UL 1062

STANDARD FOR SAFETY

Unit Substations

UL Standard for Safety for Unit Substations, UL 1062

Third Edition, Dated January 29, 1997

Summary of Topics

This revision of ANSI/UL 1062 dated August 21, 2020, is being issued to align with service equipment requirements from NFPA 70; Section 17.

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 revisions are substantially in accordance with Proposal(s) on this subject dated May 15, 2020.

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ANSI/UL 1062-2020

UL 1062

Standard for Unit Substations

Prior to the first edition, the requirements for the products covered by this standard were derived from the Standard for Enclosures for Electrical Equipment, UL 50 (when the title for UL 50 was Cabinets and Boxes); the Standard for Specialty Transformers, UL 506; the Standard for Service Equipment, UL 869; and the Standard for Dead-Front Switchboards, UL 891.

First Edition – March, 1983
Second Edition – April, 1993

Third Edition

January 29, 1997

This ANSI/UL Standard for Safety consists of the Third Edition including revisions through August 21, 2020.

The most recent designation of ANSI/UL 1062 as an American National Standard (ANSI) occurred on July 20, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover unit substations of 1000 kVA single phase and 3000 kVA 3-phase maximum having a maximum nominal primary or secondary rating of 600 volts. Their construction, installation, and use are intended to be in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 *Deleted*

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

2.1.2 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.

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

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

2.2 Units of measurement

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

2.2.2 All applicable alternating-current electrical measurements are in root-mean-square (rms) units unless otherwise stated.

2.3 Undated references

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

3 Glossary

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

3.2 DUMMY FUSE – A current-carrying part made of copper having such dimensions that it will fit its fuse mounting means with the same conditions of pressure, contact, and cross-sectional areas as are obtained on terminals of the fuse that it is intended to replace.

3.3 FILLER PLATE – A plate intended to close an opening that would otherwise be closed by the subsequent installation of a circuit breaker or other device.

3.4 NEUTRAL – Neutral refers to the grounded circuit conductor, such as:

a) The center point of a wye-connected system; or

b) The corner of a delta-connected system; or

c) The midpoint of a 3-wire, single phase or the midpoint of one side of a delta-connected system; or

d) The grounded side of a 2-wire circuit.

3.5 UNIT SUBSTATION – A transformer in combination with primary or secondary overcurrent protective devices or switching devices housed in a single enclosure.

CONSTRUCTION

4 General

4.1 A unit substation shall be complete when it is shipped from the factory. If a switch, circuit breaker, or the like, mounted in a unit substation must be interconnected in order for it to perform its intended function, such interconnecting busing or wiring shall be complete before it is shipped from the factory.

Exception No. 1: A unit substation may have provision for the installation of a switch or circuit breaker in the secondary. If appropriate, markings as covered in 40.4.5 and 40.11.1 – 40.11.5 shall be provided.

Exception No. 2: A unit substation employing circuit breakers or switches of different physical size that require branch bus bars of different physical size or shape, or in which circuit breakers or switches rated at more than 200 amperes may be added by bolted connections, is acceptable without the branch bus bars necessary for such additions being mounted in place when the unit substation is shipped from the factory provided branch bus bars complying with 15.3.19 are available, and markings as covered in 40.11.1 and 40.11.2 are provided.

4.2 A unit substation shall be designed so that any component intended to be field installed can be installed by the use of ordinary tools such as pliers, a screwdriver, or a wrench.

4.3 If a branch bus bar as covered in Exception No. 2 to 4.1 needs a barrier to comply with the spacing requirements in Spacings, Section 21, the barrier shall be attached to the unit substation or to the field-installed branch bus bar.

4.4 In a space that can physically accommodate a branch circuit switch or circuit breaker, but is not intended for this, any hole for securing a branch bus bar to the secondary bus bar shall be plugged with a solid metal rivet or one way screw. A dead-front shield over the portion of bus with holes is not acceptable in lieu of plugging or omitting the holes in the bus bars.

5 Materials

5.1 Materials used shall be combustion and moisture resistant.

Exception: The requirement does not apply to a minor part such as a handle, rubber-insulated wire, magnet insulation, and the like, or as otherwise permitted in these requirements.

6 Rust and Corrosion Resistance

6.1 Iron and steel parts of enclosing cases, walls, and barriers, all springs and other parts upon which mechanical operation may depend, and sheet steel parts of fastening devices, shall be protected against rust by enameling, galvanizing, sherardizing, plating, or equivalent means. Corrosion resistance requirements for an enclosure designated as Type 3R are covered in 8.5.8 – 8.5.12. Corrosion resistance requirements for an enclosure designated as Type 3RX are covered in Type 3RX Enclosures, Section 8.5A.

7 Mechanical Assembly

7.1 A unit substation shall be constructed to provide strength and rigidity in order that it will keep its shape and that doors will close tightly.

7.2 Metal into which a screw is threaded shall provide for the engagement of at least two full threads. A rivet, screw, bolt, or similar fastener in a sheet metal enclosure shall have a diameter at least 50 percent greater than the thickness of the finished sheet metal with which it is used.

Exception: A fastening device as described in 7.3 is acceptable.

7.3 With regard to 7.2, a different type of fastening device may be used if employed with a conventional screw. Other types of fastening devices may be used if investigated for the particular application. A single-threaded sheet metal nut designed to slip over the edge of sheet metal to receive a retaining screw may be used to secure a dead front to supports, a unit such as a switch or circuit breaker to a mounting panel, or a mounting pan to an enclosure if:

a) The nut is protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

b) The threads do not strip when a torque of 30 pound-inches (3.4 N·m) is applied.

7.4 Sheet metal may be extruded at a tapped hole to provide the thickness necessary for two full threads, provided the original metal is not less in thickness than the pitch of the thread.

7.5 Unless otherwise noted, an electrical component shall be securely mounted and prevented from turning.

7.6 A unit substation shall be provided with a means for lifting by forklift or cable and shall be marked in accordance with 40.18.1. A lifting means, if provided for lifting by cable, shall be provided with a minimum 5/8 inch (15.9 mm) diameter hole. The lifting means shall be subjected to the test specified in the Lifting Hook or Bracket Test, Section 34.

Exception: The test specified in the Lifting Hook or Bracket Test, Section 34, need not be conducted on a unit substation intended only for lifting from underneath by a forklift or other means.

8 Framework and Enclosure

8.1 Frame

8.1.1 The framework of a unit substation shall provide strength for the support of all the component parts of the device and the operation of all switching mechanisms in the intended manner.

8.2 Enclosure

8.2.1 A unit substation shall have an enclosure of moisture resistant material. The enclosure shall house all uninsulated live parts.

Exception: A bottom for the enclosure need not be provided for a unit substation intended to be pad mounted if the walls will be flush or within 3/8 inch (9.6 mm) of the pad and if the unit substation is marked in accordance with 40.14.3.

8.2.2 If a unit substation is intended to be mounted on a concrete pad, aluminum parts of an enclosure shall be located at least 1/4 inch (6.4 mm) above the mounting pad.

Exception: Aluminum parts of an enclosure coated with a metallic or nonmetallic coating may be in contact with a concrete pad if the coating is tested to demonstrate resistance to corrosion equivalent to that of galvanized (G90) steel 0.061 inch (1.55 mm) thick.

8.2.3 The enclosure shall be provided with mounting or securing means.

8.2.4 With regard to 8.2.3, for a wall mounted unit substation, the construction shall be such that, if the enclosure is mounted on a plane surface, it will make contact at points of support only, and shall maintain a clearance of not less than 1/4 inch (6.4 mm) at other points. The means for mounting shall be subjected to the test specified in the Wall-Mounting Means Test, Section 35.

8.2.5 An enclosure of polymeric material shall be made the subject of an investigation in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Among the factors to be taken into consideration are:

a) Mechanical strength,

b) Resistance to impact at low temperature,

c) Moisture absorptive properties,

d) Resistance to distortion at temperatures to which the material will be subjected under conditions of normal or abnormal use,

e) Resistance to arcing,

f) Aging characteristics, and

g) Combustibility.

8.3 Sheet metal

8.3.1 A sheet metal enclosure shall be made of iron, steel, brass, copper, or aluminum.

Exception: Other materials may be employed if, upon investigation, the material is found to be acceptable for the purpose and the enclosure is found to be equivalent to the sheet metals specified.

8.3.2 A sheet metal enclosure shall have a minimum thickness as specified in Table 8.1 or Table 8.2.

Exception No. 1: An enclosure without supporting frame may be thinner than specified in Table 8.1 and Table 8.2 if it complies with the requirements in the Compression Test, Section 31, and the Deflection Test, Section 32, but not less than 0.053 inch (1.35 mm) for uncoated steel, 0.56 inch (1.42 mm) for coated steel, and 0.075 inch (1.91 mm) for aluminum, copper, or brass.

Exception No. 2: The thickness of a cover, door, front, or panel may be as specified in 8.3.5 and 8.3.6.

Table 8.1
Minimum thickness of sheet metal for enclosures – carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness, inch (mm)			
Maximum width[a],		Maximum length,		Maximum width[a,c],		Maximum length[c],					
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	Uncoated		Metal coated	
18.0	45.7	Not limited[d]		27.0	68.6	Not limited[d]					
20.0	50.8	25.0	63.5	29.0	73.7	36.0	91.4	0.053	1.35	0.056	1.42
22.0	55.9	Not limited[d]		33.0	83.8	Not limited[d]					
25.0	63.5	31.0	78.7	35.0	88.9	43.0	109.2	0.060	1.52	0.063	1.60
25.0	63.5	Not limited[d]		39.0	99.1	Not limited[d]					
29.0	73.7	36.0	91.4	41.0	104.1	51.0	129.5	0.067	1.70	0.070	1.78
33.0	83.8	Not limited[d]		51.0	129.5	Not limited[d]					
38.0	96.5	47.0	119.4	54.0	137.2	66.0	167.6	0.080	2.03	0.084	2.13
42.0	106.7	Not limited[d]		64.0	162.6	Not limited[d]					
47.0	119.4	59.0	149.9	68.0	172.7	84.0	213.4	0.093	2.36	0.097	2.46
52.0	132.1	Not limited[d]		80.0	203.2	Not limited[d]					
60.0	152.4	74.0	188.0	84.0	213.4	103.0	261.6	0.108	2.74	0.111	2.82
63.0	160.0	Not limited[d]		97.0	246.4	Not limited[d]					
73.0	185.4	90.0	228.6	103.0	261.6	127.0	322.6	0.123	3.12	0.126	3.20

[a] The smaller dimension of a rectangular sheet metal piece that is part of an enclosure other than as covered in 8.3.7. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[b] Refer to 8.3.3 and 8.3.4.

[c] Length of sides to be measured between supporting frames as shown in Figure 8.1.

[d] "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

Table 8.2
Minimum thickness of sheet metal for enclosures – aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[b]				Minimum thickness,	
Maximum width[a],		Maximum length,		Maximum width[a,c],		Maximum length[c],			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inch	(mm)
18.0	45.7	Not limited[d]		42.0	106.7	Not limited[d]			
20.0	50.8	25.0	63.5	45.0	114.3	55.0	139.7	0.075	1.91
25.0	63.5	Not limited[d]		60.0	152.4	Not limited[d]			
29.0	73.7	36.0	91.4	64.0	162.6	78.0	198.1	0.095	2.41
37.0	94.0	Not limited[d]		87.0	221.0	Not limited[d]			
42.0	106.7	53.0	134.6	93.0	236.2	114.0	289.6	0.122	3.10
52.0	132.1	Not limited[d]		123.0	312.4	Not limited[d]			
60.0	152.4	74.0	188.0	130.0	330.2	160.0	406.4	0.153	3.89

[a] The smaller dimension of a rectangular sheet metal piece that is part of an enclosure other than as covered in 8.3.7. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

Table 8.2 Continued on Next Page

Table 8.2 Continued

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

[b] Refer to 8.3.3 and 8.3.4.

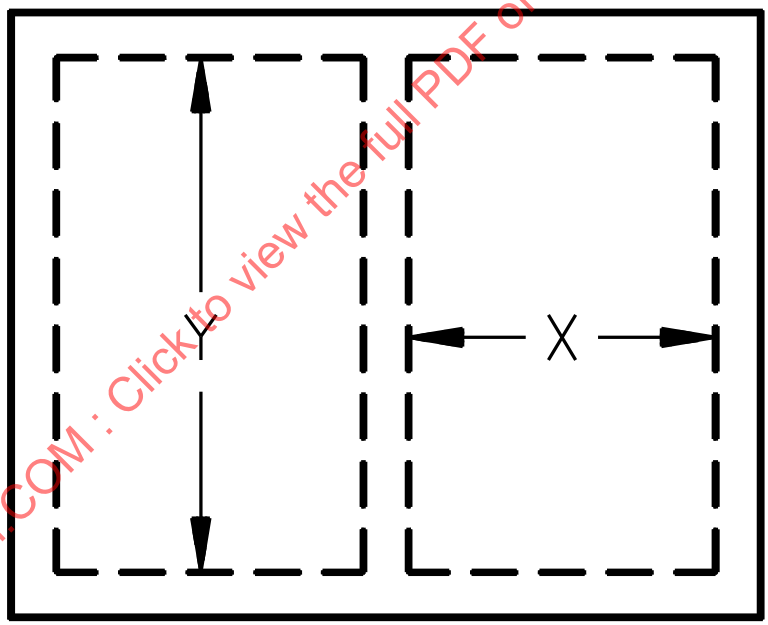
[c] Length of sides to be measured between supporting frames as shown in Figure 8.1.

[d] "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

8.3.3 A supporting frame shall be formed of angles, channels, folded rigid sections of sheet metal, or the equivalent, rigidly fastened together and having the same outside dimensions as the enclosure surfaces.

Figure 8.1

Length or width between support frames



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NOTE – X, Y – Length or width between supporting frames, see note c, Table 8.1 and Table 8.2.

8.3.4 With reference to 8.3.3 and Table 8.1 and Table 8.2, a construction is not considered to have a supporting frame if it is:

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

b) A single sheet that is corrugated or ribbed; or

c) An enclosure formed or fabricated from sheet metal.

8.3.5 With regard to Table 8.1 and Table 8.2, part of a door, front, panel, or cover that has a supporting frame may employ metal having a thickness not less than 0.056 inch (1.42 mm) if zinc-coated steel, 0.053 inch (1.35 mm) if uncoated steel, or 0.075 inch (1.91 mm) if aluminum, copper, or brass when:

a) The door, front, panel, or cover has the strength and rigidity to maintain its shape when open or unmounted; and

b) The construction complies with the test specified in 32.2.

Exception: A door that is not part of the required enclosure is not required to comply with this requirement.

8.3.6 If a door covers a small opening only, such as an opening for a latch and lock, it shall have a thickness not less than 0.035 inch (0.89 mm) if zinc-coated steel, 0.032 inch (0.81 mm) if uncoated steel, or 0.050 inch (1.27 mm) if aluminum, copper, or brass.

8.3.7 If two or more covers or panels are provided to close a single opening, the thickness of each cover or panel shall be no less than a single sheet, that would cover the complete opening, as specified in the "without supporting frame" columns of Table 8.1 or Table 8.2. The adjacent edges of such multiple panels or covers shall comply with one of the following conditions:

a) Be flanged at least 1/2 inch (12.7 mm).

b) Be supported against an inward force at 10 inch (254 mm) maximum intervals.

c) Overlap each other at least 1/2 inch and be secured together at 10 inch maximum intervals.

d) Comply with the deflection test specified in 32.2.

Exception: The cover thickness may comply with Exception No. 1 to 8.3.2 or with 8.3.5(b).

8.3.8 Sheet metal, where formed into angles or corners, shall show no evidence of fracture.

8.3.9 Slight surface crazing is not considered to be evidence of fracture.

8.4 Specific environmental conditions

8.4.1 An enclosure shall be marked as specified in 40.15.1 for a specific environmental condition as specified in Table 8.3. An enclosure that complies with the requirements for more than one type of enclosure may be marked accordingly with multiple type designations. An enclosure marked with a Type number shall comply with the applicable tests specified in Table 8.3.

8.5 Type 3R enclosures

8.5.1 A unit substation marked as Type 3R as specified in 40.16.1 shall comply with 8.5.2 – 8.5.14 and shall comply with the Rain Test, Section 26. A switch, circuit breaker, receptacle (complete with its associated attachment-plug), fuseholder, or similar device, as well as any opening associated with an

operating handle, shall be in place for the Rain Test, or shall be shielded from rain using means previously shown to provide suitable protection.

8.5.2 In an enclosure intended for horizontal pad mounting, any live part shall be located at least 4 inches (102 mm) above the enclosure mounting surface.

Table 8.3
Enclosure types

Type number	Intended use and description	Tests, as specified in	
		UL 50[a]	UL 1062[b]
1	Indoor use primarily to provide a degree of protection against contact with the enclosed equipment and against a limited amount of falling dirt.	Corrosion Protection – 5.3 or Rust Resistance – Section 38	–
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt.	Corrosion Protection – 5.3 or Rust Resistance – Section 38, and Drip – Section 31	–
3R	Outdoor use to provide a degree of protection against falling rain undamaged by the formation of ice on the enclosure.	Icing Test, Section 34	Rain Test, Section 26 and Protective Coating, 8.5.8 – 8.5.12
3RX	Indoor or outdoor use to provide a degree of protection against falling dirt, rain, sleet, and snow; undamaged by the formation of ice on the enclosure; has additional protection against enclosure corrosion.	Icing Test, Section 34 and Corrosion Resistance Test, Section 39	Rain Test, Section 26 and Protective Coating, 8.5.8 – 8.5.12

[a] Tests shall be conducted in accordance with the applicable requirements specified in the Standard for Enclosures for Electrical Equipment, UL 50.

[b] Tests shall be conducted in accordance with the applicable requirements specified in the Standard for Unit Substations, UL 1062.

8.5.3 A hole for conduit in an enclosure shall be threaded unless it is entirely located below the lowest live part within the enclosure, or unless it accommodates a specific hub or closure fitting. The area surrounding a threaded conduit hole shall be reinforced to provide metal at least 1/4 inch (6.4 mm) thick. A threaded hole for conduit shall be provided with a conduit end stop unless the thread is tapered.

8.5.4 A gasket of thermoplastic material or composition may be accepted after consideration of the effects of heat aging, distortion under conditions of use, and the means of securing the gasket to the cover or enclosure.

8.5.5 If an 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 70 ±1°C (158 ±1.8°F) in circulating air for 168 hours will have 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.

8.5.6 In an enclosure, a hinge or other attachment shall be resistant to corrosion.

8.5.7 Metals shall not be used in combinations such that galvanic action may cause an adverse effect on any part of the product.

8.5.8 A sheet steel enclosure marked Type 3R shall be made corrosion resistant by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating designation G90 in the Specification for Sheet Steel, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement. The weight of the zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M-93.

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 (0.0155 mm) on each surface, with a minimum thickness of 0.00054 inch (0.014 mm). The thickness of coating shall be established by the Coating Thickness Test, Section 30.

c) A zinc coating conforming with (1) or (2) 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 may be determined by consideration of its composition or by corrosion tests if these are considered necessary.

1) Hot-dipped, mill-galvanized sheet steel conforming with the coating designation G60 or A60 in ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single-spot test requirement. The weight of zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the test method in ASTM A90/A90M-93.

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 Coating Thickness Test, Section 30.

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 Coating Thickness Test, Section 30.

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 Coating Thickness Test, Section 30, and the paint shall be as described in (c).

f) Other finishes, including paints, metal finishes, or combinations of the two may be accepted when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) conforming with (a), indicate they provide equivalent protection. Such comparative tests are specified in the Standard for Organic Coatings for Steel Enclosures for Outdoor-Use Electrical Equipment, UL 1332.

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

8.5.10 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. Sheared or cut edges and punched holes are not required to be additionally protected.

8.5.11 If the hot-dipped, mill-galvanized G90 coating on drawn, formed, extruded, or rolled sheet steel becomes damaged during handling or fabrication to the extent that the base metal is exposed, at least one coat of an organic finish of the epoxy or alkyd-resin type, or other outdoor paint, shall be applied after fabrication to the entire area where the damage to the coating occurred.

Exception: Exposed base metal of an uncoated cross-section surface at a cut edge or at a drilled opening is acceptable.

8.5.12 Sheet steel that employs a hot-dipped, mill-galvanized G90 coating that is drawn, formed, extruded, or rolled shall be additionally painted with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint in the areas that are affected by a process that damages the coating as determined by the requirement in 8.5.10.

8.5.13 Aluminum in an enclosure shall not be in contact with concrete. A metallic or nonmetallic coating used to separate aluminum from a concrete pad shall be tested to demonstrate resistance to corrosion equivalent to that of galvanized (G90 zinc coating) steel 0.061 inch (1.55 mm) thick.

