



# UL 1812

## STANDARD FOR SAFETY

### Ducted Heat Recovery Ventilators

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

Fourth Edition, Dated May 3, 2013

### **Summary of Topics**

***This revision to UL 1812 dated May 3, 2022 includes correcting the Impact Test from 5 foot-pounds to 1.5 for non-structural nonmetallic structural parts; [45.10.2](#)***

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 February 21, 2022.

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**MAY 3, 2013**  
(Title Page Reprinted: May 3, 2022)

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**UL 1812**

**Standard for Ducted Heat Recovery Ventilators**

First Edition – April, 1990  
Second Edition – April, 1995  
Third Edition – October, 2009

**Fourth Edition**

**May 3, 2013**

This UL Standard for Safety consists of the Fourth Edition including revisions through May 3, 2022.

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>.

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**Appendix A Normative**

**Appendix B Example of Controls Performing as Operating or Protective Controls Informative**

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## 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 General

#### 2.1 Units of measurement

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

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

#### 2.2 Undated references

2.2.1 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.

### 3 Glossary

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

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

3.2.1 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.

a) 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  $\leq 2.5\text{KV}$ , an X2 capacitor is permitted.

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

3.2.2 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.

a) 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.

b) 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  $\geq 150\text{V}$  and  $\leq 300\text{V}$ .

c) 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  $\leq 150\text{V}$ .

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

3.4 CONTROL, AUXILIARY – 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.

3.5 CONTROL, MANUAL – A device that requires direct human interaction to activate or rest the control.

3.6 CONTROL, OPERATING – 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”.

3.7 CONTROL, PROTECTIVE – 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”.

3.8 CONTROL, TYPE 1 – 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 has not been declared and tested under this standard.

3.9 CONTROL, TYPE 2 – 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.

3.10 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.

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

3.12 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.

3.13 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.

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

3.15 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.

3.16 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.

3.17 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.

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

3.18 SECONDARY PROTECTION (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.

3.19 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.

3.20 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.

3.21 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.

3.22 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.

3.23 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.

## 4 Installation and Operating Instructions

4.1 Installation and operating instructions shall be furnished with units and accessories.

4.2 Instructions are to accompany each unit and accessory, either individually or with each shipment to the installer. If the instructions for the unit do not cover a field installed accessory, instructions are to be furnished with the accessory.

4.3 A copy of the installation and operating instructions or equivalent information is to be furnished with the samples submitted for investigation for use as a guide in the examination and test of the unit. For this purpose, the instructions need not be in final printed form.

4.4 The instructions shall include directions and information deemed by the manufacturer to be adequate for the intended installation, maintenance, and use of the unit, including application information as to mounting. Applicable information as to such quantities as air flow velocity and static pressure shall be made available by the manufacturer.

4.5 If a unit having provision for connection of a fresh air discharge duct does not also have provision for connection of an indoor air intake duct, or if the instructions indicate that an indoor air intake duct need not be connected, the instructions should indicate that applicable installation codes may limit the unit to installation only in a single story residence.

## CONSTRUCTION

### 5 Components

5.1 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 a component standard other than those cited in this standard is acceptable if:*

- a) The component also complies with 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 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.

5.2 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.

5.3 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) need not be applied.*

5.4 A component not anticipated 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 [5.1\(b\)](#) – (d).

5.5 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.

## 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, for example, 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 [61.8](#) 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 [61.8](#) 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 [39](#). 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.

## 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 the Standard for Attachment Plugs and Receptacles, UL 498.

*Exception: Attachment plugs and appliance couplers integral to cord sets or power supply cords shall comply with the requirements in the Standard for Cord Sets and Power-Supply Cords, UL 817, and need not comply with the Standard for Attachment Plugs and Receptacles, UL 498.*

7.2 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 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 the requirements in the Standard for Electrical Quick-Connection Terminals, UL 310.*

7.3 Single and multipole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory assembly to copper or copper alloy conductors, or for factory assembly to printed wiring boards, shall comply with the requirements in the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977. See [7.8](#).

7.4 Wire connectors shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B.

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

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

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

7.8 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 fuse, an adjustable or resettable overload relay, a manual or magnetic motor controller, a magnetically operated relay, an adjustable or resettable temperature controller, a manual switching device, a clock timer, and 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 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 effect 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 requirement 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 need not 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, or nonferrous sheet metal having a thickness of less than 0.023 inch 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 of these factors are considered with respect to aging. See Polymeric and Other Nonmetallic Materials, Section [12](#).

### 9.2 Enclosure thickness

9.2.1 Sheet metal that serves as an electrical enclosure shall comply with [Table 9.1](#) or [Table 9.2](#), whichever applies, except that if the:

- a) location of the enclosure,
- b) design and location of components, or

c) the strength and rigidity of the frame and enclosure are adequate to comply with [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 <sup>a</sup> |         | With supporting frame or equivalent reinforcing <sup>a</sup> |         | Minimum thickness in inches (mm) |         |                    |                           |                           |      |
|---------------------------------------|---------|--|---------|----------------------------------|---------|--------------------|---------------------------|---------------------------|------|
| Maximum width, <sup>b</sup>           |         | Maximum length, <sup>c</sup>                                 |         | Uncoated (MSG)                   |         | Metal coated (GSG) |                           |                           |      |
| inches                                | (cm)    | inches   | (cm)    | inches                           | (cm)    | inches             | (mm)                      |                           |      |
| 4.0                                   | (10.2)  | Not limited  |         | 6.25                             | (15.9)  | Not limited        | 0.020 <sup>d</sup> (0.51) | 0.023 <sup>d</sup> (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 <sup>d</sup> (0.66) | 0.029 <sup>d</sup> (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)              |      |
| 73.0                                  | (185.4) | 90.0   | (228.6) | 103.0                            | (261.6) | 127.0              | (322.6)                   | (10)                      | (10) |

<sup>a</sup> A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has 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:

1. single sheet with single formed flanges (formed edges),
2. a single sheet which is corrugated or ribbed, and
3. an enclosure surface loosely attached to a frame, for example, with spring clips.

