UL 977

STANDARD FOR SAFETY

Fused Power-Circuit Devices

UL Standard for Safety for Fused Power-Circuit Devices, UL 977

Fifth Edition, Dated April 30, 2012

Summary of Topics:

This revision to ANSI/UL 977 dated October 26, 2020 includes barriers to address inadvertent contact on line side of service disconnect; Section 24A and 50.37

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 new requirements are substantially in accordance with Proposal(s) on this subject dated July 10, 2020.

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Standard for Fused Power-Circuit Devices

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Fifth Edition

April 30, 2012

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The most recent designation of ANSI/UL 977 as an American National Standard (ANSI) occurred on October 26, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 977 on August 28, 1984. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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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INTRODUCTION

1 Scope

1.1 These requirements cover fused power-circuit devices to be employed in accordance with the National Electrical Code.

1.2 Fused power-circuit devices, as covered by these requirements, are considered to be either bolted pressure contact switches or high-pressure butt-type contact switches.

1.3 Bolted-pressure contact switches are devices in which the blade-jaw connections have an additional pressure or clamping action provided at both ends of the switch blades when the blades are in the fully closed position.

1.4 High-pressure butt-type contact switches are devices having butt-type contacts and a spring-charged mechanism.

1.5 These requirements do not apply to low-voltage AC power circuit protectors as covered by the Standard for Low Voltage AC Power Circuit Protectors Used in Enclosures, ANSI/IEEE C37.29, or to low-voltage AC integrally fused power circuit breakers as covered by the Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures, ANSI/IEEE C37.13.

1.6 Fused power-circuit devices may be manually or electrically operated and may incorporate electrical tripping means.

1.7 An electrically tripped device is one whose closing is performed manually or electrically but contact opening is performed by a release energized by a separate source of voltage.

1.8 A device with an electrical operator is one whose contact closing and opening is performed by electrical means.

1.9 Fused power-circuit devices have continuous current ratings of more than 600 A and voltage ratings of 600 V or less AC, DC, or both. Devices rated AC are intended for use on circuits having maximum available short-circuit currents of 100,000, 150,000, or 200,000 A (rms symmetrical). Devices rated DC are intended for use on circuits having maximum available short-circuit currents of 20,000, 50,000, 100,000, 150,000, or 200,000 A DC.

1.10 Fused power-circuit devices have provisions for mounting (or are intended to be used with upstream) Class L fuses or Class T fuses rated more than 600 A.

1.11 These requirements cover complete, enclosed fused power-circuit devices in which the switch is integral with the enclosure; open-type fused power-circuit devices intended for mounting in other equipment, such as switchboards or in a separately shipped enclosure; and enclosures intended for mounting open-type fused power-circuit devices.

1.12 These requirements also cover electrically tripped and/or operated devices that have been investigated to determine their acceptability for ground-fault protection when combined with ground-fault sensing and relaying equipment as follows:

a) Switches for use with Class I ground-fault sensing and relaying equipment including those devices that are capable of interrupting 12 times their rated current or that have integral means intended to prevent disconnecting at levels of fault current exceeding the contact interrupting capability of the switch.

b) Switches for use with Class II ground-fault sensing and relaying equipment are capable of interrupting at 10 times their rated current and are for use in ground-fault protection systems where means intended to prevent disconnecting levels at fault current exceeding the contact interrupting capabilities of the switch are incorporated within the ground-fault sensing and relaying equipment.

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

2 Components

2.1 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.

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

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

3 Units of measurement

3.1 If a value for measurement is followed by a value in other units, the use or recognition of either value can be expected to provide equivalent results in the application of such requirements.

4 References

4.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

5 General

5.1 A fused power-circuit device shall employ materials throughout that are acceptable for the particular application, and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

5.2 The construction of a fused power-circuit device shall be such as to provide ample strength and rigidity.

5.3 All parts of a fused power-circuit device shall be properly assembled in place when shipped from the factory, except as noted in 5.4, 5.6, 5.7, 5.8, and 5.9.

5.4 If a fused power-circuit device is acceptable for use without a neutral assembly as well as with such assembly, the neutral assembly need not be shipped from the factory with the switching unit provided that:

a) The neutral assembly is shipped from the factory completely assembled with the necessary barriers and all other accessories that are required for its installation and use; and

b) The neutral assembly and switch are marked in accordance with 50.12.

5.5 With reference to 5.4, hardware for mounting the neutral assembly must be furnished with that assembly but need not be assembled in place.

5.6 External operating handles need not be assembled in place but in place of such assembly, they are to be packaged and shipped with the switching unit.

5.7 When a fused power-circuit device without enclosure is shipped for assembly in a switchboard or similar equipment, the load fuse terminal assembly need not be mounted in place when all the following conditions are met:

a) All poles of the load fuse terminal assembly are secured to a common base that can be installed as a single unit by a simple assembly operation;

b) Assembly instructions and markings are provided;

c) The construction is such that alignment of fuse mounts will be assured;

d) Barriers or stops intended to prevent over-sized fusing will continue to be effective; and

e) The load fuse terminal assembly is packaged and shipped with the switching unit.

5.8 If the proper operation or installation of an open type fused power-circuit device is dependent upon an insulating barrier, liner, shield or similar member being mounted on the device or elsewhere, the insulating barrier shall be provided with the device and a marking as specified in 50.29 shall be provided.

5.9 If a fused power-circuit device is intended for use with or without an accessory assembly, the assembly need not be shipped from the factory with the fused power-circuit device provided that:

a) The fused power-circuit device is acceptable for use with or without the accessory.

b) Each accessory is acceptable for the intended use.

c) Installation instructions for the proper installation operation, and necessary adjustments are provided:

1) With the accessory;

2) With the fused power-circuit device; or

3) The accessory is marked with reference to a specific installation instruction drawing unless the construction makes the installation obvious. If a filing, drilling, or cutting operation is involved the instructions include a caution statement, that such operation is to be accomplished only in the prescribed area.

d) The installation of an accessory shall not require the use of a special tool, unless such a tool and instructions for its use are furnished with each accessory.

e) A barrier that is necessary because spacing would otherwise be less than required, or for any other reason, is securely attached at the factory to either the fused power-circuit device or to the accessory to be installed.

f) The accessory is an essentially complete unit and does not require detailed assembly in the field.

g) The accessory is provided with a marking in accordance with 50.30.

h) The fused power-circuit device is provided with a marking in accordance with 50.30.

6 Enclosure

6.1 General

6.1.1 An enclosure for a switch shall be of metal and shall be constructed so as to provide the required strength and rigidity. The enclosure shall have one or more of the type designations specified in Table 6.1.

6.1.2 An enclosure is not required for a switching unit that is intended for installation in a switchboard or other enclosure.

6.1.3 Live parts shall be enclosed whether the switching unit is in the open or closed position.

6.1.4 An enclosure shall be provided with means for reliable mounting or support.

6.1.5 Unless the enclosure is of metal that will resist corrosion, both inside and outside surfaces shall be protected by painting, galvanizing, plating, or other equivalent means.

6.2 Rainproof enclosures

6.2.1 A Type 3R enclosure shall be constructed so that it withstands a simulated beating rain as described in the Water Spray Test, Section 29. Any opening associated with an opening handle shall be shielded from rain. Hinges and other attachments shall be resistant to corrosion. Metals shall not be used in such combinations as to result in galvanic action that affects adversely any part of the device. Any live part shall be located at least 12 inches (305 mm) above the mounting surface on concrete-pad-mounted equipment. See 50.28.

Table 6.1
Enclosure types

Type number	Intended use and description	Environmental construction and performance requirements
1	Indoor use primarily to provide a degree of protection against contact with the enclosed equipment.	Corrosion protection as specified in 6.1.5, or the Rust Resistance Test described in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt.	Corrosion protection as specified in 6.1.5, or the Rust Resistance Test described in UL 50, and the Drip Test described in UL 50.
3R	Outdoor use to provide a degree of protection against falling rain, sleet, and external ice formation.	Protective coating as specified in 6.2.3 – 6.2.6, the Water Spray Test described in Section 29, and the Icing Test described in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

6.2.2 A hole for conduit in a Type 3R enclosure shall be threaded unless it is entirely located below the lowest terminal lug or other live part within the enclosure or unless it accommodates a specific hub or closure fitting (see 50.27 and 50.28). A threaded hole for conduit shall be reinforced to provide metal at least 1/4 inch (6.4 mm) thick. There shall be provision for drainage of the enclosure. A threaded hole for conduit shall be provided with a conduit end stop unless the thread is tapered.

6.2.3 A Type 3R sheet steel enclosure shall be protected against corrosion by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G90 in Table I of ASTM Designation A653/A653M-94, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM Designation. The weight of the zinc coating is permitted to be determined by any appropriate method; however, in case of question the weight of coating shall be established in accordance with the test method of ASTM Designation A90.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 inch (0.015 mm) on each surface with a minimum thickness of 0.00054 inch (0.014 mm). The thickness of coating shall be established by the metallic coating thickness test as indicated in the Metallic Coating Thickness Test, Section 41. An annealed coating shall comply with 6.2.4.

c) A zinc coating conforming with (1) or (2) below and with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint applied after forming on each surface. The acceptability of the paint is permitted to be determined by consideration of its composition or by corrosion tests when these are determined to be required.

1) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Table I of ASTM Designation A653/A653M-94, with no less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM Designation. The weight of zinc coating is permitted to be determined by any appropriate method; however, in case of question the weight of coating shall be established in accordance with the test method of ASTM designation A90.

2) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 inch (0.010 mm) on each surface with a minimum thickness of 0.00034 inch (0.009 mm). The thickness of the coating shall be established by the metallic coating thickness test as indicated in the Metallic Coating Thickness Test, Section 41. An annealed coating shall also comply with 6.2.4.

d) A cadmium coating not less than 0.0010 inch (0.025 mm) thick on both surfaces. The thickness of coating shall be established by the metallic coating thickness test as indicated in the Metallic Coating Thickness Test, Section 41.

e) A cadmium coating not less than 0.00075 inch (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established by the metallic coating thickness test as indicated in the Metallic Coating Thickness Test, Section 41, and the paint shall be as specified in (c).

f) Other finishes, including paints, special metal finishes, or combinations of the two are permitted to be accepted when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) conforming with item (a), indicate they provide equivalent protection. Among the factors which are taken into consideration when determining the acceptability of such coating systems are exposure to salt spray, moist carbon dioxide-sulphur dioxide-air mixtures, moist hydrogen sulphide-air mixtures, ultraviolet light, and water.

6.2.4 An annealed coating on sheet steel that is bent or similarly formed or extruded or rolled at edge of holes after annealing shall be additionally painted in the affected area if the process damages the zinc coating.

6.2.5 If flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification, the zinc coating is considered to be damaged. Simple sheared or cut edges and punched holes are not required to be additionally protected.

6.2.6 When a Type 3R enclosure has any opening for passage of a wire or bus bar to a switchboard section or to a wireway, auxiliary gutter or busway, a gasket or other means shall be provided that is intended to prevent the entrance of water at such opening. When the opening is for attachment of a busway, the Type 3R enclosure and the busway are to be investigated together to determine that water does not enter along the bus bars.

7 Ventilation

7.1 A ventilating opening in an enclosure shall be so constructed and located that no flame or molten metal will be emitted during arcing that may normally be encountered during operation. See 32.3.

7.2 Unless the opening is remote from the arcing part, the requirement in 7.1 may require the interposing of a flame-retardant barrier between a ventilating opening and the possible source of arcing.

7.3 A ventilating opening in an enclosure shall have such size or shape, or shall be so covered by screening or by an expanded, perforated, or louvered metal panel that a test rod having the diameter specified in 7.4 will not enter the opening.

7.4 The test rod mentioned in 7.3 shall be 33/64 inch (13.1 mm) in diameter if the plane of the opening is less than 4 inches (102 mm) from an uninsulated live part, or 49/64 inch (19.4 mm) in diameter if the plane of the opening is 4 inches or more from such part.

7.5 A louver shall not be more than 12 inches (305 mm) in length.

7.6 The size, shape, and location of a ventilating opening shall be such as not to unduly weaken the overall enclosure.

7.7 The total area of enclosure material removed from a wall for the purpose of ventilation or for the insertion of a ventilating panel or screen together with total area of ventilating openings formed from the enclosure material shall not exceed 25 percent of the area of the entire surface of any wall in which such ventilating openings are located.

7.8 The area of any ventilating opening, as defined by the opening in the enclosure proper metal, shall not exceed 200 square inches (1290 cm^2) if the ventilated closing panel is formed from material that has a thickness less than that of the enclosure proper metal. A ventilated closing panel of 0.053 inch (1.35 mm) or lighter steel or 14 AWG (2.08 mm^2) or lighter steel wire mesh shall not be used to close an opening of more than 80 square inches (516 cm^2). See 7.9 and 7.10.

7.9 The steel wires of a screen of a ventilating opening shall not be smaller than 16 AWG (1.31 mm^2) if the screen openings are 1/2 square inch (3.23 cm^2) or less in area, and not smaller than 12 AWG (3.31 mm^2) for larger screen openings. A supplementary screen of smaller openings may be additionally provided. The supplementary screen is not to be considered in the evaluation of the ventilating opening screen.

7.10 Except as noted in 7.11, perforated sheet steel and sheet steel expanded mesh shall not be less than 0.042 inch (1.07 mm) thick or 0.045 inch (1.14 mm) if zinc coated if the mesh openings or perforations are 1/2 square inch (3.23 cm^2) or less in area, and shall be not less than 0.080 inch (2.03 mm) thick or 0.084 inch (2.13 mm) if zinc coated for larger openings.