8.5.14 In an enclosure marked Type 3R, guides for latch rods shall be located so that the latch rods will not be deformed by a direct pull of 200 pounds (890 N) applied to the door handle for 1 minute in the direction that the door will open.

8.5A Type 3RX enclosures

8.5A.1 A unit substation enclosure marked as Type 3RX shall be fabricated of:

a) American Iron and Steel Institute (AISI) Type 304 Stainless steel;

b) Polymeric materials; or

c) Materials that comply with:

1) 8.5.8 and

2) The requirements of the Corrosion Resistance Test, Section 39 of the Standard for Enclosures for Electrical Equipment, UL 50

Other than the corrosion resistance requirements, a unit substation enclosure marked as Type 3RX shall comply with the requirements of Type 3R Enclosures, Section 8.5.

8.6 Components mounted on doors and covers

8.6.1 An electrical component shall be mounted independent of a door or removable cover.

Exception No. 1: A meter base may be mounted on a door as covered in 8.6.5.

Exception No. 2: Metering and monitoring equipment provided by the serving agency (electric utility or power company) may be mounted on a door or cover.

Exception No. 3: A component may be mounted on a hinged door if it complies with 8.6.2 – 8.6.4, and 8.6.6.

Exception No. 4: A meter, selector switch, pilot light, or push button station may be mounted on an unhinged cover not exceeding 12 inches (305 mm) high nor 24 inches (610 mm) wide provided a fuse is not located behind the cover.

8.6.2 With regard to Exception No. 3 to 8.6.1, a wire subject to flexing when the cover is opened shall:

a) Be stranded and if larger than 6 AWG (13.3 mm^2) shall have copper conductors of the extra flexible type;

b) Have insulation at least 1/32 inch (0.8 mm) thick; and

c) Be cabled, routed, secured, and protected so that the wire will not be damaged during opening and closing of the door or cover.

8.6.3 With regard to Exception No. 3 to 8.6.1, if a wire larger than 12 AWG (3.3 mm^2) is used for connecting components mounted on a door, the door shall:

a) Be hinged on one side and secured on the opposite side with screws or means for locking;

b) Serve as access only to a bus bar, a wiring space, a terminal block, or similar component not requiring replacement, adjustment, resetting, or removal; and

c) Be provided with means for keeping it open while installing field wiring.

8.6.4 With regard to Exception No. 3 to 8.6.1, a door having wire not larger than 12 AWG (3.3 mm^2) shall comply with:

a) The requirement in 19.11 if the door provides access to a fuse and

b) The requirement in 10.4 if the door provides access to any part requiring adjustment, or the like, after the original installation of the unit substation.

8.6.5 A meter socket base shall be mounted independently of the cover unless it is intended to be used with current transformers.

8.6.6 Any uninsulated live part involving a potential of more than 42.4 volts peak mounted on the inside of a door shall be guarded, recessed, or enclosed to reduce the risk of unintentional contact. One method of accomplishing this would be to provide a fiber barrier at least 0.028 inch (0.71 mm) thick that is secured in place.

8.7 Ventilation – general

8.7.1 A louver shall be 12 inches (305 mm) or less in length.

8.7.2 The total area of enclosure material removed from a wall for ventilation (together with the total area of ventilation openings as a result of forming the enclosure material) shall not exceed 25 percent of the area of the entire surface of any wall in which such ventilation openings are located.

Exception: The 25 percent area limitation may be exceeded provided that reinforcing means, such as stiffeners, are employed.

8.7.3 The area of any ventilation opening, as defined by the opening in the enclosure metal, shall not exceed 200 square inches (1290 cm^2) if the ventilation closing panel is formed from material having a thickness less than that of the enclosure metal. A ventilation closing panel lighter than 0.060 inch (1.52 mm) thick uncoated steel, 0.063 inch (1.60 mm) zinc-coated steel, or 0.075 inch (1.91 mm) aluminum, copper, or brass, or 14 AWG (2.1 mm^2) or lighter wire mesh, shall not be used to close an opening of more than 80 square inches (516 cm^2).

8.7.4 The wires of a screen of a ventilating opening shall have a minimum diameter of:

a) 0.054 inch (1.37 mm) for screen openings 1/2 square inch (3.2 cm^2) or less in area or

b) 0.080 inch (2.03 mm) for openings larger than 1/2 square inch in area.

8.7.5 Perforated sheet steel and sheet steel employed for expanded metal mesh shall be in accordance with Table 8.4.

Exception: If the indentation of a guard or enclosure will not alter the clearance between the uninsulated live parts and grounded metal so as to affect performance adversely or reduce spacings below the minimum values given in Table 21.1, 0.020 inch (0.51 mm) minimum expanded metal mesh [0.023 inch (0.58 mm) if zinc coated] may be employed.

Table 8.4
Minimum thickness of perforated sheet steel or sheet steel used for expanded metal mesh

Area of perforation or mesh openings,		Minimum thickness of metal			
		Uncoated,		Zinc coated,	
inches^2	(cm^2)	inches	(mm)	inches	(mm)
1/2 or less	3.2 or less	0.042	1.07	0.045	1.14
More than 1/2	More than 3.2	0.080	2.03	0.084	2.13

8.7.6 A grille construction complying with the intent of the requirements in 8.7.5 may be used if it has been found to be acceptable for the particular application.

8.7.7 A ventilation opening in the top of the enclosure shall be covered by a hood or provided with a shield so spaced with respect to the opening to reduce the risk of the entry of foreign material.

8.8 Ventilation – panelboard section

8.8.1 A ventilation opening shall be constructed, located, or provided with a barrier, in compliance with 12.4.1 and 12.4.2, so that:

a) No flame or molten metal will be emitted during arcing encountered during the operation of a fuse, switch, or circuit breaker and

b) No access to an uninsulated live part is provided.

Exception No. 1: With regard to an arcing part, the ventilation opening need not be provided with a barrier if:

a) During a switch overload test, based on the requirements of the switch involved, there is no emission of flame or molten material from the opening or

b) The opening is located at least 12 inches (305 mm) from the arcing part.

Exception No. 2: With regard to a nonarcing uninsulated live part, the ventilation opening need not be provided with a barrier if:

a) The opening is located at least 4 inches (102 mm) from the live part or

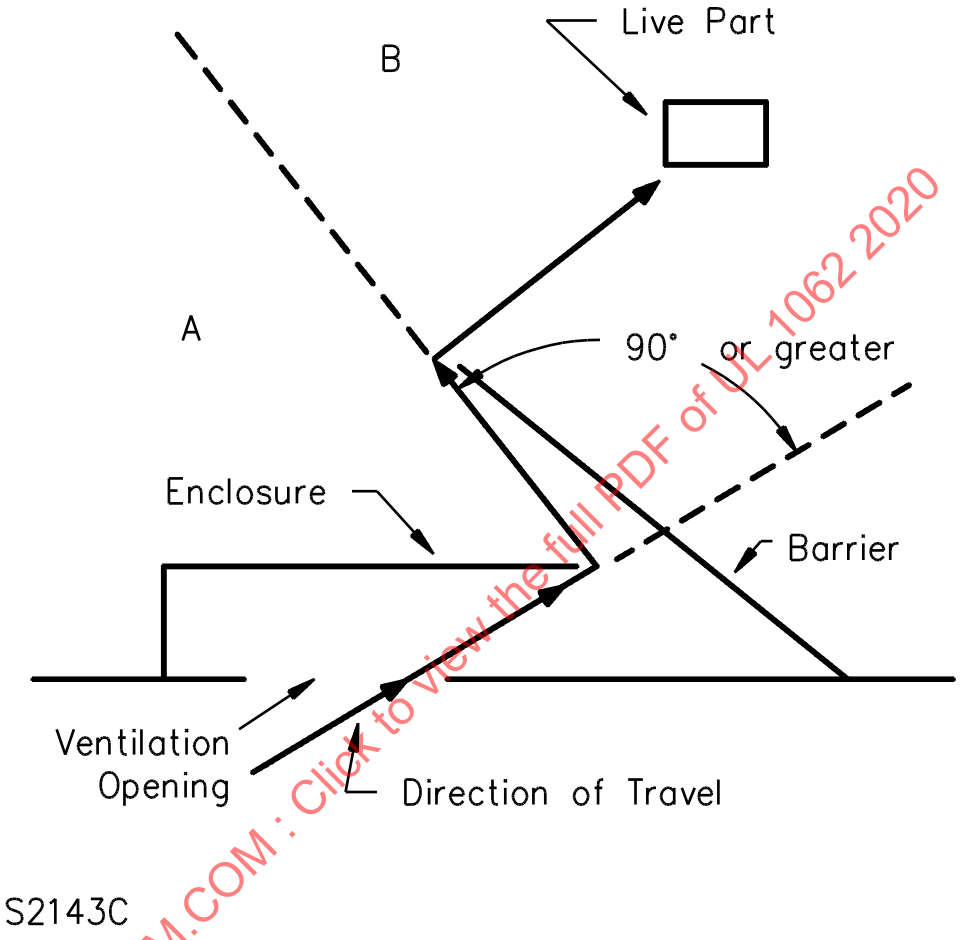
b) The live part is part of the neutral circuit.

8.8.2 A ventilation opening (slot, louver, or the like) shall be protected by one or more baffles, barriers, or other obstructions of such dimension and location that any access path to a live part requires at least two changes of direction, one of which involves an angle of 90 degrees or more from a straight line as shown in Figure 8.2. In addition, if the minor dimension of a ventilation opening is larger than 1/4 inch (6.4 mm), it shall be protected by a screen having a minor dimension no larger than 1/4 inch.

Exception: A screen is not required if live parts cannot be contacted by the articulate probe illustrated in Figure 8.3.

Figure 8.2

Angle of change of direction



NOTES –

1) A – No live parts permitted in this area.

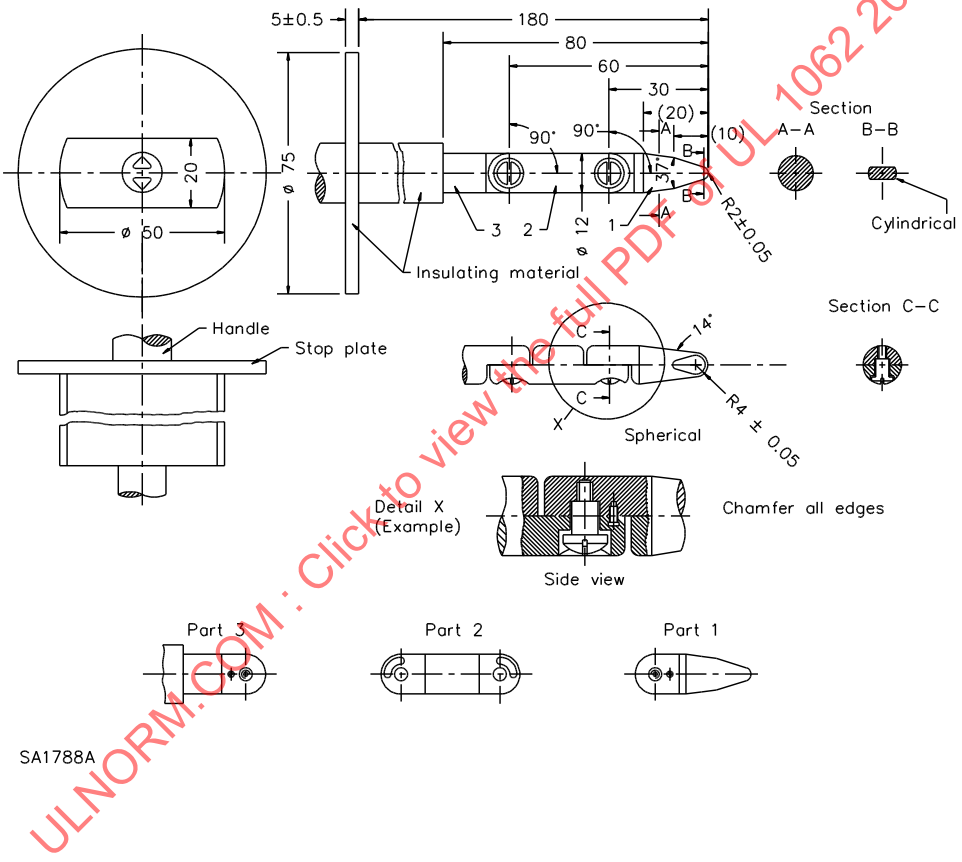
2) B – Live parts acceptable this side of barrier.

8.8.3 The probe specified in the Exception to 8.8.2 and illustrated in Figure 8.3 shall be applied to any depth that the opening will permit and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. The probe shall be applied in any possible configuration and, if necessary, the configuration shall be changed after insertion through the opening.

8.8.4 The probe specified in the Exception to 8.8.2 shall be used as a measuring instrument to judge the accessibility provided by an opening and not as an instrument to judge the strength of a material. It shall be applied with the minimum force necessary to determine accessibility.

Figure 8.3

Articulate probe



8.9 Ventilation – transformer section

8.9.1 Any opening in an enclosure shall have such size or shape that a test rod having the diameter specified in 8.9.2 will be prevented from entering.

Exception: An opening is acceptable if, by means of its size, location, baffling, or the like, it will prevent a straight rod that is 33/64 inch (13.1 mm) in diameter from passing within 4 inches (102 mm) of any uninsulated live part inside the enclosure.

8.9.2 The test rod specified in 8.9.1 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 a part.

9 Doors and Covers

9.1 General

9.1.1 A door, front, panel, or cover shall be provided with means for holding it in place.

9.1.2 A dead front shield or a removable cover shall be constructed so that it can be installed and removed without contacting a bare live part or causing damage to the insulation of any insulated live part inside the enclosure.

9.1.3 With regard to the requirement in 9.1.2, a dead front shield or cover is considered likely to fall backward into the interior unless it is supported during removal until it can be extracted directly from the enclosure without a sliding or twisting motion.

9.1.4 A door that is not part of the required enclosure is not required to comply with the requirements of 8.3.1 – 8.3.9 and 9.2.1 – 9.4.2.

9.1.5 A hinged cover or door over a live part shall be provided with a stop to reduce the risk of the cover or door from contacting the live part. The stop shall be independent of any other door or removable cover.

9.1.6 A metal cover plate intended to be opened for inspection purposes shall not exceed 12 square feet (1.12 m^2) in area or 60 pounds (27 kg) in weight unless it is equipped with lifting means or hinges.

9.1.7 A cover that is likely to be removed to permit the connection of circuit or ground conductors or to make tap changes shall not be provided with means for the connection of any wiring method.

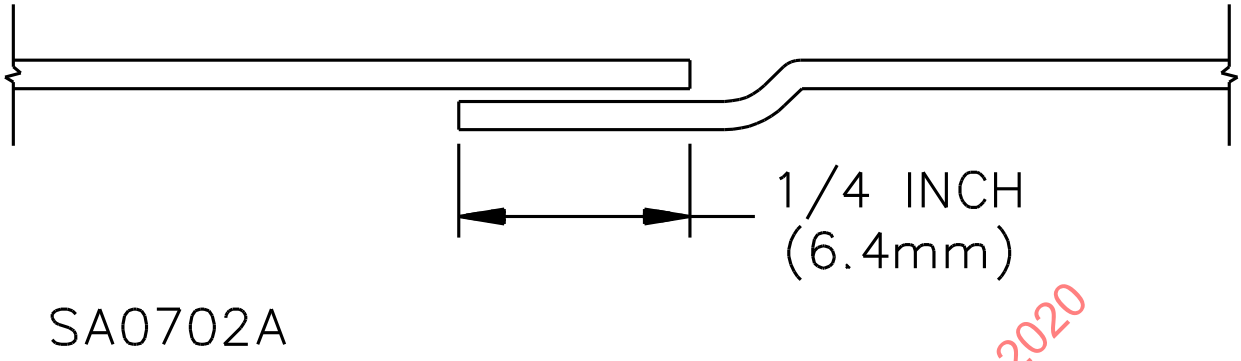
9.2 Flanges for metallic enclosures

9.2.1 A door or a cover shall shut closely against a 1/4 inch (6.4 mm) rabbet as illustrated in Figure 9.1 or have flanges for the full length of all edges.

Exception: A gasketed joint may be used in place of a 1/4 inch rabbet if the gasket is investigated for the particular application. Among the factors considered are resistance to aging, heat, cold, distortion under the conditions of use, and the means of securing the gasket in place.

Figure 9.1

Rabbet



9.2.2 A flat strip used to provide a rabbet shall not be less in thickness than 60 percent of the required thickness of the metal to which it is secured. It shall be secured at not less than two points, not more than 1-1/2 inches (38.1 mm) from each end of the strip, and at points between these end fastenings not more than 6 inches (152 mm) apart. A formed strip may be made of metal thinner than that required for a flat strip if it is formed and attached so that it provides an equivalent rabbet. A rabbet is not required behind a piano-type hinge.

9.2.3 A flange on a cover shall:

a) Fit closely with the outside wall of the box proper in accordance with Table 9.1;

b) Have a width in accordance with Table 9.1;

c) Be one of the constructions illustrated in Figure 9.2 and Figure 9.3.

Exception No. 1: A hinged cover that is flanged on all four edges to a depth of not less than 1/2 inch (12.7 mm) may be constructed as shown in Figure 9.4 on the hinge side only if the following conditions are met:

1) There are no arcing parts located behind the cover, or

2) It has been demonstrated by test that no flame or molten metal is emitted during the arcing normally encountered during the operation of a fuse, switch, or circuit breaker.

Exception No. 2: Other constructions may be evaluated.

d) Where a telescoping cover meets the cabinet or box of a surface-mounted enclosure, overlap all edges in accordance with Table 9.1.

Exception: The overlap may be as specified in 9.2.7.

9.2.4 The constructions illustrated in Figure 9.2 and Figure 9.3 are also acceptable on dead front covers that are held in place by screws. For such covers, the clearances between adjacent flanges may be as described in 9.2.6 and Figure 9.5.

9.2.5 To determine if a flanged cover complies with the requirement in 9.2.3(b), the distance between the flat portion of the cover – clear of forming radii, beads, draws, or the like – and the edge of the flanged portion of the cover is to be measured.

Table 9.1
Dimensions for flanged cover constructions

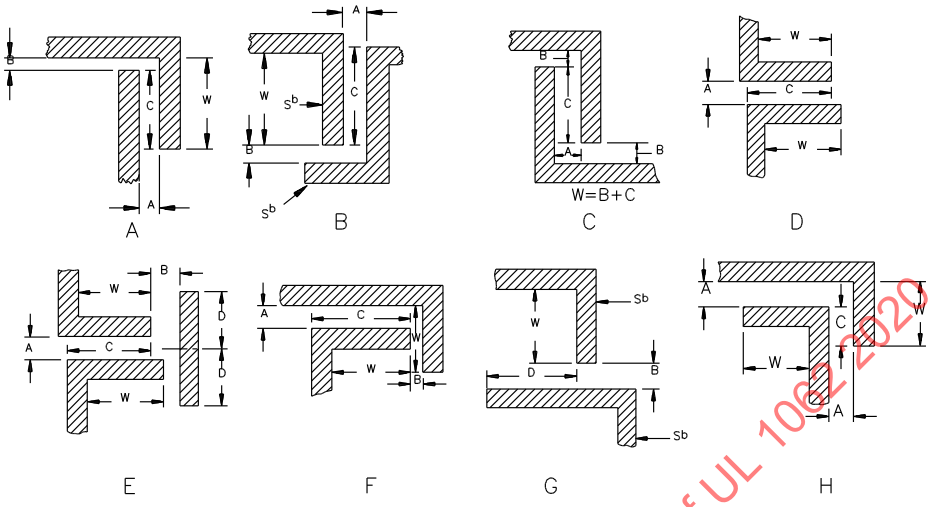
Figure 9.2 constructions	Dimensions									
	W		A		B		C		D	
	Minimum flange width[a],		Minimum space between parts,		Maximum gap,		Minimum overlap,		Minimum barrier extension,	
	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)	inch	(mm)
A	1/2	12.7	1/8	3.2	1/8	3.2	7/16	11.1	–	–
A	3/4	19.1	3/16	4.8	3/16	4.8	5/8	15.9	–	–
A	1	25.4	1/4	6.4	1/4	6.4	7/8	22.2	–	–
B	1/2	12.7	1/8	3.3	1/8	3.2	7/16	11.1	–	–
B	3/4	19.1	3/16	4.8	3/16	4.8	5/8	15.9	–	–
B	1	25.4	1/4	6.4	1/4	6.4	7/8	22.2	–	–
C	1/2	12.7	3/16	4.8	3/16	4.8	1/4	6.4	–	–
C	3/4	19.1	1/4	6.4	1/4	6.4	7/16	11.1	–	–
D	1/2	12.7	3/32	2.4	–	–	7/16	11.1	–	–
E	1/2	12.7	1/8	3.2	1/8	3.2	7/16	11.1	1/4	6.4
F	1/2	12.7	1/8	3.2	1/4	6.4	7/16	11.1	–	–
G[b]	1/2	12.7	–	–	1/8	3.2	–	–	1/2	12.7
H	1/4	6.4	1/8	3.2	–	–	3/16	4.8	–	–

[a] Tolerance: Minus 1/16 inch (1.6 mm).

