

Solid-Fuel and Combination-Fuel Central and Supplementary Furnaces



Northbrook, Illinois • (708) 272-8800

Melville, New York • (516) 271-6200

Santa Clara, California • (408) 985-2400

Research Triangle Park,
North Carolina • (919) 549-1400**Underwriters Laboratories Inc.®**

Underwriters Laboratories Inc., founded in 1894, is chartered as a not-for-profit organization without capital stock, under the laws of the State of Delaware, to establish, maintain, and operate laboratories for the examination and testing of devices, systems and materials to determine their relation to hazards to life and property, and to ascertain, define and publish standards, classifications and specifications for materials, devices, products, equipment, constructions, methods, and systems affecting such hazards.

UL Standards for Safety are developed under a procedure which provides for participation and comment from the affected public as well as industry. The procedure takes into consideration a survey of known existing standards and the needs and opinions of a wide variety of interests concerned with the subject matter of the standard. Thus manufacturers, consumers, individuals associated with consumer-oriented organizations, academicians, government officials, industrial and commercial users, inspection authorities, insurance interests and others provide input to UL in the formulating of UL Standards for Safety, to keep them consonant with social and technological advances.

A not-for-profit organization
dedicated to public safety and
committed to quality service

AVA Documents
Document Sharing Hub



Underwriters Laboratories Inc.®

A not-for-profit organization dedicated to public safety
and committed to quality service

April 13, 1995

Standard for

Solid-Fuel and Combination-Fuel Central and Supplementary Furnaces

UL 391, Third Edition

Accompanying this transmittal notice is a copy of the Third edition of UL 391.

THIS EDITION OF THE STANDARD IS NOW IN EFFECT.

Revised and/or additional pages may be issued from time to time.

APRIL 13, 1995

1

UL 391

Standard for

**Solid-Fuel and Combination-Fuel
Central and Supplementary Furnaces**

First Edition – July, 1981
Second Edition – August, 1991

Third Edition

April 13, 1995

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest published set of revision pages.

ISBN 1-55989-801-1

COPYRIGHT ©1981, 1995 UNDERWRITERS LABORATORIES INC.

CONTENTS

FOREWORD

INTRODUCTION

1 Scope	7
2 Units of Measurement	7
3 Glossary	7
4 Components	9

CONSTRUCTION

5 General	10
6 Accessibility for Servicing	12
7 Protection of Users and Service Personnel	13
8 Base	16
9 Casings	17
10 Radiation Shields or Liners	17
11 Materials in Air-Handling Compartments	18
12 Air Filters	18
13 Combustion Chambers	19
14 Radiators	19
15 Heating Surface Joints	19
16 Baffles	19
17 Flue Collars	20
18 Disposal of Combustion Products	20
19 Dampers, Shutters and Draft Regulators	20
20 Electrical Enclosures	20
21 Accessibility of Uninsulated Live Parts, Film-Coated Wire and Moving Parts	26

FIELD WIRING

22 General	31
23 Leads and Terminals	32

INTERNAL WIRING

24 General	34
25 Methods	34
26 Short-Circuit Protection	37
27 Separation of Circuits	38
28 Bonding for Grounding	39

ELECTRICAL COMPONENTS

29 General	42
30 Mounting of Electrical Components	43
31 Electrical Insulating Material	43
32 Capacitors	44

33 Motors and Motor (Overload) Protection	44
34 Safety Controls and Circuits	48
35 Switches and Controllers	49

SPACINGS

36 High-Voltage Circuits	50
37 Low-Voltage Circuits	52

PERFORMANCE

38 General	52
------------------	----

TEST INSTALLATION FOR CENTRAL FURNACES

39 Enclosure	53
40 Chimney Connector	54
41 Supply-and Return-Air Plenums and Ducts – Forced-Air Furnace	57

TEST INSTALLATION FOR SUPPLEMENTARY CENTRAL FURNACES

42 General	58
------------------	----

INSTRUMENTATION

43 Draft	58
44 Fuel Input	58
45 Power Measurement	59
46 Speed Measurement	59
47 Static Pressure	59
48 Temperature Measurement	61

INITIAL TEST CONDITIONS

49 General	64
50 Static Pressures for Tests	64
51 Solid Fuels and Test Firing Procedures	65

INITIAL TESTS

52 Combustion Test – Oil Burner and Furnace	67
53 Operation Test	68
54 Limit Control Cutout Test	69

TEMPERATURE TESTS

55 General	71
56 Continuous Operation Test	76
57 Air Flow Restriction and Disruption Tests	78

OTHER TESTS

58 Delayed Oil Ignition Test	79
59 Dielectric Voltage Withstand Test	80
60 Bonding Joint Test	80
61 Bonding Conductor Test	80
62 Knockout Security Test	81
63 Lead Stress Test	81
64 Surface Burning Test	81
65 Polymeric Materials Tests	81
66 Short Circuit Test	83

MANUFACTURING AND PRODUCTION TESTS

67 General	85
68 Production Line Dielectric Voltage Withstand Tests	85

MARKING

69 Nameplate	86
70 Supplementary	88
71 Instructions	89

APPENDIX A

Standards for Components	A1
--------------------------------	----

FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements apply to manually fueled, solid-fuel-fired central furnaces. Included are supplementary central furnaces intended for interconnection with forced-air central furnaces utilizing other fuels, and combination oil-fired and solid-fuel-fired, forced-air central furnaces.

1.2 The furnaces are intended to burn solid fuels, such as wood, coal, or any other biomass fuel, as specified by the manufacturer.

