UL 1022

STANDARD FOR SAFETY

Line Isolation Monitors

UL Standard for Safety for Line Isolation Monitors, UL 1022

Sixth Edition, Dated March 27, 2025

SUMMARY OF TOPICS

This new Sixth Edition of ANSI/UL 1022 dated March 27, 2025 incorporates editorial updates from the February 21, 2025 proposal(s) bulletin. Other editorial updates include renumbering and reformatting to align with current style.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated February 21, 2025.

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Standard for Line Isolation Monitors

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March 27, 2025

This ANSI/UL Standard for Safety consists of the Sixth Edition.

The most recent designation of ANSI/UL 1022 as an American National Standard (ANSI) occurred on March 27, 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 the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover dynamic line isolation monitors and related supplementary indicating units for supervising isolated power-supply circuits in patient care areas of health care facilities, including inhalation-anesthetizing locations in accordance with the National Electrical Code, NFPA 70.

1.2 The detectors and supplementary indicating units are intended to be:

a) Included as part of an isolated power-supply center for patient care locations of health care facilities; and

b) Installed in an Other-Than-Hazardous (Classified) Location of a health care facility as defined by the National Electrical Code, NFPA 70.

1.3 These requirements do not cover ground fault circuit interrupters for use on grounded alternating current systems in accordance with the National Electrical Code, NFPA 70.

2 Components

2.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard;

b) Be used in accordance with its ratings(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a product covered by this Standard is not required to comply with a specific component 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; or

c) Is separately evaluated when forming part of another component, provided the component is used in accordance with its established ratings and limitations.

2.3 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.

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable standard(s) that cover devices that provide those functions.

3 Units of Measurement

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

4 Referenced Publications

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.

4.2 The following publications are referenced in this Standard:

ASTM E230/E230M, *Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

NFPA 70, *National Electrical Code*

5 Glossary

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

5.2 FAULT IMPEDANCE – An impedance that may consist of balanced or unbalanced resistive, capacitive-reactive, or combined resistive-capacitive-reactive loads connected to either or both isolated conductors. See Figure 20.1 for load configurations.

5.3 HAZARD CURRENT – The test current that would flow through a low impedance connected between either isolated conductor and ground. Hazard current includes:

a) TOTAL HAZARD CURRENT (THC) – Hazard current with all devices connected, including line isolation monitors;

b) MONITOR HAZARD CURRENT (MHC) – That portion of the total hazard current contributed only by the monitor and remote indicators; and

c) FAULT HAZARD CURRENT (FHC) – That portion of the total hazard current resulting when all devices, except the line isolation monitors, are connected.

5.4 LINE ISOLATION MONITOR (LIM) – A test instrument designed to continually check the balanced and unbalanced impedances from each side of an isolated circuit to ground and equipped with a built-in test circuit to exercise an alarm without adding to the hazard current. It initiates a visual and an audible indication when the hazard current exceeds a preset threshold level.

5.5 REMOTE INDICATOR – Device connected remotely to the line isolation monitor which provides any one of the following functions; visual signal, audible signal, or both visual and audible signals which supplement the signal provided by the line isolation monitor.

5.6 VOLTAGE CLASSIFICATION –

a) HIGH-VOLTAGE – A circuit classified as high-voltage is one having circuit characteristics in excess of those of a low-voltage circuit.

b) LOW-VOLTAGE – A circuit classified as low-voltage is one involving a potential of not more than 30 volts alternating current (42.4 peak) or direct current, and supplied by a primary battery or by a Class 2 transformer or by a combination of transformer and fixed impedance which, as a unit, complies with all the performance requirements for a Class 2 transformer.

6 Instructions and Drawings

6.1 A copy of the operating and installation instructions and related schematic, wiring diagrams, and installation drawings is to be furnished with the sample submitted for investigation to be used as a guide in the examination and test of the unit, and for this purpose is not required to be in final printed form.

6.2 The instructions and drawings shall include such directions and information as deemed by the manufacturer to be adequate for attaining proper installation and maintenance. A description of the circuit functions shall be provided to facilitate understanding of the system operation.

CONSTRUCTION

7 Enclosure

7.1 General

7.1.1 A line isolation monitor enclosure shall be formed and assembled so that it has the strength and rigidity required to resist the abuses to which it is subjected without total or partial collapse resulting in reduction of spacings, loosening or displacement of parts, or other serious defects.

7.1.2 All electrical parts of a line isolation monitor shall be enclosed to provide protection against contact with uninsulated live parts.

7.1.3 A compartment enclosing electrical parts shall not be open to the floor or other support on which the unit rests.

7.1.4 An enclosure for a line isolation monitor shall have provision for connection of metal-clad cable or conduit, or a nonmetallic-enclosed wiring system (for example, nonmetallic sheathed cable) acceptable for the application under the provisions of NFPA 70.

Exception No. 1: An enclosure without provision for the connection of metal-clad cable, conduit, or a nonmetallic-enclosed wiring system is not prohibited from being used when there are furnished with it, definite instructions indicating the section(s) of the unit intended to be drilled in the field for the connection(s).

Exception No. 2: A line isolation monitor which is intended to be installed in an overall enclosure with other equipment is not required to have provision for connection of metal-clad cable or conduit.

7.1.5 A line isolation monitor which is to be installed in an overall enclosure shall not be exposed to an ambient temperature exceeding 50 °C (122 °F).

7.1.6 An enclosure shall have means for mounting which shall be accessible without disassembling any operating part of the unit. Removal of a completely assembled panel or printed wiring board to mount the enclosure is not considered to be disassembly of an operating part.

7.1.7 An enclosure for a line isolation monitor which is intended for recessed (flush) mounting shall not have any openings other than conduit hubs, knockouts, or openings for mounting screws.

7.2 Cast metal enclosures

7.2.1 The thickness of cast metal for an enclosure shall be as indicated in Table 7.1, except that cast metal having a thickness 1/32 inch (0.8 mm) less than that indicated in the Table 7.1 is not prohibited from being used when the surface under consideration is curved, ribbed, or otherwise reinforced, or when the shape and/or size of the surface is such that equivalent mechanical strength is provided.

7.2.2 When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or when an equivalent construction is employed, there shall not be less than 3-1/2 nor more than 5 threads in the metal, and the construction shall be such that a standard conduit bushing is capable of being properly attached.

7.2.3 When threads for the connection of conduit are tapped part way through a hole in an enclosure wall, there shall be at least 3-1/2 full threads in the metal, and a smooth, rounded inlet hole for the conductors, which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

Table 7.1
Cast-Metal Enclosures

Use, or dimensions of area involved	Minimum thickness			
	Die-cast metal		Cast metal of other than the die-cast type	
	inches	(mm)	inches	(mm)
Area of 24 square inches (154 cm^2) or less and having no dimension greater than 6 inches (152 mm)	1/16	(1.6)	1/8	(3.2)
Area greater than 24 square inches or having any dimension greater than 6 inches	3/32	(2.4)	1/8	(3.2)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

7.3 Sheet metal enclosures

7.3.1 The thickness of sheet metal employed for the enclosure of a line isolation monitor shall not be less than indicated in Table 7.2, except that sheet metal of two gage sizes lesser thickness is not prohibited from being used when the surface under consideration is curved, ribbed, or otherwise reinforced, or when the shape and/or size of the surface is such that adequate mechanical strength is provided.

7.3.2 At any point where conduit or metal-clad cable is to be attached, sheet metal shall be of such thickness or shall be formed or reinforced so that it has the stiffness at least equivalent to that of uncoated flat sheet steel having a minimum thickness of 0.053 inch (1.35 mm) (No.16 MSG).

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

a) 0.014 inch (0.36 mm) for steel or 0.019 inch (0.48 mm) for nonferrous metal for a hole having 1/4 inch (6.4 mm) maximum dimension or

b) 0.027 inch (0.66 mm) steel or 0.032 inch (0.81 mm) nonferrous metal for a hole having a 1-3/8 inch (34.9 mm) maximum dimension.

7.3.4 A closure for a larger hole shall have a thickness equal to that required for the enclosure of the device or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

7.3.5 A knockout in a sheet metal enclosure shall be reliably secured but shall be capable of being removed without undue deformation of the enclosure.

7.3.6 A knockout shall be provided with a flat surrounding surface adequate for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacings between uninsulated live parts and the bushing of less than those indicated in Spacings, Section 14.