[b] Equipment within the enclosure must be located on the side of the barrier extension D that is opposite the gap B.

Figure 9.2

Flanged cover constructions



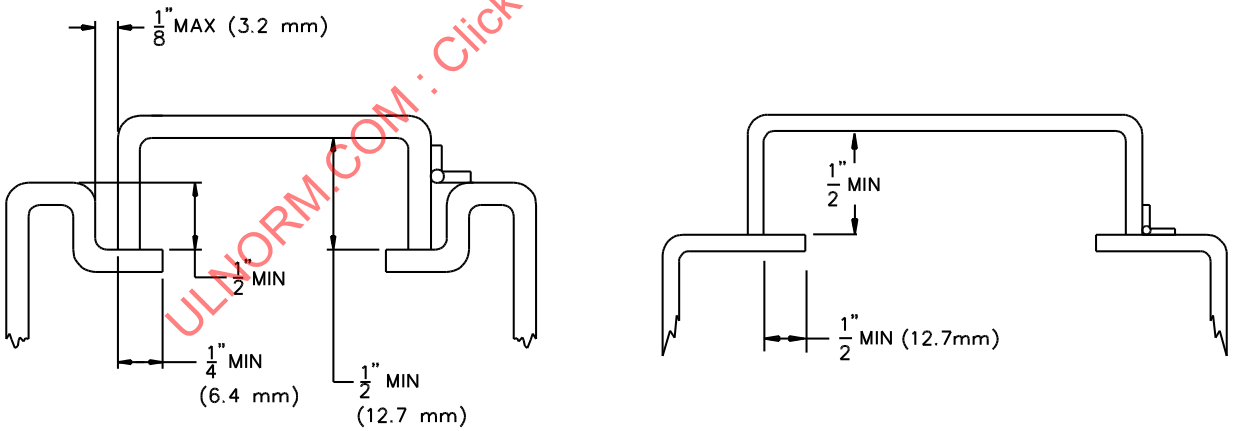
NOTES –

1) Dimensions for construction A – H are given in Table 9.1.

2) The surfaces "S" may be in line with one another – not as shown.

Figure 9.3

Flanged cover constructions



Dimensions,	
inch	(mm)
1/8	3.2
1/4	6.4
1/2	12.7

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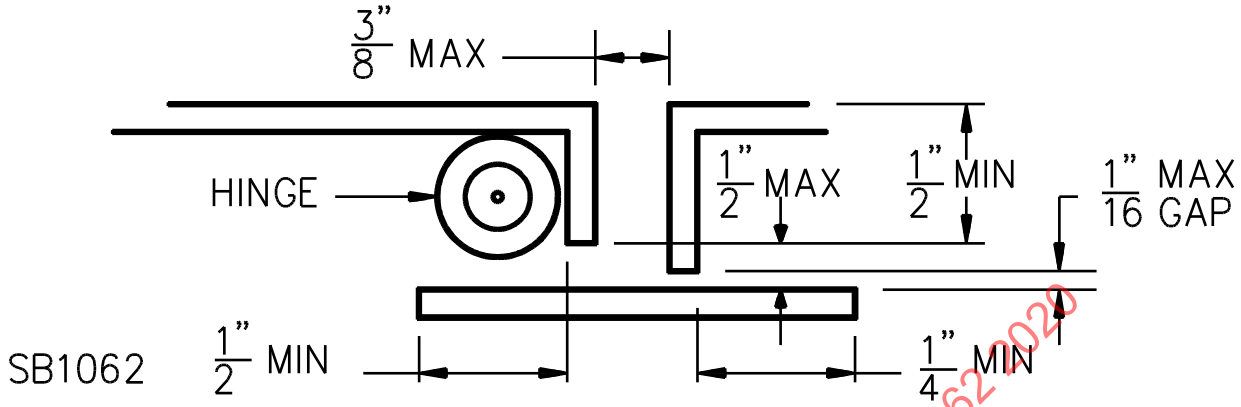
Figure 9.4

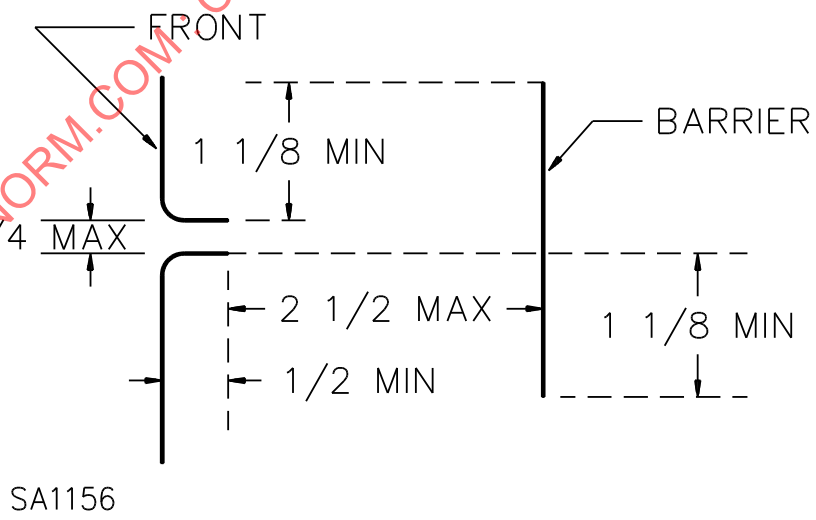
Flanges on hinge side



Dimensions,	
inch	(mm)
1/16	1.6
1/4	6.4
3/8	9.5
1/2	12.7

Figure 9.5

Barrier behind flanged opening



Dimensions,	
inch	(mm)
1/4	6.4
1/2	12.7
1-1/8	28.6
2-1/2	63.5

9.2.6 With regard to the Exception to 9.2.1, the clearance between flanges of covers that are held in place by screws may be 1/8 inch (3.2 mm) maximum. If a barrier is located behind the flanged opening as shown in Figure 9.3, if there are no live parts in the open area, and if the construction complies with 8.8.1, clearances may be 1/4 inch (6.4 mm) maximum.

9.2.7 The overlap of a telescoping cover may be not less than 1/4 inch (6.4 mm) if:

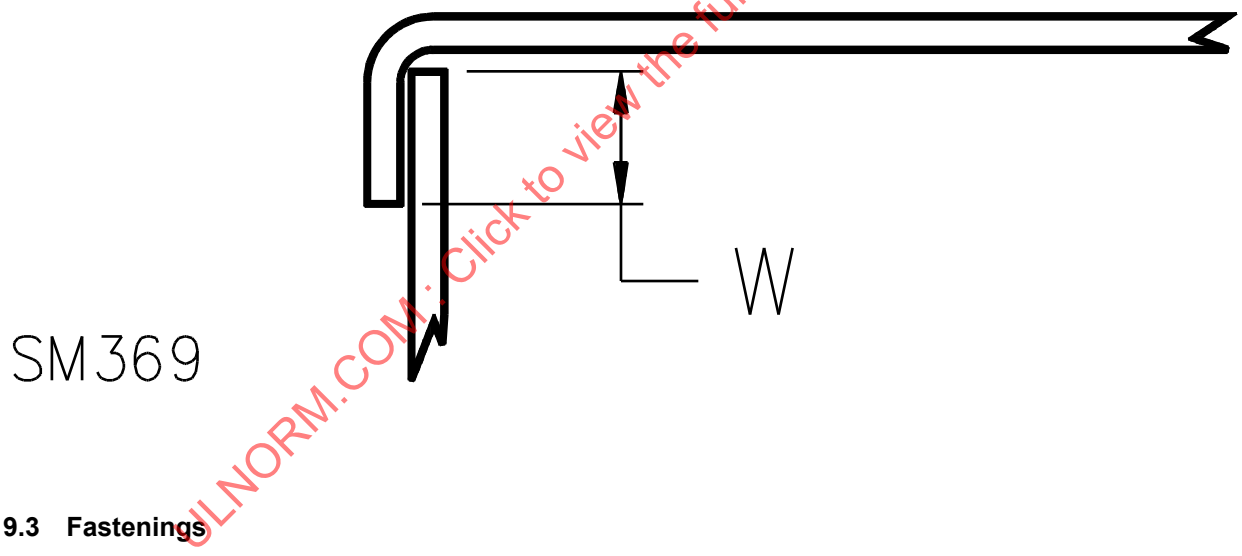
a) The cover is secured in place by screws or by a combination of hinges and screws and

b) The cover and the box wall are flanged in accordance with Sketch H of Figure 9.2.

9.2.8 To determine if a telescoping cover complies with the requirement in 9.2.3(c), the cover is to be in its closed position, and a mark is to be scribed on all walls of the box along the edge of the flange. The overlap is the measured distance W between the scribed marks and the edges of the box walls, as illustrated in Figure 9.6. In scribing the marks, the cover is to be restrained in position so that there is no displacement of the cover by the scribing tool, but without bending or distorting any portion of the box, or cover, or other part of the enclosure.

Figure 9.6

Measurement of overlap



9.3 Fastenings

9.3.1 A removable front panel or trim shall be secured by at least four fastenings. There shall be at least one fastening located not more than 6 inches (152 mm) from each of the four corners, and fastenings shall not be spaced more than 24 inches (610 mm) apart along any vertical side.

Exception No. 1: Any panel or cover having dimensions not exceeding 6 inches high by 20 inches (508 mm) wide or having flanges on all four sides and having dimensions not exceeding 9 inches (229 mm) high by 20 inches wide, or 6 inches wide by 36 inches (914 mm) high, may be fastened by one screw in each of the two opposite sides. The screws need not be at the center of the sides provided the construction is such as to hold the front panel or cover against the adjacent flange of the section.

Exception No. 2: A removable panel more than 24 inches long on any side that is flanged 1/2 inch (12.7 mm) minimum may have fastenings spaced not more than 36 inches apart and not more than 10 inches

(254 mm) from each of the four corners providing the fastenings are not less than 1/4 inch (6.4 mm) in diameter.

9.3.2 Fastening screws or the screws of clamps or hinges shall not be less than 5/32 inch (4.0 mm) in diameter (No. 8 screw size) for a panel 360 square inches (2323 cm^2) or less in area, and not less than 3/16 inch (4.8 mm) in diameter (No. 10 screw size) for a larger panel or cover.

9.3.3 Fastenings may be omitted along that vertical side of a panel that is adjacent to a panelboard, or the like, if the panel is supported at all four corners, and if the panel is either:

a) Flanged the full length of both the longer sides or

b) Flanged the full length of one of the longer sides, with the unflanged side secured to a rigid member.

9.4 Butt hinges

9.4.1 A hinge for a door or a cover shall be of metal and able to perform its intended function without distortion. A leaf of a hinge shall be securely fastened, at two or more points, to the enclosure or trim and to the door or the cover.

Exception: Means of fastening may be as provided in 9.4.4 – 9.4.7.

9.4.2 A metal hinge pin shall not be less than 5/32 inch (4 mm) in diameter if made of brass or aluminum and 1/8 inch (3.2 mm) if made of steel for a door or a cover 360 square inches (2322 mm^2) or less in area, and not less than 3/16 inch (4.8 mm) in diameter for a larger door or cover.

Exception: Other hinge constructions may be acceptable as provided in 9.4.3.

9.4.3 For constructions other than as described in 9.4.2, a hinged door or cover shall withstand a load of four times its weight, but not less than 20 pounds (9 kg), without causing permanent deformation of the hinge. The load is to be applied vertically downward through the center of gravity of the door or cover.

9.4.4 If two or more hinges are provided with each door or cover, each leaf may be secured to the door or cover, and to the enclosure by a single fastener if additional means, such as a boss or flange, is provided to maintain hinge alignment.

9.4.5 A single weld is acceptable for securing a hinge not larger than 1 inch (25.4 mm) square provided the hinge remains in place after the door or cover has been subjected to abuse such as might be expected in service.

9.4.6 Hinge securing constructions other than those described in 9.4.4 and 9.4.5 may be accepted if found to be equivalent in performance to the construction required in 9.4.1.

9.4.7 At least two hinges shall be provided for each hinged door or cover.

Exception: A single hinge may be acceptable as provided in 9.4.8.

9.4.8 The length of a single hinge used on either side of a door or cover not exceeding 5 by 9 inches (127 by 229 mm) shall be not less than 1/3 the length of the longer side. The length of a single hinge used on a door or cover having dimensions exceeding 5 by 9 inches shall be not less than 80 percent of the length of the longer side of the door or cover. A single hinge is to be centered on the door or the cover.

9.4.9 Hinges shall be spaced as specified in Table 9.2. The spacing between hinges is to be measured between centers of the hinges; the spacing between a hinge and the end of a door or cover is to be measured from the edge of the hinge.

Table 9.2
Hinge spacings for metallic enclosures

Maximum spacing				Construction of door or cover			
From each end of door or cover,		Between hinge centers,		Flange width,		Metal and minimum thickness,	
inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
4	102	24	610	None	None	–	–
4	102	32	712	None	None	Uncoated steel	
						0.093	2.4;
						Zinc coated steel	
						0.097	2.5; or
						Aluminum, copper, or brass	
						0.122	3.1
4	102	36	914	1/2	12.7	–	–
6[a]	152	36	914	1/2	12.7	–	–
10[b]	254	36	914	1/2	12.7	–	–
9	229	36	914	1	25.4	–	–
12	305	40	1016	1	25.4	Uncoated steel	
						0.093	2.4;
						Zinc coated steel	
						0.097	2.5; or
						Aluminum, copper, or brass	
						0.122	3.1

[a] Hinges may be spaced 6 inches (152 mm) from the end of a door or a cover not more than 45 inches (1.14 m) long on the hinged side.

[b] Hinges may be spaced 10 inches (254 mm) from the end of a door or a cover having three hinges.

9.5 Piano hinges

9.5.1 A continuous piano hinge shall be able to perform its intended function without distortion.

9.6 Latches

9.6.1 Each door shall be provided with a positive latch or a captive screw. A captive screw shall be operable by hand or by a conventional tool. A captive screw may be the simple 1/4 or 1/2 turn or multi-turn type.

Exception: A non-captive screw fastening may be used in the case of an enclosure that has a hinged cover but where the hinge construction is not strictly required under these requirements.

9.6.2 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.

9.6.3 A door more than 48 inches (1.22 m) long on the hinged side shall have a two point or a 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 captive screws as a fastening means.

Exception: If applicable, the fastening means may be as noted in the Exception to 9.6.1.

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

9.6.5 With regard to 9.6.4, a captive screw or other fastening that is readily grasped is considered an "equivalent means."

10 Dead Front Construction

10.1 The enclosure of a unit substation shall be such that no uninsulated live part will be exposed from the front to contact by the operator during intended operation. There shall be no unnecessary opening in the enclosure. Openings around a circuit breaker and for a switch unit shall not be larger than required to allow practical fabrication and assembly.

Exception: The requirement does not apply to the renewal of fuses.

10.2 An opening may be provided for a close-fitting operating handle if the opening, with the handle in any operating position, is such that the clearance between the edge of the opening and the handle does not exceed 3/32 inch (2.4 mm) on either side (one side only) and 1/8 inch (3.2 mm) total (both sides). The clearance is to be measured with the handle in the intended on and off positions and with the handle and its supporting member assembled in any position that will result from ordinary factory assembly.

10.3 A dead front shield of sheet steel shall have a thickness not less than 0.032 inch (0.81 mm) if uncoated and not less than 0.034 inch (0.86 mm) if galvanized, and shall be supported independent of support provided by units that will be installed in the field.

10.4 A component that requires renewal, replacement, adjustment, or the like under the intended conditions of use shall be accessible without the exposure of any live part or wiring.

10.5 A fuse and fuseholder, including a pull out switch, shall be located behind a hinged, sliding, or similarly attached door having the fastening required in 9.6.1.

Exception: Removal of a cover or a dead front to replace a fuse in a fused circuit breaker is acceptable and the integral cover in a circuit breaker over the fuse may be exposed through an opening in the unit substation cover.

11 Filler Plates

11.1 Filler plates shall be factory installed in positions in a unit substation where circuit breakers, fuseholders, or the like may be installed in the field.

11.2 Filler plates intended to be installed in a unit substation shall comply with the applicable requirements for filler plates in the Standard for Panelboards, UL 67.

12 Wiring Space

12.1 General

12.1.1 There shall be space within the enclosure of a unit substation for the installation of those wires and cables likely to be employed in connecting the mains and branch circuits, including feed through conductors that may continue to another section.

12.1.2 The adequacy of a wiring space shall be evaluated using:

a) The size, type, and conductor material of a wire used at a terminal in accordance with Table 15.1 and 16.11 – 16.14 and

b) The full complement of branch circuit devices that will result in a need for the most available space.

If a terminal is for use with two or more combinations of conductors in multiple, each of which would be appropriate for that terminal in accordance with 16.11 – 16.14, the combination necessitating the largest wiring space shall be used, unless there is a marking in accordance with 40.12.12. If a terminal is provided for conductors in multiple, the size of each conductor shall be based on the use of multiple conduits.

Exception: With regard to (a), for ampacities of 110 amperes or less the size shall be based on 60°C (140°F) insulated conductors although the marking specifies 75°C (167°F) wire.

12.2 Wire bending space

12.2.1 Wire bending space for field-installed wires shall be provided opposite any wire connector and also opposite any opening or knockout for a conduit or wireway as specified in 12.2.2 or 12.2.3.

12.2.2 If a conductor is likely to enter or leave the enclosure surface or open bottom opposite its wire connector, the wire bending space shall be as specified in Table 12.1. A wire is considered likely to enter or leave a top, back, or side surface if there is an opening or knockout for a wireway or conduit.

Exception: The wire bending space may be in accordance with Table 12.2 if a barrier is provided between the connector and the opening or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector.

12.2.3 If a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.2.

12.2.4 If there is no barrier between two sections of a group, up to 1/3 of the required wire bending space may be in the adjacent section.

12.2.5 If a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance is to be measured from the end of the barrier.

Table 12.1
Minimum wire-bending space at terminals in inches

Wire size AWG or kcmil	Wires per terminal (pole)[a]							
	1		2		3		4 or more	
14 – 10	Not specified		–		–		–	
8	1-1/2		–		–		–	
6	2		–		–		–	
4	3		–		–		–	
3	3		–		–		–	
2	3-1/2		–		–		–	
1	4-1/2		–		–		–	
1/0	5-1/2		5-1/2		7		–	
2/0	6		6		7-1/2		–	
3/0	6-1/2	(1/2)	6-1/2	(1/2)	8		–	
4/0	7	(1)	7-1/2	(1-1/2)	8-1/2	(1/2)	–	
250	8-1/2	(2)	8-1/2	(2)	9	(1)	10	
300	10	(3)	10	(2)	11	(1)	12	
350	12	(3)	12	(3)	13	(3)	14	(2)
400	13	(3)	13	(3)	14	(3)	15	(3)
500	14	(3)	14	(3)	15	(3)	16	(3)
600	15	(3)	16	(3)	18	(3)	19	(3)
700	16	(3)	18	(3)	20	(3)	22	(3)
750	17	(3)	19	(3)	22	(3)	24	(3)
800	18		20		22		24	
900	19		22		24		24	
1000	20				–		–	
1250	22		–		–		–	
1500	24		–		–		–	
1750	24		–		–		–	
2000	24		–		–		–	

[a]Wire-bending space may be reduced by the number of inches shown in parentheses under the following conditions.

1) Only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal), and

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

For SI units one inch = 25.4 mm

Table 12.2
Minimum width of gutter and wire-bending space

Size of wire		Wire per terminal (pole)									
		1		2		3		4		5	
AWG or kcmil	(mm^2)	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
14 – 10 AWG	2.1 – 5.3	Not specified		–	–	–	–	–	–	–	–
8 – 6	8.4 – 13.3	1 1/2	38.1	–	–	–	–	–	–	–	–
4 – 3	21.1 – 26.7	2	50.8	–	–	–	–	–	–	–	–
2	33.6	2 1/2	63.5	–	–	–	–	–	–	–	–
1	42.4	3	76.2	–	–	–	–	–	–	–	–
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 kcmil	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	12	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 – 1013	12	305	–	–	–	–	–	–	–	–

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

12.2.6 The distance specified in 12.2.1 – 12.2.3 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. If the connectors for a circuit are fixed in position – for example, by the walls of a recess – so that they are turned toward each other, the distance is to be measured at the wire opening nearest to the wall in a direction perpendicular to the wall.