1.3 The furnaces are intended for connection to chimneys for residential and building heating appliances in compliance with the Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances, NFPA 211, and intended for installation in compliance with the Standard for Installation of Warm Air Heating and Air Conditioning Systems, NFPA 90B; and the National Electrical Code, ANSI/NFPA 70; and applicable mechanical codes such as the BOCA National Mechanical Code, the Standard Mechanical Code, and the Uniform Mechanical Code.

1.4 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this Standard, and that involve a risk of fire, electric shock, or injury to persons shall be evaluated using the appropriate additional component and end-product requirements as determined necessary to maintain the acceptable level of safety as originally anticipated by the intent of this Standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this Standard cannot be judged to comply with this Standard. Where considered appropriate, revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this Standard.

2 Units of Measurement

2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

3 Glossary

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

3.2 **AIR SHUTTER** – An adjustable device for varying the size of the air inlet or inlets regulating primary air, secondary air, or both. It may be either manually or automatically operated.

3.3 **APPLIANCE FLUE** – The passages within the product that conduct the products of combustion (flue gases) through the product.

3.4 **BURNER, OIL** – A power-operated burner that prepares and delivers the oil and all or part of the air by mechanical process in controllable quantities for combustion.

3.5 **CHIMNEY CONNECTOR** – The pipe that connects a fuel-burning product to a chimney.

3.6 **COMBUSTIBLE MATERIAL, COMBUSTIBLE PRODUCTS, NONCOMBUSTIBLE** – These terms, as used in this standard, are defined in the Standard Glossary of Terms Relating to Chimneys, Vents, and Heat-Producing Appliances, NFPA 97-1992.

- 3.7 **CONTROL, LIMIT** – An automatic control responsive to changes in pressure or temperature and intended to limit the operation of the controlled equipment.
- 3.8 **CONTROL, PRIMARY SAFETY** – The automatic control relied upon to reduce the risk of discharge of oil at the burner in case of loss of ignition or loss of flame.
- 3.9 **CONTROL, SAFETY** – Any automatic control, such as a relay or switch, used in conjunction with other auxiliary equipment to form a safety control system that is relied upon to reduce the risk of fire, electric shock, or injury to persons.
- 3.10 **CONTROL, SAFETY COMBUSTION** – A primary control directly responsive to flame properties. Senses the presence of flame and causes fuel to be shut off in event of loss of flame.
- 3.11 **CONTROL, THERMOSTATIC DAMPER** – An automatic control responsive to changes in temperature. Usually acts through direct mechanical linkage to reduce or increase the supply of air needed for combustion, thereby regulating the combustion rate and limiting the operation of the product when the product is burning solid fuel.
- 3.12 **DAMPER** – A valve or plate that regulates draft or flow of flue gases or inlet combustion air. May be either manually or automatically operated.
- 3.13 **DRAFT REGULATOR** – A device that functions to maintain a desired draft in the product by automatically reducing the chimney draft to the desired value.
- 3.14 **ELECTRICAL CIRCUITS:**
- a) **High-Voltage Circuit** – A circuit involving a potential of not more than 600 volts and having circuit values in excess of those of a low-voltage circuit.
 - b) **Low-Voltage Circuit** – A circuit involving a potential of not more than 30 volts alternating current (42.4 peak or direct current) and supplied by a NEC Class 2 transformer, or by a battery, or by a battery and fixed impedance, or by a transformer and fixed impedance each of which, as a unit, is either in compliance with requirements for a Class 2 transformer or is otherwise limited to a maximum output of 100 volt-amperes. A circuit derived by connecting resistance in series with a high-voltage circuit as a means of limiting the voltage and current is not considered a low-voltage circuit.
 - c) **Isolated Limited Secondary Circuit** – A circuit of limited energy output derived from a isolated secondary winding of a transformer having a maximum capacity of 100 volt-amperes and open-circuit secondary voltage rating not exceeding 1000 volts.
- 3.15 **FLOOR PROTECTOR (STOVE MAT)** – The noncombustible material applied to the floor area underneath, in front of, and at the sides of the fuel charging area and underneath the chimney connector area of the product.
- 3.16 **FUEL OIL** – Any hydrocarbon oil defined by the Standard for Specification for Fuel Oils, ANSI/ASTM D396-1992.
- 3.17 **FURNACE, CENTRAL** – A self-contained indirect-fired product supplying heated air through ducts to the space to be heated. Air is circulated either by means of a power-driven fan (a forced-air furnace) or by means of natural convection (a gravity furnace).

3.18 **FURNACE, COMBINATION OIL-FIRED AND SOLID-FUEL-FIRED CENTRAL** – A central furnace burning fuel oil and solid fuel either separately or simultaneously. The furnace makes use of either separate or common combustion chambers and flues for burning the two fuels.

3.19 **FURNACE, SUPPLEMENTARY CENTRAL** – A solid-fuel-burning product intended to be interconnected with a gas- or oil-fired forced-air central furnace by means of a common warm-air supply plenum in accordance with the manufacturer's instructions.

3.20 **GRATE** – A metal frame provided by the manufacturer for supporting the fuel within a furnace.

3.21 **HEARTH** – The floor area within the fire chamber of a furnace.

3.22 **INDIRECT-FIRED VENTED PRODUCT** – A product in which the products of combustion and the medium being heated (circulating air, for example) are segregated by the walls of the fire chamber and flues; it is provided with a flue collar to accommodate a chimney connector for conveying the products of combustion to the outdoors.

3.23 **RADIATION SHIELD** – A separate panel or separate panels interposed between heating surfaces and adjacent objects for the purpose of reducing heat transmission by radiation.