Table 7.2
Sheet Metal Enclosures

Maximum enclosure dimensions				Minimum thickness of sheet metal					
				Steel				Copper, brass, or aluminum	
Any linear dimension		Area of any surface		Zinc-coated		Uncoated			
inches	(mm)	in^2	(cm^2)	inches	(mm)	inches	(mm)	inches	(mm)
12	(305)	90	(581)	0.034 [20][a]	(0.86)	0.032 [20][a]	(0.81)	0.045 [16][a]	(1.14)
24	(610)	360	(2322)	0.045 [18]	(1.14)	0.042 [18]	(1.07)	0.058 [14]	(1.47)
48	(1219)	1200	(7742)	0.056 [16]	(1.42)	0.053 [16]	(1.35)	0.075 [12]	(1.91)
60	(1524)	1500	(9678)	0.070 [14]	(1.78)	0.067 [14]	(1.70)	0.095 [10]	(2.41)
Over 60	(1524)	Over 1500	(9678)	0.097 [12]	(2.46)	0.093 [12]	(2.36)	0.122 [8]	(3.10)

[a] The figures in brackets are the Galvanized Sheet Gage numbers (for zinc-coated steel), the Manufacturers' Standard Gage numbers (for uncoated steel), and the American Wire Gage (B & S) numbers (for a nonferrous metal) which provide the required minimum thickness of metal.

7.4 Nonmetallic enclosures

7.4.1 Nonmetallic material shall not be employed for an enclosure of a line isolation monitor intended to be connected directly to rigid conduit or metal-clad cable. It is not prohibited from being used as an enclosure of a unit intended to be installed in an overall metal enclosure with other equipment, such as in an isolating power panel assembly.

7.4.2 When a nonmetallic enclosure is employed, the continuity of the grounding system shall not rely on the dimensional integrity of the nonmetallic material.

7.4.3 Among the factors taken into consideration when determining the acceptability of a nonmetallic enclosure are:

a) The mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Combustibility and resistance to ignition from electrical sources;

e) Dielectric strength, insulation resistance, and resistance to arc tracking; and

f) Resistance to distortion and creeping at temperatures to which the material is subjected under conditions of normal or abnormal usage.

All these factors are to be considered with regard to aging.

7.5 Ventilating openings

7.5.1 Ventilating openings in an enclosure, including perforated holes, louvers, and openings protected by means of wire screening, expanded metal, or perforated covers, shall be of such size or shape that no opening permits passage of a rod having a diameter of 9/64 inch (3.6 mm).

7.5.2 An enclosure housing fuses or any other overload-protective device, and provided with ventilating openings, shall afford adequate protection against the emission of flame or molten metal.

7.5.3 The average thickness of perforated sheet metal and sheet metal employed for expanded-metal mesh shall not be less than:

a) 0.042 inch (1.07 mm), 0.046 inch (1.14 mm) if zinc coated, when the mesh openings or perforations are 1/2 in^2 (323 mm^2) or less in area and

b) 0.080 inch (2.04 mm), 0.084 inch (2.14 mm) if zinc coated, for larger openings.

Exception: When the indentation of a guard or enclosure wall does not alter the clearance between uninsulated live parts and grounded metal and affect performance adversely or reduce spacings below the minimum value given under Spacings, Section 14, 0.021 inch (0.53 mm) expanded metal mesh [0.024 inch (0.59 mm) if zinc coated] is not prohibited from being used, when the exposed mesh on any one side or surface of the device so protected has an area of not more than 72 in^2 (464 mm^2) and no dimension greater than 12 inches (305 mm), or when the width of an opening so protected is not greater than 3-1/2 inches (90 mm).

7.5.4 The wires of a screen shall not be smaller than 16 AWG (1.3 mm diameter) and the screen openings shall not be greater than 1/8 inch (3.2 mm) square in area.

7.6 Covers

7.6.1 An enclosure cover shall be hinged, sliding, pivoted or similarly attached when it provides ready access to fuses or any other overcurrent protective device, the intended protective functioning of which require renewal, or when it is required to open the cover in connection with the normal operation of the unit.

7.6.2 With reference to 7.6.1, normal operation is considered to be operation of a switch for testing or for silencing an audible signal appliance or operation of any other component of a unit which requires such action in connection with its intended performance.

7.6.3 A hinged cover is not required when it is not necessary to open the cover in connection with normal operation of the unit, and the only fuse(s) enclosed is for protection of portions of internal circuits against damage resulting from a fault. The following or equivalent marking shall be indicated on the outer surface of the cover provided: "CAUTION – CIRCUIT FUSE(S) INSIDE – DISCONNECT POWER-SUPPLY PRIOR TO SERVICING. "

7.6.4 When a hinged cover is required, it shall be provided with a latch, screw, or catch to hold it closed. The hinged cover of a unit intended to be installed where it is accessible to other than authorized personnel shall be provided with a key lock or with a screw requiring a tool for removal.

7.6.5 An unhinged cover shall be securely held in place by screws or the equivalent.

7.7 Glass panels

7.7.1 A glass panel covering an observation opening, other than a meter cover, shall be securely held in place so that it cannot be readily displaced in service and shall provide adequate mechanical protection for the enclosed parts. The thickness of the glass panel shall not be less than that indicated in Table 7.3.

Table 7.3
Thickness of Glass Covers

Maximum size of opening				Minimum thickness of glass	
Length or width		Area			
inches	(mm)	in^2	(cm^2)	inches	(mm)
4	(102)	16	(103)	1/16	(1.6)
12	(305)	144	(927)	1/8	(3.2)
Over 12	(305)	Over 144	(927)	a	

[a] 1/8 inch (3.2 mm) or more, depending upon the size, shape, and mounting of the glass panel.

7.7.2 A glass panel for an opening having an area of more than 144 square inches (927 cm^2), or having any dimension greater than 12 inches (305 mm), shall be supported by a continuous flange not less than 3/16 inch (4.8 mm) deep along all four edges of the panel.

7.7.3 A transparent material other than glass, employed as a cover over an opening in an enclosure, shall have mechanical strength equivalent to that of glass, not introduce a risk of fire, distort, nor become less transparent at the temperature to which it is subjected under all conditions of intended use.

8 Electric Shock

8.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See Electric Shock Current Test, Section 28.

8.2 Each terminal provided for the connection of an external antenna shall be conductively connected to the supply circuit grounded conductor. The resistance of the conductive connection shall not exceed 5.2 megohms. The wattage rating shall be at least 1/2 watts, and the conductive connection shall be effective with the power switch in either the on or off position.

Exception: The conductive connection is not required to be provided when:

a) Such a connection is established in the event of electrical breakdown of the antenna isolating means;

b) The breakdown does not result in a risk of electric shock; and

c) In a construction employing an isolating power transformer, the resistance of the conductive connection between the supply circuit and chassis does not exceed 5.2 megohms.

8.3 The maximum value of 5.2 megohms specified in 8.2 is to include the maximum tolerance of the resistor value used; that is, a resistor rated 4.2 megohms with 20 % tolerance or a resistor rated 4.7 megohms with a 10 % tolerance is acceptable. A component comprised of a capacitor with a built-in shunt resistor that complies with the requirements for antenna isolating capacitors is not prohibited from being rated a minimum of 1/4 watt.

8.4 The insertion in any socket of any vacuum tube or its glass or metal equivalent of like designation used in the product shall not result in a risk of electric shock.

9 Corrosion Protection

9.1 Except as indicated in 9.2, iron and steel parts, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

Exception: The requirement does not apply to:

a) Bearings, and the like, where such protection is impracticable or

b) Minor parts, such as washers, screws, bolts, and the like, when corrosion of such unprotected parts does not result in a risk of fire, electric shock, or injury to persons, or impair the operation of the unit.

9.2 The requirement of 9.1 applies to all enclosing cases of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation depends. Parts made of stainless steel, properly polished or treated, when required, do not require additional protection against corrosion. Bearing surfaces shall be of such material and construction as to resist binding due to corrosion.

10 Field-Wiring System Connections

10.1 General

10.1.1 A line isolation monitor shall be provided with wiring terminals or leads for the connection of conductors of at least the size required by NFPA 70, corresponding to the rating of the unit.

10.1.2 There shall be sufficient space within a terminal or wiring compartment to permit completion of all wire connections specified by the installation wiring diagram.

10.1.3 The terminal parts to which wiring connections are made shall consist of binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position. Other terminal connections are not prohibited from being provided when determined to be equivalent.