12.2.7 A wiring space in which one or more knockouts are provided shall be of adequate width to accommodate (with regard to bending) conductors of the maximum size likely to be used at that knockout. The values of the minimum acceptable width of a wiring space, with respect to conductors entering a knockout, are the same as the values of minimum acceptable bending space given in Table 12.2. In the determination of the available width of a wiring gutter, no credit is given for the space within or immediately above a terminal compartment intended for an ungrounded conductor.

Exception: The wiring space may be of less width if:

a) Knockouts of sufficient size are provided elsewhere;

b) The wiring space at such other point or points is of adequate width to accommodate the conductors in question; and

c) The knockout or knockouts at such other points can be conveniently used in the intended wiring of the device.

12.2.8 A terminal compartment is considered to be a space into which wires will normally be brought only for connection to terminals in that space.

12.3 Clear wiring space

12.3.1 The clear wiring space, independent of any projection, obstruction, or interference from a moving part of a switching mechanism shall be:

a) Not smaller in width or in depth than the values indicated in Table 12.3.

b) Fully sized for the wiring of the device, and shall not be smaller in total area than 250 percent of the total cross-sectional area of the maximum number of wires that may be used in such space.

12.3.2 In determining if a wiring space complies with the requirement in 12.3.1, consideration is to be given to the actual size of wires that will be used in that space; but it is to be assumed that wires smaller than 12 AWG (3.3 mm^2) will not be used. In computing the area of a wiring space, consideration is to be given to all the available space that may be used for the placement of wires. Minimum areas of the more common multiple wire connections are given in Table 12.3. The area occupied by a terminal compartment, as well as the area above such a compartment, is not included when wiring space is determined; but space above or around an individual terminal or neutral located in a gutter is considered to be available space.

12.3.3 An 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 its operation.

12.3.4 Wiring space and other compartments intended to enclose wire shall be smooth and free from any sharp edge, burr, fin, or the like, that might damage the conductor insulation.

12.3.5 No uninsulated live part shall be located within a wiring space for field-installed conductors if there can be more than 8 conductors, excluding main feeders, and if one or more of these conductors can be of a polarity opposite to that of the uninsulated live part.

12.3.6 To determine if a unit substation complies with the requirement in 12.3.5, consideration is to be given to the probable ways in which it may be wired, considering the number, size, and relative location of knockouts and terminals.

12.3.7 A neutral bus or terminal strip with its line connections is a live part. It is considered as being in the wiring compartment unless covered or located so that circuit wires other than those connected to it will not be brought into contact with it.

12.3.8 An individual terminal is not considered as being in a wiring compartment if it is countersunk between closely fitting walls to such a depth that, when wired with a conductor of the size corresponding to the rating of the terminal, the top of the terminal will not be in contact with a straightedge placed across the walls. More than one terminal in the same recess will not be acceptable generally unless additional protection is provided.

Table 12.3
Wire space

Maximum size of wire or cable involved		Minimum width and depth of wiring space		Minimum areas required for multiple wires based on a factor of 2.5											
				2 wires		3 wires		4 wires		5 wires		6 wires		7 wires	
AWG or kcmil	(mm^2)	in^2	(mm^2)	in^2	(cm^2)	in^2	(cm^2)	in^2	(cm^2)	in^2	(cm^2)	in^2	(cm^2)	in^2	(cm^2)
12 AWG	3.3	3/8	9.5	0.14	0.9	0.21	1.4	0.28	1.8	0.35	2.3	0.42	2.7	0.49	3.2
10	5.3	3/8	9.5	0.23	1.5	0.34	2.2	0.46	3.0	0.57	3.7	0.68	4.4	0.80	5.2
8	8.4	1/2	12.7	0.43	2.8	0.64	4.1	0.85	5.5	1.07	6.9	1.28	8.3	1.50	9.7
6	13.3	5/8	15.9	0.62	4.0	0.93	6.0	1.24	8.0	1.55	10.0	1.86	12.0	2.17	14.0
4	21.2	3/4	19.1	0.80	5.2	1.20	7.7	1.60	10.3	2.00	12.9	2.40	15.5	2.80	18.1
3	26.7	3/4	19.1	0.91	5.9	1.36	8.8	1.82	11.7	2.27	14.6	2.72	17.6	3.18	20.5
2	33.6	7/8	22.2	1.03	6.6	1.55	10.0	2.06	13.3	2.58	16.6	3.10	20.0	3.61	23.3
1	42.4	1	25.4	1.36	8.8	2.04	13.2	2.72	17.6	3.40	21.9	4.08	26.3	4.76	30.7
1/0	53.5	1	25.4	1.55	10.0	2.33	15.0	3.10	20.0	3.88	25.0	4.66	30.1	5.43	35.0
2/0	67.4	1	25.4	1.79	11.5	2.68	17.3	3.58	23.1	4.47	28.8	5.36	34.6	6.26	40.4
3/0	85.0	1-1/8	28.6	2.08	13.4	3.11	20.1	4.16	26.8	5.19	33.5	6.22	40.1	7.27	46.9
4/0	107.2	1-1/4	31.8	2.42	15.6	3.63	23.4	4.84	31.2	6.05	39.0	7.26	46.8	8.47	54.6
250 kcmil	127	1-3/8	34.9	2.96	19.1	4.44	28.6	5.92	38.2	7.40	47.7	8.88	57.3	10.36	66.8
300	152	1-1/2	38.1	3.42	22.1	5.13	33.1	6.84	44.1	5.88	55.2	10.26	66.2	11.96	77.2
350	177	1-1/2	38.1	3.81	24.6	5.72	36.9	7.62	49.2	9.53	61.5	11.44	73.8	13.34	86.1
400	203	1-5/8	41.3	4.18	27.0	6.27	40.4	8.36	53.9	10.45	67.4	12.54	80.9	14.63	94.4
500	253	1-3/4	44.5	4.92	31.7	7.38	47.6	9.84	63.5	12.30	79.4	14.76	95.2	17.22	111.1
600	304	1-7/8	47.6	5.97	38.5	8.96	57.8	11.94	77.0	14.93	96.3	17.92	115.6	20.90	134.8
700	355	2	50.8	6.68	43.1	10.02	64.6	13.36	86.2	16.70	107.7	20.04	129.3	23.38	150.8
750	380	2	50.8	7.04	45.4	10.56	68.1	14.08	90.8	17.60	113.5	21.12	136.3	24.64	159.0
800	405	2-1/8	54.0	7.39	47.7	11.09	71.6	14.78	95.4	18.48	119.2	22.18	143.1	25.87	166.9
900	456	2-1/4	57.2	8.09	52.2	12.13	78.3	16.18	104.4	20.22	130.4	24.26	156.5	28.31	182.6
1000	506	2-1/4	57.2	8.77	56.6	13.15	84.8	17.54	113.2	21.92	141.4	26.30	169.7	30.69	198.0
1250	633	2-1/2	63.5	11.03	71.2	16.55	106.8	22.06	142.3	27.58	177.9	33.10	213.6	38.61	249.1
1500	760	2-3/4	69.8	12.74	82.2	19.11	123.3	25.48	164.4	31.85	205.5	38.22	246.6	44.59	287.7
1750	887	2-7/8	73.0	14.45	93.2	21.67	139.8	28.90	186.4	36.12	233.0	43.34	279.6	50.57	326.3
2000	1013	3-1/8	79.4	16.04	103.5	24.06	155.2	32.08	207.0	40.10	258.7	48.12	310.4	56.14	362.2

12.4 Restricting barriers

12.4.1 A sheet steel barrier shall not be less than 0.053 inch (1.35 mm) thick if uncoated and not less than 0.056 inch (1.42 mm) thick if galvanized.

Exception No. 1: A dead-front shield may have a thickness as specified in 10.3.

Exception No. 2: A metal barrier may be of steel of less thickness when its strength and rigidity are not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness.

12.4.2 A nonmetallic barrier shall be not less than 1/4 inch (6.4 mm) thick and shall be supported to provide strength and rigidity.

Exception: The thickness of a nonmetallic barrier may be less than 1/4 inch if the barrier is located so that it will not be subject to mechanical abuse during installation and is so located and supported that it will provide physical strength and rigidity.

12.4.3 An opening in a metal barrier through which a factory installed wire or cable passes, or through which a field-installed wire can pass, shall be provided with a bushing or shall be formed so that there will be no sharp edge with which insulated conductors may come in contact.

12.5 Bushings

12.5.1 A bushing employed at the opening specified in 12.4.3 may be of glass, porcelain, hard fiber, phenolic composition, or cold molded composition. A metal eyelet or grommet having a smooth rounded surface on which the wire or cable can bear is acceptable in place of a bushing. A bushing of rubber, neoprene, or hot molded shellac and tar composition is not acceptable.

12.5.2 The bushing may be of material other than those enumerated in 12.5.1 if it has been investigated and found to be equivalent to those specified.

12.6 Screw and rivet heads

12.6.1 In a unit substation employing insulating material as a covering or protection for an uninsulated live part, the head of a screw or rivet that engages the mounting strap of a switch, or that may become live through malfunction of the switch, shall be so located or protected by counter-sinking or the equivalent that it will not be exposed to unintentional contact from the front of the device.

13 Insulating Materials

13.1 An insulating material used for direct or indirect support of uninsulated live parts shall have a Performance Level Category (PLC) that does not exceed the value specified in Table 13.1 for direct support or Table Table 13.2 for indirect support of live parts as covered in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: A material may be accepted based on end-product testing as covered in UL 746C.

Table 13.1
Maximum performance level category (PLC) for direct support insulating material

Test specified	Flammability rating of material		
	V-0	V-1	V-2
Comparative Tracking Index Under Moist Conditions (CTI)[a]	3[b]	3[b]	3[b]
High Current Arc Resistance to Ignition (HAI)[a]	3	2	2
Hot Wire Ignition (HWI)[a]	4	3	2

[a] Requirements for the test are specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.
[b] A material having a comparative tracking index PLC of 4 may be used if the voltage is 250 volts or less.

Table 13.2
Maximum performance level category (PLC) for indirect support insulating material

Test specified	Flammability rating of material			
	V-0	V-1	V-2	HB
High Current Arc Resistance to Ignition (HAI)[a]	3	2	2	1
NOTE – If the material is located near an uninsulated live part within the through air or over surface minimum spacing specified in Spacings, Section 21, the material shall comply with Table 13.1. [a] Requirements for the test are specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.				

14 Coil Insulation

14.1 The voltage and temperature rating of the coil insulation system shall be rated for the operating conditions to which the system will be subjected. The coil insulating system for a Class B or higher temperature system shall comply with the Standard for Systems of Insulating Materials – General, UL 1446, for the temperature rating involved.

15 Current-Carrying Parts

15.1 General

15.1.1 A current carrying part shall be of silver, copper, aluminum, alloys of these metals, or the equivalent, and shall be of rigid construction.

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

15.2 Plating

15.2.1 A plated steel screw, nut, and stud may be used to secure a soldering lug, pressure wire connector, or bus bar. A No. 10 and larger plated steel wire binding screw may be used at a terminal, in connection with a nonferrous terminal plate. A bolt, washer, and nut at the hinge of a knife switch are considered to be parts that are not depended upon to carry current.

15.2.2 Copper and brass are not acceptable for plating wire binding screws, nuts, and stud terminals, but a plating of cadmium, zinc, tin, silver, or the like, is acceptable.

15.2.3 Each bus bar shall be plated at each joint with tin, silver, nickel, or cadmium.

Exception No. 1: A welded or brazed joint is not required to be plated.

Exception No. 2: Copper bus bars are not required to be plated if the current at the joint is 600 amperes or less.

15.3 Bus bars

15.3.1 The bending of a bus bar shall not result in visible cracks, but roughening or slight surface crazing is acceptable.

15.3.2 The phase arrangement of the primary or secondary bus bars of a secondary panelboard in a 3-phase unit substation shall be A, B, C from front to back, top to bottom, and left to right, respectively, as viewed from the front of the unit substation.

Exception: The phase arrangement in a 240-volt, 3-phase, 3-wire unit substation intended for use on a grounded B phase system is A, C with the neutral as the B phase.

15.3.3 The flat washer covered in 15.3.4 shall have a thickness of at least 1/6 that of the diameter of the rivet shank or bolt and shall have an outer diameter at least 150 percent of the rivet shank or bolt and not less than the outer diameter of the spring washer.

15.3.4 A spring washer shall be used at one end of a bolt securing current carrying parts together.

Exception No. 1: Other constructions as described in 15.3.6 may be acceptable.

Exception No. 2: A spring washer may be replaced with a split ring lock washer and flat washer as described in 15.3.3 if each aluminum bus in the joint has a tensile yield strength of at least 20,000 psi (138 MPa).

Exception No. 3: A flat washer, as described in 15.3.3, may be used in place of a spring washer if the joint does not include any aluminum or if aluminum bolts are used with aluminum bus bars.

15.3.5 A spring washer as specified in 15.3.4 is a dished washer of stainless, or hardened and tempered steel, having an outer diameter not less than 150 percent of the bolt diameter, a thickness not less than 1/8 of the bolt diameter and dished not less than 3-1/2 percent of the bolt diameter.

15.3.6 A construction other than described in 15.3.3 and 15.3.4 may be accepted if it is investigated in accordance with the applicable requirements in the Standard for Panelboards, UL 67.

15.3.7 Unless investigated for such use, a bolted connection between two bus bars or between a bus bar and another current carrying part shall not depend on any polymeric insulation to maintain the clamping force and shall not depend on thermoplastic material in any case.

Exception: The requirement does not apply to a joint rated 100 amperes or less or to a meter socket base.

15.3.8 A bolted joint in a bus bar shall be accessible for tightening without removing insulating tape.

15.3.9 Spring loaded connections to bus bars, such as at plug-in circuit breakers and switches shall be investigated in accordance with the applicable requirements in the Standard for Panelboards, UL 67.

15.3.10 Bolts, nuts, and washers shall be provided for connecting through bus to other sections. The length of the bolts shall be such that spacings in accordance with Table 21.1 are maintained.

15.3.11 If brass is used in place of copper for a bus bar or connecting strap, consideration should be given to the fact that the resistance of brass is from 2 to 4 times that of copper.

15.3.12 A current carrying part shall have adequate metal for stiffness and for preventing a temperature rise beyond the limits given in Table 25.1.

15.3.13 In a 3-phase, 4-wire, or a single phase, 3-wire construction, the neutral shall not be smaller than the size required for the main bus bars unless its ampacity (based on a heating test) is at least 200 amperes and is clearly marked on the nameplate.

15.3.14 The ampacity of a bus bar as described in 15.3.12 and 15.3.13 shall not be less than its marked rating as covered in 40.4.3 – 40.4.5 and not be less than required in 15.3.15 – 15.3.17.

15.3.15 A wire or bus bar leading to a fuseholder shall have an ampacity not less than the rating of the largest fuse the fuseholder will accommodate.

Exception: The ampacity may be less as covered in 40.4.3.

15.3.16 A wire or bus bar leading to a noninterchangeable trip circuit breaker shall have an ampacity not less than the current rating of the breaker.

15.3.17 A wire or bus bar leading to a circuit breaker frame designed for use with interchangeable trip units shall have an ampacity not less than the maximum current rating of the frame.

Exception: The ampacity may be less as covered in 40.4.3.

15.3.18 A bus bar shall either be supported independently of any unit to which it is connected (switch, circuit breaker, or the like), or shall be supported by units that are factory installed and that do not depend on the bus bar for support.

15.3.19 A unit substation shall provide the means of support for branch bus bars that can be mounted in the field. A barrier that is provided shall be an integral part of the unit substation unless the barrier is furnished as an integral part of the branch circuit bus bar, or is integral with a member necessary for mounting the branch circuit switch or circuit breaker. A base for supporting a bus bar shall be assembled in place in the unit substation before it is shipped from the factory.

Exception: A barrier need not be provided at each end of a two way branch circuit bus bar intended for field installation (a bus bar to each end of which a circuit breaker may be connected). A barrier at one end only is considered acceptable.

15.3.20 A bus bar or uninsulated live part, other than a pressure wire connector as specified in the Exception to 21.1.12, shall be secured so that ordinary vibration will not loosen the securing means, and shall be prevented from turning or shifting in position if any spacings less than half of those shown in Table 21.1 would result from such turning or shifting. A bus bar provided with one or more insulators that must be removed when a unit is installed shall be prevented from any turning that would result in spacings less than half those specified in Table 21.1 with all insulators in place, or that would result in spacings less than 1/8 inch (3.2 mm) for any voltage up to 250 volts, or 1/4 inch (6.4 mm) for any voltage of 251 to 600 volts, with any insulators omitted.

15.3.21 Friction between surfaces is not acceptable as a means to prevent turning or shifting of an uninsulated live part. Turning or shifting may be prevented by the use of two screws or rivets; by noncircular shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method. No reliance is to be placed on a single branch circuit fuseholder, circuit breaker, or switch unit for preventing turning of the branch bus feeding such unit, if such turning would reduce spacings to less than those specified in Table 21.1 or 15.3.20.

15.3.22 In determining the adequacy of means to prevent turning or shifting, any screw or nut is to be loosened and re-tightened fingertight without a tool. The bus is then to be pushed to the extent limited by the screws or other means and the resulting spacings checked.

15.3.23 If a branch circuit unit (circuit breaker, switch, or plug fuseholder) rated 600 amperes or less is removable from the front of the panel, the replacement or removal of such unit shall not result in the likelihood of a short circuit from turning or dropping of parts.

15.3.24 A bolt, nut, or washer used in securing a branch circuit unit is not considered likely to fall if they are visible and readily reached. A branch bus will usually be considered likely to fall if the same bolts that

secure the branch circuit unit to the branch bus also serve to secure the branch bus to the bus on its line side.

15.4 Wiring

15.4.1 With regard to Table 15.1 an insulated conductor provided as part of a unit substation shall be rated for the particular application and shall have an ampacity not less than the maximum current rating of the circuit in which it is connected. Insulated wire shall be a type that has been investigated and found acceptable. Type V wire, if used, shall be marked flame retardant on the tag or reel.

15.4.2 A wire within an enclosure, compartment raceway, or the like shall be located or guarded to reduce the risk of contact with any sharp edge, burr, fin, moving part, or the like, that can damage the conductor insulation.

15.4.3 The installation or bending of a factory-installed conductor shall not result in cracking or other damage to the conductor.

15.4.4 Wire types restricted to dry locations are not rated for use in a rainproof unit substation. Factory installed wires in a rainproof unit substation shall be of a type rated for at least 75° C (167° F) if a temperature test is conducted using dummy fuses.

15.4.5 Means shall be provided to space field wiring or factory installed wiring at least 3 inches (76.2 mm) away from a power transformer, ballast, heating element, or an unenclosed arcing part such as switch contacts that are not provided with arc chutes.

Exception No. 1: Wiring going directly to the terminals of the transformer, ballast, or heating element may be within 3 inches of such unit.

Exception No. 2: If the wire or insulating tubing secured over the wire is rated for at least 90°C (194°F), the wire or tubing may be in contact with the enclosure of such units. This does not apply to an open core and coil transformer. Wires may be spaced closer than specified above if the results of a temperature test show such spacing to be acceptable.

15.4.6 When the conductors of an alternating-current circuit pass through a wall or partition of metal having magnetic properties, all the phase conductors of the circuit, including, when applicable, the neutral and equipment grounding conductors, shall be routed through the same opening, except as specified in 15.4.7.

Table 15.1
Ampacity of insulated conductors

Wire size,		60°C (140°F)[a]		75°C (167°F)[b] and 90°C (194°F)[a,b]	
AWG or kcmil	(mm)^2	Copper	Aluminum	Copper	Aluminum
14	2.1	15	–	15	–
12	3.3	20	15	20	15
10	5.3	30	25	30	25
8	8.4	40	30	50[c]	40[c]
6	13.3	55	40	65[c]	50[c]
4	21.2	70	55	85[c]	65[c]
3	26.7	85	65	100[c]	75[c]

Table 15.1 Continued on Next Page

Table 15.1 Continued

Wire size,		60°C (140°F)[a]		75°C (167°F)[b] and 90°C (194°F)[a,b]	
AWG or kcmil	(mm)^2	Copper	Aluminum	Copper	Aluminum
2	33.6	95	75	115[c]	90[c]
1	42.4	110	85	130[c]	100[c]
1/0[d]	53.5[d]	e	e	150	120
2/0[d]	67.4[d]	e	e	175	135
3/0[d]	85.0[d]	e	e	200	155
4/0[d]	107.2[d]	e	e	230	180
kcmil					
250[d]	127[d]	e	e	255	205
300[d]	152[d]	e	e	285	230
350[d]	177[d]	e	e	310	250
400[d]	203[d]	e	e	335	270
500[d]	253[d]	e	e	380	310
600[d]	304[d]	e	e	420	340
700[d]	355[d]	e	e	460	375
750[d]	380[d]	e	e	475	385
800[d]	405[d]	e	e	490	395
900[d]	456[d]	e	e	520	425
1000	506	e	e	545	445
1250	633	e	e	590	485
1500	760	e	e	625	520
1750	887	e	e	650	545
2000	1013	e	e	665	560

NOTES

1) For internal wiring, ampacities larger than those specified in Table 15.1 may be permitted on the basis of a temperature test.

