTOO, SP-3, SPE-3, SPT-3	18	0.82	4/64	1.6
		16	1.3	4/64	1.6
		14	2.1	5/64	2.0
		12	3.3	5/64	2.0
		10	5.3	5/64	2.0
		8	8.4	6/64	2.4
		6	13.3	8/64	3.2
		4	21.2	9/64	3.6
		2	33.6	10/64	4.0
C	Appliance wiring material with rubber insulation; or Type S, SJ; or Type SP-3	Same as for Group B			

[a] The designated cord or cable, or types of wire other than appliance wiring material, is used without regard to the values specified in the table.

[b] Type CL wire is used within a separate metal enclosure as leads of components.

16.6 Wiring shall be enclosed in metal clad cable, conduit, electrical metallic tubing, or metal raceways, control boxes, or the equivalent. Required fittings shall be used. Wiring of the types referenced in Group B or C of Table 16.2 shall be employed in lieu of enclosed wiring, when the requirements of 16.7 are met.

Exception: Wiring of the types in Group A of Table 16.2 are employed when secured and supported to prevent damage and the requirements of 16.7 are met.

16.7 Cords or appliance wiring material, used in the cabinet of equipment, shall be enclosed so as to prevent damage to the wiring, ignition of combustible material, or emission of flame or molten metal through openings in the cabinet. Such wiring is enclosed when the cabinet or compartment enclosing the wiring has:

a) No openings in the bottom, unless a U-shaped channel or trough is located beneath the wiring, and the wires do not project through the plane of the top of the channel or trough. A bottom closure is provided when the bottom opening is always intended to be connected to a supply or return air duct;

b) No louvres or openings, other than duct openings, that permit the probe (Figure 6.1), when applied in a straight line, to contact wiring; and

c) No combustible material other than electrical insulation within the enclosure.

Exception: 16.7 (a) does not apply to wiring located above the openings in the bottom enclosure of a unit for outdoor installation, when such openings comply with the requirements of 16.8.

16.8 On a unit for outdoor installation, the bottom surface of the enclosure shall have openings, when all of the following conditions are met (applies only to hazardous voltage circuits):

a) Openings are less than 12.7 mm (1/2 in);

b) Such openings are not located within 152 mm (6 in) of each other; and

c) The total area of such openings does not exceed 1 percent of the area of the enclosure bottom surface, less any area below a component such as a finned tube coil or hermetic motor compressor that is mounted directly on that surface.

16.9 Thermoplastic or thermoset-insulated high-voltage wiring materials that are referenced in Group A of Table 16.2, and have an insulation thickness of 0.8 mm (2/64 inch) for sizes 16 AWG and 18 AWG, and 1.2 mm (3/64 inch) for sizes 14 AWG, 12 AWG, 10 AWG, and 8 AWG, are determined to be equivalent to the wiring materials referenced in Group B when the conductors are covered with thermoplastic or thermoset insulating tubing that has a wall thickness of 0.8 mm (2/64 inch) and is of a type rated for the purpose from the standpoint of electrical, mechanical, and flammability properties. For sizes 6 AWG, 4 AWG, and 2 AWG, thermoplastic or thermoset wiring materials that are referenced in Group A of Table 16.2 and enclosed in thermoplastic or thermoset tubing as described in this requirement are determined to be equivalent to the wiring materials specified in Group B when the total wall thickness (of the conductor insulation plus tubing) is not less than the value specified for Group B.

16.10 Wiring shall be protected against damage, shall be supported and routed to prevent damage due to contact with sharp edges, or parts that attain a temperature in excess of that for which the wiring insulation is rated, and shall not be immersed in water unless rated for use in wet locations. Self-draining raceways that do not retain water are not determined to require wiring for use in wet locations.

16.11 Splices in wiring shall be located, enclosed, and supported so that they are not subject to damage, flexing, motion, or vibration. A splice is determined to be enclosed when installed in a junction box, control box, or other enclosed compartment in which the wiring materials, as specified in Group A of Table 16.2, is employed. A splice in an enclosed machine compartment shall be secured to a fixed member in the compartment so that it is not subjected to movement or damage during servicing. A splice or unused lead shall be provided with insulation equivalent in thickness, voltage and temperature rating to that of the wires involved.

16.12 Stranded conductors at terminals shall be prevented from contacting other uninsulated live parts, which are not always of the same polarity as the wire, and from contacting dead metal parts. The shanks of terminal connectors shall be protected by insulating tubing, or equivalent, when the spacings specified in Section 26 are reduced by loosening the clamping means.

16.13 A hole in a wall or partition through which insulated wires or cords pass and on which they bear shall be provided with a smooth, rounded bushing or shall have a smooth, rounded surface upon which the wires or cords bear. The bushings, where required, shall be of ceramic, phenolic, cold-molded composition, fibre, or other like material. Thermoplastic or thermoset material shall not be clamped so as to cause cold-flow of the material that results in a risk of fire or electric shock.

16.14 Wiring which is subject to moisture, such as from an air conditioner evaporator coil, shall be of a type which is rated for use in moist locations.

17 Separation of Circuits

17.1 Unless having insulation suitable for the highest voltage involved, insulated conductors of different circuits (internal wiring, including wires in a junction box or compartment) shall be separated by barriers, or shall be segregated, and shall, in any case, be separated or segregated from uninsulated live parts connected to circuits of different voltages. Segregation of insulated conductors is accomplished by clamping, routing, or equivalent means that ensures permanent separation from insulated or uninsulated live parts of a different circuit.

17.2 There shall be provision for segregating or separating by barriers, field installed conductors of any circuit from field installed and factory installed conductors connected to any other circuit, unless the conductors of both circuits are or will be insulated for the maximum voltage of either circuit.

17.3 Within a compartment that is not a control enclosure junction box or its equivalent, field-installed low-voltage circuit conductors are segregated from factory-installed conductors of different circuits by locating field wiring openings, routing factory wiring, and locating electrical components, so that the factory conductors are maintained at least 127 mm (5 inches) from a line representing intended routing of the low-voltage conductors. The line is to allow for droop, and is to connect the opening provided for entrance of the low-voltage conductors to the terminals or leads to which the conductors are attached.

17.4 There shall be provision for segregating or separating by barriers field-installed conductors of a high-voltage circuit from:

a) Uninsulated live parts connected to a different circuit, other than wiring terminals; and

b) Any uninsulated live parts of electrical components such as a temperature-limiting device or other protective device where short circuiting or grounding results in unsafe operation of the equipment; except at wiring terminals.

17.5 There shall be provision for segregating or separating by barriers, field-installed conductors of a low-voltage circuit from:

a) Uninsulated live high-voltage circuits; and

b) Wiring terminals and any other uninsulated live parts of high-voltage electrical components such as a temperature-limiting device, or other protective device where short circuiting or grounding results in unsafe operation of the unit.

17.6 When a barrier is used to provide separation between the wiring of different circuits, it shall be of metal or of suitable insulating material of adequate mechanical strength, and reliably held in place.

17.7 A metal barrier shall be at least 0.66 mm (0.026 inch) thick when of uncoated steel, 0.74 mm (0.029 inch) thick when of galvanized steel, and 0.91 mm (0.036 inch) thick when of nonferrous metal. A barrier of insulating materials shall be not less than 0.71 mm (0.028 inch) thick, and shall be of greater thickness when its deformation is so readily accomplished as to defeat its purpose.

17.8 When the barrier is removable or has openings for the passage of conductors, it is acceptable provided that instructions for the use of the barrier are a permanent part of the device. In lieu of a barrier, complete instructions may be provided that, when used in conjunction with the wiring diagram, provides for the separation of the circuits of different voltages.

17.9 Field-installed conductors are segregated from other field-installed conductors and from uninsulated live parts connected to other circuits, by arranging the location of the openings in the enclosure for the various conductors, with respect to the terminals or other uninsulated live parts, so that conductors or parts of different circuits will not intermingle.

17.10 The output of a transformer device supplying a low-voltage circuit shall not be interconnected with the output of another such transformer device provided as a part of the equipment, unless the voltage and current measurements at the output terminals of the interconnected devices meet the definition of a Class 2 circuit (30 volts or less and 100 volt-amperes or less).

17.11 Two or more transformer devices supplying low-voltage circuits, and not more than 100 volt-amperes, and provided as a part of the equipment, shall be treated as separate circuits. When more than one such circuit is intended to be field-wired, the several circuits shall be segregated or separated by barriers as specified in 17.2, and the transformer output of each circuit shall be marked to warn that the separation shall be maintained.

18 Electrical Insulation

18.1 Material for the mounting of uninsulated high-voltage parts shall be heat-resistant, absorption resistant insulating material that is intended for its particular application, and that will withstand the most severe conditions that are encountered in service. Such materials include porcelain, phenolic composition, cold-molded composition, or a material having equivalent electrical and physical properties.

18.2 The acceptability of insulating materials shall include consideration of the following:

a) Mechanical strength;

b) Dielectric strength;

c) Insulation resistance;

d) Heat- and moisture-resistant properties;

e) The degree of enclosure or protection; and

f) Other factors that have a bearing on the risk of fire or electric shock under conditions of intended use.

19 Grounding and Bonding

19.1 An exposed dead metal part that becomes energized shall be bonded to the point of connection of the equipment grounding terminal or lead, and to the metal surrounding the knockout, hole, or bushing provided for field power supply connections.

19.2 Except as required in 19.3, uninsulated dead metal parts of cabinets, electrical enclosures, control mounting brackets, and electrical components, shall be bonded for grounding when contact by the user or by a service person during servicing of the equipment is possible.

19.3 Metal parts, as indicated below, need not comply with the requirements of 19.1 and 19.2:

a) An adhesive attached part such as a metal foil marking, a screw, or a handle that is located on the outside of an enclosure or cabinet and is isolated by grounded metal parts from electrical components or wiring so that it cannot become energized;

b) An isolated metal part, such as a small assembly screw that cannot come in contact with wiring and uninsulated live parts;

c) A panel or cover that does not enclose uninsulated live parts, when wiring cannot come in contact with the panel or cover so that the panel or cover cannot become energized; and

d) A panel or cover that is insulated from electrical components and wiring by a barrier of vulcanized fibre, varnished cloth, phenolic composition, or similar material not less than 0.8 mm (2/64 inch) thick, and that is secured in place.

19.4 The bonding shall be by a positive means, such as by clamping, riveting, brazing, welding, or making a bolted or screwed connection. The bonding connection shall penetrate nonconductive coatings, such as paint. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

19.5 A bolted or screwed connection that incorporates a star washer or serrations under the screwhead complies with the requirements for penetrating nonconductive coatings in 19.4.

19.6 The use of two or more screws, or two full threads engagement of a single screw in metal, complies with 19.4 when the bonding means depends upon screw threads.

19.7 Metal-to-metal hinge bearing members for doors or covers are determined to be means of bonding the door or cover for grounding when a multiple bearing pin type (piano type) hinge is used.

19.8 The size of a copper or aluminum conductor employed to bond an electrical enclosure shall be based on the rating of the branch circuit overcurrent device by which the equipment is protected. Except as noted below, the size of the conductor shall be as specified in 15.2.12. When a clamp or strap is used in place of a conductor the cross sectional area shall be no less than that of the wire required by 15.2.12.

