UL 752

STANDARD FOR SAFETY

Bullet-Resisting Equipment

UL Standard for Safety for Bullet-Resisting Equipment, UL 752

Twelfth Edition, Dated October 17, 2023

Summary of Topics

This new Twelfth Edition of ANSI/UL 752 dated October 17, 2023 includes new ballistic testing requirements.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated October 14, 2022 and June 16, 2023.

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UL 752

Standard for Bullet-Resisting Equipment

First Edition – April, 1942
Second Edition – July, 1946
Third Edition – July, 1956
Fourth Edition – February, 1973
Fifth Edition – February, 1974
Sixth Edition – October, 1979
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Ninth Edition – January, 1995
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Twelfth Edition

October 17, 2023

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

The most recent designation of ANSI/UL 752 as an American National Standard (ANSI) occurred on October 17, 2023. 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 materials, devices, and fixtures used to form bullet-resisting barriers which protect against robbery, holdup, or armed attack such as those by snipers.

1.2 This standard can also be used to determine the bullet resistance of building components that do not fit the definition of equipment, such as windows, walls, or barriers made out of bullet resistant materials.

1.3 This standard does not address personal protective equipment, such as body armor, helmets, and shields.

1.4 As used in these requirements, the term "bullet-resisting" signifies that protection is provided against complete penetration, passage of fragments of projectiles, or spalling (fragmentation) of the protective material to the degree that injury would not be caused to a person standing directly behind the bullet-resisting barrier.

1.5 These requirements also cover electrically-operated equipment, such as teller's fixtures using electrically-driven deal trays or package passers, and intercommunication or other electrical equipment that is an integral part of the bullet-resisting product.

1.6 The term "product" as used in this standard refers to all bullet-resisting equipment or any part thereof covered by this standard unless specifically noted otherwise.

2 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

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 D396-97, Standard Specification for Fuel Oils

ASTM E3062, *Specification for Indoor Ballistic Test Ranges for Small Arms and Fragmentation Testing of Ballistic-resistant Items*

ASTM E3112, *Test Method for Ballistic-resistant Products and Shoot Packs*

ASTM E3062, *Specification for Indoor Ballistic Test Ranges for Small Arms and Fragmentation Testing of Ballistic-resistant Items*

MIL-STD-750F, *Test Methods for Semiconductor Devices*

MIL-STD-810G, *Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*

NFPA 70, *National Electrical Code*

SAAMI Z299.2, *Sporting Arms and Ammunition Manufacturers' Institute*

UL 94, *Test for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 310, *Electrical Quick-Connect Terminals*

UL 486A-486B, *Wire Connectors*

UL 486E, *Equipment Wiring Terminals for Use With Aluminum and/or Copper Conductors*

UL 796, *Printed Wiring Boards*

UL 1059, *Terminal Blocks*

UL 1492, *Audio-Video Products and Accessories*

UL 2111, *Overheating Protection for Motors*

UL 1004-1, *Rotating Electrical Machines – General Requirements*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 969, *Marking and Labeling Systems*

5 Glossary

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

5.2 ELECTRICAL CIRCUITS:

a) High-Voltage (Class 1) – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage, power-limited circuit.

b) Low-Voltage – A circuit involving a potential of not more than 30 volts AC, rms, 42.4 volts DC or AC peak.

c) Power-Limited – A circuit whose output is limited as specified in Power-Limited Circuits, Section 32.

d) Class 2 – A circuit in which the voltage and power limitations are in accordance with the requirements of Table 32.1 for AC circuits and Table 32.2 for DC circuits.

e) Class 3 – A circuit in which the voltage and power limitations are in accordance with the requirements of Table 32.1 for AC circuits and Table 32.2 for DC circuits.

5.3 LEVEL 1 – Protection against hand guns of medium power, such as the 9 mm, Super 38 Automatic, and the like, with muzzle energy of 380 – 460 foot-pounds (515 – 624 J).

5.4 LEVEL 2 – Protection against hand guns of high power, such as the .357 Magnum, and the like, with muzzle energy of 548 – 663 foot-pounds (743 – 899 J).

5.5 LEVEL 3 – Protection against hand guns of super power, such as the .44 Magnum, and the like, with muzzle energy of 971 – 1175 foot-pounds (1317 – 1593 J).

5.6 LEVEL 4 – Protection against high-power hunting and sporting rifles, such as the 30-06, and the like, with muzzle energy of 2580 – 3120 foot-pounds (3498 – 4929 J).

5.7 LEVEL 5 – Protection against military ball full metal copper jacket ammunition fired from a hunting rifle such as the 308 Winchester or a military rifle with muzzle energy of 2519 – 3048 foot-pounds (3416 – 4133 J).

5.8 LEVEL 6 – Protection against multiple shots from a submachine-gun, such as a 9 mm Uzi, and the like, with muzzle energy of 540 – 653 foot-pounds (732 – 885 J).

5.9 LEVEL 7 – Protection against multiple shots from a military assault rifle, such as an M-16, and the like, with muzzle energy of 1158 – 1402 foot-pounds (1570 – 1901 J).

5.10 LEVEL 8 – Protection against multiple shots from a military assault rifle, such as an M-14, and the like, with muzzle energy of 2519 – 3048 foot-pounds (3416 – 4133 J).

5.11 LEVEL 9 – Protection against armor piercing rounds fired from an M1 Garand rifle or the like, or high-power hunting and sporting rifles with muzzle energy of 2717 to 2777 foot-pounds (3683 – 4457 J). The bullet will be a .30-06 armor piercing round such as the US Military APM2.

5.12 LEVEL 10 – Protect against one shot from a military sniper rifle, such as the Barrett M82 A1 (XM 107), with a muzzle energy of 12,439 – 12.706 foot-pounds (16, 863 – 20,404 J). The bullet will be a .50 caliber round such as the US Military M2.

5.13 SUPPLEMENTARY SHOTGUN – A supplementary test using a rifled lead slug with a muzzle energy of 2438 – 2950 foot-pounds (3306 – 4000 J) and 00 lead buckshot with a muzzle energy of 2078 – 2415 foot-pounds (2818 – 3275 J), fired from a 12-gauge shotgun. Products shall be tested with both loads. Products complying with this test may have the suffix "-SG" added to the rating designation.

CONSTRUCTION – BULLET-RESISTING EQUIPMENT AND MATERIALS

6 Gunports

6.1 Gunports shall be constructed for operation from behind the barrier only. The gun door or shutter shall close automatically, and shall be guarded against being opened from the exposed side with a rubber suction cup or similar means.

6.2 Gunports shall be constructed so that a rod 5/8-inch (15.9 mm) in diameter will have a horizontal traverse of at least 90° and a vertical traverse of at least 30° below horizontal.

6.3 For Levels 1 – 3, a gunport shall not be rendered inoperative after being struck with one projectile. For Levels 4 – 10, and supplementary shotgun, a gunport may be rendered inoperative after being struck with one projectile, but shall remain closed (see Test Sample Requirements Assemblies, Section 14).

7 Speaking Apertures

7.1 Speaking apertures shall:

a) Fulfill their intended purpose;

b) Be bullet-resisting in accordance with 1.4; and

c) Prevent the insertion of the muzzle of any firearm including weapons as small as a 0.25 caliber handgun, in such a manner as to command direct aim on persons behind the protection.

8 Deal Trays and Package Passers

8.1 Deal trays and package passer devices shall not have openings or joints which will permit spray of projectile fragments to the interior as a result of firearm tests.

8.2 Deal trays and package passers shall be guarded against forcible entry from the exposed side using any of the methods specified for gunports.

8.3 Package passers shall be constructed such that money bags and the like can be passed without providing any opening through which the muzzle of any firearm, including weapons as small as a 0.25 caliber handgun, might be inserted to command the work space.

8.4 Deal trays shall be constructed so that when installed as intended they permit no direct line of fire toward the teller's position nor the insertion of the muzzle of any firearm, including weapons as small as a 0.25 caliber handgun, in such a manner as to command direct aim on persons behind the protection.

9 Intercommunication System

9.1 An electronic intercommunication system unit shall comply with UL 1492.

10 Barriers and Building Components

10.1 Barrier devices and building components that are intended to provide protection on their own or as part of an overall protective assembly between the public and the protected side may be fixed or moved into place when required.

10.2 Protection against a specified level of attack shall extend to a minimum of 78 inches (2 m) above the floor level on the public side.

10.3 In order to prevent an attacker from climbing or vaulting the barrier, throwing objects over the barrier, or aiming and firing a firearm directly or indirectly into the protected side, the construction described in 10.4 shall be provided from the minimum 78-inch (2-m) height to the ceiling.

10.4 The area from the 78-inch (2-m) height to a height of 10 feet (3.08 m) is to be provided with a minimum construction of wire mesh screening constructed of at least 0.053 inch (1.35 mm) minimum thickness expanded sheet steel or 10 AWG (0.102 inch diameter) (5.3 mm^2) steel wire with openings not greater than 2 inches (51 mm).

Exception: The construction described need not be provided to a height of 10 feet if the installation instructions specify that the top of the barrier is to be flush with part of the building structure.

PERFORMANCE – BULLET-RESISTING MATERIALS

11 Ballistic Designations and Ammunition Specifications

11.1 The UL 752 ballistic designations and ammunition specifications given in Table 11.1, Table 11.2, and Table 11.3 shall apply.

11.2 Ammunition shall meet the projectile specifications and tolerances provided in Annex B.

Table 11.1
Handgun Designations and Ammunition Specifications

Handgun (HG)				
Designation	**Ammunition**	**Weight**	**Reference velocity**	**Kinetic energy**
UL-HG-A	9 mm Luger FMJ RN	124 grains (8.0 grams)	1305 fps (398 m/s)	467.3 ft·lb (633.6 J)
UL-HG-B	.357 Mag JSP	158 grains (10.2 grams)	1430 fps (436 m/s)	715.1 ft·lb (969.5 J)
UL-HG-C	.44 MAG JHP	240 grains (15.6 grams)	1430 fps (436 m/s)	1093.6 ft·lb (1482.7 J)
UL-HG-D	9 mm Luger FMJ RN	124 grains (8.0 grams)	1470 fps (448 m/s)	592.1 ft·lb (802.8 J)
Note: There is no hierarchy of threat severity in this list.				