2) These values of ampacity apply only where a maximum of three current-carrying conductors will be field installed in a single conduit.

[a] The numbers 60°C (140°F), 75°C (167°F), and 90°C (194°F) indicate the wire temperature rating.

[b] The ampacity of 90°C (194°F) wire shall be considered to be the same as 75°C (167°F) wire.

[c] The ampacity of these sizes shall be considered to be the same as for 60°C (140°F) wire when connected to molded case circuit breakers unless the breaker is marked 75°C.

[d] For a multiple conductor connector at a terminal, the ampacity value is to be multiplied by the number of conductors that the terminal will accommodate [1/0 AWG (53.5 mm^2) and larger].

[e] For wire sizes 1/0 AWG (53.5 mm^2) and larger, it is assumed that wire with at least a 75°C (167°F) temperature rating will be used.

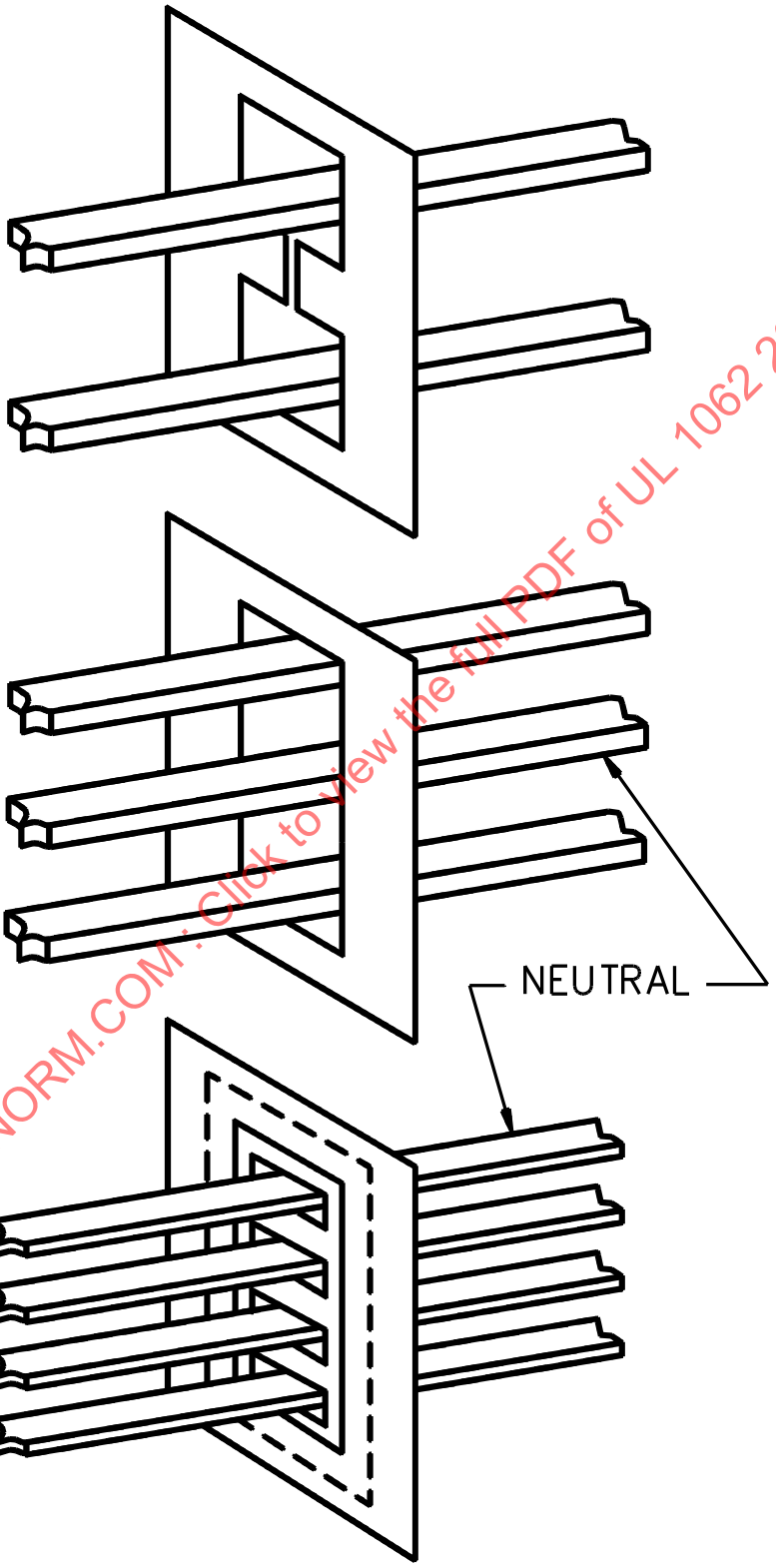
15.4.7 With regard to the requirement in 15.4.6 and to Figure 15.1, the conductors may pass through individual openings in a wall or partition if the openings are connected by slots cut in the metal wall. The conductors may be run through individual openings in an insulating block used to cover an opening in the metal wall sufficiently large for all the conductors of the circuit if no metal bracket, brace, or the like, is placed across the insulating material between the conductors.

15.4.8 Conductors in sizes 1/0 AWG (53.5 mm^2) and larger may be run in multiple provided the arrangement is such as to provide equal division of total current among all conductors involved. All of the multiple conductors shall be of the same length, same conductor material, circular-mil area, same insulation type, and terminated in the same manner; that is, if mechanical setscrew connectors are used, all connectors in the arrangement shall be of the mechanical setscrew type. If run in separate raceways or cables, the raceways, or cables shall have the same physical characteristics.

15.4.9 Aluminum wire, insulated or uninsulated, used for internal wiring interconnections between current carrying parts shall be terminated at each end by a method rated for the combination of metals involved at the connection point.

Figure 15.1

Conductors through openings



16 Wiring Terminals

16.1 A terminal (pressure wire connector or wire binding screw) shall be provided for connection of each conductor intended to be installed in the unit substation in the field.

Exception: Terminals are not required to be provided as covered in 16.2.

16.2 Pressure terminal connectors for field connection (line or load) need not be provided if the following conditions are met:

a) Component terminal assemblies are available from the unit substation manufacturer, or one or more pressure terminal connectors shall be specified for field installation on the unit substation.

b) Fastening devices such as studs, nuts, bolts, spring and flat washers, or the like, as required for an effective installation are either provided as part of the component terminal assembly, or mounted on or separately packaged with the unit substation.

c) The installation of the terminal assembly does not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector are to be readily accessible for tightening before and after installation of conductors.

d) If the pressure terminal connector provided in a component terminal assembly requires the use of a special tool for securing the conductor, any necessary instructions are to be included in the component assembly package or with the unit substation.

e) Installation of the pressure terminal connectors in the intended manner results in a product meeting the requirements of the standard.

f) The unit substation is marked in accordance with 40.12.13.

16.3 Wire binding screws or studs and nuts are acceptable for securing a 10 AWG (5.3 mm^2) or smaller conductor only.

16.4 A pressure wire connector intended for use with aluminum wire shall be a Type AL9, AL9CU, or CU9AL as covered in the Standard for Wire Connectors, UL 486A-486B, if the temperature rise exceeds 50°C (90°F) as covered in 5, 6, and 7 of Table 25.1.

16.5 A pressure wire connector provided with or specified for use with a unit substation shall comply with the Standard for Wire Connectors, UL 486A-486B.

16.6 The tightening torque for a field-wiring terminal shall be as specified by the unit substation manufacturer and shall be marked as required in 40.12.16. The specified tightening torque shall not be more than 100 percent nor less than 90 percent of the value employed in the static heating test as specified in the Standard for Wire Connectors, UL 486A-486B, for that wire size corresponding to the ampere rating of the unit substation.

Exception: The torque value may be less than 90 percent if the connector is investigated in accordance with the lesser assigned torque value in accordance with UL 486A-486B.

16.7 A wire connector intended for field wiring shall be tested as covered in the Strength Test of Insulating Base and Support, Section 33.

16.8 Markings in accordance with 40.12.1 – 40.12.25 and 40.13.1 – 40.14.1 shall be provided for a wire connector intended for connection of wire in the field.

16.9 A pressure wire connector shall be secured so as to prevent loose contact of conducting parts and also to maintain spacings as covered in 21.1.12.

16.10 If the point of attachment of a pressure terminal connector or wire binding screw or the bus to which it is secured overhangs its support, the design shall be strong enough to prevent more than 1/4 inch (6.4 mm) deflection with a force of 50 pounds (222 N) applied in any manner to the terminal. The deflection while the force is applied shall not reduce spacings to less than those required in Table 21.1 or Table 21.2 as applicable.

16.11 A main terminal shall be capable of securing the smallest conductor (or group of conductors in multiple) of standard AWG size having an ampacity adequate for the supply rating of the primary circuit overcurrent protection provided, as covered in 19.1 or as specified in the marking covered in 40.6.1.

Exception: The maximum size conductor for which the terminal is rated need not have an ampacity exceeding the primary overcurrent protection that is provided or as marked in accordance with 40.6.1.

16.12 A terminal for a branch circuit conductor shall be capable of securing the smallest conductor (or group of conductors in multiple) of standard AWG size having an ampacity rated for the application, as determined from the considerations set forth in 16.13 and 16.14.

16.13 With regard to 16.12, it is assumed that the ampacity of a wire or wires to be connected in the field to a terminal of:

a) A fuseholder is any value within the range of current ratings of fuses that the fuseholder will accommodate, unless the maximum permissible fuse size is marked in accordance with 15.3.15 and 40.4.3.

b) A circuit breaker capable of accommodating interchangeable trip units of different current ratings is:

1) Acceptable for the rating of the installed trip unit, or

2) The marked permissible rating in accordance with 40.4.3.

c) A circuit breaker not capable of accommodating interchangeable trip units of different ratings is acceptable for the current rating of the breaker.

16.14 With regard to 16.12 and Table 15.1, the size and type of a field-installed conductor shall be determined as follows:

a) For currents as indicated in Table 15.1:

1) Wire rated at 75°C (167°F) will be used for 1/0 AWG (53.5 mm^2) and larger sizes.

2) Wire rated at 60°C (140°F) will be used for the 1 AWG (42.4 mm^2).

Exception: Wire rated at 75°C may be used for 1 AWG when the unit substation is marked as covered in Exception No. 2 to 40.12.24.

3) Wire rated at 60°C will be used for 2 AWG (33.6 mm^2) and smaller sizes.

Exception: Wire rated at 75°C may be used for 2 AWG and smaller sizes when the unit substation is tested as covered in the Exception to 25.1.7, and marked as covered in Exception No. 1 to 40.12.24.

b) It is assumed that aluminum wire will be used at any terminal identified on a wiring diagram or the like as covered in 40.12.1 – 40.12.10 as being rated for use with such wire, whether or not that terminal is also identified as being rated for use with copper wire.

16.15 The requirements in 16.11 and 16.12 do not preclude use of a connector that will also accommodate a wire (or wires) of a size (or sizes) different from that specified in those paragraphs.

16.16 A wiring terminal shall hold the next larger size conductor than that required in 16.11 – 16.14 if the terminal will properly receive the larger size conductor, unless the unit substation is marked to restrict its use to the smaller size conductor.

16.17 The word "hold" in 16.16 refers to the ability of the connector to secure the wire properly during the secureness and pull out tests. It is not intended that heating or heat cycling tests be required.

16.18 A multiconductor connector provided at a wiring terminal shall be capable of securing all conductors in the intended manner. In determining the number and size of conductors, it is assumed that parallel conductors will not be smaller than 1/0 AWG (53.5 mm^2).

16.19 A wire binding screw or stud of a wiring terminal shall not be smaller than No. 10, with no more than 32 threads per inch. The terminal shall be provided with upturned lugs, a cupped washer, or the equivalent, capable of retaining a 14 AWG (2.1 mm^2) solid conductor even though the screw or nut becomes slightly loose.

Exception: A No. 8 machine screw having not more than 32 threads per inch may be used at a terminal intended only for the connection of a 14 AWG conductor.

16.20 A wire binding screw terminal design is one in which the conductor is intended to encircle the terminal screw at least 3/4 of the distance without overlapping.

16.21 A wire binding screw shall thread into metal.

16.22 A terminal plate tapped for a wire binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick. There shall be two or more full threads in the metal, which may be extruded if necessary to provide the threads.

16.23 A terminal of a switch or circuit breaker shall be connected directly to a bus bar by means of a screw, stud, and nut, or an equivalent fastening means that has an ampacity rated for the current carrying parts.

16.24 If its terminal is not directly connected by a screw threaded into the bus bar, a circuit breaker or switch shall be secured independently of its terminal connection.

16.25 The number of individual branch circuit neutral terminals shall not be less than 75 percent of the total branch circuits provided in the unit substation.

16.26 A wiring terminal shall be located so that:

a) It is accessible for examination and

b) Connections may be tightened or branch circuit wires removed without loosening any screw that secures a bus bar, switch, circuit breaker, fuseholder, or the like.

With regard to (a), a construction is acceptable even though it may be necessary to remove a circuit breaker cover, the trim, or the like, to make a connection accessible. Using available tools, it shall be

possible to retighten the conductor securing means of a wire connector without removal of the connector from the terminal plate or bus, or without removal of any conductor from the connector.

16.27 A load terminal, including a neutral load terminal and connection to the ground bus or a load equipment grounding conductor, shall be located so that:

a) There is no need to reach across or beyond an uninsulated ungrounded bus in order to make a load connection and

b) A tool 10 inches (254 mm) long or less used to tighten a load connection does not contact a live part that, as viewed from the front of the unit, is not an obviously live part. This shall be determined with branch units connected.

16.28 If a unit substation incorporates ground fault protection, the load termination part of the neutral bus, marked in accordance with 40.9.2 shall be insulated from the enclosure and shall have no terminal or other provision for grounding or bonding.

Exception No. 1: If the ground fault protection is of the zero sequence or residual type, all neutral load terminations on the neutral bus shall be on the load side of the sensing elements but provision for grounding and bonding shall be on the line side of the sensing element.

Exception No. 2: For ground fault protection of the ground return type, grounding and bonding of the neutral shall be effected only by means of a conductor (or conductors), the current through which is detected by the sensing element.

17 Service Equipment Use

17.1 A unit substation marked for service equipment use shall be provided with both primary overcurrent protective and disconnection means for the service conductors as well as means for connecting the grounded service conductor, if one is provided, to the equipment grounding terminal as specified in the Reference Standard for Service Equipment, UL 869A.

17.2 Guarding against inadvertent contact

17.2.1 Service equipment shall be constructed such that, with the service disconnect in the off position, no ungrounded uninsulated live part is exposed to inadvertent contact by persons while servicing any field connected load terminal, including a neutral load terminal, a branch circuit equipment grounding terminal, or the neutral disconnect link.

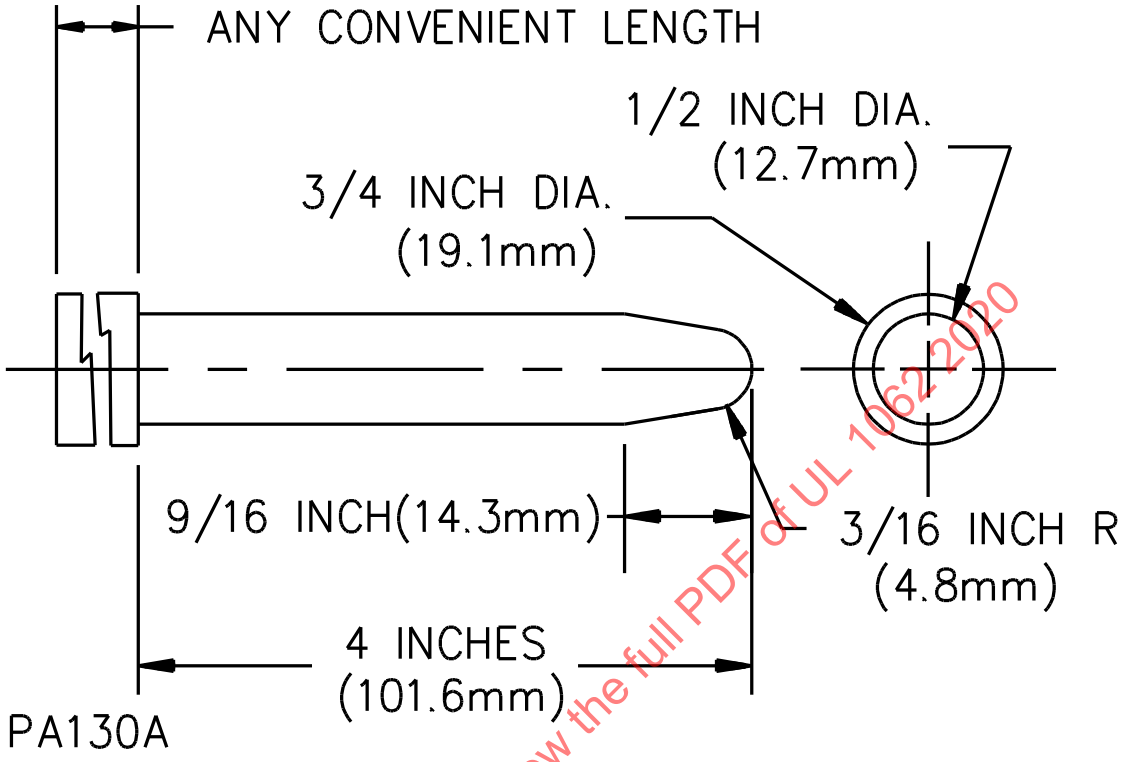
Note: In accordance with the Standard for Electrical Safety in the Workplace, NFPA 70E, an electrically safe work condition should be established prior to working on electrical equipment. Accessibility requirements do not endorse working on energized electrical equipment.

17.2.2 In a device having provision for the connection of a grounded service conductor, the disconnecting means referred to in 17.1 shall simultaneously interrupt the grounded service conductor, or other means shall be provided for disconnecting the grounded service conductor from the interior wiring of the building.

17.2.3 Exposure to inadvertent contact is determined by use of the probe illustrated in Figure 17.1. 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 16.12 through 16.14 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.

Figure 17.1

Straight Probe



18 Disconnecting Means

18.1 General

18.1.1 A unit substation marked for service equipment use shall be designed so that all ungrounded load conductors can be disconnected from the source of supply by the operation of the operating handle of a disconnecting means intended to be installed at the factory or in the field. Operation of the handle shall simultaneously disconnect all ungrounded conductors of the circuit. Markings in accordance with 40.7.1 – 40.7.3, 40.9.1 – 40.9.3, and 40.10 shall be provided.

Exception: An additional disconnecting means for the control circuit of a power operable service disconnect may be connected to the source on the line side of the service disconnect.

18.1.2 The device disconnecting means (a circuit breaker or fused switch) shall be capable of external manual operation to disconnect all ungrounded conductors under rated load conditions.

18.2 Ground fault protection

18.2.1 In a unit substation marked for service equipment use, ground fault protection of equipment shall be provided for a supply side service disconnecting means rated 1000 amperes or more in a 3-phase, wye-connected circuit of more than 150 volts to ground. The ground fault sensing and relaying equipment provided shall operate to cause the service disconnecting means to open all ungrounded conductors of the faulted circuit. The maximum setting of the ground fault protection shall be 1200 amperes. The system is assumed to be solidly grounded unless the unit substation is marked as covered in 40.9.5.

Exception No. 1: If marked in accordance with 40.9.4 (a) or (b), ground fault protection need not be provided for a source intended to supply power to a continuous industrial process system.

Exception No. 2: If marked in accordance with 40.9.6, ground fault protection need not be provided for a source intended to supply power to a fire pump, or an alternate source for an emergency or legally required standby system.

18.2.2 If ground fault protection is provided, though not required in 18.2.1, it shall comply with the requirements for the installation of ground fault protection equipment in this standard.

Exception: If the unit substation is marked in accordance with 40.9.7, the ground fault protection may initiate an audible or visual signal rather than open an alternate source for emergency or legally required standby systems.

18.2.3 A ground fault protection system that employs a sensing element that encircles the neutral conductor (if any) and all ungrounded conductors of the protected circuit (zero sequence type) shall be installed in such a manner that the sensing element is located on the load side of any grounding or bonding connections to the neutral. It may be on the line or load side of the disconnecting device for the protected circuit.

18.2.4 A ground fault protection system that combines the outputs of separate sensing elements for the neutral (if any) and each ungrounded conductor (residual type) 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 disconnecting device for the protected circuit.

18.2.5 A ground fault protection system that employs a single sensing element to detect the actual fault current (ground return type) 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 unit substation that may be made to the neutral. This will require that the neutral be insulated from noncurrent-carrying metal.