19.9 A bonding conductor to an electrical component need not be larger than the conductor supplying the component.

19.10 Bonding conductors in equipment shall have insulation equivalent to that of live conductors, when there is any likelihood of accidental contact with uninsulated live parts.

19.11 Splices shall not be employed in wire conductors used for bonding.

19.12 When more than one size branch circuit overcurrent device is involved, the size of the bonding conductor shall be based on the rating of the overcurrent device intended to provide ground fault protection for the component bonded by the conductor. For example, when an electrical component is individually protected by a branch circuit overcurrent device smaller than other overcurrent devices used with the equipment, a bonding conductor for that component shall be sized on the basis of the overcurrent device intended for ground fault protection of the component.

20 Mounting of Components

20.1 Electrical components (for example, switches, fuseholders, lampholders, attachment plug receptacles) shall be mounted securely, and except as permitted by 20.2, shall be prevented from turning. High-voltage or safety circuit (see 24.3) electrical parts shall not be attached to removable covers. Friction between surfaces is not acceptable as the sole means of preventing shifting or turning of a live part, but a properly applied lock washer is acceptable.

20.2 The requirement that a switch be prevented from turning is waived when the following conditions exist:

a) The switch is of a plunger or other type that does not tend to rotate when operated;

b) The means for mounting the switch is not subject to loosening as the result of operation of the switch;

c) Spacings are not reduced below the minimum required values by rotation of the switch; and

d) Rotation of the switch cannot apply strain on the conductors or their terminal connections.

20.3 Fuseholders shall comply with the Standard for Safety Fuseholders – Part 1: General Requirements, UL 4248-1, and the Standard for Safety Fuseholders – Part 4: Class CC, UL 4248-4 or the:

a) Standard for Safety Fuseholders – Part 5: Class G, UL 4248-5; or

b) Standard for Safety Fuseholders – Part 6: Class H, UL 4248-6; or

c) Standard for Safety Fuseholders – Part 8: Class J, UL 4248-8; or

d) Standard for Safety Fuseholders – Part 9: Class K, UL 4248-9; or

e) Standard for Safety Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse, UL 4248-11; or

f) Standard for Safety Fuseholders – Part 12: Class R, UL 4248-12; or

g) Standard for Safety Fuseholders – Part 15: Class T, UL 4248-15; or

h) Outline of Investigation for Fuseholders – Part 17: Class CF, UL 4248-17.

21 Switches and Fan Controllers

21.1 A contactor, time-delay relay, or similar device, such as a silicon controlled rectifier, that controls a fan or blower motor shall comply with the requirements for a fan control as given in the Standard for Limit Controls, UL 353; or the Standard for Automatic Electrical Controls, Part 1: General Requirements, UL 60730-1 and the Standard for Automatic Electrical Controls, Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

21.2 When the handle of a single throw switch is operated vertically, the “on” handle position shall be the up position.

21.3 A switching device that interrupts the main power supply circuit to a heater shall be on the supply side of any fuses in the heater and shall be such that, when opened, the device will disconnect all ungrounded conductors of the power supply circuit when the switching device itself (or the pilot device that controls the switching device) has a marked on or off position.

21.4 Control equipment, including transformers, and heaters, when located within the discharge or return air space, shall be so designed, enclosed, or protected that dense smoke will not be generated or flame emitted under any conditions that occur in service.

21.5 A duct heater shall have terminals or leads for field connection of an interlock circuit for a circulating fan motor unless an airflow interlock is provided as an integral part of the heater and arranged so that no heating element circuit can be energized unless the interlocking contacts are closed or the interlocking power supply energized. This does not preclude the use of a fan delay control that complies with the applicable requirements for a fan control.

21.6 A component, such as a pilot light or resistor shall not be connected across the contact terminals of a safety control, such as a temperature-limiting control, unless the reliability of the component not to bypass the safety control can be determined.

21.7 A contact or similar device, such as a silicon controlled rectifier, actuated by a limit control shall comply with the requirement for a limit control when it is a part of the limit-control circuit.

21.8 A contactor or similar device, such as a silicon controlled rectifier, required for use with a limit control shall be provided by the manufacturer of the heater, but need not be mounted on the heater. See 45.1.7.

21.9 A low-temperature setting on a thermostat shall not be identified as a true off position and shall not be so marked unless the thermostat does not reclose when cooled to a temperature of minus 35°C (minus 31°F).

21.10 When an auxiliary control device, such as a thermostat, or a combination thermostat and control switch in a duct heater or remote control assembly has a marked on or off position, or is marked with another wording or symbol, such as “NO HEAT”, “COLD”, “O”, or similar wording that conveys the same meaning as off, it shall disconnect the element or elements and controls from all ungrounded conductors of the supply circuit when placed in that position. This requirement applies to a thermostat in a remote control assembly that is referred to on the product nameplate, but does not apply to a remote auxiliary control device in a Class 2 circuit such as a room thermostat.

21.11 An auxiliary control is determined to be one that is intended primarily for regulating time, temperature, or equivalent, under conditions of intended operation, but is not intended for protection against overload or excessive temperature conditions, or equivalent.

21.12 Clock-operated switches shall comply with the Standard for Clock-Operated Switches, UL 917.

21.13 Enclosed and dead-front switches shall comply with the Standard for Enclosed and Dead-Front Switches, UL 98.

21.14 General-use snap switches shall comply with the Standard for General-Use Snap Switches, UL 20.

21.15 Special-use switches shall comply with the Standard for Special-Use Switches, UL 1054.

21.16 Switches for duct heaters shall comply with the Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1.

21.17 Programmable controllers shall comply with the Standard for Programmable Controllers – Part 2: Equipment Requirements, UL 61131-2.

22 Transformers

22.1 Transformers intended for supplying power to low-voltage circuits shall be such that there is no electrical connection, other than by electromagnetic induction, between the low-voltage circuit and the primary circuit.

22.2 A transformer, or combination of transformer and fixed impedance, as the source of supply of a low-voltage circuit, and intended for connection to Class 2 open wiring, shall be subjected to an output test with the primary energized at full rated voltage. Under any noncapacitive conditions of loading from no load to the short circuiting of any or all secondary (low-voltage) installation wiring terminals, and without disturbing internal connections, the secondary output current shall be not greater than that required for a Class 2 transformer.

22.3 A transformer (including an autotransformer), other than that described in 22.9 and 22.10 shall:

a) Be provided with thermal overload protection in accordance with the requirements of 22.5; or

b) Be protected by an overcurrent device in accordance with the requirements of 22.6; or

c) Comply with the Transformer Burnout Test, Section 39.

Exception: A transformer rated less than 50 volt-amperes that supplies only a motor control circuit and is located in the same enclosure as the motor controller need not comply with this requirement.

22.4 When a transformer (with a high-voltage primary circuit) incorporates a thermal overload protective device, the device shall be arranged to interrupt primary current, and shall limit the temperatures of the transformer windings, under overload conditions, to those required by the particular class of insulation of the transformer windings.

Exception: When the thermal overload protective device is a nonrenewable thermal cutoff, a burnout test rather than an overload test shall be conducted to determine compliance with this requirement.

22.5 A thermal cutoff shall comply with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691. A manual or automatic resetting thermal protector shall have an endurance rating of not less than 6000 cycles and shall comply with the Standard for Temperature Indicating and Regulating Equipment, UL 873, or shall be a type-2 action thermal cut-out, as specified in the Standard for Automatic Electrical Controls, Part 1: General Requirements, UL 60730-1 and the Standard for Automatic Electrical Controls; Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

22.6 When a transformer having a high-voltage primary is protected by an overcurrent device, such protection shall comply with the requirements specified in 22.7, 22.8, 22.11, and 22.13.

22.7 Except as noted in 22.8, a transformer having a high-voltage primary shall be protected by an overcurrent device (or devices) located in the primary circuit, and rated or set as indicated in Table 22.1. See 22.11.

Exception: When the rated primary current of the transformer is 9 amperes or more, and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device is used.

Table 22.1
Rating of overcurrent device

Rated primary current, A	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300[a]
2 or more, less than 9	167
9 or more	125

[a] Does not apply to an autotransformer; is increased to 500 percent when transformer supplies a motor control circuit.

22.8 When the circuit supplying a transformer other than an auto transformer is provided with overcurrent protection rated or set at not more than 250 percent of the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit, when the secondary circuit is protected at not more than 125 percent of the rated secondary current of the transformer. See 22.12.

Exception No. 1: When the rated secondary current of the transformer is 9 amperes or more, and 125 percent of this current does not correspond to a standard rating of fuse or circuit breaker, the next higher standard rating of protective device is used in the secondary circuit.

Exception No. 2: When the rated secondary current of the transformer is less than 9 amperes, the overcurrent device (or devices) in the secondary circuit is rated or set at not more than 167 percent of the rated secondary current.

22.9 Except as indicated in 22.10, a transformer having a rated output of not more than 30 volts and 100 volt-amperes shall be protected by an overcurrent device located in the primary circuit. The overcurrent device shall be rated or set at not more than 167 percent of the primary current rating of the transformer. See 22.11.

22.10 When the transformer is Class 2, compliance with 22.9 is not required.

22.11 Overcurrent protection in the primary circuit of a transformer, as described in 22.7 and 22.9, need not be provided when, based on the marked ratings of the equipment, the rating of the branch circuit overcurrent protective device does not exceed the values specified in 22.7 or 22.9, as applicable.

22.12 Overcurrent protection in the secondary circuit of a transformer, as required by 22.8, shall be provided as part of the equipment.

22.13 A required transformer overcurrent protective device shall be provided as specified in 24.7.

22.14 With reference to 22.13, the fuses need not be provided when the fuseholder is factory-installed in the product and when the fuse ratings are marked as specified in 46.3(a).

22.15 The secondary of a transformer supplying power to low-voltage circuits shall be grounded when (see 24.4):

a) The primary is energized from a source rated at more than 150 volts-to-ground; or

b) It supplies power to a control circuit that is a safety circuit.

22.16 General-purpose transformers shall comply with the Standard for Low Voltage Transformers: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers: General Purpose Transformers, UL 5085-2.

22.17 Class 2 and Class 3 transformers shall comply with the Standard for Low Voltage Transformers: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers: Class 2 and Class 3 Transformers, UL 5085-3.

Exception: Transformers located in a low voltage circuit, and that do not involve a risk of fire or personal injury, need not comply with this requirement.

22.18 Specialty transformers shall comply with the Standard for Specialty Transformers, UL 506.

23 Electric Heaters

23.1 General

23.1.1 A heating element shall be supported in its intended position in a substantial and reliable manner and shall be protected against mechanical injury and contact with outside objects. In determining when a

heating element complies with this requirement, consideration is to be given to sagging, loosening, and other similar conditions resulting from:

a) Continuous heating of the element; and

b) Flexing of the element supports or related wiring due to alternate heating and cooling of the element.