10.1.4 A wire binding screw employed at a wiring terminal shall not be smaller than No. 6 (3.5 mm diameter). The screw shall thread into metal.

10.1.5 Except as noted in 10.1.6, a terminal plate tapped for a No. 6 (3.5 mm diameter) wire-binding screw shall be of metal not less than 0.030 inch (0.77 mm) thick. It shall not have less than two full threads in the metal, and shall be prevented from turning.

10.1.6 A terminal plate is not prohibited from having the metal extruded at the tapped hole for the wire-binding screw so as to provide two full threads. Other constructions are not prohibited when they provide equivalent security.

10.1.7 Field wiring terminals shall be secured to their supporting surfaces by methods other than friction between surfaces so that they are prevented from turning or shifting in position when such motion results in reduction of spacings to less than those required. This is capable of being accomplished by:

a) Two screws or rivets;

b) Square shoulders or mortices;

c) A dowel pin, lug, or offset;

d) A connecting strap or clip fitted into an adjacent part; or

e) Some other equivalent method.

10.1.8 All leads provided for field connections shall be:

a) At least 6 inches (152 mm) long;

b) Provided with strain relief; and

c) Not smaller than 18 AWG (0.82 mm^2).

Exception: The leads are not prohibited from being less than 6 inches (152 mm) in length when it is evident that the use of a longer lead is capable of damaging the insulation.

10.1.9 Rubber or thermoplastic insulation for leads provided for field connections shall not be less than 1/32 inch (0.8 mm) thick.

10.2 Equipment grounding connection

10.2.1 A line isolation monitor shall be provided with a clearly identified separate equipment grounding terminal or lead. The grounding terminal or lead shall be connected to all exposed dead-metal parts as described in 12.1.

10.2.2 A terminal solely for connection of an equipment grounding conductor shall be capable of securing a conductor of the gage size equivalent to that of the conductors supplying the unit.

10.2.3 A terminal screw intended for the connection of an equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified, such as being marked G, GR, GROUND, GROUNDING, or the equivalent; or by a marking on a wiring diagram provided on the device. The grounding terminal shall be located so that is unlikely to be removed during normal servicing of the device.

10.2.4 The surface of an insulated lead intended solely for the connection of an equipment grounding conductor shall be green, with or without one or more yellow stripes. No other lead visible to the installer, other than grounding conductors, shall be so identified.

11 Internal Wiring

11.1 General

11.1.1 The internal wiring of a unit shall consist of insulated conductors suitable for the current rating of the unit, and having insulation rated for the potential involved and the temperatures to which it is subjected. The wiring shall be routed away from moving parts and sharp projections and shall be held in place with clamps, string ties, or equivalent, unless of sufficient inherent rigidity to retain a shaped form.

11.1.2 When the use of a short length of insulated conductor is not feasible (for example, a short coil lead or the like) electrical insulating tubing is not prohibited from being employed. The tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, and shall not contact sharp edges, projections, or corners. The wall thickness of the tubing shall conform to the requirements for such tubing, except that the wall thickness at any point for polyvinyl chloride tubing of 3/8 inch (9.5 mm) diameter or less, shall not be less than 0.017 inch (0.43 mm). For insulating tubing of other types, the wall thickness shall not be less than that required to at least equal the mechanical strength, dielectric properties, heatand moisture-resistant characteristics, and the like of polyvinyl chloride tubing having a wall thickness of 0.017 inch (0.43 mm).

11.1.3 Leads or a cable assembly connected to parts mounted on a hinged cover shall be of sufficient length to permit the full opening of the cover without applying stress to the leads or their connections. The leads shall be secured or equivalently arranged to prevent abrasion of insulation and jamming between parts of the enclosure.

11.1.4 Internal wiring of circuits which operate at different potentials shall be separated by barriers (see 11.4.1) or shall be segregated, unless the conductors of the circuits are provided with insulation equivalent to that required for the highest voltage involved. Segregation of insulated conductors is accomplished by clamping, routing, or equivalent means which insures permanent separation.

11.1.5 Stranded conductors clamped under wire binding screws or similar parts shall have the individual strands soldered together or be equivalently arranged to provide reliable connections.

11.2 Wireways

11.2.1 Wireways shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like, which are capable of abrading the conductor insulation. See 11.5.1 – 11.5.4.

11.3 Splices

11.3.1 Each splice and connection shall be mechanically secured and bonded electrically.

11.3.2 A splice shall be provided with insulation equivalent to that of the wires involved when permanence of electrical spacing between the splice and uninsulated metal parts cannot be maintained.

11.3.3 Splices shall be located, enclosed, and supported so that they are not subject to damage from flexing, motion, or vibration.

11.4 Barriers

11.4.1 A metal barrier shall have a thickness at least equal to that required by Table 7.2, based on the size of the barrier. A barrier of insulation material shall not be less than 0.028 inch (0.71 mm) thick and shall be of greater thickness when its deformation is capable of defeating its purpose.

11.4.2 Any clearance between the edge of a barrier and a compartment wall shall not exceed 1/16 inch (1.6 mm).

11.5 Bushings

11.5.1 Where a lead or wire harness passes through an opening in a wall, barrier, or enclosing case, there shall be a metal or insulating type bushing, or the equivalent, which shall be substantial, reliably secured in place, and shall have a smoothly rounded surface against which the wire bears.

Exception No. 1: When the opening is in phenolic composition or other suitable nonconducting material, or in metal thicker than 0.042 inch (1.07 mm), a smooth surface having rounded edges is considered to be the equivalent of a bushing.

Exception No. 2: An insulating metal grommet is not prohibited from being used in place of an insulating bushing when the insulating material used is at least 1/32 inch (0.8 mm) thick and fills completely the space between the grommet and the metal in which it is mounted.

11.5.2 Ceramic materials and some molded composition are not prohibited from being used for insulating bushings. Separate bushings of wood and of hot-molded shellac are not to be used.

11.5.3 Fiber is not prohibited from being used where:

a) It is not subjected to a temperature higher than 90 °C (194 °F) under normal operating conditions;

b) When the bushing is not less than 1/16 inch (1.6 mm) in thickness, with a minus tolerance of 1/64 inch (0.4 mm) for manufacturing variations; and

c) When it is formed and secured in place so that it is not affected adversely by ordinary ambient conditions of humidity.

11.5.4 When a soft rubber bushing is employed in a hole in metal, the hole shall be free from sharp edges, burrs, projections, and the like, which are capable of cutting into the rubber.

11.6 Strain relief

11.6.1 A strain relief means shall be provided for the field supply leads, and all internally connected wires or cords which are subject to movement in conjunction with the installation, operation, or normal servicing of a unit to prevent any mechanical stress from being transmitted to terminals and internal connections. Inward movement of the cord or leads provided with a ring-type strain relief means shall not damage internal connections or components, or result in a reduction of electrical spacings.

11.6.2 Each lead employed for field connections or an internal lead subjected to movement or handling during installation and normal servicing shall be capable of withstanding for 1 minute a pull of 10 pounds (44.5 N) without any evidence of damage or of transmitting the stress to internal connections.

12 Bonding for Grounding

12.1 An exposed (see 12.2) noncurrent-carrying metal part of a high-voltage unit which is liable to become energized shall be reliably bonded to the point of connection of the field-equipment grounding terminal or lead, when provided or required, and to the metal surrounding the knockout, hole, or bushing provided for field power-supply connections.

12.2 Except as indicated in 12.3, uninsulated metal parts of electrical enclosures, controller mounting brackets, capacitors, and other electrical components shall be bonded for grounding when they are capable of being contacted by the user or by a serviceman in servicing the equipment.

12.3 Metal parts as described below are not required to comply with the requirement of 12.2.

a) Adhesive-attached, metal foil markings; screws; handles; and the like, which are located on the outside of the enclosure and isolated from electrical components or wiring by grounded metal parts so that they are not likely to become energized.

b) Isolated metal parts, such as small assembly screws, and the like, that are separated from wiring and uninsulated live parts.

c) Panels and covers that do not enclose uninsulated live parts when wiring is positively separated from the panel or cover so that it is not likely to become energized.

d) Panels and covers that are insulated from electrical components and wiring by an insulating barrier or vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

12.4 A bonding conductor shall be of material suitable for use as an electrical conductor. When made of ferrous metal, it shall be protected against corrosion by painting, plating, or the equivalent. The conductor shall not be smaller than the maximum size wire employed in the circuit wiring of the component or part. A separate bonding conductor or strap shall be installed in such a manner that it is protected from mechanical damage.