3.24 **RADIATOR** – Auxiliary heat transfer surfaces within the casing, connected between the combustion chamber and the flue collar.

3.25 **SERVICING** – The periodic tasks usually performed to operate and maintain a product, such as air, fuel, and pressure adjustments, cleaning of flues and chimney, lubrication, and resetting of controls. Repair and replacement of parts other than those expected to be renewed periodically, such as replacement of air filters, is not considered to be servicing. Some examples of servicing are:

- a) Cleaning or replacing nozzles;
- b) Setting ignition electrodes;
- c) Cleaning or replacing strainer or filter elements;
- d) Resetting safety control; and
- e) Replacing igniter cable.

4 Components

4.1 Except as indicated in 4.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

4.2 A component need not comply with a specific requirement that:

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

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

4.4 Specific components are recognized as being 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 for which they have been recognized.

CONSTRUCTION

5 General

5.1 A furnace shall be factory built as a complete assembly and shall include all the components necessary for its intended installation and operation. A furnace may be shipped as two or more major subassemblies.

5.2 Major subassemblies of a furnace are considered to be:

- a) The burner;
- b) The heat exchanger, including its base, combustion chamber, casing, and safety controls;
- c) The blower assembly, including its base, filters, and casing; and
- d) The blower motor, if not included as part of the blower assembly.

A wiring harness may be packaged with one of the major subassemblies.

5.3 A furnace shall be arranged in major subassemblies, if the furnace is not assembled by the manufacturer as a unit. Each subassembly shall be capable of assembly into the final assembly without the installer altering, cutting, drilling (except as indicated in 5.4), threading, welding, or performing similar tasks. If the intended installation and operation of the furnace so requires, two or more subassemblies shall either:

- a) Be arranged and constructed so that they can be incorporated into the complete assembly only in the intended manner; or
- b) Be assembled, tested, and shipped from the factory as one element.

5.4 Cutting or drilling complies with the requirements of 5.3 if it is needed for either:

- a) The attachment of a return or supply plenum or an optional filter rack; or
- b) The provision of a return-air opening in the furnace casing. If a return-air opening is to be cut in the casing panel by the installer, either the necessary instructions and template shall be furnished with the furnace, or the corners of the opening shall be embossed in knockout form.

5.5 A radiation shield or baffle relied upon to reduce the risk of temperatures in excess of those intended shall:

- a) Be assembled as part of the furnace;
- b) Be part of a subassembly that must be attached to the furnace for its intended operation; or
- c) Be constructed so that the furnace cannot be assembled for operation without first attaching a required shield or baffle in its intended position.

5.6 Alteration or removal of a baffle, insulation, or radiation shield needed to reduce the risk of excessive temperatures shall not be required for any intended furnace installation.

5.7 The construction of a furnace shall permit the user to operate those parts requiring the user's attention or adjustment in anticipated usage.

5.8 An adjustable or movable part shall be provided with a locking device to secure it against unintended shifting.

5.9 A screw or bolt used to attach a part that may be detached for care or servicing of the product shall hold its position upon the application of the torque specified in Table 5.1 after removal and replacement of the part.

Table 5.1
Torque requirements for screws or bolts

American standard screw size		Torque		I.S.O. screw size	Torque	
No.	mm	Lb-Inch	N·m	mm	N·m	Lb-Inch
—	—	—	—	4	1.6	14
8	4.2	18	2.0	4.5	2.6	23
10	4.8	30	3.4	5	4.2	37
Inch	mm	Lb-Inch	N·m	mm	N·m	Lb-Inch
1/4	6.4	100	11.3	6	8.7	77
—	—	—	—	7	15.0	133
5/16	7.9	200	22.6	8	23.5	208
—	—	—	—	9	33.6	297
3/8	9.5	350	39.6	10	45.2	400
7/16	11.1	575	65.0	12	81.0	715
1/2	12.7	850	96.0	14	128.0	1130
9/16	14.3	1200	136.0	—	—	—
5/8	15.9	1600	181.0	16	185.0	1640

5.10 Any external door providing access to the combustion chamber of a furnace and intended for installation with a clearance of less than 24 inches (610 mm) from the face of the door or 48 inches (1220 mm) above the door shall be self-closing.

5.11 A furnace intended for installation in the cooled-air path, downstream from a cooling coil, shall comply with (a) – (d):

- a) All interior surfaces of the heat exchanger, combustion chamber (including its bottom), radiators, and flues shall resist corrosion by moisture.
- b) The firebox liner shall resist deterioration from wetting by condensation.
- c) Condensation shall not drip on burner parts or other parts vulnerable to corrosion if corrosion of any of the parts may cause a risk of fire, electric shock, or injury to persons.
- d) The heat exchanger and appliance flue shall not contain traps or pockets in which condensation may collect.

5.12 An oil burner shall be secured so that it will not twist, slide, or drop out of position.

5.13 A grate shall be used in a furnace intended to burn coal.

5.14 When a user's hand is withdrawn from a separable door handle (if provided) that is intended to be used either during solid-fuel loading and ash removal or with products requiring manual operation, the handle shall not remain in a position that allows temperatures on the handle to rise above those specified in Table 55.1.

5.15 Provision shall be made for storing a separable handle on the furnace. When the handle is stored in its intended position, its temperature shall not exceed the appropriate temperature specified in Table 55.1.

5.16 Fuel-loading and ash-removal doors shall not warp or misalign when the furnace is subjected to the tests specified in the Performance section of this standard if air leaking into the combustion chamber because of the warping or misalignment can result in a risk of overfiring or fire outside the furnace.