23.1.2 Heating elements shall be so supported that, even when heaters are subjected to extreme conditions of operation, including the tests specified in Section 32, short circuits cannot occur between turns, between sections of the heating elements, or between uninsulated live parts and noncurrent-carrying metal parts, and the spacings of Table 26.1 and Table 26.2 are maintained.

23.1.3 Coiled wire heating elements are not prohibited from being supported on porcelain, hook type insulators depending upon the stiffness of the coil, the spacing between hooks, and the shape of the hook, or similar factors. Porcelain insulators of all types will be required to be retained in place by means other than the heating element.

23.1.4 Heating elements shall be securely fastened to terminals (under the heads of terminal binding screws) in such a manner that the wire does not become loosened during the lifetime of the heater.

23.2 Overcurrent protection

23.2.1 A duct heater employing resistance type heating elements shall be protected at not more than 60 amperes, and the protected circuit shall not have a concurrent load exceeding 48 amperes. These heating elements shall be connected in protected subdivided circuits when any total concurrent load of the unit exceeds 48 amperes based on nameplate ratings. When the overcurrent protective devices are in a separate assembly for independent mounting, as described in 23.2.2, the rating of the overcurrent protective devices also shall not exceed 1.5 times the current rating of the connected load, when such rating is more than 13.3 amperes.

Exception: When a heater assembly is provided with means for field connection to a power supply for only the resistance type elements, with or without their control circuit, in a wiring enclosure having a separate cover and physically separated from the power supply for other loads, the rating of the other loads need not be considered in applying this requirement.

23.2.2 The overcurrent protective devices for subdivided circuits, as required by 23.2.1, shall be provided by the product manufacturer as a separate assembly for independent mounting when not provided in the duct heater.

23.2.3 The overcurrent protection specified in 23.2.1 and 23.2.2 shall be circuit breakers, cartridge fuses, or Type S plug fuses, of a type and rating appropriate for branch circuit protection, in accordance with the requirements of the National Electrical Code, ANSI/NFPA 70. Plug fuses shall not be used in circuits exceeding 150V to ground; screw shells of plug fuses shall be connected to the load side of the circuit.

23.3 Heater controls

23.3.1 A duct heater shall be equipped with one or more automatically resetting temperature-limiting controls, as determined by 23.3.3, that will disconnect the heating element or elements from the supply circuit to prevent temperatures from exceeding the limits specified in Table 28.2. These temperature-limiting controls shall be factory-installed as an integral part of the heater.

23.3.2 The temperature-limiting controls shall comply with the applicable requirements of the Standard for Limit Controls, UL 353, or shall be a type-2 action thermal cut-out, as specified in the Standard for

Automatic Electrical Controls, Part 1: General Requirements, UL 60730-1 and the Standard for Automatic Electrical Controls, Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

23.3.3 The number of automatic reset limit controls provided in a duct heater, or in several duct heaters mechanically fastened together to form a larger unit, shall be the larger of the values determined by applying (a) and (b):

a) One control for each equal size module. The number of modules is equal to the product of X and Y. See Table 23.1 and 23.3.5 and 23.3.6.

b) One control for the first 150 kilowatts or less of the rating of the heater, plus an additional control for each additional 150 kilowatts or less.

Table 23.1
X and Y

Depth				Length			
Inches				Feet			
More than	No more than	(mm)	X	More than	No more than	(m)	Y
0	40	(0 – 1016)	1	0	10	(0 – 3.05)	1
40	80	(1016 – 2032)	2	10	20	(3.05 – 6.10)	2
80	120	(2032 – 3048)	3	20	30	(6.10 – 9.15)	3
120	160	(3048 – 4572)	4				
160	200	(4572 – 5080)	5				
200	240	(5080 – 6096)	6				

23.3.4 The position of the sensing element of each control, relative to the heating element or elements to which it is primarily intended to respond, is to be identical in each module.

23.3.5 With reference to Table 23.1 unless otherwise defined by the required markings, depth and length signify, respectively, the shorter and the longer dimensions of the rectangular assembly of the heating element proper in a direction perpendicular to the airflow during operation.

23.3.6 When the depth of the heater is greater than 6096 mm (240 inches) and/or length greater than 9.15 m (30 feet), the values of X and Y are determined from the following formulas, except that when the resulting quotient is not an integer, the next higher integer is to be used for value of X and/or Y. The terms in parentheses are to be used for metric values.

$$X = \frac{Inches \quad (mm)}{40 \quad (1016)} \qquad Y = \frac{Feet \quad (m)}{20 \quad (3.05)}$$

23.3.7 A safety control or a temperature-limiting control intended to prevent heater operation that results in risk of fire, electric shock, or injury to persons, shall be operative whenever the heater is connected to its power supply, and shall interrupt operation of a sufficient number of heating elements to prevent temperatures from exceeding applicable temperature limits.

23.3.8 The temperature-limiting control shall interrupt the power supply to the heater by direct means or by means of a single magnetically operated relay device or contactor that complies with the requirements for the endurance test for the limit control.

23.3.9 A duct heater shall be provided with one or more manually resettable or replaceable backup protective devices of the type specified in 23.3.7 that, with the contacts of the automatically reset limit control permanently closed, limit the temperatures to comply with the requirements specified in the Backup Protection Tests, Section 33.

23.3.10 The manually resettable or replaceable protective devices specified in 23.3.9 shall be functionally independent of the automatically reset limit control. The following types of controls comply with this requirement:

a) One or more thermal cutoffs, nonresettable limit controls, or manually resettable limit controls connected to open a sufficient number of ungrounded conductors to permit the unit to comply with the specified temperature limits.

b) A combination consisting of one or more normally open magnetic contactors and thermal cutoffs, nonresettable limit controls, or manually resettable limit controls. The thermal cutoff or limit control shall be connected in the coil circuit of the contactor. The combination shall be integral with the product; be able to open a sufficient number of ungrounded supply conductors to permit the product to comply with the specified temperature limits; and be independent of control by an automatic cycling device with the unit.

23.3.11 A thermal cutoff or nonresettable limit control shall be secured in place and located so that it accessible for replacement without damage to other connections or internal wiring, in compliance with 23.3.13 and 23.3.15.

23.3.12 A thermal cutoff or nonresettable limit control shall comply with the requirements of the Backup Protection Tests, specified in Section 33.

23.3.13 Replacement of a thermal cutoff or nonresettable limit control shall not necessitate any of the following:

a) Removal of the duct heater assembly from its installation, except as specified in 23.3.14;

b) Disconnection of the field wiring systems;

c) Stretching or similar displacement of the heater element wire that causes permanent displacement or distortion to the extent that the performance of the heater is affected; or

d) Release of the heater element wire from its attachment when this results in displacement of the element.

Exception: A thermal cutoff or nonresettable limit control that is not required in order to comply with any of the requirements in this standard need not comply with (a) and (b).

23.3.14 With reference to the requirements of 23.3.13(a), removable heating elements or an element assembly shall be withdrawn, or a heater shall be partially withdrawn, to replace a thermal cutoff or nonresettable limit control, when withdrawal will not result in noncompliance with the requirements of 23.3.13 (b), (c), and (d).

23.3.15 Wiring connected to a thermal cutoff or nonresettable limit control shall be secured so that replacement of the thermal cutoff or nonresettable limit control will not result in displacement or disturbance of internal wiring other than leads to the cutoff or limit control, or leads to a heating element assembly on which the cutoff or limit control is mounted.

23.3.16 A thermal cutoff or nonresettable limit control shall not function during any test performed on a product employing electric heaters, when the automatically resettable limit control is connected in the circuit.

23.3.17 Sequence controls, such as thermal relays or mechanical step controls, used to control one or more sections of the heater element load, shall be able to withstand 100,000 cycles of making and breaking the load controlled, unless the unit withstands required tests without sequence controls.

23.3.18 Mercury or magnetic contactors used on open coil electric duct heaters shall break all ungrounded conductors. Phase break on three phase heaters shall not be permitted. Where silicon controlled rectifiers (SCR's) are used, the safety contactor shall break all ungrounded conductors. This requirement does not apply to sheathed type electric duct heaters.

23.3.19 Motor starters shall comply with the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1 and the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

23.4 Duct heaters employed in ductwork or plenums that may contain A2L flammable refrigerants employed in the air conditioning system

23.4.1 Duct heaters which may be exposed to leakage of A2L refrigerants shall be permitted to exceed the 700°C element surface temperature, during the tests of Section 29, Power Input, when one of the following requirements are met:

a) The indoor fan is provided with a fan failure switch capable of detecting that the fan is not operating as intended.

b) The heat source cannot be energized if the fan failure switch detects that the fan is not operating as intended; and

c) Airflow through the heating source greater than 1.02 m/s (200 fpm).

23.4.2 If a refrigerant detection system input is provided which de-energizes the heat source when a leak is detected a fan failure switch is not required.

24 Control Circuits

24.1 For the purpose of these requirements, a direct connected, high-voltage control circuit is one that is supplied from a branch circuit separate from a branch circuit that supplies other loads within the equipment. It is not tapped from the load side of the overcurrent device of the controlled circuits within the equipment.

24.2 For the purpose of these requirements, a control circuit is one that carries electric signals directing the performance of a controller which, in turn, governs power delivered to a load in the equipment. A control circuit does not carry main power current. A tapped, high-voltage control circuit is one that is tapped within the equipment from the load side of the overcurrent device for the controlled load.

24.3 A control circuit is determined to be a safety circuit when it includes contacts of any controls integral with, or external to, the equipment that are intended to prevent unsafe operation of the equipment due to circuit wiring becoming grounded, open circuited, or short circuited, such as a temperature limit switch, the failure of which to operate results in an unsafe operation.

24.4 In a control circuit that is a safety circuit, the contacts of a safety device shall be connected in the ungrounded side of the control circuit. When the control circuit is derived from an external voltage source the control circuit shall either:

a) Be grounded within the unit; or

b) Be marked to caution that the side of the control circuit employing the safety device shall not be grounded.

24.5 Conductors of high-voltage control circuits shall be provided with overcurrent protection. The rating of the overcurrent protective device or devices shall not exceed the applicable values specified in Table 24.1.

Exception No. 1: Conductors of 18 AWG, 16 AWG, and 14 AWG, that do not exceed 1.2 m (4 feet) in length between points of opposite polarity shall be protected by overcurrent protective devices rated 60 amperes or less.

Exception No. 2: An overcurrent protective device of a higher rating is used when the conductors withstand short-circuiting when tested as specified in the Short-Circuit Test, Section 37.

Exception No. 3: A lead, 305 mm (12 inches) or less in length need not be provided with overcurrent protection.

Exception No. 4: A control circuit conductor, supplied from the secondary of a single-phase transformer that is connected so that only a two-wire (single voltage) secondary is used, shall be protected by an overcurrent device located on the primary side of the transformer, when this protection is in accordance with requirements specified in Section 22, Transformers, and that the rating of the device does not exceed the applicable values specified in Table 24.1 multiplied by the ratio of secondary to primary rated transformer voltage.

Exception No. 5: A control circuit conductor that is tapped from the main power circuit at a point outside of the control equipment enclosure shall be protected as specified in Column A of Table 430-72(b) of the National Electrical Code, ANSI/NFPA 70. The correction factors of the referenced tables need not be applied.