Table 11.2
Rifle Designations and Ammunition Specifications

Rifle (RF)				
Designation	**Ammunition**	**Weight**	**Reference velocity**	**Kinetic energy**
UL-RF-A	.30-06 Springfield JSP (7.62 x 63 mm)	180 grains (11.7 grams)	2700 fps (823 m/s)	2922.5 ft·lb (3962.4 J)
UL-RF-B	7.62 x 51 mm M80 Ball, NATO FMJ, Steel Jacket	149 +0/-3 grains (9.7 +0/-0.2 grams)	2780 fps (847 m/s)	2566.3 ft·lb (3479.4 J)
UL-RF-C	.243 Winchester, Pointed Soft Point (PSP)	100 grains (6.2 grams)	3000 fps (914 m/s)	1910.1 ft·lb (2589.7 J)

Table 11.2 Continued on Next Page

Table 11.2 Continued

Rifle (RF)				
Designation	**Ammunition**	**Weight**	**Reference velocity**	**Kinetic energy**
UL-RF-D	.270 Winchester, Pointed Soft Point (PSP)	130 grains (8.4 grams)	3100 fps (945 m/s)	2766.4 ft·lb (3750.7 J)
UL-RF-E	5.56 mm M193 FMJ BT, (5.56 x 45 mm)	56 +0/-2 grains (3.6 +0/-0.1 grams)	3390 fps (1033 m/s)	1416.7 ft·lb (1920.8 J)
UL-RF-F	5.56 mm M855 FMJ BT, (5.56 x 45 mm)	61.8 ±1.5 grains (4.0 ±0.1 grams)	3190 fps (972 m/s)	1393.7 ft·lb (1889.6 J)
UL-RF-G	7.62 x 39 mm Type 56, MSC FMJ, Copper-Plated Steel Jacket, Mild Steel Core Note: Surrogate round is under development.	124 +0/-2 grains (8.04 +0/-0.1 grams)	2480 fps (756 m/s)	1694.6 ft·lb (2297.8 J)
UL-RF-H	7.62 x 51 mm M80 Ball, NATO FMJ, Steel Jacket	149 +0/-3 grains (9.7 +0/-0.2 grams)	2780 fps (847 m/s)	2566.3 ft·lb (3479.4 J)
UL-RF-I	.30 caliber M2 AP FMJ, (7.62 x 63 mm)	165.7 +0/-7 grains (10.8 +0/-0.5 grams)	2880 fps (878 m/s)	3070.3 ft·lb (4162.8 J)
UL-RF-J	.50 caliber M33 FMJ Ball, mild steel core	660 grains (42.7 grams)	2910 fps (887 m/s)	12389.2 ft·lb (16797.5 J)
Note: There is no hierarchy of threat severity in this list.				

Table 11.3
Shotgun Designations and Ammunition Specifications

Rifle (RF)				
Designation	**Ammunition**	**Weight**	**Reference velocity**	**Kinetic energy**
UL-SG-A	Winchester, Ranger LE, 12 Ga., 2-3/4 Inch, 1 oz. Slug (Most common slug available)	437.5 grains (28.3 grams)	1200 fps (366 m/s)	1398.0 ft·lb (1895.5 J)
UL-SG-B	12-gauge 00 lead buckshot (12 pellets)	650 grains (42 grams)	1200 fps (366 m/s)	2074.8 ft·lb (2813.1 J)
Note: There is no hierarchy of threat severity in this list.				

11.3 During these tests the velocity of the projectile is to be recorded and shall be within ±30 ft/s (±9.1 m/s) of the specified velocity shown in Table 11.1, Table 11.2, and Table 11.3.

12 Test Sample Requirements: Bullet-Resisting Material

12.1 The applicable UL 752 ballistic designation(s) shall be declared for which the material will be tested.

12.2 A sufficient number of test samples fully representative of production products shall be provided.

NOTE: Spare test samples are recommended.

12.3 Each test sample of a material shall be 12 by 12 inches ±0.5 inches (305 by 305 mm ±12.7 mm). If test results indicate that a more severe condition would involve the testing of a larger size test sample, then the larger size sample up to the maximum overall size commercially produced shall be tested.

12.4 Each test sample shall be finished to the degree that there are no visible imperfections in the material, such as delaminations, air bubbles, and the like.

NOTE: UL 752 requires that test samples be fully representative of production products. If it is normal that minor flaws or fibers be present during production, then the manufacturer can submit such samples for testing.

12.5 Test samples shall be subjected to ballistic testing in accordance with Section 15.

12.6 Solid open-hearth steel not less than 3/16 inch (4.8 mm) thick, having an ultimate tensile strength of 50,000 psi (345 MPa), is acceptable for UL-HG-A designation and, therefore, is not required to be tested.

13 Test Sample Requirements: Bullet-Resisting Glazing Material

13.1 The applicable UL 752 ballistic designation(s) shall be declared for which the glazing material will be tested.

NOTE: Spare test samples are recommended.

13.2 Each test sample shall be 12 by 12 inches ±0.5 inches (305 by 305 mm ±12.7 mm). If bullet-resisting glass, plastic, or any combination thereof is produced with any lateral dimension smaller than test sample size, then the smallest section sample is also to be tested. If test results indicate that a more severe condition would involve the testing of a larger size test sample, then the larger size sample up to the maximum overall size commercially produced shall be tested.

13.3 Each assembly of bullet-resisting glazing material tested shall be finished to the degree that there are no visible imperfections in the materials, such as delaminations, air bubbles, and the like.

13.4 Test samples shall be subjected to ballistic testing in accordance with Section 15.

14 Test Sample Requirements: Assemblies

14.1 Bullet-resisting assemblies include gunports, deal trays, package passers, voice panels, door operating mechanisms, and the like.

14.2 A sufficient number of test samples fully representative of production products shall be provided and be in assemblies (including frames and glazing) that are representative of how those products are commonly built or applied.

NOTE: Spare test samples are recommended.

14.3 The applicable UL 752 ballistic designation(s) shall be declared for which the assembly will be tested.

14.4 The manufacturer shall provide a build sheet and dimensioned diagram indicating the location of potential weak points of an assembly. See 15.8.2 for examples of assembly weak points.

15 Ballistics Testing

15.1 Performance requirements

15.1.1 There shall be no complete penetration of the projectile through the test sample, and there shall be no spalling of material on the protected side of the test sample to the extent that fragments embed into or damage the witness panel.

15.1.2 Spalling of material from the protected side of the test sample is permitted for the 2-shot pattern (see 15.3.3) and for unsupported edge shots (see 15.3.5).

15.1.3 After the shot, there shall be no opening in the test sample greater than the projectile diameter.

15.2 Test range setup and requirements

15.2.1 The test range shall be set up in accordance with and meet the requirements of ASTM E3062.

15.2.2 Each test sample of a material shall be mounted in a rigidly fixed frame, (provided by the testing laboratory)., The frame shall and shall meet the following requirements:

a) The frame shall have two layers such that the test sample is sandwiched between the layers and restrained with mechanical or pneumatic clamping devices at each of the four corners of the frame.

b) The frame shall be aluminum or steel, approximately 0.20 inch (0.5 cm) thick.

c) The internal window of the frame shall be at least 9.0 by 9.0 inch (23.0 by 23.0 cm) square.

d) The frame shall be at least 1.4 inches (3.6 cm) wide, and the test sample shall extend to the outer edges of the frame.

15.2.3 Each test sample of an assembly shall be mounted in its intended use configuration and shall be rigidly held in place.

15.2.4 A witness panel shall be installed behind the test sample and shall meet the witness panel requirements specified in ASTM E3112,.

15.2.5 Each shot shall be fired singly for each test. For each shot the weapon is to be aimed, loaded with a single round and then fired.

15.3 Shot patterns

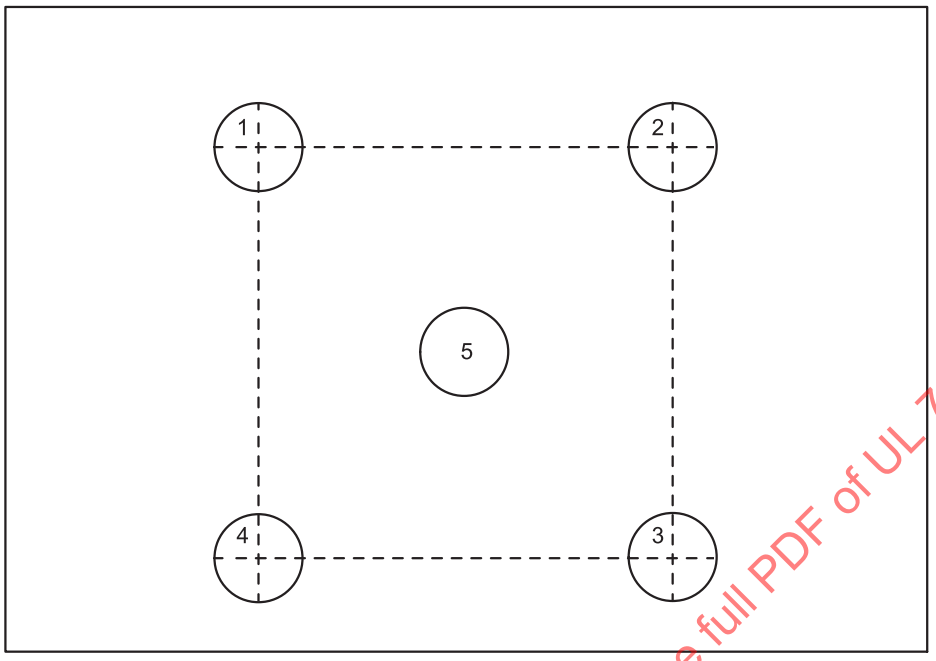
15.3.1 5-Shot pattern

15.3.1.1 Five shots shall be placed in the center of the test sample in a dice pattern, with shot order, as shown in Figure 15.1.

Exception: The placement of the shot pattern for samples of 15.8.2.2 shall be placed on the part of the assembly determined to be the weakest area. More than one location may be subjected to this test.