7.11 Where the indentation of a guard or enclosure will not alter the clearance between uninsulated live parts and grounded metal, so as to affect performance adversely or reduce spacings below the minimum values given in Table 20.1 and Table 20.2, 0.020 inch (0.51 mm) minimum expanded steel mesh, 0.023 inch (0.58 mm) if zinc coated, may be employed; see 7.7.

8 Sheet-Metal Enclosures

8.1 A sheet-metal enclosure shall employ metal not less than 0.108 inch (2.74 mm) thick if of uncoated steel and not less than 0.111 inch (2.82 mm) thick if of a zinc-coated steel. A sheet aluminum enclosure shall employ metal not less than 0.122 inch (3.10 mm) thick. The grade and thickness of aluminum employed shall be such that the enclosure will have mechanical strength and rigidity at least that of an enclosure formed of 0.108 inch sheet steel.

9 Doors and Covers

9.1 Any door, front, or cover shall be provided with means for holding it securely in place.

9.2 A door or cover intended to give access to fuses shall be hinged, sliding, or similarly attached in a manner intended to prevent its being removed.

9.3 The thickness of a sheet-metal door, front cover, or auxiliary door shall not be less than that indicated for the enclosure.

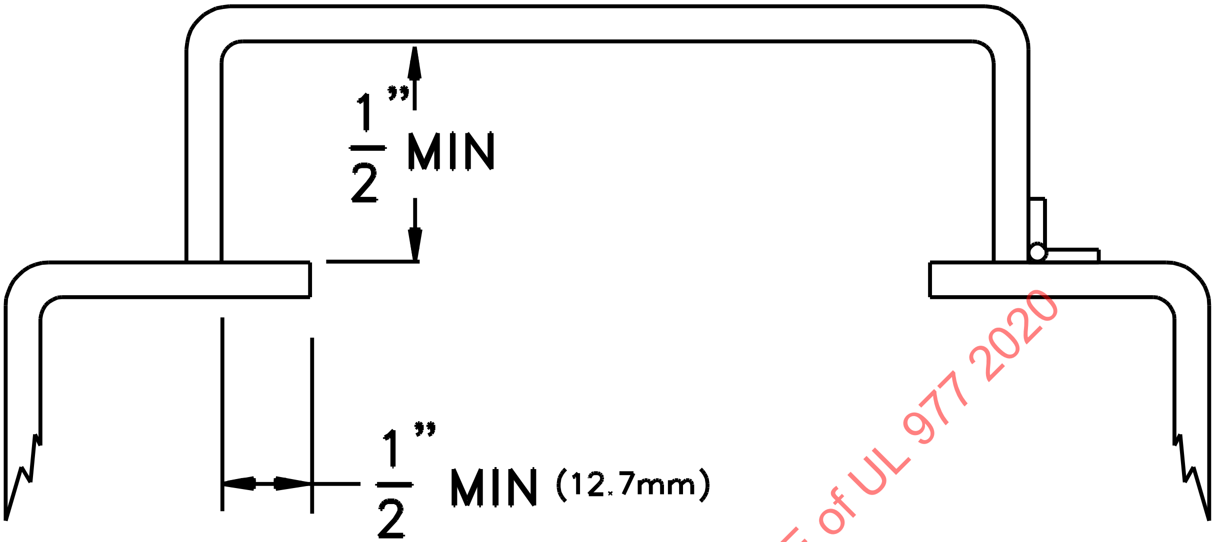
9.4 A flat door or cover shall shut closely against a 1/4 inch (6.4 mm) rabbet or the equivalent on all sides – except that if a piano type hinge is used, the rabbet may be omitted in the area of the hinge.

9.5 The flanges of the flanged door or cover shall fit closely with the outside walls of the enclosure proper and shall be not less than 1/2 inch (12.7 mm) in depth.

9.6 A combination of flange and rabbet is acceptable. Typical acceptable constructions are illustrated in Figure 9.1.

Figure 9.1

Flanged-door construction



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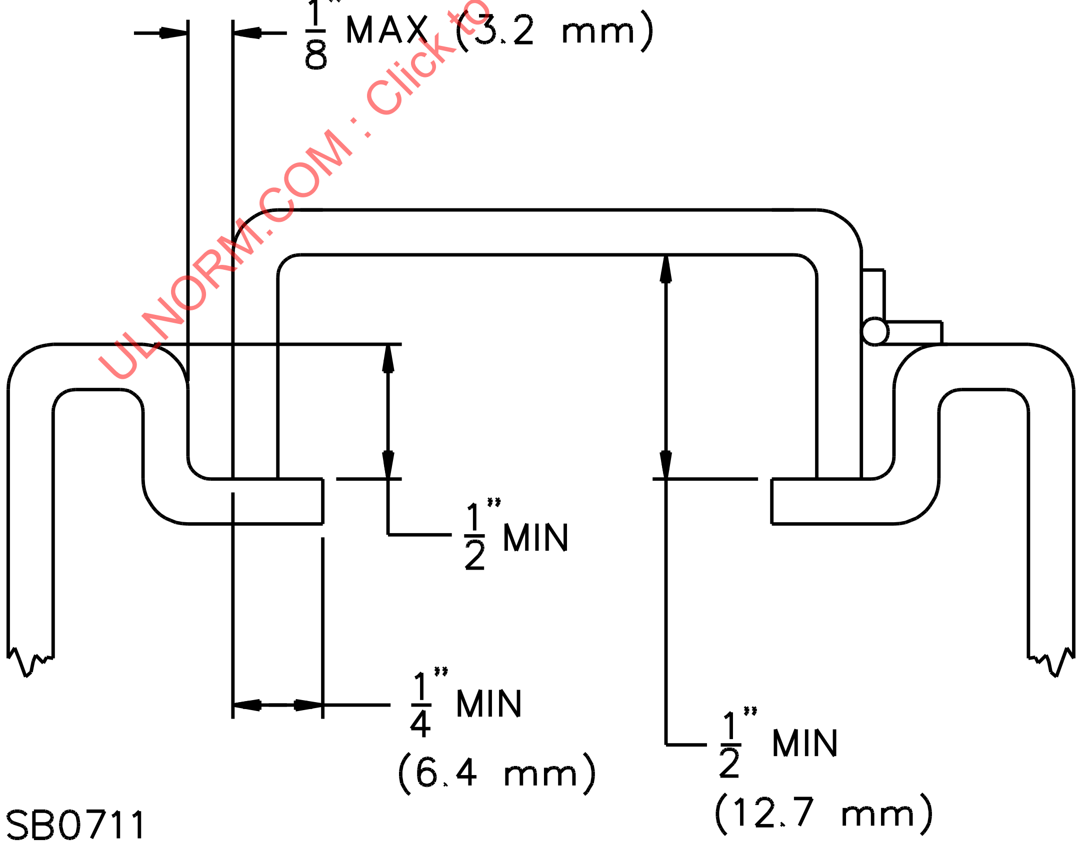

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10 Hinges

10.1 Door hinges shall be of metal, of strong and durable design. A leaf of a hinge shall be securely fastened at two or more points to the enclosure or trim and to the door or cover.

10.2 At least two hinges shall be provided for each hinged door or a continuous piano-type hinge may be used.

10.3 Except as noted in 10.4, hinges shall be spaced not more than 30 inches (762 mm) apart. Hinges shall be located not more than 4 inches (102 mm) from each end of a door. All hinge spacings shall be measured from the center of hinges.

10.4 On a steel flanged type door 45 inches (1.14 m) high or less, two hinges not more than 36 inches (914 mm) apart and not more than 5 inches (127 mm) from the ends of the door are acceptable.

11 Latches

11.1 A latch or a hand-operated captive screw shall be provided for each door, and shall be positive in action and of substantial design and construction; except that ordinary screw fasteners may be used in place of a latch in the case of an enclosure that has a hinged cover, but where the contemplated use of the device is such that hinges are not required on the cover.

11.2 A door more than 48 inches (1.22 m) long on the hinged side shall have at least two fastening means. Acceptable examples are a two-point or three-point latch operated by a single knob or handle, two or more spring latches, one knob-operated latch and one spring latch, or two or more hand operated captive screws as a fastening means.

11.3 A spring latch consisting of a strip of steel spot welded or riveted to the wall of an enclosure and cooperating with a slot in the cover shall be so formed and attached that it will engage the edge of the cover slot away from the wall or shall otherwise be acceptable for the particular application.

11.4 A knob, door handle, or equivalent means shall be provided for opening a door.

11.5 With respect to 11.4, a captive screw or other fastening which is readily grasped is considered an equivalent means.

12 Operating Mechanism

12.1 General

12.1.1 The construction of the operating mechanism shall be such as to provide strength and rigidity. Screws and nuts serving to attach operating parts to crossbars or other movable members shall be staked, upset, or otherwise locked in position to keep them from loosening under the jars of continued use.

12.1.2 Unless a switch is intended for electrical operation only, an operating handle shall be provided. An operating handle of conducting material shall be in electrical connection with the enclosure or shall be so constructed that when mounted in the conventional manner it will be grounded.

12.1.3 A metal rod using the wall of the box as a bearing is considered to be in electrical connection with the enclosure.

12.1.4 An electrically operated switching mechanism shall be provided with means for manually opening without opening the enclosure. If a manual closing means is provided for normal operation, it shall be possible to close the switching unit with all enclosure covers closed.

12.1.5 A special tool that cannot be left in place with the door closed and that is to be used for maintenance purposes only is exempted from complying with 12.1.4.

12.1.6 An electrically operated mechanism shall be such that the operation shall be completed should loss of power occur during any portion of the closing or opening operations where the switch blades have started to move.

12.1.7 The operating mechanism of an electrically tripped fused power-circuit device shall be such that at the moment when the switch contacts close, the operating mechanism shall immediately be in a condition to open the switch contacts by the electrical tripping means without further operation, manual or otherwise.

12.1.8 A fused power-circuit device having an electrical operator shall have means to disconnect the energy from the operator after the operator has performed its intended function.

12.1.9 If the open or closed condition of the switching unit is indicated by the position of the operating handle, there shall be definite open and closed positions for the handle, and the construction of the operating mechanism shall be such that the handle cannot be left at or near the open position when the switching unit contacts are closed. See 50.18.

12.1.10 If a switch handle is operated vertically, the "on" handle position shall be the up position.

Exception: Double-throw switches need not comply with this requirement.

12.1.11 A handle or other member that indicates the position of the switch blades or contacts (closed or open) shall be so constructed that the door, front, or cover cannot be secured in place in the intended manner with the handle or member indicating open while the switch blades or contacts are in the closed position.

12.1.12 The mechanism of an electrically tripped or electrically operated switch shall be so arranged that electrical operation will not result in an injury to persons in the vicinity of the switch due to sudden movement of an external part such as a manual operating handle.

12.1.13 There shall be provision for locking a fused power-circuit device in the open position without opening the enclosure, and there may be a provision for locking a manual device in the closed position.

12.1.14 Except for bearings and the like, whose protection is impractical, all metal parts unless of corrosion-resistant material shall be galvanized, painted, or otherwise protected against corrosion.

12.1.15 Metal parts that are zinc-coated or cadmium-plated, painted, or enameled are considered to be acceptably protected against corrosion.

12.1.16 Means shall be provided for mechanically applying contact pressure at both ends of a contacting member when the member has reached the end of its travel in the closing direction.

12.1.17 A separate door or cover that gives access to fuses shall be interlocked with the operating mechanism so that the door or cover is held closed when the device is in the closed position. Provision shall be made for defeating an interlock while the device is in the closed position.

12.1.18 If the removal of the operating handle– in the closed position – permits opening of the separate door or cover noted in 12.1.17, such removal may be considered as being an acceptable defeating means.

12.2 Electrical operators

12.2.1 An electrical operator shall be acceptable for the particular application, and shall be capable of handling its maximum intended load without introducing any electrical risk or risk of injury to persons.

12.2.2 A winding shall be such as to resist the absorption of moisture and shall be formed and assembled in a workmanlike manner.

12.2.3 With reference to the requirement in 12.2.2, film-coated wire is not required to be additionally treated to resist absorption of moisture, but fiber slot liners, cloth coil wrap, and similar moisture-absorptive materials should be provided with impregnation or otherwise treated to resist moisture absorption.

12.2.4 Means shall be provided that is intended to prevent the electrical operator from functioning during manual operation if electrical operation can result in an electrical risk or risk of injury to operating personnel.

13 Ground Fault Protection

13.1 A fused power-circuit device rated 1000 A or more that is marked for service equipment use, and is intended to operate on a solidly grounded wye service of more than 150 V to ground but not exceeding 600 V phase-to-phase, shall be provided with ground-fault protection. The ground-fault sensing and relaying equipment provided shall operate to cause the fused power-circuit device to open all ungrounded conductors of the faulted circuit. The maximum setting of the ground-fault protection shall be 1200 A.

Exception No. 1: If the fused power-circuit device is provided with a shunt trip that is acceptable for use with ground fault protection, the ground-fault sensors or relaying equipment or both may be in a separate enclosure if the combination is found acceptable and the fused power-circuit device is marked as covered in 50.34.

Exception No. 2: Ground-fault protection need not be provided if a device is marked in accordance with 50.35.

13.2 Compliance with the requirements specified in 13.1 anticipates that the fused power-circuit device to which the requirement applies is provided with automatic tripping means for actuation by ground-fault sensing and relaying equipment that may, although not required, be a part of the fused power-circuit device.

13.3 The short-circuit withstand rating of the ground-fault sensing and relaying equipment shall be equal to or greater than the short-circuit withstand rating of the fused power-circuit device.

13.4 Ground-fault sensing and relaying equipment that is not a part of the fused power-circuit device shall be mounted in the fused power-circuit device enclosure and be connected to the fused power-circuit device and power source, if any. The rating of the control circuit shall be compatible with that of the sensing and relaying components.

13.5 If ground-fault protection is provided, though not required by 13.1, it shall comply with the requirements for the installation of ground-fault protection equipment as specified in these requirements.