Table 24.1
Overcurrent protective device rating for control circuit conductors

Tapped control-circuit conductor size, AWG (mm^2)		Maximum rating of overcurrent protective device, amperes			
		Conductors contained in control equipment enclosure equipment		Conductors extending beyond control enclosure	
		Copper	Aluminum[a]	Copper	Aluminum[a]
18	(0.82)	25	–	5	–
16	(1.3)	40	–	10	–
14	(2.1)	100	–	45	–
12	(3.3)	120	100	60	45
10	(5.3)	160	140	90	75
Larger than 10		b	b	c	c

[a] Includes copper-clad aluminum.

[b] 400 percent of value specified for 60°C conductors in Table 310-17 of the National Electrical Code, ANSI/NFPA 70. The correction factors of the referenced Table need not be applied.

[c] 300 percent of value specified for 60°C conductors in Table 310-16 of the National Electrical Code, ANSI/NFPA 70. The correction factors of the referenced Table need not be applied.

24.6 Overcurrent protection for a conductor of a high-voltage control circuit, as required by 24.5, shall be provided as part of the equipment, when, based on the marked rating of the equipment, the rating of the branch circuit overcurrent protective device exceeds the applicable values specified in Table 24.1.

Exception: When the unit employs a direct-connected high-voltage circuit, and the overcurrent protective devices are not provided as part of the unit, the unit shall be marked to specify the maximum size of overcurrent device for the unit. The type of overcurrent protection shall be specified in the marking.

24.7 Overcurrent protective devices shall be provided for all ungrounded conductors, and have a voltage rating not less than the circuits in which they are used. The devices shall be either a circuit breaker that provides branch circuit protection or a fuse that provides branch circuit protection such as Class CC, CF, G, H, J, K, L, R, or T, or a Type S plug fuse.

Exception: When the control circuit is tapped from a circuit supplying other loads in the equipment, a device used for overcurrent protection is not prohibited from being of the supplementary type (a type other than indicated for branch circuit protection provided the fuse has a short circuit rating as specified in Table 37.1), when it has a short circuit rating acceptable for the circuit in which it is used. See 46.3 for fuse replacement marking.

24.7.1 Fuses shall comply with the Standard for Safety Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; and the Standard for Safety Low-Voltage Fuses – Part 4: Class CC Fuses, UL 248-4, or the:

a) Standard for Safety Low-Voltage Fuses – Part 5: Class G Fuses, UL 248-5; or

b) Standard for Safety Low-Voltage Fuses – Part 6: Class H Non-Renewable Fuses, UL 248-6; or

c) Standard for Safety Low-Voltage Fuses – Part 8: Class J fuses, UL 248-8; or

d) Standard for Safety Low-Voltage Fuses – Part 9: Class K fuses, UL 248-9; or

e) Standard for Safety Low-Voltage Fuses – Part 11: Plug Fuses, UL 248-11; or

f) Standard for Safety Low-Voltage Fuses – Part 12: Class R Fuses, UL 248-12; or

g) Standard for Safety Low-Voltage Fuses – Part 15: Class T Fuses, UL 248-15; or

h) Outline of Investigation for Low-Voltage Fuses – Part 17: Class CF Fuses, UL 248-17.

24.7.2 Circuit breakers shall comply with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception: Circuit breakers used in telecommunications circuitry that comply with the Standard for Circuit Breakers For Use in Communications Equipment, UL 489A, need not comply with UL 489.

24.7.3 Circuit breakers having integral ground fault circuit interrupter capability for protection against electrical shock shall additionally comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943.

24.8 Where the equipment has part of a control circuit included within it, and is intended to have the circuit completed at the time of installation by external wiring to a safety device located outside the equipment, the equipment shall be marked to show that the external wiring is to comply with the requirements for a Class 1 circuit.

24.9 Control circuit devices shall comply with the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1 and the Standard for Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches, UL 60947-5-2.

24A Controls

24A.1 End product test parameters

24A.1.1 Spacings of controls shall comply with the electrical spacing, or clearances and clearance distance requirements of the applicable control standard as determined in Section 3.8.

24A.1.2 Where reference is made to declared deviation and drift, this indicates the manufacturer's declaration of the control's tolerance before and after certain conditioning tests.

24A.2 Auxiliary controls

24A.2.1 Auxiliary controls shall not introduce a risk of electric shock, fire, or personal injury hazard.

24A.2.2 Auxiliary controls shall comply with the requirements of this end product standard.

Exception: An auxiliary control that complies with a component standard(s) specified in Section 3.8 is considered to fulfill this requirement.

24A.3 Operating controls (regulating controls)

24A.3.1 The following test parameters shall be among the items considered when judging the acceptability of an operating control investigated using UL 60730-1. Appendix A provides more examples of controls intended to be used as operating controls:

a) Control action Types 1 or 2;

b) Unless otherwise specified manual and automatic controls shall be tested for 6,000 cycles with under maximum normal load conditions, and 50 cycles under overload conditions;

c) Installation class 2 per IEC 61000-4-5;

d) For the applicable Overvoltage Category, see Table 24A.1;

e) For the applicable Material Group, see Table 24A.2;

f) For the applicable Pollution Degree, see Table 24A.3.

Table 24A.1
Overvoltage categories

Equipment	Overvoltage category
Intended for fixed wiring connection	III
Portable and stationary cord-connected	II
Control located in low-voltage circuit	I
NOTE – Applicable to low-voltage circuits if a short circuit between the parts involved may result in operation of the controlled equipment that would increase the risk of fire or electric shock.	

Table 24A.2
Material group

CTI PLC value of insulating materials	Material group
CTI ≥ 600 (PLC = 0)	I
CTI ≥ 400 < 600 (PLC = 1)	II
CTI ≥ 175 < 400 (PLC = 2 or 3)	IIIa
CTI ≥ 100 < 175 (PLC = 4)	IIIb
NOTE – PLC stands for Performance Level Category, and CTI stands for Comparative Tracking Index as specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.	

Table 24A.3
Degrees of pollution

Duct heater control microenvironment	Pollution degree
No pollution or only dry, nonconductive pollution. The pollution has no influence. Typically hermetically sealed or encapsulated control without contaminating influences, or printed wiring boards with a protective coating can achieve this degree.	1
Normally, only nonconductive pollution. However, a temporary conductivity caused by condensation may be expected. Typically indoor duct heaters for use in household or commercial clean environments achieve this degree.	2
Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation that is expected. Typically controls located near and may be adversely affected by motors with graphite or graphite composite brushes, or outdoor use duct heaters achieve this degree.	3

24A.3.2 The following test parameters shall be among the items considered when judging the acceptability of an operating control investigated using other than UL 60730-1. Appendix A provides more examples of controls intended to be used as protective controls:

a) Control action Types 1 or 2;

b) Unless otherwise specified manual and automatic controls shall be tested for 6,000 cycles with under maximum normal load conditions, and 50 cycles under overload conditions;

c) Installation class 2 per IEC 61000-4-5;

d) For the applicable Overvoltage Category, see Table 24A.1;

e) For the applicable Material Group, see Table 24A.2;

f) For the applicable Pollution Degree, see Table 24A.3.

24A.4 Protective controls (limiting controls)

24A.4.1 An electronic control that performs a protective function shall comply with the requirements in Section 3.8 while tested using the parameters in this section. Examples of protective controls are: a control used to sense abnormal temperatures of components within the duct heater; temperature protection of the motor due to locked rotor, running overload, loss of phase; or other function intended to reduce the risk of electric shock, fire, or injury to persons.

24A.4.2 The following test parameters shall be among the items considered when judging the acceptability of an electronic protective control investigated using UL 60730-1:

a) Failure-Mode and Effect Analysis (FMEA) or equivalent risk analysis method;

b) Power Supply Voltage Dips, Variation and Interruptions within a temperature range of 10°C and the maximum ambient temperature determined by conducting the Normal Temperature Test; see Section 28;

c) Surge immunity test – installation class 3 shall be used;

d) Electrical fast transient/burst test, a test level 3 shall be used;

e) Electrostatic Discharge Test;

f) Radio-frequency electromagnetic field immunity:

1) Immunity to conducted disturbances – When applicable, test level 3 shall be used; and

2) Immunity to radiated electromagnetic fields; field strength of 3 V/m shall be used;

g) Thermal Cycling test of clause H.17.1.4.2 shall be conducted at ambient temperatures of 10 ±2° C (50 ±4°F) and the maximum ambient temperature determined by conducting the Normal Temperature Test; The test shall be conducted for 14 days; and

h) Overload shall be conducted based on the maximum declared ambient temperature (T_{max}) or as determined by conducting the Normal Temperature Test;

i) If software is relied upon as part of the protective electronic control, it shall be evaluated as software class B.

24A.4.3 The test parameters and conditions used in the investigation of the circuit covered by Clause 24A.4.1 shall be as specified in UL 991, using the following test parameters:

a) With regard to electrical supervision of critical components, for attended duct heaters, a motor operated system becoming permanently inoperative with respect to movement of an exposed portion of the appliance meets the criteria for trouble indication. For unattended duct heaters, electrical supervision of critical components may not rely on trouble indication;

b) A field strength of 3 V per meter is to be used for the Radiated EMI Test;

c) The Composite Operational and Cycling Test is to be conducted for 14 days at temperature extremes of 0°C (32°F) and 70°C (158°F);

d) The Humidity Class is to be based on the appliance's intended end use and is to be used for the Humidity Test;

e) A vibration level of 5 g is to be used for the Vibration Test;

f) When a Computational Investigation is conducted, lp shall not be greater than X failures/106 hours for the entire system. The Operational Test is to be conducted for 14 days;

g) When the Demonstrated Method Test is conducted, the multiplier for the test acceleration factor is to be 576.30 for intermittent use appliances, or 5763.00 for continuous use appliances. The test acceleration factor equation is to be based on a 25°C (77°F) use ambient;

h) The Endurance Test is to be conducted concurrently with the Operational Test. The control shall perform its intended function while being conditioned for 14 days in an ambient air temperature of 60°C (140°F), or 10°C (18°F) greater than the operating temperature of the control, whichever is higher. During the test, the control is to be operated in a manner representing normal use;

i) For the Electrical Fast Transient Burst Test, test level 1 is to be used;

j) Conduct a failure-mode and effect analysis (FMEA); and

k) If software is relied upon as part of the protective electronic control, it shall be evaluated as software class 1 in accordance with the Standard for Software in Programmable Components, UL 1998.

24A.4.4 Unless otherwise specified, protective controls shall be evaluated for 100,000 cycles for Type 2 devices, and 6,000 cycles for Type 1 devices, with rated current.

24A.5 Controls using a temperature sensing device

24A.5.1 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control, shall be tested using the following number of cycles when testing a sensing device in accordance with the endurance test:

a) For a device employed as a operating device – 6000 cycles;

b) For a device employed as a protective device – 100,000 cycles; or

c) For a device employed as a combination operating and protective device – 100,000 cycles.