5.17 Fuel-loading and ash-removal doors shall close by gravity or shall be provided with a latch. Combination oil-fired and solid-fuel-fired furnace doors shall not open during delayed oil ignition unless it can be determined that particles of burning solid fuel cannot be expelled through the door opening by the force of the delayed oil ignition. See Delayed Oil Ignition Test, Section 58.

5.18 A combination oil-fired and solid-fuel-fired central furnace shall be provided with an interlock relied upon to reduce the risk of firing of the oil burner with either or both the solid-fuel loading door or the ash-removal door open, if this operation can result in the risk of fire, explosion, or injury to persons.

6 Accessibility for Servicing

6.1 A furnace shall be provided with means of access for cleaning of parts, such as internal heating surfaces in contact with combustion products, oil-inlet pipes, and oil strainers, without major dismantling of the furnace or removal of parts required to be factory-assembled.

6.2 With reference to the requirements of 6.1, the removal of access panels, burners, blowers, caps, plugs, and the like, permitting removal and replacement of parts for servicing, and the detachment of the chimney connector are not considered major dismantling.

6.3 All burners, controls, and safety devices shall be accessible for cleaning, inspection, repair, and replacement when the furnace is installed as intended by the manufacturer. Parts in the assembly removable for servicing shall be arranged so that their restoration, following removal, will not necessitate their realignment to secure their intended relationship with other parts of the assembly. Special facilities required for servicing to be performed by the operator shall accompany the furnace as supplied by the user.

7 Protection of Users and Service Personnel

7.1 An uninsulated, high-voltage live part or a moving part that creates a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintended contact by personnel performing service functions that may have to be performed while the equipment is energized.

7.2 Service functions that may have to be performed while the equipment is energized include:

- a) Adjusting the setting of temperature controls that do or do not have marked dial settings;
- b) Resetting a control trip mechanism;
- c) Operating manual switches; and
- b) Adjusting air-flow dampers.

A factory-set and -sealed control is not considered adjustable.

7.3 The requirements of 7.1 are not applicable to mechanical service functions not anticipated to be performed while the equipment is energized. Such functions include adjusting or replacing belts and cleaning and replacing strainers and oil filters.

7.4 Adjustable or resettable electrical control or manual switching devices may be located or oriented with respect to uninsulated high-voltage live parts so that manipulation of the mechanism for adjustment, resetting, or operation can be accomplished in the intended direction of access if uninsulated, high-voltage live parts or moving parts involving a risk of injury to persons are:

- a) Not located in front of or in the direction of access to the mechanism; and
- b) Are not located within 6 inches (150 mm) of the mechanism, whether the parts are positioned on any side of the mechanism or whether they are behind it, unless they are guarded.

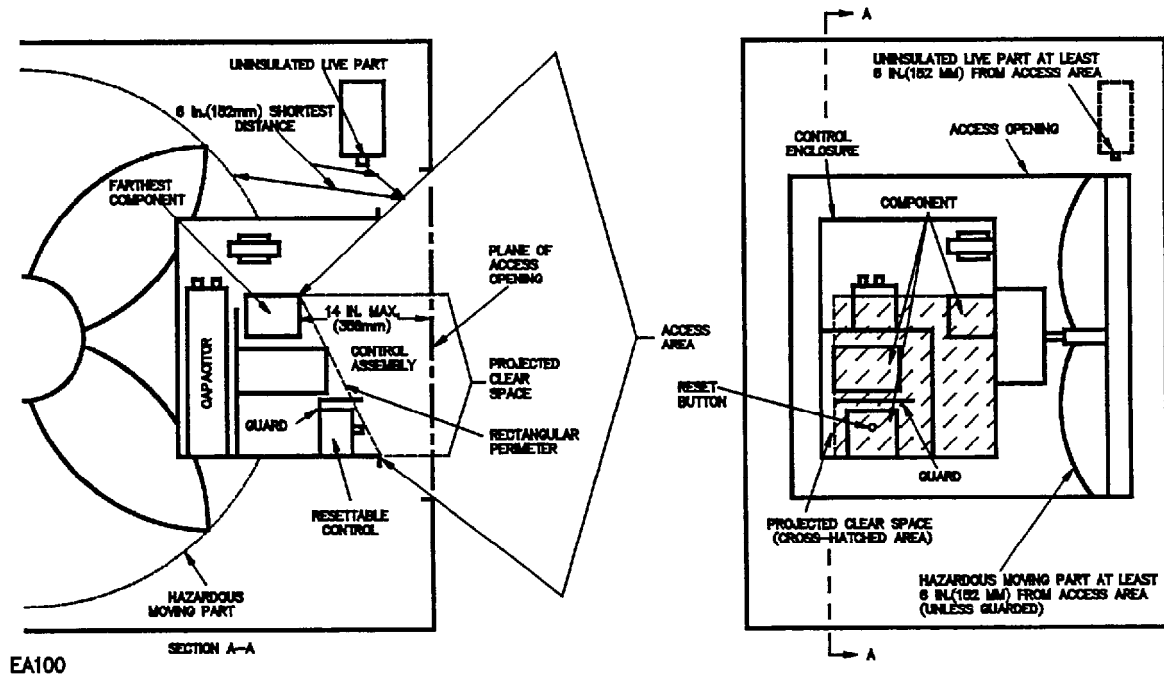
7.5 The location and mounting of an electrical control component relative to other components and grounded metal parts shall not subject service personnel to risk of electric shock from adjacent uninsulated live parts or the risk of injury from adjacent moving parts if components need to be reached while it is energized.