13.6 A ground fault protection system, described as a zero-sequence type, that employs a sensing element that encircles the neutral conductor, if any, and all ungrounded conductors of the protected circuit shall be installed in such a manner that the sensing element is located on the load side of any grounding or bonding connection to the neutral. It may be on the line or load side of the fused power-circuit device for the protected circuit.

13.7 A ground-fault protection system, described as the residual type, that combines the outputs of separate sensing elements for the neutral, if any, and each ungrounded conductor shall be installed in such a manner that the neutral sensing element is located on the load side of any grounding or bonding connection to the neutral. The ungrounded conductor sensors may be on the line or load side of the fused power-circuit device for the protected circuits.

13.8 A ground-fault protection system, described as the ground-return type, that employs a single sensing element to detect the actual fault current shall be installed in such a manner that the sensing element detects any current that flows in the grounding-electrode conductor, the main bonding jumper, and any other grounding connections within the equipment that may be made to the neutral. This will require that, except for these connections, the neutral be insulated from the noncurrent-carrying metal as covered in 20.3.

13.9 If the construction of ground-fault sensing and relaying equipment is such that a reset operation is required to restore the equipment to functional status following operation due to a ground fault or test, the construction shall be such that closing and maintaining contact of the fused power-circuit device to be controlled by the ground-fault sensing and relaying equipment will not occur until the reset operation is performed.

13.10 Overcurrent protection is not required for the operating coil of a fused power-circuit device where the coil is connected on the load side of the disconnecting switch of the fused power-circuit device as covered in 13.11.

13.11 The primary of a ground-fault protection control-circuit transformer may be connected to the line or load side of the fused power-circuit device. The primary of the control-circuit transformer shall be connected to two line voltage parts, not line and neutral. When connected to the line side of the fused power-circuit device, overcurrent protection of not more than 300 percent shall be installed ahead of the transformer or control circuit or both. Overcurrent protection is not required for the control circuit when wired to the load side of the fused power-circuit device, unless the control circuit wiring leaves the enclosure. A fuse shall be Class CC, G, T, R or J. A fuse or circuit breaker shall have a current-interrupting rating not less than that of the fused power-circuit device.

13.12 The secondary circuit of a control power transformer shall be grounded under any of the following conditions if the circuit extends or may extend beyond the equipment in which the transformer is mounted:

a) When the secondary is less than 50 V and the transformer supply is over 150 V to ground or the transformer supply at any voltage is ungrounded.

b) When the secondary is 50 V or greater and the secondary circuit can be so grounded that the maximum voltage to ground on the ungrounded conductors does not exceed 150 V.

13.13 If a transformer secondary is required to be grounded in accordance with 13.12, a main bonding jumper shall be factory connected to the transformer secondary and to the enclosure or ground bus. The size of the connection to the transformer secondary shall be not less than 14 AWG (2.1 mm^2) copper or 12 AWG (3.3 mm^2) aluminum or have equivalent respective cross-sectional area.

13.14 In fused power-circuit devices incorporating ground-fault protection of the ground return type as described in 13.8, the main bonding jumper shall be factory connected to the neutral bus and to the enclosure or the ground bus.

13.15 Fused power-circuit devices with ground-fault protection shall be subjected to a factory production test as described in 45.1 and 45.2 and shall be marked as specified in 50.31 – 50.33.

14 Insulating Material

14.1 A base for mounting of uninsulated live parts shall be strong, not easily ignited, moisture-resistant and insulating. The base shall be so constructed that, considering the material used, it will withstand the most severe conditions encountered in service.

14.2 Insulating material, including barriers between parts of opposite polarity or material which may be subjected to the influence of the arc formed by the opening of the device, shall be acceptable for the particular application.

14.3 Live screw heads or nuts on the underside of a base intended for surface mounting shall be counter-sunk not less than 1/8 inch (3.2 mm) in the clear, and then covered with a waterproof, insulating, sealing compound that will not soften at a temperature 15°C (27°F) higher than the temperature observed at the point where it is used, but not lower than 90°C (194°F) in any case; except that if such parts are staked, upset, or otherwise secured in a manner intended to prevent loosening, they may be insulated from the mounting surface by material other than sealing compound or by the provision of a spacing through air from the mounting surface of not less than 1/2 inch (12.7 mm).

14.4 A lockwasher, properly applied, is acceptable as a means of preventing the loosening of a screw or nut as required in 14.3.

14.5 A determination of the softening point of a sealing compound is to be made in accordance with the American Society for Testing and Materials Test for Softening Point by Ring and Ball Apparatus, ASTM E28.

15 Current-Carrying Parts

15.1 Iron or steel shall not be used for a part that is depended upon to carry current continuously.

15.2 Plated-steel screws, nuts, and studs may be used to secure pressure wire connectors.

15.3 Copper and brass are not acceptable for the plating of steel screws, nuts, and stud terminals; but a plating of cadmium or zinc is acceptable.

15.4 Bolts, washers, and nuts at hinges of switching units are considered to be parts that are not depended upon to carry current.

15.5 A metal other than silver, a silver alloy, copper, or a copper alloy, if used for current-carrying parts, shall be acceptable for the particular application.

15.6 All contact joints, bolted or clamped, shall be plated with cadmium, nickel, silver, or tin if other than of silver or silver alloy.

15.7 Uninsulated live parts, including terminations that are to be field installed, shall be so secured to the mounting surface in a manner intended to prevent turning.

15.8 Friction between surfaces is not acceptable as a means to prevent turning of uninsulated live parts. Turning may be prevented by the use of two screws or rivets:

a) By a connecting strap or clip fitted into an adjacent part; or

b) By some other equivalent method.

15.9 Where parts are held together by screws, a threaded part shall have not less than two full clean-cut conventional machine screw threads – if the screw passes entirely through the piece. If the screw does not pass entirely through the threaded part, it shall engage full, clean-cut conventional machine screw threads for a distance of not less than the diameter of the screw.

15.10 Aluminum conductors, insulated or uninsulated, used as internal wiring – such as for interconnection between current-carrying parts or as motor windings – shall be terminated at each end by a method acceptable for the combination of metals involved at the connections point.

15.11 If a wire-binding screw construction, or a pressure wire connector is used as a terminating device, it shall be acceptable for use with aluminum under the conditions involved (for example, temperature, heat cycling, vibration).

16 Wiring Terminals

16.1 Terminals shall be so designed as to accommodate either bus bars or wire connectors acceptable for carrying the rated current of the switch. Unless the switch is specifically intended for the connection of bus bars (see 50.6), pressure wire connectors that will accommodate wire corresponding to the continuous ampere rating of the switch shall be available.

16.2 A pressure wire connector provided with or specified for use with a fused power-circuit device shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E. See 50.7.

16.3 The tightening torque for a field-wiring terminal shall be as specified by the fused power-circuit device manufacturer and shall be marked as required in 50.14. The specified tightening torque shall not be less than 90 percent and not more than 100 percent of the value employed in the static heating test as specified in the Standard for Wire Connectors, UL 486A-486B or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, for that wire size corresponding to the ampere rating of the fused power-circuit device. See 27.1.

Exception: Torque values may be less than 90 percent if the connector is investigated in accordance with UL 486A-486B or UL 486E, using the lesser assigned torque value.

16.4 The terminal connections shall be such that the connection of field-installed bus bars or cables will not cause overheating due to inductive effects.

16.5 A fused power-circuit device that is marked for service equipment use shall have a terminal for a grounded-service conductor even though it has no provision for a grounded-load conductor. If there is no provision for a grounded-load conductor, this terminal:

a) Shall accommodate a conductor of the same size as the main bonding jumper shown in Table 24.1;

b) Shall be bonded to the enclosure; and

c) Shall be connected to the grounding-electrode conductor terminal.

17 Control Circuit

17.1 Except as noted in 17.2, a control circuit for an electrical operator whose source of power is derived from either the line or load side of the switch and connections are made within the switch shall have overcurrent protection having an interrupting rating not less than the maximum available fault current rating of the switch.

17.2 A control circuit for an electrical tripping mechanism for use with ground-fault sensing and relaying equipment that is located wholly within the switch enclosure and that derives its power from the load side of the disconnecting switch need not have overcurrent protective devices.

17.3 A control circuit as referred to in 17.1 shall have disconnecting means that will disconnect the control circuit from all sources of power other than a current transformer, when such disconnecting means is in the open position.

18 Lockout

18.1 An electrically tripped bolted-pressure contact switch intended and marked for use as a disconnecting device in conjunction with Class I ground-fault sensing and relaying equipment shall have means intended to prevent automatic opening (lockout) if the current in any phase exceeds 850 percent of the switch interrupting rating unless the switch has been shown to be capable of interrupting 12 times its normal rating in accordance with 36.1.

19 Fusing

19.1 Fuse mounts shall be constructed so that reliable electrical contact with a fuse of the rating for which they are designed will be provided. See Figure 19.1 and Table 19.1 for Class L, fuses and Figure 19.2 and Table 19.2 for Class T fuses.

Exception: Fuse mounts for Class L fuses may have different mounting holes or slots, if they comply with the requirements in 19.2.

19.2 Fuse mounts shall be constructed so that they cannot accept a fuse having a current rating greater than the rating of the device. Class L fuse mounts shall accept Class L fuses only. Class T fuse mounts shall accept Class T fuses only. Class L fuses and Class T fuses shall not be interchangeable.

19.3 Barriers, stops, and the like provided to comply with 19.2 for Class L fuses are to be substantial and not readily removable. They are to cause a displacement of an oversize fuse of not less than 3/4 inch (19.1 mm) to provide an indication that the misuse of the fuse is obvious.

19.4 Class L fuses and fuseholders are classified at 600 V, as follows:

a) 601 – 800 A;

b) 801 – 1200 A;

c) 1201 – 1600 A;

d) 1601 – 2000 A;

e) 2001 – 2500 A;

f) 2501 – 3000 A;

g) 3001 – 4000 A;

h) 4001 – 5000 A; and

i) 5001 – 6000 A.

19.5 Class T fuses and fuseholders are classified as follows:

a) 601 – 800 A, 300 V;

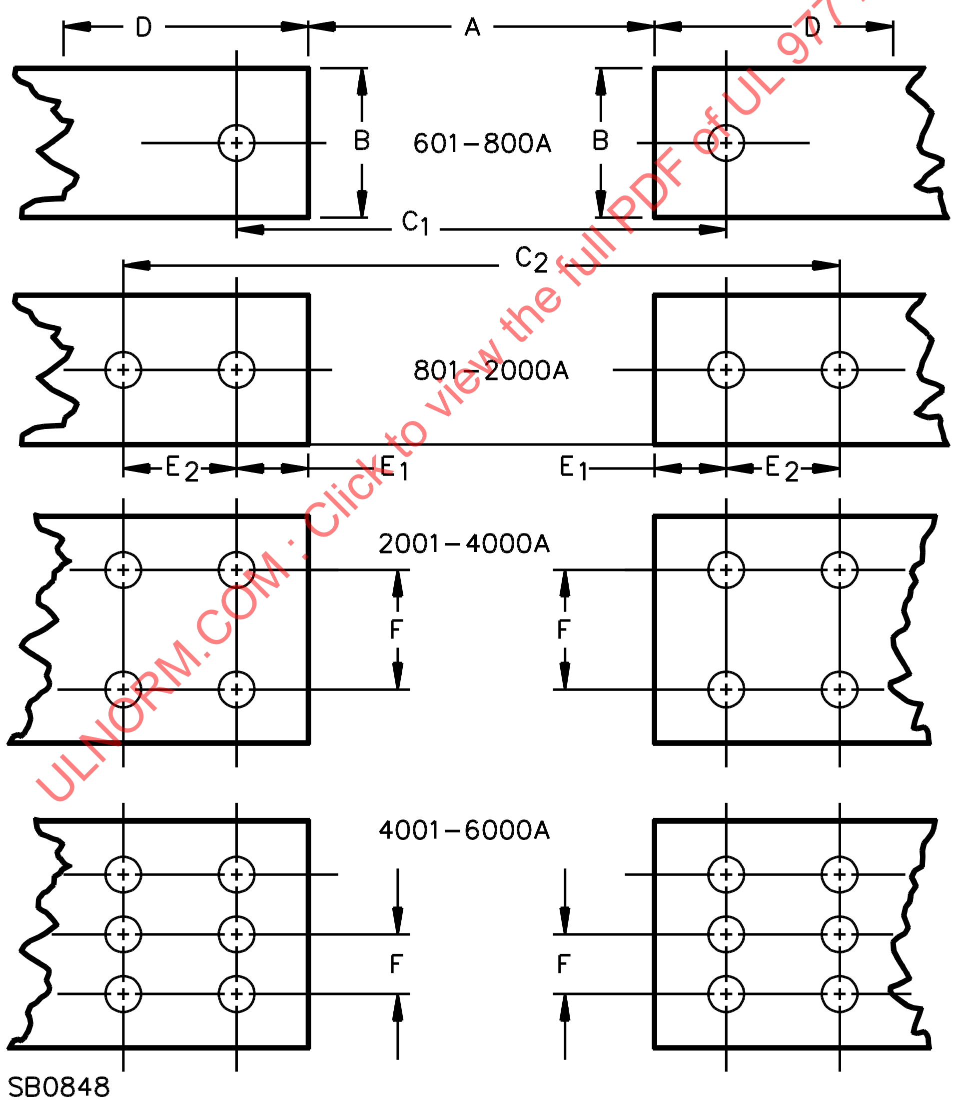
b) 601 – 800 A, 600 V; and

c) 801 – 1200 A, 300 V.

19.6 The design and construction of a fused power-circuit device shall be such that fuses will be readily accessible, when the device is open, so that they may be replaced without a person touching any live part. Fuses shall be installed on the load side of the switching unit.