12.5 The bonding shall be by a positive means, such as by clamping, riveting, bolted or screwed connection, brazing, or welding. The bonding connection shall penetrate nonconductive coatings such as paint. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

12.6 A bolted or screwed connection that incorporates a star washer under the screwhead, is not prohibited from being used for penetrating nonconductive coatings.

12.7 When the bonding means depends upon screw threads, two or more screws or two full threads of a single screw engaging metal shall be employed.

12.8 Metal-to-metal, hinge-bearing members for doors or covers are not prohibited from being used as a means for bonding the door or cover for grounding when a multiple, bearing-pin type hinge is employed.

12.9 Splices shall not be employed in conductors used to bond electrical enclosures or components.

13 Components

13.1 Current-carrying parts

13.1.1 A current-carrying part shall be rated for the application and shall be made of metal such as silver, copper or copper alloy, or the equivalent.

13.1.2 Bearings, hinges, and the like, are not to be used for carrying current between inter-related fixed and moving parts.

13.1.3 The insulation of coil windings of relays, transformers, and the like, shall resist the absorption of moisture.

13.1.4 Enameled wire is not required to be given additional treatment to prevent moisture absorption.

13.2 Insulating material

13.2.1 Among the factors to be considered in evaluating electrical insulation are:

a) Mechanical and electrical strength;

b) Resistance to burning, moisture, arcing, and creep;

c) Flow due to stress; and

d) Resistance to temperatures anticipated in use.

Examples of some materials capable of being used include phenolic or cold-molded composition. Other insulating materials are not prohibited from being used when they possess equivalent mechanical and electrical properties.

13.2.2 Vulcanized fiber is not prohibited from being used for insulating bushings, washers, separators, and barriers, but not for the sole support of live parts.

13.2.3 The thickness of a flat sheet of insulating material, such as phenolic composition employed for panel-mounting of parts, shall not be less than that indicated in Table 13.1.

Table 13.1
Thickness of Insulating Material

Maximum dimension		Maximum area		Minimum thickness	
inches	(mm)	in^2	(cm^2)	inches	(mm)
24	(610)	360	(2,322)	3/8[a]	(9.5)
48	(1,219)	1152	(7,434)	1/2	(12.7)
48	(1,219)	1728	(11,200)	5/8	(15.9)
Over 48	(1,219)	Over 1728	(11,200)	3/4	(19.1)

[a] Material less than 3/8 inch (9.5 mm) but not less than 1/8 inch (3.2 mm) in thickness is not prohibited from being used for a panel when the panel is adequately supported or reinforced to provide rigidity not less than that of a 3/8 inch sheet. Material less than 1/8 inch is not prohibited from being used for subassemblies, such as supports for terminals for internal wiring, resistors, and other components.

13.2.4 A terminal block mounted on a metal surface which may be grounded shall be provided with an insulating barrier between the mounting surface and all live parts on the underside of the base which are not staked, upset, sealed or equivalently prevented from loosening to prevent such parts and the ends of replaceable terminal screws from coming in contact with the supporting surface.

13.2.5 A countersunk, sealed part shall be covered with a waterproof insulating compound that will not melt at a temperature 15 °C (27 °F) higher than the maximum intended operating temperature of the assembly, and not less than 65 °C (149 °F) in any case. The depth or thickness of sealing compound shall be at least 1/8 inch (3.2 mm).

13.2.6 An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material employed where spacings would otherwise be insufficient, shall be not less than 0.028 inch (0.69 mm) in thickness; except that a liner or barrier not less than 0.013 inch (0.33 mm) in thickness is not prohibited from being used in conjunction with an air spacing of not less than one-half of the through air spacing required. The liner shall be located so that it is not affected adversely by arcing.

Exception: Insulating material having a thickness less than that specified is not prohibited from being used, when it has equivalent insulating, physical, and flammability properties.

13.3 Lampholders and lamps

13.3.1 At least of two lamps, one green, one red, shall be mounted on the unit. Additional lamps are not prohibited from being provided for indication of supplementary features.

13.3.2 Each lampholder shall have a current and voltage rating not less than that of the circuit in which it is connected when the device is operated under any condition of intended service.

13.4 Meters

13.4.1 A meter marked to indicate the total hazard current in milliamperes shall be provided integral with the unit and additionally marked to indicate the alarm and nonalarm zones. The Total Hazard Current, specified in 20.1(c), shall be at approximately the center of the scale.

13.4.2 A digital meter shall distinguish the alarm level current display from lower current value displays by flashing of the display or by energization of an additional character.

13.5 Printed-wiring boards

13.5.1 Printed-wiring boards shall be acceptable for the application. Components shall be secured to the board against displacement or disconnection and the spacings between circuits shall be maintained. The board shall be mounted so that deflection of the board during servicing shall not result in damage to the board or risk of fire, electric shock, or injury to persons.

13.6 Switches

13.6.1 A switch provided as part of a line isolation monitor shall have a current and voltage rating not less than that of the circuit that it controls when the device is operated under any condition of intended service.

13.6.2 A test switch, mounted on the monitor, shall be provided to indicate an alarm condition. The switch shall be of a momentary contact type.

13.7 Protective devices

13.7.1 Fuseholders, fuses, and circuit breakers provided on a line isolation monitor shall be rated for the application.

13.8 Alarm silencing means

13.8.1 A switch or other means shall be provided on the line isolation monitor for silencing the audible alarm.

13.9 Audible signaling appliance

13.9.1 The line isolation monitor shall have provision either for an integral audible signaling appliance or wiring terminals or leads for connection to a remote device.

13.10 Mounting of components

13.10.1 All parts of a line isolation monitor shall be securely mounted in position and prevented from turning or loosening when such motion affects adversely the normal performance of the unit.

13.10.2 A switch, lampholder, attachment-plug receptacle, plug connector, or similar electrical component, shall be mounted securely and, except as noted in 13.10.3 and 13.10.4, shall be prevented from turning.

13.10.3 The requirement that a switch be prevented from turning is not prohibited from being waived when all of the following conditions are met:

a) The switch is of a plunger or other type that does not tend to rotate when operated. A toggle switch is considered to be subject to forces that tend to turn the switch during normal operation of the switch.

b) The means of mounting the switch makes it unlikely that operation will loosen the switch.

c) The spacings are not reduced below the minimum acceptable values if the switch does rotate.

d) The normal operation of the switch is to be by mechanical means rather than by direct contact by persons.

13.10.4 The lampholder of a type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in by a nonremovable jewel, is not required to be prevented from turning when rotation cannot reduce spacings below the minimum acceptable values.

13.10.5 The means for preventing turning of a device shall consist of more than friction between surfaces. However, a lock washer, properly applied, is acceptable as the means for preventing a small stem-mounted, switch or other device having a single-hole mounting means from turning.

13.10.6 Uninsulated live parts, including terminals, shall be secured to their supporting surfaces by methods other than friction between surfaces, so that they are prevented from turning or shifting in position when such motion results in the reduction of spacings to less than those required. The security of contact assemblies shall provide for the continued alignment of contacts.

13.11 Operating components

13.11.1 Operating components, such as switches, relays, and similar devices, shall be individually protected against fouling by dust or by other material which are capable of adversely affecting their normal operation. The use of an individual dust cover enclosing operating components, or a gasket between the unit enclosure and cover, is not prohibited.

13.11.2 Moving parts shall have sufficient play at bearing surfaces to prevent binding.

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

13.11.4 Manually-operated parts shall have sufficient strength to withstand the stresses to which they are subjected in operation.

14 Spacings

14.1 Spacings between uninsulated live parts and dead-metal parts, and between uninsulated live parts of opposite polarity, shall not be less than those indicated in Table 14.1.

Exception: The spacings requirements in Table 14.1 do not apply to the inherent spacings of a component which is provided as part of the device. Such spacings are evaluated on the basis of the requirements for the component. The electrical clearance resulting from the assembly of a component into the complete device, including clearances to dead metal or enclosures, shall be those indicated in Table 14.1.

14.2 The spacing between uninsulated live parts and a wall or cover of a metal enclosure, a fitting for conduit or metal-clad cable, and any dead-metal part shall not be less than that indicated in Table 14.1.