Exception: This requirement does not apply when service personnel make voltage measurements using jacks or terminals specifically intended for the purpose.

7.6 Accessibility to each compartment and protection of persons from the risk of electric shock and contact with moving parts that can cause injury may be obtained by mounting the control components in an assembly so that unimpeded access is provided to each compartment through an access cover or panel in the outer cabinet and through the cover of the control assembly enclosure described in (a) – (e). See Figure 7.1.

- a) The components shall be located with respect to the access opening in the outer cabinet so that the farthest component in the control assembly is not more than 14 inches (355 mm) from the plane of the access opening.
- b) Uninsulated live parts that lie outside the control assembly's projected clear space (except for live parts within a control panel) or unguarded moving parts that create a risk of injury to persons shall be located not closer than 6 inches (150 mm) to any side of the access area. The projected clear space is considered to be bounded on the sides by the projection of the smallest rectangular perimeter that can surround the outside edge of the components or control enclosure, when such an enclosure is provided. The access area is considered to be bounded on the sides by the projection of the perimeter of the access opening in the outer cabinet to the closest rectangular perimeter surrounding the outside edge of the component or control enclosure.
- c) The volume generated by the projected clear space of the control assembly to the access opening in the outer cabinet (within the access area) shall be free of obstructions, including wiring.
- d) Access to the components in the control assembly shall not be impeded in the direction of access by other components or by wiring in this assembly.
- e) Extractor-type fuseholders and snap switches mounted through the control assembly enclosure shall be located so that:
 - 1) There is unimpeded access to these components through the access opening in the outer cabinet; and
 - 2) The components are not immediately adjacent to uninsulated live parts outside the control assembly enclosure, unless these parts are guarded. See 38.4.

Figure 7.1
Accessibility and protection



7.7 A component in a low-voltage circuit shall comply with the requirements of 7.5 in its relation to uninsulated live parts in a high-voltage circuit and to moving parts that can cause a risk of injury to persons.

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

- a) Coils of controllers, relays, and solenoids;
- b) Transformer windings, if the coils and windings are provided with insulating overwraps;
- c) Enclosed motor windings;
- d) Insulated terminals and splices; and
- e) Insulated wire.

7.9 A moving part, such as a fan blade, blower wheel, pulley, or belt that may cause injury to persons, shall be enclosed or guarded.

7.10 The distance from an opening in the guard or enclosure specified in 7.9 to the moving part shall be as specified in Table 7.1, but the minor dimension of the opening shall not exceed 3 inches (76 mm). For an opening having a minor dimension intermediate between two of the values indicated in the table, the distance from the opening to the moving part shall be not less than that found by appropriate interpolation between the corresponding values in the right-hand column of the table. The minor dimension of the opening is to be determined by the largest hemispherically tipped cylindrical probe that can be inserted through the opening with a force of 5 pounds (22 N).

Table 7.1
Dimensions of openings in enclosure

Minor dimensions of opening ^a		Minimum distance from opening to moving part	
Inches	(mm)	Inches	(mm)
1/4	6.4	1/2	12.7
3/8	9.5	1-1/2	38.1
1/2	12.7	2-1/2	63.5
3/4	19.1	4-1/2	114
1	25.4	6-1/2	165
1-1/2	38.1	10-1/2	267
2	50.8	14-1/2	368.0
Over 2	over 50.8	30	762.0

^a Openings less than 1/4 inch (6.4 mm) are not to be considered.

7.11 A moving part is not to be considered when compliance with the requirements of 7.1 and 7.9 is determined, if the part is unlikely to be contacted through the opening because of intervening fixed components, including baffles.

7.12 An interlocking device that disconnects the drive motor from its source of power when a door or panel is opened or removed to provide access to moving parts complies with the requirement of 7.9.

7.13 A moving part, as specified in 7.9, driven by a motor that is started or restarted by an automatic cycling device such as a fan control or thermal protector, shall be guarded if it is exposed when air filters are changed or anticipated adjustments are made.

Exception: This requirement does not apply if the access door or panel requires the use of a tool for opening or removal or if an interlock device of the type specified in 7.12 is provided.

7.14 The scroll of a centrifugal blower is a suitable guard for the blower wheel.

8 Base

8.1 The base of a furnace shall be constructed of metal or of other nonflammable material providing strength and durability equivalent to that of metal.

9 Casings

9.1 An outer casing or jacket shall be made of steel or material of equivalent strength, reinforced or formed if necessary to reduce the risk of damage from handling in shipment, installation, and use. Sheet metal casings shall be made of steel having a minimum thickness of 0.020 inch (0.51 mm) if the steel is uncoated, or 0.023 inch (0.58 mm) if galvanized. Casings may also be of nonferrous sheet metal having an average thickness of not less than 0.029 inch (0.74 mm).

9.2 Access panels that may be removed for servicing or for other reasons shall permit repeated removal and replacement without damage and without impairment of any required insulating property.

9.3 A removable panel through which air is drawn for combustion shall be constructed so that it cannot be attached in a manner that may affect the intended performance of the furnace.

9.4 A removable panel shall be constructed so that it will not be interchangeable with other panels on the same furnace if interchange may impair the intended operation of the furnace.

9.5 The casing of a furnace for installation on combustible flooring material shall completely close the bottom or be constructed to provide an effective radiation barrier between the heat exchanger and the floor. However, an opening intended to be permanently connected to a circulating-air distribution duct meets the intent of the requirement.