Figure 19.1

Class L fuse mounting dimensions



Holes: Tapped holes – 1/2 inch (12.7 mm); Clearance holes– 5/8 inch (15.8 mm) plus 1/32 (0.08), minus (2.4).

Table 19.1
Class L fuse mounting dimension in inches

Cartridge size, amperes	A	B[a]	C[b] Hole centers		D[c]	E[b] Hole locations			F[b]
	Fuse gap (minimum)	Bus width	C_1	C_2	Unobstructed distance minimum	Minimum	E_1 maximum	E_2	Hole centers
601 – 800	4-1/4	2	5-3/4	–	2-1/4	5/8	3/4	–	–
801 – 1200	4-1/4	2	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	–
1201 – 1600	4-1/4	2-3/8	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	–
1601 – 2000	4-1/4	2-3/4	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	–
2001 – 2500	4-1/4	3-1/2	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	1-5/8
2501 – 3000	4-1/4	4	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	1-5/8
3001 – 4000	4-1/4	4-3/4	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	3-1/4
4001 – 5000	4-1/4	5-1/4	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	1-5/8
5001 – 6000	4-1/4	5-3/4	5-3/4	9-1/4	3-3/8	5/8	3/4	1-3/4	1-5/8

NOTE – All tolerances ±1/16 inch unless otherwise indicated.

[a] Maximum bus width B not specified but stops shall be provided to prevent over fusing. Tolerance on dimensions given: 1/16 inch for ratings 601 – 1600 A; -1/8 inch for ratings 1601 – 6000 A.

[b] Hole or stud center to center spacings ±1/32 inch.

[c] Maximum clearance D not specified but stops to prevent over-fusing of 800 A rating required.

inches	1/32	1/16	3/32	1/8	1/2	5/8	3/4	1-3/8	1-3/4
mm	0.8	1.6	2.4	3.2	12.7	15.9	19.1	41.3	44.5
inches	2	2-1/4	2-3/8	2-3/4	3-1/4	3-3/8	3-1/2	4	4-1/4
mm	50.8	57.2	60.3	69.9	82.6	85.7	88.9	102	108
inches	4-3/4	5-1/4	5-3/4	9-1/4					
mm	121	133	146	235					

Figure 19.2
Class T fuse mounting dimensions

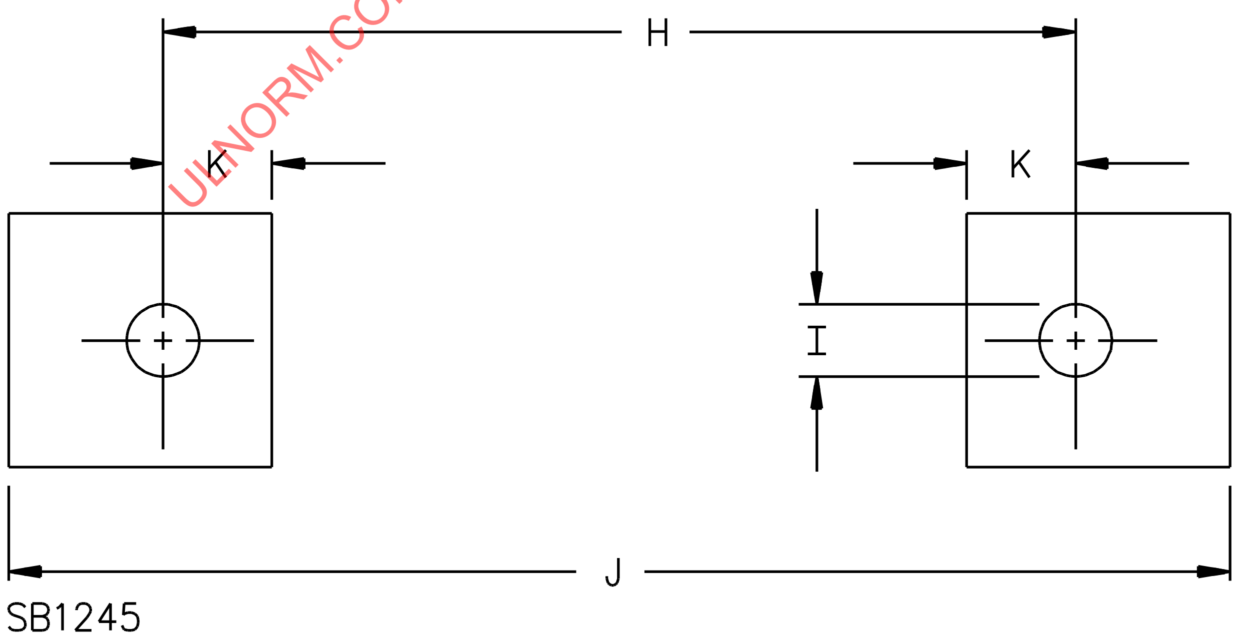


Table 19.2
Class T mounting dimensions

Rating of fuse, volts	Rating of fuse, amperes	H: Center-to-center of studs of threaded holes,[a] inches	H (mm)	I: Size of stud or threaded hole,[b] inch	I (mm)	J: Minimum obstructed clearance, inches	J (mm)	J: Maximum clearance between end stops,[b] inches	J (mm)	K: End-of-terminal to center of stud or threaded hole – maximum, inch	K (mm)
300	800	2.219	53.36	1/2	12.70	3.415	86.74	3.940	100.08	0.650	16.51
	1200	2.531	64.29	9/16	14.29	4.040	102.62	–	–	0.710	18.03
600	800	3.172	80.57	1/2	12.70	4.368	110.96	–	–	0.630	16.00

[a] Tolerance is 0.015 inch (0.38 mm) for rigid studs or threaded holes.

[b] End stops that prevent insertion of larger case size fuse in a smaller fuseholder are required if captive stud floats in fuseholder or if stud or threaded hole dimension I is 1/16 inch (1.59 mm) smaller size than that specified.

20 Spacings

20.1 Except as noted in 20.5, the spacings in a fused power-circuit device shall be as indicated in Table 20.1 and Table 20.2. Grounded dead metal in Table 20.1 and Table 20.2 includes the enclosure and dead metal which may be in electrical connection with the enclosure.

Table 20.1
Power circuit spacings

Voltage between parts involved	Between uninsulated live parts of opposite polarity – Over surface, inches	(mm)	Between uninsulated live parts of opposite polarity – Through air, inch	(mm)	Between uninsulated live parts and any grounded dead metal – Over surface, inch	(mm)	Between uninsulated live parts and any grounded dead metal – Through air, inch	(mm)
0 – 240	1-1/4	31.8	3/4	19.1	1/2	12.7	1/2	12.7
241 – 600	2	50.8	1	25.4	1	25.4	1/2	12.7

20.2 Spacings between live parts of a neutral assembly and opposite polarity parts are to be based upon the maximum voltage of the device.

20.3 Terminals and other live parts intended to be connected to the grounded conductor of a circuit are considered to be uninsulated live parts unless such parts are mounted directly on or in permanent electrical connection with the enclosure and the device is marked in accordance with 50.21.

20.4 If the connection mentioned in 20.3 is solely by means of a strap, or other bonding device that can be readily removed and is not depended upon to perform a mechanical function, the device shall:

a) Comply with the requirement in 20.1 when the bonding device is removed; or

b) Be marked as described in 50.20.

Table 20.2
Control circuit spacings

Voltage between parts involved	Minimum spacing					
	Between uninsulated live parts of opposite polarity and between an uninsulated live part and an exposed or uninsulated dead metal part other than the enclosure				Between uninsulated live parts and the walls of a metal enclosure, including fittings for conduit or armored cable	
	Over surface,		Through air,		Shortest distance,	
	inch	(mm)	inch	(mm)	inch	(mm)
120 or less	1/4	6.4	1/8[a]	3.2	1/2	12.7
121 – 240	3/8	9.5	1/4	6.4	1/2	12.7
241 – 600	1/2	12.7	3/8	9.5	1/2	12.7

[a] The spacing between wiring terminals of opposite polarity shall not be less than 1/4 inch (6.4 mm) in any case if the terminals are in the same plane. A metal piece attached to the enclosure shall be considered to be a part of the enclosure for the purpose of this note if deformation of the enclosure is likely to reduce the spacing between the metal piece and a live part.

20.5 The spacings given in Table 20.1 are not required to be maintained between switch blades and the enclosure cover when the switch is in the off position and the blades are dead, but such spacing is to be not less than 1/8 inch (3.2 mm).

20.6 All insulating barriers or liners shall be of a material acceptable for the mounting of uninsulated live parts.

20.7 An insulating barrier or liner used as the sole separation between uninsulated live parts and grounded dead metal parts, including the enclosure, or between uninsulated live parts of opposite polarity, shall not be less than 0.028 inch (0.71 mm) thick.

20.8 Except as noted in 20.9, an insulating barrier or liner that is used in addition to an air space shall not be less than 0.028 inch (0.71 mm) thick.

20.9 A barrier or liner that is used in addition to not less than one-half the required spacing through air may be less than 0.028 inch (0.71 mm) but not less than 0.013 inch (0.33 mm) thick provided that it is of adequate mechanical strength if exposed or otherwise likely to be subjected to mechanical damage, reliably held in place, and so located that it will not be affected adversely by operation of the equipment in service.

20.10 Insulating material having a thickness less than that indicated in 20.7 and 20.9 may be used if, upon investigation, it is found to be acceptable for the particular application.

20.11 The spacings at wiring terminals employing pressure wire connectors are to be measured with the device wired with conductors corresponding to the current rating of the switch.

20.12 Where bus bars used, spacings are to be measured with the bus bars connected.

20.13 In measuring an over-surface spacing, an isolated metallic part such as a screw head or washer interposed between uninsulated live parts of opposite polarity or between uninsulated live parts and grounded metal is considered as reducing the spacing by an amount equal to the dimension of the isolated metallic part in the direction of the measurement.

21 Wiring Space

21.1 The clear wiring space, independent of all projections, obstructions, or interference from moving parts of the operating mechanism, shall be fully adequate for the wiring of the device, and shall be not less in total area than 250 percent of the total cross-sectional area of the maximum number of wires which may be used in such space.

21.2 Minimum values for some of the more common multiple-wire conditions are given in Table 21.1.

21.3 To determine if a wiring space complies with the requirements of 21.1, consideration is to be given to the actual size of wires which will be used in that space. In computing the actual area of a wiring space, consideration is to be given to all the available space that may be used properly for the placement of wires.

21.4 For a fused power-circuit device, the wire-bending space at the line and load terminals shall be as specified in Table 21.2 for the conductor size that corresponds with the maximum ampere rating of the fused power-circuit device.

21.5 The line and load wiring spaces are not required if the line and load connections are intended to be made using bus bars.

21.6 The wire-bending space from a connector to any barrier or other obstruction that is part of a fused power-circuit device shall be as specified in Table 21.3.

21.7 If a wire is restricted by barriers or other means from being bent in a 90-degree or S bend from the terminal to any usable location in the wall of the enclosure, the distance is to be measured from the end of the barrier or other obstruction.

21.8 The distance mentioned in 21.4 and 21.6 is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any reliable means provided to prevent its turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure.

21.9 The construction and arrangement of the operating mechanism and its relation to the wiring space shall be such that it will not cause damage to wires with which it may come in contact during operation.

Table 21.1
Wiring space

Maximum size of wire or cable involved	Minimum width and depth of wiring space,		Minimum areas in square inches (mm^2) required for multiple wires based on factor of 2.5											
			Two-wires,		Three-wires,		Four-wires,		Five-wires,		Six-wires,		Seven-wires,	
	in.	(mm)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)
1/0 AWG	1	25.4	1.55	1000	2.33	1503	3.10	2000	3.88	2503	4.66	3006	5.43	3503
2/0	1	25.4	1.79	1155	2.68	1729	3.58	2310	4.47	2884	5.36	3458	6.26	4039
3/0	1-1/8	28.6	2.08	1342	3.11	2006	4.16	2684	5.19	3348	6.22	4013	7.27	4690
4/0	1-1/4	31.8	2.42	1561	3.63	2342	4.84	3123	6.05	3903	7.26	4684	8.47	5465
250 MCM	1-3/8	34.9	2.96	1910	4.44	2865	5.92	3819	7.40	4774	8.88	5729	10.36	6684
300	1-1/2	38.1	3.42	2206	5.13	3310	6.84	4413	8.55	5516	10.26	6619	11.96	7716

Table 21.1 Continued on Next Page

Table 21.1 Continued

Maximum size of wire or cable involved	Minimum width and depth of wiring space,		Minimum areas in square inches (mm^2) required for multiple wires based on factor of 2.5											
			Two-wires,		Three-wires,		Four-wires,		Five-wires,		Six-wires,		Seven-wires,	
	in.	(mm)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)	$in.^2$	(mm^2)
350	1-1/2	38.1	3.81	2458	5.72	3690	7.62	4916	9.53	6148	11.44	7381	13.34	8606
400	1-5/8	41.3	4.18	2967	6.27	4045	8.36	5394	10.45	6742	12.54	8090	14.63	9439
500	1-3/4	44.5	4.92	3174	7.38	4761	9.84	6348	12.30	7935	14.76	9523	17.22	11110
600	1-7/8	47.6	5.97	3852	8.96	5781	11.94	7703	14.93	9632	17.92	11561	20.90	13484
700	2	50.8	6.68	4310	10.02	6465	13.36	8619	16.70	10774	20.04	12929	23.38	15083
750	2	50.8	7.04	4542	10.56	6813	14.08	9084	17.60	11355	21.12	13626	24.64	15896
800	2-1/8	54.0	7.39	4768	11.09	7155	14.78	9535	18.48	11923	22.18	14310	25.87	16690
900	2-1/4	57.2	8.09	5219	12.13	7826	16.18	10439	20.22	13045	24.26	15652	28.31	18624
1000	2-1/4	57.2	8.77	5658	13.15	8484	17.54	11316	21.92	14142	26.30	16968	30.69	19800
1250	2-1/2	63.5	11.03	7116	16.55	10677	22.06	14232	27.58	17794	33.10	21355	38.61	24910
1500	2-3/4	69.9	12.74	8219	19.11	12329	25.48	16439	31.85	20548	38.22	24658	44.59	28768
1750	2-7/8	73.0	14.45	9323	21.67	13981	28.90	18645	36.12	23303	43.34	27961	50.57	32626
2000	3-1/8	79.4	16.04	10348	24.06	15523	32.08	20697	40.10	25871	48.12	31045	56.14	36219