24B UL 60335-1 BASED REQUIREMENTS FOR THE EVALUATION OF ELECTRONIC CIRCUITS

24B.1 Introduction

24B.1.1 Scope

24B.1.1.1 Throughout this Section, when reference is made to requirements in “this Standard,” the reference is to requirements in the main body of the Standard and not to other requirements of this Section.

24B.1.1.2 These requirements provide alternate requirements for the investigation of electronic controls and other circuits used in appliances covered by this standard.

24B.1.1.3 Thermal motor protectors in direct contact with motor windings and intended for direct control of the motor supply are outside the scope of this Section even if they incorporate one or more electronic components.

24B.1.2 General

24B.1.2.1 The requirements of this Section are intended to apply to the electronic circuit and how it is integrated in the appliance. The overall appliance construction, performance testing and marking requirements are applicable as specified in this Standard except as cited in the following requirements.

24B.1.3 Glossary

24B.1.3.1 DANGEROUS MALFUNCTION – Unintended operation of the appliance that may impair safety. Operating control functions whose failure would result in a dangerous malfunction would be considered safety critical functions. See 24B.1.3.8.

Note 1 – Control functions whose failure might result in a dangerous malfunction would include:

a) Unexpected operation of the appliance where the operation would result in risk of electric shock, fire or mechanical hazard.

b) Unattended energization of a heating appliance where the user has placed flammable materials near the appliance based on the assumption the appliance would remain off.

Note 2 – See 24B.1.3.8.

24B.1.3.2 ELECTRONIC DISCONNECTION – The de-energizing of the functional load of the appliance by an electronic device of a circuit with no air gap.

24B.1.3.3 INTENTIONALLY WEAK PART – A part intended to rupture under conditions of abnormal operation to prevent the occurrence of a condition which could impair compliance with this standard.

24B.1.3.4 LOW-POWER CIRCUIT – A circuit or parts of circuits farther from the supply source than a low-power point.

24B.1.3.5 LOW-POWER POINT – A point closest to the supply source in an electronic circuit where the maximum available power to an external load at the end of 5 seconds does not exceed 15 watts.

24B.1.3.6 PROTECTIVE ELECTRONIC CIRCUIT (PEC) – An electronic circuit that prevents a hazardous situation under abnormal operating conditions. The function of a protective electronic circuit would be considered a safety critical function. See 24B.1.3.9.

24B.1.3.7 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist within a circuit unless the circuit meets one of the following criteria. The circuit shall be supplied by an isolating source such that:

a) The voltage does not exceed 30 V rms;

b) The voltage does not exceed 42.4 V peak;

c) The voltage does not exceed 60 V dc continuous;

d) The voltage does not exceed 24.8 V peak for DC interrupted at a rate of 200 Hz or less with approximately 50 percent duty cycle; or

e) When protective impedance is used, the current available through a 1500 ohm resistor between the part or parts and either pole of the supply source does not exceed 0.7 mA peak or 2 mA DC:

1) For frequencies exceeding 1 kHz, the limit of 0.7 mA (peak value) is multiplied by the value of the frequency in kHz but shall not exceed 70 mA peak;

2) For voltages over 42.4 V peak and up to and including 450 V (peak value) the capacitance shall not exceed 0.1 µF.

24B.1.3.8 RISK OF FIRE – A risk of fire is considered to exist at any two points in a circuit where a power of more than 15 watts can be delivered into an external resistor connected between the two points.

24B.1.3.9 SAFETY CRITICAL FUNCTION – Control, protection and monitoring functions which are being relied upon to reduce the risk of fire, electric shock or casualty hazards.

24B.2 Construction

24B.2.1 Components

24B.2.1.1 Capacitors

24B.2.1.1.1 A capacitor connected between two line conductors in a primary circuit, or between one line conductor and the neutral conductor or between primary and accessible secondary circuits or between the primary circuit and protective earth (equipment grounding conductor connection) shall comply with one of the subclasses of the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14 and shall be used in accordance with its rating. Note – Details for damp heat, steady state test can be found in 4.12 of IEC 60384-14.

24B.2.1.2 Isolation devices

24B.2.1.2.1 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this Standard shall be constructed in accordance with the Standard for Optical Isolators, UL 1577, and shall be able to withstand for 1 minute, without breakdown, an ac dielectric voltage withstand potential of 2500 volts as specified in 35.1 between the input and output circuits.

24B.2.1.2.2 A power switching semiconductor device that is relied upon to provide isolation to ground shall be constructed in accordance with the Standard for Electrically Isolated Semiconductor Devices, UL 1557. The dielectric voltage withstand tests required by UL 1557 shall be conducted at a dielectric potential of 2500 volts as specified in 35.1 for 1 minute.

24B.2.1.2.3 A power switching semiconductor device that is relied upon to provide isolation between primary and secondary circuits or between other circuits shall be a device (such as a solid state motor controller) that complies with the Standard for Industrial Control Equipment, UL 508.

Exception: A power switching semiconductor device located within a component that has been separately evaluated to the requirements for that component is not required to be further evaluated, provided the component is used within its established ratings and limitations.

24B.2.1.2.4 A relay that is relied upon to provide isolation between primary and secondary circuits shall comply with the Standard for Industrial Control Equipment, UL 508.

24B.2.1.3 Printed wiring boards

24B.2.1.3.1 Printed wiring boards shall comply with the Standard for Printed Wiring Boards, UL 796, and shall have a flammability rating and other characteristics as specified in this Standard.

Exception: A printed circuit board solely in a Low-Power Circuit and whose failure would not constitute a risk of electric shock need not comply with UL 796.

24B.2.1.4 Switch mode power supplies

24B.2.1.4.1 Bridging components – switch mode power supplies

24B.2.1.4.1.1 Components connected between the primary and secondary circuits of an isolating device such as a switching transformer or between primary and secondary earth reference points shall be

evaluated to provide the specified level of isolation for the application under normal and abnormal (single component fault) conditions.

24B.2.1.4.1.2 A capacitor connected between primary and accessible secondary circuits shall comply with Capacitors, Section 24B.2.1.1. This shall consist of a single Class Y1 capacitor or two Class Y2 capacitors connected in series.

24B.2.1.4.2 Switch mode power supply insulation system

24B.2.1.4.2.1 Insulation used within a transformer of switch mode power supply shall comply with the Standard for Systems of Insulating Materials – General, UL 1446, for the specified temperature class of the insulation system or the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

24B.2.2 Identification of safety critical circuit functions

24B.2.2.1 General

24B.2.2.1.1 Electronic circuits or parts of circuits shall be analyzed to determine if the function of the control is necessary for compliance with this Standard. A function is considered a safety critical function (SCF) if failure (loss or malfunction) of its functionality would result in the risk of fire, electric shock, mechanical hazard or a dangerous malfunction.

24B.2.2.1.2 Safety critical functions shall be identified as either protective electronic circuits as detailed in Section 24B.2.2.2 or as those of operating circuits that mitigate dangerous malfunctions as detailed in Section 24B.2.2.3.

24B.2.2.1.3 In the evaluation of electronic circuits, all the contacts of relays or contactors that cycle during the Normal Temperature Test shall be simultaneously short-circuited.

24B.2.2.2 Protective electronic circuits

24B.2.2.2.1 An electrical component shall not be connected across the contacts of a protective electronic circuit.

Exception: Electrical components may be connected across the contacts provided that any single component fault does not result in a loss of protective function.

24B.2.2.2.2 Protective electronic circuit functions are as specified in this standard.

24B.2.2.3 Operating circuits that mitigate a dangerous malfunction of the appliance

24B.2.2.3.1 The suitability of stand-by or electronic disconnect circuits shall be as specified in this Standard.

24B.2.2.3.2 An electronic disconnection circuit whose failure could result in a dangerous malfunction shall have at least two components whose combined operation provides the load disconnection.

24B.2.2.3.3 Operating circuits whose functions are relied upon to mitigate dangerous malfunctions of the appliance are as specified in this standard.

24B.2.3 Evaluation of the different types of electronic circuits

24B.2.3.1 All types of circuits

24B.2.3.1.1 All circuit functions mandated by this standard shall be validated. This includes operating functions not designated as safety critical functions.

24B.2.3.1.2 All circuits shall be evaluated to determine the effects of electronic circuit faults.

24B.2.3.1.3 When the applicable component/hardware faults specified in 24B.3.3.1.10 are imposed one at a time they shall not result in:

a) The appliance presenting a risk of fire, electric shock or mechanical hazard; or

b) The loss of any safety critical function either in that circuit or others.

24B.2.3.1.4 The risk of electrically generated fire from the faults of 24B.3.3 is considered to be mitigated in low-power circuits.

24B.2.4 Circuits that provide safety critical functions

24B.2.4.1 General

24B.2.4.1.1 In addition to the requirements of 24B.2.3, circuits that provide safety critical functions shall incorporate measures to control the fault/error conditions that would impair the safety functions.

24B.2.4.1.2 The evaluation of the programmable component shall be in accordance with Annex R of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1, Edition 5.

24B.2.4.1.3 Circuits that provide safety critical functions that rely upon a programmable component for one or more of its safety functions shall be subjected to the test of the Programmable component reduced supply voltage test, Section 24B.3.4, unless restarting at any point in the operating cycle after interruption of operation due to a supply voltage dip will not result in a hazard. The test is carried out after removal of all batteries and other components intended to maintain the programmable component supply voltage during mains supply voltage dips, interruptions and variations.

24B.2.4.1.4 Circuits that provide safety critical functions shall maintain their required functions when subjected to the EMC related stresses specified in the Electromagnetic compatibility (EMC) requirements – immunity, Section 24B.3.5.

24B.2.4.1.5 The tests of Sections 24B.3.5 are carried out with surge protective devices disconnected, unless they incorporate spark gaps.

24B.3 Performance

24B.3.1 General conditions for the tests

24B.3.1.1 Details

24B.3.1.1.1 An electronic control shall be tested in the appliance under the Performance test conditions and order of tests specified in this Standard.

Exception: Except as noted elsewhere in this Section, upon the agreement of the manufacturer and with due consideration of the relevant compliance criteria, an electronic control may be tested outside of the appliance.

24B.3.1.1.2 Cumulative stress resulting from successive tests on electronic circuits is to be avoided. It may be necessary to replace components or to use additional samples.

24B.3.1.1.3 User adjustable electronic controls shall be adjusted to their most unfavorable setting.

24B.3.1.2 Intentionally weak parts

24B.3.1.2.1 If a conductor of a printed circuit board or other component becomes open-circuited, the appliance is considered to have withstood the particular test, provided both of the following conditions are met:

a) The base material of the printed circuit board withstands the test of Needle-Flame Test (NFT) of Annex E of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1;

b) Any loosened conductor does not reduce electrical spacings (clearances or creepage distances) between live parts and accessible metal parts below the values specified in this Standard; and

c) The same result is obtained when the test is run three times.

Exception: The base material of the printed wiring board need not comply with the Needle-Flame Test of (a) if the base material has a flammability rating of V-0 and a CTI of minimum 100.

24B.3.1.2.2 Fuses other than as noted in 24B.3.1.3.2 are considered to be intentionally weak parts in accordance with 24B.3.1.2.