Exception: Connections to the neutral may be made as covered in 21.1.5 and 22.1.13.

18.2.6 A ground fault protection sensor shall be securely mounted to reduce the possibility of damage to it or its leads during shipment.

18.2.7 If the design 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:

a) The design shall be such to prevent closing and maintaining contact of the disconnecting device to be controlled by the ground fault sensing and relaying equipment until the reset operation is performed; or

b) Such means shall be incorporated in the disconnect device.

18.3 Neutral disconnecting means

18.3.1 In a unit substation having a neutral and intended for service equipment use, means shall be provided for disconnecting the neutral service conductor from the interior wiring. This may be incorporated in the disconnecting means referred to in 18.1.1 or may be in the form of one or more removable links. The disconnecting means shall be on the load side of the grounding electrode terminal and of the main bonding jumper.

18.3.2 The disconnect link specified in 18.3.1 shall take the form of a link, or similar conducting piece, designed to make connection between two terminals. Simple removal of bolts from a single bus bar joint is not acceptable.

18.3.3 A disconnect link shall be located, guarded, recessed, or enclosed so that unintentional contact with any uninsulated, ungrounded part on the line side of the main switch or circuit breaker will not occur while the link is being removed or replaced.

18.3.4 The disconnect link shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by the serving agency (electric utility or power company).

19 Overcurrent Protection

19.1 A unit substation shall contain transformer primary overcurrent protection rated not more than 125 percent of the transformer primary current rating.

Exception No. 1: Primary overcurrent protection rated not more than 250 percent of the primary current may be used if the unit substation is provided with a single main secondary overcurrent protective device rated not more than 125 percent of the transformer secondary current rating.

Exception No. 2: A unit substation not marked as suitable for use as service equipment, but marked for location in the circuit in accordance with the requirement in 40.6.1, is not required to contain overcurrent protection in the primary circuit.

19.2 A fuse or circuit breaker pole shall be provided for the protection of each outgoing ungrounded load conductor.

Exception: Overcurrent protection in the secondary of the transformer is not required for a single phase transformer having a 2-wire (single voltage) secondary and for a three-phase, delta-delta connected transformer having a 3-wire (single-voltage) secondary if the unit substation has primary overcurrent protection that complies with the following conditions:

a) The rating of the overcurrent protective device shall not exceed the value determined by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio and

b) The overcurrent protective device shall be rated not more than:

1) 125 percent of the transformer primary current rating when the transformer is rated 9 amps or more;

2) 167 percent of the transformer primary current rating when the transformer is rated less than 9 amps; and

3) 300 percent of the transformer primary current rating when the transformer is rated less than 2 amps.

19.3 A 2-pole circuit breaker used in a 3-phase unit substation marked for use on an end grounded delta system shall be rated 3-phase.

19.4 The primary overcurrent protection required in 19.1 may consist of a main overcurrent device (a fuse or a circuit breaker pole) in series with each ungrounded service conductor, or of not more than six overcurrent devices connected on the line side to each ungrounded service conductor that feeds separate loads.

19.5 No overcurrent device shall be placed in any permanently grounded conductor unless it simultaneously opens all conductors of the circuit.

19.6 A fuseholder shall be of the cartridge type, Type S, or Edison base plug type.

19.7 A plug fuse or fuseholder shall not be used in a circuit exceeding 125 volts between conductors.

Exception: A plug fuse or fuseholder may be used in a circuit supplied by a system having a grounded neutral and having no conductor at more than 125 volts to ground.

19.8 A cartridge fuse or fuseholder of the 300-volt type shall not be used in a circuit of more than 300 volts between conductors.

Exception: A cartridge fuse or fuseholder rated 300 volts complies with the intent of the requirement when it is used in a single-phase circuit supplied by a system having a grounded neutral and having no conductor at more than 300 volts to ground.

19.9 The screw shell of a plug type fuseholder shall be connected to the load side of the circuit.

19.10 A disconnecting means shall be provided on the supply side of each cartridge fuse.

19.11 A unit substation shall be designed and constructed so that fuses will be readily accessible, when the disconnecting means specified in 19.10 is open, so that they may be replaced without a person touching any live part.

19.12 An interchangeable circuit breaker trip unit need not be factory installed if it can be mounted in place without disassembly of any electrical connection other than terminal connectors.

19.13 An accessible means shall be provided in a unit substation so that each branch circuit can be independently de-energized. A switch, a plug fuse or other device incorporating a screw shell, and a circuit breaker are acceptable as such means.

19.14 The primary of a ground fault protection control circuit transformer may be connected on the line or load side of the main disconnect or may be connected to an external source. The primary of such a transformer shall be connected to two line voltage parts (not line and neutral). If connected to the line side of the main, or an external source, a fused disconnect switch or circuit breaker rated for use as service equipment and providing overcurrent protection shall be installed ahead of the transformer or control circuit. Overcurrent protection is not required for the control circuit if wired to the load side of the main disconnect unless the control circuit wiring leaves the unit substation or the control circuit contains a snap switch. Markings as covered in 40.9.3 or 40.10.4 shall be provided if the transformer is not connected to the load side of the main disconnect.

19.15 The control circuit of a ground fault protection system shall be connected on the line side of the main disconnect if a test or monitor panel is provided and if such connection is required for proper functioning of the panel.

19.16 The conductors of a remote control switch circuit are considered to be protected by overcurrent devices rated at not more than 300 percent of the ampacity of the conductors. It will be assumed that the control circuit conductors outside the unit substation will be 14 AWG (2.1 mm^2) minimum.

19.17 If a unit substation contains a lighting or appliance type panelboard as covered in 19.18, the panelboard shall be protected by a main overcurrent protective device not exceeding the panelboard bus ampacity. The main overcurrent protection provided in the primary circuit may serve to protect a

panelboard in the secondary circuit of a single phase transformer having a two-wire (single voltage) secondary if the protection does not exceed the value determined by multiplying the panelboard current rating by the secondary-to-primary transformer voltage ratio.

19.18 A lighting or appliance branch circuit panelboard as specified in 19.17 is one having more than 10 percent of its overcurrent devices rated 30 amperes or less, for which neutral connections are provided.

19.19 A lighting or appliance branch circuit panelboard shall not have more than 42, nor provision for more than 42, overcurrent protective devices other than those in the mains.

19.20 The minimum ampere rating of a lighting or appliance panelboard shall be as covered in the Standard for Panelboards, UL 67.

19.21 A lighting or appliance panelboard shall comply with the requirements for a Class CTL panelboard as covered in the Standard for Panelboards, UL 67.

20 Switching Means

20.1 A switching means shall be acceptable for the particular application and shall have a current and voltage rating not less than the circuit it controls.

20.2 A switching device controlling a coil shall be rated for both the inrush and sealed or steady state current of the coil.

20.3 A device that is rated for across the line motor starting of an alternating-current motor is acceptable for alternating-current pilot duty without further tests provided the power factor for the motor test was 0.5 or less and the overload test current was at least 150 percent of the pilot duty inrush current at the same voltage. Switching devices rated in accordance with Table 20.1 are considered to comply with this requirement.

Table 20.1
Horsepower rating versus pilot duty rating

Horsepower rating 1-phase (120 – 600 volts)	Alternating current pilot duty rating
1/10	125 VA (light duty)
1/2	360 VA (standard duty)
1	720 VA (heavy duty)

20.4 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use. This would include a switch used for switching a voltmeter, frequency meter, and power factor meter between various phases.

20.5 A switching and overcurrent protective device that is rated for continuous operation at 100 percent of its current rating shall be installed in accordance with instructions provided by the manufacturer for such a unit concerning minimum compartment size, amount of necessary ventilation, type and size of conductor, or the like.

20.6 The design and construction of a switching device shall be such that live parts will not be exposed during intended operation, and shall be such as to provide ample strength and rigidity.

20.7 There shall be a positive off position for the operating handle and stops to remove undue strain from switch parts shall be provided.

20.8 A handle or other member that indicates the position of switch or breaker contacts (closed or open) shall be designed so that the door, front, or cover cannot be secured in place in the intended manner so that the handle or member indicates off with the switch blades or contacts in the closed position.

20.9 If a circuit breaker or switch is mounted such that movement of the operating handle, either vertically or rotationally, between the on and off positions results in one position being above the other position, the upper position shall be the on position. This requirement does not apply to a circuit breaker or switch that is operated horizontally or that is operated rotationally with the on and off positions at the same level nor to a switching device having two on positions such as a transfer switch or a double throw switch.

20.10 Screws and nuts serving to attach operating parts to a moveable member shall be staked, upset, or otherwise locked in position to prevent loosening under continued use.

20.11 If there are both switches and fuses in either mains or branches, the current rating of a switch shall be not less than the maximum rating of the fuse the fuseholder will accommodate.

21 Spacings

21.1 General

21.1.1 The spacings in a unit substation shall be as indicated in Table 21.1.

Exception No. 1: The distance between a door or cover over a fuseholder and:

a) The center contact of an Edison-base fuseholder shall not be less than 1-9/16 inches (39.7 mm).

b) The center contact of a Type S fuseholder shall not be less than 1-5/16 inches (33.3 mm).

Exception No. 2: The spacings between screw shells of plug fuseholders that are protected by surrounding walls of insulating material, and a metal cover plate, shall not be less than 1/4 inch (6.4 mm) if the depth of the receptacle as measured from the top of the wall to the plane of the center contact is not less than 3/4 inch (19.1 mm). The measurement is to be made without a Type S adapter in place.

Exception No. 3: Spacings within a component, such as industrial control equipment, a heating element, a clock-operated switch, and the like within a unit substation and located on the load side of the service disconnect and overcurrent protection shall comply with the requirements applicable to the component. Spacings between exposed live parts of the component and the overall enclosure (other than inherent spacings) and spacings between exposed live parts of individual components shall comply with Table 21.1 or Table 21.2 as applicable.

Exception No. 4: Spacings in the control circuit of a magnetically operated device may be as covered in 21.1.10.

21.1.2 In applying Table 21.1 and Table 21.2 it is assumed that:

a) The voltage from a live part (other than the neutral) to grounded dead metal equals the line-to-line voltage of the system.

b) The voltage from a neutral live part to grounded dead metal equals the line-to-neutral voltage of the system.

Exception: Spacings are not required for constructions as covered in 21.1.4.

c) Spacings at a fuseholder are to be measured with a fuse of the maximum standard dimensions (including the maximum projections for assembly screws and rivets) in place. Dimensions of fuses

and fuseholders will be found in the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; the Standard for Low-Voltage Fuses – Part 4: Class CC Fuses, UL 248-4; the Standard for Low-Voltage Fuses – Part 5: Class G Fuses, UL 248-5; the Standard forLow-Voltage Fuses – Part 6: Class H Non-Renewable Fuses, UL 248-6; the Standard for Low-Voltage Fuses – Part 7: Class H Renewable Fuses, UL 248-7; the Standard for Low-Voltage Fuses – Part 8: Class J Fuses, UL 248-8; the Standard for Low-Voltage Fuses – Part 10: Class L Fuses, UL 248-10; the Standard for Low-Voltage Fuses – Part 11: Plug Fuses, UL 248-11; and the Standards for Fuseholders, UL 4248 series.

d) Spacings are to be measured through cracks unless a clamped insulating joint has passed the test covered in 27.3.1, a clamped insulating joint is a joint between two pieces of insulation that are under pressure as shown in Figure 21.1. Adhesives, cements, or the like, if used to effect a seal in lieu of a tightly mated joint, shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Table 21.1
Minimum acceptable spacings

Voltage involved		Minimum spacing between live parts of opposite polarity				Minimum spacing through air and over surface between live parts and grounded metal parts,	
		Through air,		Over surface,			
Greater than	Maximum	inch	(mm)	inch	(mm)	inch	(mm)
0	125	1/2	12.7	3/4	19.1	1/2	12.7
125	250	3/4	19.1	1-1/4	31.8	1/2	12.7
250	600	1	25.4	2	50.8	1[a]	25.4

NOTE – Minimum acceptable spacings other than as covered in 21.1.1 and Table 21.2.

[a] A through air spacing of not less than 1/2 inch (12.7 mm) is acceptable:

1) At a circuit breaker or a switch, other than a snap switch;

2) Between uninsulated live parts of a meter mounting base and grounded dead metal; and

3) Between grounded dead metal and the neutral of a 277/480-volt, 4-wire unit substation.

21.1.3 With regard to Table 21.1 and Table 21.2:

a) An isolated dead metal part (such as a screw head or a washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement. An electrostatic shield in a transformer is considered to be:

1) An opposite polarity part if it is or has provision to be connected in the field to an electric potential;

2) A grounded part if it is or has provision to be connected to ground; or

3) An isolated metal part if not connected as covered in (1) or (2).

b) In measuring an over surface spacing, any slot, groove, or the like, 0.013 inch (0.33 mm) wide or less in the contour of insulating material is to be disregarded.

c) In measuring an over surface spacing, an air space of 0.013 inch or less between a live part and an insulating surface is to be disregarded, and the live part considered in contact with the insulating material.

d) A film-coated wire is considered insulated with respect to other turns of the same winding, but is otherwise considered an uninsulated live part.

Table 21.2
Motor circuit or control circuit spacings

Voltage involved		Minimum acceptable spacings					
		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	
		Through air[a],		Over surface,		Shortest distance,	
More than	Maximum	inch	(mm)	inch	(mm)	inch	(mm)
0	150	1/8	3.2	1/4	6.4	1/2	12.7
150	300	1/4	6.4	3/8	9.5	1/2	12.7
300	600	3/8	9.5	1/2	12.7	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.

21.1.4 Terminals and other 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 grounded dead metal.

21.1.5 If the enclosure or ground bus is factory bonded to the neutral as covered in 22.1.12 and 22.1.13, any conductive part connected to the neutral that would interfere with the operation of a ground fault protection system, if in contact with the enclosure, shall be insulated and provided with at least 1/8 inch (3.2 mm) spacings through air or over surface to the enclosure. For zero sequence type ground fault protection, or the residual type ground fault protection, parts that would interfere with its operation if grounded include all neutral parts on the load side of the neutral current sensing means. For the ground return type, parts that would interfere with its operation if grounded include all conductive parts connected to the neutral except those on the ground side of the sensing means.

21.1.6 The spacing (through air and over surface) shall be not less than 1/8 inch (3.2 mm) between uninsulated live parts of the same polarity:

a) On the load side of their respective switches or circuit breakers for parts in different circuits and

b) On the line and load sides of a fuseholder, switch, or circuit breaker.

Exception: With regard to Exception No. 3 to 21.1.1 and the Exception to 21.1.7, the spacings within a component on the load side of a service disconnect and overcurrent protection may be less than 1/8 inch (3.2 mm).

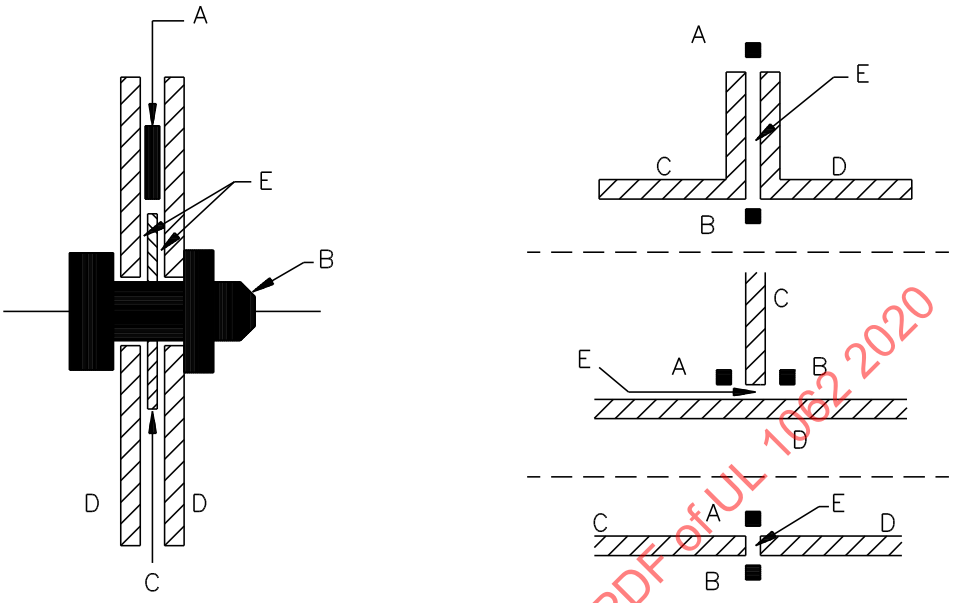
21.1.7 Spacings of a component serving as the service disconnect shall comply with Table 21.1 and 21.1.6. Spacings less than those of Table 21.1 in a meter socket base are subjected to a dielectric voltage-withstand test in accordance with the Exception to 27.1.1.

Exception: Spacings within a circuit breaker or a molded case switch may be as covered by the requirements applicable to that component.

21.1.8 Spacings are to be measured with all terminals unwired and wired with conductors terminated in accordance with 16.11 – 16.14, but no conductor smaller than 12 AWG (3.3 mm^2) is to be employed.

Figure 21.1

Clamped insulating joint



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NOTES –

1) Parts A, B – Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required in Table 21.1 or Table 21.2.

2) Parts C, D – Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

3) Part E – The clamped insulating joint.

21.1.9 In measuring between an uninsulated live part and a conduit bushing installed at a knockout, it is to be assumed that a bushing having the dimensions indicated in Table 21.3 (but without a locknut inside the enclosure) is in place.

Table 21.3
Conduit bushing dimensions

Trade size of conduit,	Overall diameter,		Height,	
inch	inch	(mm)	inch	(mm)
1/2	1	25.4	3/8	9.5
3/4	1-15/64	31.4	27/64	10.7
1	1-19/32	40.5	33/64	13.1
1-1/4	1-15/16	49.2	9/16	14.3
1-1/2	2-13/64	56.0	19/32	15.1
2	2-45/64	68.7	5/8	15.9
2-1/2	3-7/32	81.8	3/4	19.1
3	3-7/8	98.4	13/16	20.6
3-1/2	4-7/16	113	15/16	23.8
4	4-31/32	126	1	25.4
4-1/2	5-35/64	140	1-1/16	27.0
5	6-7/32	156	1-3/16	30.2
6	7-7/32	183	1-1/4	31.8

21.1.10 All screws and nuts, other than those specified in 20.10, shall be staked, headed over, upset, or otherwise prevented from loosening such as by use of a locknut or lock washer.

Exception: Prevention of loosening is not required if it can be shown that no reduction of spacings can result from the loosening or falling out of such threaded parts.

21.1.11 The spacings in the control circuits of a magnetically operated device shall be as indicated in Table 21.2.

21.1.12 A pressure wire connector shall be prevented from turning that would result in less than the minimum acceptable spacings. The means for turn prevention shall be reliable, such as a shoulder or boss; a lock washer alone is not acceptable.

Exception: Means to prevent turning need not be provided if spacings are not less than the minimum acceptable values:

a) When the connector, and any connector of opposite polarity, have each been turned 30 degrees toward the other, and

b) When the connector has been turned 30 degrees toward other opposite polarity live parts and toward grounded dead metal parts.

21.2 Insulating barriers

21.2.1 The barrier referred to in 21.2.2 and 21.2.3 is insulating material that separates uninsulated live parts of opposite polarity or separates an uninsulated live part from a grounded dead metal part (including the enclosure) if the through air spacing between the parts would otherwise be less than the minimum acceptable value.

21.2.2 A barrier that is used in conjunction with a through air spacing of less than 0.013 inch (0.33 mm) shall:

a) Be of material acceptable for direct support of an uninsulated live part as covered in Insulating Materials, Section 13, and

b) Have a minimum thickness of 0.028 inch (0.71 mm).

Exception: A barrier of insulating material may have a thickness less than 0.028 inch if the material withstands a 60-Hz, dielectric voltage-withstand of 5000 volts applied in accordance with 27.4.1.

21.2.3 A barrier used in conjunction with a minimum through air spacing of 0.013 inch (0.33 mm) shall:

a) Comply with the requirements for internal barriers in the Standard for Polymeric Materials– Use in Electrical Equipment Evaluations, UL 746C, and

b) Have a minimum thickness of 0.028 inch (0.71 mm).

Exception No. 1: A barrier of insulating material may have a thickness less than 0.028 inch if the material withstands a 60-Hz, dielectric voltage-withstand of 2500 volts applied in accordance with 27.4.1.

Exception No. 2: Material other than vulcanized fiber used in conjunction with an air space of 1/2 or more of the required through air spacing may have a thickness no less than 0.013 inch or less than 0.013 inch if the material withstands a 60-Hz, dielectric voltage-withstand of 2500 volts applied in accordance with the requirements in 27.4.1.