Table 21.2
Minimum wire-bending space at terminals in inches

Wire size AWG or MCM (mm^2)		Wires per terminal (pole)[a]							
		1		2		3		4 or more	
0	(53.5)	5-1/2		5-1/2		7		–	
2/0	(67.4)	6		6		7-1/2		–	
3/0	(85.0)	6-1/2	(1/2)	6-1/2	(1/2)	8		–	
4/0	(107)	7	(1)	7-1/2	(1-1/2)	8-1/2	(1/2)	–	
250	(127)	8-1/2	(2)	8-1/2	(2)	9	(1)	10	
300	(152)	10	(3)	10	(2)	11	(1)	12	
350	(177)	12	(3)	12	(3)	13	(3)	14	(2)
400	(203)	13	(3)	13	(3)	14	(3)	15	(3)
500	(253)	14	(3)	14	(3)	15	(3)	16	(3)
600	(304)	15	(3)	16	(3)	18	(3)	19	(3)
700	(355)	16	(3)	18	(3)	20	(3)	22	(3)
750	(380)	17	(3)	19	(3)	22	(3)	24	(3)
800	(405)	18		20		22		24	
900	(456)	19		22		24		24	
1000	(507)	20		–		–		–	
1250	(633)	22		–		–		–	
1500	(760)	24		–		–		–	
1750	(887)	24		–		–		–	
2000	(1013)	24		–		–		–	

Table 21.2 Continued on Next Page

Table 21.2 Continued

Wire size AWG or MCM (mm^2)	Wires per terminal (pole)[a]			
	1	2	3	4 or more

NOTE – For SI units, one inch = 25.4 mm

[a] Wire bending space shall be permitted to be reduced by the number of inches shown in parentheses under the following conditions:

1. Only removable wire connectors receiving one wire each are used, (there may be more than one removable wire connector per terminal);

2. The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be reinstalled with the conductor in place.

Table 21.3
Minimum width of gutter and wire-bending space in inches (mm)

Size of wire AWG or MCM (mm^2)		Wires per terminal (pole)					
		1		2	3	4	5
1/0– 2/0	(53.5 – 67.4)	3-1/2	(88.9)	5 (127)	7 (178)	–	–
3/0 – 4/0	(85.0 – 107)	4	(102)	6 (152)	8 (203)	–	–
250	(127)	4-1/2	(114)	6 (152)	8 (203)	10 (254)	–
300 – 350	(152 – 177)	5	(127)	8 (203)	10 (254)	12 (305)	–
400 – 500	(203 – 253)	6	(152)	8 (203)	10 (254)	12 (305)	14 (356)
600 – 700	(304 – 355)	8	(203)	10 (254)	12 (305)	14 (356)	16 (406)
750 – 900	(380 – 456)	8	(203)	12 (305)	14 (356)	16 (406)	18 (457)
1000 – 1250	(507 – 633)	10	(254)	–	–	–	–
1500 – 2000	(760 – 1010)	12	(305)	–	–	–	–

NOTE – The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

22 Disconnecting Means

22.1 If a fused power-circuit device, that is marked to indicate it is acceptable for use as service equipment, has provision for the connection of a grounded load conductor and does not interrupt the grounded load conductor, other means shall be provided for disconnecting the grounded service conductor from the load conductor.

22.2 The disconnecting means required in 22.1 may be a link or similar conducting piece constructed to make connection between two terminals or it may be a terminal plate or stud provided with wire connectors.

22.3 A single wire connector may be employed for the disconnecting means between the grounded load conductor and the grounded service conductor, as well as the connection of the grounding electrode conductor, provided the grounded load conductor can be removed without disturbing any other conductors.

22.4 If disconnecting means as described in 22.2 is provided, there shall be provision for the separate connection of the grounded line and load conductors.

22.5 The grounding-electrode conductor terminal covered in 23.1 and the main bonding jumper covered in 24.1 shall connect to the neutral on the supply side of the service disconnecting means for the neutral covered in 22.1.

23 Provision for Grounding

23.1 A fused power-circuit device marked as being acceptable for use as service equipment and that is provided with a neutral shall have provision for connection of the grounding-electrode conductor to the neutral terminal in accordance with Table 23.1. The connection shall not depend upon solder for securing the grounding conductor.

Exception: The provision may be on the equipment-grounding terminal assembly, bus or the like if the main-bonding jumper is a bus bar or wire and is connected directly from the neutral to equipment-grounding terminal assembly.

Table 23.1
Size of grounding electrode conductors

Ampere rating	AWG size of service grounding electrode conductor	
	Copper	Aluminum
601 – 800	2/0	4/0
Above 800	3/0	250 MCM

24 Provision for Bonding

24.1 A fused power-circuit device marked as being acceptable for service equipment and having an insulated neutral shall be provided with a separate screw, strap, or other means to bond the enclosure to the grounded circuit conductor of an alternating-current circuit, and the construction shall be such that when this main bonding jumper is not used, the spacings given in Table 20.1 will exist. Unless the intended use and method of installation of the bonding means are obvious, instructions for its installation shall be provided.

24.2 All neutral conductors or terminals shall be insulated from the enclosure and, as the unit is shipped, shall not be bonded to the enclosure.

Exception: Neutral conductors or terminals need not comply with 24.2 when marked in accordance with 50.21.

24.3 The main bonding jumper shall be of copper or aluminum and shall have a cross sectional area as indicated in Table 24.1.

Table 24.1
Size of main bonding jumper conductors

Ampere rating not exceeding	Size of main bonding jumper (minimum)[a,b] (AWG or MCM)		Cross section of main bonding jumper in square inches (mm^2) (minimum)[a,b]			
	Copper	Aluminum	Copper		Aluminum	
800	2/0	4/0	0.105	(67.7)	0.166	(107)
1000	3/0	250	0.132	(85.2)	0.196	(126)

Table 24.1 Continued on Next Page

Table 24.1 Continued

Ampere rating not exceeding	Size of main bonding jumper (minimum)[a,b] (AWG or MCM)		Cross section of main bonding jumper in square inches (mm^2) (minimum)[a,b]			
	Copper	Aluminum	Copper		Aluminum	
1200	250	250	0.177	(114)	0.196	(126)
1600	300	400	0.236	(150)	0.295	(190)
2000	400	500	0.295	(190)	0.353	(228)
2500	500	700	0.353	(228)	0.516	(332)
3000	600	750	0.412	(266)	0.589	(380)
4000	750	1000	0.589	(380)	0.810	(523)
5000	900	1250	0.707	(456)	0.957	(617)
6000	1250	1500	0.884	(570)	1.178	(760)

[a] The cross section may be reduced to 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase on equipment rated 1200 A and above. This applies when the cross section of the service conductors is limited by the wire terminal connectors provided.

[b] For equipment rated 1200 A or more and that has wiring terminals intended to connect service conductor wires sized larger than 600 MCM copper or 750 MCM aluminum, the cross section of the main bonding jumper shall be at least 12.5 percent of the total cross section of the largest main service conductor(s) of the same material (copper or aluminum) for any phase.

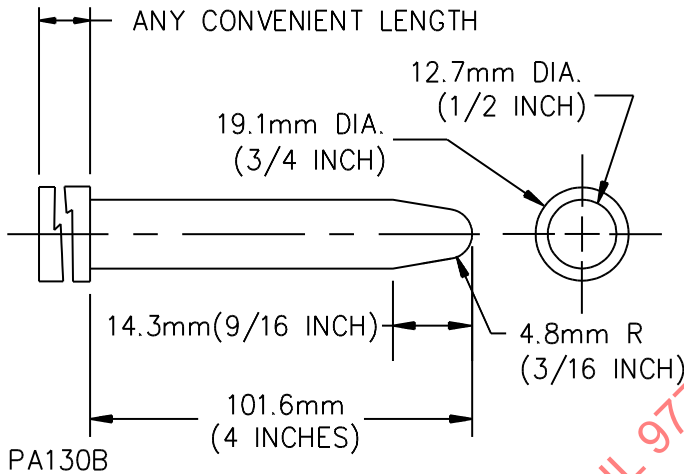
24A Accessibility of Live Parts in Service Equipment

24A.1 Fused power-circuit devices marked for service equipment use shall be constructed such that, with the switch in the off position, no ungrounded uninsulated live part is exposed to inadvertent contact by persons while servicing any field connected load termination, including a neutral load terminal, an equipment grounding terminal, or the neutral disconnect link. Exposure to inadvertent contact is determined by use of the probe illustrated in Figure 24A.1. If restriction to the line-side of the service disconnect is dependent on the installation of field installed service conductors, conductors sized in accordance with Table 26.1 shall be installed in the terminals when determining exposure to inadvertent contact. All live parts of the line side service terminal, including the connector body and pressure screw shall be evaluated. For devices suitable for more than one type of terminal, the evaluation shall be conducted with all types of terminals.

NOTE: In accordance with the Standard for Electrical Safety in the Workplace, NFPA 70E, an electrically safe work condition should be established prior to working on electrical equipment. Accessibility requirements do not endorse working on energized electrical equipment.

Figure 24A.1

Straight probe



24A.2 Metal barriers provided to limit exposure to inadvertent contact shall:

a) Have a thickness not less than 0.032 inch (0.81 mm) if uncoated, not less than 0.034 inch (0.86 mm) if galvanized, and not less than 0.050 inch (1.27 mm) if aluminum.

b) Be constructed so that it can be readily removed or repositioned, and then re-installed, without the likelihood of contacting bare live parts or damage the insulation of any insulated live part.

Exception: Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

24A.3 Nonmetallic barriers provided to limit exposure to inadvertent contact shall:

a) Comply with requirements in 20.9 for barriers used in conjunction with a minimum air space of 0.013 inch (0.33 mm).

b) Be constructed so that it can be readily removed or repositioned, and then re-installed, to allow access to the terminal for servicing.

Exception: Factory installed barriers that limit access to factory installed wiring and terminations are not required to be constructed so that they can be removed or repositioned.

24A.4 Fused power-circuit devices marked “Suitable for use as service equipment” shall be permitted to provide the protection from inadvertent contact in 24A.1 in a field installable kit when marked in accordance with 50.37.

PERFORMANCE

25 General

25.1 The temperature, operation, endurance, 200 percent overload, and dielectric voltage-withstand tests shall be conducted in the order named on one sample of the size and rating being investigated. The same sample may then be reconditioned and used for the close-open and repeated dielectric voltage-withstand tests but a previously untested sample may be employed at the option of the manufacturer. Either of the above samples may be reconditioned or a new sample used for the contact opening and repeat dielectric voltage-withstand tests. Any of the above samples may be reconditioned or a new sample used for the withstand, closing, and low-level dielectric voltage-withstand tests.

25.2 A fused power-circuit device rated for AC or DC shall be investigated for the marked rating by the test program described in 25.1. A fused power-circuit device rated for AC and DC shall be investigated for both ratings. The AC rating is to be verified by the test program described in 25.1. To verify the DC rating, representative samples of the device shall be subjected to the 200 percent overload, close-open, and contact opening tests, each followed by the dielectric voltage-withstand, short-circuit withstand, and closing tests. The dielectric voltage-withstand test is to be performed with AC voltage; all other tests are to be performed with DC voltage.

25.3 A fused power-circuit device for use as a tie switch shall be investigated for reverse feed.

25.4 When the identical device and its operating mechanism are available in more than one enclosure, the enclosure with the least volume and the enclosure that results in the shortest spacings between the enclosure and live parts shall be used for the tests.

25.5 An open-type switch shall be tested in an enclosure that is representative of all enclosures in which the switch may be used.

25.6 Unless a device is intended for use on a single-phase circuit only, all tests with the exception of the temperature test and dielectric voltage-withstand tests shall be made on a 3-phase circuit. The temperature test may be made on either a 3-phase or a single-phase circuit (all poles in series) if acceptable to those concerned.

25.7 The temperature test may be conducted at any convenient voltage.

25.8 The frequency of the AC test voltage in each test in which the switch is energized shall be the rated value, except for the Short-Circuit Withstand Test, Section 38, and the Closing Test, Section 39, when any frequency between 48 – 62 Hz is determined to comply with the intent of this requirement.

25.9 The circuit on which the 200 percent overload, close-open, and contact opening tests are conducted shall have a recovery voltage (the normal frequency rms or DC voltage after the circuit has been interrupted and high frequency transients have subsided) equal to the rated voltage of the device, except that the recovery voltage is not required to be determined when the closed-circuit voltage is not less than 90 percent of the rated voltage of the device. The open-circuit voltage shall not be more than 110 percent of the rated voltage. However, a higher open-circuit voltage is not prohibited from being used when agreeable to those concerned.

25.10 Reactive components of the load employed may be paralleled if of the air-core type but no reactances are to be connected in parallel with resistances, except that an air-core reactor(s) in any phase may be shunted by resistance, the loss in which is approximately one percent of the total power consumption in that phase. The shunting resistance used with an air-core reactor may be calculated from the formula:

$$R_{SH} = 100\left(\frac{1}{PF} - PF\right)\frac{E}{I}$$

in which:

PF is the power factor,

E is the closed-circuit phase voltage, and

I is the phase current.