24B.3.1.3 Test results determined by overcurrent protection operation

24B.3.1.3.1 If compliance with these requirements under any of the fault conditions depends on the operation of an overcurrent device incorporated within the electronic control, the fuse and/or circuit breaker shall comply with the requirements for that component.

24B.3.1.3.2 If compliance with the requirements of this standard depends upon the operation of a miniature fuse-link complying with IEC 60127-1 – Miniature Fuses – Part 1 Definitions for miniature fuses and general requirements for miniature fuse-links, during any of the fault conditions specified in 24B.3.4.1, the test is repeated but with the miniature fuse-link replaced by an ammeter. If the current measured:

a) Does not exceed 2.1 times the rated current of the fuse-link, the circuit is not considered to be adequately protected and the test is carried out with the fuse-link short-circuited;

b) Is at least 2.75 times the rated current of the fuse-link, the circuit is considered to be adequately protected;

c) Is between 2.1 times and 2.75 times the rated current of the fuse-link, the fuse link is short-circuited and the test is carried out:

1) For the relevant period or for 30 min, whichever is the shorter, for quick acting fuselinks;

2) For the relevant period or for 2 min, whichever is the shorter, for time lag fuse-links.

24B.3.1.3.3 In case of doubt, the maximum resistance of the fuse-link has to be taken into account when determining the current.

24B.3.1.3.4 The verification whether the fuse-link acts as a protective device is based on the fusing characteristics specified in IEC 60127-1, which also gives the information necessary to calculate the maximum resistance of the fuse-link.

24B.3.2 Low power circuits

24B.3.2.1 Low power circuit determination

24B.3.2.1.1 The appliance shall be supplied at rated voltage and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source. The resistance is then decreased until the power consumed by the resistor reaches a maximum. Points closest to the supply source at which the maximum power delivered to this resistor does not exceed 15 W at the end of 5 s are called Low-Power Points. The part of the circuit farther from the supply source than a low-power point is considered to be a Low-Power Circuit. See Figure 24B.1.

24B.3.2.1.2 The measurements shall be made from only one pole of the supply source, preferably the one that gives the fewest low-power points.

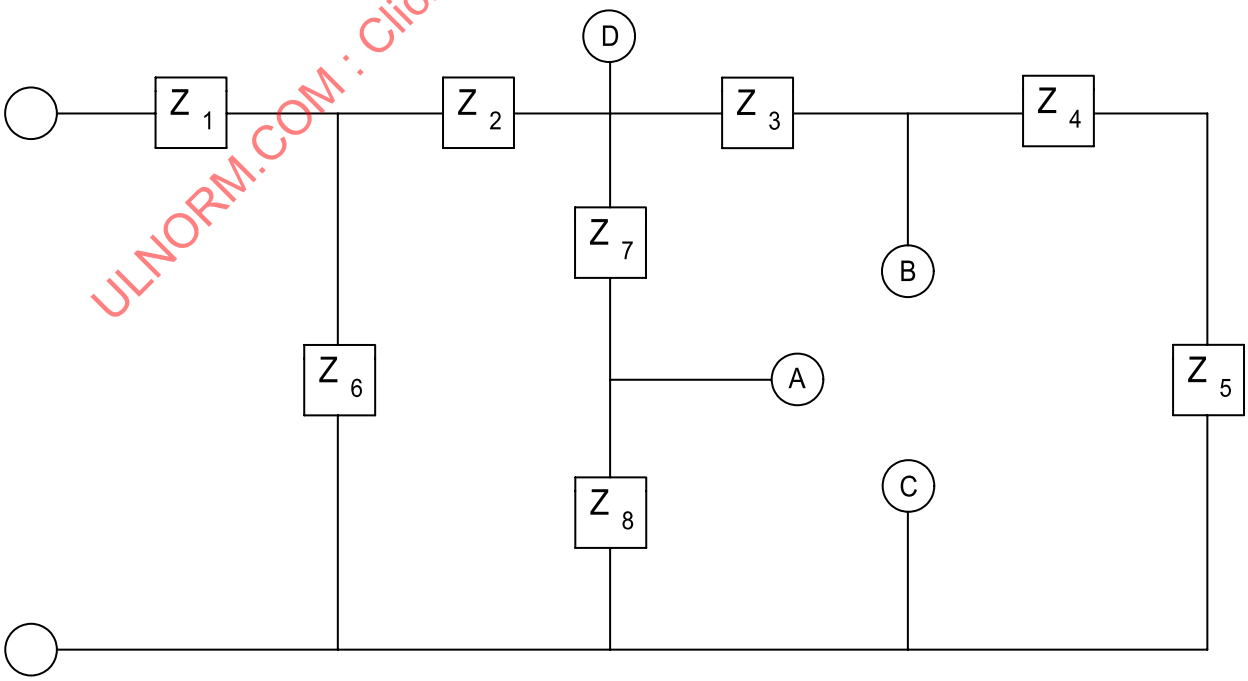
24B.3.2.1.3 When determining the low-power points, measurements shall start with points close to the supply source.

24B.3.2.1.4 The power delivered to the variable resistor shall be measured by a wattmeter.

24B.3.2.1.5 If power is interrupted to parts of circuits by intentionally weak parts, the test shall be repeated two more times to confirm a consistent result.

Figure 24B.1

Example of an electronic circuit with low-power points



24B.3.3 Abnormal operation and fault tests

24B.3.3.1 General

24B.3.3.1.1 Electronic controls shall be constructed so that the compliance criteria for risk of fire, electric shock and injury to persons as a result of abnormal operating conditions of the appliance specified in this Standard are fulfilled.

24B.3.3.1.2 Unless otherwise specified, the tests are continued until a non-self-resetting thermal cutout operates or until steady conditions are established. If an intentionally weak part becomes permanently open-circuited, the relevant test is repeated on two additional samples.

24B.3.3.1.3 Unless otherwise specified, only one abnormal condition is simulated at any one time. If more than one of the tests is applicable to the same appliance, these tests are carried out consecutively after the appliance has cooled down to room temperature.

24B.3.3.1.4 Fault condition 24B.3.3.1.10(f) is applied to encapsulated and similar components if the circuit cannot be assessed by other methods.

24B.3.3.1.5 For application of the fault conditions, the appliance is operated under the conditions specified in the Normal Temperature Test of this Standard.

24B.3.3.1.6 When any of the fault conditions are simulated, the duration of the test is until ultimate results are known but no longer than as specified for the Normal Temperature Test of this Standard. In each case, the test is ended if a non-selfresetting interruption of the supply occurs within the appliance.

24B.3.3.1.7 If an electronic timer or programmer must operate to ensure compliance with the test before the maximum period under the conditions of the test is reached, it shall be additionally investigated as a Protective Electronic Circuit.

24B.3.3.1.8 The contacts of relays, contactors or other devices that cycle during the Normal Temperature Test shall be short-circuited.

24B.3.3.1.9 Unless otherwise specified, any electronic control that limits the temperature during the Normal Temperature Test of this Standard is short-circuited for abnormal operation tests. If the appliance incorporates more than one control, they are short-circuited, or rendered inoperative, in turn.

24B.3.3.1.10 Electronic circuit faults as specified in (a) – (g) shall be considered. If considered necessary they shall be applied one at a time:

a) Short circuit of spacings if clearances or creepage distances are less than the required values;

b) Open circuit at the terminals of any component;

c) Short circuit of capacitors, unless they comply with UL 60384-14;

d) Short circuit of any two terminals of an electronic component, other than an integrated Circuit. This fault condition is not applied between the two circuits of an optocoupler that complies with UL 1577;

e) Failure of triacs in the diode mode;

f) Failure of microprocessors and integrated circuits except components such as thyristors and triacs. All possible output signals are considered for faults occurring within the component. If it can

be shown that a particular output signal is unlikely to occur, then the relevant fault is not considered; and

g) Failure of an electronic power switching device in a partial turn-on mode with loss of gate (base) control.

Exception No. 1: Positive temperature coefficient thermistors are not short-circuited if they are used within the manufacturer's specification and comply with the Standard for Thermistor-Type Devices, UL 1434, or Annex J of the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1. However, PTC-S thermistors are short-circuited unless they comply with Clause 14.5.3 of the Standard for Audio, Video and Similar Electronic Apparatus – Safety Requirements, UL 60065.

Exception No. 2: Components in Low-Power Circuits whose failure also does not result in the loss of a Safety Critical Function

24B.3.3.1.11 The fault conditions of 24B.3.3.1.10 (a) – (g) shall be applied, one at a time to the components on the supply side of the low-power points determined in 24B.3.2.1. The appliance shall not present a risk of fire, electric shock or mechanical hazard.

24B.3.3.1.12 If the appliance incorporates a protective electronic circuit which operates to ensure compliance with Clause 24B.3.3, the relevant test is repeated with a single fault simulated in the protective electronic circuit, as indicated in a) to f).

24B.3.3.2 Low-power circuit fire tests

24B.3.3.2.1 Each low-power point identified by the test of 24B.3.3.1 shall be individually tested. It shall be shorted or loaded to the maximum available between the point and the supply return used for the 15 watt determination. The appliance shall not present a risk of fire, electric shock or mechanical hazard.

24B.3.3.3 Switch mode power supply overload test

24B.3.3.3.1 Each output winding, or section of a tapped winding, is overloaded in turn, one at a time, while the other windings are kept loaded or unloaded, whichever load conditions of normal use is the least favorable.

24B.3.3.3.2 Overloading is carried out by connecting a variable resistor (or an electronic load) across the power supply output. The resistor is adjusted as quickly as possible and readjusted, if necessary, after 1 minute to maintain the applicable overload. No further readjustments are then permitted.

24B.3.3.3.3 For this test, any protective devices such as a fuse, manual reset circuit protector, thermal protector, etc. is allowed to remain in the circuit.

24B.3.3.3.4 If overcurrent protection is provided by an overcurrent protection device, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 hr. If this value cannot be derived from the specification, it is to be established by test.

24B.3.3.3.5 If no overcurrent protection is provided, the maximum overload is the maximum power output obtainable from the power supply.

24B.3.3.3.6 In case of voltage foldback, the overload is to be slowly increased to the point which causes the output voltage to collapse. The overload is then established at the point where the output voltage recovered and held for the duration of the test.

24B.3.3.3.7 The duration of the test is to be for 7 hours or until ultimate results are reached. At the conclusion of the test, there shall be no charring or burning of electrical insulation, no opening of any protective device or any circuit component.

24B.3.4 Programmable component reduced supply voltage test

24B.3.4.1 General

24B.3.4.1.1 The appliance is supplied at rated voltage and operated under normal operation. After approximately 60 s, the power supply voltage is reduced to a level such that the appliance ceases to respond to user inputs, or parts controlled by the programmable component cease to operate, whichever occurs first. This value of supply voltage is recorded. The appliance is then supplied at rated voltage and operated under normal operation. The voltage is then reduced to a value of approximately 10 percent less than the recorded voltage. It is held at this value for approximately 60 s and then increased to rated voltage. The rate of decrease and increase of the power supply voltage is to be approximately 10 V/s. The appliance shall continue to either operate normally from the same point in its operating cycle at which the voltage decrease occurred or a manual operation shall be required to restart it.