9.6 The casing of a forced-air-type furnace shall have no uncovered opening communicating with the circulating air compartments unless:

- a) Such an opening is intended to be permanently connected to a circulating air distribution duct; or
- b) The opening is automatically closed by a shutter or cover when the circulating-air fan or blower is operated, and the automatic closing latches the shutter or cover in the closed position and requires manual opening.

9.7 The furnace shall be constructed so that the operation of an air-circulating fan will not affect the combustion air supply or draw products of combustion into the circulating air.

9.8 A connection between the heat exchanger and the casing enclosing circulating air shall be constructed so that combustion products will not leak into the circulating air.

9.9 An access opening to a return-air compartment shall be completely covered.

9.10 A furnace shall provide for the attachment of warm-air outlet ducts and cold-air return ducts.

10 Radiation Shields or Liners

10.1 A radiation shield or liner shall be constructed, formed, and supported so that it will be installed as intended and will resist distortion or sagging in service. A shield or liner shall be protected against corrosion if its deterioration can cause excessive temperature when the furnace is tested in accordance with the requirements in the Performance section of this Standard. Any finish applied to obtain the required resistance to corrosion shall not be damaged by heat when the furnace is tested under these requirements.

11 Materials in Air-Handling Compartments

11.1 A material in a compartment handling air for circulation through a duct system shall comply with the requirements of the Surface Burning Test, Section 64. This requirement does not apply to the following:

- a) An air filter, drive belt, wire insulation, or paint applied for corrosion protection.
- b) A gasket forming an air or water seal between metal parts.
- c) Any miscellaneous small part, such as a resilient or vibration mount, wire tie, clamp, label, or the like.
- d) An adhesive that, when tested in combination with the specific insulation material, complies with the requirement of this paragraph.
- e) A molded or formed component made of polymeric materials having a total surface area in the compartment of not more than 10 square feet (0.93 m²). See 11.2. However, thermal or acoustic insulating liners are not exempted from the requirements of 11.1.

11.2 Polymeric materials not subject to the requirements of 11.1 shall have a flame-spread rating not greater than 25. Otherwise, they shall comply with the requirements of the Polymeric Materials Tests, Section 65.

11.3 Exposed unimpregnated asbestos material shall not be used in an air handling compartment. The unprotected edge of a gasket sandwiched between two parts is considered to be exposed.

11.4 Thermal or acoustic insulating material shall be secured in position if:

- a) Loosening may reduce or block air flow to cause temperatures or pressures in excess of those specified in the temperature tests;
- b) Loosening will result in reduction of electrical spacings below the required values; or
- c) Loosening will result in electrical short-circuiting or grounding. Leading edges of insulation shall be shielded against damage from the effects of the velocity of the moving air.

11.5 With reference to 11.4, the use of one mechanical fastener for each square foot (0.9 m²) of exposed surface is suitable for positioning insulating liners. Mechanical fasteners may be bolts, metal clamps, wire rods, or the equivalent. Butting the edges of insulation against bulkhead shall shield leading edges against damage from effects of the velocity of moving air. A rigid or semirigid sheet of insulating material does not require fastening to the extent needed for less rigid material or shielding of leading edges.

11.6 An adhesive used for securing insulation shall retain its adhesive qualities at any temperature attained by the adhesive when the product is tested under the performance requirements of this standard and at 0°F (minus 17.8°C) or minus 20°F (minus 29°C) for outdoor-use equipment.

12 Air Filters

12.1 An air filter supplied as a part of the furnace shall be accessible for inspection or replacement without the use of special tools and without need to dismantle the furnace.

13 Combustion Chambers

13.1 A combustion chamber and flueway within the air-handling compartment shall be constructed of cast iron, sheet steel, or equivalent material. Sheet steel shall have strength, rigidity, durability, resistance to corrosion, and other physical properties, equivalent to those of sheet steel having a minimum thickness of 0.042 inch (1.07 mm).

13.2 Combustion-chamber (firebox) lining material shall be secured in place and shall be accessible for replacement with material equivalent to the original.

14 Radiators

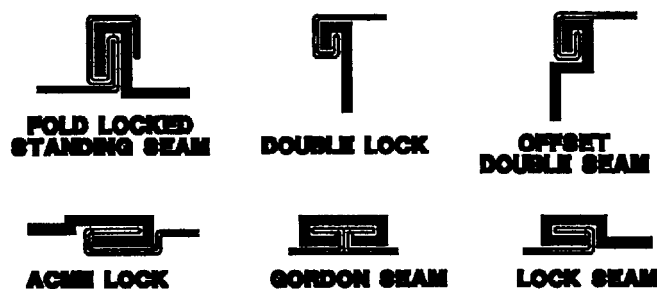
14.1 A radiator shall be made of material not lighter than that specified in 13.1 for a combustion chamber and shall be accessible for cleaning.

15 Heating Surface Joints

15.1 Joints in heating surfaces shall be welded, locked-seamed, machined, and bolted or riveted. The tightness of a joint shall be equivalent to that afforded by lock-seaming and shall not depend primarily on cement for tightness. A slip or lap joint shall not depend solely upon friction of the joint itself for strength.

15.2 Examples of lock-seams that meet the intent of this requirement are illustrated by Figure 15.1.

Figure 15.1
Lock-seams



ED100

16 Baffles

16.1 A baffle positioned in a flue-gas passage or otherwise exposed to combustion products shall be fixed in position. A flue baffle shall be made of material having resistance to corrosion equivalent to the resistance of hot-rolled sheet steel having a minimum thickness of 0.042 inch (1.07 mm), unless deterioration of the material will not cause temperatures in excess of those specified in Table 55.1 when the furnace is tested in compliance with the performance requirements.