25.11 In the 200 percent overload, close-open, short-circuit withstand, and closing tests, the device shall be tested with the enclosure connected through a fuse to the live pole least likely to strike to ground. The fuse is to be a 30 A non-renewable, non-time delay fuse having a voltage rating not less than the rating of the device being tested.

25.12 A device intended for use with bus bars only and a device intended for use with either bus bars or cable shall be tested using bus bars at terminal connections.

25.13 When the device can only be tested using insulated conductors, the conductors are to be secured to the switch terminals by pressure wire connectors.

25.14 Insulated conductors are to enter and leave the enclosure through one or more short lengths of the appropriate size of rigid conduit, each end of which is to terminate in an insulating bushing. Conductors inside the switch enclosure are to be routed and secured as they would be in practice. Except during the temperature test, conductors outside the enclosure beyond the conduit stub are to be securely laced or otherwise anchored to withstand the forces exerted.

25.15 Bus bars are to enter and leave the enclosure through the openings provided and in the manner intended. They are to be securely anchored outside the enclosure to withstand the forces exerted during the tests.

25.16 In general, tests conducted on a three-pole device on 3-phase test circuits will represent a two-pole device of the same or comparable design, pole spacings, and the like, at the same or lower voltage rating for use on a single-phase circuit.

25.17 The acceptable methods and practices for instrumentation and measurement of high capacity circuits are described in 42.1 – 44.5.3.

25.18 A test sample may be serviced during the close-open, and contact opening tests, but there shall be no servicing of the test samples during any other tests. A test sample shall not be serviced or reconditioned in any manner upon completion of a test and the conducting of the related dielectric withstand test.

25.19 Servicing a sample is considered to be filing, deburring, lubrication, and the like, but no disassembling of the sample except for such parts as arc tips that are intended to be serviced in the field. Servicing is not to include replacement of any part. Reconditioning of a sample may include servicing, and replacing of parts, or rebuilding of parts, as may be necessary.

25.20 If mechanical operation is required or chosen as the means of test operation, the device shall be caused to operate with no greater effort and speed than that expected to be provided by a person.

26 Temperature Test

26.1 The device in its enclosure with fuses that provide typical heat generation in place, shall carry 100 percent of rated current without:

a) The clearing of any fuse;

b) A temperature rise of more than 60°C (108°F) above room temperature at the device terminals; and

c) Any temperature rise that will adversely affect any insulating materials used.

26.2 Temperatures are to be measured by thermocouples consisting of wires no larger than 24 AWG (0.21 mm^2) and no smaller than 30 AWG (0.05 mm^2), except that a coil temperature is to be determined by the change-of-resistance method if the coil is inaccessible for mounting thermocouples. When thermocouples are used in determining temperatures in electrical equipment, it is standard practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type instrument whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. A temperature is considered to be constant when three successive readings, taken at 30 minute intervals indicate no change.

26.3 A thermocouple junction and the adjacent thermocouple lead wire are to be securely held in good thermal contact with the surface of the material whose temperature is being measured. In most cases, adequate thermal contact will result from securely taping or cementing the thermocouple in place but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

26.4 The resistance method consists of the determination of the temperature of a copper or aluminum winding by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature, according to the formula:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise;

R is the resistance of the coil at the end of the test;

r is the resistance of the coil (coil at t_1) at the beginning of the test;

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum (values of the constant for other grades must be determined);

t_1 is the room temperature °C at the beginning of the test; and

t_2 is the room temperature °C at the end of the test.

26.5 As it is generally necessary to deenergize the winding before measuring R, the value of R at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time may be plotted and extrapolated to give the value of R at shutdown.

26.6 The ambient room temperature, which may be measured by means of a thermometer or by a thermocouple having a heat-sink attached, is to be within the range 10 – 4°C (50 – 104°F).

26.7 Unless the manufacturer's installation instructions indicate otherwise, bus bars of the size given in Table 26.1 shall be used for connecting the device to a source of supply except that, if there is only provision for cable connection, the cables of the size indicated or other cables of no greater total capacity and representative of field installation shall be used. The spacing between multiple bus bars is to be 1/4 inch (6.4 mm) with no intentional wider spacing except as necessary at the individual terminals of the device. The bus bars for the 3000 and 4000 A switch test are to be arranged in pairs with not more than 4 inches (102 mm) between pair centers. The bus bars for the 5000 and 6000 ampere switch test are to be arranged in sets of three with not more than 4 inches between centers of adjacent sets.

Table 26.1
Conductor sizes for temperature test

Device rating amperes	Size of copper bus bar – inches[a]	Size of copper cable – MCM[b]
800	(1) 1/4 by 3	(3) 300
1200	(1) 1/4 by 4	(4) 350
1600	(2) 1/4 by 3	(5) 400
2000	(2) 1/4 by 4	(6) 400
2500	(2) 1/4 by 5	(6) 600
3000	(4) 1/4 by 4	
4000	(4) 1/4 by 5	
5000	(6) 1/4 by 5	
6000	(6) 1/4 by 6	

[a] The numbers in parentheses indicate the number of bus bars per conductor.

[b] The numbers in parentheses indicate the number of wires rated at 75°C (167° F) per cable.

inch	1/4	3	4	5	6
mm	6.4	76.2	102	127	152

26.8 The maximum temperature rise on a coil or winding intended for continuous duty shall be not greater than that indicated in Table 26.2, when operated at rated voltage.

Table 26.2
Coil temperature rise

Kind of coil	Coil insulation systems	Maximum acceptable temperature rise	
		By thermocouple method	By resistance method
Multiple-layer	Class 90	50°C (90°F)	70°C (126°F)
	Class 105	65°C (117°F)	85°C (153°F)
	Class 130	85°C (153°F)	105°C (189°F)
	Class "over 200"	No limit is specified	
Single-layer coil with exposed surfaces uninsulated or enameled	Class 105	90°C (162°F)	– –

26.9 The temperature test on a coil may be conducted with the coil mounted in the switch as intended with the switch carrying rated current or the coil may be tested separately in an ambient that is representative of the operating ambient conditions within the switch.

27 Strength of Insulating Base and Support

27.1 The insulating base of a fused power-circuit device shall not be damaged when wire connectors, securing short lengths of conductors of rated ampacity, are torqued to 110 percent of the value marked on the fused power-circuit device.

27.2 Damage is considered to have occurred if:

a) The base insulating material cracks or rotates;

b) Bosses, recesses, or other means to prevent turning do not perform their intended function;

c) Straps or bus bars bend or twist; or

d) Members move at electrical joints.

Minor chipping or flaking of brittle insulating material is acceptable if the performance is not otherwise impaired. Momentary flexing of metallic members without permanent deformation is acceptable.

28 Overvoltage Test

28.1 A coil or winding intended for continuous duty shall be capable of withstanding 110 percent of its rated voltage continuously.

29 Water Spray Test

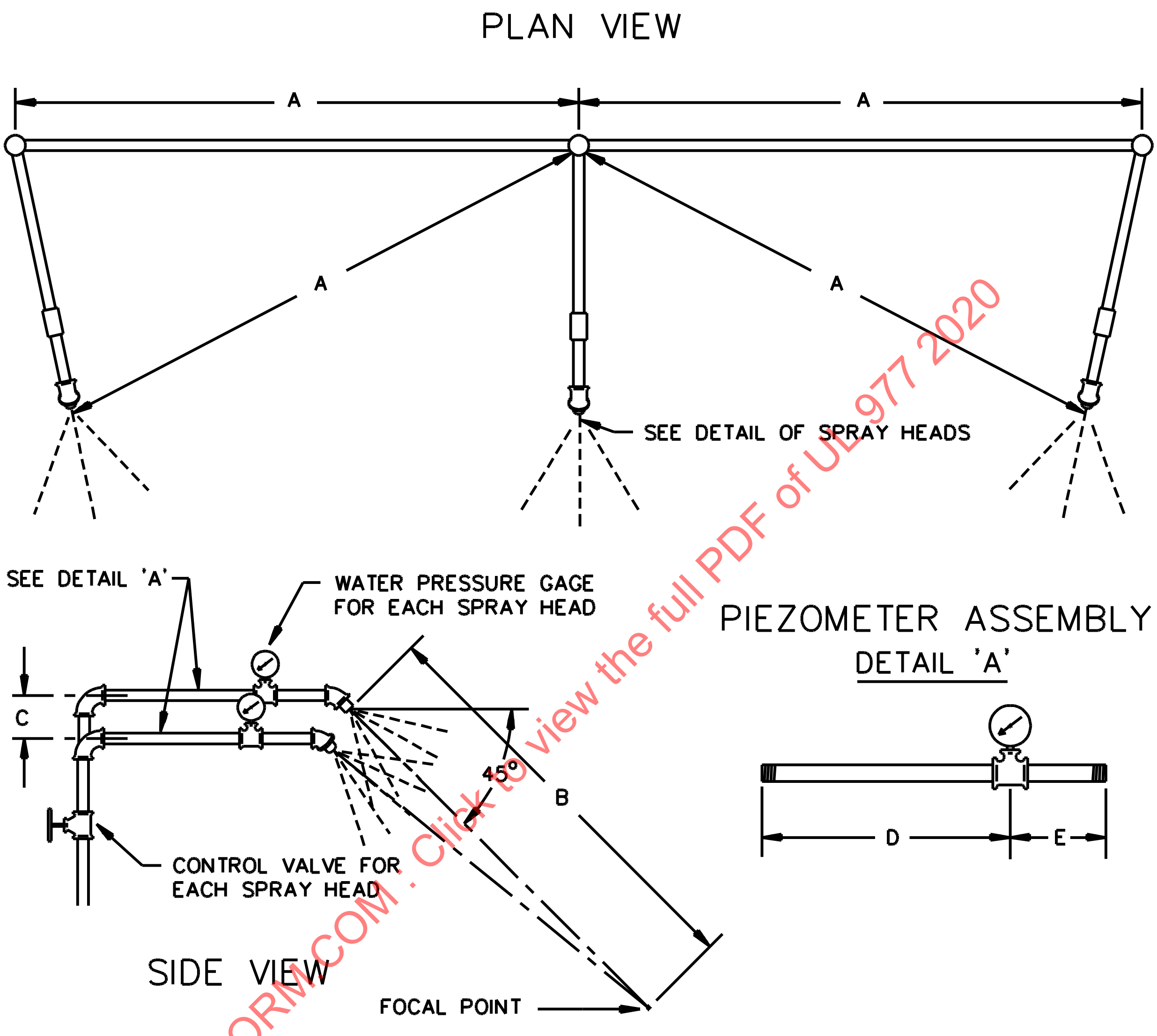
29.1 To determine compliance with the requirements in 6.2.1, the enclosure shall be subjected to the water spray tests described in 29.2 and 29.3. There shall be no significant accumulation of water within the enclosure and no water shall enter the enclosure at a level higher than the lowest live part, except that water may enter above live parts if the equipment is so constructed that no water is visible on the live parts, insulating material, or operating mechanism parts, and no water has entered any space above the live parts within the enclosure in which wiring may be present under any proper installation conditions.

29.2 The device is to be set up as in an intended installation with conduit connections, without pipe compound, if so intended. The device is to be positioned in the focal area of the three spray heads that the greatest quantity of water is likely to enter the device. The water pressure is to be maintained at 5 pounds per square inch (34 kPa) at each spray head. The device is to be exposed to the water spray for 1 hour. Figure 29.1 and Figure 29.2 indicate the spray head piping and nozzle construction.

29.3 Following the test described in 29.2, the device is to be subjected to a water spray simulating a lawn sprinkler for 1 hour. Using a single nozzle, Figure 29.2, but with the pressure adjusted to 15 pounds per square inch (103 kPa), the nozzle is to be located at the bottom of the enclosure 3 feet (0.91 m) from the enclosure and aimed at a point on the enclosure 2 feet (0.61 m) above the bottom. If the enclosure is over 48 inches (1.22 m) high, the test is to be repeated with the nozzle directed at a level 4 feet (1.2 m) above the bottom of the enclosure.

Figure 29.1

Water-spray piping

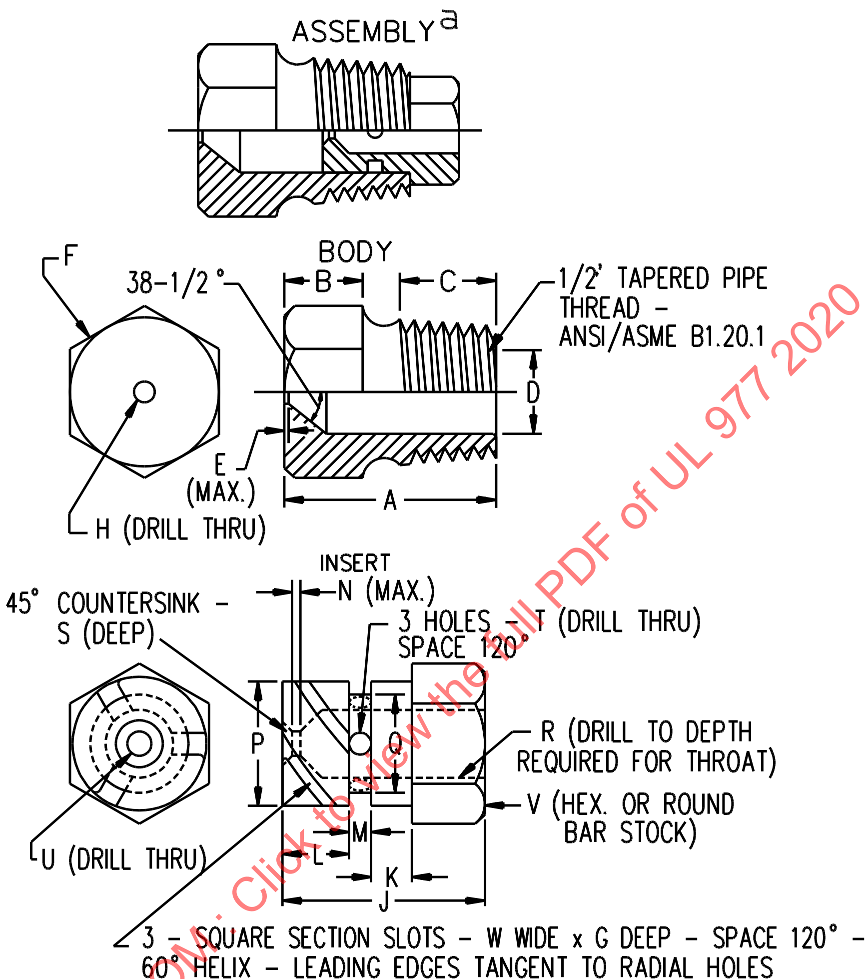


Item	inch	mm
A	28	710
B	55	1400
C	2-1/4	55
D	9	230
E	3	75

RT101D

Figure 29.2

Spray head



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

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

[b] ANSI B94.11M Drill Size

[c] Optional – To serve as a wrench grip.