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

<sup>c</sup> For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a continuous flange at least 1/2 inch (12.7 mm) wide.

<sup>d</sup> 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 <sup>a</sup>     |  | With supporting frame or equivalent reinforcing <sup>a</sup> |  |   |  | Minimum thickness<br>inches (mm) AWG |
|---|--|--|--|---|--|--------------------------------------|
| Maximum width <sup>b</sup><br>inches (cm) | Maximum length <sup>c</sup><br>inches (cm) | Maximum width <sup>b</sup><br>inches (cm)                    | Maximum length <sup>c</sup><br>inches (cm) | Maximum width <sup>b</sup><br>inches (cm) | Maximum length <sup>c</sup><br>inches (cm) |                                      |
| 3.0 (7.6)                                 | Not limited                                | 7.0 (17.8)   | Not limited                                | 7.0 (17.8)                                | Not limited                                | 0.023 <sup>d</sup> (22)              |
| 3.5 (8.9)                                 | 4.0 (10.2)                                 | 8.5 (21.6)   | 9.5 (24.1)                                 | 8.5 (21.6)                                | 9.5 (24.1)                                 | (0.58)                               |
| 4.0 (10.2)                                | Not limited                                | 10.0 (25.4)  | 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)                                | 10.5 (26.7)                               | 13.5 (34.3)                                | (0.74)                               |
| 6.0 (15.2)                                | Not limited                                | 14.0 (35.6)  | 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)                                | 15.0 (38.1)                               | 18.0 (45.7)                                | (0.91)                               |
| 8.0 (20.3)                                | Not limited                                | 19.0 (48.3)  | 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)                                | 21.0 (53.3)                               | 25.0 (63.5)                                | (1.14)                               |
| 12.0 (30.5)                               | Not limited                                | 28.0 (71.1)  | 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)                                | 30.0 (76.2)                               | 37.0 (94.0)                                | (1.47)                               |
| 18.0 (45.7)                               | Not limited                                | 42.0 (106.7)   | 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)                               | 45.0 (114.3)                              | 55.0 (139.7)                               | (1.91)                               |
| 25.0 (63.5)                               | Not limited                                | 60.0 (152.4)   | 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)                               | 64.0 (162.6)                              | 78.0 (198.1)                               | (2.41)                               |
| 37.0 (94.0)                               | Not limited                                | 87.0 (221.0)   | 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)                              | 93.0 (236.2)                              | 114.0 (289.6)                              | (3.10)                               |
| 52.0 (132.1)                              | Not limited                                | 123.0 (312.4)  | 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)                              | 130.0 (330.2)                             | 160.0 (406.4)                              | (3.89)                               |

<sup>a</sup> A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has 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:

1. single sheet with single formed flanges (formed edges),
2. a single sheet which is corrugated or ribbed, and
3. an enclosure surface loosely attached to a frame, for example, with spring clips.

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

<sup>c</sup> For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a continuous flange at least 1/2 inch (12.7 mm) wide.

<sup>d</sup> 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 9.2.1(a), 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, not less than 0.023 inch (0.58 mm) if galvanized steel, not less than 0.036 inch (0.91 mm) if aluminum, and not 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 9.2.1(b), 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 (64 mm) from the surface, and

b) four gage sizes less if the components are located at least 5 inches (128 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 [9.2.1\(c\)](#), 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:

- a) if it 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) if uninsulated live parts are exposed during the replacement of the fuse or resetting of the manually resettable device.

Such a door or cover shall also be provided with an automatic latch or the equivalent, and, if live parts other than the screw shell of a plug fuseholder are exposed inside the enclosure, shall 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 need not comply with the requirements in [9.3.1](#).

9.3.4 A spring latch, a magnetic latch, a dimple, or 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 that:

- a) must be engaged in the closed position of the cover before any uninsulated live part is energized, and
- b) will secure the cover in the closed position, if provided as the sole means for securing the door or cover closed, is considered to comply with the requirement for an automatic latch in [9.3.1](#).

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 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 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 34.1](#) or [Table 34.2](#), 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                 | 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 |

## 9.5 User servicing

9.5.1 Uninsulated high-voltage live parts of a unit shall be located, guarded, or enclosed so as to reduce the likelihood of unintentional contact by persons performing operations such as oiling motors, replacing filters, or adjusting controls. See [61.1](#).

9.5.2 A rubber or neoprene boot over the terminal of a motor capacitor that is accessible during user servicing:

- a) shall not be less than 1/32 inch (0.8 mm) thick,
- b) shall resist thermal degradation, and
- c) shall incorporate means to secure the boot in place, such as a molded lip that fits over the flange of the capacitor case.

9.5.3 Fan blades, blower wheels, pulleys, belts, and the like, shall be enclosed or guarded to reduce the risk of injury to persons. See [9.5.4](#) – [9.5.8](#).

9.5.4 The degree of protection required in [9.5.3](#) depends upon the general design and the intended use of the unit. Factors to be taken into consideration in judging the acceptability of protection against contact with moving parts are:

- a) the degree of exposure afforded by intended locations in use,
- b) the sharpness of the moving parts,
- c) the likelihood of unintentional contact with the moving parts,
- d) the speed of movement, and
- e) the likelihood of fingers, arms, or clothing being drawn into the moving parts (such as at points where gears mesh, where belts travel onto a pulley, or where moving parts close in a pinching or shearing action).