16.2 A flue baffle shall be accessible for cleaning. A flue baffle that is removable for cleaning shall facilitate its removal and subsequent replacement only in its intended position.

17 Flue Collars

17.1 A flue collar shall provide for the attachment of the chimney connector.

17.2 A flue collar, flue collector part, or an extension outside the air handling compartment shall have rigidity, heat, and corrosion-resistance at least equivalent to those of sheet steel having a thickness of not less than 0.016 inch (0.41 mm).

17.3 A flue collar or a flue collector part within the air handling compartment shall have rigidity, heat, and corrosion resistance at least equivalent to those of sheet steel having a thickness of not less than 0.042 inch (1.07 mm).

18 Disposal of Combustion Products

18.1 The construction of a furnace shall not allow the products of combustion to mix with the circulating air.

19 Dampers, Shutters and Draft Regulators

19.1 A combustion-air damper or shutter for control of solid-fuel combustion shall have a maximum opening stop and shall shut off or reduce the supply of combustion air in the event that the linkage malfunctions, if temperatures higher than intended would otherwise be developed when the furnace is tested under the requirements of this standard.

19.2 An adjustable damper for oil combustion shall be equipped with minimum and maximum operating stops. The minimum operating stop shall be located to permit a sufficient air supply for complete oil combustion at minimum-rated burner input.

19.3 A furnace intended to be equipped with a barometric draft regulator shall not require the regulator to be installed in a false ceiling, in a different room, or in any position that will permit a difference in pressure between the air in the vicinity of the regulator inlet and the air in the vicinity of the combustion-air inlet.

20 Electrical Enclosures

20.1 General

20.1.1 An uninsulated, live, high-voltage part shall be enclosed or guarded to reduce the risk of contact by persons during intended use of the equipment. This requirement applies also to any part located in a compartment into which access is required for service operations, such as resetting controls, replacing filters, lubricating, and cleaning.

20.1.2 Among the factors to be taken into consideration when evaluating an enclosure are its:

- a) Mechanical strength;
- b) Resistance to impact;
- c) Moisture-absorptive properties;

- d) Flammability;
- e) Resistance to corrosion; and
- f) Resistance to distortion at temperatures to which the enclosure may be subjected under conditions of intended or unanticipated use.

For a nonmetallic enclosure or part of an enclosure, all these factors are to be considered with respect to thermal and chemical aging.

20.1.3 The enclosure shall block the emission of molten metal, burning insulation, flaming particles, or the like, through openings onto flammable material, including the surface on which the equipment is mounted.

20.1.4 The terminal housing of a motor to which connections are to be made in the field shall be of metal and shall be sized in accordance with the National Electrical Code, ANSI/NFPA 70-1993.

20.1.5 A steel enclosure shall be protected from corrosion by painting, plating, or equivalent means.

20.1.6 The thickness of sheet metal serving as the individual enclosures of electrical components shall be as indicated in Tables 20.1 and 20.2.

20.1.7 Where the construction and location of the component and the strength and rigidity of the outer cabinet warrant, an individual enclosure of thinner metal than specified in Table 20.1 or 20.2, whichever applies, may be employed.

20.1.8 If insulating material other than electrical insulation is provided within the enclosure, consideration is to be given to the burning characteristics and flammability of the material and to the proximity of an ignition source.

20.1.9 All intended mounting positions of the unit are to be considered when determining compliance with the requirement of 20.1.3.

20.1.10 A junction box, a portion of which is formed by another part, such as a fan scroll or a motor casing, shall fit in such a way that:

- a) An opening between the box and motor frame having a dimension exceeding 1/2 inch (12.7 mm) does not permit a flat feeler gauge, 5/64 by 1/2 inch (2.0 by 12.7 mm), to enter.
- b) An opening between the box and motor frame having no dimension exceeding 1/2 inch (12.7 mm) does not permit the entrance of a rod 13/64 inch (5.2 mm) in diameter.

Table 20.1
Minimum thickness of sheet metal for
enclosures-carbon steel or stainless steel

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

^a A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments which 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 that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

- 1) Single sheet with single formed flanges (formed edges);
- 2) A single sheet that is corrugated or ribbed; and
- 3) An enclosure surface loosely attached to a frame, for example, 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 a panel which is not supported along one side, for example, a panel of a box, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

Table 20.2
Minimum thickness of sheet metal for
enclosures-aluminum, copper, or brass

Without supporting frame ^a			With supporting frame or equivalent reinforcing ^a				Minimum thickness
Maximum width ^b		Maximum length ^c	Maximum width ^b		Maximum length	Inches (mm)	
Inches	(cm)	Inches (cm)	Inches	(cm)	Inches (cm)		
3.0	(7.6)	Not limited	7.0	(17.8)	Not limited	0.023	
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	
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	
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	
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	
14.0	(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	
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	
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	
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	
60.0	(152.4)	74.0 (188.0)	130.0	(330.2)	160.0 (406.4)	(3.89)	

^a A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments that 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, such as with spring clips.

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

^c For a panel that is not supported along one side, for example, a panel of a box, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

20.1.11 The criteria for evaluating an opening in an electrical enclosure are given in Section 21, Accessibility of Uninsulated Live Parts, Film-Coated Wire and Moving Parts.

20.1.12 When compliance with the requirements of 20.1.11 is determined, any part of the enclosure (including air filters) that can be removed without the use of tools is to be removed.

20.1.13 A mounting screw and nut shall be constructed or located so that sharp edges will not damage wiring. A screw shall have a flat or blunt end. The end of the screw shall have no burrs, fins, or sharp edges that might abrade wire insulation and shall not project more than 3/16 inch (4.8 mm) into a wireway.