RT100E

29.4 When a Type 3R enclosure is provided with a rubber or rubber-like gasket, the quality of the gasket shall be such that samples subjected to a temperature of 69 – 70°C (156 – 158°F) in circulating air for 168 hours shows a tensile strength of not less than 60 percent and an elongation of not less than 75 percent of the values determined with unaged samples.

30 Operation Test

30.1 An electrically operated trip mechanism shall operate successfully at 75 percent of its rated voltage to open the switch, except that an electrical trip device designed to function when a ground fault exists, shall operate successfully at 55 percent of its rated voltage.

30.2 A motor operated mechanism shall operate successfully at 85 percent of its rated voltage to both close and open the switch, except that a motor operated mechanism designed to function when a ground fault exists shall operate successfully to open the switch at 55 percent of its rated voltage.

30.3 An electrically operated mechanism intended to be powered by a source independent of the circuit controlled by the switch shall operate successfully at 85 percent of its rated voltage regardless of the intended switch function.

30.4 The capacitors of electrically operated trip mechanisms in which the tripping power is derived from capacitors, shall hold sufficient charge to open the switch a minimum of 5 seconds after loss of charging power when the capacitors have been supplied from a source of voltage 75 percent of the system rated voltage.

31 Endurance Test

31.1 A fused power-circuit device shall be capable of being operated under no-load conditions for the number of operations indicated in Table 31.1. There shall be no mechanical malfunction or undue wear of the operating parts of the device.

31.2 Any convenient speed that enables normal functioning of all parts may be used.

31.3 If a fused power-circuit device is provided with an electrical or mechanical tripping mechanism or both, in addition to the normal operating mechanism, each such mechanism shall be capable of performing successfully for 10 percent of the number of operations shown in Table 31.1. These operations may be performed as part of the endurance test of 31.1.

Table 31.1
No-load endurance test operations

Rating in amperes	Number of operations
800	3500
1200	2500
1600	2000
2000	2000
2500	2000
3000	1000
4000	1000
5000	1000
6000	1000

32 200-Percent Overload

32.1 A fused power-circuit device shall perform successfully when operated for the number of cycles of operation indicated in Table 32.1, when making and breaking 200 percent of its rated current at the rate specified. The rate of operation of any switch is not prohibited from being increased when agreeable to those concerned. The test is to be conducted at the rated voltage of the switch. For testing AC-rated devices, the power factor shall be from 70 – 80 percent, except that a lower power factor complies with the intent of this requirement when it is agreeable to those concerned, and the switch is to be connected as shown in Figure 32.1. For DC-rated devices, the test is to be conducted with DC, and the device connected so that the enclosure is positive in potential with regard to the nearest arcing point. The DC circuit is to have a time constant not less than 0.003 second. The time constant is the time measured on the oscillogram of the test current where the value is 63.2 percent of the maximum current.

Table 32.1
200-percent overload operations

Device rating – amperes	Number of operations	Rate of operations per minute
800	100	2
1200	100	1
1600 and larger	50	1

32.2 When the capacity of the load bank requires, or at the option of the manufacturer, the operations are to be performed in groups of five or more with an interval of unstated length between groups of operations. During this interval, the cover or door of the switch is to be opened to purge the enclosure unless the manufacturer prefers not to exercise this option.

32.3 A cotton pad indicator shall be used over any louvers or other openings to determine compliance with 7.1.

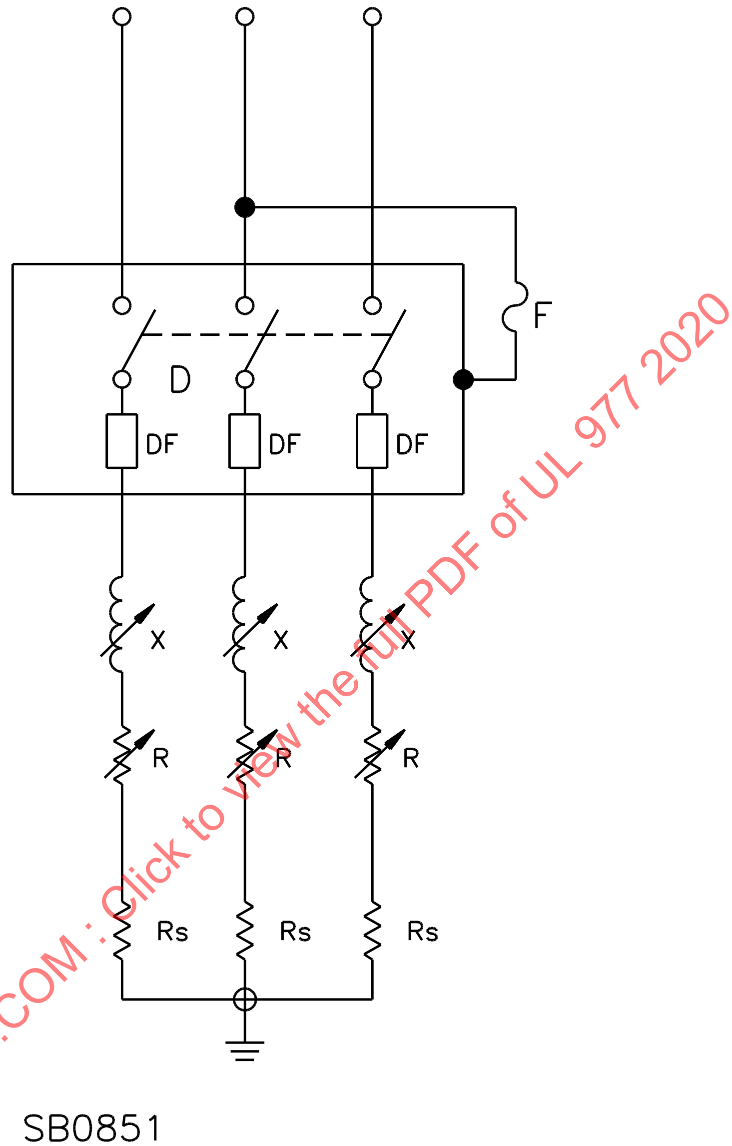
32.4 Dummy fuses shall be installed in the switch for the 200 percent overload test. If the fuse mounting means are located in or near the arcing zone of the switch, the fuses shall closely resemble the intended fuse in physical configuration.

32.5 No adjustment of mechanism or contacts is to be made during this test.

32.6 At the conclusion of the test, the device is to be in operable condition or capable of being put into operable condition by servicing, but such servicing shall not be performed prior to the dielectric voltage-withstand test, 33.1 – 33.3. The fuse indicated in 25.9 connected to indicate arc-over to the enclosure or grounded metal shall not have opened.

Figure 32.1

Circuit for 200 percent-overload, close-open, and contact-opening tests



X – Variable-tap air-core reactor

R – Variable resistor

F – Enclosure fuse

D – Device under test

Rs – Shunts for metering current

DF – Dummy fuse

Supply – Rated voltage: 3-phase, 60-hertz

Common connection of outer shells of coaxial shunts may be grounded if no other grounds on the circuit.

33 Dielectric Voltage-Withstand Test

33.1 A switch, with fuses in place, shall withstand for 1 minute without breakdown the application of a 60-Hz essentially sinusoidal potential of 1000 V plus twice the maximum rated voltage:

a) Between live parts and the enclosure, with the switch closed;

b) Between terminals of opposite polarity with the switch closed; and

c) Between line and load terminals with the switch open.

33.2 If an electrically actuated operating mechanism is associated with the switch, the test potential shall be twice the maximum rated control voltage plus 1000 V and shall be applied between live parts of the actuating mechanism and the frame, except that a motor which is part of such a circuit and is rated 250 V or less is required to withstand a maximum potential of 1000 V.

33.3 To determine if a device complies with the requirements of 33.1 and 33.2, it is to be stressed by means of a transformer having a capacity of at least 500 VA, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test value is reached and is to be held at that value for 1 minute. The increase in the applied potential is to be at a uniform rate and as rapidly as consistent with its value being correctly indicated by the voltmeter.

33.4 For some constructions, such as at a control transformer, it may be necessary to open a ground connection or one side of a circuit to conduct the tests.

34 Close-Open Test

34.1 Except as noted in 34.2, a fused power-circuit device shall be capable of being operated to make and break 600 percent of its rated current for the number of operations indicated in Table 34.1. The contacts of the switch are not prohibited from being serviced. However, the contacts of the switch are not to be replaced after each operation. The test is to be conducted at the rated voltage of the switch. For an AC rating, the switch is to be connected as shown in Figure 32.1 to a circuit as specified in 34.5. The close-open test is not prohibited from being combined with the contact opening test when agreeable to those concerned as long as the limiting impedance is on the load side of the switch as shown in Figure 32.1. For a DC rating, the switch is to be connected as specified in 32.1. The DC circuit is to have a time constant not less than 0.003 second. The time constant is the time measured on the oscillogram of the test current where the value is 63.2 percent of the maximum current.

Table 34.1
Close-open test operations

Type of switch	Number of operations
Polyphase and DC-rated	3
Single phase	5

34.2 If pinch effect, as determined by test of two samples, prevents the opening at 600 percent of rated current, the test current shall be reduced to that at which the switch can be opened but to not less than 480 percent of rated current. If the switch does not open by 480 percent, it is considered unacceptable.

34.3 If agreeable to those concerned, each closing and opening operation cycle may consist of:

a) Closing under load;

b) Opening under no-load;

c) Closing under no-load; and

d) Opening under load.

All required operations, however, are to be made using the same test sample. Servicing is only permitted after each complete cycle.

34.4 In the closing operations indicated in 34.1 – 34.3, the contacts are not required to go to the full extent of their travel if such is the result of forces resulting from the overload current which is passing through the device. A switch that does not close fully or will not open at 600 percent of rated current is to be investigated to determine if any electrical risk or risk of injury to persons or overheating is caused.

34.5 The test-circuit power factor shall be as indicated in Table 34.2 except that a lower power factor may be used if agreeable to those concerned.

Table 34.2
Test circuit power factor

Switch ampere rating	Power factor
800 – 1200	0.45 – 0.50
1600 – 2500	0.25 – 0.30
3000 – 6000	0.15 – 0.20

34.6 At the conclusion of the test, the device is to be in operable condition or capable of being put into operable condition by servicing, but such servicing shall not be performed prior to the dielectric voltage-withstand test, 34.1. The fuse, indicated in 25.9, connected to indicate arc-over to the enclosure or grounded metal shall not have opened.

35 Dielectric Voltage-Withstand (Repeated) Test After the Close-Open Test

35.1 The dielectric voltage-withstand test described in 33.1 – 33.3 shall be repeated following the close-open test.

36 Contact Opening Test

36.1 A fused power-circuit device that is electrically operated or that has an electrical tripping mechanism shall be capable of being operated electrically to break levels of current as indicated in Table 36.1. The number of operations shall be in accordance with Table 34.1. All required operations are to be made using the same test sample. The contacts of the device are not prohibited from being serviced. However, the contacts are not to be replaced after each operation. The test is to be conducted at the rated voltage of the switch. For testing with AC, the switch is to be connected as shown in Figure 32.1, except that a switch that has been tested at 600 percent of rated current in accordance with 34.1 is not prohibited from being connected as shown in Figure 38.1 with the external fuses omitted. The test circuit is to be as specified in 36.2. For testing with DC, the switch is to be connected as specified in 32.1. The DC circuit is to have a time constant not less than 0.003 second. The time constant is the time measured on the oscillogram of the test current where the value is 63.2 percent of the maximum current.

36.2 The test circuit power factor shall be in accordance with 34.5 and Table 34.2.

36.3 Dummy fuses shall be installed in the switch for the contact opening test. If the fuse mounting means are located in or near the arcing zone of the switch, the dummy fuses shall closely resemble the intended fuse in physical configuration.

Table 36.1
Contact opening

Type of switch	Test current
Electrically-operated, bolted-pressure contact switch	10 times rated[a]
Electrically-tripped, bolted-pressure contact switch	10 times rated
Electrically-tripped, bolted-pressure contact switch – For use with Class II ground fault sensing and relaying equipment	10 times rated
Electrically-tripped, bolted-pressure contact switch– With integral lockout (see 18.1) – For use with Class I, ground-fault sensing and relaying equipment	10 times rated
Electrically-tripped, bolted-pressure contact switch – Without integral lockout (see 18.1) – for use with Class I, ground-fault sensing and relaying equipment	12 times rated
Any power circuit protector (butt-type contacts)	12 times rated

[a] May be six times rated current if the time required to open the switch with the electrical operator is not less than 1-1/2 seconds after initiation of the operator. Need not be performed if test in 34.1 was conducted at six times rated current.

