UL 1812

STANDARD FOR SAFETY

Ducted Heat Recovery Ventilators

UL Standard for Safety for Ducted Heat Recovery Ventilators, UL 1812

Fifth Edition, Dated April 1, 2025

Summary of Topics

This new Fifth edition of UL 1812 dated April 1, 2025 incorporates editorial changes including renumbering and reformatting to align with current style.

The new requirements are substantially in accordance with Proposal(s) on this subject dated November 1, 2024 and January 16, 2025.

No Text on This Page

APRIL 1, 2025

UL 1812

Standard for Ducted Heat Recovery Ventilators

First Edition –April, 1990
Second Edition –April, 1995
Third Edition –October, 2009
Fourth Edition –May, 2013

Fifth Edition

April 1, 2025

This UL Standard for Safety consists of the Fifth Edition.

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

No Text on This Page

CONTENTS

PART 1 – ALL EQUIPMENT

INTRODUCTION

CONSTRUCTION

CONSTRUCTION – ELECTRICAL COMPONENTS

CONSTRUCTION – SPACINGS

PERFORMANCE

MANUFACTURING AND PRODUCTION TESTS

PART 1 – ALL EQUIPMENT

INTRODUCTION

1 Scope

1.1 These requirements cover ducted heat recovery ventilators intended to remove air from buildings, replace it with outside air, and in the process transfer heat from the warmer to the colder air. These units are intended to be connected to duct systems that interconnect rooms or spaces within buildings for exhausting the indoor air and/or distributing the outdoor air.

1.2 These requirements cover heat recovery ventilators rated at 600 volts or less and intended to be installed in ordinary locations in accordance with the National Electrical Code, NFPA 70. These units may also include means for air filtration.

1.3 These requirements apply to heat recovery ventilators employing gas-, oil-, or gas-oil-fired or electric resistance heating means. The requirements for the construction and performance of gas, oil, and gas-oil burners, heat exchangers, electric resistance heaters, and components for the direct control of the utilization of these heating means are to be those included in other applicable standards.

1.4 Heat recovery ventilators 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.

2 Components

2.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component;

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; and

d) Additionally comply with the applicable requirements of this end product Standard.

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;

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 the requirements in a component standard other than those cited in this Standard is acceptable if:

a) The component also complies with the requirements in the applicable component standard; or

b) The component standard:

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

2) Considers long-term thermal properties of polymeric insulating materials in accordance with UL 746B; and

3) Any use limitations of the other component standard are 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 requirements in the relevant component standard may assume user expertise not common in household applications.

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

2.3 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 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 appliance, the additional component standard(s) are not required to be applied.

2.4 A component not described by the requirements of this Standard and that involves a potential risk of electric shock, fire, or personal injury shall be additionally evaluated in accordance with the applicable standard and shall comply with 2.1 (b) – (d).

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

3 Units of Measurement

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

3.2 Unless otherwise indicated, all voltage and current values mentioned in this Standard are rms.

4 Referenced Publications

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.

4.2 The following publications are referenced in this Standard:

ASHRAE 34, *Designation and Safety Classification of Refrigerants*

ASME B94.11M, *Twist Drills*

ASTM A90/A90M, *Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings*

ASTM A653/A653M, *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*

ASTM D256, *Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D790, *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

ASTM D1822, *Standard Test Method for Determining the Tensile-Impact Resistance of Plastics*

ASTM E230/E230M, *Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

CSA B51, *Boiler, Pressure Vessel, And Pressure Piping Code*

IEC 61000-4-5, *Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurement Techniques – Surge Immunity Test*