24B.3.4.1.2 This test may be performed on a control outside the appliance provided that the conditions of test appropriately represent the control environment within the appliance.

24B.3.5 Electromagnetic compatibility (EMC) requirements – immunity

24B.3.5.1 General

24B.3.5.1.1 Protective electronic controls and control with functions necessary to prevent dangerous malfunctions shall continue to provide their desired safety function when subjected to the EMC related stresses specified in (a) – (g), applied one at a time:

a) The appliance is subjected to electrostatic discharges in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test , IEC 61000-4-2, test level 4 being applicable. Ten discharges having a positive polarity and ten discharges having a negative polarity are applied at each preselected point;

b) The appliance is subjected to radiated fields in accordance with the Standard for Electromagnetic Compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test , IEC 61000-4-3, test level 3 being applicable. The dwell time for each frequency is to be sufficient to observe a possible malfunction of the protective electronic circuit;

c) The appliance is subjected to fast transient bursts in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test , IEC 61000-4-4. Test level 3 is applicable for signal and control lines. Test level 4 is applicable for the power supply lines. The bursts are applied for 2 min with a positive polarity and for 2 min with a negative polarity.

d) The power supply terminals of the appliance are subjected to voltage surges in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test , IEC 61000-4-5, five positive impulses and five negative impulses being applied at the selected points. Test level 3 is applicable for the line-to-line coupling mode, a generator having a source impedance of 2 Ω being used. Test level 4 is applicable for the line-to-earth coupling mode, a generator having a source impedance of 12 Ω being used. In addition:

1) Grounded heating element sheaths in grounded appliances are disconnected during this test, and

2) For appliances having surge arresters incorporating spark gaps, the test is repeated at a level that is 95 percent of the flashover voltage.

e) The appliance is subjected to injected currents in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio frequency fields , IEC 61000-4-6, test level 3 being applicable. During the test, all frequencies between 0.15 MHz to 80 MHz are covered. The dwell time for each frequency is to be sufficient to observe a possible malfunction of the Protective Electronic Circuit;

f) The appliance is subjected to the class 3 voltage dips and interruptions in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests, IEC 61000-4-11. The values specified in Table 1 and Table 2 of IEC 61000-4-11, are applied at zero crossing of the supply voltage; and

g) The appliance is subjected to mains signals in accordance with the Standard for Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signaling at a.c. power port, low frequency immunity tests , IEC 61000-4-13, test level class 2 being applicable.

24B.3.5.1.2 The tests are carried out with the appliance supplied at rated voltage, the device being set in the off position or in the stand-by mode.

24B.3.5.1.3 The tests of 24B.3.5.1.1 are carried out after the protective electronic circuit has operated during the relevant Abnormal Operation Test of this standard. However, appliances that are attended during use are not subjected to the tests for electromagnetic phenomena.

24B.4 Manufacturing and production line testing

24B.4.1 General

24B.4.1.1 In addition to the regular production and manufacturing tests of this Standard, the manufacturer shall verify the correct function of circuits that are considered to provide safety critical functions.

24B.5 Appendix

24B.5.1 General

Table 24B.1
Safety critical functions

Function[a]	Hazard	Location of parameters and tests
Air outlet temperature limit	Risk of fire or casualty hazard	Section 30
Restricted inlet	Risk of fire or electric shock	Section 32.2
Fan Failure	Risk of fire or electric shock	Section 32.3
Blocked outlet	Risk of fire or electric shock	Section 32.4

Table 24B.1 Continued on Next Page

Table 24B.1 Continued

Function[a]	Hazard	Location of parameters and tests
Backup protection	Risk of fire or electric shock	Section 33
Overload test – high voltage transformers	Risk of fire or electric shock	Section 38
Burnout test – high voltage transformers	Risk of fire or electric shock	Section 39

[a] Functions specified in the table represent the common safety critical circuit functions of pumps. It is not intended to represent all possible safety critical functions. Any function involved in the control, protection, and monitoring of safety related attributes of a pump whereby a loss/malfunction of its functionality would represent an unacceptable risk of fire, electric shock, or casualty hazards would be considered a safety critical function.

25 Moisture

25.1 A duct heater through which air from a humidifier passes, shall be so designed that water from the humidifier is prevented from entering the control compartment or affecting any electrical equipment or wiring.

26 Spacings

26.1 Hazardous voltage circuits

26.1.1 In circuits up to and including 600 volts, the spacings between an uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded part other than the outer enclosure, an exposed metal part that is isolated (insulated), or the outer enclosure, shall be not less than as specified in Table 26.1 and Table 26.2.

Exception No. 1: The above spacing requirements do not apply to the inherent spacings (internal) of a component part of the unit for which spacing requirements have been judged on the basis of the component standard.

Exception No. 2: At closed-in points only, such as the screw and washer construction of an insulated terminal mounted in metal, a spacing of not less than 1.2 mm (3/64 inch) complies, when the potential involved is 300 volts or less, and a spacing of not less than 6.4 mm (1/4 inch) complies when the potential is 300 – 600 volts.

Exception No. 3: The spacings "to enclosure" are not to be applied to an individual enclosure of a component within an outer enclosure or cabinet.

Table 26.1
Minimum spacings at locations other than electric heating elements

Rating[d]		Minimum spacing					
		Through air,		Over surface,		To enclosure[a],	
Volt-amperes	Volts	inch	mm	inch	mm	inch	mm
0 – 2000	**0 – 300[b]**	**1/8**	**3.2**	**1/4**	**6.3**	**1/4**	**6.3**
More than	0 – 150	1/8	3.2[c]	1/4	6.3	1/2	12.5
2000	151 – 300	1/4	6.3	3/8	9.5	1/2	12.5
		3/8	9.5	1/2	12.5	1/2	12.5

Table 26.1 Continued on Next Page

Table 26.1 Continued

Rating[d]		Minimum spacing					
		Through air,		Over surface,		To enclosure[a],	
Volt-amperes	Volts	inch	mm	inch	mm	inch	mm
0 – 2000	0 – 300[b]	1/8	3.2	1/4	6.3	1/4	6.3

[a] These spacings do not apply to an individual enclosure of a component part within an outer enclosure or cabinet.

[b] When over 300 volts, the spacings in the last line of the table apply.

[c] The spacings between wiring terminals of opposite polarity or between a wiring terminal and ground shall not be less than 6.3 mm (1/4 inch), except that when short circuiting or grounding of such terminals will not result from projecting strands of wire, the spacing need not be greater than that given in the above Table. Wiring terminals are those connected in the field and not factory-wired.

[d] The spacings at an individual component part are to be judged on the basis of the total measured volt-ampere consumption of the load or loads, which the components control. For example, a component that controls a heating element is judged on the basis of the measured volt-amperes of a heating element. A component that controls loads in addition to a heating element is judged on the basis of the sum of the volt-amperes of the loads so controlled, except that in a component that independently controls separate loads is judged on the basis of the volt-amperes of the larger load. The volt-ampere values for the load referred to above are to be determined by the marked rating of the load; except that for loads that are not required to have a marked rating, the measured input is to be used in determining the volt-ampere values.

Table 26.2
Minimum spacings at electric heating elements

Description of spacing	Potential involved, volts	Spacing	
		Inch	mm
Between uninsulated live parts of opposite polarity; and between an uninsulated live part and a dead metal part, other than the enclosure, that either is exposed to contact by persons or is grounded	0 – 250, 251 – 600	1/16, 1/4[a]	1.6, 6.4[a]
Between a live part and the enclosure	0 – 600	1/4	6.4

Notes –

1 These spacings are applicable only to parts of the heating element and its terminals located inside the heated air handling compartment. If an uninsulated live part is not rigidly supported, or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that at least the minimum spacing is maintained under all operating conditions and under all normal conditions of handling. Spacings at a thermal cutoff shall comply with Table 26.1.

2 Metal-sheathed heater elements that have spacings at terminations between live parts and noncurrent-carrying metal parts less than 3.2 mm (0.13 inch) [6.3 mm (0.25 inch) for 300 – 600 volts], but not less than 1.6 mm (0.06 inch) [3.2 mm (0.13 inch) for 300 – 600 volts] shall be sealed against moisture.

[a] A spacing of not less than 1.6 mm (1/16 inch) is permissible at a heating element rated for 300 volts or less.

26.1.2 An insulating liner or barrier of vulcanized fiber, varnished cloths, mica, phenolic composition, or similar material, employed where spacings would otherwise be insufficient, shall be not less than 0.7 mm (0.028 inch) thick.

Exception No. 1: A liner or barrier not less than 0.3 mm (0.013 inch) thick is used in conjunction with an air spacing of not less than 1/2 of the through air spacing required. The liner shall be located so that it will not be oxidized or otherwise deteriorated by arcing.

Exception No. 2: Insulating material less than 0.7 mm (0.028 inch) thick is used, when it has insulating, physical, and flammability properties equivalent to those of the materials specified above.

26.2 Low-voltage circuits

26.2.1 For a safety circuit, spacings shall be as follows, when operation of the product with a short circuit or grounded circuit results in unsafe operation of the controlled device.

a) The spacing between uninsulated live parts and the walls of a metal enclosure, including conduit fittings, or the like, shall not be less than 3.2 mm (1/8 inch).

b) The spacing between wiring terminals intended for connection of Class 1 wiring, irrespective of polarity, and between wiring terminals and metal parts (including the enclosure) that are grounded when the device is installed, shall not be less than 6.3 mm (1/4 inch).

c) The spacing between uninsulated live parts, irrespective of polarity, and between uninsulated live parts and metal parts, other than the enclosure, which is grounded when the device is installed, shall not be less than 0.8 mm (1/32 inch) when the parts are constructed in such a way that spacings are maintained.

26.2.2 For nonsafety circuits, spacings are not specified.

26A Clearance and Creepage Distances

26A.1 As an alternative approach to the spacing requirements specified in Spacings, Section 17, and other than as noted in 26A.2 and 26A.3, clearances and creepage distances may be evaluated in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, as described in 26A.3.

26A.2 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Spacings, Section 26.

26A.3 In conducting evaluations in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, the following guidelines in Table 24A.1 – Table 24A.3 shall be used.

PERFORMANCE

27 General

27.1 General

27.1.1 In the selection of one or more test samples to represent a line of duct heaters, consideration is to be given to the volume of the heater, the size of the duct opening, and the wattage density of the unit (total W per square foot or per square meter of duct-heater face area). When the manufacturer's instructions cover the multiple installation of duct heaters in various configurations, such as stacked vertically, lined up horizontally, or arranged in tandem, tests of multiple units may also be necessary.

27.2 Supply connections

27.2.1 All tests are to be conducted with the duct heater or heaters supplied from a circuit of rated frequency and of voltage in accordance with 28.9. All components of the system are to be connected in accordance with the instructions mentioned in 47.1. When the instructions specify a downflow system or any other system not contemplated in these requirements, appropriate modification of the test procedure may be necessary.

