UL 1008S

STANDARD FOR SAFETY

Solid-State Transfer Switches

UL Standard for Safety for Solid-State Transfer Switches, UL 1008S

First Edition, Dated November 15, 2012

SUMMARY OF TOPICS:

This revision of ANSI/UL 1008S dated April 22, 2025 includes the withdrawal and replacement of ANSI/ISA MC96.1, Temperature-Measurement Thermocouples, 32.12.

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated March 7, 2025.

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HISTORICAL NOTE

Prior to the publication of this first edition these requirements were covered by Supplement A of the Standard for Safety for Transfer Switch Equipment, UL 1008.

UL 1008S

Standard for Solid-State Transfer Switches

First Edition

November 15, 2012

This ANSI/UL Standard for Safety consists of the First edition including revisions through April 22, 2025.

The most recent designation of ANSI/UL 1008S as an American National Standard (ANSI) occurred on April 22, 2025. 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 ULSE at any time. Proposals should be submitted via a Proposal Request in ULSE's Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

INTRODUCTION

1 Scope

1.1 These requirements cover solid state automatic transfer switches intended for use in ordinary locations to provide for lighting and power only in optional stand-by systems in accordance with Article 702 of the National Electrical Code, ANSI/NFPA 70.

1.2 Solid-state transfer switches are not for use as service entrance equipment unless marked as such.

1.3 These requirements cover transfer switch equipment rated at 6000 A or less and 600 V or less.

1.4 These requirements cover transfer switches together with their associated control devices including voltage sensing relays, frequency sensing relays, time delay relays, and the like.

1.5 An automatic transfer switch as covered by these requirements is a device that automatically transfers a common load from a normal supply to an alternate supply in the event of failure of the normal supply, and automatically returns the load to the normal supply when the normal supply is restored.

Exception: An automatic transfer switch is allowed to be provided with a logic control circuit that inhibits automatic operation of the device from either a normal to an alternate supply, or from an alternate to a normal supply when the switch reverts to automatic operation upon loss of power to the load.

1.6 A non-automatic transfer switch as covered by these requirements is a device, operated manually by a physical action, or electrically by a remote control, for transferring a common load between a normal and alternate supply.

1.7 A transfer switch may incorporate overcurrent protection for the main power circuits.

1.8 These requirements cover completely enclosed transfer switches and also open types intended for mounting in other equipment such as switchboards.

1.9 Transfer switches are rated in amperes and are generally considered to be acceptable for total system transfer, which includes control of motors, electric-discharge lamps, electric-heating loads, and tungsten-filament lamp loads as referred to in 1.10.

1.10 A transfer switch intended for total system transfer as indicated in 1.9 is considered to be acceptable for the control of tungsten-filament lamp loads not exceeding 30 percent of the switch ampere rating unless the switch has been investigated for a higher percentage of lamp load and marked accordingly.

1.11 A transfer switch may be limited to use with one or more specific types of load if investigated accordingly and marked as indicated in 47.11.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

2.4 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.

2.5 A component not marked with a short-circuit current rating is considered rated for use in a circuit having a maximum available fault current as shown in Table 2.1.

2.6 The short-circuit current available in the secondary circuit of a transformer rated 10 kVA or less is considered to be 5000 amperes or less.

2.7 The short-circuit current available on the load side of a 15 ampere current-limiting circuit breaker or Class CC, G, J, RK1, RK5, or T fuse is considered to be 5000 amperes. In a single phase 120-volt circuit, the short-circuit current available on the load side of a 20 ampere circuit breaker or Class CC, G, J, RK1, RK5, or T fuse is considered to be 10,000 amperes or less.

Table 2.1
Assumed maximum short-circuit current ratings for unmarked components

Component	Short-circuit current rating, kA
1. Circuit breaker (including GFCI type)	5
2. Clock-operated switch	5
3. Fuseholder	10
4. Lighting fixture (circuit) internal	5
5. Miniature fuse	10[a]
6. Plug fuse	10
7. Industrial control equipment:	
a. Auxiliary device	5
b. Motor controllers or switches (other than mercury tube type)	5
c. Mercury tube switches:	
Rated over 60 amperes or over 250 volts	5
Rated 250 volts or less, 60 amperes or less, and over 2 kVA	3.5[b]
Rated 250 volts or less and 2 kVA or less	1[b]
8. Meter socket base	10
9. Photoelectric switches	5
10. Receptacle (GFCI type)	2
11. Receptacle (other than GFCI type)	10
12. Snap switch	5
13. Terminal block	10
14. Thermostat	5

Table 2.1 Continued on Next Page

Table 2.1 Continued

Component	Short-circuit current rating, kA
[a] The use of these fuses is limited to 125-volt circuits that do not leave the transfer switch.	
[b] This rating is below the minimum specified in Table 35.1 and the component shall either:	
1) Be investigated for the minimum short-circuit current rating specified in Table 35.1, or	
2) Be located on the load-side of a suitable current-limiting overcurrent protective device.	

3 Units of Measurement

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

4 Undated References

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

5 Glossary

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

5.2 ACCESSIBLE PART – A part located so that it can be contacted by a person, either directly or by means of a probe or tool during user servicing, or that is not recessed the required distance behind an opening.

5.3 BARRIER – A partition for the insulation or isolation of electric circuits, for the isolation of electric arcs, or for isolation of moving parts or hot surfaces. In this respect, a barrier may serve as a portion of an enclosure or as a functional part.

5.4 CONTROL CIRCUIT – A circuit that carries electric signals directing the performance of a transfer switch. A control circuit does not carry main power current.

5.5 ENCLOSURE – That portion of a transfer switch that reduces the accessibility and unintentional contact of a part that may involve a risk of fire, electric shock or injury to persons, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.6 LIVE PART – Denotes metal or conductive parts that, during intended use, have a potential difference with respect to ground or any other conductive part.

5.7 OPERATOR – Trained persons having familiarity with the construction and operation of the equipment, and the risks involved, including, but not limited to, persons who may periodically open a transfer switch to repair or maintain electrical or mechanical components.

5.8 POLLUTION DEGREE 1 – No pollution or only dry, nonconductive pollution occurs. The pollution has no influence.

5.9 POLLUTION DEGREE 2 – Normally, only nonconductive pollution occurs; however, temporary conductivity caused by condensation may be expected.

5.10 POLLUTION DEGREE 3 – Conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation that is expected.

5.11 PRIMARY CIRCUIT – Wiring and components that are conductively connected to the preferred or alternate source of supply or another branch circuit.

5.12 PRINTED-WIRING BOARD – The finished combination of a pattern of conductive paths either on, in, or both on and in (multilayer) a sheet of insulating material, including printed components, and the base material.

5.13 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any part if the potential between the part and earth ground or any other accessible part is greater than 42.4 V peak AC or 60 V DC, and the continuous current flow through a 1500 Ω resistor connected across the potential exceeds 5 mA.

5.14 RISK OF INJURY TO PERSONS – A condition that exists when stationary parts (such as sharp metal edges and projections), moving parts, falling objects, inadequate mechanical strength of material, or the physical instability of the equipment are such that injury to persons may result.

5.15 SECONDARY CIRCUIT – A circuit conductively connected to the secondary winding of an isolating power supply transformer.

5.16 SERVICING – Any form of servicing that can be performed by personnel other than those who are trained to maintain the unit. Some examples of user servicing are:

a) The installation of accessories.

b) The replacement of lamps and fuses, or the resetting of circuit breakers located in a user access area.

c) The making of routine operating adjustments necessary to adapt the unit for different intended functions.

d) Routine cleaning.

5.17 SWITCH, TRANSFER – An automatic or nonautomatic device for transferring load conductor connections from one power source to another.

5.18 TOOL – A hand-held implement, such as a wrench, screwdriver, or any other object that may be used during servicing, including a coin, key or other object that can be used to operate a lock, screw latch, or similar fastening means.

CONSTRUCTION

6 General

6.1 A transfer switch intended for use as service equipment shall comply with the applicable requirements for service equipment and be marked in accordance with 47.3.

7 Enclosure

7.1 An enclosure provided shall comply with the Standard for Industrial Control Equipment, UL 508. See also 7.2 and 7.3.

7.2 For a transfer switch intended for use as service equipment, the enclosure thickness shall not be less than 0.053 inch (1.35 mm) if of uncoated steel, 0.056 inch (1.42 mm) if of zinc–coated steel, and 0.075 inch (1.91 mm) if of aluminum.

7.3 The enclosure of a transfer switch may be provided with ventilating openings which comply with the requirements in 7.4 – 7.18.

7.4 A ventilating opening shall be designed and located so that no flame or molten metal is emitted during arcing normally encountered during acceptable performance of the overload test described in the Overload Test, Section 31, and the withstand and closing tests described in Withstand, Section 35.

7.5 Unless the opening is remote from the arcing part, the requirement in 7.4 necessitates the interposing of an acceptable barrier between a ventilating opening and a possible source of arcing such as a switch, fuse, and the like, as noted in 7.6 – 7.8.

7.6 The barrier shall be of such dimensions and so located that straight lines drawn from any arcing part past the edge of the barrier define an area at the plane of the opening 1/4 inch (6.4 mm) beyond the edges of the opening.

7.7 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 zinc-coated.

Exception: The barrier may be of steel of less thickness provided that its strength and rigidity is not less than that of a flat sheet of steel having the same dimensions as the barrier and having the specified thickness.

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

Exception: The thickness of a nonmetallic barrier may be less than 1/4 inch (6.4 mm) if the barrier is so located and supported that it is not subject to mechanical abuse during installation and is so located that it has acceptable strength and rigidity.

7.9 A ventilating opening in an enclosure shall have such size or shape, or shall be so covered by screening or by an expanded, perforated, or louvered metal panel, that a test rod having the diameter specified in 7.10 will not enter the opening.

7.10 The test rod mentioned in 7.9 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 (102 mm) or more from such parts.

7.11 A louver shall not be more than 12 inches (305 mm) long.

7.12 The size, shape, and location of a ventilating opening shall not unduly weaken the overall enclosure.

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

7.14 The 25 percent limitation mentioned in 7.13 may be exceeded provided that means of reinforcement, such as stiffeners, are employed and the enclosure complies with 7.12.

7.15 The area of an opening covered by a louvered, perforated, or expanded metal panel that is thinner than the enclosure, shall not exceed 200 square inches (0.129 m^2). A ventilated closing panel of 0.053 inch (1.35 mm) if uncoated, 0.056 inch (1.42 mm) if zinc-coated or thinner steel or wire mesh of 14 AWG

(1.63 mm diameter) or smaller wire shall not be used to enclose an opening of more than 80 square inches (0.052 m^2).

7.16 The wires of a screen of a ventilating opening shall not be smaller than 16 AWG (1.29 mm diameter) if the screen openings are 1/2 square inch (323 mm^2) or less in area, and not smaller than 12 AWG (2.05 mm diameter) for larger screen openings. A supplementary screen of smaller openings may be additionally provided. The supplementary screen shall not be considered in the evaluation of the ventilating opening screen.

7.17 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall not be less than 0.042 inch (1.07 mm) thick if uncoated, or 0.045 inch (1.14 mm) thick if zinc-coated, if the mesh openings or perforations are 1/2 square inch (323 mm^2) or less in area, and shall be not less than 0.080 inch (2.03 mm) thick if uncoated or 0.084 inch (2.13 mm) thick if zinc-coated for larger openings.

Exception: Where the indentation of a guard or enclosure cannot alter the clearance between uninsulated live parts and grounded metal so as to affect performance adversely or reduce spacings below the minimum values in Table 26.1, 0.020 inch (0.51 mm) if uncoated or 0.023 inch (0.58 mm) if zinc-coated expanded metal mesh may be employed. See 7.15.

7.18 A ventilating opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening to reduce the possibility of the entry of foreign material.

7.19 An enclosure shall be marked with a type number indicating the external conditions for which it is acceptable. See Table 7.1. The marking may be on the inside or outside surface, but shall be visible after installation. See 47.54.

Table 7.1
Enclosure types and tests

Designation	Intended use and description	Requirement or qualification tests[a]
1	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.	Rod Entry[b] and Rust Resistance or Corrosion Protection.
2	Indoor use to provide a degree of protection against limited amounts of falling water and dirt.	Drip, Rod Entry[b], and Rust Resistance or Corrosion Protection.
3	Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.	Outdoor Dust or Hose, Icing, Protection Against Corrosion, and Rain.
3R	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Icing, Protection Against Corrosion, Rain and Rod Entry.
3S	Outdoor use to provide a degree of protection against windblown dust, windblown rain, and sleet; external mechanisms remain operable while ice laden.	Outdoor Dust or Hose, Icing, Protection Against Corrosion, and Rain.
4	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure.	Hosedown, Icing and Protection Against Corrosion.
4X	Either indoor or outdoor use to provide a degree of protection against falling rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure; resists corrosion.	Hosedown, Icing, and Protection Against Corrosion.

Table 7.1 Continued on Next Page

Table 7.1 Continued

Designation	Intended use and description	Requirement or qualification tests[a]
6	Indoor or outdoor use to provide against the entry of water during temporary, limited submersion, undamaged by the formation of ice on the enclosure.	Icing, Protection Against Corrosion, and Submersion.
6P	Indoor and outdoor use to provide a degree of protection against the entry of water during prolonged submersion at limited depths.	Air Pressure, Icing, and Protection Against Corrosion.
12, 12K	Indoor use to provide a degree of protection against dust, dirt, fiber flyings, dripping water, and external condensation of noncorrosive liquids.	Indoor Dust or Atomized Water, Drip and Rust Resistance or Corrosion Protection
13	Indoor use to provide a degree of protection against lint, dust seepage, external condensation and spraying of water, oil, and noncorrosive liquids.	Oil and Rust Resistance or Corrosion Protection

[a] For description of tests, see the Standard for Enclosures for Electrical Equipment, UL 50.

[b] For description of tests, see 7.10.

7.20 An enclosure that complies with the requirements for more than one type of enclosure may have multiple designations.

7.21 An enclosure marked Type 3, 3S, 4, 4X, 6, or 6P may additionally be marked "Raintight" or "Rainproof". An enclosure marked Type 3R may additionally be marked "Rainproof". See 47.54.

7.22 An external operating means – such as those for a disconnect, a pilot device, or a resetting operation – mounted on or through an enclosure shall withstand the tests specified for the enclosure.

7.23 Marking and instructions on the exterior of an enclosure shall be permanent. See 48.1.

7.24 An enclosure shall be subjected to the tests specified in Table 7.1, and shall comply with the construction requirements applicable to an enclosure of the type number or numbers with which it is marked.

7.25 A watertight connection at conduit entrances shall be a conduit hub or the equivalent, such as a knockout or fitting, located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure is found to be acceptable when subjected to the tests specified in Table 7.1.

8 Connections for Wiring Systems

8.1 If knockouts are provided in the enclosure of transfer switches, they may be of any size; but at least two of them (or more when multiple conduits are involved) shall be so located that the installation of bushings will not result in spacings between live parts and bushings of less than the minimum requirements in Spacings, Section 26, when they are reamed for the size of conduit required for the maximum number and gauge of wires necessitated by the switch rating.

8.2 A conduit hub for rigid conduit shall be threaded. The hub shall have a wall thickness not less than that of the corresponding trade-size of rigid conduit before the hub is threaded. The conduit hub shall not depend upon friction alone to prevent its turning, and shall comply with the Conduit Hub Secureness Test, Section 43.

8.3 A tapped hole for the attachment of threaded rigid conduit shall be provided with:

a) An end-stop, or shall be so located that a standard bushing may be attached to the end of the conduit, and

b) A tapered thread in equipment for outdoor use, if not provided with an end stop, and

c) At least three full threads when tapped all the way through the wall of an enclosure, or with at least 3-1/2 full threads and a smooth, well-rounded inlet hole having a diameter approximately the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing.

9 Corrosion Protection

9.1 Iron and steel parts other than bearings and so forth, where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, Sherardizing, plating, or other equivalent means.

9.2 The requirement of 9.1 applies to all enclosing cases whether of sheet steel or cast iron, and to all springs and other parts upon which proper mechanical operation may depend. It does not apply to parts such as washers, screws, bolts, and the like, if any damage of such unprotected parts would not be likely to result in the equipment being affected adversely. Parts made of stainless steel (properly polished or treated, if necessary) do not require additional protection against corrosion. Bearing surfaces should be of such materials and construction to resist binding due to corrosion.

10 Insulating Material

10.1 Material for the support of uninsulated live parts shall be porcelain, phenolic or cold molded composition, or other material acceptable for the support of such parts, and shall be capable of withstanding the most severe conditions likely to be met in service.

10.2 Insulating material, including barriers between parts of opposite polarity and material that may be subject to the influence of the arc formed by the opening of a switch, shall be acceptable for the particular application.

11 Bases

11.1 A base, if consisting of a flat sheet of phenolic composition, shall not be less in thickness than indicated in Table 11.1.

Table 11.1
Thickness of bases

Maximum dimensions of base in inches (mm)	Minimum acceptable thickness of base in inches[a] (mm)[a]
15 x 24 (381 x 610)	3/8 (9.5)
24 x 48 (610 x 1220)	1/2 (12.7)
36 x 48 (914 x 1220)	5/8 (15.9)
larger than 36 x 48 (914 x 1220)	3/4 (19.1)

[a] Material of less thickness is acceptable if found to have the strength and rigidity required for the application.

11.2 A live screwhead or nut on the underside of a base designed for surface mounting shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and covered to a depth of not less than 1/8 inch (3.2 mm) with a waterproof, insulating sealing compound.

Exception: If the screw or nut is prevented from loosening by being staked or upset, by a lock washer, or by other means, it may be insulated from the mounting surface by material other than sealing compound or by providing a spacing from the mounting surface not less than that indicated in Table 26.1.

11.3 The sealing compound mentioned in 11.2 shall not melt at a temperature 15°C (27°F) higher than its operating temperature, and not less than 90°C (194°F) in any case.

11.4 A determination of the softening point of a sealing compound shall be made in accordance with the Test for Softening Point by Ring and Ball Apparatus, ASTM E28 (1992).

12 Mounting of Parts

12.1 All parts of transfer switches shall be securely mounted in position and prevented from loosening or turning if such motion may affect adversely the intended performance of the equipment, or may affect the risk of fire and injury to persons incident to the operation of the equipment.

12.2 Uninsulated live parts other than pressure wire connectors, shall be secured to their supporting surfaces so that they will be prevented from turning or shifting in position if such motion may result in a reduction of spacings to less than those indicated in Table 26.1. The security of contact assemblies shall be such as to provide the continued alignment of contacts. See 26.17.

12.3 Friction between surfaces is not acceptable as a means to prevent turning, loosening, or shifting of a part as required in 12.1 and 12.2, but a lock washer, properly applied, may be accepted.

13 Guarding and Accessibility of Live Parts

13.1 Uninsulated live parts of control circuits mounted on doors shall be guarded or enclosed, to reduce the risk of unintentional contact, when the door is opened for maintenance of equipment or removal of drawout equipment.

Exception: Uninsulated live parts of control circuits that operate at less than 30 V and are supplied in accordance with 26.10 need not be so guarded or enclosed.

13.2 Any barrier intended to be removed during routine maintenance or servicing shall be marked in accordance with 47.53.

14 Currrent-Carrying Parts

14.1 A current-carrying part shall have mechanical strength and current-carrying capacity for the service, and shall be of metal that is acceptable for the particular application.

14.2 If parts are held together by screws, a threaded part shall have no fewer than two full, clean-cut threads engaged. If the screw does not extend all the way through a threaded part, the taper or lead and the first full thread are to be disregarded in a determination of the number of threads engaged.

15 Field Wiring Terminals

15.1 Transfer switch equipment shall be provided with terminals (pressure wire connectors) for the connection of each conductor intended to be field installed. The terminals shall be sized to accommodate conductors having an ampacity equal to or greater than the current rating of the circuit for which they provide connection.

Exception No. 1: A wire binding screw is not prohibited from being provided as noted in 15.6.

Exception No. 2: No terminals are required in a transfer switch intended for connection to bus bars.

Exception No. 3: Terminal connectors for field connection (line or load) are not required to be provided when all the following conditions are met:

a) Component terminal assemblies shall be available from the transfer switch manufacturer, or one or more pressure terminal connectors shall be specified for field installation on the transfer switch;

b) Fastening devices such as studs, nuts, bolts, washers, and similar parts, as required for an effective installation shall either be provided as part of the component terminal assembly, or be mounted on or separately packaged with the transfer switch; and

c) Marking is provided in accordance with 47.43 and 47.44.

15.2 With reference to conductor ampacity in 15.1, sizes of field-installed conductors shall be determined as follows. For current specified in Table 15.1:

a) 75°C (167°F) ampacity shall be used for 1/0 AWG (53.5 mm^2) or larger conductors and

b) 60°C (140°F) ampacity shall be used for 1 AWG (42.2 mm^2) or smaller conductors.

Exception: 75°C ampacity shall be used for 1 AWG or smaller conductors when the switch is marked 75°C wire in accordance with 47.41.

Table 15.1
Ampacity of insulated conductors[a,b]

Wire size		60°C (140°F)		75°C (167°F)	
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	40
6	13.3	55	40	65	50
4	21.2	70	55	85	65
3	26.7	85	65	100	75
2	33.6	95	75	115	90
1	42.4	100	85	130	100
1/0	53.5			150	120
2/0	67.4			175	135
3/0	85			200	155
4/0	107.2			230	180
250	127			255	205
300	152			285	230
350	177			310	250
400	203			335	270
500	253			380	310
600	304			420	340

Table 15.1 Continued on Next Page

Table 15.1 Continued

Wire size		60°C (140°F)		75°C (167°F)	
700	355			460	375
750	380			475	385
800	405			490	395
900	456			520	425
1000	507			545	445
1250	633			590	485
1500	760			625	520
1750	887			650	545
2000	1010			665	560

[a] For a multiple-conductor at a terminal, the value shall be multiplied by the number of conductors that the terminal accommodates (1/0 AWG or larger).

[b] These values of ampacity apply only when not more than 3 conductors are intended to be field installed in the conduit. When 4 or more conductors, other than a neutral that carries the unbalanced current, are intended to be installed in a conduit (which is possible because of the number of conduit hubs provided in an outdoor switch, because the number of wires in certain polyphase systems, or other reasons) the ampacity of each of those conductors is 80 percent of the value given in the when 4 – 6 conductors are involved, and 70 percent of that value when 7 – 24 conductors are involved.

15.3 A wiring terminal without a marked wire size range shall hold the next larger size conductor than that specified in 15.2 when the terminal is sized to receive the larger size conductor.

Exception: This requirement does not apply to equipment marked to restrict its use to the smaller size conductor.

15.4 The terminal (pressure wire connector) provided shall be the same type as employed during the short-circuit test.

Exception No. 1: Alternate wire connectors are not prohibited from being used in a transfer switch without conducting a short circuit test when the short circuit current let-through divided by the number of conductors per phase results in a current of 50,000 A RMS (70,700 A peak) per conductor or less, and the short circuit current rating of the transfer switch is less than 100,000 A RMS.

Exception No. 2: Alternate wire connectors are not prohibited from being used in a transfer switch in which the short circuit current rating per conductor is greater than 50,000 A without conducting a short circuit test providing the short-circuit current rating of the transfer switch is less than 100,000 A, and the following conditions are met:

a) The number of conductors per lug is equal to or greater than the number of conductors as tested, and

b) The average pullout force – in accordance with the Standard for Wire Connectors, UL 486A-486B – of three samples of the alternate wire connector is equal to or greater than the average pullout force of three samples of the wire connectors used in the short circuit test.

15.5 Pressure wire connectors shall be employed for 8 AWG (8.4 mm^2) and larger conductors. For 10 AWG (5.3 mm^2) and smaller wires, the parts to which wiring connections are made shall consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

15.6 If a wire-binding screw is employed, the screw shall not be smaller than No. 8 (4.2 mm diameter); except that a No. 6 screw (3.5 mm diameter) may be used for the connection of a 14 AWG (2.1 mm^2) or smaller conductor.

15.7 A wire-binding screw shall thread into metal.

15.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick for a No. 8 (4.2 mm diameter) or larger screw, and not less than 0.030 inch (0.76 mm) thick for a No. 6 (3.5 mm diameter) screw, and shall have no fewer than two full threads in the metal.

Exception: A terminal plate may have the metal extruded at the tapped hole for the binding screw so as to provide two full threads. Other constructions may be employed if they provide equivalent ruggedness of the terminal plate and thread security of the wire-binding screw.

15.9 A pressure wire connector provided with or specified for use with a transfer switch shall comply with the Standard for Wire Connectors, UL 486A-486B.

15.10 The tightening torque for a field-wiring terminal shall be as specified by the transfer switch manufacturer and shall be marked as required by 47.52. The specified tightening torque shall not be 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 transfer switch. See 47.1.

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

16 Field Wiring Leads

16.1 The requirements described in 16.2 – 16.5 apply to leads provided at the factory for wiring in the field:

16.2 The field wiring leads of a transfer switch shall be sized in accordance with 15.1.

16.3 A field wiring lead shall be provided with strain relief. The strain relief shall reduce transmittal of forces due to compression, tension, or rotation to the leads of terminals, splices, or wiring within the switch. The strain relief shall reduce the likelihood of displacement that is able to result in:

a) Mechanical damage to the leads,

b) Exposure of the leads to a temperature higher than its rated temperature,

c) Reduction of spacings that force the lead to contact other than intended live parts, or

d) Other detrimental effects.

16.4 The strain relief mentioned in 16.3 shall withstand the stress of normal handling without damage to itself or the equipment. See Strain Relief Tests for Leads, Section 42.

16.5 Green coloring with or without one or more yellow stripes and white or gray coloring shall not be used for the covering of a conductor unless intended for connection to grounding and grounded conductors respectively.

16.6 The free length of a wiring lead shall be as required for the application, but not less than 6 inches in length.

17 Conduit

17.1 When conduit is supplied at the factory, the size, length, wiring ampacity, and fittings shall comply with the requirements of Safety Requirements for Special Equipment (Chapter 3) of the National Electrical Code, ANSI/NFPA 70.

17.2 If leads are provided and brought out through factory-attached conduit, a conduit fitting shall be provided at the free end of the conduit, or the conductor insulation at the free end of the conduit shall be protected from the sharp edges of the conduit during shipping by means of a tape wrap, a fiber bushing secured in place, or the equivalent.

17.3 If conduit is supplied, the enclosure shall be accessible to tighten the locknut of the conduit or conduit fitting.

Exception No. 1: Access to the fitting or locknut is not required if the conduit opening is threaded and complies with the Standard for Enclosures for Electrical Equipment, UL 50.

Exception No. 2: Access to the fitting or locknut is not required if a conduit hub is used.

18 Inlets for Generator Connection

18.1 The requirements of 18.2 – 18.7 apply to enclosed multiple pole power inlets which are intended for use with transfer equipment to provide means for cord connection to a portable generator. These requirements do not apply to inlets consisting of single pole separable connectors.

18.2 The inlet shall be of a construction with male phase and neutral mating contacts. An inlet shall have a rating no less than the rating of the transfer switch to which it is intended to be connected.

18.3 The inlet shall have sufficient number of poles to accommodate the ground, neutral, and all ungrounded supply conductors in one connector.

18.4 The inlet shall be of a design such that the ground connection is the first connection made when inserting a plug, and is the last connection to be opened when removing the plug.

18.5 The inlet shall be suitable for connection and disconnection under load.

18.6 The inlet shall be completely enclosed. When intended for outdoor use in wet locations, enclosures shall comply with all requirements for Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosures, as detailed in Enclosure, Section 7, with the cord connector installed as well as with the connector withdrawn.

18.7 Enclosed power inlets shall comply with 47.62, 47.63, and 47.64.

19 Transfer Switches with Integral Inlets for Generator Connections

19.1 The requirements in 19.2 – 19.7 are applicable to transfer equipment that is provided with an integral multiple pole inlet or with single pole separable connectors for cord connection to a portable generator.

19.2 An integral multiple pole inlet or single pole separable connector shall be of a construction with male phase and neutral mating contacts, and shall have a rating no less than the rating of the portion of the transfer switch to which it is connected.

19.3 An integral multiple pole inlet shall have sufficient number of poles to accommodate the ground, neutral, and all ungrounded supply conductors in one connector. When single pole separable connectors are provided, there shall be a sufficient number to accommodate the ground, neutral, and all ungrounded supply conductors, and these connectors shall be grouped together.

19.4 An integral multiple pole inlet shall be of a design such that the ground connection is the first connection made when connecting the mating connector, and is the last connection to be opened when removing the mating connector.

19.5 An inlet shall be rated for connection and disconnection under load.

19.6 Other than as noted in 19.7, a multi-pole or separable single pole inlet shall be arranged such that the current carrying parts of the inlet are energized only when the mating attachment connector is connected to the inlet.

19.7 For separable single pole inlets, 19.6 applies only upon connection of all of the connectors for all phases. The marking of 47.68 shall be provided.

19.8 Separable single pole inlets may be paralleled only when the inlets are rated more than 200 A. Multi-pole connectors shall not be used in parallel.

19.9 Transfer equipment with an inlet which is intended for outdoor use in wet locations shall comply with the requirements for Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosures, as detailed in Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, with the cord connector installed as well as with the connector withdrawn. Transfer equipment with an inlet which is intended only for use in dry locations, shall comply with 47.64.

19.10 Transfer equipment with an inlet shall be provided with branch circuit protection for the circuits supplied through the inlet, or shall be marked in accordance with 47.59. The rating of the branch circuit protection shall not be greater than the rating of the inlet. Where multiple inlets are connected in parallel, the rating of the branch circuit protection shall be not greater than the sum of the ratings of the inlets.

19.11 When provided with an inlet, transfer equipment that does not switch the neutral conductor shall be marked in accordance with 47.60.

19.12 When provided with an inlet, transfer equipment that switches the neutral conductor shall be marked in accordance with 47.61.

19.13 Transfer equipment with a multiple pole inlet or with single pole separable connectors shall comply with 47.64.

19.14 Other than as noted in 19.15, single pole separable connectors shall be mechanically interlocked in such a manner that mating connectors must be connected in the following sequence and disconnected in the reverse order:

a) Equipment-grounding conductor connection; then

b) Grounded circuit conductor connection, if provided; and then

c) Ungrounded conductor connections.

19.15 Transfer equipment, with separable single pole connectors rated above 200 A, need not comply with 19.14 when marked in accordance with 47.65 – 47.67.

20 Internal Wiring

20.1 The internal wiring of transfer switches shall consist of general use wire or appliance wiring material acceptable for the particular application when considered with respect to the temperature and voltage and conditions of service to which the wiring is likely to be subjected.

20.2 Appliance wiring material of one or more of the types indicated in Table 20.1 may be used for internal wiring when considered with respect to the requirements in 20.1.

20.3 Appliance wiring material having lesser thicknesses of insulation than those indicated in Table 20.1 may be used for a particular application, provided the insulation, when considered with respect to temperature and voltage and condition of service, is equivalent to one of those given in that table.

Table 20.1
Appliance-wiring material

Type of insulation	Minimum acceptable thickness of insulation	
	600-V applications	300-V applications
Thermoplastic	0.028 inch (0.71 mm)	0.028 inch (0.71mm)[a]
Rubber	0.028 inch (0.71 mm) plus an impregnated-braid cover	0.013 inch (0.33 mm) plus an impregnated-braid cover, or 0.028 inch (0.71 mm) without a braid cover
Neoprene	0.041 inch (1.04 mm)	0.013 inch (0.33 mm) plus an impregnated-braid cover, or 0.028 inch (0.71 mm) without a braid cover
Silicone	0.028 inch (0.71 mm) plus an impregnated-braid cover 0.028 inch (0.71 mm) without a braid cover[b]	0.013 inch (0.33 mm) plus an impregnated-braid cover[b] 0.028 inch (0.71 mm) without a braid cover

[a] May be 0.013 inch (0.33 mm) only for short, moving pigtails or coil leads in a small device, provided such leads make no more than casual contact with parts of opposite polarity and with grounded parts.

[b] Only if routed away from live parts of opposite polarity and protected from mechanical damage both during installation of field wiring and while in operation, unless material has resistance to mechanical damage equivalent to 0.028 inch (0.71 mm) with braid.

20.4 Supplementary insulation, such as coated-fabric or extruded thermoplastic insulating tubing, shall not be adversely affected physically or electrically by the temperature to which it may be subjected in service.

20.5 Wireways shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like, which may cause abrasion of the conductor insulation. Holes in sheet-metal walls through which insulated wires pass shall be provided with a bushing if the wall is 0.042 inch (1.06 mm) or less thick. Holes in walls thicker than 0.042 inch shall have smooth, well-rounded edges.

20.6 All joints and connections shall be mechanically secure and shall provide effective electrical contact without strain on connections and terminals.

20.7 Stranded conductors clamped under wire-binding screws or similar parts shall have the individual strands restrained by being soldered together or by cupped washers or the equivalent to provide connections.

20.8 A splice shall be provided with insulation equivalent to that of the wires involved.

21 Grounding and Bonding

21.1 Transfer switches shall have provision for grounding all dead metal parts that are exposed or that are likely to be touched by a person during adjustment or intended operation of the device, and that are likely to become energized.

21.2 Small, isolated (insulated) dead metal parts are not required to be grounded.

21.3 The provision of a knockout or other opening in a metal enclosure for the connection of armored cable, conduit, metal raceway, or the like is acceptable as means for grounding.

21.4 A transfer switch marked as being acceptable for use as service equipment shall have provision for connection of the grounding electrode conductor to the grounded service conductor. The size of the grounding electrode conductor shall be assumed to be in accordance with Table 21.1. A soldering lug or other connection means that depends upon solder is not acceptable.

21.5 The provision for connection of the grounding-electrode conductor mentioned in 21.4 shall be on the neutral, if a neutral is provided.

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

21.6 A transfer switch that is marked for service equipment use shall have a terminal for a grounded service conductor even though it has no provision for a load conductor to be connected to the grounded service conductor. If there is no provision for such a grounded load conductor, the grounded service conductor terminal shall:

a) Accommodate a conductor of the same size as the main bonding jumper specified in Table 21.1,

b) Be bonded to the enclosure, or have provisions for being bonded, and

c) Be directly connected to the grounding electrode conductor terminal, or have provisions for being directly connected to the grounding electrode conductor terminal.

Exception: The terminals may be omitted if the transfer switch is marked as covered in 47.10.

Table 21.1
Size of grounding electrode conductors and main bonding jumper

Ampere rating not exceeding	Size of main bonding jumper (minimum)[e,g,h]		Cross section of main bonding jumper in square inches (mm^2) (minimum)[e,g]				Size of grounding electrode conductor (minimum)	
	Copper	Aluminum	Copper		Aluminum		Copper	Aluminum
90	8 AWG	6 AWG	0.013[a]	(8.4)[a]	0.021[a]	(13.5)[a]	8 AWG	6 AWG
100	6	4	0.021[a]	(13.5)[a]	0.033[a]	(21.3)[a]	6	4
125	6	4	0.021[a]	(13.5)[a]	0.033[a]	(21.3)[a]	6	4
150	6	4	0.021[b]	(13.5)[b]	0.033[b]	(21.3)[b]	6	4
200	4	2	0.033[b]	(21.3)[b]	0.052[b]	(33.5)[b]	4	2
225	2	0	0.052[c,d]	(33.5)[c,d]	0.083[c,d]	(53.5)[c,d]	2	0

Table 21.1 Continued on Next Page

Table 21.1 Continued

Ampere rating not exceeding	Size of main bonding jumper (minimum)^{e,g,h}		Cross section of main bonding jumper in square inches (mm^2) (minimum)^{e,g}				Size of grounding electrode conductor (minimum)	
	Copper	Aluminum	Copper		Aluminum		Copper	Aluminum
400	0[f]	3/0[f]	0.083[d,f]	(53.5)[d,f]	0.132[d,f]	(85.2)[d,f]	0[f]	3/0[f]
500	0	3/0	0.083	(53.5)	0.132	(85.2)	0	3/0
600	2/0	4/0	0.105	(67.7)	0.166	(107)	2/0	4/0
800	2/0	4/0	0.105	(67.7)	0.166	(107)	2/0	4/0
1000	3/0	250 MCM	0.132	(85.2)	0.196	(126)	3/0	250 MCM
1200	250 MCM	250	0.177	(114)	0.196	(126)	3/0	250
1600	300	400	0.236	(152)	0.294	(190)	3/0	250
2000	400	500	0.294	(190)	0.353	(228)	3/0	250
2500	500	700	0.353	(228)	0.515	(332)	3/0	250
3000	600	750	0.412	(266)	0.589	(380)	3/0	250
4000	750	1000	0.589	(380)	0.810	(523)	3/0	250

[a] A No. 8 (4.2 mm diameter) or larger brass or No. 10 (4.8 mm diameter) or larger steel screw may be used.

[b] A No. 10 or larger brass or steel screw may be used.

[c] A No. 10 or larger brass screw maybe used.

[d] A 1/4 inch (6.4 mm) diameter or larger brass or steel screw may be used.

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

[f] When the ampere rating is 400 and the wire terminal connectors for the main service conductors are acceptable for two 3/0 AWG copper or two 250 MCM aluminum conductor, but will not accept a 600 MCM conductor, these values may be reduced to 2 AWG (0.052 square-inch) (33.5 mm^2) copper or 0 AWG (0.083 square-inch) (53.5 mm^2) aluminum.

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

[h] These are also sizes for the grounded service conductor of 21.5.

21.7 A transfer switch marked as being acceptable for service equipment shall be provided with a main bonding jumper consisting of a separate screw, strap, or other means to bond the enclosure to the grounded circuit conductor of an alternating–current circuit, and the construction shall be such that when the bonding means is not used, the spacings given in Table 26.1 will exist. Unless the intended use and method of installation of the bonding means are obvious, instructions for its installation shall be provided.

21.8 If there is provision for a load conductor to be connected to the grounded service conductor, a conductor or terminal connected to the grounded service conductor shall be insulated from the enclosure as the unit is shipped from the factory.

21.9 The main bonding jumper shall be of copper or aluminum and shall have a cross sectional area as specified in Table 21.1.

Exception: Steel or brass screws may be used as covered in the footnotes of Table 21.1.

22 Disconnecting Means

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

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

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

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

22.5 The grounding-electrode conductor terminal covered in 21.4 and the main bonding jumper covered in 21.5 shall connect to the neutral on the supply side of the service disconnecting means for the neutral covered in 21.1. See 21.5.

23 Power Switch Assembly

23.1 A transfer switch shall be constructed to provide reliable and positive electrical and mechanical performance under all conditions of intended operation.

23.2 Provision shall be made to reduce the possibility of adjusting screws and similar adjustable parts from loosening under the conditions of actual use.

23.3 An automatic transfer switch shall incorporate the required control equipment to initiate transfer from the normal supply to the alternate supply upon the interruption of any or all phases of the normal supply.

23.4 An automatic transfer switch shall be permitted to be additionally controlled by equipment to provide a time delay in either or both directions of transfer. Equipment shall also be permitted to be provided to initiate transfer under low normal voltage conditions and by voltage-frequency measurement in the alternate supply.

23.5 A transfer switch intended for use with parallel engine-generator sets may be arranged to disconnect from the alternate source (generators) in the event of shutdown of one or more of the paralleled engine-generator sets. See 47.17.

23.6 A transfer switch marked for service equipment use in accordance with 47.3 or 47.5 shall be provided with an externally accessible, manually operable means to disconnect all ungrounded supply conductors of both the normal and the alternate sources under any condition of the normal and alternate supplies. The disconnect device shall provide an air gap between each ungrounded source conductor and the inputs to the transfer switch.

23.7 An externally operable disconnect means shall be capable of being operated without exposing the operator to contact with live parts.

23.8 A transfer switch that incorporates integral overcurrent protective devices in the main power circuits and that will not automatically transfer from one source to another as a result of the opening of one or more of these overcurrent devices shall be marked in accordance with 47.18.

23.9 A transfer switch provided with means to permit manual transfer shall have such means externally operable without opening the enclosure.

23.10 Means shall be provided to reduce the possibility of automatic operation during the manual transfer if automatic operation can result in risk of electric shock or injury to operating personnel.

23.11 If the means used to comply with 23.12 renders the control circuit non-functional, audio, or visual signals or equivalent means shall be provided to indicate the status of the control circuit.

23.12 An automatic transfer switch shall be provided with at least one manually operated dead front test switch to simulate loss of the normal supply or provision shall be made for the connection of a remote test switch or switches.

23.13 Circuits for remote test switches for automatic transfer switches shall be arranged so that shorting or opening of the circuit or test switch does not reduce the possibility of transfer to the alternate source in the event of loss of the normal source.

23.14 Control circuits that are depended upon for the proper operation of a transfer switch shall be located wholly within the transfer switch enclosure and shall not have overload protective devices connected in them, but may have short-circuit and ground-fault protection.

Exception No. 1: The control circuit of a transfer switch shall have short-circuit protection and a disconnecting means suitable for the available current of the supply if the transfer switch is marked for service equipment use in accordance with 47.3 or 47.5 and its control circuit is connected ahead of the service disconnecting means.

Exception No. 2: There may be provision for extending the control circuits from a transfer switch to an adjacent by-pass/isolation switch or to (an) external engine-generator set(s), if a marking indicates that the control circuit wiring shall be in conduit. See 47.29.

Exception No. 3: In a transfer switch limited to use on an optional standby systems in accordance with Article 702 of the National Electrical Code, the control circuit may extend outside the enclosure if misoperation of the circuit cannot result in asynchronous paralleling of the two sources.

24 Ground-Fault Protection

24.1 A transfer switch marked for use as service equipment for 3-phase, 4-wire, wye-connected services rated in excess of 1000 A and 150 V to ground, but not exceeding 600 V phase-to-phase, shall be provided with ground-fault protection. The ground-fault sensing and relaying equipment provided shall operate to cause the service disconnecting means to open all ungrounded conductors of the faulted circuit. The maximum setting of the ground–fault protection shall be 1200 A.

Exception No. 1: If each service disconnecting means rated 1000 A or more is provided with a shunt trip that is acceptable for use with ground-fault protection, the ground-fault sensors or relaying equipment or both may be in a separate enclosure if the combination is found acceptable and the transfer switch is marked as required by 47.49.

Exception No. 2: Ground-fault protection need not be provided for a transfer switch marked in accordance with 47.50.

Exception No. 3: Ground-fault protection need not be provided on that side of a transfer switch intended for connection to the alternate source, provided that the transfer switch is marked in accordance with 47.51.

24.2 A transfer switch intended and marked for use as a disconnecting device in conjunction with Class I ground-fault sensing and relaying equipment shall have means to reduce the possibility of automatic opening (lockout) if the current in any phase exceeds 850 percent of the switch ampere rating unless tested in accordance with Table 24.1.

Table 24.1
Contact opening – current multiplier

Type of switch	Test current
Electrically tripped – Without integral lockout – For use with Class 1 ground-fault sensing and relaying equipment	10 times rated

24.3 Compliance with the requirements specified in 24.1 anticipates that each service disconnect device to which the requirement applies is provided with automatic tripping means for actuation by ground–fault sensing and relaying equipment that may, although not required, be a part of the service disconnect device.

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

Exception: As specified in Exception No. 1 to 24.1.

24.5 If ground-fault protection is provided, although not required in 24.1, it shall comply with the requirements for the installation of ground-fault protection equipment as specified in these requirements.

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

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

24.8 A ground-fault protection system described as the ground return type that employs a single sensing element to detect the actual fault current shall be installed in such a manner that the sensing element detects any current that flows in the grounding electrode conductor, the main bonding jumper, and any other grounding connections within the equipment that may be made to the neutral. This requires that, except for these connections, the neutral be insulated from the noncurrent-carrying metal as covered in 26.18.

24.9 If the design of ground-fault sensing and relaying equipment necessitates a reset operation for restoring the equipment to functional status following operation due to a ground fault or test, the design shall reduce the possibility of 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.

Exception: The reset means may be incorporated in the disconnect device.

24.10 Overcurrent protection is not required for the operating coil (such as the shunt trip of a circuit breaker) used with ground-fault protection in which the coil is connected to the load side of the transfer switch.

24.11 The primary of a ground-fault protection control-circuit transformer may be connected on the line or load side of the main disconnect. The primary of the control circuit transformer shall be connected to two line-voltage parts (not to line and neutral). When connected to the line side of the main, a fused disconnect switch or circuit breaker acceptable for service equipment and providing overcurrent protection shall be installed ahead of the transformer or control circuit or both. Overcurrent protection is not required for the control circuit when wired to the load side of the main disconnect unless the control circuit wiring leaves the enclosure.

24.12 In equipment incorporating ground-fault protection of the ground-return type as described in 24.8, the main bonding jumper shall be factory connected to the neutral bus and to the enclosure or the ground bus.

24.13 A transfer switch having ground-fault protection shall be subjected to a factory test as described in Manufacturing and Production Tests, Section 45, and shall be marked as specified in 47.46 – 47.49.

25 Transformer Grounding

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

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

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

25.2 If a transformer secondary is required to be grounded in accordance with 25.1, a main bonding jumper shall be factory connected to the transformer secondary and to the enclosure or ground bus. The size of the main bonding jumper shall be as specified in Table 21.1 based on the transformer-secondary current rating. A grounding-electrode conductor connector of a size complying with Table 21.1 shall be provided on the neutral or on the ground bus.

26 Spacings

26.1 The spacing in transfer switches shall not be less than those indicated in Table 26.1.

Exception: The spacings indicated in Table 26.1 do not apply across switching contacts.

26.2 Spacings in a component used in power circuits, such as industrial control equipment, nonautomatic circuit interrupters and the like within a transfer switch shall comply with the requirements applicable to that component, except that the spacings to the overall enclosure (other than inherent spacings) and spacings between individual components shall comply with Table 26.1.

26.3 The spacings in a component device (such as a snap switch, lampholder, and the like) supplied as part of a transfer switch, other than in a power circuit, are not less than the minimum spacings required for the component device or the spacings indicated in Table 26.1 whichever are smaller.

Table 26.1
Minimum acceptable spacings in inches (mm)

Potential involved in volts		Power circuits rated 400 A maximum and control circuits					
		51 – 150		151 – 300		301 – 600	
Between any uninsulated live part and an uninsulated live part of opposite polarity	Through air or oil	1/8[a]	(3.2)[a]	1/4	(6.4)	3/8	(9.5)
	Over surface[d,e]	1/4	(6.4)	3/8	(9.5)	1/2	(12.7)
Between any uninsulated live part and an uninsulated grounded part, other than the enclosure, or exposed metal part	Through air or oil	1/8[a]	(3.2)[a]	1/4	(6.4)	3/8	(9.5)
	Over surface[d,e]	1/4	(6.4)	3/8	(9.5)	1/2	(12/7)
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable[b]	Shortest distance[d,e]	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)
Potential involved in volts		**Power circuits rated over 400 A**					
		51 – 150		**151 – 300**		**301 – 600**	
Between any uninsulated live part and an uninsulated live part of opposite polarity	Through air or oil	1/2	(12.7)	3/4	(19.1)	1	(25.4)
	Over surface[d,e]	3/4	(19.1)	1-1/4	(31.8)	2	(50.8)
Between any uninsulated live part and an uninsulated grounded part, exposed metal part, or walls of a metal enclosure, including fittings for conduit or armored cable[b]	Through air or oil	1/2	(12.7)	1/2	(12.7)	1[c]	(25.4)[c]
	Over surface[d,e]	1/2	(12.7)	1/2	(12.7)	1	(25.4)

[a] The spacing between wiring terminals of opposite polarity and the spacing between a wiring terminal and a grounded part shall not be less than 1/4 inch (6.4 mm) if short-circuiting or grounding of such terminals may result from projecting strands of wire.

[b] For the purpose of this requirement, a metal piece attached to the enclosure shall be considered a part of the enclosure if deformation of the enclosure is likely to reduce spacings between the metal piece and uninsulated live parts.

[c] A through-air spacing of not less than 1/2 inch (12.7 mm) is acceptable (1) at the main terminals, and (2) between grounded dead metal and the neutral of a 277/480 V, 3-phase, 4-wire transfer switch.

[d] In measuring over-surface spacings, any slots, grooves, and the like, 0.013 inch (0.33 mm) wide or less in the contour of insulating material are to be disregarded.

[e] An air space of 0.013 inch (0.33 mm) or less between a live part and an insulating surface shall be disregarded and the part shall be considered in contact with the insulating material when measuring spacings.

26.4 In applying Table 26.1 it shall be 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 on an insulated neutral to grounded dead metal equals the line-to-neutral voltage of the system.

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

26.5 Terminals and other parts intended to be connected to the grounded conductor of a circuit are to be considered uninsulated live parts unless such parts are mounted directly on or in permanent electrical connection with grounded dead metal.

26.6 If the connection mentioned in 26.5 is solely by means of a screw, strap, or other bonding device that can be readily removed and is not depended upon to perform a mechanical function, the transfer switch shall:

a) Comply with the requirement in Table 26.1 when the bonding device is removed, or

b) Be marked as described in 47.8.

26.7 Spacings provided on printed wiring boards may be less than indicated in Table 26.1, but not less than 1/32 inch (0.8 mm) provided the board is coated or encapsulated and an investigation is conducted to determine the acceptability of the coating or encapsulation.

26.8 The investigation mentioned in 26.7 is to include temperature and humidity conditioning, preceded and followed by dielectric voltage-withstand tests. Flammability tests are to also be conducted on the combination of the coating or encapsulation and the board.

26.9 Control circuits are defined as those circuits that sense and control the transfer from normal to alternate power sources.

26.10 In a circuit involving potential of not more than 50 V, spacings at field–wiring terminals may be 1/8 inch (3.2 mm) through air and 1/4 inch (6.4 mm) over surface, and spacings elsewhere may be 1/16 inch (1.6 mm) through air and over surface, provided that insulation and clearances between the low potential circuit and any high potential circuit are in accordance with the requirements that are applicable to the high-potential circuit. Spacings are not specified for a circuit involving a potential of not more than 30 V and supplied by a primary battery or by a Class 2 transformer or by a combination of transformer and fixed impedance having output characteristics in compliance with those required for a Class 2 transformer.

26.11 In 26.12 – 26.16, the liner or barrier referred to is insulating material that separates uninsulated live parts of opposite polarity, or separates an uninsulated live part and a grounded dead-metal part – including the enclosure – where the through–air spacing between the parts would otherwise be less than the required value.

26.12 A barrier or liner that comprises the sole separation:

a) Shall be of material acceptable for supporting an uninsulated live part, except that a barrier between the enclosure and an uninsulated part electrically connected to a grounded circuit conductor (neutral) may be of fiber.

b) Shall be not less than 0.028 inch (0.71 mm) thick, unless a lesser thickness is found to be acceptable for the particular application.

26.13 A barrier or liner used in conjunction with an air space shall be not less than 0.028 inch (0.71 mm) thick, unless a lesser thickness is found to be acceptable for the particular application or the barrier is used in conjunction with an air space of one-half or more of the required spacings as described in 26.15.

26.14 If the barrier mentioned in 26.13 is of material, other than fiber, that is not acceptable for the support of uninsulated live parts, the air space shall be acceptable for the particular application.

26.15 A barrier or liner used in conjunction with an air space of one-half or more of the required through-air spacing may have a thickness of not less than 0.013 inch (0.33 mm) if it is:

a) Of material acceptable for supporting uninsulated live parts,

b) Of adequate strength if exposed or otherwise likely to be subjected to physical damage,

c) Reliably held in place, and

d) So located that it will not be adversely affected by operation of the equipment in service.

Exception: Insulating material having a thickness less than 0.013 inch (0.33 mm) may be accepted if it is found to be acceptable for the particular application.

26.16 In measuring between an uninsulated live part and a bushing installed at a knockout, it shall be assumed that a bushing having the dimensions indicated in Table 26.2, but without a locknut inside the enclosure, is in place.

Table 26.2
Bushing dimensions

Trade size of conduit in inches	Overall diameter in inches (mm)		Height in inches (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	(112.7)	15/16	(23.8)
4	4-31/32	(126.2)	1	(25.4)
4-1/2	5-35/64	(140.9)	1-1/16	(27.0)
5	6-7/32	(158.0)	1-3/16	(30.2)
6	7-7/32	(183.4)	1-1/4	(31.8)

26.17 A pressure wire connector shall be prevented by a restraint, such as a shoulder or boss, from turning so as to reduce spacings to values less than those required. A lock washer alone is not acceptable for this purpose.

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

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

b) The lug or connector has been turned 30 degrees toward other opposite–polarity live parts and toward grounded dead metal parts.

26.18 Any conductive part connected to a neutral factory bonded to the ground bus or enclosure that would interfere with the operation of the 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, and the residual type ground-fault protection, parts that would interfere with operation if grounded include all neutral parts on the load side of the neutral sensing means. For the ground return type, parts that would interfere with operation if grounded include all neutral parts except those on the ground side of the sensing means.

27 Wiring Space

27.1 There shall be ample space within the enclosure of a transfer switch for the installation of all wires and cables to be employed, based on the ampere rating of the transfer switch. See Table 27.1, Table 27.2, and Table 27.3.

27.2 The arrangement of the wiring space shall be such that the normal and alternate supply conductors can be kept separated.

27.3 For a transfer switch the wire-bending space at the line and load terminals shall be as specified in Table 27.2 for the conductor size that corresponds with the maximum ampere rating of the transfer switch.

27.4 The wire-bending space from a connector to any barrier or other obstruction that is part of a transfer switch shall be as specified in Table 27.1.

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

Table 27.1
Minimum width of gutter and wire-bending space in inches (mm)[a]

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

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

Table 27.2
Minimum wire-bending space at terminals in inches

Wire size AWG or MCM	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		–		–		–	
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 shall be permitted to be reduced by the number of inches shown in parentheses under the following conditions:

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

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

For SI units one inch = 25.4 mm

Table 27.3
Wiring space

Max. size of wire or cable involved	Minimum width and depth of wiring space		Minimum areas in square inches (mm^2) required for multiple wires based on factor of 2.5											
			Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
	inch	mm	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2
12 AWG	3/8	9.5	0.14	90	0.21	135	0.28	181	0.35	226	0.42	271	0.49	316
10	3/8	9.5	0.23	148	0.34	219	0.46	297	0.57	368	0.68	439	0.80	516
8	1/2	12.7	0.43	277	0.64	413	0.85	548	1.07	690	1.28	826	1.50	968
6	5/8	15.9	0.62	400	0.93	600	1.24	800	1.55	1000	1.86	1200	2.17	1400
4	3/4	19.1	0.80	516	1.20	774	1.60	1032	2.00	1290	2.40	1548	2.80	1806
3	3/4	19.1	0.91	587	1.36	877	1.82	1174	2.27	1465	2.72	1755	3.18	2052
2	7/8	22.2	1.03	665	1.55	1000	2.06	1329	2.58	1665	3.10	2000	3.61	2329
1	1	25.4	1.36	877	2.04	1316	2.72	1755	3.40	2194	4.08	2632	4.76	3071
1/0	1	25.4	1.55	1000	2.33	1503	3.10	2000	3.88	2503	4.66	3006	5.43	3503
2/0	1	25.4	1.79	1155	2.68	1729	3.58	2310	4.47	2884	5.36	3458	6.26	4039
3/0	1-1/8	28.6	2.08	1342	3.11	2006	4.16	2684	5.19	3348	6.22	4013	7.27	4690
4/0	1-1/4	31.8	2.42	1561	3.63	2342	4.84	3123	6.05	3903	7.26	4684	8.47	5465
250 MCM	1-3/8	34.9	2.96	1910	4.44	2865	5.92	3819	7.40	4774	8.88	5729	10.36	6684
300	1-1/2	38.1	3.42	2206	5.13	3310	6.84	4413	8.55	5516	10.26	6619	11.96	7716
350	1-1/2	38.1	3.81	2458	5.72	3690	7.62	4916	9.53	6148	11.44	7381	13.34	8606
400	1-5/8	41.3	4.18	2967	6.27	4045	8.36	5394	10.45	6742	12.54	8090	14.63	9439
500	1-3/4	44.5	4.92	3174	7.38	4761	9.84	6348	12.30	7835	14.76	9523	17.22	11110
600	1-7/8	47.6	5.97	3852	8.96	5781	11.94	7703	14.93	9632	17.92	11561	20.90	13484
700	2	50.8	6.68	4310	10.02	6465	13.36	8619	16.70	10774	20.04	12929	23.38	15083
750	2	50.8	7.04	4542	10.56	6813	14.08	9084	17.60	11355	21.12	13626	24.64	15896
800	2-1/8	54.0	7.39	4768	11.09	7155	14.78	9535	18.48	11923	22.18	14310	25.87	16690
900	2-1/4	57.2	8.09	5219	12.13	7826	16.18	10439	20.22	13045	24.26	15652	28.31	18264
1000	2-1/4	57.2	8.77	5658	13.15	8484	17.54	11316	21.92	14142	26.30	16968	30.69	19800
1250	2-1/2	63.5	11.03	7116	16.55	10677	22.06	14232	27.58	17794	33.10	21355	38.61	24910

Table 27.3 Continued on Next Page

Table 27.3 Continued

Max. size of wire or cable involved	Minimum width and depth of wiring space		Minimum areas in square inches (mm^2) required for multiple wires based on factor of 2.5													
			Two wires		Three wires		Four wires		Five wires		Six wires		Seven wires	
	inch	mm	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2	inch	mm^2
1500	2-3/4	69.9	12.74	8219	19.11	12329	25.48	16439	31.85	20548	38.22	24658	44.59	28768
1750	2-7/8	73.0	14.45	9323	21.67	13981	28.90	18645	36.12	23303	43.34	27961	50.57	32626
2000	3-1/8	79.4	16.04	10348	24.06	15523	32.08	20697	40.10	25871	48.12	31045	56.14	36219

27.6 The distance mentioned in 27.3 and 27.4 shall 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 shall 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 shall 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 shall be measured at the wire opening nearest to the wall in a direction perpendicular to the wall.

27.7 The clear wiring space, independent of all projections, obstructions, or interference from moving parts of a switching mechanism:

a) Shall not be smaller in width or in depth than the values indicated in Table 27.3.

b) Shall be acceptable 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.

27.8 In determining whether or not a wiring space complies with the requirement of 27.7, consideration shall be given to the actual size of wires which will be used in that space; but it shall be assumed that wires smaller than 12 AWG will not be used. In computing the area of a wiring space, consideration shall be given to all the available space which may be used properly for the placement of wires. Minimum areas of the more common multiple-wire connections are given in Table 27.3.

27.9 Wiring space and other compartments intended to enclose wires shall be smooth and free from sharp edges, burrs, fins, and the like, which might damage the conductor insulation.

27.10 A transfer switch intended to be installed with one or more sets of conductors, lines or load or both passing into the enclosure at the same end shall have ample space for them to pass from their terminals to the point of entrance.

28 Protective Circuits

28.1 Circuitry shall be such that it reduces the possibility of inadvertent interconnection of the normal and alternate supplies.

28.2 Detection circuitry shall be provided such that, in the event of shorting of one or more of the solid-state switching devices, an action is taken to prevent interconnection of the normal and alternate supplies.

28.3 Protective circuitry shall be factory connected and located entirely within the transfer device enclosure.

28.4 The protective circuitry shall be analyzed in order to determine the effect of failure of any component in any mode. When such a failure analysis indicates that failure of one or more components results in an unacceptable condition, or renders the system inoperative, the component shall be evaluated to the requirements of the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991.

28.5 An alarm and test means shall be provided to indicate an inoperative condition of the protective circuitry when the failure analysis indicated in 28.4 demonstrates shows that a single failure renders the protective circuitry inoperative.

28.6 The protective circuitry shall continue to operate in the intended manner at the conclusion of the performance tests. In addition, all wiring connections shall be examined to determine that there has been no adverse effect – for example, connections shall not become loose, parts shall not rotate, and the like.

PERFORMANCE

29 General

29.1 The performance of automatic transfer switches shall be investigated by subjecting a representative sample or samples in commercial form to the tests described in Sections 30 – 44. The order of tests, as far as applicable, shall be as indicated in Table 29.1 and, unless otherwise indicated, the various tests are to be conducted at rated supply frequency and at the test potential indicated in that table.

Table 29.1
Voltage for tests

Test	Voltage rating of device and corresponding test potential in volts[a]			
	110 – 120	220 – 240	440 – 480	550 – 600
Normal Operation	120	240	480	600
Overload[c]	120	240	480	600
Temperature[b]	120	240	480	600
Endurance[c]	120	240	480	600
Dielectric Voltage-Withstand	Refer to Dielectric Voltage-Withstand Test, Section 34			
Withstand	120	240	480	600
Circuit Closing	120	240	480	600
Dielectric Voltage-Withstand (Repeated)	Refer to Dielectric Voltage-Withstand Test (Repeated), Section 40			
Abnormal Operation	120	240	480	600

[a] When the rating of the device does not fall within any of the indicated voltage ranges, it shall be tested at its rated voltage.

[b] Refer to 31.10 and 31.11.

[c] When a manufacturer supplies transformer or magnet coils for various voltage ratings within specified range (for example, 110, 115, or 120 V), and when a coil is supplied for the maximum voltage ratings of each range, tests are to be conducted on representative coils within each range based on the marked voltage ratings of the coils specified for testing. Unless a coil is provided for the maximum voltage rating for each range, tests are to be conducted on all coils at the test potential indicated in the table.

29.2 All tests shall be conducted on enclosed samples. One sample is to complete the overload, temperature, endurance, and dielectric voltage-withstand tests. A previously untested sample is allowed to be used for the withstand and closing tests. When multiple specific load uses are specified, additional samples are allowed to be used.

30 Normal Operation Test

30.1 Automatic transfer switches shall be capable of operating in an acceptable manner as determined by the manufacturer, for all conditions of their marked intended performance.

30.2 The normal supply voltage sensing circuit shall initiate transfer to the alternate supply for any value of normal supply voltage specified by the manufacturer. See 47.14.

30.3 If voltage-frequency sensing circuits are provided to determine availability of the alternate supply, operation shall be effected within the marked limits specified by the manufacturer. See 47.15.

30.4 If time delayed transfer features are provided either from the normal to alternate source, alternate to normal source, or both, the transfers shall be within the marked limits specified by the manufacturer. See 47.16.

30.5 To determine whether an automatic transfer switch complies with the requirements in 30.1 – 30.4, the switch shall be mounted in the intended manner and the normal and alternate supply terminals are to be connected to separate circuits of rated voltage and frequency. The switch with no load connected shall be caused to operate by the following means:

a) Test switch,

b) Interrupting and then restoring, in turn each conductor of the normal supply,

c) Low normal supply voltage, or

if a voltage-frequency sensing is provided, the operating values of voltage and frequency may be determined by

d) Increasing alternate supply frequency with voltage set at minimum specified operating voltage, and

e) Increasing the alternate supply voltage with frequency set at minimum specified operating frequency,

or by any other equivalent method.

31 Overload Test

31.1 Transfer switch equipment shall perform in an acceptable manner, as intended by the manufacturer, when subjected to an overload test consisting of the number of operations specified in Table 31.1, controlling a test current as described in Table 31.2.

Table 31.1
Overload test

Switch rating, amperes	Number of cycles of operation	Rate of operation[a]
0 – 300	50	1 per minute
301 – 400	50	1 per 2 minutes
401 – 600	50	1 per 3 minutes
601 – 800	50	1 per 4 minutes
801 – 1600	50	1 per 5 minutes
1601 – 2500	25	1 per 5 minutes
2501 and above	3	1 per 5 minutes

[a] May be conducted at a faster rate if agreeable to those concerned.

Table 31.2
Method of determining test current for overload tests on transfer switches

Device used for	Device rated in amperes	Power test current	Factor
Motor loads or total system load	a-c	6 times rated current	0.40 – 0.50
	d-c	10 times rated current	a
Incandescent lamp control or resistive load[a]	a-c	1.5 times rated current	0.75 – 0.80
	d-c	1.5 times rated current	a
Electric-discharge-lamp control	a-c	3 times rated current	0.40 – 0.50

[a] Noninductive resistive load.

31.2 A transfer switch having a ventilated enclosure shall have a cotton-pad indicator at least 1/2 inch (12.7 mm) thick attached to the outside of and completely covering any louvers or other openings to determine compliance with 7.4.

31.3 A cycle is defined as making and breaking the required test current on both the normal and alternate contacts. During the test, the alternate source shall be displaced 120 electrical degrees from the normal source for a 3 phase supply or 180 electrical degrees for a single phase supply.

31.4 The test for a 3-phase rating will be considered to cover the same device for single-phase at the same rating.

31.5 The minimum on time in each contact position shall be 1/6 second (ten electrical cycles based on a 60-Hz source), unless automatic tripping of the overcurrent device occurs.

31.6 All sensing and control relays shall be energized at their rated voltage and the relay contacts shall make and break their intended load.

31.7 Time delay, undervoltage, and frequency sensitive relays and the like may be bypassed to facilitate testing of the main power circuit contacts.

31.8 The transfer switch shall be operated through a test switch that will simulate normal source failure.

31.9 There shall be no electrical or mechanical malfunction of the device.

31.10 Other than as noted in 31.11, the test circuit shall have a closed-circuit voltage between 100 and 110 percent of the test potential indicated in Table 29.1.

31.11 For a transfer switch rated more than 100 A, the closed-circuit voltage may be between 85 and 100 percent of the test potential indicated Table 29.1, if the open-circuit voltage is adjusted to be as much above the required test potential as the closed-circuit voltage is below the required test potential, or 110 percent of the required test potential, whichever is less.

31.12 Alternating-current interrupting tests are to be made on a circuit at rated frequency.

31.13 The overload test or tests are to cover the conditions of maximum voltage, power, and current interrupted.

31.14 Reactive components of the load employed may be paralleled if of the air-core type, but no reactances are to be connected in parallel with resistances, except that an air-core reactor in any phase may be shunted by resistance (R_{SH}) the loss in which is approximately 1 percent of the total power consumption in that phase calculated in accordance with the following formula

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

in which:

PF is the power factor,

E is the closed-circuit phase voltage, and

I is the phase current.

31.15 A transfer switch intended for use on circuits having one conductor grounded shall be tested with the enclosure connected to the grounded conductor through a 30-A nontime delay Class RK5 or K5 cartridge fuse, having a voltage rating not less than the rating of the transfer switch. If the switch is intended for use on other types of circuits, the enclosure shall be connected through the fuse mentioned above to the live pole least likely to strike to ground. This connection shall be made with 10 AWG copper wire, having a length of 4 – 6 feet (1.2 – 1.8 m). The ground fuse shall not open during the test.

31.16 Switches provided with overload detection circuitry which prevents operation of the switching devices by automatically closing a bypass circuit under overload conditions are to be tested using the maximum current at which the circuitry allows the solid-state switching devices to operate. The automatic bypass circuit shall comply with the requirements of Sections 31, 32, and Sections 35 – 38.

32 Temperature Test

32.1 Transfer switches when tested under the conditions described in 32.2 – 32.12 shall not attain a temperature at any point high enough to constitute a risk of fire or to damage any materials employed in the device, and shall not show temperature rises at specific points greater than those indicated in Table 32.1.

32.2 For the temperature test the transfer switch shall be operated under intended use conditions and is to carry its test current continuously at the test potential specified in Table 29.1.

Exception: A low-potential source of supply may be used for temperature tests on parts other than coils. The tests on all parts shall be made simultaneously as the heating of one part may affect the heating of another part.

32.3 The test current shall be 100 percent of the rated current.

Exception: A transfer switch incorporating integral overcurrent protective devices in the main power circuit may be tested at 80 percent of its rated current if it is marked in accordance with 47.13.

32.4 A transfer switch incorporating Class L fuses shall be tested with fuses installed and shall carry 100 percent rated current continuously without the fuses opening.

Table 32.1
Maximum acceptable temperature rises

Materials and compounds	°C	°F
1. Knife-switch blades and contact jaws	30[a]	54
2. Fuse clips	30	54
3. Rubber- or thermoplastic-insulated conductors[b,c]	35	63
4. Field-wiring terminals:[d]		
Maximum 400 amperes	50	90
Over 400 amperes	60[e]	108
5. Class 90 insulation systems:		
Thermocouple method	50	90
Resistance method	70	126
6. Connecting straps and buses	65	117
7. Class 105 insulation systems:		
Thermocouple method	65	117
Resistance method	85	153
8. Class 130 insulation systems:		
Thermocouple method	85	153
Resistance method	105	189
9. Class 105 insulation systems on a single-layer series coil with exposed surfaces either uninsulated or enameled:		
Thermocouple method	90	162
10. Phenolic composition[b]	125	225
11. Fiber employed as electrical insulation[b]	65	117
12. Urea composition[b]	75	135
13. Melamine[b]	125	225
14. The softening point of any sealing compound minus 15°C (27°F) (See 11.3).		

[a] Applicable only to devices for use with Class H fuses when tested with dummy fuses installed.

[b] The limitations on insulating materials do not apply to a material or compound that has been investigated and has special heat resistance-properties.

[c] For standard insulated conductors other than those specified in Item 3 of Table 32.1, reference shall be made to the National Electrical Code, ANSI/NFPA 70. The maximum allowable temperature rise in any case is 25°C (45°F) less than the allowable temperature limit of the wire in question.

[d] The temperature on a wiring terminal or lug is measured at the point that will be contacted by the insulation of a conductor installed as in actual service.

[e] See 47.42 for information on the marking required for devices for which the maximum temperature rise recorded on its terminals exceeds 50°C (90°F).

32.5 Transfer switch equipment that has wiring terminals shall be connected with not less than 4 feet (1.2 m) of Type RH, TW, THW, THHN, or THWN copper wire, provided with black insulation, per terminal. The wire size is to correspond to the rating of the transfer switch as given in 16.2. For a transfer switch rated 100 A or less, and more than 30 A, the wire size is also to be based on the temperature rating of the wire as marked on the transfer switch. Where a dual temperature rating is marked, such as 60/75°C (140/167°F) wire, the test shall be conducted with 75°C (167°F) wire. When agreeable to those concerned, insulation of a color other than black is not prohibited from being used.

Exception: When there is only provision for the connection of bus bars to a transfer switch rated at 800 A or more, copper bus bars of the size shown in Table 32.2 and at least 4 feet (1.2 m) in length shall be used.

The spacing between multiple bus bars shall be 1/4 inch (6.4 mm) or less with no intentional wider spacing except as required at the individual terminals of the transfer switch.

Table 32.2
Size of copper bus bar connections for temperature test

Device rating amperes	Bus bars per terminal	
	Number	Size in inches (mm)
800	1	1/4 by 3 (6.4 by 76)
1200	1	1/4 by 4 (6.4 by 102)
1600	2	1/4 by 3 (6.4 by 76)
2000	2	1/4 by 4 (6.4 by 102)
2500	2 or 4	1/4 by 5 (6.4 by 127) 1/4 by 2-1/2 (6.4 by 76.2)
3000	4	1/4 by 4 (6.4 by 102)
4000	4	1/4 by 5 (6.4 by 127)
5000	6	1/4 by 5 (6.4 by 127)
6000	6	1/4 by 6 (6.4 by 152)

32.6 For a device employing a fuseholder, a copper bar, copper tubing, or an equivalent material with negligible impedance instead of a fuse shall be used during the test.

Exception: A transfer switch incorporating Class L fuses shall be tested with fuses installed and shall carry 100 percent rated current continuously without the fuses opening.

32.7 The thermocouple method consists of the determination of temperature by the application of thermocouples to the hottest accessible parts.

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

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

in which

Δt is the temperature rise,

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

r is the resistance of the coil 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 and 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other grades must be determined.

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

32.10 The temperature readings are to be obtained by means of thermocouples and an indicating instrument. A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previous elapsed duration of the test, but not less than 10-minute or more than 20-minute intervals, indicate that stable conditions have been reached.

32.11 The primary (preferred) method of measuring the temperature of a coil is the resistance method; but temperature measurements by either the thermocouple or resistance method are acceptable, except that the thermocouple method shall not be employed for a temperature measurement at any point at which supplementary insulation is employed.

32.12 Temperatures are to be measured by thermocouples consisting of wires no larger than 24 AWG (0.21 mm^2) and no smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer–type instrument are to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouple wire is to conform with the requirements listed in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ASTM E230/E230M. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice.

32.13 Junction temperatures of solid-state switching devices shall not exceed the peak operating junction temperature limits specified by the manufacturer under steady-state and recurrent overload conditions. The junction temperature is obtained by measuring the case temperature and device power dissipation at the maximum operating ambient temperature of the device. Under transient (surge) conditions the junction temperature is allowed to increase above the peak operating junction temperature limit. In this case, the non-repetitive half-cycle surge shall not exceed the device manufacturing ratings.

33 Endurance Test

33.1 A transfer device shall be subjected to an endurance test controlling the test current and number of cycles as described in Table 33.1 and Table 33.2. The device shall perform in its intended manner as specified by the manufacturer at the conclusion of the endurance test.

Table 33.1
Method of determining test current for endurance tests

Device used for	Device rated in amperes	Test current	Power factor
Total system load, motor load or Electric discharge lamp control	a-c	Rated current	0.75 – 0.80
Resistive loads	a-c	Rated current	a
Incandescent lamp control	a-c	Rated current[a]	b

[a] Noninductive resistive load.

[b] The load shall consist of tungsten-filament lamps or a load having equivalent characteristics. See 33.3 and 33.6.

Table 33.2
Endurance test cycles

Switch rating	Rate of operation [a,c]	Number of cycles of operation [b,d]
0 – 300	1 per minute	4000
301 – 400	1 per minute	1000
401 – 600	1 per minute	1000
601 – 1600	1 per 2 minutes	500
1601 – 2500	1 per 4 minutes	500
Over 2500	1 per 4 minutes	250

[a] Conducting the test at a faster rate is not prohibited if agreeable to those concerned, but not faster than one operation per minute for tungsten ratings unless a synthetic load is employed.

[b] The test shall be conducted at 100 percent of rated current.

[c] The test cycle shall be 1 second "on" and 59 seconds "off". A controller may be operated at a rate of more than 1 cycle per minute if synthetic loads are used or if a sufficient number of banks of lamps controlled by a commutator are employed so that each bank will cool for at least 59 seconds between successive applications of current.

[d] For transfer switches rated for total system transfer, motor loads, or electric-discharge lamp loads, the test shall be conducted for one half of the specified number of operations at 200 percent of rated current and for one half of the specified number of operations at 100 percent of rated current. Switches provided with overload detection circuitry which prevents operation of the switching devices by automatically closing a bypass circuit under overload conditions are to be tested using the maximum current at which the circuitry allows the solid-state switching devices to operate. The automatic bypass circuit shall comply with the requirements of Sections 29 – 32, and Sections 35 – 38.

33.2 The conditions for the endurance test shall be the same as conditions for the overload test as indicated in 31.3 – 31.16.

33.3 If tungsten-filament lamps are used as the load, the load shall be made up of the smallest possible number of 500-W lamps, or of larger lamps if agreeable to those concerned. One or two lamps smaller than the 500-W size are to be used if necessary to make up the required load. Only one set of contacts (normal or alternate) are required to perform on tungsten-filament lamp load if the construction of both sets of contacts is identical and the transfer switch has additional ratings.

33.4 With regard to 33.3, the circuit shall be such that the peak value of the inrush current will be reached in 1/240 of a second after the circuit is closed and the inrush current shall be ten times the normal current.

33.5 A synthetic load may be used in place of tungsten-filament lamps, and may consist of noninductive resistors if they are so connected and controlled that a portion of the resistance is shunted during the closing of the switch under test. A synthetic load may also consist of a noninductive resistor or resistors, connected in parallel with a capacitor.

33.6 If a synthetic load is used in place of tungsten-filament lamps, it shall be equivalent to a tungsten-filament lamp load on the test circuit in question, and the inrush current shall be not less than ten times the normal current in any case.

34 Dielectric Voltage-Withstand Test

34.1 A transfer device shall be capable of withstanding for 1 minute without breakdown the application of a 60-Hz sinusoidal potential of 1000 V plus twice maximum rated voltage between:

a) Uninsulated live parts and the enclosure with the transfer device alternately closed to each supply source.

b) Terminals of opposite polarity with the transfer device alternately closed to each supply source.

c) Uninsulated live parts of different circuits.

34.2 With reference to 34.1(b), a transformer, a coil, or a similar device connected between lines of opposite polarity shall be disconnected from one side of the line during the test.

34.3 To determine whether a transfer device complies with the requirements in 34.1, the device shall be tested by means of a 500 VA or larger capacity transformer, the output voltage of which is capable of being varied. The waveform of the voltage is to simulate a sine wave. The applied potential shall be increased gradually from zero to the required test value, and shall be held at that value for 1 minute. The increase in the applied potential shall be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter in the output circuit of the test transformer.

35 Withstand

35.1 When tested under the conditions described in 35.2 – 35.27, a transfer switch shall withstand the designated levels of current until the overcurrent protective devices open or for a time as designated in 35.8. At the conclusion of the test, the transfer switch shall comply with 35.2 – 35.27.

35.2 The switch shall be capable of being operated by its intended means, as demonstrated by 35.3, based on the intended use of the switch.

35.3 For transfer switches intended for optional standby systems only, the switch shall comply with items (a) – (c) below.

a) For electrically operated devices, it shall be possible to operate the transfer switch to the off position, if provided by the electrical means. If no off position is provided, it shall be possible to operate the transfer switch to the untested source (close the switch onto the source which was not subjected to the short-circuit withstand and short-circuit closing test) by the electrical means.

b) There shall be no continuity between the normal and alternate source terminals with the switch operator in any position. Continuity between either set of source terminals and the load terminals is not required.

c) If the transfer switch can be moved to the untested source such that there is continuity between any of the untested source side terminals and any of the load terminals, the transfer switch shall comply with (1) and (2) below:

1) There shall be continuity on all phases, including any contacts which switch the grounded circuit conductor (the neutral).

2) There shall be no damage to the untested side of the switch.

35.4 Compliance is verified at the conclusion of each test by the following criteria:

a) No flames, molten metal, or burning particles shall be emitted as detected by cotton indicators;

b) The static transfer switches STS shall be fully functional with the exception that power switching components are permitted to fail. If a switching device fails shorted, the feed through protection circuitry shall still be operative;

c) There shall have been no arcing from live parts to the static transfer switches STS chassis or enclosure; Note: The use of an enclosure test fuse as described in 35.21 provides a positive method of verification (fuse opening indicates failure of the test);

d) There shall be no damage to the static transfer switches STS to the extent that the integrity of the mounting of live parts is impaired;

e) The enclosure door shall not be blown open prevented only by its latch;

f) No conductor shall have pulled out of its terminal connector and there shall be no damage to the conductor or conductor insulation (see 47.56);

g) The test unit shall successfully pass the dielectric tests as specified in the Dielectric Voltage-Withstand Test, Section 34;

h) For a plug in or draw out unit, the point of contact shall be the same both mechanically and electrically as before the test.

35.5 The tests specified in 35.1 shall be performed on both the normal source and alternate source circuits.

Exception: If the construction of the normal and alternate source circuits are representative of each other, the test need be conducted on only one circuit.

35.6 The overcurrent protective devices specified in 35.1 shall be one of the following:

a) The integral circuit breaker provided in the transfer switch, if such circuit breaker is part of the design,

b) The maximum ampere rated fuse that can be inserted if integral fuseholders are provided, or

c) If no provisions are made for integral overcurrent protective devices, an externally connected circuit breaker or fuses, as marked on the transfer switch, shall be used. The ampere rating of such circuit breakers or fuses shall not be less than 125 percent of the transfer switch ampere rating.

35.7 The tests specified in 35.1 may be performed without overcurrent protective devices if it can be shown that the test circuit current is maintained for a period of time at least equal to the opening time of the specified overcurrent protective devices at the level of current involved.

35.8 The test current shall be maintained for at least 3 cycles (50 ms). See 47.19.

Exception No. 1: A transfer switch with an integral overcurrent protection device is to have the test current maintained until the overcurrent protection device interrupts the circuit. See 47.21.

Exception No. 2: A transfer switch marked as requiring a specific overcurrent protection device is to have the test current maintained until the overcurrent device interrupts the circuit. See 47.21.

Exception No. 3: A transfer switch marked as requiring an external overcurrent protection device, and equipped internally with a short circuit device, is to have the test current maintained until the short circuit device interrupts the current. See 47.21.

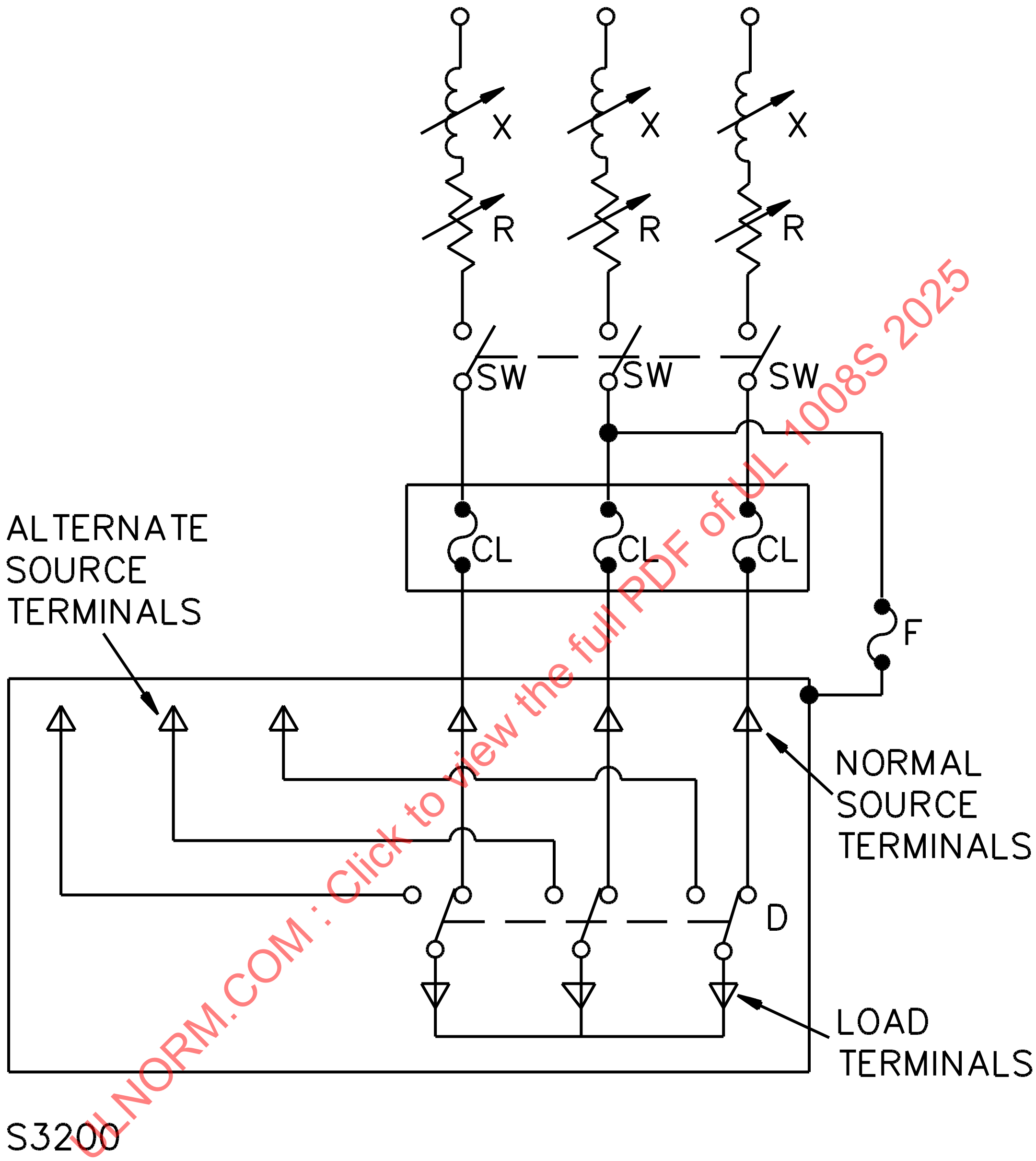
35.9 When testing a transfer switch rated 400 A or less on a 10,000 A circuit with a molded case circuit breaker as the specific overcurrent protective device, the circuit breaker manufacturer is not required to be specified when the transfer switch withstands 1-1/2 cycles (25 ms). See 47.19.

35.10 If fuses are used for tests at current levels greater than 10,000 A, a fuse shall be installed in each conductor. The fuse may be external to the switch as shown in Figure 35.1. Except as noted in 35.11, each of the fuses shall be of such characteristics that, when tested on a single phase circuit having an available current of not less than the short-circuit rating of the transfer switch, the peak let-through current and maximum clearing I^2t would be not less than the corresponding values specified in the requirements for the class of fuse (J, L, T, or RK-5) and the current and voltage ratings of the fuse intended for use with the device being tested. To obtain the required values of these characteristics, it may be necessary to employ a fuse of a different class or having a current rating higher than that of the fuse specified for use with the device. The values of I_p and I^2t are to be determined at the voltage rating of the fuse.

Exception: With the concurrence of those concerned, the determination of I_p and I^2t may be made at the voltage rating of the transfer switch.

Figure 35.1

Circuit for withstand and closing tests



Supply – Rated Voltage 3 Phase

X – Variable tap air-core reactor

R – Variable resistor

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

F – Enclosure fuse

D – Device under test

CL – Protective fuses if used

35.11 The fuse referred to in 35.10 may be any Class J, L, T, or R(RK-5) fuse without regard to its peak let-through current and maximum clearing I^2t if the test current is below the point (threshold value of the fuse) where the fuse is considered to be current limiting.

35.12 If a transfer switch has a maximum withstand rating higher than 20 times the switch ampere rating, and if the fuse specified for the test is considered to be current limiting above 20 times the switch rating, the transfer switch shall be subjected to withstand tests:

a) At the maximum withstand rating with fuses in accordance with 35.10, and

b) At 20 times the switch ampere rating with fuses in accordance with 35.11.

A separate sample may be used for the second test.

35.13 If fuses are used for tests at current levels of 10,000 A or less, they shall comply with the limits specified for high-interrupting-capacity Class RK-5 fuses. The fuses, if external, shall be connected as described in 35.6.

35.14 A transfer switch intended for use on an alternating-current system shall be tested with alternating current at rated frequency on a circuit as indicated in Figure 35.1. The test shall be performed in accordance with the following:

a) The open-circuit voltage of the power-supply circuit shall not be less than the maximum rated voltage of the switch.

b) Except as noted in (c), the available short-circuit rms symmetrical current in amperes at the test source terminals shall not be less than that shown in Table 35.1.

c) The available short-circuit current for a transfer switch incorporating circuit breakers shall not be greater than the marked interruption current rating of the breaker.

d) The test source circuit shall include the necessary measuring equipment and the fuse-mounting means if necessary.

e) The power factor of the circuit shall be 0.40 – 0.50 for currents of 10,000 A or less, 0.25 – 0.30 for currents of 10,001 – 20,000 A and 0.20 or less for currents greater than 20,000 A. Lower power factors may be used if agreeable to those concerned.

f) The test source terminals are to be included in the circuit, for the connections described in 35.16. In determining the available short-circuit current of the circuit these terminals, as well as the fuse-mounting means shall be short-circuited in each instance by bus bars.

Table 35.1
Available short-circuit current

Switch rating	Current in amperes[a]
100 A or less	5,000
101 – 400 A	10,000
401 A and greater	20 times rating, but not less than 10,000 A

[a] May be higher (see Table 47.1) at the option of the manufacturer.

35.15 The reactive components of the impedance in the line shown in Figure 35.1 may be paralleled if of the air-core type, but no reactance shall be connected in parallel with resistances except that an air-core reactor(s) in any phase may be shunted by resistance as determined in accordance with 37.4.19.

35.16 For the performance of the test, the line terminals of the switch are to be connected to the corresponding test circuit terminals by the conductor or conductors described in 32.5. Lengths are to be in accordance with 35.18 – 35.20 and as specified in Exception No. 3 to 37.2.1. The load terminals are to be similarly connected to a short-circuiting bus bar.

35.17 Separate short-circuit tests are to be conducted with copper cable and with compact aluminum cable. The cable is to enter the line end of the enclosure at a point that provides the maximum length of unsupported cable within the enclosure. The line terminals are to be wired and tightened to the torque that was used in the investigation of the terminals in accordance with the Standard for Wire Connectors, UL 486A-486B. There shall be no bracing of the cable inside the enclosure unless the design includes instructions for bracing the conductors as covered in 47.56. The provision for bracing is not prohibited from being provided with the transfer switch. Bracing hardware not provided as part of the switch shall be available to the installer. A cable shall be braced as it leaves the enclosure on the supply side.

Exception No. 1: The sample shall be tested with copper cable when the transfer switch is restricted to use with copper cable in accordance with 47.33.

Exception No. 2: The sample shall be tested with aluminum or copper cable when the short circuit current rating divided by the number of cables per phase results in a current of 50,000 A per cable or less.

Exception No. 3: A transfer switch that does not have provision for wire connection shall be connected with bus bars in accordance with Table 32.2.

Exception No. 4: When the short circuit test current rating is greater than 50,000 A per conductor, the test sample shall be tested with either compact aluminum or copper cable when the type of cable used for the short circuit test has a lower pull out force than the untested cable material.

35.18 The total length of rated phase conductor or conductors in the test circuit is not to exceed 8 feet (2.4 m) per conductor unless the excess length is included in the test circuit calibration as specified in Exception No. 3 of 37.2.1.

35.19 In a transfer switch provided with integral fuseholders, the supply conductor shall be connected to the terminals of the transfer switch. The test fuses specified in 35.10 are to be installed in the fuseholder. When the size of the test fuse is such that it cannot fit in the fuseholder, an external fuseholder shall be used. The external fuseholder shall be inserted:

a) Between the load side of the transfer switch and the shorting bar, or

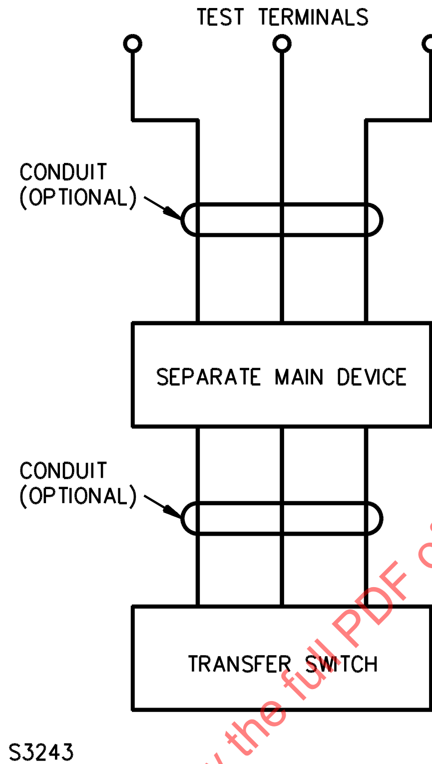
b) On the line side of the transfer switch.

When external fuses are used, a copper bus or tube (dummy fuse) shall be installed in each fuseholder of the transfer switch. The combined length of the supply conductor and of all other conductors, other than the conductors on the load side of the switch, shall be part of the calibrated circuit or shall be in accordance with 35.18.

35.20 When a separate main device is used, the method of line connection shall be as shown in Figure 35.2. In the case of a separate fusible main, fuses are to be installed in an external fuseholder. The main device terminals are to be connected by a conductor in accordance with 35.18. The combined length of each conductor (line, external fuseholder, and connections between the separate main device and transfer switch) shall not exceed the length permitted by 35.18.

Figure 35.2

Line connection for tests



35.21 The enclosure shall be connected through a 30 A, nondelay type cartridge fuse to the line lead of the pole least likely to arc to the enclosure. The fuse is to have a voltage rating not less than the rated voltage of the equipment being tested. This connection shall be made on the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire 4 – 6 feet (1.2 – 1.8 m) long. See Figure 35.1.

35.22 With the switch in the fully closed position, the test circuit shall be closed on the switch. For magnetically operated devices, the magnet shall be held closed electrically.

35.23 A three-phase transfer switch shall be tested on a three-phase circuit.

35.24 A single-phase transfer switch, including a design employing adjacent poles of a three-phase construction shall be tested on a single–phase circuit.

35.25 Closing for the Withstand Test on a single-phase circuit shall be controlled so that the closing angle with respect to the zero point of the supply voltage is within +10 degrees.

35.26 A transfer switch having:

a) A switched neutral of different construction than a power pole,

b) A neutral bus that is spaced closer to a line bus than the spacing between adjacent line buses, or

c) A different means of support for the neutral bus shall be tested with a line-to-neutral fault in addition to the line-to-line test.

35.27 Neutral short-circuit tests shall be made at the marked line to neutral voltage and short-circuit current rating of the transfer switch. The neutral and nearest phase bus are to be used for this test.

36 Receptacle Withstand

36.1 A receptacle provided as part of a transfer switch shall be tested as specified in 36.3 – 36.5 and shall comply with the requirements as specified in 36.2.

Exception No. 1: A non-GFCI-type receptacle in a transfer switch marked with a short-circuit current rating of 10,000 amperes or less is not required to be tested if the overcurrent protective device ahead of the receptacle has a minimum short-circuit current rating of 10,000 amperes.

Exception No. 2: A GFCI-type receptacle with a marked short-circuit current rating of 5,000 or 10,000 amperes in a transfer switch having the same short-circuit current rating is not required to be tested if the overcurrent protective device ahead of the receptacle has a minimum short-circuit current rating of 5,000 or 10,000 amperes, respectively.

36.2 Upon completion of the tests specified in 36.3 – 36.5:

a) A transfer switch shall comply with the withstand requirements specified in 35.1;

b) The cord shall not be visibly damaged and, after removing the shorting pressure wire connector, the cord shall withstand a 900-volt potential applied between the individual conductors;

c) A GFCI-type receptacle, if included, shall either open the circuit when the test button is pushed or at the completion of the short circuit test, have permanently opened the circuit, and

d) A GFCI-type receptacle, if included, shall withstand a 900-volt potential applied between the line and load sides after opening as specified in (c).

36.3 The attachment plug shall be wired with 10 inches (254 mm) per terminal of the cord of wire gauge as specified in Table 36.1 and inserted in the receptacle as intended in service. At the end of the attachment plug, the cord conductors are to be joined in a pressure wire connector rated for the size of conductors involved.

36.4 The branch circuit overcurrent protective device, consisting of either a fused switch or a circuit breaker, and all the main overcurrent protective devices, integral or separate, are to be in the fully closed position. The test circuit shall be closed on the switch by an external switching means.

36.5 All switches and overcurrent protective devices, integral or separate, are to be in the fully closed position. The attachment plug, wired with the maximum-sized cord, is to close the circuit by being mechanically inserted into the receptacle.

Table 36.1
Wire size for attachment plug test leads

Rating of receptacle accommodating attachment plug, amperes	Single phase test leads				3-Phase test leads			
	Minimum		Maximum		Minimum		Maximum	
	AWG	(mm^2)	AWG	(mm^2)	AWG	(mm^2)	AWG	(mm^2)
15	18	0.82	14	2.1	18	0.82	14	2.1
20	18	0.82	12	3.3	18	0.82	12	3.3
30	16	1.3	10	5.3	18	0.82	8	8.4
40	12	3.3	8	8.4	12	3.3	6	13.3
50	12	3.3	6	13.3	12	3.3	4	21.1
NOTE – Type SJ cord for sizes 18 – 10 AWG and Type SO cord for 8 AWG and larger.								

37 Instrumentation and Calibration of High Capacity Circuits

37.1 General

37.1.1 In order to determine that the specified current is available when the system is short-circuited in accordance with 37.2.1 and that the test circuit has the characteristics specified in 35.6, an oscillograph shall be used in measuring the circuit characteristics.

37.2 Test circuit calibration

37.2.1 The available rms symmetrical current shall be determined at the line terminals of the separate main device or, if no separate main device is used, at the line terminals of the transfer switch.

Exception No. 1: For circuits rated 25,000 A or less, the available current may be determined at the test station terminals.

Exception No. 2: The available current may be determined at the test station terminals if:

a) For circuits between 25,001 – 50,000 A, the available current is determined to be 5 percent higher than the required test current; or

b) For circuits between 50,001 – 200,000 A, the available current is determined to be 10 percent higher than the required test current.

Exception No. 3: If the available current is determined at the test station terminal and the physical arrangement in the test station requires leads longer than specified, the additional length of leads shall be included in the circuit calibration.

37.3 Alternating current

37.3.1 For an alternating-current circuit intended to deliver 5000 or 10,000 A, the determination of current and power factor shall be in accordance with 37.3.2. For circuits designed to deliver more than 10,000 A, the determination of the current and power factor shall be in accordance with the requirements of 37.4.12 – 37.4.20. Instrumentation used to measure test circuits of over 10,000 A shall meet the requirements of 37.4.1 – 37.4.11.

37.3.2 The current in a 3-phase test circuit shall be checked by averaging the root-mean-square (rms) values of the first complete cycle of current in each of the three phases; the current in a single-phase test circuit shall be checked by determining the root-mean-square value of the first complete cycle when the circuit is closed to produce an essentially symmetrical current wave form. The d-c component shall not be added to the value obtained when measured as shown. In order to obtain the desired symmetrical waveform of the single-phase test circuit, controlled closing is recommended although random closing methods may be used. The power factor shall be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through an appropriate timing wave, the power factor shall be computed as an average of the values obtained by using these two current zero points, and the voltage to neutral shall be used in the case of a 3-phase circuit.

37.4 Galvanometers

37.4.1 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing are to be of a type having a flat (± 5-percent) frequency response from 50 to 1200 Hz.

37.4.2 Galvanometers shall be calibrated as indicated in 37.4.3 – 37.4.6.

37.4.3 When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage shall be applied to cause the galvanometer to deflect in both directions. Additional calibrations are to be made using approximately 50 percent and approximately 150 percent of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150 percent, such as in the case of a symmetrically closed single-phase circuit, any other appropriate calibration point shall be chosen. The sensitivity of the galvanometer circuit in volts per inch (or millimeter) shall be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per inch (or millimeter) is obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor is used for the determination of the rms current as described in 37.4.12.

37.4.4 A sine-wave potential may be used for calibrating the galvanometer circuit, using the same general method described in 37.4.3. The resulting factor must be multiplied by 1.414.

37.4.5 When a circuit transformer is used to determine the circuit characteristics, an alternating current is used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short-circuit current is flowing in the primary. Additional calibrations are to be made at approximately 50 percent and approximately 150 percent of the current used to obtain the deflection indicated above except that if the anticipated maximum deflection is less than 150 percent, such as in the case of a symmetrically closed single-phase circuit, any other appropriate calibration point shall be chosen. The sensitivity of the galvanometer circuit in rms amperes per inch (or millimeter) shall be determined in each case and the results averaged. The average sensitivity is multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per inch. This constant is used for the determination of the rms current as described in 37.4.12.

37.4.6 All the galvanometer elements employed are to line-up properly in the oscillograph, or the displacement differences are to be noted and used as needed.

37.4.7 The sensitivity of the galvanometers and the recording speed shall be sufficient to provide a record from which values of voltage, current, and power factor can be measured accurately. The recording speed shall not be less than 60 inches per second (1.52 m/s) and higher speeds are recommended.

37.4.8 With the test circuit adjusted to provide the specified values of voltage and current and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests indicated in 37.4.9 and 37.4.10 are to be conducted to verify the accuracy of the manufacturer's instrumentation.

37.4.9 With the secondary open-circuited, the transformer shall be energized and the voltage at the test terminals observed to determine if rectification is taking place. If rectification is occurring, the circuit is not acceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings are to be made to demonstrate that residual flux in the transformer core will not cause rectification as evidenced by both the voltage and current waves appearing sinusoidal. If testing is done by closing the secondary circuit, this check can be omitted providing testing is not started before the transformer has been energized for approximately 2 seconds, or longer, if an investigation of the test equipment shows that a longer time is necessary.

37.4.10 With the circuit short-circuited by connecting the test terminals together by means of a copper bar, a single-phase circuit shall be closed as nearly as possible at the angle which will produce a current wave with maximum offset. The short-circuit current and voltage are to be recorded. The primary voltage shall be recorded if primary closing is used. The current measured by the reference shunt shall be within 5 percent of that measured using the manufacturer's instrumentation and there shall be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

37.4.11 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt shall be removed from the circuit and it shall not be used during the final calibration of the test circuit nor during the testing of the switches.

37.4.12 The rms symmetrical current shall be determined, with the supply terminals short-circuited, by measuring the alternating–current component of the wave at an instant 1/2 cycle – on the basis of a 60 Hz timing wave – after the initiation of the short-circuit. The current shall be calculated in accordance with Figure 7 of the Test Procedure for AC High-Voltage Circuit Breakers Rated On A Symmetrical Current Basis ANSI/IEEE C37.09-1979.

37.4.13 For a 3-phase test circuit, the rms symmetrical current shall be the average of the currents in the three phases as long as the components of the circuit are such that equal impedance (and currents) exists in all phases. The rms symmetrical current in any one phase shall be no less than 90 percent of the value of the switch marked short-circuit current.

37.4.14 For a single-phase circuit, closing to produce minimum asymmetry may be selected, but one test is also to be made at the closing angle that will produce maximum asymmetry since this is required for power factor determination.

37.4.15 The test circuit and its transients are to be such that 3 cycles (1/20 second) after initiation of the short-circuit, the symmetrical alternating component of current will not be less than 90 percent of the symmetrical alternating component of current at the end of the first half-cycle. In 3-phase circuits the symmetrical alternating component of current of all three phases shall be averaged.

37.4.16 The power factor shall be determined at an instant one-half cycle – on the basis of a 60 Hz timing wave – after the short–circuit occurs. The total asymmetrical rms amperes are to be measured in accordance with 37.4.17 and the ratio M_A or M_M calculated as follows:

$$Ratio\ M_A\ (for\ 3\phi\ tests) = \frac{Av.\ 3\ phases\ Asymmetrical\ RMS\ Amperes}{Av.\ 3\ phases\ Symmetrical\ RMS\ Amperes}$$

$$Ratio\,M_M\ (for\,1\,\phi\ tests) = \frac{Asymmetrical\,RMS\,Amperes}{Symmetrical\,RMS\,Amperes}$$

Using ratio M_A or M_M the power factor is determined from Table 37.1.

Table 37.1
Short-circuit power factor

Short-circuit power factor, percent	Ratio M_M	Ratio M_A	Short-circuit power factor, percent	Ratio M_M	Ratio M_A
0	1.732	1.394	30	1.130	1.066
1	1.697	1.374	31	1.122	1.062
2	1.662	1.354	32	1.113	1.057
3	1.630	1.336	33	1.106	1.053
4	1.599	1.318	34	1.098	1.050
5	1.569	1.302	35	1.091	1.046
6	1.540	1.286	36	1.085	1.043
7	1.512	1.271	37	1.079	1.040
8	1.486	1.256	38	1.073	1.037
9	1.461	1.242	39	1.068	1.034
10	1.437	1.229	40	1.062	1.031
11	1.413	1.216	41	1.058	1.029
12	1.391	1.204	42	1.053	1.027
13	1.370	1.193	43	1.049	1.025
14	1.350	1.182	44	1.045	1.023
15	1.331	1.172	45	1.041	1.021
16	1.312	1.162	46	1.038	1.019
17	1.295	1.152	47	1.035	1.017
18	1.278	1.144	48	1.032	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.016	1.008
22	1.219	1.112	60	1.009	1.004
23	1.205	1.105	65	1.005	1.002
24	1.193	1.099	70	1.002	1.001
25	1.181	1.092	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.0001
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.076	100	1.00000	1.00000
29	1.139	1.071			

37.4.17 The power factor of a 3-phase circuit may be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. Each phase would then have the power factor determined using the method described for single–phase circuits in 37.4.16. The power factor of the 3-phase circuit is considered to be the average of the power factors determined for each of the phases.