NEMA C80.1, *Electrical Rigid Steel Conduit (ERSC)*

NFPA 70, *National Electrical Code*

NFPA 90A, *Installation of Air-Conditioning and Ventilating Systems*

NFPA 90B, *Installation of Warm Air Heating and Air-Conditioning Systems*

UL 1, *Flexible Metal Conduit*

UL 6, *Electrical Rigid Metal Conduit – Steel*

UL 20, *General-Use Snap Switches*

UL 44, *Thermoset-Insulated Wires and Cables*

UL 62, *Flexible Cords and Cables*

UL 67, *Panelboards*

UL 83, *Thermoplastic-Insulated Wires and Cables*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 98, *Enclosed and Dead-Front Switches*

UL 207, *Refrigerant-Containing Components and Accessories, Nonelectrical*

UL 224, *Extruded Insulating Tubing*

UL 244A, *Solid-State Controls for Appliances*

UL 248-1, *Low-Voltage Fuses – Part 1: General Requirements*

UL 248-2, *Low-Voltage Fuses – Part 2: Class C Fuses*

UL 248-4, *Low-Voltage Fuses – Part 4: Class CC Fuses*

UL 248-5, *Low-Voltage Fuses – Part 5: Class G Fuses*

UL 248-6, *Low-Voltage Fuses – Part 6: Class H Non-Renewable Fuses*

UL 248-7, *Low-Voltage Fuses – Part 7: Class H Renewable Fuses*

UL 248-8, *Low-Voltage Fuses – Part 8: Class J Fuses*

UL 248-9, *Low-Voltage Fuses – Part 9: Class K Fuses*

UL 248-10, *Low-Voltage Fuses – Part 10: Class L Fuses*

UL 248-11, *Low-Voltage Fuses – Part 11: Plug Fuses*

UL 248-12, *Low-Voltage Fuses – Part 12: Class R Fuses*

UL 248-15, *Low-Voltage Fuses – Part 15: Class T Fuses*

UL 310, *Electrical Quick-Connect Terminals*

UL 353, *Limit Controls*

UL 360, *Liquid-Tight Flexible Metal Conduit*

UL 429, *Electrically Operated Valves*

UL 467, *Grounding and Bonding Equipment*

UL 486A-486B, *Wire Connectors*

UL 486C, *Splicing Wire Connectors*

UL 486E, *Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors*

UL 496, *Lampholders*

UL 498, *Attachment Plugs and Receptacles*

UL 508, *Industrial Control Equipment*

UL 508C, *Power Conversion Equipment*

UL 510, *Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape*

UL 514A, *Metallic Outlet Boxes*

UL 514B, *Conduit, Tubing, and Cable Fittings*

UL 514C, *Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers*

UL 635, *Insulating Bushings*

UL 651, *Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings*

UL 719, *Nonmetallic-Sheathed Cables*

UL 723, *Test for Surface Burning Characteristics of Building Materials*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 796, *Printed Wiring Boards*

UL 797, *Electrical Metallic Tubing – Steel*

UL 810, *Capacitors*

UL 817, *Cord Sets and Power-Supply Cords*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 867, *Electrostatic Air Cleaners*

UL 900, *Air Filter Units*

UL 917, *Clock-Operated Switches*

UL 935, *Fluorescent-Lamp Ballasts*

UL 969, *Marking and Labeling Systems*

UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*

UL 1004-1, *Rotating Electrical Machines – General Requirements*

UL 1004-2, *Impedance Protected Motors*

UL 1004-3, *Thermally Protected Motors*

UL 1004-7, *Electronically Protected Motors*

UL 1012, *Power Units Other Than Class 2*

UL 1029, *High-Intensity-Discharge Lamp Ballasts*

UL 1059, *Terminal Blocks*

UL 1063, *Machine-Tool Wires and Cables*

UL 1097, *Double Insulation Systems for Use in Electrical Equipment*

UL 1283, *Electromagnetic Interference Filters*

UL 1310, *Class 2 Power Units*

UL 1434, *Thermistor-Type Devices*

UL 1441, *Coated Electrical Sleeving*

UL 1446, *Systems of Insulating Materials – General*

UL 1565, *Positioning Devices*

UL 1581, *Reference Standard for Electrical Wires, Cables, and Flexible Cords*

UL 1598, *Luminaires*

UL 1917, *Solid-State Fan Speed Controls*

UL 1977, *Component Connectors for Use in Data, Signal, Control and Power Applications*

UL 1998, *Software in Programmable Components*

UL 2043, *Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces*

UL 4248-1, *Fuseholders – Part 1: General Requirements*

UL 4248-4, *Fuseholders – Part 4: Class CC*

UL 4248-5, *Fuseholders – Part 5: Class G*

UL 4248-6, *Fuseholders – Part 6: Class H*

UL 4248-8, *Fuseholders – Part 8: Class J*

UL 4248-9, *Fuseholders – Part 9: Class K*

UL 4248-11, *Fuseholders – Part 11: Type C (Edison Base) and Type S Plug Fuse*

UL 4248-12, *Fuseholders – Part 12: Class R*

UL 4248-15, *Fuseholders – Part 15: Class T*

UL 5085-1, *Low Voltage Transformers – Part 1: General Requirements*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 8750, *Light Emitting Diode (LED) Equipment for Use in Lighting Products*

UL 60335-2-40, *Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers*

UL 60691, *Thermal-Links – Requirements and Application Guide*

UL 60730-1, *Automatic Electrical Controls – Part 1: General Requirements*

UL 60730-2-8, *Automatic Electrical Controls - Part 2-8: Particular Requirements for Electrically Operated Water Valves, Including Mechanical Requirements*

UL 60730-2-9, *Automatic Electrical Controls - Part 2-9: Particular Requirements for Temperature Sensing Controls*

UL 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirements*

UL 61058-1, *Switches for Appliances – Part 1: General Requirements*

UL 61131-2, *Programmable Controllers – Part 2: Equipment Requirements and Tests*

UL 61800-5-1, *Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy*

UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

5 Glossary

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

5.2 AUTOMATIC CONTROL – A control in which at least one aspect is non-manual.

5.3 AUXILIARY CONTROL – A device or assembly of devices that provides a functional utility, is not relied upon as an operational or protective control, and therefore is not relied upon for safety. For example, an efficiency control not relied upon to reduce the risk of electric shock, fire, or injury to persons during normal or abnormal operation of the end product is considered an auxiliary control.

5.4 BARRIER – A partition for the insulation or isolation of electrical circuits or isolation of electrical arcs.

5.5 CONTROL CIRCUIT – The circuit that carries the electric signals directing the performance of a controller. A control circuit does not carry the main power current.

5.6 CONTROLLER – A device or group of devices that governs power delivered to a motor or other load in the equipment.

5.7 DIRECT-CONNECTED HIGH-VOLTAGE CONTROL CIRCUIT – A circuit 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(s) of the controlled circuit(s) within the equipment.

5.8 ENCLOSURE – That part of a unit which by itself or in conjunction with barriers reduces the risk of contacting all or any parts of the unit that may otherwise present a risk of electric shock or injury to persons and/or prevents propagation of flame initiated by electrical disturbances occurring within.

5.9 FUNCTIONAL PART – A part other than an enclosure or structural part that is necessary for the intended operation of a unit.

5.10 HEATER ASSEMBLY – A complete or partial assembly of the heating element, electrical insulation (for example, refractory or mica), metal sheath, thermal insulation, and frame or adaptor for holding the assembly together and fastening it in the heater enclosure; and leads and terminal connections, or both.

5.11 HEATING ELEMENT – The electrical conducting medium that is intended to be heated by an electric current.

5.12 HIGH-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage circuit.

5.13 LOW-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 30 volts alternating current (42.4 volts peak) or direct current, and supplied by:

a) A primary battery;

b) A Class 2 transformer; or

c) A combination of transformer and fixed impedance which, as a unit, complies with all the performance requirements for a Class 2 transformer.

A circuit derived from a high-voltage circuit by connecting resistance in series with the supply circuit as a means of limiting the voltage and current is not considered to be a low-voltage circuit.