20.2 Doors and covers

20.2.1 A cover or access panel of an enclosure for uninsulated high-voltage parts shall be provided with means for securing it in place.

20.2.2 A hinged or pivoted panel or cover shall be positioned or arranged so that it is not subject to falling or swinging from an open position due to gravity or vibration if either movement of the cover or exposure of moving parts or uninsulated live parts within the enclosure results in a risk of injury to persons.

20.2.3 The assembly shall be arranged to permit replacement of a fuse or other overcurrent protective device, the protective functioning of which requires renewal, and to permit manual-reset devices to be reset without removing parts other than a service cover, a service panel, or a cover or door enclosing the device. See 20.2.6.

20.2.4 A required protective device shall be inaccessible from outside the product unless a door or cover is opened.

Exception: The operating handle of a circuit breaker, the reset button of a manually resettable limit control, and similar parts may project outside the product enclosure.

20.2.5 An opening in an enclosure to provide clearance around a dial, knob, lever, or handle shall not allow a rod having a diameter of 9/64 inch (3.6 mm) to enter at any setting or position of the part.

20.2.6 A fuseholder shall be constructed, installed, or shielded so that uninsulated high-voltage live parts within 4 inches (100 mm) of the fuseholder will not be exposed to contact by persons removing or replacing fuses. An insulating barrier of vulcanized fiber or equivalent material employed for this purpose shall be not less than 0.028 inch (0.71 mm).

Exception: The screw shell of a plug fuseholder, a cartridge fuse clip, or a wiring terminal to a fuseholder need not comply with this requirement.

20.2.7 The door or cover of an enclosure shall be hinged if it gives access to fuses or any motor overload-protective device, the intended functioning of which requires renewal, or if the cover must be opened in connection with the intended operation of the protective device. Resetting a manual-reset overload-protective device is an example of such an operation. Exceptions to this requirement are specified in 20.2.8.

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

- a) Control-circuit fuses, provided that the fuses and control-circuit loads (other than a fixed control-circuit load, such as a pilot lamp) are within the same enclosure;
- b) Supplementary-type fuses of 2 amperes or less intended for small auxiliary resistance heaters with a maximum rating of 100 watts;
- c) Extractor-type fuses with their own enclosures; or
- d) Fuses in low-voltage circuits.

20.2.9 A hinged cover shall not be held closed solely by screws or other similar means requiring the use of tools but shall be provided with a catch or spring latch.

20.2.10 A spring latch, a magnetic latch, a dumpee, or any other mechanical arrangement that will hold the door in place and requires manipulation to open the door meets the intent of the requirement in 20.2.9.

20.2.11 A door or cover giving direct access to fuses in other than low-voltage circuits shall shut closely against a 1/4-inch (6.4-mm) rabbet or the equivalent; otherwise, it shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the wall of the box and shall overlap the edges of the box by not less than 1/2 inch (12.7 mm). A construction that affords equivalent protection, such as a fuse enclosure within an outer enclosure, or a combination of flange and rabbet, meets the intent of this requirement.

20.2.12 If a strip is used to provide a rabbet or an angle strip is fastened to the edges of a door, it shall be secured at not less than two points not more than 1-1/2 inches (38 mm) from each end of each strip and at points between these end fastenings not more than 6 inches (150 mm) apart.

20.2.13 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part removed to install field wiring or to operate the equipment. A sheet-metal screw may thread into a sheet-metal nut that is permanently mounted and protected against corrosion, and a machine screw or self-tapping machine screw may thread directly into a sheet-metal wall.

20.3 Field wiring system connections

20.3.1 Sheet metal to which a wiring system is to be connected in the field shall have a thickness of not less than 0.032 inch (0.81 mm) if uncoated steel, not less than 0.032 inch (0.81 mm) if uncoated steel, not less than 0.034 inch (0.86 mm) if galvanized steel, and not less than 0.045 inch (1.14 mm) if nonferrous.

20.3.2 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 be not less than three nor more than five threads in the metal, and the construction of the device shall enable a conduit bushing to be attached. 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 be not less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors. The inlet surface shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and shall have an internal diameter approximating that of the corresponding trade size of rigid conduit.

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

20.3.4 A knockout in a sheet-metal enclosure shall be secured but shall be capable of being removed without deformation of the enclosure. See Knockout Security Test, Section 62.

20.3.5 A knockout shall be provided with a flat surrounding surface for seating of a conduit bushing and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacings less than those required between uninsulated live parts and the bushing.

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

- a) 0.014 inch (0.36 mm) if of steel or 0.019 inch (0.48 mm) if of nonferrous metal where the hole has a maximum dimension of 1/4 inch (6.4 mm); and
- b) 0.027 inch (0.69 mm) if of steel or 0.032 inch (0.81 mm) if of nonferrous metal where the hole has a maximum dimension of 1-3/8 inch (35 mm).

Either a closure for a larger hole shall have a thickness equal to that required for the enclosure of the device (see Tables 20.1 and 20.2), or a standard knockout seal shall be used. Such a plate or plug shall be mechanically secured.

21 Accessibility of Uninsulated Live Parts, Film-Coated Wire and Moving Parts

21.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated wire or injury to persons from a moving part, an opening in an enclosure shall comply with either (a) or (b):

- a) For an opening that has a minor dimension (see 21.5) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 21.1.
- b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 21.1.

Exception: A motor need not comply with these requirements if it complies with the requirements in 21.2.