14.3 The Through-air and Over-surface spacings at an individual component part are to be evaluated on the basis of the volt-amperes used and controlled by the individual component. However, the spacings from one component to another, and from any component to the enclosure or to other uninsulated dead-metal parts excluding the component mounting surface, are to be evaluated on the basis of the maximum voltage and total volt-ampere rating of all components in the enclosure.

14.4 Enamel insulated wire is considered to be a bare current-carrying part in determining compliance of a device with the spacing requirements, but enamel is acceptable as turn-to-turn insulation in coils.

Table 14.1
Minimum Spacings

Point of application	Voltage range, volts	Minimum spacings			
		Through-air		Over-surface	
		in[a]	(mm)	in[a]	(mm)
To walls of enclosure[b]					
Cast metal enclosures	0 – 300	1/4	(6.4)	1/4	(6.4)
Sheet metal enclosures	0 – 300	1/2	(12.7)	1/2	(12.7)
Installation wiring terminals					
With barriers – See 13.2.6	0 – 30	1/8	(3.2)	3/16	(4.8)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
Without barriers	0 – 30	3/16	(4.8)	3/16	(4.8)
	31 – 150	1/4	(6.4)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
Rigidly clamped assemblies[c]					
100 volt-amperes or less	0 – 30	1/32	(0.8)	1/32	(0.8)
Over 100 volt amperes	0 – 30	3/64	(1.2)	3/64	(1.2)
	31 – 150	1/16	(1.6)	1/16	(1.6)
	151 – 300	3/32	(2.4)	3/32	(2.4)
Other parts	0 – 30	1/16	(1.6)	1/8	(3.2)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)

[a] Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case is the wire to be smaller than 14 AWG (2.1 mm^2).

[b] The To-enclosure spacings are not to be applied to an individual enclosure of a component part within an outer enclosure.

[c] Rigidly clamped assemblies include such parts as contact springs on relays or cam switches, printed wiring boards, and the like.

15 Servicing and Maintenance

15.1 An uninsulated live part and hazardous moving parts within the enclosure shall be located, guarded, or enclosed so as to minimize the risk of unintentional contact by persons performing service or testing functions which are performed with the equipment energized. See 15.5.

15.2 Manual switching devices are not prohibited from being located or oriented with regard to uninsulated live parts or hazardous moving parts, so that manipulation of the mechanism is accomplished in the normal direction of access, when uninsulated live parts or hazardous moving parts are not located in front (in the direction of access) of the mechanism, and are not located within 6 inches (152 mm) on any side or behind the mechanism, unless guarded.

15.3 In determining compliance with 15.2, only uninsulated live parts in high-voltage circuits are to be considered. The following are not considered to be uninsulated live parts:

a) Coils of controllers, relays, and solenoids, and transformer windings, if the coils and windings are provided with suitable insulating overwraps;

b) Enclosed motor windings;

c) Terminals and splices with suitable insulation and insulated wire.

15.4 An electrical control component which requires examination, adjustment, servicing, or maintenance while energized, shall be located and mounted with regard to other components and with regard to grounded metal parts so that it is accessible for electrical service functions without subjecting persons to the risk of electric shock from adjacent uninsulated live parts or unintentional contact with adjacent hazardous moving parts.

15.5 Other arrangements of location of components, or guarding, or both, are acceptable where electrical components are accessible for service as indicated by 15.4; for example, electrical components located within enclosures having covers or panels requiring tools for their removal. The outside surface of the cover or panel shall be marked with the following or equivalent wording: "CAUTION – DISCONNECT POWER-SUPPLY BEFORE REMOVING THIS COVER (PANEL)."

PERFORMANCE

16 General

16.1 The performance of a line isolation monitor with related indicating devices shall be investigated by subjecting a representative sample to the following tests and, as far as applicable, in the sequence presented.

16.2 When a unit is to be mounted in a definite position in order to function properly as detailed by the installation instructions or markings on the unit, it shall be tested in that position.

16.3 Unless specifically specified otherwise the test voltage for each test shall be as follows at rated frequency:

Detector rated voltage, nameplate	Test voltage
110 to 120	120
220 to 240	240
Other	Marked rating

17 Normal Operation Test

17.1 A line isolation monitor shall be capable of operating as intended when employed in conjunction with related indicating devices to form any system combination covered by the installation wiring diagram and any supplementary information provided.

17.2 To determine when a line isolation monitor complies with the requirements of 17.1, indicating devices as described in 17.3, and power-supply circuits are to be connected to the monitor to form a typical combination.

17.3 The indicating devices employed are to be those lamps, remote indicators, buzzers, etc., specified by the installation wiring diagram of the monitor, except that substitute devices are not prohibited from being used when they are determined by investigation to produce signal indication and circuit loading equivalent to those of the specified devices.

17.4 A line isolation monitor shall be in a normal standby condition and prepared for normal signaling operation when it is connected to a source of supply in accordance with 16.3 and to related devices and circuits as specified in 17.1 – 17.3. The green signal lamp shall be energized and the meter shall read in the nonalarm or safe zone. The enclosure of the device shall be grounded to the test apparatus enclosure.

17.5 When continuous monitoring is not provided, the minimum sweep frequency of a line isolation monitor, as determined by an oscilloscope or equivalent means, shall not be less than 1 cycle per second for sampling of each side of line.

17.6 Operation of the test switch with the unit in a normal standby condition shall result in de-energization of the green signal lamp and the energization of the red signal lamp and audible signal. This switch shall transfer the grounding terminal of the line isolation monitor from the reference grounding point to a test impedance arrangement having a magnitude sufficient to produce a monitor meter reading of at least 2 mA at rated line voltage. The operation of this switch shall not add to the risk of electric shock within the system in actual use, nor will the test include the effect of the line-to-ground stray impedance of the system. It shall be impossible to inadvertently leave the test switch in the test position. The same results shall be obtained when the device is subjected to the Overvoltage and Undervoltage Test, Section 21.

17.7 When a non-automatically-reset-type, alarm-silencing switch is operated to the off-normal position with the unit in a normal standby condition, a visual indication other than the green or red signal lamps shall be obtained. The de-energizing of a light, other than red or green or an equivalent arrangement, which indicates the normal position of the alarm silencing switch, is capable of being used for this indication.

17.8 With the monitor and indicator unit(s) in a normal standby condition, each line is to be grounded, in turn, to the reference ground. This shall de-energize the green lamp and energize the red lamp and audible alarm signal to indicate an alarm condition. The meter shall read in the alarm zone or above (off-scale). Removal of the ground fault shall re-energize the green lamp and de-energize the red lamp and the audible alarm signal to indicate restoration of the system to a normal standby condition.

17.9 The delay in annunciation of the alarm threshold shall not exceed 5 seconds.

17.10 Operation of the silencing means with the monitor in an alarm condition shall de-energize the audible signal with the red signal lamp remaining energized. Removal of the ground fault with the monitor in a silenced condition shall re-energize the green signal lamp and de-energize the red signal lamp. When the audible alarm silencing circuit does not reset automatically when the ground fault is removed, an audible or distinctive visual signal, other than the green and red signal lamps, shall indicate that the audible alarm signal is silenced. Operation of a resetting means, such as restoration of a silencing switch to the normal position, shall then complete the restoration of the system to a normal standby condition.

17.11 The operation of a remote indicator unit shall be the same as for the line isolation monitor for the components employed.

18 Sampling Circuit Supervision Test

18.1 Provision shall be made on a line isolation monitor to indicate failure of a monitoring circuit which samples each line when the failure is not indicated during operation of the test switch.

18.2 For this test the line isolation monitor and related devices shall be connected to a source of supply, in accordance with 16.3, and a single fault shall be applied, in turn, to various components in the monitoring circuit. Examples of common faults include stoppage of pulsing-type relay contacts in an open or closed condition, open or short on a component which is likely to fail over a period of time (such as an electrolytic capacitor), and the like.

19 Power Input Test

19.1 The current or wattage input to a line isolation monitor and remote indicating unit shall not exceed 110 % of the rated value when the units are connected to a source of supply in accordance with 16.3 and operated in the maximum normal load condition.

20 Leakage Current Measurements Test

20.1 Leakage current measurements of a line isolation monitor shall comply with the following:

a) The test circuit leakage shall not exceed 20 microamperes (μA).

b) The Monitor Hazard Current (MHC) shall not exceed 1.0 mA.