27.3 Airflow

27.3.1 When different values of airflow are specified for different combinations (numbers) of duct heaters that are used in the main supply duct of the system, Normal Tests, Section 31, are to be conducted for each group of heaters using the minimum specified airflow for that group; but, in the Abnormal Tests, Section 32, only the minimum and maximum numbers of heaters are to be used. When a single value of airflow is specified for the system, only the maximum number of heaters for that airflow need be tested.

27.4 Inlet air

27.4.1 Except as indicated in 27.4.2, the temperature of the inlet air to a heater or group of heaters under test is to be maintained at 25 ±2°C (77 ±4°F), except when the inlet air is the outlet air from another heater or group of heaters, in which case the inlet air temperature should be no less than the temperature of the outlet air of the other heater or heaters with which it is to be used. The inlet air should then be 38°C (100°F) minimum. In any case, both inlet and outlet air temperatures are to be observed and recorded, and the thermocouples employed are to be so located that they are not affected directly by radiation from the heater elements.

27.4.2 The inlet air to a duct heater being tested for use with heat pumps is to be maintained at 25 ±2°C (77 ±4°F) for all of the applicable tests in 32.2.1 – 32.4.1. All of these tests are then to be repeated with the inlet air to the duct heater increased to 38°C (100°F) minimum.

27.4.3 Air velocity is to be measured by any recognized means; but when it is possible to measure the outlet air velocity only, the inlet air velocity is to be computed from the outlet air velocity.

27.4.4 The inlet air velocity is computed by means of the formula:

$$V = \frac{PvK}{A(T_2 - T_1)}$$

in which:

V is the inlet air velocity, feet per minute (meters per second)

P is the power input, kilowatts (kilowatts)

v is the specific volume of air, cubic feet per pound mass (cubic meters per kilogram mass)

K is the constant, 132 (T_1 and T_2 in degrees C) 237 (T_1 and T_2 in degrees F) (1 (T_1 and T_2 in degrees C)

A is the duct cross-sectional area, square feet (square meters)

T_1 is the inlet air temperature, as applicable (degrees C), and

T_2 is the outlet air temperature, as applicable (degrees C)

27.5 Outlet air

27.5.1 On the outlet side of the heater or heaters, the main supply duct is to terminate at and discharge into an attached outlet duct of the same cross-sectional area. The outlet duct is to extend away from and at right angles to the main supply duct for a distance of 914 mm (36 inches) or more, measured to the inside corner of the connected ducts. A grid consisting of nine thermocouples of identical length wired in parallel is to be installed in the outlet duct to measure the temperature of the outlet air. The thermocouples are to be located in a plane perpendicular to the axis of the duct, and:

a) For a rectangular duct – each located at the center of an equal sized rectangular area with the areas arranged in three rows to cover the entire cross section, or

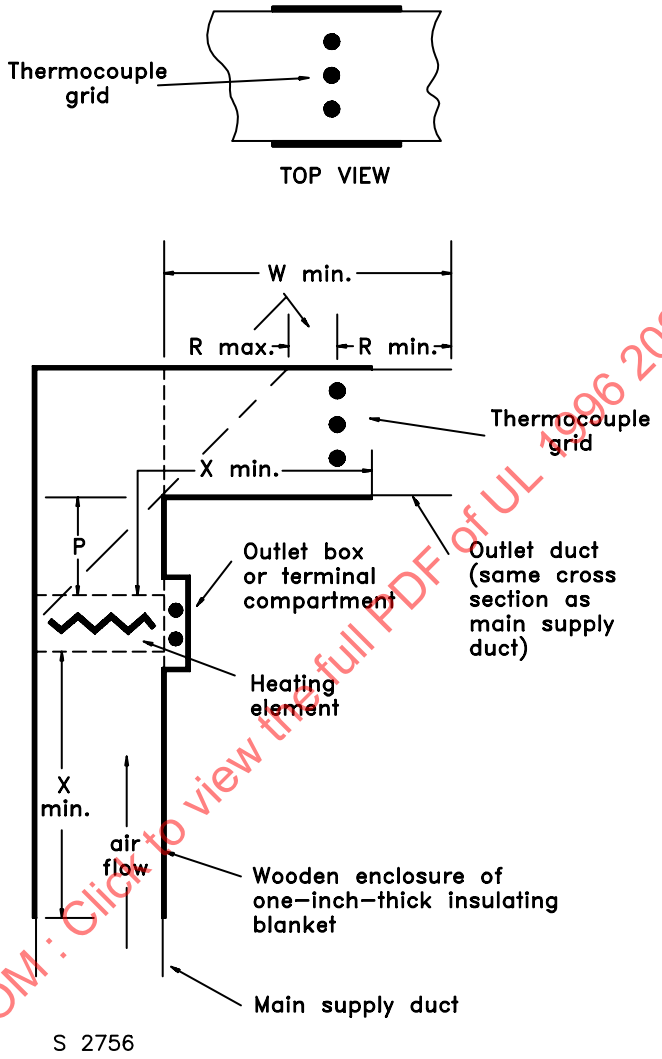
b) For a round duct – one located at the center and the others equally spaced along the circumference of a concentric circle having a radius of two-thirds of the duct radius. The grid is to be located no more than 152 mm (6 inches) downstream from the location nearest to the heater at which no thermocouple is affected directly by radiation from the heating element, and not less than 152 mm (6 inches) from the outlet end of the outlet duct.

27.6 Test enclosure

27.6.1 Except as noted in 27.6.4, a wooden test enclosure, see Figure 27.1, is to be employed to enclose the main supply, and outlet ducts, and is to extend at least 1.2 m (4 feet) on either side of the heater or heaters in the main supply duct. The enclosure is to be made of 19 mm (3/4 inch) plywood or boards having a nominal thickness of 25.4 mm (1 inch). The inside surfaces are to be painted flat black, and all joints are to be sealed.

Figure 27.1

Enclosure for duct heaters



Dimensions

Code	Inch	Millimeter
P	21 ±3	533 ±76
R	6	152
W	36	914
X	48	1219

Note

This represents a side view of a vertical installation in which the airflow is up, and a plan view of a horizontal installation in which the airflow is horizontal.

27.6.2 The enclosure is to house completely and be in direct contact with the main supply duct and the outlet duct, except that for a duct heater rated at more than 50 kilowatts, a definite clearance between the enclosure and combustible material may be specified by the manufacturer. When such a clearance is specified, that spacing is to be maintained between the heated surfaces of the equipment and the wooden enclosure. The terminal box or control compartment is to be enclosed by the wooden enclosure unless the installation instructions and the manufacturer's marking specify installation of the duct heater without the terminal box or control compartment being enclosed by adjacent surfaces.

27.6.3 When no clearance is specified, temperatures on the metal surfaces of the equipment, measured by means of thermocouples soldered to the metal, are to be observed and recorded. When a clearance is specified, temperatures on the inside surfaces of the wooden enclosure are to be observed and recorded.

27.6.4 As an alternative to the use of the previously mentioned wooden enclosure and, when no clearance is specified, an insulating blanket 25 mm (1 inch) thick and having a density no less than 16 kg/m^3 (1 pound per cubic foot) wrapped closely around the outlet duct and the main supply duct and also the heater when the heater is of the exposed (flange) type meets the intent of the requirement.

27.6.5 A duct heater 50 kilowatts or less shall be tested for installation with zero spacing between the duct and combustible surfaces. A duct heater rated more than 50 kilowatts necessitates that such spacings be larger than zero. See 45.1.3(h).

28 Temperature Tests

28.1 A duct heater shall be subjected to all the tests indicated in 30.1 – 32.4.1. In each test the heater shall not attain a temperature at any point sufficiently high to cause a risk of fire or to adversely affect any material employed in the heater. The observed temperature rise above the temperature of the inlet air at any designated point shall be no more than the limits indicated in those paragraphs, and during the tests indicated in 31.1 – 32.4.1, the temperature rise on any particular material shall be no higher than the specific rise given in Table 28.2, except that an additional 30°C (54°F) temperature rise is permissible during the first hour only of an abnormal test, see 32.2.1 – 32.4.1. All tests shall be continued until the temperatures under observation become stabilized, except that when a manual reset limit control functions during an Abnormal Test, Section 32, the maximum temperature is to be observed without resetting the control.

28.2 The 1-hour interval mentioned in 28.1 begins with the initial operation of the first limit control to function in each abnormal test and is not to be repeated during that abnormal test.

28.3 All values in Table 28.2 are based on an assumed ambient temperature of 25°C (77°F), but a test conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F) meets the intent of the requirement. However, no observed temperature higher than 25°C (77°F) plus the specified maximum rise complies, when the operation of an automatic thermal control during the test limits the temperatures under observation.

28.4 Temperatures are to be measured by thermocouples consisting of 24 AWG – 30 AWG (0.21 – 0.05 mm^2) wires, except that a coil temperature determined by the change of resistance method meets the intent of the requirement. See 28.7.

28.5 A temperature is considered to be constant when three successive readings, taken at 10 minute intervals that stabilized temperatures have been established (no more than a 1 percent net increase between the two last readings). When the temperatures measured are within 5 percent of the values specified in Table 28.2, the test shall be continued until two successive 10 minute readings indicate constant temperatures.

28.6 A thermocouple junction is to be securely held in good thermal contact with the surface of the material whose temperature is being measured. Adequate thermal contact obtained from taping, cementing, brazing or soldering the thermocouple in place meets the intent of the requirement.

28.7 Ordinarily a thermocouple is to be used for determining temperature of a coil or winding when it can be mounted, without removal of encapsulating compound or equivalent:

a) On the integrally applied insulation of a coil without a wrap, or

b) On the outer surface of a wrap that is no more than 0.8 mm (1/32 inch) thick and consists of cotton, paper rayon, or equivalent, but not of thermal insulation.

The change of resistance method is to be used when the thermocouple measurement cannot be conducted in accordance with the foregoing considerations.

28.8 At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by means of a thermocouple is higher by the following amount than the maximum indicated in Table 28.2, when the temperature rise of the coil measured by the resistance method is no greater than specified in Table 28.2:

Item in Table 28.2	Additional Temperature Rise	
	Degrees C	Degrees F
7	15	27
8	20	36

28.9 To determine when a heater complies with the requirement in 28.1, it is to be operated continuously until constant temperatures have been reached. The test voltage is to be as indicated in Table 28.1, except that, when the application of the indicated test voltage does not result in the measured wattage input to the heater being equal to or more than the marked wattage rating, the test voltage is to be increased until the measured wattage input equals the marked wattage rating.

Table 28.1
Voltage or temperature test

Marked voltage rating	Test potential in volts
Value within one of the specific ranges	Highest value of corresponding specified ranges
Value not within one of the specified ranges	Rated Voltage
Note: Specified range refers to any of the ranges of voltage mentioned in 45.1.3(c).	

Table 28.2
Maximum acceptable temperature rises

Materials and component parts		Degrees	
		C	F
1.	Air filter	65	117
2.	Any point within a wiring compartment in which field-installed conductors are to be connected, including such conductors themselves.	50	90

Table 28.2 Continued on Next Page