21.2.4 If the barrier specified in 21.2.3 is of fiber, the air space shall be 1/32 inch (0.8 mm) or more.

21.2.5 If the barrier specified in 21.2.3 is of material (other than fiber) that is not rated for the support of an uninsulated live part, the air space shall be adequate for the particular application.

21.2.6 A wrap of thermoplastic tape, rated for use as sole insulation, may be employed if the tape is not subject to compression, is not wrapped over a sharp edge, and if at a point where the spacing prior to the application of the tape is:

a) Not less than half the required through air spacing, the wrap is not less than 0.013 inch (0.33 mm) thick and is applied in two or more layers.

b) Less than half the required through air spacing, the wrap is not less than 0.028 inch (0.71 mm) thick.

21.2.7 If spacings would otherwise be less than the minimum acceptable values, thermoplastic tubing may be employed if:

a) It is not subjected to compression, repeated flexure, or sharp bends;

b) All edges of the conductor covered with the tubing are rounded and free from sharp edges;

c) For chemically dilated tubing, a solvent recommended by the tubing manufacturer is used;

d) Its wall thickness (after assembly) is not less than 0.022 inch (0.56 mm) for tubing 1/2 inch (12.7 mm) or less in diameter, not less than 0.027 inch (0.69 mm) for tubing 9/16 or 5/8 inch (14.3 or 15.9 mm) in diameter, and is not less than 0.028 inch (0.71 mm) for larger tubing; and

e) Its temperature marking is not less than the temperature rise observed during the temperature test plus 25°C (77°F) for an indoor unit substation, or 40°C (104°F) for a rainproof unit substation. If

a temperature test is not required or if the temperature test is conducted using dummy fuses, the temperature marking is to be 80°C (176°F) for an indoor unit substation, or 105°C (221°F) for a rainproof unit substation.

22 Grounding and Bonding

22.1 General

22.1.1 There shall be provision for grounding a unit substation and, in addition, where accessible to other than qualified persons, for grounding the case of a frame or instrument transformer; the case of an instrument, meter or relay; or the secondary circuit of a current or potential transformer. With regard to 38.1, all exposed dead metal parts and the grounding contact of a grounding type receptacle shall be in contact with the means for grounding. The resistance shall not exceed:

a) 0.1 ohm between the ground bus and either an exposed dead metal part or the grounding contact of a grounding type receptacle rated 30 amperes or less or

b) 0.005 ohm between the ground bus and the grounding contact of a grounding type receptacle rated more than 30 amperes.

The resistance of the connection between a busway, ground bus, wireway, or an auxiliary gutter and a unit substation enclosure shall not exceed 0.005 ohm. The resistance between the unit substation enclosure and a wire connector for a grounding or bonding conductor larger than 8 AWG (8.4 mm^2) copper or 6 AWG (13.3 mm^2) aluminum shall not exceed 0.005 ohm. Paint shall be removed as necessary to keep the resistance within the above limits.

Exception No. 1: Provision for grounding is not required as noted in 22.1.2 and 22.1.3.

Exception No. 2: A switch operating handle of conducting material need not be grounded if it is effectively insulated.

22.1.2 The case or frame of a current transformer, the primary of which is not over 150 volts to ground and is used exclusively to supply current to a meter, is not required to be grounded.

22.1.3 The case of an instrument, relay meter, or similar device, if mounted on a grounded metal surface and secured thereto by means of metal screws, is considered to be adequately grounded.

22.1.4 There shall be provision for permanently and effectively grounding a metal barrier that covers an uninsulated live part.

Exception: The provisions for grounding the barrier need not be included if the plate is provided with means for insulating it from a live part or is located so that it is unlikely to become energized.

22.1.5 A pressure wire connector provided as the grounding means shall be capable of receiving and holding a conductor of the size indicated in Table 22.1.

Table 22.1
Size of bonding, equipment grounding, and grounding electrode conductors and ground bus

Maximum ampere rating[a]	Size of equipment grounding or bonding conductor, minimum (AWG or kcmil)[b]		Size of grounding electrode conductor, minimum (AWG or kcmil)		Size of main bonding jumper, minimum (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
15	14	12	–	–	–	–
20	12	10	–	–	–	–
30	10	8	–	–	–	–
40	10	8	–	–	–	–
60	10	8	–	–	–	–
90	8	6	8	6	8	6
100	8	6	6	4	6	4
150	6	4	6	4	6	4
200	6	4	4	2	4	2
300	4	2	2	1/0	2	1/0
400	3	1	1/0[c]	3/0[c]	1/0[c]	3/0[c]
500	2	1/0	1/0	3/0	1/0	3/0
600	1	2/0	2/0	4/0	2/0	4/0
800	1/0	3/0	2/0	4/0	2/0	4/0
1000	2/0	4/0	3/0	250	3/0	250
1200	3/0	250	3/0	250	250[d]	250
1600	4/0	350	3/0	250	300[c]	400[c]
2000	250	400	3/0	250	400[c]	500[c]
2500	350	600	3/0	250	500[c]	700[c]
3000	400	600	3/0	250	600[c]	750[c]
4000	500	800	3/0	250	750[c]	1000[c]
5000	700	1200	3/0	250	900	1250
6000	800	1200	3/0	250	1250	1500

NOTE – See Table 22.2 for equivalent area of bus. The size of ground bus to be as specified in Table 22.2 based on columns 1 – 3 of this table.

[a] Based on the maximum supply ampere rating of a unit substation or circuit overcurrent device ahead of equipment grounding means.

[b] Grounding and bonding conductors that are larger than those specified in this table comply with the intent of the requirement when it has been determined that a larger conductor is required to clear a fault current of any ampacity.

[c] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 3/0 AWG copper or two No. 250 kcmil aluminum conductors and are not capable of accepting a 600 kcmil conductor, the reduction of those values to 2 AWG copper or 1/0 AWG aluminum complies with the intent of this requirement.

[d] The cross section may be reduced to 12.5 percent of the total cross section of the largest main service conductor of the same material (copper or aluminum) for any phase in a unit substation rated 200 amperes and greater. This applies when the cross-section of the service conductors is limited by the wire terminal connectors provided.

22.1.6 A unit substation marked for service equipment use and provided with a primary circuit neutral shall have a terminal for the connection of the grounding electrode conductor to the neutral bus or to the ground bus sized in accordance with Table 22.1. The connections shall not depend on solder for securing the grounding electrode conductor. If located on the neutral bus, the terminal shall be on the supply side of a switching type disconnect means as specified in 18.3.1 or a disconnect link as specified in 18.3.2.

22.1.7 The terminal for the grounding electrode conductor shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by the serving agency (electric utility or power company).

22.1.8 In a unit substation marked as shown in 40.7.3, a main bonding jumper shall be provided to bond the enclosure and the ground bus to the primary circuit neutral of an alternating-current circuit. The construction shall be such that when the bonding means is not used, the spacings given in Table 21.1 will exist. Unless the intended use and method of installation of the bonding means are obvious, instructions for its installation shall be provided.

22.1.9 The secondary circuit of a unit substation transformer shall be grounded.

22.1.10 A main bonding jumper shall be factory connected to the transformer secondary and to the ground bus or to the enclosure if a ground bus is not provided. The size of the main bonding jumper shall be as specified in Table 22.1 and Table 22.2 based on the transformer secondary current rating. A grounding electrode conductor connector sized in accordance with Table 22.1 (columns 4 and 5) and Table 22.2 shall be provided on the ground bus (if any) in the section containing the transformer or in an adjoining section, and a marking as covered in 40.13.1 shall be provided.

22.1.11 The enclosure shall not be bonded to the primary circuit neutral when the unit is shipped.

Exception: The enclosure may be bonded to the primary circuit neutral as covered in 22.1.12 and 22.1.13.

22.1.12 With regard to 22.1.8, a unit substation may have the main bonding jumper factory connected to the primary circuit neutral bus and to the ground bus (or to the unit substation frame if a ground bus is not provided), in which case the unit substation shall be marked in accordance with 40.7.4.

22.1.13 In a unit substation incorporating ground fault protection of the ground return type as described in 18.2.5, the main bonding jumper as covered in 22.1.8 shall be factory connected to the primary circuit neutral bus and to the ground bus (or the unit substation frame if a ground bus is not provided) and the unit substation shall be marked in accordance with 40.7.4.

22.1.14 A main bonding jumper shall be sized as specified in Table 22.1. The connection of the main bonding jumper to the primary circuit neutral shall be on the supply side of a switching type disconnect means as specified in 18.3.1 or a disconnect link as specified in 18.3.2.

22.1.15 The main bonding jumper shall be accessible without opening a compartment intended to be sealed or otherwise rendered inaccessible by a utility.

Table 22.2
Equivalent cross-sectional areas

Wire size, (AWG or kcmil)	Minimum cross-section,	
	inch^2	(mm^2)
14 AWG	0.003	1.93
12	0.005	3.23
10	0.008	5.16
8	0.013	8.39
6	0.021	13.55
4	0.033	21.29
3	0.041	26.45
2	0.052	33.55
1	0.066	42.58
1/0	0.083	53.55

Table 22.2 Continued on Next Page

Table 22.2 Continued

Wire size, (AWG or kcmil)	Minimum cross-section, inch^2	(mm^2)
2/0	0.105	67.74
3/0	0.132	85.16
4/0	0.166	107.1
250 kcmil	0.196	126.45
300	0.236	152.26
350	0.275	177.42
400	0.314	202.58
500	0.393	253.55
600	0.471	303.87
700	0.550	364.84
750	0.589	380.0
800	0.628	405.16
1000	0.785	506.45
1200	0.942	607.73
1250	0.981	632.90
1500	1.178	760.0

22.2 Equipment grounding terminals

22.2.1 A unit substation shall be provided with means for terminating equipment grounding conductors for both the primary circuit equipment grounding conductor and for the branch circuit equipment grounding conductor sized in accordance with Table 22.1.

Exception No. 1: Means for terminating equipment grounding conductors need not be provided in a unit substation marked in accordance with 40.12.21 or 40.12.22.

Exception No. 2: For a unit substation marked in accordance with 40.7.3 or 40.7.4, a terminal for connection of the grounding electrode conductor provided in accordance with 22.1.6 may be considered to be the primary circuit equipment grounding conductor means if it is acceptable for the wire size required in Table 22.1.

22.2.2 With regard to 22.2.1 and Table 22.1, the size of the primary circuit equipment grounding conductor shall be based on the rating of the primary circuit overcurrent protection as covered in 19.1, and the size of the secondary branch circuit equipment grounding conductors shall be based on the rating of the branch circuit device that may be installed in the unit substation.

22.2.3 If there is provision for a field-installed equipment grounding conductor terminal assembly, the assembly shall comply with the Standard for Panelboards, UL 67, and the unit substation shall be marked in accordance with 40.12.21.

22.2.4 In addition to the grounding means required in 22.2.1 and 22.2.3, a unit substation not marked for service equipment use only may have an equipment grounding bus bar or terminal strip sized as indicated in 22.2.2 that is insulated from the enclosure.

PERFORMANCE

23 General

23.1 An operating handle for a circuit breaker or switch that is not supplied as part of the circuit breaker or switch is to be subjected to a no load endurance test together with the particular circuit breaker or switch. The number of operations is to be the same as for the circuit breaker or switch concerned.

23.2 An open type switching mechanism not containing overload relays rated more than 15 amperes full load, such as a magnetic switch or transfer switch, need not have the overload or endurance tests repeated if the dimensions of the compartment in which the device is mounted in the unit substation are not less than 150 percent of the overall dimensions (width, length, and height) of the device.

23.3 For test purposes, the energized winding of a transformer shall be considered the primary winding.

23.4 The weight of a unit substation shall be determined and, if applicable, the unit substation shall be marked in accordance with 40.15.1.

24 Impedance Test

24.1 The percent impedance of a unit substation transformer rated 25 kVA or more shall be determined. The determined value is acceptable if it is ±10 percent of the marked value.

24.2 With regard to 24.3, the determination of impedance shall be made within 15 minutes of energizing the transformer from a room temperature start.

24.3 The percent impedance is to be determined by multiplying by 100 the ratio of the primary impedance voltage to the rated primary voltage. The primary impedance voltage is the primary winding voltage required to cause rated current to flow in the short-circuited secondary winding.

24.4 An autotransformer shall be tested for impedance with its internal connections unchanged, by short circuiting one set of terminals to cause its rated line current to flow. A typical test circuit is shown in Figure 24.1.

Figure 24.1

Autotransformer test circuit

24.5 A 3-phase transformer shall be tested with 3-phase voltage. All three terminals of one winding are to be short-circuited together, and balanced 3-phase voltage of rated frequency is to be applied to the terminals of the other winding with a magnitude to cause rated currents to circulate. A typical test circuit is shown in Figure 24.2.

Exception No. 1: A 3-phase transformer may be tested with single-phase voltage. To determine the impedance of a 3-phase voltage, the windings to which voltage is to be applied are to be connected in a delta configuration, and a corner of the delta opened to apply the single-phase voltage. The other winding may be either connected in a delta, in which no short-circuiting is necessary, or in a wye configuration with its terminals short-circuited to the neutral. The percent impedance is then determined in accordance with the following equation:

$$Impedance\ \% = \frac{V}{300\ V_R}$$

in which:

V is primary impedance voltage and

V_R is rated primary voltage.

Exception No. 2: A single-phase test voltage source may be used by short-circuiting the three-line leads of one winding and applying single-phase voltage, adjusted to circulate rated line current, at rated frequency to two terminals of the other winding. After three successive readings are taken on the three pairs of leads, the impedance voltage is determined by the following equation:

$$V_Z = \frac{0.866\,(V_1 + V_2 + V_3)}{3}$$

in which:

V_Z is impedance voltage;

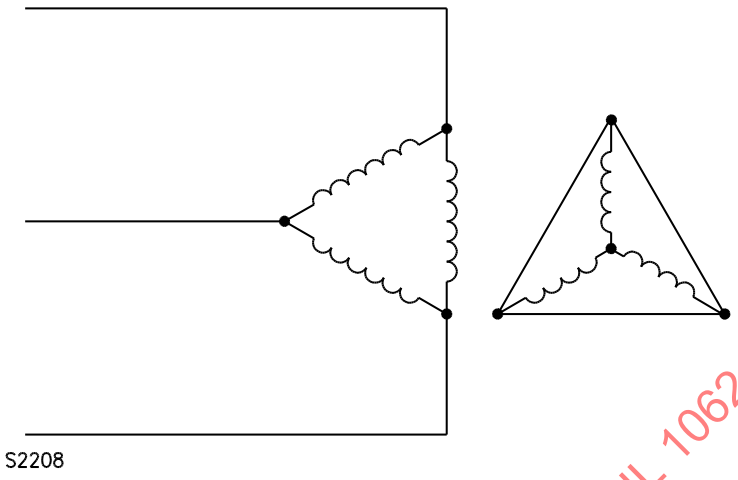
V_1 is voltage at first pair;

V_2 is voltage at second pair; and

V_3 is voltage at third pair.

Figure 24.2

3-phase test circuit



25 Temperature Test

25.1 General

25.1.1 A unit substation shall be tested under the conditions described in 25.1.3 – 25.1.19. The results are acceptable if:

a) The temperature at any point is not so high as to cause a fire or damage any material employed and

b) No temperature rise at specific points is higher than as specified in Table 25.1.

25.1.2 A separate test for a neutral bus is not required if the neutral has been tested in accordance with the requirements in the Standard for Panelboards, UL 67.

25.1.3 During the test the unit substation is to be mounted or supported as in service and operated under conditions approximating those of intended operation. The test is to be made with fuses installed in fuseholders. Class H fuseholders shall be tested with dual element time-delay Class K5 or Class RK5 fuses. Currents are to be as shown in 25.1.7.

Exception: Dummy fuses or the equivalent may be used in place of regular fuses in fuseholders intended for plug fuses, Class H fuses, or 0 – 200 ampere Class J fuses.

25.1.4 If there are branch circuit units (circuit breakers or fused switches) in the unit substation, the selection of ratings of branch circuit units to carry current is to be in accordance with the requirements in the Standard for Panelboards, UL 67. The total secondary current shall be the rated secondary current of the transformer.

Exception: If there is a single main circuit breaker provided in the secondary circuit, the secondary current need not exceed 80 percent of the secondary main circuit breaker rating.

Table 25.1
Maximum temperature rises

	Materials and components	°C	(°F)
1.	Unplated bus bar at a joint except as covered in item 2	50	90
2.	Any bus within 6 inches (152 mm) of a fuseholder along the current path when tested with dummy fuses	30	54
3.	Any part that may be contacted by field wiring except as specified in items 5 and 6	50[a,b]	90[a,b]
4.	Pressure terminal connectors for field installed conductors except as noted in items 5 and 6	50[a,b]	90[a,b]
5.	Pressure terminal connectors for field wiring to switches or circuit breakers as covered in items 2 – 6 of Table 25.2 if marked in accordance with 40.12.18 and for internal wiring with copper conductors	60[a,c]	108[a,c]
6.	Pressure terminal connectors used in circuits rated 110 amperes or less and marked for use with 75°C (167°F) wire	65[a,c]	117[a,c]
7.	Pressure terminals or wire connectors for internal wiring involving aluminum conductors unless the connector has been investigated for higher temperatures	50[a,c]	90[a,c]
8.	Plated bus bar at the point of connection to a molded case circuit breaker	55[d]	99[d]
9.	Plated bus bar except as covered in items 2, 3, and 8	65[a]	117[a]
10.	Wire insulation or insulating tubing	35[a,b]	63[a,b]
11.	Electrical tape	55[a,b]	99[a,b]
12.	Varnished cloth insulation	60[a,b]	108[a,b]
13.	Fiber used as electrical insulation	65[a,b]	117[a,b]
14.	Phenolic composition used as electrical insulation or as a part whose failure would result in an undesired condition	125[a,b]	225[a,b]
15.	Other insulating materials	e	e
16.	External metal handles, knobs, and other surfaces subject to contact by a person	35	63
17.	External nonmetallic handles, knobs, and other surfaces subject to contact by a person	60	108
18.	Enclosure parts of transformer compartment except as indicated in 25.5.1 and 25.6.1	50 (65)	90 (117)
19.	Coil winding by change-of-resistance method except as covered in item 20:		
	Class 130 insulation system	60	108
	Class 155 insulation system	85	153
	Class 180 insulation system	110	198
	Class 200 insulation system	130	234
20.	Coil winding by change-of-resistance method for transformers with encapsulated coils or that are compound-filled:		
	Class 105 insulation system	70	126
	Class 130 insulation system	95	171
	Class 155 insulation system	115	207
	Class 180 insulation system	135	243
	Class 200 insulation system	150	270
	Class 220 insulation system	165	297

[a] In a unit substation tested with dummy fuses, the recorded temperature rise shall be increased 20°C (36°F) to represent the heating of fuses except that where only a few fuses such as control circuit fuses are involved, the increase shall only apply to parts within 12 inches (305 mm) of the fuses.

[b] This limitation does not apply to an insulated conductor or other material as covered in 25.1.11 that has been investigated and rated for a higher temperature.

Table 25.1 Continued on Next Page

Table 25.1 Continued

Materials and components	°C	(°F)
[c] Applicable to a connector for copper wire. Also applicable to a connector for aluminum wire or an aluminum bodied connector if the connector has a temperature rating of 90°C (194°F).		
[d] A plated bus may have a 65°C (117°F) rise at the point of connection to a molded case circuit breaker if the circuit breaker is marked for and tested with 75°C (167°F) wire for circuits rated 110 amperes or less or if the circuit breaker is marked for and tested at 100 percent of its continuous rating.		
[e] See 25.1.11.		

25.1.5 For other than a coil or heating element any convenient voltage supply may be used provided the specified current is caused to flow.

25.1.6 If a low voltage current is used through contacts of switching devices, the contacts may be conditioned by closing on a circuit of rated voltage and current.

25.1.7 A minimum of 4 feet (1.22 m) of wire is to be attached to each field wiring terminal. The size of wire to be used is to be the smallest size having an ampacity in accordance with Table 15.1 and 16.14(a) of at least 125 percent of the test current for motor loads and at least 100 percent for other loads. If the terminal will not receive the size of wire required for testing in accordance with 25.1.9, the maximum allowable wire size is to be used.

Exception: For wire of 1 AWG (42.4 mm^2) or smaller, the wire size used is to correspond to the 75°C (167° F) ampacities of Table 15.1 if the unit substation is marked as covered in Exception No. 1 to 40.12.24.

25.1.8 The current used during the test is to be as shown in Table 25.2 , but the current in the smallest branch circuit unit may be less to produce the required section bus current.

25.1.9 All values in Table 25.1 are based on an assumed ambient (room) temperature of 25°C (77°F), but a test may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). However, if the operation of an automatic thermal control during the test limits the temperatures under observation, no observed temperature higher than 25°C plus the specified maximum rise is acceptable.