36.4 At the conclusion of the test, the device is to be in operable condition or capable of being put into operable condition by servicing, but such servicing shall not be performed prior to the dielectric voltage-withstand test, 37.1. The fuse, indicated in 25.9, connected to indicate arc-over to the enclosure or grounded metal shall not have opened.

37 Dielectric Voltage-Withstand (Repeated) Test After the Contact Opening Test

37.1 The dielectric voltage-withstand test described in 33.1 – 33.3 shall be repeated following the contact opening test.

38 Short-Circuit Withstand Test

38.1 A circuit of the maximum fault current for which a fused power-circuit device is rated shall be closed on the device. After the circuit is opened:

a) The fuse connected to the enclosure shall not have opened.

b) There shall be no breakage to the extent that the integrity of the mounting of live parts is impaired.

c) The door shall be prevented by its latch, without bolt or lock installed therein, from being blown open. Deformation of the case alone is not considered an unacceptable result, and

d) The device shall be capable of being opened by its regular manual operating means.

38.2 AC-rated devices shall be tested as described in 38.3 and 38.4 – 38.10. DC-rated devices shall be tested in accordance with 38.4, 38.5, 38.10 – 38.18.

38.3 For the test specified in 38.1:

a) The open-circuit voltage of the power-supply circuit is to be not less than the maximum rated voltage of the device.

b) The available short-circuit current in amperes (rms symmetrical), is to be not less than the marked withstand current rating of the device.

c) The circuit is to be as indicated in Figure 38.1 and is to include the required measuring equipment and fuse-mounting means.

d) The power factor of the circuit is to be 0.20 or less.

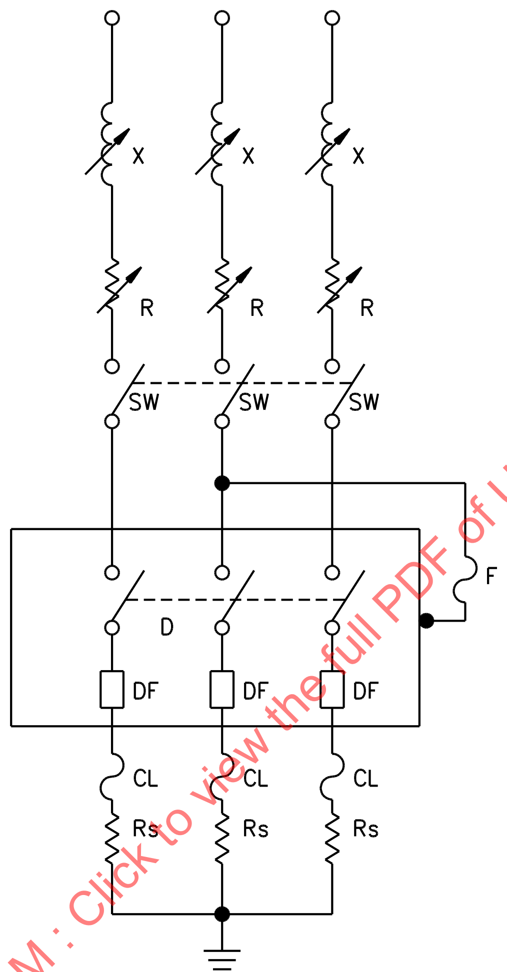
e) The enclosure of the device is to be connected through a 30 A nonrenewable, non-time delay fuse, having a voltage rating not less than the rating of the device being tested, to the pole of the switch determined to be the least prone to arc to the enclosure. This connection is to be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire 4 – 6 feet (1.2 – 1.8 m) long.

38.4 Fuses, having characteristics representing the peak let-through current (I_p) and maximum I^2 t values associated with the maximum rated fuses the device is intended to accept, are to be installed on the load side of the device as shown in Figure 38.1 with dummy fuses mounted in the device. Each of these fuses is to be of such characteristics that, when tested on a single-phase circuit, it will permit a peak let-through current and a maximum clearing of I^2 t not less than the corresponding values specified in the requirements for the current and voltage ratings of the Class L or Class T fuse intended for use in the device being tested. To obtain the required values of these characteristics, it may be necessary to employ a fuse having a current rating larger than that of the fuse which the device accommodates.

38.5 Fuses used for tests are to be selected from a lot from which one sample has been selected and calibrated to determine that its I^2 t and I_p characteristics comply with the prescribed values called for in 38.4.

Figure 38.1

Circuit for withstand and closing tests



X – Variable-tap air-core reactor

R – Variable resistor

SW – Closing switch – may be located as shown or ahead of limiting impedance

F – Enclosure fuse

D – Device under test

Rs – Shunts for metering current

CL – Current-limiting fuses used during test. To be installed in switches or mounted externally as shown

DF – Dummy fuse

Supply – rated voltage: 3-phase, 60-hertz

Common connection of outer shells of coaxial shunts may be grounded if no other grounds on the circuit.

38.6 The reactive components of the impedance in the line shown in Figure 38.1 may be paralleled if of the air-core type but no reactance is to be connected in parallel with resistance except that an air-core reactor(s) in any phase may be shunted by resistance as determined in accordance with 38.7.

38.7 The shunting resistance used with an air-core reactor having negligible resistance may be calculated from the formula:

$$R = 167\frac{E}{I}$$

in which:

E is the voltage across the air-core reactor with current I flowing as determined by oscillographic measurements during the short-circuit calibration or, by proportion, from meter measurements at some lower current.

38.8 The current available and other circuit characteristics are to be determined as indicated in 44.1.1 – 44.5.3.

38.9 With the device in the full closed position, the test circuit is to be closed on the device. For two-pole devices tested on a single-phase circuit, synchronous closing shall be employed so that maximum current flow (I_p) is obtained.

38.10 At the option of the manufacturer, the withstand test may be conducted without the current-limiting (see Figure 38.1) fuses, in which case the interruption means shall be such that the maximum I_p and I^2 t as required above are obtained.

38.11 A fused power-circuit device intended for use on a DC system is to be tested with DC and with the device connected so that the frame and enclosure are positive in potential with regard to the nearest arcing point. The device is to be tested with the enclosure connected as specified in 38.3 (e).

38.12 For a DC source, the requirements of 38.13 – 38.18 are to be applied. The time constant of the test circuit is to be determined by the method shown in Figure 38.2 and shall not be less than 0.010 second.

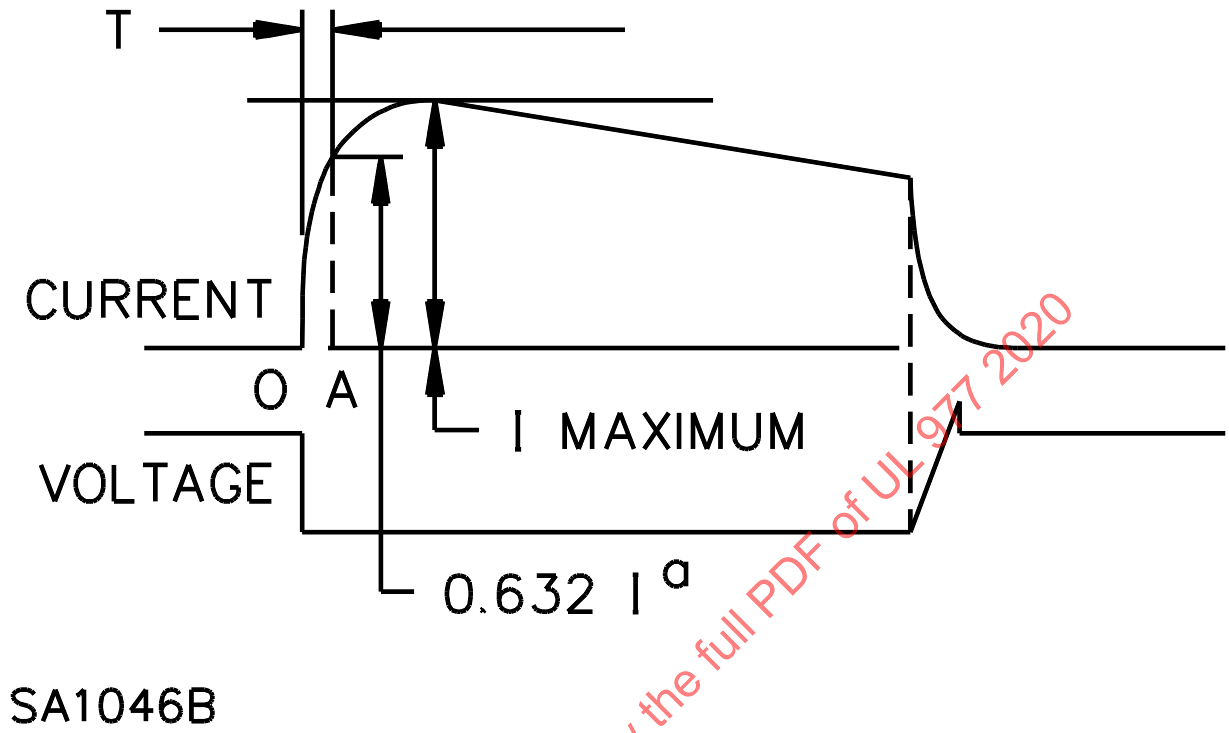
38.13 The DC open-circuit voltage of the test circuit is to be not less than 100 percent nor more than 105 percent of the rated voltage of the unit under test, except that a higher voltage is not prohibited from being used when agreeable to all concerned. In addition, the open-circuit voltage, as determined by the arithmetic average of the maximum and minimum values of the voltage wave read from an oscillogram, is to be within 99 percent and 105 percent of the rated voltage of the device, except that a higher voltage is not prohibited from being used when agreeable to all concerned.

38.14 The minimum point on the DC voltage wave is to be not less than 90 percent of the rated voltage of the device.

38.15 The available DC capacity of the test circuit is to be not less than the withstand rating of the device. The prospective current is to be determined with the supply terminals short circuited by measuring the maximum displacement on an oscillogram at a time, after the start of current, of not less than four times the required time constant. Any overshoot above time-current curve (exponential curve) is not to be regarded.

Figure 38.2

Determination of the short-circuit time constant (oscillographic method) of DC circuits



[a] The value of the time constant is given by the abscissa OA corresponding to the ordinate 0.632 I of the oscillograph of calibration of the circuit.

38.16 The time constant of the circuit is the time measured on the oscillogram where the current is 63.2 percent of the prospective current.

38.17 When the current source has a ripple, measurements are to be made from the midpoint of the ripple.

38.18 With the device in the fully closed position, the test circuit is to be closed on the device.

39 Closing Test

39.1 A fused power-circuit device shall be closed on a circuit of the maximum fault current for which the device is rated. A device rated for a fault current at more than 100,000 A (rms symmetrical) or DC shall have a reconditioned or previously untested sample also subjected to a closing test on a 100,000 A circuit. After the fault has cleared:

a) The fuse connected to the enclosure shall not be open;

b) There shall be no breakage to the extent that the integrity of the mounting of live parts is impaired;

c) The door shall be prevented by its latch, without bolt or lock installed therein, from being blown open (deformation of the case alone is not regarded as a result that does not comply with the requirements); and

d) The device shall be capable of being opened by its regular manual-operating means.

39.2 If the switch will not open as specified in 39.1 (d), two additional attempts by the manual means are to be made. If the switch still does not open the results are to be considered unacceptable.

39.3 The conditions of the closing test are to be the same as for the short-circuit withstand test, 38.2 – 38.18, except that the current limiting fuses are always to be used. Complete physical closure of the switch contacts is not required to be established.

40 Low-Level Dielectric Voltage-Withstand Test

40.1 The dielectric voltage-withstand test described in 33.1 – 33.3 shall be repeated following the closing test. The test potential shall be twice the rated voltage used for the closing test, but no less than 900 V.

41 Metallic Coating Thickness Test

41.1 The method of determining the thickness of coating by the metallic coating thickness test is described in 41.1 – 41.9.

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

41.3 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube of approximately 0.025 inch (0.64 mm) inside bore and 5.5 inches (140 mm) long. The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.05 milliliter each. To preserve an effectively constant level, a small glass tube is inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that, when the stopcock is open, the rate of dropping is 100 ±5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

41.4 The sample and the test solution is to be kept in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at a room temperature of 70.0 – 90.0°F (21.1 – 32.0°C).

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

41.6 The sample to be tested is to be supported from 0.7 to 1 inch (17 to 25 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested should be inclined about 45 degrees from the horizontal.

41.7 After cleaning, the sample to be tested is to be put in place under the orifice. The stopcock is to be opened and the time in seconds is to be measured with a stop watch until the dropping solution dissolves the protective metal coating, exposing the base metal. The end point is the first appearance of the base metal recognizable by the change in color at that point.

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

41.9 To calculate the thickness of the coating being tested, select from Table 41.1 the thickness factor appropriate for the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as noted in 41.7 above.

Table 41.1
Coating thickness factors

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

INSTRUMENTATION AND CALIBRATION OF HIGH-CAPACITY CIRCUITS

42 Galvanometers

42.1 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and fuse testing shall have a flat (±5 percent) frequency response from 50 to 1200 Hz.

42.2 Using an audio-oscillator having output impedance and output voltage adequate for driving a magnetic-oscillograph galvanometer and capable of delivering at least 100 mA rms with a wave form which remains sinusoidal over a frequency range of 50 – 1200 Hz, gradually increase the frequency of the signal applied to the galvanometer and determine that the peak-to-peak amplitude of the galvanometer deflection does not increase or decrease by more than 5 percent from the deflection at 60 Hz throughout this frequency range when corrected output voltage is supplied to the galvanometer, and the sensitivity is adjusted to produce a deflection not less than 25 mm.

42.3 Galvanometers shall be calibrated as described in 42.4 – 42.8.

42.4 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit