



# UL 1047

## STANDARD FOR SAFETY

### Isolated Power Systems Equipment

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UL Standard for Safety for Isolated Power Systems Equipment, UL 1047

Sixth Edition, Dated October 15, 2015

### **SUMMARY OF TOPICS**

***This revision of ANSI/UL 1047 dated July 2, 2020 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.***

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

The requirements are substantially in accordance with Proposal(s) on this subject dated May 8, 2020.

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**OCTOBER 15, 2015**  
(Title Page Reprinted: July 2, 2020)



**ANSI/UL 1047-2010 (R2020)**

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**UL 1047**

**Standard for Isolated Power Systems Equipment**

First Edition – August, 1976  
Second Edition – December, 1990  
Third Edition – March, 1995  
Fourth Edition – September, 2003  
Fifth Edition – October, 2010

**Sixth Edition**

**October 15, 2015**

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through July 2, 2020.

The most recent designation of ANSI/UL 1047 as a Reaffirmed American National Standard (ANS) occurred on June 23, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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## INTRODUCTION

### 1 Scope

1.1 These requirements cover isolated power systems equipment rated 600 Vac or less, intended for installation and use in nonhazardous areas in health care facilities in accordance with the requirements in Article 517 of the National Electrical Code, NFPA 70, and in the Standard for Health Care Facilities, NFPA 99.

1.2 These requirements cover isolated power centers, either cord-connected or permanently wired, consisting of a distribution panel that incorporates an isolation transformer, one or more isolated ungrounded secondary circuits terminating in integrally mounted grounding-type receptacles, a reference grounding bus bar, and line isolation monitor. Isolated power centers may have provision for connection of grounding conductors to remote grounding jacks, the room bonding points, and patient equipment grounding points. A permanently wired isolated power center may also have provision for connection to remote receptacles or indicators.

1.3 These requirements cover convertible system units that facilitate a temporary conversion of the power supply for a power center from a grounded supply to an isolated supply.

1.4 These requirements cover isolated power panelboards that incorporate the same features as permanently wired isolated power centers except that:

- a) They may be supplied from remote isolation transformers, and
- b) The secondary isolated circuits are intended to be connected by conduit to remotely located receptacles.

1.5 These requirements cover wall modular units containing isolated power systems.

1.6 These requirements cover cord-connected isolated power centers, and panels intended to supply x-ray equipment only.

### 2 Glossary

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

2.2 CONVERTIBLE SYSTEM UNIT – An enclosed assembly incorporating an isolation transformer and line isolation monitor with interconnecting cord assemblies that facilitate temporary conversion of the power supply for a power center from a grounded supply to an isolated supply. The unit is intended for use only with the specific power centers for which it has been designed.

2.3 FIELD-WIRING TERMINAL – A terminal to which a supply or other wire can be connected by an installer in the field is a field-wiring terminal unless a lead is provided as part of a pressure terminal connector, or other means for making the connection is factory-assembled to the wire.

2.4 LINE ISOLATION MONITOR – A test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built-in test circuit to actuate an alarm without adding to the leakage current.

2.5 MOMENTARY RATING – A rating based on an operating interval that does not exceed 5 s.

2.6 PATIENT EQUIPMENT GROUNDING POINT – A jack or terminal bus that serves as the collection point for redundant grounding of electric appliances serving a patient vicinity or for grounding other items in order to eliminate electromagnetic interference problems.

2.7 REFERENCE GROUNDING POINT – A terminal bus that is an extension of the equipment grounding bus and is a convenient collection point for grounding all electric appliances, equipment, and exposed conductive surfaces in a patient vicinity.

2.8 ROOM BONDING POINT – A grounding terminal bus that serves as the collection point for grounding exposed metal or conductive building surfaces in a room.

2.9 WALL MODULAR UNIT – A factory-built wall section or sections typically containing various combinations of gas outlets, lighting fixtures, clocks, intercommunication units, and the like for use in, within, or as part of health-care facilities. Only units containing isolated power systems equipment are covered by this standard. Grounded power circuits that are physically segregated and separated may also be included.

### 3 General

#### 3.1 Components

3.1.1 Except as indicated in [3.1.2](#), a component of a product covered by this standard shall comply with the requirements for that component. See Appendix [A](#) for a list of standards covering components generally used in the products covered by this standard.

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

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

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

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

#### 3.2 Units of measurement

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

#### 3.3 Undated reference

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

## CONSTRUCTION

### 4 General

4.1 Isolated power systems equipment shall employ materials throughout that are acceptable for the application, and shall be made and finished with the degree of uniformity and grade of workmanship practicable in a well-equipped factory.

4.2 A convertible system unit shall be designed to convert a specific power center from a grounded supply to an isolated supply. The specific power center shall consist of overcurrent protection devices, receptacles, grounding jacks and components other than the transformer and line isolation monitor that have been previously permanently installed. Also the grounding conductor from the grounded supply to the distribution panel or modular wall section shall remain continuous and so arranged that it is not interrupted by the converting procedure.

4.3 An enclosure, an opening, a frame, a guard, a knob, a handle, or the like shall not be sufficiently sharp to cause a risk of injury in normal maintenance or use.

4.4 Equipment shall be formed so that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings, loosening or displacement of parts or other serious defects.

### 5 Enclosure

5.1 The enclosure of isolated power systems equipment shall comply with the Standard for Enclosures for Electrical Equipment, UL 50.

*Exception: An enclosure may be ventilated in accordance with Ventilation, Section 6.*

5.2 An enclosure cover or door shall be hinged, sliding, or similarly attached so that it cannot be wholly detached without the use of a tool, if it gives access to a fuse or any other overload-protective device the normal functioning of which requires renewal, or if it is necessary to open the cover during normal operation of the device.

### 6 Ventilation

6.1 A ventilating opening in an enclosure shall be constructed and located so that no flame or molten metal will be emitted during the arcing encountered during the operation of fuses, switches, or circuit breakers.

6.2 Unless the opening is remote from the arcing part, the requirement in [6.1](#) necessitates the interposing of a noncombustible barrier between a ventilating opening and a possible source of arcing such as a switch, fuse, and the like.

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

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

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

6.5 The thickness of a nonmetallic barrier may be less than 1/4 in (6.4 mm) if the barrier is located so that it will not be subject to mechanical abuse during installation and is located and supported so that it will have the necessary mechanical strength and rigidity.

6.6 A ventilating opening in an enclosure shall have such size or shape, or shall be covered by screening or by an expanded, perforated, or louvered metal panel so that a test rod of the diameter specified in [6.7](#) will not enter the opening.

6.7 The test rod mentioned in [6.6](#) shall be 33/64 inch (13.2 mm) in diameter if the plane of the opening is less than 4 in (102 mm) from an uninsulated live part, or 49/64 inch (19.4 mm) in diameter if the plane of the opening is 4 in or more from such part.

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

6.9 The area of a ventilating opening in an enclosure shall not exceed 80 in<sup>2</sup>.

6.10 The wires of a screen required to protect a ventilating opening shall not be smaller than 16 AWG (1.3 mm<sup>2</sup>) if the screen openings are 1/2 in<sup>2</sup> or less in area, and not smaller than 12 AWG (3.3 mm<sup>2</sup>) for larger screen openings. A supplementary screen of smaller openings may be additionally provided. The supplementary screen is not to be considered in the evaluation of the ventilating opening screen.

6.11 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall not be less than 0.042 in (1.07 mm) thick if uncoated, or 0.045 in (1.14 mm) if galvanized if the mesh openings or perforations are 1/2 in<sup>2</sup> or less in area, and shall not be less than 0.080 in (2.03 mm) thick if uncoated, or 0.084 in (2.13 mm) thick if galvanized 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 given in [Table 20.1](#), perforated sheet steel and sheet steel employed as expanded metal-mesh not less than 0.020 in (0.51 mm) thick if uncoated, or if galvanized 0.023 in (0.58 mm) thick may be used.*

6.12 A grill construction complying with the intent of the requirements in [6.11](#) may be accepted if it has been found to be suitable for the particular application.

6.13 The length of ventilating louvers in an enclosure shall not exceed 12 in (305 mm).

6.14 A separate louvered panel that is riveted or welded in place over a ventilating opening in the enclosure may be of not less than 0.032 in (0.81 mm) thick if uncoated and not less than 0.034 in (0.86 mm) thick if galvanized sheet steel.

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

## **7 Connections for Wiring Systems**

7.1 Knockouts provided in the enclosure shall be of the proper size; and 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 specified in [Table 20.1](#). At least two of the knockouts shall be sized to accommodate the largest size wiring which could be used in the installation of the panel.

## 8 Corrosion Protection

8.1 Iron and steel parts shall be suitably protected against corrosion by enameling, galvanizing, sherardizing, plating or other equivalent means.

8.2 The requirement of [8.1](#) 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 bearings, laminations, and the like, if the failure of such unprotected parts would not be likely to result in a hazardous condition or in the equipment's operation being affected adversely. Parts made of stainless steel of the type having inherent resistance to corrosion (properly polished or treated, if necessary) do not require additional protection against corrosion. Bearing surfaces should be of such materials and design to ensure against binding due to corrosion.

## 9 Bases – Insulating Material

9.1 A base for mounting uninsulated live parts shall be strong, not easily ignited, moisture-resistant and insulating. The base shall be of such material that it will withstand the most severe conditions likely to be met in service.

9.2 Ordinary fiber, rubber, and so-called hot-molded shellac and tar compositions are not acceptable for the mounting of uninsulated live metal.

9.3 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 contacts shall be suitable for the particular application.

9.4 A live screw head or nut on the underside of an insulating base shall be reliably prevented from loosening and shall be adequately insulated or spaced from the mounting surface. This may be accomplished by:

- a) Countersinking such parts not less than 1/8 inch (3.2 mm) in the clear and then covering them with a waterproof, insulating sealing compound that does not soften at a temperature 15°C (27°F) higher than its normal operating temperature in the device, and not less than 90°C (194°F) in any case; or
- b) Reliably securing such parts and insulating them from the mounting surface by means of a barrier, or the equivalent, or by means of through-air or over-surface spacings not less than the minimum values specified in [Table 20.1](#).

9.5 With reference to [9.4](#), a lock washer, properly applied, is acceptable as a means of preventing the loosening of a screw or nut.

9.6 With reference to [9.4\(a\)](#), determination of the softening point of a sealing compound is to be made in accordance with the American Society for Testing and Materials Standard Test for Softening Point by Ring and Ball Apparatus, ASTM E28-1967.

## 10 Mounting of Parts

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

10.2 Uninsulated live metal parts 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 20.1](#). The security of contact assemblies shall be such as to ensure the continued alignment of contacts. See also [13.9](#).

10.3 With reference to [10.1](#) and [10.2](#), friction between surfaces is not acceptable as a means to prevent turning, loosening, or shifting of a part; but a suitable lock washer, properly applied, may be accepted.

10.4 The wiring of an electrical component mounted on a door or hinged cover shall be factory installed using suitable pressure wire connectors, at each end, that comply with the Standard for Wire Connectors, UL 486A-486B. There shall be no provision for connection of field wiring.

*Exception No. 1: Quick-connect terminals may be used for signal lights, buzzers or switches, if clamps or the equivalent are provided where necessary to prevent stress on the terminations.*

*Exception No. 2: Provision may be made for field-installation of clocks, timers, or lighting fixtures by means of plugs and receptacles.*

10.5 Wires connected to a component mounted on a door or hinged cover shall:

- a) Not be larger than 12 AWG (3.3 mm<sup>2</sup>),
- b) Be stranded,
- c) Have at least 1/32 in (0.79 mm) thick insulation, and
- d) Be cabled or routed so as to avoid being damaged during opening and closing of the door or hinged cover.

*Exception No. 1: A bundle or cable of not more than 12 wires, in addition to the bonding wire mentioned in [10.6](#), may contain 10 AWG (5.3 mm<sup>2</sup>) wires.*

*Exception No. 2: A bundle or cable of not more than 4 wires, in addition to the bonding wire mentioned in [10.6](#), may contain 10 AWG wires.*

10.6 A door or hinged cover on which electrical components are mounted shall be bonded to the box with a wire not smaller than 10 AWG (5.3 mm<sup>2</sup>).

10.7 Electrical parts of a component mounted on a cover shall be located or enclosed so that with the cover open, persons are protected against unintentional contact with uninsulated live parts.

*Exception: Live parts may be accessible if the voltage involved is 42.4 V peak or less or if the available current measured through a 1500 Ω noninductive resistor is 0.5 mA or less.*

10.8 Not more than six receptacles and six grounding jacks shall be mounted on a single cover of a remote assembly.

10.9 Receptacles and grounding jacks mounted on a cover of a remote assembly shall be factory wired to pressure wire terminals in the remote assembly box.

*Exception No. 1: Factory wiring is not required if:*

- a) Not more than six devices (receptacles, grounding jacks and signal lights) are provided,
- b) The field installed wires do not exceed six 12 AWG (3.3 mm<sup>2</sup>) plus one grounding conductor,

- c) *It is not necessary to remove the devices from the cover in order to do the wiring, and*
- d) *The assembly is not intended for wiring other than that associated with the receptacles and jacks.*

*Exception No. 2: A single grounding wire may be field wired if no reference grounding bus is provided in the remote assembly box.*

10.10 Factory wiring of receptacles and grounding jacks mounted on a cover of a remote assembly shall be stranded and shall have at least 1/32-in (0.79-mm) thick insulation.

10.11 The enclosure of a remote assembly shall have a depth that accommodates the reinstallation of the cover after wiring is completed without forcing conductors against parts mounted on the cover. Parts mounted in the box such as wire terminating means shall be located so that wires connected to parts on the cover are not forced against such parts after the cover is reinstalled.

10.12 The cover of a remote assembly that is intended to be field wired shall have suitable means for its support during field wiring so that the cover assembly does not hang completely on the connected wires. This may be accomplished by the use of hinges, by instructions and design to permit hanging the cover from the lower box cover screws, or the equivalent.

10.13 If parts are held together by screws, a metal 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.

10.14 The transformer may be shipped separately from the equipment providing:

- a) The equipment is marked to identify the transformer and the location where it is to be mounted;
- b) All wiring in the equipment is provided necessitating only the line, load and grounding connections as required, to the transformer to be made; and
- c) All necessary mounting hardware is provided on the equipment.

10.15 A power center interior or a panelboard interior may be shipped separately from its enclosure providing:

- a) The enclosure, interior, and transformer when required, are marked to indicate units that are to be used together;
- b) The equipment is marked with instructions for proper field-installation and wiring;
- c) The interior is capable of being installed without removing or displacing enclosure parts other than a cover;
- d) All wiring is provided necessitating field connections only:
  - 1) To line, load, and ground,
  - 2) Between transformer primary and the main switch or circuit breaker, when provided,
  - 3) Between transformer secondary and interior,
  - 4) Between the reference ground bus and the enclosure, and
  - 5) Between the transformer core and the reference ground bus of the enclosure;



- e) All necessary mounting hardware is provided on the equipment;
- f) The necessary wiring connections and routing of wiring complies with the requirements in Separation of Circuits, Section [18](#); and
- g) All wiring has been precabled so as to reduce the likelihood of damage, and strain relief is provided to prevent stress from being transmitted to the wiring connections.

## 11 Current-Carrying Parts

11.1 A current-carrying part shall have mechanical strength and ampacity necessary for the service, and shall be of metal that is acceptable for the application.

## 12 Permanently Connected Equipment

12.1 Permanently-connected isolated power systems equipment shall have provision for the connection of a wiring system.

*Exception: Permanently connected equipment may be acceptable without provision for the connection of a wiring system if instructions indicating the locations that are intended to be drilled in the field for the connection of raceways are included with the equipment.*

## 13 Field-Wiring Terminals and Leads

13.1 Permanently connected equipment shall be provided with wiring terminals or leads for the connection of all field-installed conductors. Wiring terminals shall be acceptable for use with conductors having an ampacity not less than the ampere rating of the equipment.

13.2 With reference to [13.1](#), sizes of field-installed conductors corresponding to a specific ampacity rating shall be determined according to [Table 13.1](#), based on the following:

a) The use of:

- 1) Wire rated 75°C (167°F) for 1/0 AWG (53.5 mm<sup>2</sup>) and larger.
- 2) Wire rated 60°C (140°F) for 1 AWG (42.4 mm<sup>2</sup>) and smaller, except 75°C (167°F) wire if the equipment is marked for use with 75°C wire in accordance with [39.28](#).

b) The use of aluminum wire at any terminal indicated on a wiring diagram or the like as being acceptable for use with such wire, whether or not that terminal is also indicated as being acceptable for use with copper wire. See [39.10](#) – [39.19](#).

13.3 A wiring terminal shall be capable of holding the next larger size conductor than that required by [13.1](#) if the terminal will properly receive the larger size conductor, unless the equipment is marked to restrict its use to the smaller size conductor.

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



**Table 13.1  
Ampacity of insulated conductors**

Wire size		Ampacity			
		60°C (140°F)		75°C (167°F)	
AWG or kcmil	(mm <sup>2</sup> )	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)	110	85	130	100
1/0	(53.5)	–	–	150	120
2/0	(67.4)	–	–	175	135
3/0	(85.0)	–	–	200	155
4/0	(107.2)	–	–	230	180
250	(127)	–	–	255	205
300	(152)	–	–	285	230

NOTE – These values of ampacity apply only where a maximum of three current-carrying conductors are to be field installed in a single conduit. When four or more conductors other than a grounding conductor or a neutral that carries the unbalanced current are to be installed in a conduit, the ampacity of each of these conductors is to be reduced as shown in the following table. These reduced values do not apply to internal wiring unless it is enclosed in conduit.

Number of conductors	Percent of value in table
4 – 6	80
7 – 24	70
25 – 42	60
43 or more	50

13.5 If a wire-binding screw is employed the screw shall not be smaller than No. 10.

*Exception: A No. 8 or 6 screw may be used for the connection of a 14 AWG (2.1 mm<sup>2</sup>) or smaller remote indicator or control-circuit conductor.*

13.6 A wire-binding screw shall thread into metal, and shall not have less than two full threads.

13.7 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 in (1.27 mm) thick.

*Exception No. 1: A plate not less than 0.030 in (0.76 mm) thick is acceptable if the metal is extruded at the tapped hole so as to provide two full threads.*

*Exception No. 2: Other constructions may be employed if they provided equivalent strength of the terminal plate and thread security of the wire-binding screw.*

13.8 Terminals or leads to which isolated output conductors will be field connected shall be color-coded as follows:

Orange – Isolated Conductor No. 1, with a distinctive colored stripe other than white, green, or gray,

Brown – Isolated Conductor No. 2, with a distinctive colored stripe other than white, green, or gray, and

Yellow – Isolated Conductor No. 3 (three-phase system only), with a distinctive colored stripe other than white, green, or gray.

*Exception: The terminals need not be color-coded if a wiring diagram or other marking, located near the terminals, is provided to clearly indicate the proper connections.*

13.9 A wiring terminal including a pressure wire connector shall be prevented by a restraint (such as a shoulder or boss— a lock washer alone is not acceptable for this purpose) from turning so as to reduce spacings to values less than those specified in [Table 20.1](#).

*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 from their normal position toward the other, and*

*b) The lug or connector has been turned 30 degrees toward other opposite-polarity live parts and toward grounded noncurrent-carrying parts.*

13.10 A pressure wire connector provided with or specified for use with the equipment shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B.

13.11 The tightening torque for a field-wiring terminal shall be as specified by the equipment manufacturer and shall be marked as required by [39.26](#). The specified tightening torque shall not be less than 90 percent of the value employed in the static heating test as specified in the requirements in the Standard for Wire Connectors, UL 486A-486B, for that wire size corresponding to the ampere rating of the equipment. See [33.1](#).

*Exception: The 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.*

## 14 Cord-Connected Equipment

### 14.1 General

14.1.1 A cord-connected isolated power center shall consist of an isolation transformer, line-isolation monitor, branch-circuit panel, reference grounding bus, receptacle as described in [25.1](#), and grounding jacks – see [26.1](#) – all mounted within a common enclosure and supplied by a power-supply cord.

14.1.2 A cord-connected convertible-system unit shall comply with [14.1.1](#) and in addition shall contain an output cord-connector body or receptacle. The reliability of the grounding connection shall be determined in accordance with the requirements for hospital grade receptacles.

14.1.3 The power supply cord of a cord-connected isolated power center or convertible-system unit shall consist of a three conductor 10 AWG minimum, Type S or equivalent hard service cord. Cord-connected equipment rated 20 A or less shall terminate in either a nonhazardous location locking-type, attachment plug designated "Hospital Only" or a conventional two-blade with grounding pin attachment plug designated "Hospital Grade" and shall be marked in accordance with [39.3](#). Cord-connected equipment

rated over 20 A shall terminate in an acceptable attachment plug. The reliability of the grounding connection shall be investigated in accordance with the applicable requirements for hospital grade plugs.

## 14.2 Strain relief

14.2.1 Strain relief shall be provided to prevent a mechanical stress on a flexible cord, such as a pull or twist, from being transmitted to terminals, splices, or interior wiring.

14.2.2 A clamp may be employed to provide strain relief.

14.2.3 Means shall be provided to prevent the flexible cord from being pushed into an appliance through the cord-entry hole when such displacement results in:

- a) Subjecting the cord to mechanical damage,
- b) Exposing the cord to a temperature higher than that for which the cord is rated,
- c) Reducing spacings, such as to a metal strain-relief clamp, below the minimum required values, or
- d) Damaging internal connections or components.

The cord shall comply with Push-Back Relief, Section [35](#).

14.2.4 When tested in accordance with [14.2.5](#), the strain relief means provided on the flexible cord shall withstand for 1 min, without displacement, a pull of 35 lbf (156 N) applied to the cord with the connections within the equipment disconnected.

14.2.5 A 35-lb (16-kg) weight is to be suspended on the cord and supported by the equipment so that the strain-relief means will be stressed from any angle that the construction of the equipment permits. The strain relief is not acceptable if, at the point of disconnection of the conductors, there is movement of the cord indicating that stress would have resulted on the connections.

## 14.3 Bushings

14.3.1 A bushing or the equivalent shall be provided at a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case. The bushing shall be substantial and reliably secured in place, and shall have a smooth well-rounded surface against which the cord may bear.

## 15 X-Ray Equipment

15.1 An isolated power center intended to supply x-ray equipment only is considered to be intended for intermittent duty. The equipment shall consist of an isolation transformer, line isolation monitor, secondary branch-circuit protection, and a ground bus. The output of the equipment shall provide for only one circuit at a time that is provided with secondary overload protection of 60 A maximum.

*Exception: An isolated power center may supply more than one circuit at a time if the electrical system is in accordance with the Exception to Article 12-4.1.2.6 (d) or with Article 12-4.1.2.6 (e) in the Standard for Health Care Facilities, NFPA 99-1993.*

## 16 Wall Modular Units

16.1 A wall-modular unit containing isolated power systems circuits shall not have grounded output-power-systems circuits.

16.2 The surface burning characteristics of the building materials used in wall-modular units shall have the following maximum ratings applied to the finished panel and to core material (if used) in comparison with asbestos-cement boards as zero and untreated red oak lumber as 100:

- a) Flame spread rating 75.
- b) Smoke developed 200.

16.3 Except for the enclosures of isolated power systems equipment contained in or supported by a wall-modular unit (see Enclosure, Section [5](#)), the minimum thickness of materials comprising the wall-modular unit is not specified, but the wall-modular unit shall have sufficient strength and rigidity to mount and support all components.

16.4 Wall-modular units may be shipped without incorporating component accessories such as gas outlets, lighting fixtures, clocks, and intercommunication units.

16.5 A raceway utilized for multiple installation of electrical outlets, switches, ground jacks, clinical gas valves, and the like, shall comply with the requirements in the Standard for Surface Metal Raceways and Fittings, UL 5.

16.6 A gas outlet shall comply with the requirements for gas and vacuum systems in the Standard for Health Care Facilities, NFPA 99.

16.7 Wiring shall be segregated in accordance with Separation of Circuits, Section [18](#). In addition, patient-monitoring-circuit wiring shall be routed in an enclosure or a conduit separate from all other wiring.

16.8 Each raceway provided to accommodate a field-installed circuit, shall be marked to indicate the circuit that is to be routed through the raceway. The marking may be in the form of a wiring diagram that clearly indicates the location of the raceway.

## 17 Internal Wiring

17.1 The internal wiring of isolated power systems equipment shall consist of general-use wire, such as Type RH, T, or THW, or equivalent appliance wiring material having insulation at least 0.028 in (0.71 mm) thick and that is acceptable for the application when considered with respect to the temperature, voltage, and conditions of service to which the wiring is likely to be subjected.

17.2 The insulation on internal wiring of isolated power systems equipment shall be color-coded as follows:

Orange – Isolated Conductor No. 1, with a distinctive colored stripe other than white, green, or gray,

Brown – Isolated Conductor No. 2, with a distinctive colored stripe other than white, green, or gray, and

Yellow – Isolated Conductor No. 3 (three-phase system only), with a distinctive colored stripe other than white, green, or gray.

17.3 Supplementary insulation, such as coated-fabric or extruded thermoplastic insulating tubing, shall be rated for the temperature to which it may be subjected in service. See [20.14](#).

17.4 A wireway shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like that may cause abrasion of the conductor insulation. A hole in a sheet-metal wall through which insulated wires pass shall be provided with a bushing if the wall is 0.042 in (1.07 mm) or less in thickness.

A hole in a wall thicker than 0.042 in shall have smooth, well-rounded edges, or shall be provided with a bushing.

17.5 All joints and connections shall be mechanically secure and shall provide acceptable electrical contact without placing stress on connections and terminals.

17.6 A stranded conductor clamped under a wire-binding screw or similar part shall have the individual strands restrained by being soldered together or by a cupped washer or the equivalent.

## 18 Separation of Circuits

### 18.1 Factory installed

18.1.1 Unless provided with insulation rated for the highest voltage involved, factory installed insulated conductors of different circuits, such as primary and secondary circuits, circuits of different voltages, communication circuits, different branch circuits, and the like shall be separated by barriers or shall be segregated; and shall, in any case, be separated or segregated from uninsulated live parts connected to different circuits.

18.1.2 Segregation of insulated conductors may be accomplished by clamping, routing, or equivalent means that provides permanent separation from insulated or uninsulated live parts of a different circuit.

18.1.3 A barrier used to provide separation between the wiring of different circuits shall be of metal or insulating material having mechanical strength acceptable for the application, and shall be reliably held in place.

### 18.2 Field-installed Class 2

18.2.1 Means shall be provided for field-installed Class 2 conductors to be separated by barriers or to be segregated as indicated in [18.1.2](#) from:

- a) Field-installed and factory-installed conductors connected to any circuit other than Class 2.
- b) Uninsulated live parts of any other circuit of the equipment.

18.2.2 With reference to [18.2.1](#) (a), if the intended uses of the equipment are such that in some applications a barrier is required for separation while in other applications no barrier is required, a removable barrier or one having openings for the passage of conductors may be employed. Instructions for the use of such a barrier are to be a permanent part of the equipment. Complete instructions in conjunction with a wiring diagram may be acceptable in lieu of a barrier if, upon investigation, the combination is found to be acceptable.

18.2.3 Field-installed Class 2 conductors may be segregated in accordance with [18.2.1](#) by arranging the location of openings in an enclosure for the various conductors – with respect to the terminals or other uninsulated live parts – so that there is no likelihood of intermingling of the conductors or parts of different circuits.

- a) If the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the equipment, and if each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening will be connected to the terminal opposite that opening.
- b) If more than the minimum number of openings are provided, it is to be assumed that conductors will enter an opening other than the one opposite the terminal to which they are intended to be

connected. In such a case, there shall not be a likelihood of the conductors contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit.

18.2.4 To determine if equipment complies with the requirements of [18.2.1](#), it is to be wired as it would be in service. In doing so, slack is to be left in each conductor, within the enclosure, and no more than average care is to be exercised in stowing the slack into the wiring compartment.

## 19 Field-Wiring Space

### 19.1 General

19.1.1 The space for field-installed connections within the enclosure of isolated power systems equipment shall be sufficient to provide room for the distribution of the maximum size supply and load wires required for the proper wiring of the equipment, as based on the rating of the equipment.

### 19.2 Wire bending space

19.2.1 Wire bending space for field installed wires shall be provided opposite any wire connector and also opposite any opening or knockout for a wiring system as specified in [19.2.2](#), [19.2.3](#), or [19.2.7](#).

19.2.2 If a conductor is likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in [Table 19.2](#). A wire is considered likely to enter or leave a top, back or side surface if there is an opening or knockout for a wiring system or if instructions are provided in accordance with the Exception to [12.1](#).

*Exception: The wire bending space may be in accordance with [Table 19.1](#) if drawings are provided specifying that the conductors are not to enter or leave the enclosure surface that is opposite the wire connector.*

**Table 19.1**  
Minimum acceptable width of gutter and wire-bending space at terminals

Wire size, AWG or kcmil (mm <sup>2</sup> )	Minimum bending space, terminal to wall, in <sup>a</sup>
14 – 10 (2.1 – 5.3)	Not specified
8 (8.4)	1-1/2
6 (13.3)	1-1/2
4 – 3 (21.2 – 26.7)	2
2 (33.6)	2-1/2
1 (42.4)	3
1/0 – 2/0 (53.5 – 67.4)	3-1/2
3/0 (85.0)	4
4/0 (107.2)	4
250 (127)	4-1/2
300 (152)	5

NOTES –

1 Multiple-conductor combinations may be given further consideration.

2 For ampacities of 110 A or less, wire-bending space shall be based on the lowest-temperature insulated wire the marking specifies.

3 See [19.2.3](#) and [19.2.7](#).

<sup>a</sup> For SI units 1 in = 25.4 mm.

**Table 19.2**  
**Minimum acceptable wire-bending space at terminals**

Wire size, AWG or kcmil (mm <sup>2</sup> )	Minimum bending space, terminal to wall, in <sup>a</sup>
14 – 10 (2.1– 5.3)	Not Specified
8 (8.4)	1-1/2
6 (13.3)	2
4 (21.2)	3
3 (26.7)	3
2 (33.6)	3-1/2
1 (42.4)	4-1/2
0 (53.5)	5-1/2
2/0 (67.4)	6
3/0 (85.0)	6-1/2 [1/2] <sup>b</sup>
4/0 (107.2)	7 [1] <sup>b</sup>
250 (127)	8-1/2 [2] <sup>b</sup>
300 (152)	10 [3] <sup>b</sup>

NOTES –

1 Multiple-conductor combinations may be given further consideration.

2 For ampacities of 110 A or less, wire-bending space shall be based on the lowest-temperature insulated wire the marking specifies.

3 See [19.2.2](#).

<sup>a</sup> For SI units 1 in = 25.4 mm.

<sup>b</sup> For removable wiring terminals intended for only one wire, bending space may be reduced by the amount shown in brackets. See [19.2.5](#).

19.2.3 If a conductor is not likely to enter or leave the enclosure opposite its wire connector, the wire bending space shall be as specified in [Table 19.1](#).

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

19.2.5 For the purpose of these requirements a removable wiring terminal is one that can be removed from its intended location without disturbing structural or electrical parts, other than a cover, and that can be reinstalled with the conductor in place.

19.2.6 The distance specified in [Table 19.2](#) is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. The wire terminal is to be turned to all positions that it can assume without defeating any reliable means provided to prevent its turning, such as a box, shoulder, walls of a recess, or multiple bolts securing the connector.

*Exception No. 1: Bending space specified in [Table 19.1](#) may be measured in a straight line from the center of the wire opening in the direction the wire leaves the terminal. However, it is to be assumed that the connector is not oriented so that the wire will be directed into a corner of the box to such extent that the transverse wall would necessitate additional bending. If the connectors for a circuit are fixed in position – for example, by the walls of a recess – so that they are turned toward each other, the distance is to be measured at the wire opening nearest to the wall in a direction perpendicular to the wall.*

*Exception No. 2: If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure.*

19.2.7 A wiring space in which one or more openings or knockouts are provided or are intended for openings in accordance with the Exception to [12.1](#) shall be of adequate width to accommodate (with respect to bending) conductors of the maximum size likely to be used at that location. The values of the minimum acceptable width of a wiring space, with respect to conductors entering at that location, are the same as the values of minimum acceptable bending space given in [Table 19.1](#).

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

- a) *Knockouts of sufficient size are provided elsewhere or designated in accordance with the Exception to [12.1](#),*
- b) *The wiring space at such other location is of adequate width to accommodate the conductors in question, and*
- c) *This location can be conveniently used in the normal wiring of the device.*

19.2.8 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 specified in [Table 19.3](#).
- 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.

19.2.9 In determining whether or not a wiring space complies with the requirement in [19.2.8](#), consideration is to be given to the actual size of wires that will be used in that space; but wires smaller than 12 AWG (3.3 mm<sup>2</sup>) shall not be used. In computing the area of a wiring space, consideration is to be given to all the available space that may be properly used for the placement of wires. Minimum areas of the more common multiple-wire connections are given in [Table 19.3](#).

19.2.10 The acceptability of wiring spaces shall be judged using:

- a) The size and conductor material of a wire used at a terminal in accordance with [13.2](#), except that for ampacities of 110 A or less the size shall be based on 60°C (140°F) insulated conductors if the marking specifies 60, 75, or 90°C (140, 167, or 194°F) wire; and
- b) The full complement of branch-circuit devices necessitating the largest wiring space installed. If a terminal is acceptable for use with two or more combinations of conductors in multiple, each of which would be appropriate for that terminal in accordance with [13.2](#), the combination necessitating the largest wiring space shall be used. If a terminal is provided for conductors in multiple, the size of each of the conductors will be run in a separate conduit. See note a to [Table 13.1](#).



**Table 19.3**  
**Wiring space**

Maximum size of wire or cable involved, AWG or kcmil (mm <sup>2</sup> )	Minimum width and depth of wiring space in inches	Minimum areas in square inches required for multiple areas based on factor of 2.5					
		Two wires	Three wires	Four wires	Five wires	Six wires	Seven wires
12 (3.3)	3/8	0.14	0.21	0.28	0.35	0.42	0.49
10 (5.3)	3/8	0.23	0.34	0.46	0.57	0.68	0.80
8 (8.4)	1/2	0.38	0.57	0.76	0.95	1.14	1.33
6 (13.3)	5/8	0.62	0.93	1.24	1.55	1.86	2.17
4 (21.2)	3/4	0.80	1.20	1.60	2.00	2.40	2.80
3 (26.7)	3/4	0.91	1.36	1.82	2.27	2.72	3.18
2 (33.6)	7/8	1.03	1.55	2.06	2.58	3.10	3.61
1 (42.4)	1	1.36	2.04	2.72	3.40	4.08	4.76
1/0 (53.5)	1	1.55	2.33	3.10	3.88	4.66	5.43
2/0 (67.4)	1	1.79	2.68	3.58	4.47	5.36	6.26
3/0 (85.0)	1-1/8	2.08	3.11	4.16	5.19	6.22	7.27
4/0 (107.2)	1-1/4	2.42	3.63	4.84	6.05	7.26	8.47
250 (127)	1-3/8	2.96	4.44	5.92	7.40	8.88	10.36
300 (152)	1-1/2	3.42	5.13	6.84	8.55	10.26	11.96
350 (177)	1-1/2	3.81	5.72	7.62	9.53	11.44	13.34

NOTE – For SI units 1 in = 25.4 mm.

## 20 Spacings

20.1 Spacings in isolated power systems equipment shall not be less than the applicable value specified in [Table 20.1](#).

*Exception No. 1: Spacings within components such as isolation transformers, line isolation monitors, receptacles, and the like shall comply with the requirements applicable to that component.*

*Exception No. 2: Spacings for components in the signaling circuit for the line isolation monitor such as buzzers, lampholders and associated conductors shall be in accordance with the requirements for line isolation monitors.*

20.2 Spacings in a component used in isolated power systems equipment (such as isolation transformers, line isolation monitors, and receptacles) shall comply with the requirements applicable to that component except that spacings between the component and the overall enclosure (other than inherent spacings) and spacings between individual components shall comply with those specified in [Table 20.1](#).

20.3 In applying the minimum spacings specified in [Table 20.1](#) it is assumed that the spacings at a fuseholder are to be measured with a fuse of the maximum standard dimensions (including the maximum projections for assembly screws and rivets) in place.

**Table 20.1**  
**Minimum spacings**

Voltage involved, V	Minimum spacings between uninsulated live parts of opposite polarity and between an uninsulated live part and a grounded part of dead metal <sup>a</sup>			
	Through air <sup>b</sup>		Over surface <sup>b</sup>	
	in	(mm)	in	(mm)
0 – 50	1/8	(3.2)	1/4	(6.4)
51 – 250	1/2	(12.7)	1/2	(12.7)
251 – 600	1	(25.4)	1	(25.4)

<sup>a</sup> An isolated part of conductive material (such as a screwhead or washer) interposed between uninsulated live parts of opposite polarity or between an uninsulated live part and grounded dead metal is considered to reduce the spacing by an amount equal to the dimension of the interposed part along the path of measurement.

<sup>b</sup> A minimum spacing of 1 in (25.4 mm) is required between a live part and a metal enclosure.

20.4 The distance between a door or cover over a fuseholder and:

- a) The center contact of an Edison-base fuseholder shall not be less than 1-9/16 in (39.7 mm).
- b) The center contact of a Type S fuseholder shall not be less than 1-5/16 in (33.3 mm).

20.5 The spacings between screw shells of plug fuseholders that are protected by surrounding walls of insulating material, and between such screw shells and a metal cover plate, may not be less than 1/4 in (6.4 mm) if the depth of the receptacle as measured from the top of the wall to the plane of the center contact is not less than 3/4 in (19.1 mm).

20.6 The liner or barrier referenced in [20.7](#) – [20.12](#) 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 value indicated in [Table 20.1](#).

20.7 A barrier or liner which comprises the sole separation:

- a) Shall be of material suitable for supporting an uninsulated live part, except that a barrier between the enclosure and an uninsulated part electrically connected to a grounded circuit conductor may be of fiber.
- b) Shall have a thickness of 0.028 in (0.71 mm) or more, except as indicated in [20.12](#).

20.8 A barrier or liner used in conjunction with an air space shall have a thickness of 0.028 in (0.71 mm) or more, except as noted in [20.11](#) and [20.12](#).

20.9 If the barrier mentioned in [20.8](#) is of fiber, the air space shall be 1/32 in (0.79 mm) or more.

20.10 If the barrier mentioned in [20.8](#) is of material (other than fiber) that is not suitable for the support of uninsulated live parts, the air space shall be adequate for the particular application.

20.11 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 in (0.33 mm) if it is:

- a) Of material suitable for supporting uninsulated live parts,
- b) Of adequate strength if exposed or otherwise likely to be subjected to damage,

- c) Reliably held in place, and
- d) So located that it will not be adversely affected by operation of the equipment in service.

20.12 Insulating material having a thickness less than that indicated in [20.7\(b\)](#) and [20.8](#) and [20.11](#) may be accepted if it has been found to be suitable for the particular application.

20.13 If spacings are less than those required in [Table 20.1](#), thermoplastic tape that complies with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510, may be employed if:

- a) At point where the spacing (see [Table 20.1](#)) prior to the application of the tape is not less than half the required through-air spacing, the wrap is not less than 0.013 inch (0.33 mm) in thickness, and is applied in two or more layers.
- b) At point where the spacing prior to the application of the tape is less than half the required through-air spacing, the wrap is not less than 0.028 inch (0.71 mm) in thickness.
- c) The tape is not subject to compression.
- d) The tape is not wrapped over a sharp edge.
- e) The tape is not to be subjected to a temperature in excess of 80°C (176°F).

20.14 If spacings are less than those required in [Table 20.1](#), thermoplastic tubing that complies with the Standard for Extruded Insulating Tubing, UL 224, may be employed if:

- a) Not subjected to compression, repeated flexure, or sharp bends;
- b) All edges of the conductor covered with the tubing are well rounded and free from the sharp edges;
- c) For chemically dilated tubing, a solvent recommended by the tubing manufacturer is used;
- d) Its wall thickness (after assembly) is not less than 0.022 in (0.56 mm) for tubing 1/2 in (12.7 mm) or less in diameter, and is no less than 0.028 in (0.71 mm) for larger tubing; and
- e) Not subjected to a temperature higher than that for which the tubing is acceptable.

20.15 Spacings are to be measured with all terminals unwired, and wired with conductors of a size appropriate for the current involved. For field-wiring terminals no conductor smaller than 12 AWG (3.3 mm<sup>2</sup>) is to be employed except 14 AWG (2.1 mm<sup>2</sup>) is to be employed for control circuits.

20.16 In measuring spacings between an uninsulated live part and a bushing installed at a knockout of the enclosure, it is to be assumed that a bushing having the dimensions indicated in [Table 20.2](#) (but without a locknut inside the enclosure) is in place.

**Table 20.2  
Bushing dimensions**

Trade size of conduit in inches	Overall diameter in inches	Height in inches
1/2	1	3/8
3/4	1-15/64	27/64
1	1-19/32	33/64

**Table 20.2 Continued on Next Page**

Table 20.2 Continued

Trade size of conduit in inches	Overall diameter in inches	Height in inches
1-1/4	1-15/16	9/16
1-1/2	2-13/64	19/32
2	2-45/64	5/8
2-1/2	3-7/32	3/4
3	3-7/8	13/16
3-1/2	4-7/16	15/16
4	4-31/32	1

NOTE – For SI units 1 in = 25.4 mm.

## 21 Isolation Transformers

21.1 Isolation transformers shall be of the multiple-winding type with no electrical connection between the primary and secondary windings. The transformer shall comply with the provisions for low voltage transformers in the Standards for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1 and the Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2, or the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3, and in addition shall be of such construction that the primary and secondary windings are physically separated in order to reduce the likelihood of the primary circuit potential from being impressed on the secondary circuits. Physical separation may be accomplished in one of the following manners:

- a) Primary and secondary windings are to be assembled one on the other but wholly separated from each other by either a copper barrier not less than 0.005 in (0.13 mm) thick or a barrier which complies with [21.3](#). The core is to be electrically connected to the reference grounding bus.
- b) Primary and secondary windings are not assembled one on the other and are wholly separated from each other by either a spacing of not less than 1/2 in (12.7 mm) through air and over surface or a barrier of phenolic or melamine resin composition or the equivalent, not less than 0.028 in (0.71 mm) thick. The core is to be either electrically connected to the reference grounding bus or wholly covered with insulation.

21.2 The copper barrier mentioned in [21.1\(a\)](#) shall be connected to the core by a conductor sized in accordance with [Table 27.1](#) or connected to the reference grounding bus by means of a copper conductor equivalent in cross section to the largest load conductor.

21.3 A barrier employed to comply with [21.1\(a\)](#) and the Exception to [21.7](#) shall be:

- a) 0.007 in (0.18 mm) thick mica,
- b) Other material that has a flame-spread rating of zero when tested in accordance with the Standard for Tests for Surface Burning Characteristics of Building Materials, UL 723, or
- c) A material that complies with the abnormal operation test prescribed in Abnormal Operation, Section [34](#).

21.4 Transformer core insulation employed to comply with the requirement in [21.1\(b\)](#), shall comply with the requirements for insulation systems and comply with the abnormal operation test prescribed in Abnormal Operation, Section [34](#).

21.5 An uninsulated transformer core shall be electrically connected to the reference grounding bus by means of a copper conductor having an ampacity at least equal to that of the largest load conductor, or

enclosure by the transformer mounting means. Continuity of the grounding circuit shall not depend wholly or in part on solder.

21.6 Insulation of leads shall be noted for the conditions of service, shall not be less than 0.028 in (0.71 mm) thick, and shall comply with the requirements for materials classified V-0 in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

*Exception No. 1: These requirements do not apply to turn-to-turn insulation of a winding.*

*Exception No. 2: These requirements do not apply to thermoplastic tubing and insulated wire, that complies with:*

- a) *The requirements for the material see components, Section [3.1](#)*
- b) *The requirements in [20.14](#) and [17.1](#), and*
- c) *The Type FR-1 flammability requirements.*

21.7 Leads brought out of windings shall be insulated as required by [21.6](#) and shall be separated from each other and from windings proper by not less than 1/4 in (6.4 mm) through air and 3/8 in (9.5 mm) over surface where separation between primary and secondary is involved.

*Exception: A lesser spacing is acceptable where a barrier that complies with the requirements in [21.3](#) is employed.*

21.8 Transformer regulation shall not exceed 3 percent when tested as described in [28.1](#).

21.9 Transformer leakage current shall not exceed the levels specified in [Table 30.2](#) when tested as described in [30.1](#) and [30.4](#).

## 22 Line Isolation Monitor

22.1 Each isolated power systems equipment shall be provided with a continuously operating line isolation monitor that indicates possible leakage or fault current from the isolated circuit to any part of the equipment that may be grounded in service – enclosure or primary circuit.

22.2 A line isolation monitor shall comply with the requirements in the Standard for Line Isolation Monitors, UL 1022.

22.3 Input leads to a line isolation monitor shall not be smaller than 20 AWG (0.52 mm<sup>2</sup>). A line isolation monitor shall be protected by fuses or a circuit breaker having a voltage rating equal to or more than the rating of the isolated secondary and a current rating no more than 15 A. Overcurrent protection for a line isolation monitor that is located remote from the enclosure in which wiring to it originates shall be acceptable for branch-circuit protection.

22.4 With reference to [22.3](#), the fuses may be integral with the line isolation monitor.

22.5 Type S plug fuses and Class G, H, J, K, R, and T fuses are acceptable for branch-circuit protection.

22.6 If provision is made for the connection of a remote indicator or signal circuit, there shall be sufficient space for routing and connecting the conductors for such circuits. See Separation of Circuits, Section [18](#).

## 23 Overcurrent Protection

23.1 Overcurrent protection provided for the primary circuit shall be rated not more than 125 percent of the ampere rating of the primary circuit.

*Exception: The next higher standard rating is acceptable if 125 percent of the ampere rating does not correspond to a standard rating of a fuse or circuit breaker. For a transformer rated less than 1000 VA, the overcurrent protection shall not be rated more than 167 percent of the primary current.*

23.2 A circuit breaker connected in the primary circuit shall open all ungrounded conductors.

*Exception: If the equipment has provision for connection of a grounded neutral conductor, individual single-pole circuit breakers are acceptable as the protection for each ungrounded conductor of a 3-wire single-phase circuit or for each ungrounded conductor of a 4-wire, 3-phase circuit, provided that no conductor involves a potential to ground in excess of 150 V.*

23.3 Branch circuits supplied from the secondary of an isolation transformer shall have overcurrent protection in each circuit conductor. If circuit breakers are used they shall be the 2-pole (3-pole for three-phase circuits) common-trip type. Overcurrent protection shall be acceptable for branch-circuit protection.

23.4 Overcurrent protection in a circuit supplying an integral receptacle shall be rated the same as the receptacle.

23.5 There shall not be more than 16 branch circuits in one panel, not counting the line isolation monitor circuit.

23.6 The on-off position of each circuit breaker shall be clearly indicated. If a circuit breaker handle is operated vertically, rather than horizontally or rotationally, the up position of the handle shall be the on position.

## 24 Switches

24.1 A switch shall be provided in an isolated power center for each circuit supplied from the secondary of the isolation transformer, except for the line isolation monitor circuit. Each switch shall open all supply-circuit conductors. If circuit breakers are used to comply with [23.3](#), they may serve as the switches required by this paragraph.

24.2 The on-off position of each switch shall be clearly indicated. If a switch handle is operated vertically, rather than horizontally or rotationally, the up position of the handle shall be the on position.

24.3 If cartridge-type fuses are employed to comply with [23.3](#), a switch that opens all supply circuit conductors shall be provided on the supply side of each cartridge fuseholder such that each branch circuit, except the line-isolation-monitor circuit, can be independently disconnected from the source of the supply.

## 25 Receptacles

25.1 Power receptacles that are an integral part of isolated power systems equipment shall be either the nonhazardous location locking type receptacle designated "Hospital Only" or a conventional 2-blade receptacle designated "Hospital Grade" and having a grounding pin.

25.2 The grounding terminal of each receptacle shall be connected to the reference grounding bus, or, for a remotely mounted receptacle, to the common grounding point mentioned in [25.3](#), by means of an insulated copper conductor sized in accordance with [Table 27.2](#).

25.3 Receptacles in common enclosure shall be connected to a common grounding point. Means shall be provided for connecting this grounding point to a reference grounding bus bar using a 10 AWG (5.3 mm<sup>2</sup>) insulated copper wire.

25.4 With reference to [17.2](#), for a circuit providing a 125-V, single-phase, 15- and 20-A receptacles, the orange conductor or conductors shall be connected to the terminal on the receptacle that is identified for connection of the grounded circuit conductor.

## 26 Grounding Jacks and Cord Assemblies

26.1 When provided, a jack for grounding nonelectrical equipment, conductive metal, furnishings, or other metal shall be of the single pole type, acceptable for the purpose.

26.2 An individual grounding jack shall be connected to the reference grounding bus by a single insulated 10 AWG (5.3 mm<sup>2</sup>) stranded copper conductor. Grouped jacks shall be connected to the reference grounding bus by an insulated, continuous, stranded copper conductor, not smaller than 10 AWG. See [Table 27.2](#).

26.3 An acceptable grounding-cord assembly consisting of a single pole plug, single conductor, and terminal connector shall be available.

26.4 The grounding conductor shall have 3/64 in (1.2 mm) minimum insulation, and be stranded copper, not smaller than 10 AWG (5.3 mm<sup>2</sup>). The color of the cord insulation shall be green with or without one or more yellow stripes.

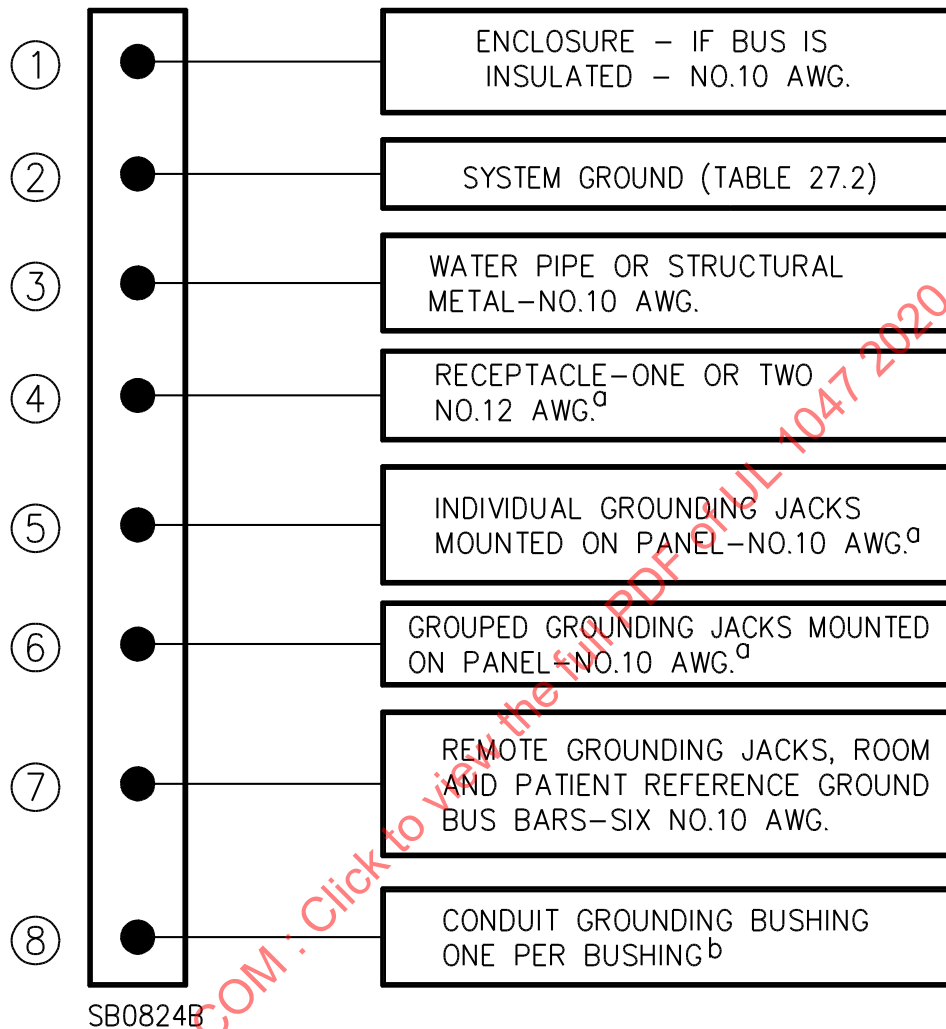
26.5 The resistance of the cord assembly measured from the tip of the grounding plug to the terminal connector shall not exceed 0.03 Ω.

## 27 Reference Grounding Bus

27.1 Isolated power centers, isolated power panelboards, and wall modular units shall be provided with an accessible silver, copper, or copper alloy bare metal reference grounding bus bar having sufficient area to accommodate the number of connections shown in [Figure 27.1](#). The cross-section shall be no less than indicated in [Table 27.1](#), based on an overcurrent protective device rated 125 percent of the current rating of the primary of the isolation transformer, and if provided with wire binding screws the thickness shall be no less than 0.050 in (1.27 mm). See [13.7](#).

Figure 27.1

## Reference grounding bus bar connections



Notes –

1) <sup>a</sup> Not required for isolated power centers for x-ray equipment only.2) <sup>b</sup> Required for wall modular units. See note c of [Table 27.2](#).



27.2 The reference grounding bus bar is able to be mounted directly on the metal of the enclosure or insulated from the enclosure. Where insulated, the reference grounding bus bar shall be connected to the enclosure by an insulated stranded copper conductor not smaller than 10 AWG (5.3 mm<sup>2</sup>). Sheet-metal screws shall not be used to connect grounding conductors to the enclosure.

**Table 27.1  
Grounding conductor**

Maximum ampere rating of overcurrent device protecting primary of isolation transformer	Size of copper grounding conductor		Cross-section of grounding means
	Minimum AWG (mm <sup>2</sup> )		in <sup>2</sup> – minimum
60	10	(5.3)	0.008
100	8	(8.4)	0.013
200	6	(13.3)	0.021

NOTE – For SI units 1 in = 25.4 mm.

27.3 The reference grounding bus bar shall have provision for the connection of not less than the number and size conductors indicated in [Table 27.2](#). All terminations on the reference grounding bus bar shall be suitable for stranded copper conductors and shall have provision for mechanically securing internal bonding conductors and supply grounding conductors without the use of solder.

27.4 All dead metal parts of a wall modular unit (not reliably bonded to the grounding system) shall be connected to the reference grounding bus bar by means of insulated stranded copper conductors not smaller than 10 AWG (5.3 mm<sup>2</sup>). All raceways shall be similarly connected by means of threaded rigid conduit or the equivalent.

**Table 27.2  
Reference grounding bus bar connections**

Item	Connection to	Number	AWG size (mm <sup>2</sup> )
1	Enclosure – if reference grounding bus bar is insulated from enclosure	1	10 (5.3)
2	Building Service Ground	1	<a href="#">Table 27.1</a>
3	Water Pipe or Structural Metal	1	10 (5.3)
4	Power Receptacles	1 <sup>a,b</sup>	12 (3.3)
5	Individual Grounding Jacks Mounted on Panel	1 <sup>b</sup>	10 (5.3)
6	Grouped Grounding Jacks Mounted on Panel	1 <sup>b</sup>	10 (5.3)
7	Remote Grounding Jacks, Room Bonding Bus or Patient Equipment Grounding Bus	6	10 (5.3)
8	Conduit Grounding Bushings	1 <sup>c</sup>	10 (5.3)

NOTE – See [Figure 27.1](#).

<sup>a</sup> It is recommended that two grounding connections, appropriately color coded, be provided for each power receptacle to provide for future redundant grounding.

<sup>b</sup> Not required for isolated power centers for x-ray equipment only.

<sup>c</sup> Only required for wall modular units. Shall be provided on the transformer enclosure at the entrance way for the primary supply leads.

## PERFORMANCE

### 28 Regulation

28.1 The inherent regulation of the transformers at rated input voltage shall be such that the difference between output voltage at no load and output voltage at rated current at unity power factor shall not exceed 3 percent of the output voltage at rated current. The transformer shall be operated at 1/4 load for 2 h prior to making measurements.

### 29 Temperature

29.1 When tested under the conditions described in [29.2](#) – [29.17](#), an isolated power systems equipment shall not attain a temperature at any point sufficiently high to constitute a risk of fire, to damage any of the materials employed, or to exceed the temperature rises specified in [Table 29.1](#).

**Table 29.1**  
**Maximum temperature rises**

Materials and components	°C	°F
<b>A. BUS BARS</b>		
1. A bus within 6 in (12.7 mm) of a fuseholder along the current path when tested with dummy fuses	30	54
2. An unplated bus bar and joint not covered by item 1	30	54
3. A plated bus bar at the point of connection to a molded-case circuit breaker <sup>a,b</sup>	55	99
4. A plated bus bar except as covered by items 1 and 3 <sup>b,c</sup>	65	117
<b>B. PRESSURE TERMINAL CONNECTORS</b>		
1. A pressure terminal connector for a field-installed conductor except as noted in item 2 <sup>c</sup>	50	90
2. A pressure terminal connector used in a circuit rated 110 A or less and marked for use with 75°C (167°F) wire <sup>d</sup>	65	117
3. A pressure terminal or wire connector for internal wiring involving aluminum conductors unless the connector has been investigated for a higher temperature <sup>c</sup>	50	90
<b>C. INSULATING MATERIALS</b>		
1. Wire insulation and insulating tubing <sup>c,e</sup>	35	63
2. Phenolic composition employed as electrical insulation or as a part, the deterioration of which would result in a risk of fire or electric shock <sup>c,e</sup>	125	225
<b>D. COMPONENTS</b>		
1. Transformer windings	Temperature rating of insulation less 25°C (77°F)	
<b>E. SURFACES</b>		
1. A part that may be contacted by field wiring <sup>c</sup>	50	90
2. Exposed surface of enclosure		
Portable equipment	25	45
Wall-mounted equipment	30	54
3. Any point on the enclosure other than item 2	65	117

<sup>a</sup> A plated bus at the point of connection to a molded-case circuit breaker marked for and subjected to this test (1) at 100 percent continuous rating, or (2) using 75°C (167°F) wire for circuits rated 110 A or less may have a 65°C (117°F) rise.

**Table 29.1 Continued on Next Page**

Table 29.1 Continued

Materials and components	°C	°F
<p><sup>b</sup> Both surfaces of a joint shall be plated but not necessarily the entire length of the bus bar.</p> <p><sup>c</sup> In equipment tested with dummy fuses, the recorded temperature rise shall be increased 20°C (36°F) to represent the heating of fuses except that if only a few fuses, such as control-circuit fuses are involved, the increase shall only apply to parts within 12 in (305 mm) of the fuses. See <a href="#">39.5</a>.</p> <p><sup>d</sup> Applicable to a connector for copper wire. Also applicable to a connector for aluminum wire or an aluminum-bodied connector provided the connector has a temperature rating of 90°C (194°F).</p> <p><sup>e</sup> This limitation does not apply to an insulated conductor or other material that has been investigated and found acceptable for a higher temperature.</p>		

29.2 For the test, the equipment is to be mounted or supported as in service and operated under conditions approximating those of normal operation.

29.3 Permanently-connected isolated power systems equipment is to be supported on the surface of a wood wall not less than 3/8 in (9.5 mm) thick, coated with flat black paint. Two or more such walls having such width and height that they extend not less than 2 ft (0.6 m) beyond the physical limits of the equipment are to be fastened together to form a 90-degree angle. The equipment is to be located as close to the inside corner of the wall as its construction will permit.

29.4 Surface-mounted equipment is to be mounted directly on the surface of the wall in the manner described in [29.3](#).

29.5 Flush-mounted equipment is to be mounted in a box-like structure of 3/8-in (9.5-mm) thick wood or the equivalent, coated with flat black paint on the inside surface, the walls of the box are to be perpendicular to its back. The internal dimensions of the box-like structure are to be such that the walls make a close fit with the equipment enclosure on the four sides and the rear, and has a flat front surface simulating the wall surface in which the equipment is designed to be mounted. The assembly of the equipment and wood box is to be mounted in an appropriate opening in the wall described in [29.3](#).

29.6 The isolating transformer is to be connected to a source of rated primary voltage and the secondary connected to a resistive load adjusted to draw rated secondary current. As an alternate to the resistive-load method, the load-back method described in [29.7](#) may be employed. See also [29.8](#).

*Exception: The isolating transformer of an isolated power center intended for x-ray equipment only shall be connected to a source of rated primary voltage and the secondary connected to a resistance load adjusted to draw 80 percent of the rating of the overcurrent-protective device associated with the secondary circuit.*

29.7 In the load-back method the primary and secondary windings of the transformer under test are to be connected in parallel to the primary and secondary windings, respectively, of a similar auxiliary transformer. The primary windings are to be connected to a source of rated primary voltage for the test transformer and rated full-load secondary current is to be circulated in the secondaries by impressing a voltage across a break in the secondary circuit. The impressed voltage, which may be introduced by a loading transformer, is to be just sufficient to circulate full-load rated secondary current.

29.8 The distribution section (with transformer operating in the load-back method) shall be loaded as indicated in [29.9](#) and [29.10](#) so that rated currents will be caused to flow in the main bus bars. Any convenient voltage supply may be used as long as rated current flows through the unit. This test may also be combined with [29.6](#) if the resistive-load method is used.

29.9 If the branch circuits are protected by fuses, dummy fuses or the equivalent shall be used in place of regular fuses in the fuseholders. All branch circuits used shall be loaded to 100 percent of the rating of

the branch circuits, except that one branch circuit may be loaded to a lesser value as necessary to achieve the required test current in the main bus bars.

29.10 If the branch circuits are protected by circuit breakers, each branch circuit used shall be loaded to 80 percent of the rating of the branch circuits, except that one branch circuit may be loaded to a lesser value as necessary to achieve the required test current in the main bus bars.

29.11 For an isolated power center for x-ray equipment only with multiple noninterlocked secondary overcurrent-protective devices, the temperature test shall be performed under the conditions of the Exception to [29.6](#) on one circuit only with the remaining circuits having no load.

29.12 All values in [Table 29.1](#) are based on an assumed ambient (room) temperature of 25°C (77°F), but a test may be conducted at any ambient temperature with the range of 10 – 40°C (50 – 104°F).

29.13 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm<sup>2</sup>) and not smaller than 30 AWG (0.05 mm<sup>2</sup>) except that a coil or transformer winding temperature shall be determined by the resistance method. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer-type indicating instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

29.14 A temperature is considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test (but not less than 15-min intervals), indicate no change. The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform with the requirements specified in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

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

29.16 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:

$\Delta t$  is the temperature rise,

$R$  is the resistance of the winding at the end of the test,

$r$  is the resistance of the winding at  $t_1$  at the beginning of the test,

$t_1$  is the room temperature in °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.

29.17 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.

**30 Leakage Current**

30.1 While in a well-heated condition following the temperature test, when tested under the conditions of [30.2](#) – [30.6](#), the leakage current to the enclosure and primary grounding circuit conductor from each isolated circuit conductor shall not exceed the values tabulated in [Table 30.1](#) and [Table 30.2](#).

**Table 30.1  
Maximum allowable panel leakage**

Maximum panel rating, kVA	Maximum panel leakage current, $\mu$ A	
	Secondary volts	
	120	208, 240, and 277
5	40	60
10	50	75
25	70	100
Wall modular units	100	100

**Table 30.2  
Maximum allowable transformer leakage**

Maximum transformer rating, kVA	Maximum transformer leakage current, $\mu$ A	
	Secondary volts	
	120	208, 240, and 277
5	20	30
10	25	37
15	30	40
25	35	50

30.2 The primary of the isolated power systems equipment shall be connected to a source of rated voltage, with no loads connected to the isolated circuit and with the ground connection to the line isolation monitor removed. Measurements shall be made under all possible switch combinations as shown in [Figure 30.1](#) or [Figure 30.2](#).

*Exception: Measurements may be made in accordance with [Figure 30.3](#) if the equipment is marked in accordance with [39.24](#).*

30.3 A wall modular unit shall be tested as described in [30.2](#) except that all circuits shall be energized but fixed devices such as lamps, elapsed time indicators, and so forth shall be disconnected by means of their respective control switches.

30.4 The primary of the isolation transformer shall be connected to a source of rated voltage and with no connections to the secondary, measurements shall be made under all possible switch combinations as shown in [Figure 30.4](#) or [Figure 30.5](#).

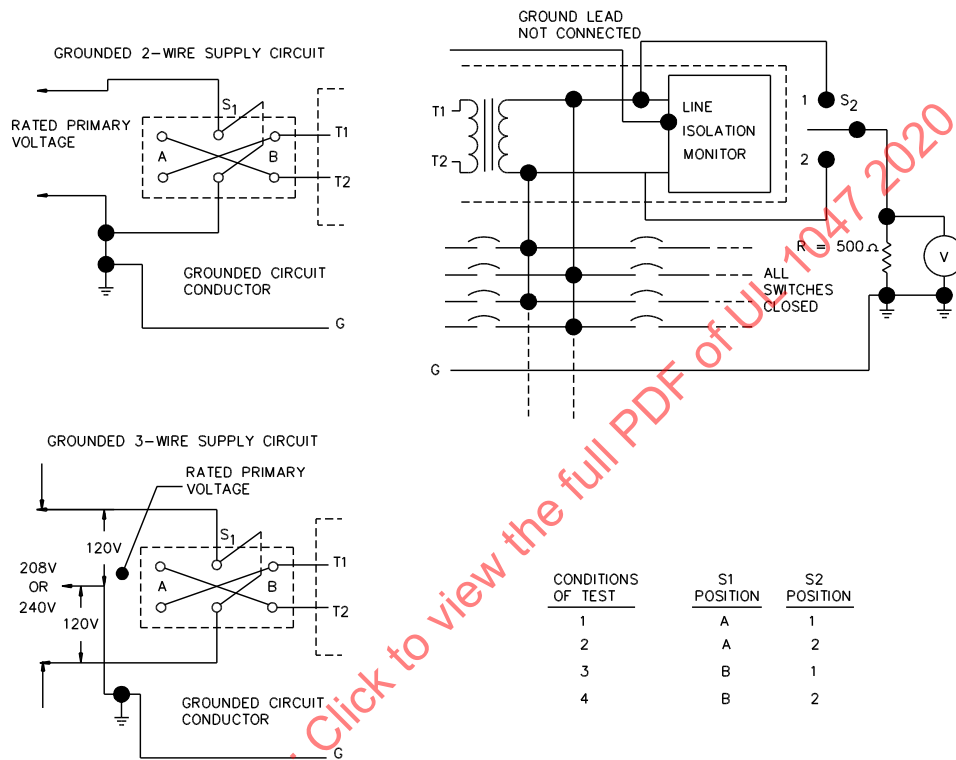
*Exception: Measurements may be made in accordance with [Figure 30.6](#) if the equipment is marked in accordance with [39.24](#).*

30.5 The leakage current shall be determined by measuring the voltage across a 500- $\Omega$  resistor connected between the isolated conductor and the grounded circuit conductor bonded to the enclosure.

30.6 The voltmeter shall have a minimum input impedance of 1 M $\Omega$ .

Figure 30.1

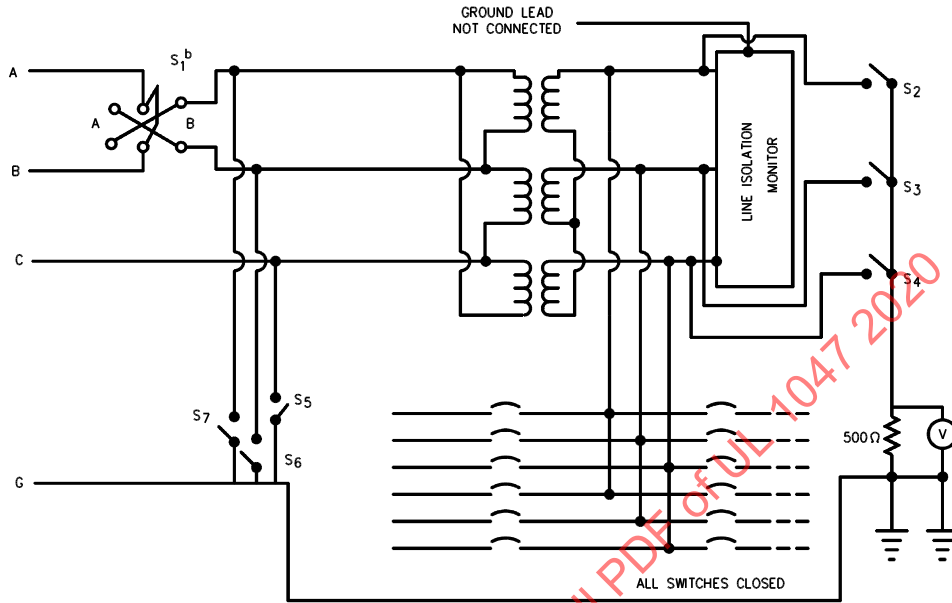
Method of measuring leakage current for complete single-phase equipment



SB0825 - 2

Figure 30.2

Method of measuring leakage current for complete three-phase equipment delta to wye or delta to delta (not diagramed)



S3302

Condition of test <sup>a</sup>	Switch position						
	S <sub>1</sub> <sup>b</sup>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
1	A	C	O	O	C	O	O
2	A	C	O	O	O	C	O
3	A	C	O	O	O	O	C
4	A	C	O	O	O	O	O
5	B	C	O	O	C	O	O
6	B	C	O	O	O	C	O
7	B	C	O	O	O	O	C
8	B	C	O	O	O	O	O

NOTES –

1) O – Open

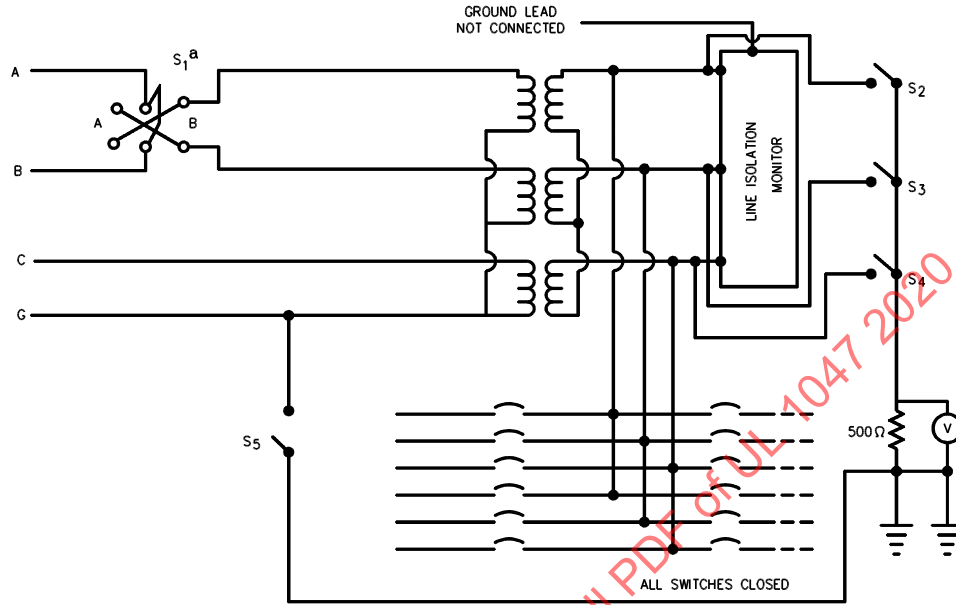
2) C – Closed

<sup>a</sup> Repeat test sequence: open S<sub>2</sub>, open S<sub>4</sub>, and then close S<sub>3</sub>. Repeat test sequence open S<sub>2</sub>, open S<sub>3</sub>, and then close S<sub>4</sub>.

<sup>b</sup>S<sub>1</sub> to be moved to lines B – C and the test sequence repeated.

Figure 30.3

Method of measuring leakage current for complete three-phase equipment for connection only to a three-phase, 4-wire wye supply wye to wye or wye to delta (not diagramed)



S3303

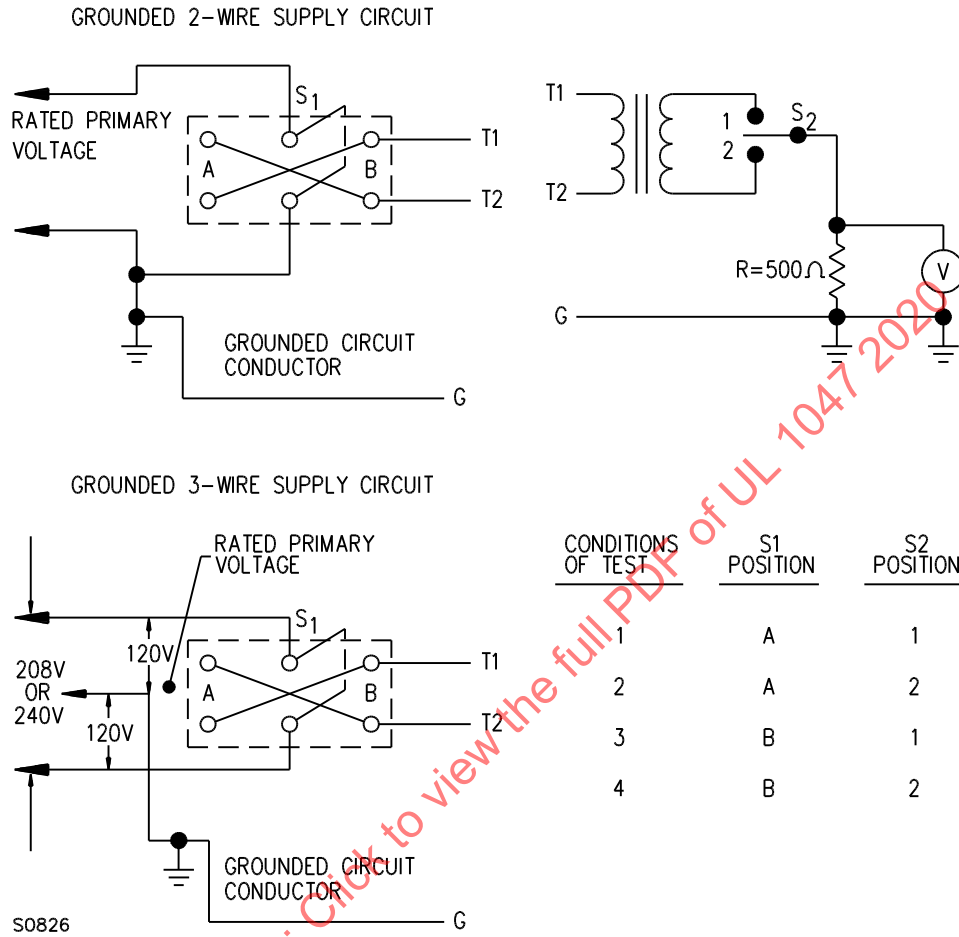
Condition of test	Switch position				
	S <sub>1</sub> <sup>a</sup>	S <sub>2</sub>	S <sub>3</sub> <sup>b</sup>	S <sub>4</sub>	S <sub>5</sub>
1	A	C	O	O	C
2	B	C	O	O	O
3	A	O	C	O	C
4	B	O	C	O	O
5	A	O	O	C	C
6	B	O	O	C	O

NOTES –  
 1) O – Open  
 2) C – Closed  
<sup>a</sup> S<sub>1</sub> to be moved to lines B – C and the test sequence repeated.  
<sup>b</sup> Open S<sub>2</sub> and S<sub>4</sub> before closing S<sub>3</sub>.



Figure 30.4

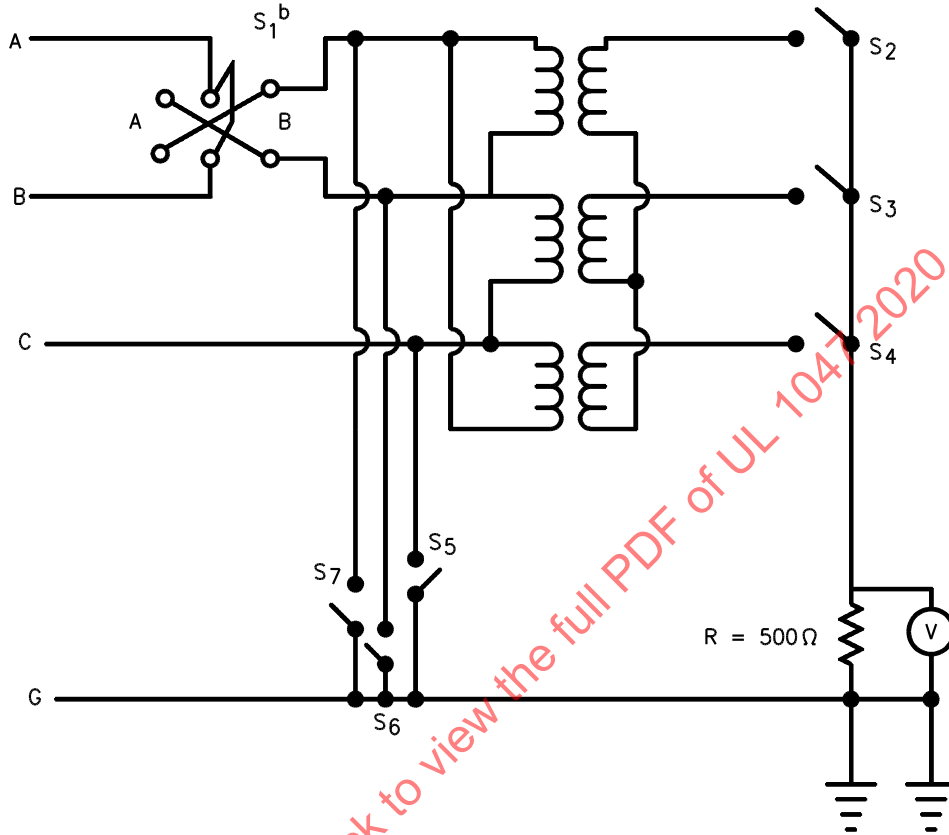
Method of measuring leakage current for a single-phase isolation transformer



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Figure 30.5

Method of measuring leakage current for three-phase isolation transformer delta to wye or delta to delta (not diagramed)



S3304

Condition of test <sup>a</sup>	Switch position						
	S <sub>1</sub> <sup>b</sup>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	S <sub>6</sub>	S <sub>7</sub>
1	A	C	O	O	C	O	O
2	A	C	O	O	O	C	O
3	A	C	O	O	O	O	C
4	A	C	O	O	O	O	O
5	B	C	O	O	C	O	O
6	B	C	O	O	O	C	O
7	B	C	O	O	O	O	C
8	B	C	O	O	O	O	O

NOTES –

1) O – Open

2) C – Closed

<sup>a</sup> Repeat test sequence: open S<sub>2</sub>, open S<sub>4</sub>, and then close S<sub>3</sub>. Repeat test sequence: open S<sub>2</sub>, open S<sub>3</sub>, and then close S<sub>4</sub>.

<sup>b</sup> S<sub>1</sub> to be moved to lines B – C and the test sequence repeated.