25.1.10 Ambient temperature is to be determined by taking the average of the readings of three thermocouples or thermometers placed as follows:

a) Level with the top of the structure;

b) 12 inches (305 mm) above the bottom of the structure; and

c) Midway between (a) and (b).

All thermometers are to be placed 36 inches (914 mm) from the structure and in locations unaffected by drafts caused by the structure or appreciable radiation from the equipment. When the ambient temperature is subject to variations that might result in errors in taking the temperature rise, the thermometers for determining the ambient temperatures should be immersed in a liquid such as oil in a heavy metal cup.

Table 25.2
Current through fuseholders and other types of overcurrent devices

Type device	Percent of device rating
1. Dummy fuse	100
2. Low-voltage AC power switching devices and fused power-circuit devices	100
3. Molded-case circuit breakers marked for 100 percent loading	100
4. Class L fuses in fused power-circuit devices or in transfer switches	100
5. Class L fuses in miscellaneous switches, 1200 amperes or less	80
6. 200 – 600 amperes Class T and 400 – 600 ampere Class J fuses	80
7. All other fuses or circuit breakers	80

25.1.11 The acceptability of an insulating material, other than those specified in Table 25.1, is to be determined with regard to properties such as flammability, arc resistance, and the like, based on the temperature rise plus 40°C (104°F).

25.1.12 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). If thermocouples are used in determining temperatures in electrical equipment, it is standard practice to employ thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wire and a potentiometer-type instrument, and such equipment will be used whenever referee temperature measurements by thermocouples are necessary.

Exception: The temperature of a coil is to be determined by the change of resistance method by comparing the resistance of the winding at the temperature to be determined with the resistance of the winding at a known temperature, in accordance with the following 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 at the beginning of the test,

t_1 is the room temperature °C at the beginning of the test,

t_2 is the room temperature °C at the end of the test, and

k is 234.5 for copper or 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades must be determined.

Values of the constant for other grades must be determined.

25.1.13 Temperatures determined by the change of resistance method are to be those at the time of shutdown, extrapolated from the measurements taken after shutdown.

25.1.14 A temperature rise is considered to be constant when it does not vary more than 2°C (3.6°F) during a continuous 3-hour period.

25.1.15 The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

25.1.16 A thermocouple junction and adjacent thermocouple lead wire are to be held in thermal contact with the surface of the material whose temperature is being measured. In most cases, thermal contact will result from 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.

25.1.17 The transformer may be disconnected from the rest of the unit substation so that low voltage may be used for testing the other components. However, the combination is to be tested simultaneously.

25.1.18 The transformer temperature test may be conducted by the direct load method, load back method, impedance kVA method, or short circuit method, in accordance with the Standard Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12.91.

25.1.19 If rated primary test voltage is to be used, it shall be:

a) The maximum of the range if the unit substation is rated with a voltage range or if the transformer is rated with a single value that falls within the range 110 – 120, 220 – 240, 440 – 480, or 550 – 600 volts or

b) The single rating if such rating falls outside the range specified in (a).

25.1.20 If a transformer is provided with one or more primary winding taps, the lowest rated full capacity tap shall be used.

25.1.21 Tests at more than one frequency may be required if the unit substation is marked with a range of frequencies.

25.1.22 During the temperature test, the unit substation is to be mounted in its intended manner. If marked with a specific clearance to an adjacent wall or ceiling provided in accordance with 40.14.1, the unit substation is to be mounted in an alcove as described in 25.5.2 for a unit substation intended for wall mounting or 25.6.2 for a unit substation intended for floor mounting.

Exception: If a unit substation is marked with a clearance of 6 inches (152 mm) or more, the unit substation need not be tested in an alcove as described in 25.5.1 – 25.6.2.

25.2 Direct loading method

25.2.1 *Deleted*

25.3 Load back method

25.3.1 *Deleted*

25.4 Impedance kVA method – 3-phase transformer

25.4.1 *Deleted*

Figure 25.1

Single phase test circuit

Figure deleted

Figure 25.2

3-phase test circuit

Figure deleted

Figure 25.3

kVA method test circuit

Figure deleted

25.5 Units for wall mounting

25.5.1 The temperature rise on the enclosure of a unit substation intended for wall mounting may be more than 35°C (63°F) for 16 of Table 25.1, 60°C (108°F) for 17 of Table 25.1, or 50°C (90°F) for 18 of Table 25.1, but not more than 65°C (117°F) during the temperature test if:

a) The temperature test is conducted with the unit substation mounted in an alcove as described in 25.5.2 and as shown in Figure 25.4;

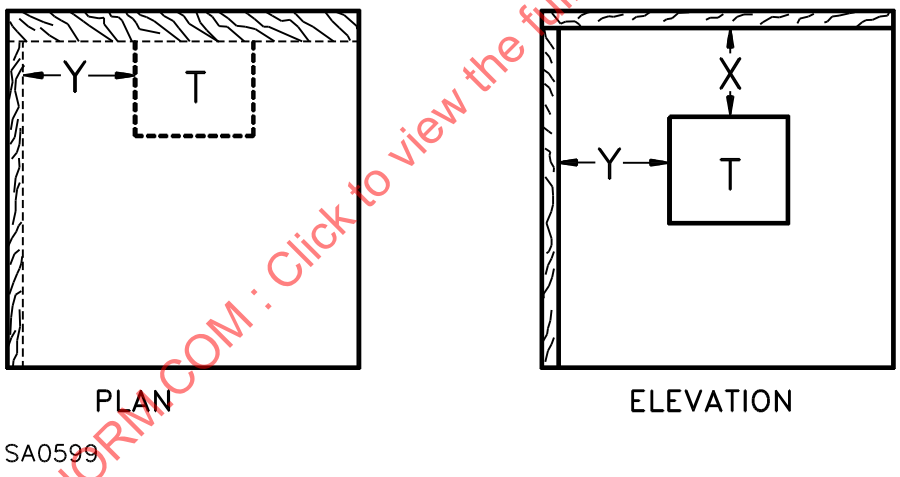
b) The temperature rise at any point on the inner surfaces of the alcove is not more than 50°C, and

c) The unit substation is marked in accordance with 40.14.1 and 40.14.2.

25.5.2 The side wall and the top of the test alcove represented in Figure 25.4 are of 3/8 inch (9.5 mm) thick fir plywood, and the rear wall (on which the transformer is mounted) is of 3/4 inch (19.1 mm) thick fir plywood. The inner surfaces of the test alcove are to be painted dull black, and the unit substation is to be mounted in the intended manner. The horizontal dimensions of the walls and the top are to extend beyond the unit substation at least 12 inches (305 mm). The dimensions X and Y are to be the minimums specified by the manufacturer, as provided by the markings specified in 40.14.1.

Figure 25.4

Test alcove for wall mounted unit substation



NOTES –

T – Unit substation.

X – Minimum spacing between top of enclosure and surface above.

Y – Minimum spacing between hotter end of the unit substation and adjacent side wall. If the temperature of the right end of the unit substation is higher than that of the left end, the side wall is to be to the right instead of to the left as shown.

25.6 Units for floor mounting

25.6.1 The temperature rise on the enclosure of a unit substation intended for floor mounting may be more than 50°C (90°F) but not more than 65°C (117°F) for 18 of Table 25.1 during the temperature test if:

a) The temperature test is conducted with the unit substation mounted in an alcove as described in 25.6.2 and as shown in Figure 25.5;

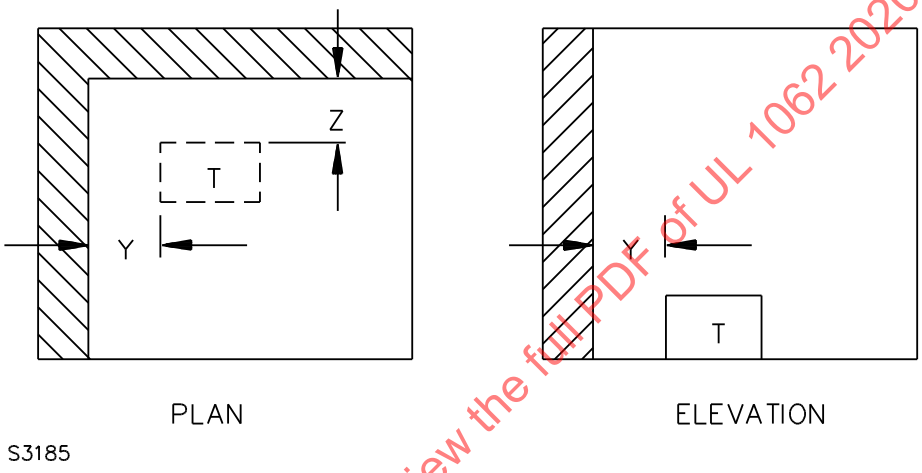
b) The temperature rise at any point on the inner surfaces of the alcove is not more than 50°C, and

c) The unit substation is marked in accordance with 40.14.1 and 40.14.2.

25.6.2 The side wall of the test alcove represented in Figure 25.5 is of minimum 3/8 inch (9.5 mm) thick fir plywood, and the rear wall and floor are of minimum 3/4 (19.1 mm) thick fir plywood. The inner surfaces of the test alcove are to be painted dull black, and the unit substation is to be mounted in the intended manner. The horizontal and vertical dimensions of the walls are to extend beyond the unit substation at least 12 inches (305 mm). The dimensions Y and Z are to be the minimums specified by the manufacturer, as provided by the marking specified in 40.14.1.

Figure 25.5

Test alcove for floor mounted unit substation



NOTES –

T – Unit substation.

Y – Minimum spacing between hotter end of the unit substation and adjacent side wall. If the temperature of the right end of the unit substation is higher than that of the left end, the side wall is to be to the right instead of to the left as shown.

Z – Minimum spacing between the rear of the unit substation and the adjacent wall.

25.7 Dielectric voltage-withstand

25.7.1 Within 1 hour after conclusion of the temperature test, a transformer, other than an autotransformer, of the unit substation shall be subjected for 1 minute to an applied potential between each winding and every other winding of the transformer to which it is not conductively connected, and between each winding and metal of the core or enclosure. The applied potential is to be in accordance with the Dielectric Voltage-Withstand Test, Section 27. The results are acceptable if there is no dielectric breakdown.

25.7.2 Within 1 hour after conclusion of the temperature test, an autotransformer shall be subjected for 1 minute to an applied potential between the windings and the core or enclosure. The applied potential is to be in accordance with the Dielectric Voltage-Withstand Test, Section 27. The results are acceptable if there is no dielectric breakdown.

26 Rain Test

26.1 To determine compliance with the requirements in this section, an enclosure shall be subjected to the water spray test described in 26.2 – 26.8.

26.2 The water spray is to be applied to the top and side of the assembly using the apparatus and positioning described in 26.3 – 26.8.

26.3 The sample is to be placed such that the top of the section under test is located 39 inches (991 mm) below the level of the center spray head. Additionally, the test sample is to be located in such a position that the center point of the outermost part of the side being subjected to the spray is located within 24 – 48 inches (610 mm – 1.2 m) in front of, and within 18 inches (457 mm) to each side of the center spray head.

26.4 The rain test apparatus is to consist of three spray heads mounted in a water supply pipe rack as shown in Figure 26.1.

26.5 Spray heads are to be constructed in accordance with the details as shown in Figure 26.2.

26.6 The water pressure for all tests is to be maintained at 5 psi (34,474 Pa) in each spray head.

26.7 The water spray as described in 26.2 – 26.6 is to be applied to the area of test for 1 hour.

26.8 An enclosure which has been subjected to the water spray test is acceptable if, at the conclusion of the test:

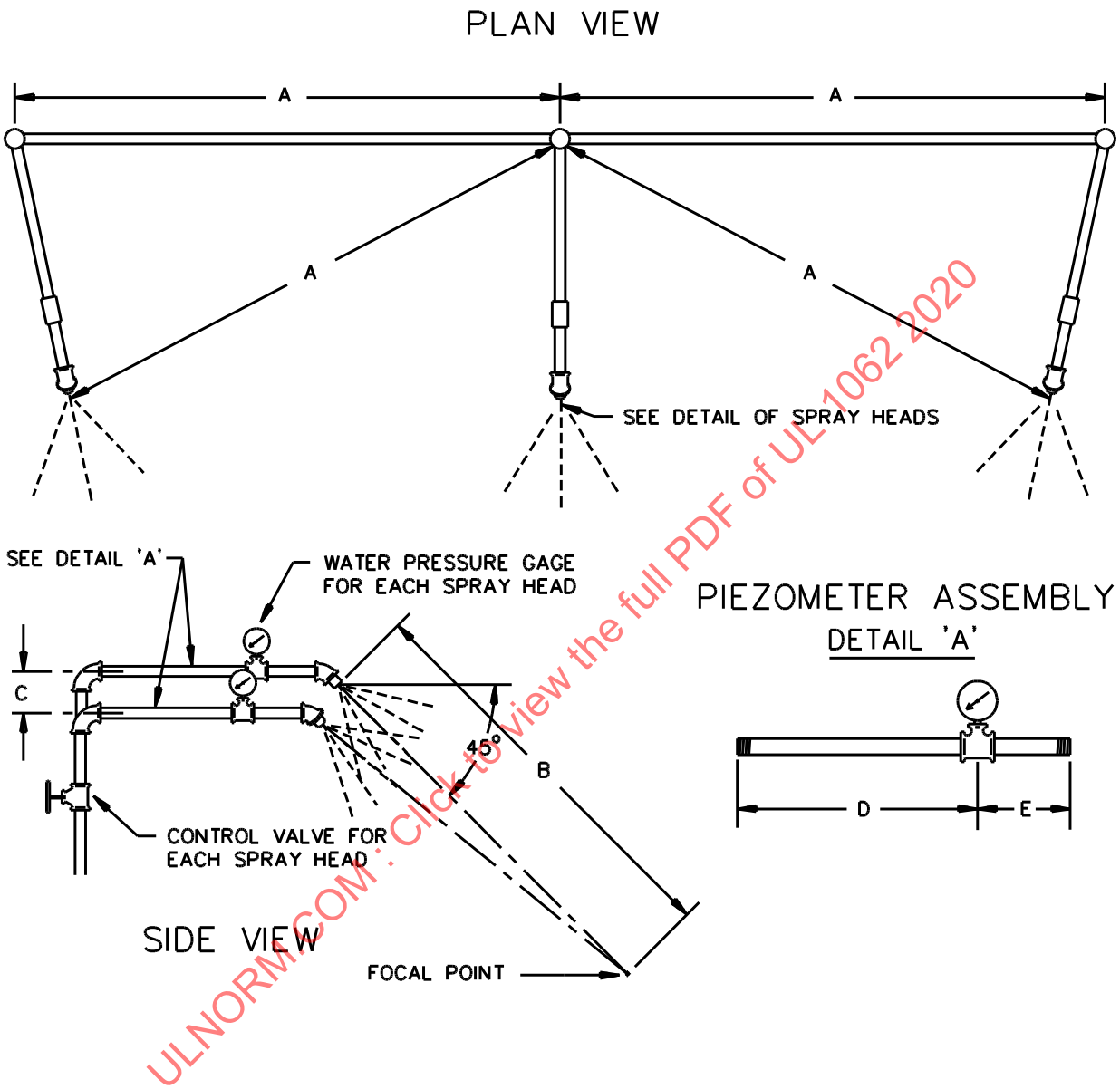
a) No water is visible on insulation or on any electrical component or mechanism of the assembly;

b) No significant accumulation of water is retained by the structure or other noninsulating parts – to reduce corrosion; and

c) No water has entered any area of the enclosure that may contain wiring installed as intended and located above any live part.

Figure 26.1

Spray-head piping

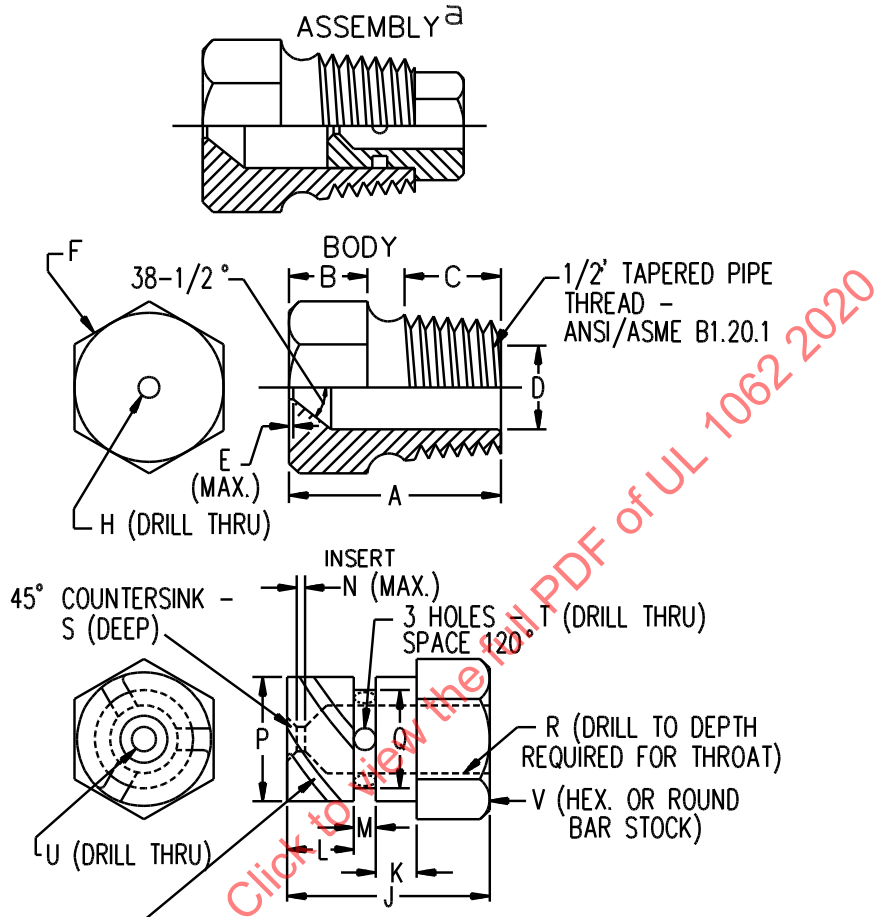


Item	inch	mm
A	28	710
B	55	1400
C	2–1/4	55
D	9	230
E	3	75

RT101D

Figure 26.2

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

27 Dielectric Voltage-Withstand Test

27.1 Applied potential

27.1.1 With regard to (a) and (b), a unit substation is to be subjected for 1 minute to the application of a 60 hertz essentially sinusoidal potential of 1000 volts plus twice the rated voltage. The results are acceptable if there is no dielectric breakdown. A transformer, coil, or other device normally connected between lines of opposite polarity is to be disconnected from one side of the line during the test in (b):

a) Between a live part and a dead metal part with all switching devices closed.

b) Between live parts of opposite polarity, with all switching devices closed.

Exception: A separate test of an electrostatic shield in a transformer is not necessary if there is no provision for field connection of the shield to ground or to a live part.

27.1.2 If an overcurrent device, such as a fuse or interchangeable trip unit, is not in place during the tests described in 27.1.1 (a) and (b), it is necessary to repeat these tests on the load side of the switching device or to install a shorting link in place of the missing fuse or trip unit during the tests.

27.1.3 The test potential is to be supplied from a 500 volt-ampere or larger capacity testing transformer, the output voltage of which can be varied. The applied potential is to be increased from zero at an essentially uniform rate and as rapidly as is consistent with its value being correctly indicated by the voltmeter until the required test value is reached, and is to be held at that level for 1 minute. The voltage is then to be reduced to zero at the same uniform rate.

Exception: A 500-volt ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter to measure directly the applied output potential.

27.1.4 If practicable, the dielectric voltage-withstand test on a unit substation is to be made with current carrying parts at intended operating temperatures.

27.2 Induced potential

27.2.1 A winding of the unit substation transformer shall be subjected to an alternating potential of twice the rated voltage with the ends of all other windings opened. The potential shall be applied for 60 seconds at any frequency not more than 120 hertz. For frequencies greater than 120 hertz, the potential need be applied for only 7200 cycles.

27.2.2 The test voltage required by 27.2.1 is to be initiated at one-fourth or less of the full value and brought up gradually to the full value in not more than 15 seconds. After being held for the time specified, the voltage is to be reduced slowly, but within 5 seconds, to 1/4 of the maximum value or less, and the circuit opened.

27.3 Clamped joint

27.3.1 With regard to 21.1.2 (d), a clamped joint between two insulators is to be tested using two samples.

a) The first sample is to have the clamped joint opened up to produce a space 1/8 inch (3.2 mm) wide. This may be accomplished by loosening the clamping means or by drilling a 1/8 inch diameter hole at the joint between the insulators at a point of minimum spacing between the metal parts on the opposite sides of the joint. The drilled hole shall not decrease spacings between the opposite polarity parts as measured through the crack between the insulators. The 60 hertz