Exception: The current through a line isolation monitor of the low-impedance type may be between the threshold value and twice the threshold value for not longer than 5 milliseconds while any point of the isolated system is grounded.

c) An alarm signal shall be obtained when the Total Hazard Current (THC) reaches a threshold value of not more than 5.0 mA, but not less then 2.0 mA. At the threshold value, the alarm condition shall be continuous, but a pulsating signal is permissible.

Exception: The threshold value is not prohibited from being less than 2.0 mA when:

a) The Fault Hazard Current is not less than 35 % of the Total Hazard Current and

b) The Monitor Hazard Current is not more than 50 % of the Total Hazard Current.

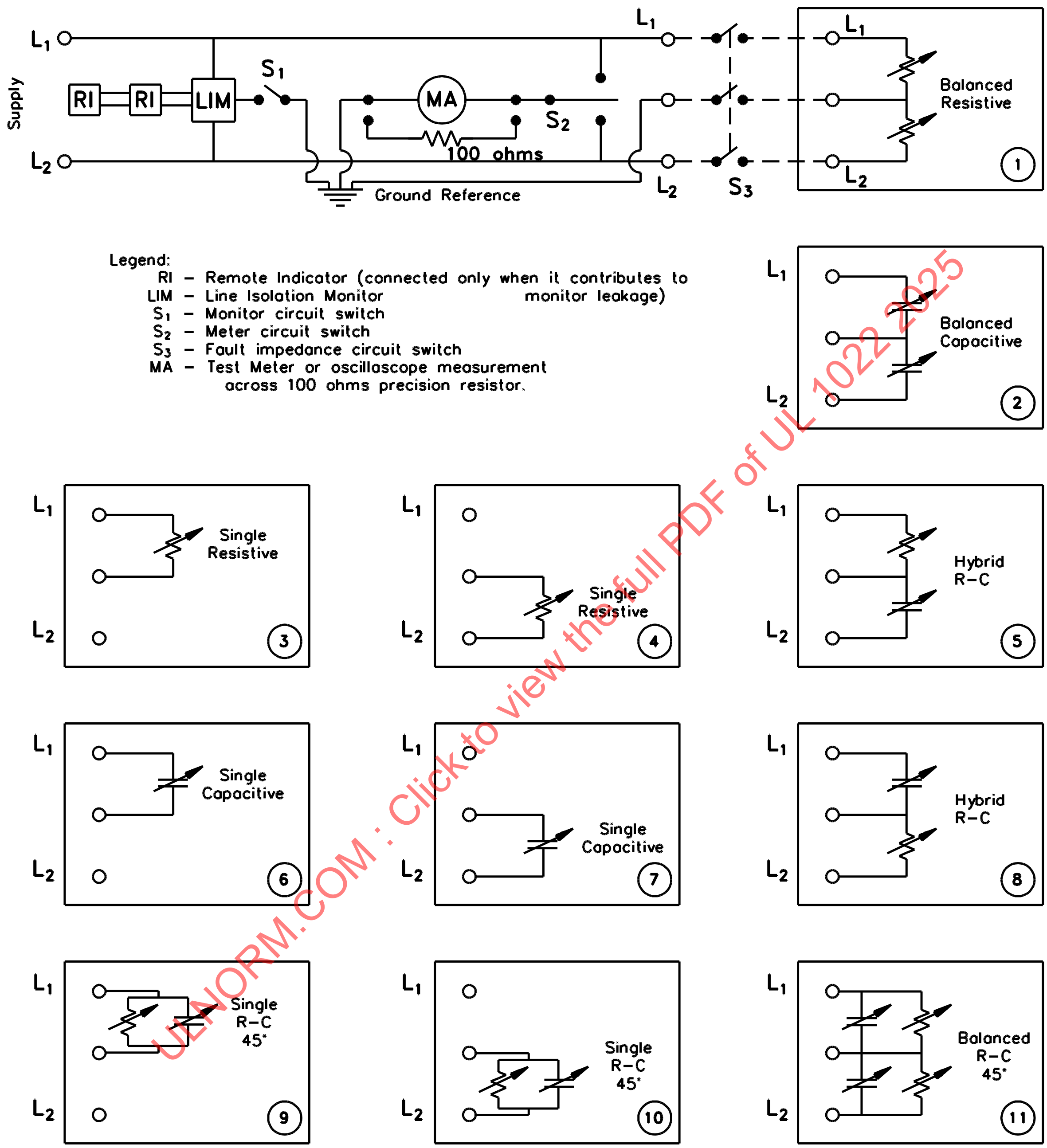
d) The line isolation monitor shall not alarm for a Fault Hazard Current (FHC) of 3.7 mA or less.

e) All monitor meter readings shall be within 10 % of the test meter or oscilloscope readings at the alarm threshold. Above this value, the meter may be read in the red alarm zone.

20.2 For this test the line isolation monitor and the maximum number of remote indicator units (when used) are to be energized from a source of supply in accordance with 16.3 and connected, in turn, to the balanced and unbalanced impedances, resistive, capacitive-reactance, combination resistive-capacitive-reactive, illustrated in Figure 20.1. The enclosure of the device is to be grounded to the apparatus enclosure.

Figure 20.1

Balanced and Unbalanced Impedance Circuits



MONITOR HAZARD CURRENT (MHC) – Leakage contributed by monitor and indicators. S_1 closed, S_3 open, S_2 connected in turn to each side of line.

FAULT HAZARD CURRENT (FHC) – Leakage contributed by fault impedance only. S_1 open, S_3 closed, S_2 connected in turn to each side of line.

TOTAL HAZARD CURRENT (THC) – Leakage contributed by monitor, remote indicators, and fault impedance. S_1 and S_3 closed, S_2 connected in turn to each side of line.

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20.3 Employing the test circuit in Figure 20.1, the following measurements are to be recorded for each test impedance using the related procedure:

a) TEST CIRCUIT LEAKAGE CURRENT – Leakage current contributed only by the supply with the fault impedance, monitor, and remote indicators disconnected. Switches S_1 and S_3 are to be open. S_2 is to be connected, in turn, to each side of line. If the leakage current is greater than 20 μA, adjustments of the supply circuit and connected wiring are to be made to reduce the leakage current to 20 μA or less.

b) MONITOR HAZARD CURRENT (MHC) – Leakage current contributed only by the monitor and indicators. For this measurement the fault impedance is to be disconnected. Switch S_1 is to be closed, S_3 open, and S_2 is to be connected, in turn, to each side of line.

c) TOTAL HAZARD CURRENT (THC) – Leakage current contributed by the monitor, indicators and connected fault impedance. Switches S_1 and S_3 are to be closed, Switch S_2 is to be connected, in turn, to each side of line. For each fault impedance configuration, the impedance applied initially is to be of a high enough value that an alarm is not obtained and is then to be reduced gradually to a value where an alarm is indicated.

d) FAULT HAZARD CURRENT (FHC) – Leakage current contributed by the connected fault impedance only. For this measurement the monitor and indicators are to be disconnected. Following each leakage current measurement at which an alarm occurs during the test specified in (c), Switch S_1 is to be opened, S_3 closed, and S_2 connected, in turn to each side of the line.

e) All monitor meter current readings recorded at the moment of alarm.

20.4 Although the Test Circuit Leakage Current is included in the readings of 20.3 (b) – (e), its minute value is considered negligible.

20.5 For the leakage current measurements only those remote indicators are to be connected which receive their source of energy from the detector.

20.6 The internal monitoring (sampling of each line) by the line isolation monitor circuit is to be stopped by electrical or mechanical means, if feasible, to obtain the maximum reading.

20.7 The higher of the two readings available for each line L_1 and L_2 is to be employed in evaluating compliance with the requirements of this section.

20.8 Spikes superimposed on the current wave-form are not prohibited from being disregarded when their energy content does not exceed 0.3 micro-joules per second.

20.9 When the sampling by the line isolation monitor can be stopped, either by electrical or mechanical means, and the maximum distortion from a pure sine wave is not greater than 10 %, including transient spikes, a test meter is not prohibited from being used to measure the leakage current. The meter used to measure the leakage current is to be an average responding alternating-current milliammeter, which:

a) Indicates the root mean square (RMS) value of a pure sine wave;

b) Has an error of not greater than 5 %;

c) An input impedance of not more than 1500 ohms; and

d) Is shunted by a capacitance of 0.15 microfarad (μF).

20.10 When the sampling by the line isolation monitor cannot be stopped to obtain a direct meter reading, or when the maximum distortion from a pure sine wave is greater than 10 %, except for a square wave-type waveform (see 20.11), a precision resistor (R) of not more than 100 ohms is to be employed in conjunction with a peak-reading, alternating-current memory voltmeter or an oscilloscope calibrated in millivolts (mV). The value of the leakage current (I) is then to be calculated by the equation:

$$I = 0.707\frac{V}{R}$$

in which:

V is the higher of the two peak readings measured from the highest point on the waveform, including any transients.

20.11 When a square-type waveform is obtained, the oscilloscope measurement is to be employed. However, the leakage current is to be calculated as follows:

$$I = \frac{V}{R}$$

in which:

I, *V*, and *R* are as defined by 20.10.

20.12 When an oscilloscope is used as specified in 20.10, the 100-ohm resistor is not prohibited from being shunted by a 5-ohm resistor in series with a 1.5-µF capacitor to eliminate extraneous higher frequencies in the test measurements.

21 Overvoltage and Undervoltage Test

21.1 Voltage operation

21.1.1 A line isolation monitor and associated remote indicating units shall withstand 110 % of the test voltage specified by 16.3, continuously without injury during the normal standby condition and shall operate successfully for normal signaling performance at the increased voltage. Leakage current measurements shall comply with the requirements specified in the Leakage Current Measurements Test, Section 20, except that a ±10 % change from the readings measured at rated voltage is acceptable.

21.1.2 For operation at the higher voltage the monitor is subjected to the increased voltage in the normal standby condition for at least 16 hours and then tested for normal signaling performance and leakage current measurements.

21.2 Undervoltage operation

21.2.1 A line isolation monitor shall operate successfully for its normal signaling performance while energized from a supply of 85 % of the test voltage specified by 16.3. Leakage current measurements shall comply with the requirements specified in the Leakage Current Measurements Test, except that a ±15 % proportional change from the readings measured at rated voltage is permitted. During this test, the test switch shall comply with the requirements of 17.6.

21.2.2 For operation at the reduced voltage the line isolation monitor is energized from a rated source of voltage following which the voltage is reduced to 85 % of rating and then tested for normal signaling performance and leakage current measurements.

22 Jarring Test

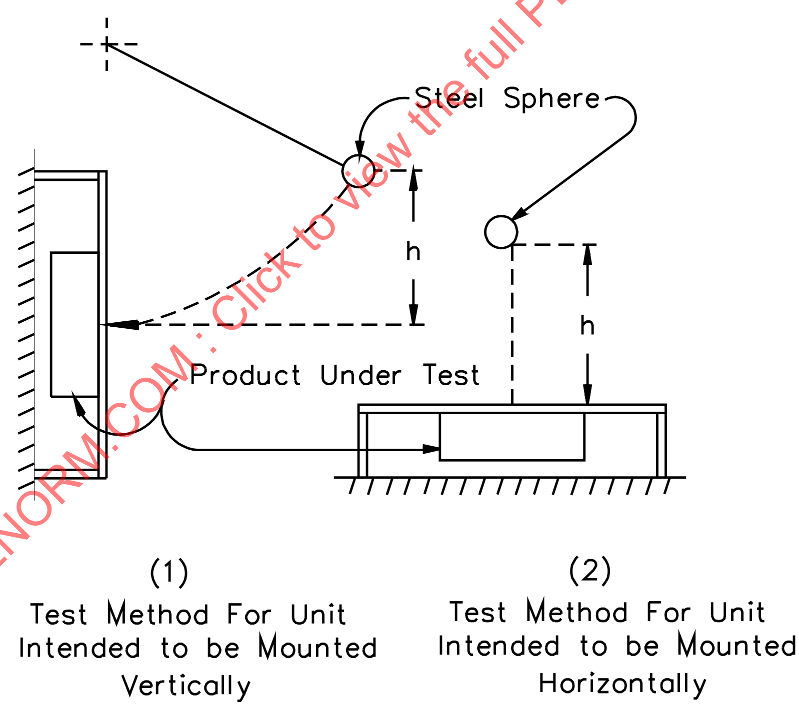
22.1 A line isolation monitor and remote indicating devices shall be capable of withstanding jarring resulting from impact and vibration such as that experienced in service, without causing signaling operation of any part and without affecting adversely its subsequent normal operation.

22.2 The monitor and associated equipment, if any, are to be mounted in a position of intended use to the center of a 6- by 4-foot (1.8 by 1.2 m), 3/4-inch (19.1-mm) thick plywood board which is secured in place at four corners. One 3 foot-pound (4.2 J) impact is to be applied to the center of the reverse side of this board by means of a 1.18 pound (0.534 kg), 2-inch (50.8-mm) diameter steel sphere swung through a pendulum arc, from a sufficient height (h) of 30.5 inches (775 mm) to apply the 3 foot-pound (4.2 J) impact. See Test method (1) in Figure 22.1.

22.3 The effects of jarring are to be determined by supporting the monitor in the position of its intended use, and conducting the jarring while the unit is in the normal standby condition and connected to a source of supply in accordance with 16.3. Following the jarring the unit is to be tested for normal signaling performance.

Figure 22.1

Jarring Test



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23 Temperature Test

23.1 The materials or components employed in a line isolation monitor shall not be affected adversely by the temperatures attained under any condition of normal operation. A material or component is considered as being adversely affected when it is subject to a temperature rise greater than that indicated in Table 23.1.

23.2 To determine compliance with this test, a monitor and related devices are to be connected to a source of supply in accordance with 16.3 and operated under the following conditions:

a) NORMAL STANDBY – (16 hours) Constant temperatures.

b) ALARM – (1 hour) Audible signal operating.

c) ALARM – (7 hours) Audible signal silenced.

23.3 All values for temperature rises apply to equipment intended for use with ambient temperatures normally prevailing which usually are not higher than 25 °C (77 °F).

23.4 When equipment is intended specifically for use with a prevailing ambient temperature constantly more than 25 °C (77 °F), the test of the equipment is made with such higher ambient temperature, and the allowable temperature rises specified in Table 23.1 are to be reduced by the amount of the difference between that higher ambient temperature and 25 °C (77 °F).

23.5 Temperature measurements on equipment intended for recessed mounting are to be made with the unit installed in an enclosure of nominal 3/4 inch (19 mm) wood having clearances of 2 inches (50.8 mm) on the top, sides, and rear, and the front extended to be flush with the monitor cover.

23.6 A temperature is considered to be constant when three successive readings, taken at not less than 5-minute intervals, indicate no change.

23.7 Except at coils, temperatures are to be measured by means of thermocouples. The preferred method of measuring the temperature of a coil is the thermocouple method, but a temperature measurement by either the thermocouple or resistance method is acceptable, except that the thermocouple method is not to be employed at any point where supplementary thermal insulation is employed.

23.8 When thermocouples are used in the determination of temperatures it is standard practice to employ thermocouples consisting of 24 – 30 AWG (0.21 – 0.06 mm^2) iron and constantan wires and a potentiometer-type indicating instrument. Such equipment will be used whenever referee temperature measurements by thermocouples are required.

23.9 The thermocouple wire is to conform with the requirements for Special Tolerances as listed in the Tolerances on Initial Values of EMF versus Temperature tables in ASTM E230/E230M.

Table 23.1
Maximum Temperature Rises

Device or material	°C	(°F)
1. Any point on rectifiers:		
a) Copper oxide	30	(54)
b) Germanium	50	(90)
c) Magnesium-copper sulphide	95	(171)
d) Selenium	50	(90)
e) Silicon	75	(135)
2. Rubber or thermoplastic insulation	35[a]	(63[a])
3. Varnished cloth insulation	60	(108)

Table 23.1 Continued on Next Page

Table 23.1 Continued

Device or material	°C	(°F)
4. Fuses	65	(117)
5. Surfaces adjacent to or upon which the unit may be mounted in service	65	(117)
6. Wood or other combustible material	65	(117)
7. Fiber used as electrical insulation	65	(117)
8. Class A (Class 105) insulation	65[c]	(117[c])
9. Class B (Class 130) insulation	85[c]	(153[c])
10. Phenolic composition used as electrical insulation	125	(225)
11. Capacitors	40	(72)
12. Solid-State devices (transistors, silicon-controlled rectifiers, and the like.)	See d	
13. Wirewound resistor	150[b]	(302[b])
14. Carbon resistor	50[b]	(122[b])
15. Sealing compound	15 °C (27 °F) less than the melting point[b]	

[a] This limitation does not apply to an insulated conductor, or a material which has been investigated and accepted for a higher temperature.

[b] These are limiting temperatures, not temperature rises.

[c] 10 °C (18 °F) higher on coil insulation when measured by the resistance method.

[d] The temperature of a solid-state device shall not exceed 50 % of its rating during the normal standby condition. The temperature of a solid-state device shall not exceed 75 % of its rated temperature under any other condition of operation of the complete unit which produces the maximum temperature dissipation of its components. For reference purposes 0 °C (32 °F) shall be considered as 0 %. For integrated circuits the loading factor shall not exceed 50 % of its rating under the normal standby condition and 75 % under any condition of operation. Both solid-state components and integrated circuits may be operated up to the maximum ratings under any one of the following conditions.

1. All components comply with the Mil-Spec requirements of Mil-Std. 883C.

2. All components are screened through an acceptable quality control program established by the manufacturer.

3. Each assembled unit is subjected to a burn-in test for 24 hours while connected to a source of supply in accordance with 16.3 in an ambient of 49 °C (120 °F), followed by operational test.

23.10 The temperature of a copper coil winding is determined by the resistance method by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature by means of the equation:

$$T = \frac{R}{r}(234.5 + t) - 234.5$$

in which:

T is the temperature to be determined in °C;

t is the known temperature in °C;

R is the resistance in ohms at the temperature to be determined; and

r is the resistance in ohms at the known temperature.

23.11 As it is generally necessary to de-energize the winding before measuring *R*, the value of *R* at shutdown can 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 can be plotted and extrapolated to give the value of *R* shutdown.

23.12 The monitor is to be subjected to the Dielectric Voltage-Withstand Test, Section 30, following the above test.

24 Overload Test

24.1 Monitor

24.1.1 A line isolation monitor and connected indicating units shall be capable of operating in its intended manner after being subjected for 50 cycles of alarm signal operation at a rate of not more than 6 cycles per minute with the supply circuit to the monitor at 115 % of the test voltage specified by 16.3. Each cycle shall consist of starting with the monitor energized in the normal standby condition, application of a ground fault, and restoration to normal standby.

24.1.2 Rated test loads are to be connected to those output circuits of the monitor which are energized from the monitor power supply, such as remote indicators, buzzers, etc. The test loads shall be those devices, or the equivalent, normally intended for connection. When an equivalent load is employed for a device consisting of an inductive load, a power factor of 60 % is to be used. The rated loads are to be established initially with the monitor connected to a source of supply in accordance with 16.3, following which the voltage is to be raised to 115 % of rating.

24.1.3 For direct-current signaling circuits, an equivalent inductive test load is to have the required direct-current resistance for the test current and the inductance (calibrated) to obtain a power factor of 60 % when connected to a 60-hertz (Hz), alternating-current potential equal to the rated direct current test voltage. When the inductive load has both the required direct-current resistance and the required inductance, the current measured with the load connected to an alternating-current circuit will be equal to 0.6 times the current measured with the load connected to a direct-current circuit when the voltage of each circuit is the same.

24.2 Separately energized circuits

24.2.1 Separately energized circuits of a line isolation monitor, such as dry contacts, shall operate as intended after being subjected to 50 cycles of signal operation at a rate of not more than 6 cycles per minute while connected to a source of supply in accordance with 16.3. There shall be no electrical or mechanical malfunction of the switching circuit.

24.2.2 During the test described in 24.2.1, the output circuits that do not receive energy from the monitor are to be connected to test loads set at 150 % of rated current at 0.6 power factor, while connected to a separate power source of supply in accordance with 16.3.

25 Endurance Test

25.1 Monitor

25.1.1 A line isolation monitor shall operate as intended following 30,000 cycles of alarm signal operation at a rate of not more than 10 cycles per minute while connected to a source of supply circuit in accordance with 16.3, and with related devices or equivalent loads connected to the output circuits. There shall be no electrical or mechanical malfunction of the monitor or its components.

25.2 Devices and separately energized circuits

25.2.1 An operating device, such as test switch, relay, or the like, supplied as part of a line isolation monitor, shall operate as intended following 30,000 cycles of operation at a rate of not more than 10 cycles per minute. When an electrical load is involved, the contacts of the device shall be caused to make and break the normal load current at a test voltage in accordance with 16.3. The load is to represent the load that the device is intended to control. The test is not prohibited from being conducted in conjunction with the endurance test of the monitor (see 25.1.1). There shall be no electrical or mechanical malfunction of the device.

26 Variable Ambient Temperature Test

26.1 A line isolation monitor and related indicators shall operate as intended with the temperature of the ambient air at any temperature over the range from 49 °C (120 °F) to 10 °C (50 °F).

26.2 Leakage current measurements are to be recorded before and during exposure to each ambient condition in accordance with the Leakage Current Measurements Test, Section 20, employing the fault impedance configurations that resulted in the maximum and minimum leakage currents.

26.3 The product is to be operated in an ambient temperature of 75 °C (167 °F) for at least 90 days while connected to a source of rated voltage and frequency. Following this preconditioning period, the ambient temperature is to be reduced to 50 °C (122 °F), and the unit shall comply with the requirements of the Normal Operation Test, Section 17, and the Leakage Current Measurement Test, Section 20.

26.4 The product then is to be operated in an ambient temperature of 10 °C (50 °F) until thermal equilibrium has been reached, and the unit is then to be tested for intended operation while connected to a source of rated voltage and frequency.

26.5 Each unit shall operate as intended in each ambient. The leakage currents measured with the units in each ambient temperature shall be in compliance with the requirements of the Leakage Current Measurement Test, Section 20.

27 Humidity Test

27.1 A line isolation monitor shall operate as intended while energized from a source of supply in accordance with 16.3, and after having been exposed for 24 hours to moist air having a relative humidity of 85 ±5 % at a temperature of 30 ±2 °C (86 ±3 °F). The performance is to be determined with the monitor in the humid atmosphere.

27.2 Leakage current measurements are to be recorded before and during exposure to the humidity condition in accordance with the Leakage Current Measurements Test, Section 20, employing the fault impedance configuration that resulted in the maximum and minimum leakage currents. The leakage current measured with the unit in the humid atmosphere shall comply with the requirements of Section 20.

28 Electric Shock Current Test

28.1 When the open circuit potential between any part that is exposed only during operator servicing and either earth ground or any other exposed accessible part exceeds 42.4 volts peak, the part shall comply with the requirements of 28.2 – 28.4, as applicable.

28.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in when the resistor is connected between any part that is exposed only during operator servicing and either earth ground or any other exposed accessible part.

Table 28.1
Maximum Current During Operator Servicing

Frequency, hertz[a]	Maximum acceptable current through a 500-ohm resistor, milliamperes peak
0 – 100	7.1
500	9.4
1000	11.0
2000	14.1
3000	17.3
4000	19.6
5000	22.0
6000	25.1
7000 or more	27.5

[a] Linear interpolation between adjacent values may be used to determine the maximum acceptable current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

28.3 The transient current flowing through a 500-ohm resistor connected as described in 28.2 shall not exceed 809 milliamperes, regardless of duration; and the duration of the transient current shall not exceed the value determined by the following equation:

$$T \leq \left(\frac{20\sqrt{2}}{I} \right)^{1.43}$$

in which:

T is the interval, in seconds, between the time that the instantaneous value of the current first exceeds 7.1 milliamperes and the time that the current falls below 7.1 milliamperes for the last time and

I is the peak current in milliamperes.

The interval between occurrences shall be equal to or greater than 60 seconds when the current is repetitive. Typical calculated values of maximum acceptable transient current duration are shown in 26.2.

28.4 The maximum capacitance between the terminals of a capacitor that is accessible during operator servicing shall comply with the following equations:

$$C = \frac{88{,}400}{E^{1.43}\left(\ln E - 1.26\right)} \quad \text{for } 42.4 \leq E \leq 400$$

$$C = 35{,}288E^{-1.5364} \quad \text{for } 400 \leq E \leq 1000$$

in which:

C is the maximum capacitance of the capacitor in microfarads and

E is the potential in volts across the capacitor prior to discharge. *E* is to be measured 5 seconds after the capacitor terminals are made accessible, such as by the removal or opening of an interlocked cover, or the like.