5.14 MANUAL CONTROL – A device that requires direct human interaction to activate or reset the control.

5.15 MANUAL RESET THERMAL PROTECTOR – A device that incorporates a bimetal that is calibrated to open the motor circuit upon reaching a certain temperature and requires manual resetting to reclose the motor circuit.

5.16 OPERATING CONTROL – A device or assembly of devices, the operation of which starts or regulates the end product during normal operation. For example, a thermostat, the failure of which a thermal cutout/limiter or another layer of protection would mitigate the potential hazard, is considered an operating control. Operating controls are also referred to as "regulating controls".

5.17 PROTECTIVE CONTROL – A device or assembly of devices, the operation of which is intended to reduce the risk of electric shock, fire, or injury to persons during normal and reasonably anticipated abnormal operation of the appliance. For example, a thermal cutout/limiter, or any other control/circuit relied upon for normal and abnormal conditions, is considered a protective control. Protective controls are also referred to as "limiting controls" and "safety controls".

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

5.19 SECONDARY (BACK-UP) PROTECTION – A protector that does not operate under normal running or locked rotor test conditions, without further stress applied to the motor by increased winding temperature, ambient temperature, or voltage.

5.20 SINGLE-OPERATION DEVICE – A device that incorporates a bimetal that is calibrated to open the motor circuit upon reaching a certain temperature and is resettable only by cooling to minus 35 °C (minus 31 °F) or lower.

5.21 STRUCTURAL PART – A part used in such a manner that failure of the part may present a risk of electric shock or injury to persons.

5.22 TAPPED HIGH-VOLTAGE CONTROL CIRCUIT – A circuit that is tapped within the unit from a circuit supplying one or more loads that are not part of the control circuit.

5.23 THERMAL CUTOFF – A device that incorporates a melting alloy or other material that is calibrated to permanently open the motor circuit upon reaching a certain temperature.

5.24 THERMAL MOTOR PROTECTOR – A protective device that acts automatically to de-energize the windings of a motor and is sensitive to temperature and current of the windings.

5.25 TOTALLY ENCLOSED MOTOR – A motor that is enclosed to prevent the free exchange of air between the inside and outside of the enclosure for windings but not sufficiently enclosed to be airtight. Drain holes are acceptable.

5.26 TYPE 1 CONTROL – The actuation of an automatic control for which the manufacturing deviation and the drift (tolerance before and after certain conditions) of its operating value, operating time, or operating sequence have not been declared and tested under this Standard.

5.27 TYPE 2 CONTROL – The actuation of an automatic control for which the manufacturing deviation and the drift (tolerance before and after certain conditions) of its operating value, operating time, or operating sequence have been declared and tested under this Standard.

CONSTRUCTION

6 General

6.1 A component of a unit intended to be manually operated or adjusted by the user or that will require periodic servicing by the user (e.g. replacement or cleaning) shall be accessible by use of ordinary tools or without the use of tools. See 6.2.

6.2 With reference to 6.1, ordinary tools are considered to be pliers, flat-bladed and cross-recessed head (Phillips) screwdrivers, and hexagonal-recessed head screw (Allen) wrenches.

6.3 Other than as indicated in 6.4 and 6.5, a unit shall be completely assembled when shipped from the factory.

6.4 If the markings described in 76.8 are provided, a motor, a blower-drive package, a remote or unit mounted control assembly, or a control to be mounted on the outside of the unit may be shipped from the factory separate from the remainder of the unit.

6.5 A louvered panel or grille for indoor air intake or fresh air discharge intended to be installed as part of a unit intended for built-in installation or an enclosure panel that is not required for every intended installation of a unit may be shipped separately if:

a) The unit complies with the performance requirements without the panel or grille installed;

b) Markings in accordance with 76.8 are provided; and

c) Instructions provided describe installation of the panel or grille.

6.6 Any installation that requires the cutting of wiring or the soldering of connections by the installer is not acceptable. Installations that require cutting, drilling, or welding are not acceptable in electrical enclosures

and in other areas where such operations may damage electrical components and wiring within the enclosure. In general, a distance of 6 inches (152 mm) from the opening is considered adequate to reduce the risk of damage due to drilling or cutting, but other forms of protection may be acceptable.

6.7 A unit shall be so arranged that condensate from the heat exchanger will not wet uninsulated live parts or film-coated wire.

6.8 A condensate pan shall be designed and located so that overflow due to a blocked drain will not wet uninsulated live parts other than motor windings. See 6.9 and Section 42, Overflow Tests. Overflowing water also shall not be retained within the enclosure containing electrical parts or wiring.

6.9 A suitably located overflow spout or cutout in the condensate pan may be acceptable for preventing dripping of water on electrical parts.

6.10 Each ducted heat-recovery ventilator incorporating electrostatic air cleaning functions shall be constructed and tested in accordance with UL 867.

7 Attachment Plugs, Receptacles, Connectors, and Terminals

7.1 Attachment plugs, receptacles, appliance couplers, appliance inlets (motor attachment plugs), and appliance (flatiron) plugs shall comply with the requirements in UL 498.

Exception: Attachment plugs and appliance couplers integral to cord sets or power supply cords shall comply with the requirements in UL 817 and are not required to comply with UL 498.

7.2 The attachment plug of the power supply cord of an appliance provided with a 15- or 20-ampere general-use convenience receptacle shall be of the 3-wire grounding type. The attachment plug of the power supply cord of all other appliances not required to be grounded shall be polarized or of the grounding type.

7.3 Quick-connect terminals, both connectors and tabs, for use with one or two 22 – 10 AWG copper conductors, having nominal widths of 0.110, 0.125, 0.187, 0.205, and 0.250 inch (2.8, 3.2, 4.8, 5.2, and 6.3 mm), intended for internal wiring connections in appliances or for the field termination of conductors to the appliance shall comply with the requirements in UL 310.

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

7.4 Single and multipole connectors that are for use in data, signal, control, and power applications within and between electrical equipment and that are intended for factory assembly to copper or copper alloy conductors or to printed wiring boards shall comply with the requirements in UL 1977. See 7.9.

7.5 Wire connectors shall comply with the requirements in UL 486A-486B.

7.6 Splicing wire connectors shall comply with the requirements in UL 486C.

7.7 Equipment wiring terminals for use with all alloys of copper, aluminum, or copper-clad aluminum conductors shall comply with the requirements in UL 486E.

7.8 Terminal blocks shall comply with the requirements in UL 1059 and, if used for field wiring connection, shall be rated for field wiring.

7.9 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 rated for current interruption of the specific type of load when evaluated with its mating plug or connector.

8 Protection of Service Personnel

8.1 An uninsulated high-voltage live part and a moving part within the cabinet shall be located, guarded, or enclosed so as to reduce the risk of injury as the result of contact by service personnel performing mechanical service functions that may need to be performed with the unit energized. See 8.2 and 8.3.

8.2 Mechanical service functions that may have to be performed with the unit energized include:

a) Adjusting the setting of temperature controls with or without marked dial settings;

b) Resetting the control trip mechanism;

c) Operating manual switches; and

d) Adjusting air flow dampers.

A factory set and sealed control is not considered to be adjustable.

8.3 The requirements in 8.1 are not applicable to mechanical service functions that are not intended to be performed with the equipment energized. Such functions include opening of drain plugs, adjusting or replacing drive belts, replacing components, and the like.

8.4 Other than as indicated in 8.5, an electrical component that may require examination, adjustment, servicing, or maintenance is one of the following:

a) A fuse;

b) An adjustable or resettable overload relay;

c) A manual or magnetic motor controller;

d) A magnetically operated relay;

e) An adjustable or resettable temperature controller;

f) A manual switching device;

g) A clock timer; and

h) An incremental voltage-tap or motor-speed-tap terminals for a variable-speed motor.

Such a component in a low-voltage circuit shall comply with the requirements in 8.1 in relation to an uninsulated live part in a high-voltage circuit and to a moving part likely to cause a risk of injury to persons.

8.5 Under certain conditions, some of the components referred to in 8.4 are not required to be accessible for service. These components are as follows:

a) A nonadjustable magnetic motor controller or a magnetically operated relay that is inaccessible for service while energized because it is located behind subbases and the like and is not visible when the access panel(s) is removed;

b) An enclosed potential or current type single phase motor starting relay; and

c) An incremental voltage tap or a motor speed tap for a variable speed motor that requires contact with a bare live part of the voltage or speed tap to affect the speed or voltage change, such as an uninsulated screw or quick-connect terminal.

8.6 The following are not considered to be uninsulated live parts:

a) Coils of controllers, relays, solenoids, and transformer windings, if the coils and windings are provided with insulating overwraps;

b) Enclosed motor windings;

c) Terminals and splices with insulation; and

d) Insulated wire.

9 Enclosures

9.1 General

9.1.1 An enclosure shall be so formed and assembled that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected without total or partial collapse in shipment, installation, and use resulting in reduction of spacings, loosening or displacement of parts, or other defects.

9.1.2 An enclosure for an individual electrical component, an outer enclosure, and a combination of the two are to be considered in determining compliance with the requirements in 9.1.1.

9.1.3 The enclosure of a unit shall be provided with means for mounting in the intended manner. Any unique fittings necessary for such mounting shall be shipped with the unit. Other than as indicated in 9.1.4, a freestanding, floor-supported unit is not required to be provided with mounting means. See also 9.9.2.

9.1.4 A unit designed for installation in a mobile home shall have provision for securing it in place.

9.1.5 The enclosure of a unit shall not have any projections likely to cause persons to trip when walking near the unit after it is installed in the intended manner.

9.1.6 An outer cabinet is to be judged with respect to the size, shape, thickness of metal, and its acceptability for the particular application. Sheet steel having a thickness of less than 0.020 inch (0.51 mm) if uncoated or 0.023 inch (0.58 mm) if galvanized and nonferrous sheet metal having a thickness of less than 0.023 inch (0.58 mm) shall not be used except for relatively small areas or for surfaces that are curved or otherwise reinforced.

9.1.7 Among the factors that are taken into consideration when judging the acceptability of a polymeric enclosure or an enclosure of magnesium are:

a) Flame resistance;

b) Mechanical strength;

c) Resistance to impact;

d) Moisture absorptive properties; and

e) Resistance to distortion at temperatures to which the material may be subjected under conditions of normal or abnormal usage.

For a polymeric enclosure, all these factors are considered with respect to aging. See Section 12, Polymeric and Other Nonmetallic Materials.

9.2 Enclosure thickness

9.2.1 Sheet metal that serves as an electrical enclosure shall comply with the requirements in Table 9.1 or Table 9.2, whichever applies.

Exception No. 1: If the location of the enclosure is adequate to comply with the requirements in 9.1.1, an enclosure thinner than specified in Table 9.1 and Table 9.2 may be employed. See 9.4.1.

Exception No. 2: If the design and location of components are adequate to comply with the requirements in 9.1.1, an enclosure thinner than specified in Table 9.1 and Table 9.2 may be employed. See 9.4.1.

Exception No. 3: If the strength and rigidity of the frame and enclosure are adequate to comply with the requirements in 9.1.1, an enclosure thinner than specified in Table 9.1 and Table 9.2 may be employed. See 9.4.1.

Table 9.1
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 inches (mm)			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated (MSG)		Metal coated (GSG)	
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)				
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)	0.023[d]	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)	(24)		(24)	
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)	0.029[d]	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)	(22)		(22)	
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)	(20)		(20)	
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)	(18)		(18)	
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)	(16)		(16)	
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)	(15)		(15)	
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)	(14)		(14)	
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)	(13)		(13)	
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)	(12)		(12)	
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)	(11)		(11)	
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)

Table 9.1 Continued on Next Page

Table 9.1 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness in inches (mm)	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated (MSG)	Metal coated (GSG)
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)		
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)	(10)	(10)

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

a) A single sheet with single formed flanges (formed edges);

b) A single sheet which is corrugated or ribbed; and

c) An enclosure surface loosely attached to a frame (e.g. with spring clips).

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

[c] For panels which are not supported along one side (e.g. 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 continuous flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet steel for an enclosure intended for outdoor use shall comply with the requirements for Outdoor Use Equipment.

Table 9.2
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 inches (mm) AWG	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)		
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023[d]	(22)
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)	(0.58)	
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited		0.029	(20)
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)	(0.74)	
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited		0.036	(18)
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)	(0.91)	
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited		0.045	(16)
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	(1.14)	
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited		0.058	(14)
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	(1.47)	
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited		0.075	(12)
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)	(1.91)	
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited		0.095	(10)
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)	(2.41)	
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited		0.122	(8)
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)	(3.10)	
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited		0.153	(6)
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)	(3.89)	

Table 9.2 Continued on Next Page

Table 9.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness inches (mm) AWG
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure which is a rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

a) A single sheet with single formed flanges (formed edges);

b) A single sheet which is corrugated or ribbed; and

c) An enclosure surface loosely attached to a frame (e.g. with spring clips).

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

[c] For panels which are not supported along one side (e.g. 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 continuous flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use shall comply with the requirements for Outdoor Use Equipment.

9.2.2 With reference to Exception No. 1 to 9.2.1, the surface of an enclosure that will be protected from damage, such as by being mounted against a duct, may not be less than 0.020 inch (0.51 mm) if uncoated steel, less than 0.023 inch (0.58 mm) if galvanized steel, less than 0.036 inch (0.91 mm) if aluminum, and less than 0.033 inch (0.84 mm) if copper or brass, unless a lesser thickness would be acceptable in accordance with Table 9.1 and Table 9.2.

9.2.3 With reference to Exception No. 2 to 9.2.1, the surface of an enclosure may be:

a) Two gage sizes less than indicated in Table 9.1 and Table 9.2 if the electrical components are located at least 2-1/2 inches (63.5 mm) from the surface; and

b) Four gage sizes less if the components are located at least 5 inches (127 mm) from the surface.

The thickness shall not be less than No. 24 MSG or GSG (steel) or 18 AWG (aluminum, copper, or brass) unless a lesser thickness would be acceptable in accordance with Table 9.1 and Table 9.2. An example of two gage sizes less is No. 18 MSG instead of No. 16 MSG. An example of four gage sizes less is No. 20 MSG instead of No. 16 MSG.

9.2.4 With reference to Exception No. 3 to 9.2.1, consideration is to be given to the degree of deflection or distortion that may affect the results contemplated by the requirements in 9.1.1.

9.3 Doors and covers

9.3.1 Except as indicated in 9.3.2 and 9.3.3, the door or cover of an enclosure shall be hinged if:

a) The door or cover gives access to any fuse, circuit-breaker handle, or manually resettable lever of a temperature control in other than a low-voltage circuit; and

b) Replacement of the fuse or resetting of the manually resettable device exposes uninsulated live parts.

Such a door or cover shall also be provided with an automatic latch or the equivalent. If live parts other than the screw shell of a plug fuseholder are exposed inside the enclosure, such a door or cover shall also

be provided with a captive screw or equivalent means requiring the use of a tool to open and to reliably secure the door or cover in place. See 9.3.4 and 9.3.5.

9.3.2 A hinged cover is not required for a device in which the only fuses enclosed are:

a) Control circuit fuses, provided the fuses and control circuit loads (other than a fixed control circuit load, such as a pilot lamp) are within the same enclosure; or

b) An extractor type fuse with its own enclosure that is accessible without exposing live parts other than a fuse contact of the fuseholder.

9.3.3 The removable portion of a fused pullout switch that complies with the requirements in 9.1.1 and 9.1.2, 9.1.6 – 9.2.4, 9.3.7, and 9.3.8 is considered to be an acceptable cover for the fuseholder and is not required to comply with the requirements in 9.3.1.

9.3.4 A spring latch, a magnetic latch, a dimple, or any other mechanical arrangement that will hold the door closed and would require some effort on the user's part to open is considered to provide the "automatic latching means" for holding the door closed as required in 9.3.1.

9.3.5 A cover interlocking mechanism is considered to comply with the requirements for an automatic latch in 9.3.1 if:

a) It must be engaged in the closed position of the cover before any uninsulated live part is energized; and

b) It will secure the cover in the closed position, if provided as the sole means for securing the door or cover closed.

9.3.6 A screw with a knurled and slotted head (for securing with a screwdriver) and that can be manually turned is not acceptable as a required enclosure securing means.

9.3.7 A door or cover giving direct access to fuses in other than a low-voltage circuit shall shut closely against a 1/4-inch (6.4 mm) rabbet or the equivalent or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges and angle strips shall fit closely with the outside of the wall of the box proper and shall overlap the edges of the box by no less than 1/2 inch (12.7 mm).

Exception: A construction that affords equivalent protection or a combination of flange and rabbet is acceptable.

9.3.8 A strip used to provide a rabbet and an angle strip fastened to the edges of a door shall be secured:

a) At no less than two points;

b) No more than 1-1/2 inches (38.1 mm) from each end of each strip; and

c) At points between these end fastenings no more than 6 inches (152 mm) apart.

9.4 Field wiring system connections

9.4.1 Sheet metal to which a wiring system is to be connected in the field shall have a thickness not less than:

a) 0.032 inch (0.81 mm) if uncoated steel;

b) 0.034 inch (0.86 mm) if galvanized steel; and

c) 0.045 inch (1.14 mm) if nonferrous material.

9.4.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or if an equivalent construction is employed, there shall not be less than three or more than five threads in the metal. The construction of the device shall be such that a conduit bushing can be attached.

9.4.3 If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal. There shall be a smooth, rounded inlet hole for the conductors that shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and that shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

9.4.4 A knockout in a sheet metal enclosure shall be capable of being removed without deformation of the enclosure that would affect the intended attachment of a conduit fitting.

9.4.5 A knockout shall remain in place when a force of 10 pounds (44 N) is applied at right angles to the knockout by a 1/4 inch (6.4 mm) diameter mandrel with a flat end. The mandrel shall be applied at the point most likely to cause movement of the knockout.

9.4.6 A knockout shall be provided with a flat surrounding surface for seating of a conduit bushing and shall be so located that installation of a bushing at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing less than those specified in Table 35.1 or Table 35.2, as applicable.

9.4.7 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout, it is to be assumed that a bushing having the dimension indicated in Table 9.3 is in place in conjunction with a single locknut on the outside of the enclosure.

Table 9.3
Knockout or Hole Sizes and Dimensions of Bushings

Trade size of conduit		Knockout or hole diameter		Bushing dimensions			
				Overall diameter		Height	
inches	(mm OD)	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	(102)	4-1/8	(105)	4-7/16	(113)	15/16	(23.8)
4	(114)	4-5/8	(118)	4-31/32	(126)	1	(25.4)
4-1/2	(127)	5-1/8	(130)	5-35/64	(141)	1-1/16	(27.0)
5	(141)	5-5/8	(143)	6-7/32	(158)	1-3/16	(30.2)
6	(168)	6-3/4	(172)	7-7/32	(183)	1-1/4	(31.8)