Figure 15.1

5-Shot Pattern



su4965

15.3.1.2 The corner shots shall be spaced with 4.5 ±0.5 inches (114.0 ±12.7 mm) between impact centers.

15.3.1.3 The center shot shall be placed equidistant between other impact centers.

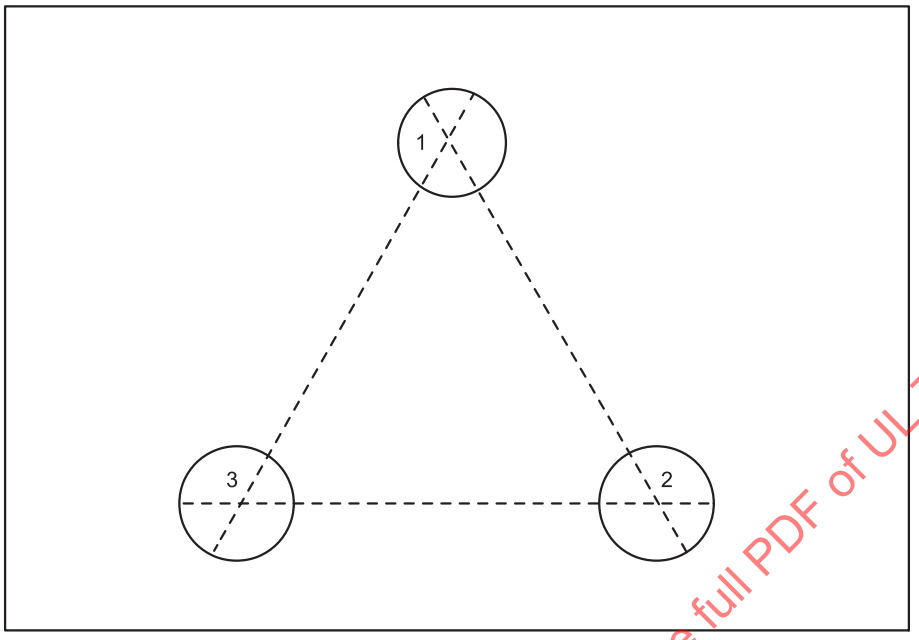
15.3.1.4 Each shot shall impact the test sample within 0.25 inches (6.0 mm) of the marked location.

15.3.2 3-Shot pattern

15.3.2.1 Three shots shall be placed in the center of the test sample in a triangle pattern, with shot order, as shown in Figure 15.2.

Figure 15.2

3-Shot Pattern



su4905

15.3.2.2 The shots shall be spaced with 4.0 ±0.5 inches (102.0 ±12.7 mm) between impact centers.

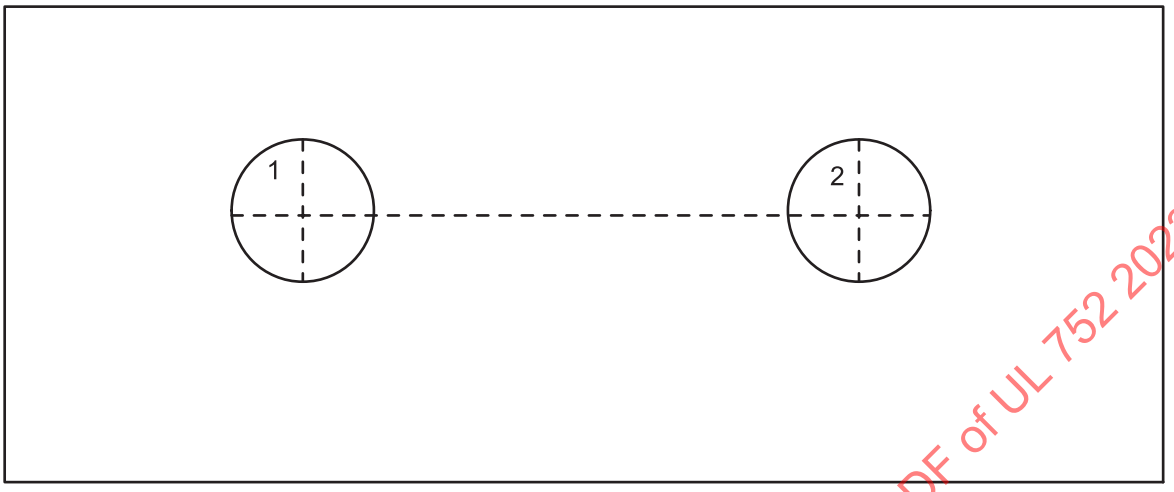
15.3.2.3 Each shot shall impact the test sample within 0.25 inches (6.0 mm) of the marked location.

15.3.3 2-Shot pattern

15.3.3.1 Two shots shall be placed in the center of the test sample, with shot order, as shown in Figure 15.3.

Figure 15.3

2-Shot Pattern



su4906

15.3.3.2 The shots shall be spaced with 1.5 ±0.25 inches (38.1 ±6.4 mm) between impact centers.

15.3.3.3 Each shot shall impact the test sample within 0.25 inches (6.0 mm) of the marked location.

15.3.4 Single shot

15.3.4.1 A single shot shall be placed in the center of the test sample.

15.3.4.2 The manufacturer may choose to replace the single shot with a 2-shot pattern (See 15.3.3). This would count as two single shots.

15.3.5 Unsupported edge shot

15.3.5.1 The test item shall be mounted in a frame with three of the four edges providing support and one edge unsupported. A single shot shall be placed on the test sample in the horizontal center and 1.25 ±0.25 inches (31.8 ±6.4 mm) from the unsupported edge.

Exception: Bullet-resisting material that is to be used in a fully-supported manner need not be subjected to this test.

15.4 Fair hit

15.4.1 The fair hit requirements specified in ASTM E3112, shall apply to all shots.

15.4.2 For a shot to be considered a fair hit, it shall meet the specified impact location requirements, and the measured velocity shall either:

a) Be within ±30 ft/s (9.1 m/s) of the reference velocity for the specified bullet;

b) Be less than the minimum velocity and produce a perforation; or

c) Be greater than the maximum velocity and not produce a perforation.

15.5 Conditioning procedures

15.5.1 Controlled ambient conditioning for indoor use products

15.5.1.1 The test sample shall be conditioned for at least 12 hours at 68 ±10 °F (20.0 ±5.6 °C) and relative humidity of 50 ±20 %.

15.5.2 Heated strike face conditioning for outdoor use products

15.5.2.1 The test sample shall be conditioned for a minimum of 3 hours, not to exceed 4 hours, with the strike face held at 120 ±5 °F (49 ±3 °C) and the opposite face held at 68 ±10 °F (20.0 ±5.6 °C).

15.5.2.2 The starting temperature shall be controlled ambient.

15.5.3 Cooled strike face conditioning for outdoor use products

15.5.3.1 The test sample shall be conditioned for a minimum of 3 hours, not to exceed 4 hours, with the strike face held at minus 26 ±5 °F (minus 32 ±3 °C)and the opposite face held at 68 ±10 °F [20.0 ±5.6 °C].

15.5.3.2 The starting temperature shall be controlled ambient.

15.5.4 High temperature conditioning for outdoor use products

15.5.4.1 Conditioning shall be performed in accordance with constant temperature exposure procedures of MIL-STD-810G, Method 501.5, Procedure I (high temperature).

15.5.4.2 The starting temperature shall be controlled ambient.

15.5.4.3 The test sample shall be heated to 120 ±5 °F (49 ±3 °C) for a minimum of 3 hours, not to exceed 4 hours.

15.5.5 Low temperature conditioning for outdoor use products

15.5.5.1 Conditioning shall be performed in accordance with constant temperature exposure procedures of MIL-STD-810G, Method 502.5, Procedure I (low temperature).

15.5.5.2 The starting temperature shall be controlled ambient.

15.5.5.3 The test sample shall be cooled to minus 26 ±5 °F (minus 32 ±3 °C) for a minimum of 3 hours, not to exceed 4 hours.

15.6 Required conditioning and testing for indoor use and steel materials and assemblies

15.6.1 Indoor use materials and assemblies and steel for indoor or outdoor use shall be conditioned and tested as shown in Table 15.1.

15.6.2 The minimum number of shots required in Table 15.1 does not include necessary weak point shots.

Table 15.1
Conditioning and Testing for Indoor Use and Steel Materials and Assemblies

UL designation	Required shot patterns	Quantity of each shot pattern	Conditioning prior to ballistic testing	Minimum number of shots	Minimum number of samples
UL-HG-A	3-shot triangle pattern	3	Controlled ambient	18	3
	2-shot pattern	3	Controlled ambient		
	Unsupported edge shot	3	Controlled ambient		
UL-HG-B	3-shot triangle pattern	3	Controlled ambient	18	3
	2-shot pattern	3	Controlled ambient		
	Unsupported edge shot	3	Controlled ambient		
UL-HG-C	3-shot triangle pattern	3	Controlled ambient	18	3
	2-shot pattern	3	Controlled ambient		
	Unsupported edge shot	3	Controlled ambient		
UL-RF-A	Single shot	3	Controlled ambient	6	3
	Unsupported edge shot	3	Controlled ambient		
UL-RF-B	Single shot	3	Controlled ambient	6	3
	Unsupported edge shot	3	Controlled ambient		
UL-RF-C	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-D	5-shot dice pattern	3	Controlled ambient	15	3
UL-HG-D	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-E	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-F	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-G	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-H	5-shot dice pattern	3	Controlled ambient	15	3
UL-RF-I	Single shot	3	Controlled ambient	6	3
	Unsupported edge shot	3	Controlled ambient		
UL-RF-J	Single shot	3	Controlled ambient	3	3
UL-SG-A (Supplemental Shotgun for UL-HG- A, UL-HG-B, and UL-HG-C)	2-shot pattern	3	Controlled ambient	18	3
	3-shot triangle pattern	3	Controlled ambient		
	Unsupported edge shot	3	Controlled ambient		
UL-SG-B (Supplemental Shotgun for UL-HG- A,	2-shot pattern	3	Controlled ambient	18	3
	3-shot triangle pattern	3	Controlled ambient		
	Unsupported edge shot	3	Controlled ambient		

Table 15.1 Continued on Next Page

Table 15.1 Continued

UL designation	Required shot patterns	Quantity of each shot pattern	Conditioning prior to ballistic testing	Minimum number of shots	Minimum number of samples
UL-HG-B, and UL-HG-C)					
UL-SG-A (Supplemental Shotgun for UL-RF-A and UL- RF-B)	3-shot triangle pattern	3	Controlled ambient	12	3
	Unsupported edge shot	3	Controlled ambient		
UL-SG-B (Supplemental Shotgun for UL-RF-A and UL- RF-B)	3-shot triangle pattern	3	Controlled ambient	12	3
	Unsupported edge shot	3	Controlled ambient		
NOTE: Refer to Annex C for comparison of the Legacy UL Levels to UL Designations.					

15.6.3 The shots should be distributed across the test samples.

15.6.4 The manufacturer has the option to choose from (a) or (b) below:

a) A different test sample is used for each different shot pattern.

b) A single test sample is used for one or more shot patterns.

NOTE: For example, the manufacturer may choose to have a single 12 by 12 inch test sample subjected to an unsupported edge shot and a 3-shot triangle pattern (or another combination of shot patterns). The manufacturer assumes the risk for choosing to place multiple shot patterns on a single test sample.

15.6.5 Ballistic testing shall be completed on the test samples within 30 minutes of removal from conditioning.

15.6.6 If ballistic testing cannot be completed within 30 minutes and the test sample has been out of conditioning for 1 hour or less, recondition the test sample for a minimum of 1 hour before continuing ballistic testing. If the test sample has been out of the conditioning chamber for more than 1 hour, recondition the test sample for at least 3 hours before continuing ballistic testing.

15.7 Required conditioning and testing for outdoor use materials (excluding steel) and assemblies

15.7.1 Outdoor use materials and assemblies (excluding steel) shall be conditioned and tested as shown in Table 15.2.

15.7.2 The minimum number of shots required in Table 15.2 does not include necessary weak point shots.

Table 15.2
Conditioning and Testing for Outdoor Use Materials (Excluding Steel) and Assemblies

UL designation	Required shot patterns	Quantity of each shot pattern	Conditioning prior to ballistic testing	Minimum number of shots	Minimum number of samples
UL-HG-A	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	24	4
	2-shot pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-HG-B	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	24	4
	2-shot pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-HG-C	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	24	4
	2-shot pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-RF-A	Single shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	8	4
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-RF-B	Single shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	8	4
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		

Table 15.2 Continued on Next Page

Table 15.2 Continued

UL designation	Required shot patterns	Quantity of each shot pattern	Conditioning prior to ballistic testing	Minimum number of shots	Minimum number of samples
UL-RF-C	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-D	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-HG-D	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-E	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-F	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-G	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-H	5-shot dice pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	20	4
UL-RF-I	Single shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	8	4
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-RF-J	Single shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	4	4
UL-SG-A (Supplemental Shotgun for UL- HG-A, UL-HG-B, and UL-HG- C)	2-shot pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	24	4
	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		

Table 15.2 Continued on Next Page

Table 15.2 Continued

UL designation	Required shot patterns	Quantity of each shot pattern	Conditioning prior to ballistic testing	Minimum number of shots	Minimum number of samples
UL-SG-B (Supplemental Shotgun for UL- HG-A, UL-HG-B, and UL-HG- C)	2-shot pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	24	4
	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-SG-A (Supplemental Shotgun for UL-RF-A and UL-RF-B)	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	16	4
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
UL-SG-B (Supplemental Shotgun for UL-RF-A and UL-RF-B)	3-shot triangle pattern	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature	16	4
	Unsupported edge shot	4 (1 per condition)	(1) Heated Strike Face (2) Cooled Strike Face (3) High Temperature (4) Low Temperature		
NOTE: Refer to Annex C for comparison of the Legacy UL Levels to UL Designations.					

15.7.3 The shots should be distributed across the test samples.

15.7.4 The manufacturer has the option to choose from the following:

a) A different test sample is used for each different condition.

b) A single test sample is subjected to one or more conditioning procedures, given that the minimum number of test samples required in Table 15.2 is met.

c) A different test sample is used for each different shot pattern.

d) A single test sample is used for one or more shot patterns.

NOTE: For example, the manufacturer may choose to have a single 12 inch by 12 inch test sample subjected to an unsupported edge shot and a 3-shot triangle pattern or another combination of shot patterns. The manufacturer assumes the risk for choosing to place multiple shot patterns on a single test sample.

15.7.5 Ballistic testing shall be completed on the test samples within 30 minutes of removal from conditioning.

15.8 Required conditioning and testing for assemblies

15.8.1 General

15.8.1.1 The materials of the assembly shall be subjected to the appropriate materials testing in either 15.6 or 15.7 prior to testing the complete assembly.

15.8.1.2 Each dissimilar material of the assembly shall be subjected to a minimum of 3 shots, per dissimilar area.

15.8.1.3 In the case of a dissimilar material cannot take more than one shot, the manufacturer shall submit additional test samples (reference 12.3 or 13.3 as applicable) that are representative of the dissimilar material for tests.

15.8.1.4 Assembly test samples shall be exposed to controlled ambient conditioning prior to ballistic testing.

15.8.1.5 Test samples of an assembly designated as UL-HG-A, UL-HG-B, UL-HG-C, UL-RF-A, UL-RF B, UL-RF-I, or UL-RF-J, shall have a single shot placed in the area of locking cylinders, door-operating mechanisms, and the like.

15.8.1.6 Test samples of an assembly designated as UL-HG-D, UL-RF-C, UL-RF-D, UL-RF-E, UL-RF-F, UL-RF-G, or UL-RF-H shall have two shots placed in the area of locking cylinders, door-operating mechanisms, and the like.

15.8.2 Assembly weak point shots

15.8.2.1 A list of common types of potential weak points and shot placement with respect to weak points is provided in Table 15.3.

Table 15.3
Common Types of Potential Weak Points and Respective Shot Requirements

Example weak points	Shot placement with respect to weak points
Windows inside doors or other ballistic panels	Interface [gap] between transparent and nontransparent portions
Hardware, including hinges, fasteners, handles, locking cylinders, door-operating mechanisms	45 ±6 mm [1.75 ±0.25 in.]
Joints, seams, welds, or bends forming a corner	0 +6 mm [0 +0.25 in.] of midpoint
Mullions	Center shot on mullion
Cutouts or holes	45 ±6 mm [1.75 ±0.25 in.]
Edges; if corners are present, at least one edge shot shall be taken at the corner midpoint; perimeter corners shall take precedence over cutout corners	45 ±6 mm [1.75 ±0.25 in.]

15.8.2.2 Using the designated ammunition, at least 3 shots shall be placed at potential weak points on the assembly that are considered most likely to allow penetration of the projectile, fragments of the projectile, or fragments of the assembly. More than one test sample will be required if 3 shots will not fit on a single test sample.

15.8.2.3 Perceived weak point shots shall be taken at 0°.

Exception: The testing laboratory, in coordination with the test sponsor, may decides to shoot perceived weak points at an angle other than 0° if when the likelihood of penetration is greater for an angled shot.

15.8.3 Shots on assemblies that open and close

15.8.3.1 Test samples of an assembly that is opened and closed as part of its intended operation shall have the test shots fired at the ballistic material with the assembly fully closed and fully opened as designated by the manufacturer. If a partially opened condition will create a greater possibility of penetration, the assembly shall be tested with a partially open position.

Exception No. 1: A gunport, door, or window assembly shall not to be subjected to a ballistics test while in the open position.

Exception No. 2: Package passers shall be tested twice:

a) With one door open and the other closed; and

b) With doors in opposite positions.

15.8.4 Shotgun Tests of Assemblies

15.8.4.1 All fixed or movable package passers, speaking apertures, and similar devices, shall be tested, and the shotgun pellets shall not penetrate the assembly.

15.8.4.2 The assembly is to be mounted as described in 15.2.2 and a single shot from a No. 20 gauge shotgun using UL-SG-B is to be fired into the assembly from a distance of approximately 15 feet (4.6 m) at a location determined most likely to allow passage of the shotgun pellets through the assembly.

CONSTRUCTION – GENERAL

16 Enclosures

16.1 General

16.1.1 The frame and enclosure of a product shall be sufficiently strong and rigid to resist total or partial collapse with the attendant reduction of spacings, loosening or displacement of parts, and development of other conditions that impair operation of the product or increase the risk of fire, electric shock, or injury to persons. See Mechanical Strength Tests for Enclosures, Section 50.

16.1.2 Electrical parts of a product shall be located or enclosed to provide protection against unintentional contact with uninsulated high-voltage live parts.

16.1.3 An operating part, such as a gear mechanism, light-duty relay, or similar device, shall be enclosed to protect against malfunction from dust or other foreign material that may impair its intended operation.

16.1.4 The mounting means of an enclosure shall be accessible without disassembly of any operating part of the product. Removal of a completely assembled panel to mount the enclosure is not considered to be disassembly of an operating part.

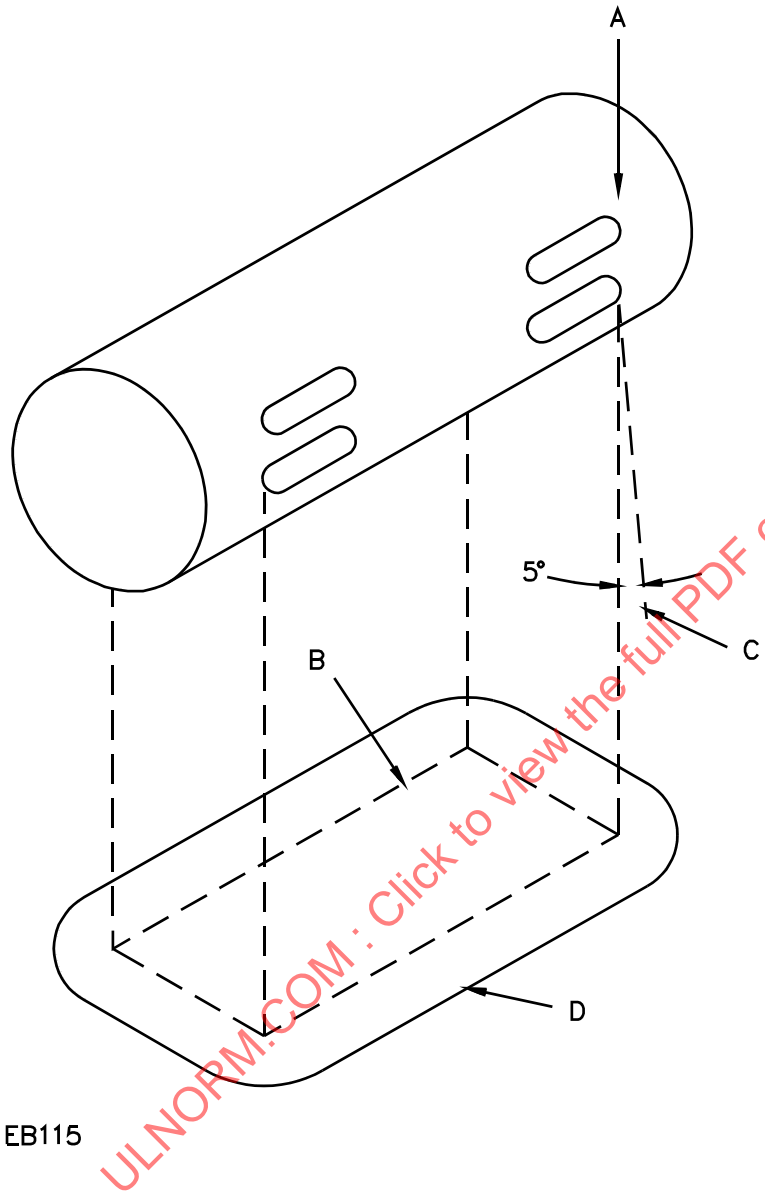
16.1.5 An enclosure shall be constructed to reduce the risk of fire from emission of flame, molten metal, flaming or glowing particles, or flaming drops. See Abnormal Operation Test, Section 44; Solenoid Burnout Test, Section 45; and Ignition Through Bottom-Panel Openings Tests, Section 49.

16.1.6 A nonflammable bottom in accordance with 16.2.4, or a protective barrier as described in Figure 16.1, shall be used under all areas containing flammable materials.

Exception: A nonflammable bottom or protective barrier need not be provided under a material or assembly classified V-1 or less flammable in accordance with UL 94.

Figure 16.1

Protective Pan



A. The entire component under which a barrier (flat or dish with or without a lip or other raised edge) of noncombustible material is required to be provided. The sketch above is of a metal enclosed component with ventilating openings to show that the protective barrier is required only for those openings from which flaming parts might come. If the component or assembly does not have its own noncombustible enclosure, the area to be protected would be the entire area occupied by the component or assembly.

B. Outline of the area of the component (A) for which a bottom barrier is required, projected vertically downward onto the horizontal plane of the lowest point on the outer edge (D) of the barrier.

C. Inclined line that traces out an area (D) on the horizontal plane of the barrier. Moving around the perimeter of the area for which a bottom barrier is required (B), this line projects at a 5° angle from the line extending vertically at every point around the perimeter of (A) and oriented to trace out the largest area, except that the angle may be less than 5° if the barrier or portion of the bottom cover contacts a vertical barrier or side panel of noncombustible material, or if the horizontal extension of the barrier (B) to (D) would exceed 6 inches (150 mm).

D. Minimum outline of the barrier, except that the extension B – D need not exceed 6 inches (150 mm) (flat or dished with or without lip or other raised edge). The bottom of the barrier may be flat or formed in any manner if every point of area (D) is at or below the lowest point on the outer edge of the barrier.

16.1.7 A construction employing individual barriers under components, groups of components or assemblies, as specified in Figure 16.1, is considered to comply with the requirement in 16.1.6.

16.2 Openings

16.2.1 An opening directly over uninsulated high-voltage live parts shall not exceed 0.187 inch (4.75 mm) in any dimension unless the configuration is such that direct entry to uninsulated high-voltage live parts is prevented. See Figure 16.2 for examples of top cover designs and Figure 16.3 for side openings that are considered to prevent direct entry. See also 16.2.2.

Figure 16.2

Cross Sections of Top Cover Designs

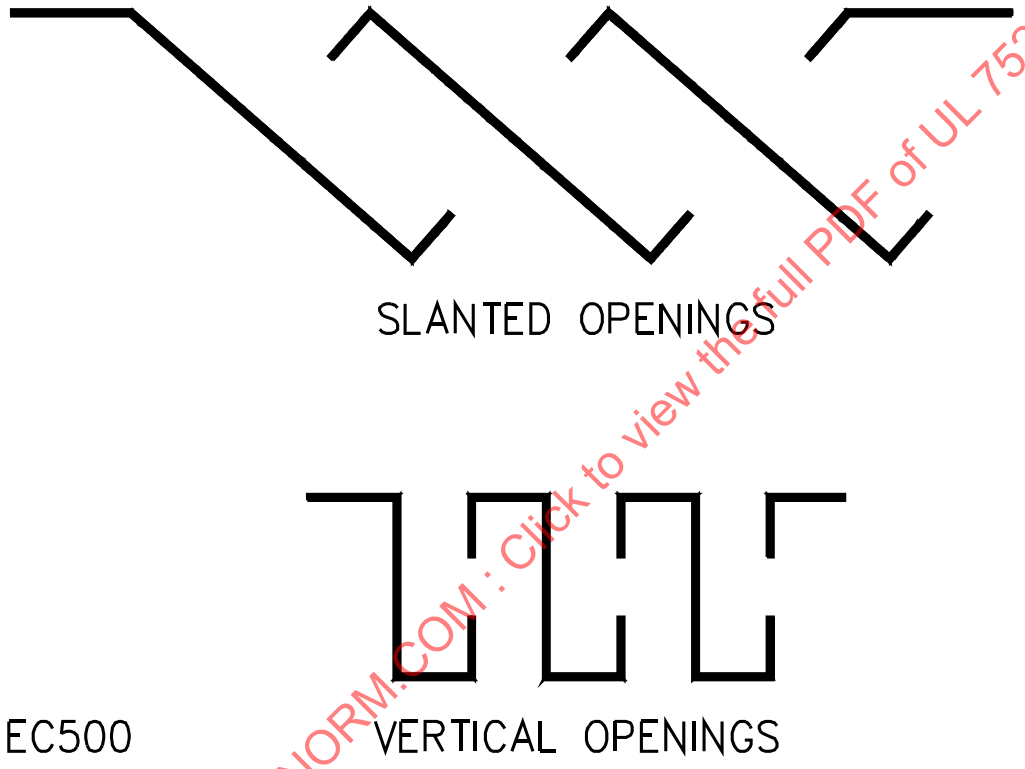
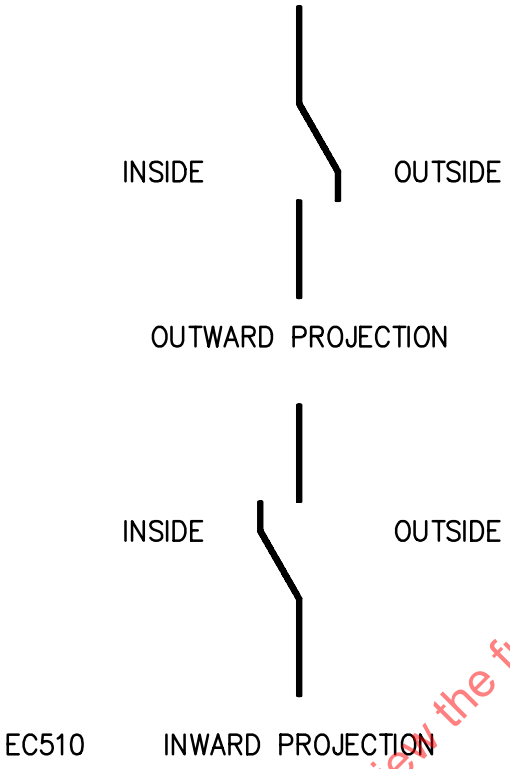


Figure 16.3

Louver Designs

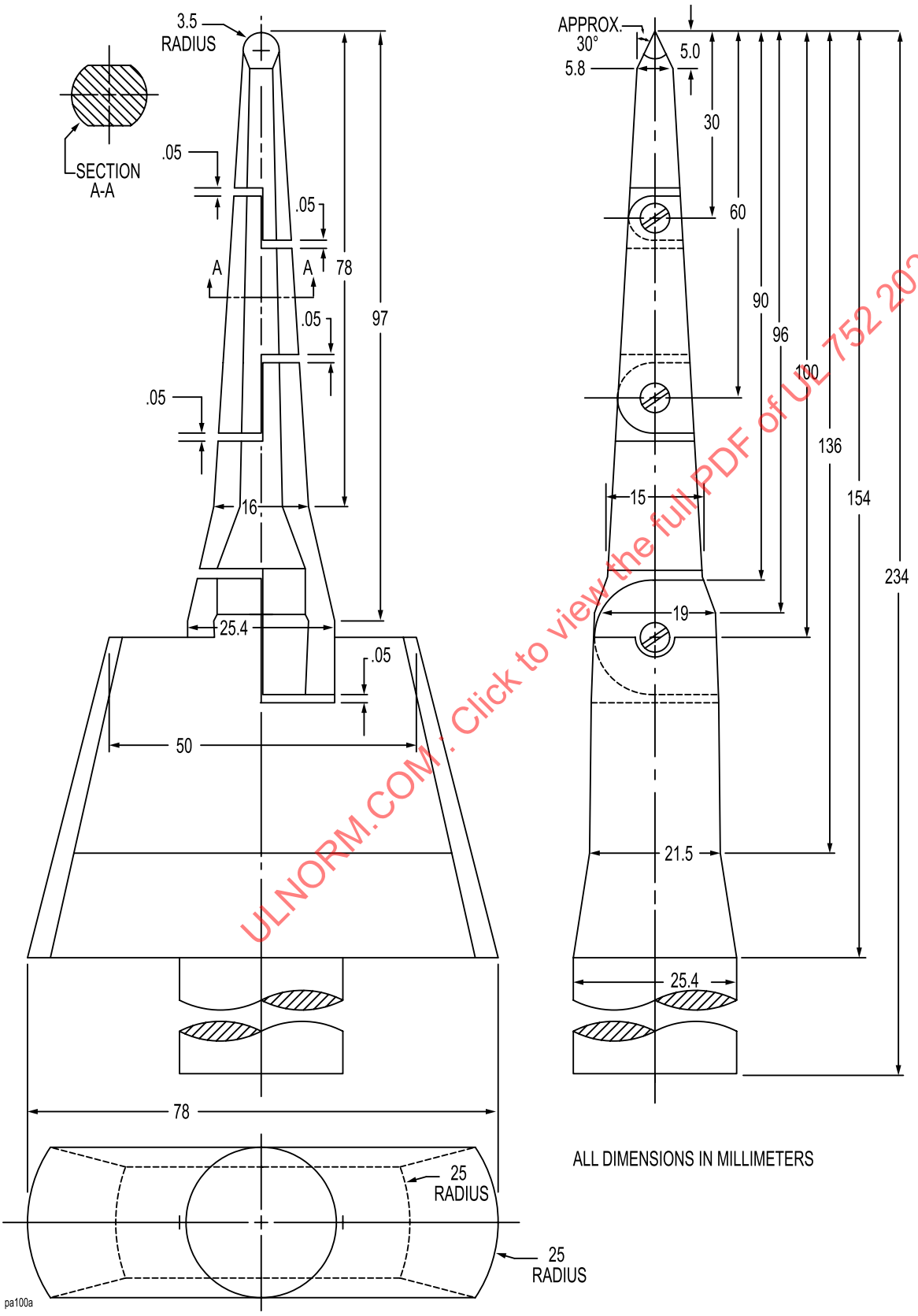


16.2.2 An opening shall not permit entrance of a 1-inch (25.4-mm) diameter rod and shall be sized and arranged so that a probe, as illustrated in Figure 16.4, cannot be made to contact any uninsulated live electrical part (other than low-voltage) when inserted through the opening in a straight or articulated position. The probe may also be inserted into any opening that is created during the normal operating cycle of the product.

Exception: An opening may permit entrance of a 1-inch diameter rod under the conditions specified in 16.2.3.

Figure 16.4

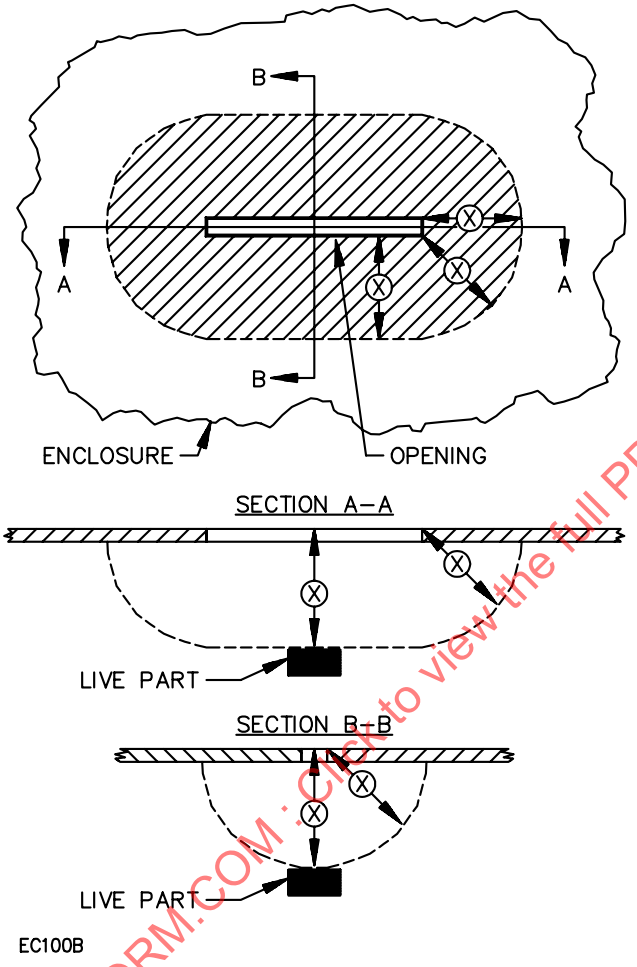
Articulate Probe



16.2.3 An opening that permits entrance of a 1-inch (25.4-mm) diameter rod may be used under the conditions described in Figure 16.5.

Figure 16.5

Opening in Enclosure

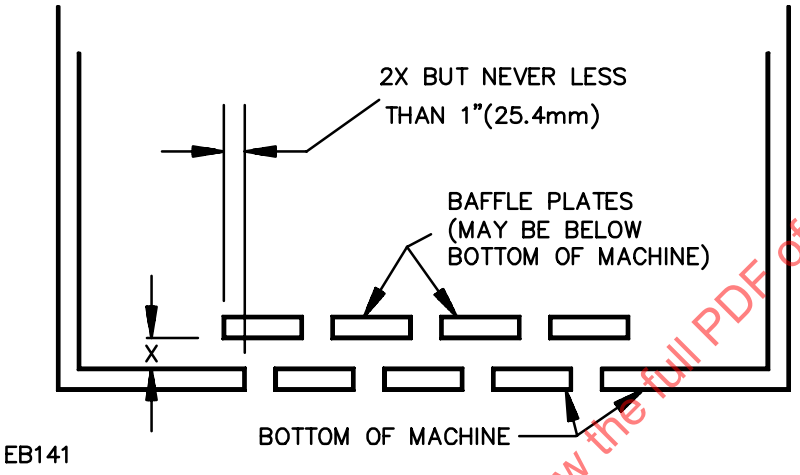


NOTE – The opening is to be used when, within the enclosure, there is no uninsulated live metal part or film-coated wire less than X inches (mm) from the perimeter of the opening, as well as within the volume generated by projecting the perimeter X inches (mm) normal to its plane. X equals five times the diameter of the largest diameter rod that is capable of being inserted through the opening, and not less than 6-1/16 inches (154 mm).

16.2.4 Openings may be provided in the bottom panels or protective pans under areas containing materials not classified at least V-1 in accordance with UL 94, if constructed in a manner that prevents materials from falling directly from the interior of the product. Figure 16.6 illustrates a type of baffle that meets this requirement. A second construction is a 0.040-inch (1.02-mm) thick sheet steel bottom panel in which 5/64-inch (2.0-mm) maximum round holes are spaced not closer than 1/8 inch (3.2 mm) center to center. Other constructions may be used if they comply with the requirements of the Ignition Through Bottom-Panel Openings Tests, Section 49.

Figure 16.6

Baffle



16.2.5 Openings in the bottom of the enclosure under areas containing only materials classified at least V-1 shall not be larger than 1/16 square inch (40.3 mm^2).

16.2.6 Openings may be used without limitation of the size or number of openings in areas:

a) Containing only PVC, TFE, CTFE, FEP, and neoprene-insulated wire cable;

b) Containing plugs and receptacles; and

c) Underneath impedance- or thermally-protected motors.

16.3 Cast metal

16.3.1 The thickness of cast metal for an enclosure shall be as indicated in Table 16.1.

Exception: Cast metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, it provides equivalent mechanical strength. See Mechanical Strength Tests for Enclosures, Section 50.

Table 16.1
Cast-Metal Enclosures

Use, or dimensions of area involved[a]	Minimum thickness			
	Die-cast metal		Cast metal of other than the die-cast type	
	inch	(mm)	inch	(mm)
Area of 24 square inches (155 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)

[a] The area limitation for metal 1/16 inch (1.6 mm) thick may be obtained by the provision of reinforcing ribs subdividing a larger area.

16.4 Sheet metal

16.4.1 The thickness of sheet metal used for the enclosure of a product shall not be less than that indicated in Table 16.2 or Table 16.3, whichever applies.

Exception: Sheet metal of lesser thickness may be used if, consideration being given to the shape, size, and function of the enclosure, it provides equivalent mechanical strength. See Mechanical Strength Tests for Enclosures, Section 50.

Table 16.2
Minimum thickness of sheet metal for electrical enclosures carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness in inches (mm)			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated [MSG]		Metal coated [GSG]	
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)				
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020	(0.51)	0.023	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)	[24]		[24]	
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026	(0.66)	0.029	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)	[22]		[22]	
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)	[20]		[20]	
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)	[18]		[18]	
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)	[16]		[16]	
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)	[15]		[15]	
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)	[14]		[14]	
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)

Table 16.2 Continued on Next Page

Table 16.2 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness in inches (mm)	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated [MSG]	Metal coated [GSG]
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)		
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)	[13]	[13]
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093 (2.36)	0.097 (2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)	[12]	[12]
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108 (2.74)	0.111 (2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)	[11]	[11]
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123 (3.12)	0.126 (3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)	[10]	[10]

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) A single sheet with single formed flanges (formed edges),

2) A single sheet which is corrugated or ribbed, and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

Table 16.3
Minimum thickness of sheet metal for electrical enclosures aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited			
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)	0.023	(0.58)
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited			
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)	0.029	(0.74)
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited			
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)	0.036	(0.91)
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited			
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	0.045	(1.14)
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited			
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	0.058	(1.47)
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited			
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)	0.075	(1.91)
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited			

Table 16.3 Continued on Next Page

Table 16.3 Continued

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

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and which has sufficient torsional rigidity to resist the bending moments which may be applied via the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure which is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

1) A single sheet with single formed flanges (formed edges),

2) A single sheet which is corrugated or ribbed, and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

[b] The width is the smaller dimension of a rectangular sheet metal piece which is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

16.4.2 The thickness of a sheet metal member to which a wiring system is to be connected in the field shall be at least:

a) 0.032 inch (0.81 mm) if of uncoated steel,

b) 0.034 inch (0.86 mm) if of galvanized steel, and

c) 0.045 inch (1.14 mm) if of nonferrous metal.

16.5 Nonmetallic

16.5.1 Nonmetallic material used for an enclosure shall be evaluated in accordance with 16.5.2 and shall have a wall thickness of not less than 1/16 inch (1.6 mm).

16.5.2 Among the factors taken into consideration when judging the acceptability of a nonmetallic enclosure are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Flammability 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 may be subjected.

All these factors are considered with regard to aging in accordance with the requirements in the Polymeric Materials Test, Section 47. See Mechanical Strength Tests for Enclosures, Section 50.

16.5.3 Perforated sheet steel and sheet steel used for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) thick [0.045 inch (1.17 mm) if zinc coated] if the mesh openings or perforations are 1/2 square inch (161 mm^2) or less in area, and shall not be less than 0.080 inch (2.03 mm) thick [0.084 inch (2.13 mm) if zinc coated] for larger openings. The largest dimension shall not exceed 4 inches (102 mm).

Exception: If the indentation of a guard or the enclosure will not alter the clearance between uninsulated live parts and grounded metal so as to impair performance or reduce spacings below the minimum required values (see Spacings, Section 28), 0.020 inch (0.51 mm) expanded steel mesh or perforated sheet steel [0.023 inch (0.58 mm) if zinc coated] may be used if the exposed mesh on any one side or surface of the product so protected has an area of not more than 72 square inches (464 cm^2) and has no dimension greater than 12 inches (305 mm), or the width of an opening so protected is not greater than 3-1/2 inches (89 mm).

16.5.4 The wires of a screen shall not be less than 16 AWG (1.3 mm^2) steel if the screen openings are 1/2 square inch (161 mm^2) or less in area, and not less than 14 AWG (2.1 mm^2) steel for larger screen openings.

17 Accessibility of Live or Moving Parts

17.1 Electric shock

17.1.1 Any part that is exposed only during operator servicing shall not present the risk of electric shock. See Electric Shock Current Test, Section 38.

17.2 General

17.2.1 The uninsulated live parts and hazardous moving parts of a product shall be located or enclosed so that protection is provided against the risk of fire, electric shock, and injury to persons from unintentional contact with the parts. Insulated brush caps do not require an additional enclosure.

17.2.2 Devices employing glass envelopes, such as electron tubes, glass-enclosed relays, and the like, shall be enclosed or protected against mechanical damage.

17.2.3 Fan blades, blower wheels, pulleys, belts, and the like shall be enclosed or guarded so as to reduce the risk of injury to persons.

17.2.4 An interlocking mechanism that operates to disconnect power to a motor when a cover or panel is removed or opened for access to moving parts is considered to comply with 17.2.3.

17.2.5 The degree of protection required in 17.2.3 depends upon the general construction and the intended use of the product. The location where the product ordinarily will be used is considered when evaluating the degree of exposure of mechanical parts. Other factors taken into consideration in evaluating the acceptability of exposed moving parts are:

a) The degree of exposure;

b) The sharpness of the moving parts;

c) The likelihood of unintentional contact with the hazardous moving parts;

d) The speed of movement of those parts; and

e) The likelihood of fingers, arms, or clothing being drawn into the moving parts, such as at points where belts travel onto a pulley or where moving parts close in a pinching or shearing action.

17.2.6 Where the starting or restarting of a motor driving a moving part such as described in 17.2.3 is provided by an automatic cycling device, such as an overcurrent device or thermal protector, the requirement of 17.2.3 will necessitate the use of a guard if the part is exposed when making operating adjustments or changing replaceable parts, or if the part is accessible without requiring the use of tools.

17.2.7 With reference to 17.2.6, the scroll of a centrifugal blower may be used as a guard for the blower wheel.

17.2.8 If any part of the external enclosure of a product must be removed for operator servicing, that part shall be removed before the product is examined in connection with the requirement in 17.2.1.

17.2.9 Thumbscrews; finger latches; screwdriver-, wrench-, and coin-operated latches; magnetic and spring latches that cannot be unintentionally bumped open; and similar parts that hold or support a door, cover, or panel may be used for securing doors, covers, and panels that are not opened or removed for operator servicing if supplementary guards, or the like, are provided as described in 56.1 – 56.3.

17.2.10 Panels as described in 17.2.9 are not to be opened or removed for the application of the probe mentioned in 16.2.2 in connection with the investigation of the accessibility of live or hazardous moving parts. See also 17.2.7.

17.3 Interlocks and protective devices

17.3.1 An interlock provided for the purpose of protecting an operator or serviceman against electric shock or injury to persons shall be of a type or in such a location that it requires an intentional operation to bypass.

17.3.2 The bypass means shall be such that the interlock is self-restoring as the unit is returned to its intended operation.

17.3.3 A protective device provided to remove a stored-energy charge from an internal circuit shall operate automatically when the circuit is de-energized.

17.4 Covers

17.4.1 An enclosure cover shall be hinged, sliding, pivoted, or similarly attached so as to prevent its being removed if:

a) It gives access to fuses or any other overcurrent protective device, the intended functioning of which requires renewal or

b) It is necessary to open the cover in connection with the intended operation of the product.

17.4.2 If the fuse(s) enclosed is intended to provide protection to portions of internal circuits, such as may be used on a separate printed-wiring board or circuit subassembly to prevent excessive circuit damage resulting from a fault, a hinged cover is not required. The word "CAUTION" and the following or equivalent marking shall be indicated on the cover if the risk of electric shock is present: "Circuit Fuse(s) – Disconnect Power Prior To Servicing."

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

18 Mechanical Assembly

18.1 All components of a product shall be securely mounted in position and prevented from turning or loosening if such motion may reduce electrical spacings or affect the performance of the product. See 18.4 for further specifications.

18.2 A switch (other than a through-cord switch), a lampholder, an attachment-plug receptacle, a motor-attachment plug, or similar component shall be mounted securely and, except as noted in 18.5 (a) and (b), shall be prevented from turning. See 18.6 for further specifications.

18.3 Uninsulated live parts, including terminals, shall be secured to their supporting surfaces by methods other than friction between surfaces so that they will be prevented from turning or shifting in position if such motion may result in reduction of spacings to less than those required. See Spacings, Section 28.

18.4 Friction between surfaces shall not be the sole means of preventing a device from turning in its mounting. A small stem-mounted switch or other device having a single hole mounting may be prevented from turning with the use of a lock washer having both spring take-up and an interference lock.

18.5 The requirement that a switch be prevented from turning may be waived if all four 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 intended operation of the switch).

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

c) The spacings are not reduced below the minimum required values if the switch rotates.

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

18.6 A lampholder of the type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel, need not be prevented from turning if rotation cannot reduce spacings below the minimum required values.

19 Protection Against Corrosion

19.1 Iron and steel parts, other than bearings and the like, where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other equivalent means.

19.2 The requirement of 19.1 applies to all enclosures of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend. Bearing surfaces shall be of such materials and construction as to resist binding due to corrosion.

Exception No. 1: This requirement does not apply to parts, such as washers, screws, bolts, and the like, if impaired operation of such unprotected parts would not be likely to result in a risk of fire, electric shock, or unintentional contact with a moving part that can cause risk of injury to persons or impair the operation of the unit.

Exception No. 2: Parts made of stainless steel, polished or treated, if necessary, do not require additional protection against corrosion.

19.3 Metal shall be used in combinations that are galvanically compatible.

Exception: This requirement does not apply if galvanic action does not result in improper operation of the product, risk of fire, electric shock, or unintentional contact with moving parts that can cause risk of injury to persons.

19.4 Cabinets and enclosures of corrosion-resistant material may be used without special corrosion protection.

20 Field Wiring Connections

20.1 General

20.1.1 Wiring terminals or leads shall be provided for connection of conductors of at least the size required by NFPA 70.

20.2 Field wiring compartment

20.2.1 The field wiring compartment to which connections are to be made shall be of the intended size for completing all wiring connections as specified by the installation wiring diagram.

20.2.2 Internal components in the wiring area and wire insulation shall be protected from sharp edges by insulating or metal barriers having smooth, rounded edges or by the word "CAUTION" and the following or equivalent instructions located in the wiring area: "When Making Installation, Route Field Wiring Away From Sharp Projections, Corners And Internal Components."

20.3 Permanently-connected equipment

20.3.1 A product intended for permanent installation shall have provision for connection of metal-clad cable or conduit, or a nonmetallic-enclosed wiring system, such as nonmetallic sheathed cable.

Exception: An enclosure without provision for the connection of metal-clad cable, conduit, or a nonmetallic-enclosed wiring system, may be used if specific instructions are furnished indicating the section(s) of the product intended to be drilled in the field for the connection(s).

20.4 Terminals (general application)

20.4.1 As used in these requirements, field-wiring terminals are those terminals to which power supply (including equipment grounding) or control connections will be made in the field when the product is installed.

20.4.2 A field-wiring terminal shall comply with the requirements in:

a) UL 486A-486B; or

b) UL 486E; or

c) The field-wiring requirements (Code 2) in UL 1059; or

d) The field-wiring requirements in UL 310; or

e) 20.4.4 – 20.4.8.

The current-carrying parts shall be silver, copper, copper alloy, or a similar nonferrous conductive material. Securing screws and the like may be plated steel. Equipment provided with quick-connect terminals intended for field termination of electrical conductors to the equipment and complying with UL 310 shall be provided with strain relief and the installation instructions shall include instructions for effecting the strain relief and include reference to the specific connectors to be used.

20.4.3 A field-wiring terminal shall be prevented from turning or shifting in position. This may be accomplished by means such as:

a) Two screws or rivets;

b) Square shoulders or mortises;

c) A dowel pin, lug, or offset; or

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

Friction between surfaces shall not be used for preventing movement of the terminals.

20.4.4 Nonferrous soldering lugs or solderless (pressure) wire connectors shall be used for 8 AWG (8.4 mm^2) and larger wires. If the connectors or lugs are secured to a plate, the plate thickness shall not be less than 0.050 inch (1.27 mm). Securing screws may be plated steel.

20.4.5 A wire binding screw intended for connection of the power supply (line voltage) source shall not be smaller than No. 10 (4.8 mm diameter). The screw may be of plated steel.

Exception: A No. 8 (4.2 mm diameter) screw may be used for the connection of one 14 AWG (2.1 mm^2) conductor and a No. 6 (3.5 mm diameter) screw may be used for the connection of a 16 AWG (1.3 mm^2) or 18 AWG (0.82 mm^2) conductor.

20.4.6 For connection of other than power supply (line voltage) circuits using 10 AWG (5.3 mm^2) and smaller wires, a wire binding screw shall not be smaller than No. 8 (4.2 mm diameter).

Exception: A No. 6 (3.5 mm diameter) screw may be used for the connection of a 14 AWG (2.1 mm^2) or smaller conductor and a No. 4 (2.8 mm diameter) screw may be used for a 19 AWG (0.65 mm^2) or smaller conductor.

20.4.7 Terminal plates tapped for wire binding screws shall:

a) Have not less than two full threads in the metal (the terminal plate metal may be extruded to provide the two full threads) and shall have upturned lugs, clamps, or the equivalent, to hold the wires in position. Other constructions may be used if they are determined to provide equivalent thread security of the wire binding screw.

b) Be of a nonferrous metal not less than 0.050 inch (1.27 mm) thick for a No. 8 (4.2 mm diameter) or larger screw, and not less than 0.030 inch (0.76 mm) thick for a No. 6 (3.5 mm diameter) or smaller screw.

20.4.8 If two or more conductors are intended to be connected by wrapping under the same screw, a nonferrous intervening metal washer shall be used for each additional conductor. A separator washer is not required if two conductors are separated and intended to be secured under a common clamping plate. If the wires protrude above terminal barriers, the nonferrous separator shall include means, such as upturned tabs or sides, to retain the wire.

20.5 Terminals (qualified application)

20.5.1 Any of the following terminal configurations may be used for connection of field wiring provided all of the conditions in 20.5.2 are met (see Tests on Special Terminal Assemblies, Section 51):

a) Telephone Type Terminals – Nonferrous terminal plates using a narrow V-shaped slot for securing of a conductor in a special post design. Requires special tool for wire connection.

b) Solderless Wrapped Terminals – Solderless wrapped nonferrous terminals which require a special tool and terminal post design.

c) Quick-Connect Terminals – Nonferrous quick-connect (push type) terminals consisting of male posts permanently secured to the device and provided with compatible female connectors for connection to field wiring. Requires special tool for crimping of field wires. Mating terminals shall be shipped with the product with instructions for their installation.

d) Push-In Terminals – Nonferrous (screwless) push-in terminals of the type used on some switches and receptacles. Solid conductors are pushed into slots containing spring-type contacts. The leads can be removed by means of a tool inserted to relieve the spring tension of the conductor. Push-in terminals shall not be used with aluminum conductors. The marking adjacent to the terminal shall indicate that copper conductors only are to be used.

e) Solder Terminals – Conventional nonferrous solder terminals.

f) Other Terminals – Other terminal connections may be used if determined to be equivalent to (a) – (e) and limited to the same restrictions.

Exception: Terminals complying with the requirements in any of the standards specified in 20.4.2 are not required to be subjected to Tests on Special Terminal Assemblies, Section 51.

20.5.2 If any of the terminal configurations described in 20.5.1 are used for connection of field-wiring all of the following conditions shall be met:

a) If a special tool is required for connection, its use shall be indicated on the installation wiring diagram by name of manufacturer and model number, or equivalent, along with information as to where the tool may be obtained.

b) The range of wire sizes shall be indicated on the installation wiring diagram. See 20.1.1.

c) The wire size to be used shall have the ampacity of the circuit application.

d) If a lead is to be disconnected for testing or routine servicing it shall comply with the requirements of 51.2.

20.6 Leads

20.6.1 Leads provided in lieu of wiring terminals shall be at least 6 inches (152 mm) long.

Exception: The lead may be less than 6 inches (152 mm) long if it is evident that the use of a longer lead may result in damage to the lead insulation or product, or result in a risk of fire, injury to persons, or electric shock, or is not required for the intended operation of the product.

20.7 Polarity identification

20.7.1 In a product intended to be connected to a grounded circuit, one terminal or lead shall be identified for the connection of the grounded conductor. The identified terminal or lead shall be the one

which is connected to the screw shells of lampholders and to which no primary overcurrent-protective devices or other switching devices of the single-pole type are connected.

20.7.2 A terminal intended for the connection of a grounded supply conductor shall be composed of or plated with metal that is substantially white in color and shall be distinguishable from the other terminals; or identification of the terminal shall be clearly shown in some other manner, such as on an attached wiring diagram. A lead intended for the connection of a grounded power-supply conductor shall be finished to show a white or gray color and shall be distinguishable from the other leads.

20.8 Cord-connected equipment

20.8.1 Equipment requiring cord connections to facilitate use or disconnection for maintenance and repair is capable of being provided with a flexible cord and attachment plug for connection to the supply source.

20.8.2 The type of cord and plug used for the connection shall be intended for the maximum current and voltage to which the product is subjected in service. The flexible cord shall be Type SE, SEO, SJ, SJE, SJEO, SJO, SJT, SJTO, S, SO, ST, or STO and not less than 6 feet (1.8 m) in length.

Exception: The cord is not prohibited from being less than 6 feet when use of the longer cord is capable of resulting in electric shock, a risk of fire, or unintended operation of the product, or is not required for the intended operation of the product.

20.8.3 The cord shall be provided with strain relief means so that a stress on the cord is not transmitted to terminals, splices, or internal wiring. See Strain Relief Test, Section 48.

20.8.4 When a knot in a flexible cord serves as strain relief, a surface against which the knot bears or with which it comes into contact shall be free from projections, sharp edges, burrs, fins, and the like, which are capable of abrading the insulation on the conductors.

20.8.5 Clamps of any material (metal or otherwise) are not to be used on cords and supply leads without varnished-cloth insulating tubing or the equivalent under the clamp unless it is evaluated that the tubing or the equivalent is not required to prevent the clamp from damaging the cord or supply leads.

20.8.6 Means shall be provided to prevent the supply cord or supply leads from being pushed into the unit through the cord-entry hole when such displacement subjects the cord or supply leads to mechanical damage or to exposure to a temperature higher than that for which the cord or supply leads are intended, or reduces spacings (such as to a metal strain-relief clamp) below the minimum intended values or damages internal connections or components. See 48.3.1, 48.3.2, and Figure 48.1.

20.9 Bushings

20.9.1 At a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case, there shall be a bushing or the equivalent to provide a smooth, rounded surface against which the cord bears.

20.9.2 When the cord hole is of phenolic composition or other nonconducting material, or of metal more than 0.042 inch (1.07 mm) thick, a smooth, rounded surface is determined to be the equivalent of a bushing.

20.9.3 Ceramic materials and some molded compositions are capable of being used for insulating bushings.

20.9.4 Fiber may be used where it will not be subjected to a temperature higher than 90 °C (194 °F) under intended operating conditions if the bushing is not less than 3/64 inch (1.2 mm) thick and it will not be exposed to moisture.

20.9.5 A soft rubber bushing may be used in the frame of a motor if the bushing is not less than 3/64 inch (1.2 mm) thick and if the bushing is located so that it will not be exposed to oil, grease, oily vapor, or other substance which may have a deleterious effect on rubber. If a soft rubber bushing is used in a hole in metal, the hole shall be free from sharp edges, burrs, projections, and the like, which could cut into the rubber.

20.9.6 An insulating-metal grommet may be used in lieu of an insulating bushing if the insulating material used is not less than 1/32 inch (0.8 mm) thick and fills completely the space between the grommet and the metal in which it is mounted.

21 Internal Wiring

21.1 General

21.1.1 Internal wiring shall have thermoplastic or rubber insulation not less than 1/64 inch (0.4 mm) thick for 0 – 300 volts if:

a) Power is less than 375 VA;

b) Current is less than 5 amperes; and

c) The wiring is not subject to flexing or mechanical abuse.

Otherwise, thermoplastic or rubber insulation not less than 1/32 inch (0.8 mm) thick and rated 600 volts shall be used. Other insulating materials of lesser thickness may be used if determined to be equivalent.

21.1.2 Leads or a cable assembly connected to parts mounted on a hinged cover shall have a length that permits 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.

21.1.3 Insulation, such as coated fabric and extruded tubing, shall not be affected physically or electrically by the temperature or other environmental conditions to which it may be subjected in its intended use.

21.1.4 Wireways shall be smooth and entirely free from sharp edges, burrs, fins, moving parts, and the like which may cause abrasion of the conductor insulation. Holes in sheet metal walls through which insulated wires pass shall be provided with a bushing if the wall is not greater than 0.042 inch (1.07 mm) thick. Holes in walls more than 0.042 inch thick shall have smooth, rounded edges.

21.1.5 Each splice and connection shall be mechanically secure and bonded electrically.

21.1.6 Stranded conductors clamped under wire-binding screws or similar parts shall have the individual strands soldered together or equivalently arranged.

21.1.7 Each splice shall be provided with insulation equivalent to that of the wires involved.

21.1.8 A printed wiring assembly shall comply with UL 796.

21.1.9 A printed-wiring assembly employing insulating coatings or encapsulation shall be tested for dielectric withstand before and after being treated. If it is impractical to use untreated samples, finished samples shall be subjected to the Dielectric Voltage-Withstand Test, Section 42, after they are subjected to the Humidity Test, Section 36; Temperature Test, Section 43; and other applicable tests described in this standard.

21.2 Separation of circuits

21.2.1 Internal wiring of circuits which operate at different potentials shall be separated by barriers, clamps, routing, or other means determined to be equivalent, unless all conductors are provided with insulation which is rated for the highest potential involved. See 21.2.3.

21.2.2 A barrier used to provide separation between the wiring of different circuits shall be of metal or of insulating material. A barrier of insulating material shall be at least 0.028 inch (0.71 mm) thick. Any clearance between the edge of a barrier and a compartment wall shall not be more than 1/16 inch (1.6 mm).

21.2.3 When Class 2, Class 3, and power-limited fire protection circuit conductors are to occupy the same enclosure as electric light, power, Class 1, or nonpower-limited fire protection circuit conductors, both of the following conditions shall be met:

a) The enclosure shall provide a minimum of two conductor entry openings so that the Class 2, Class 3, and power-limited fire protection circuit conductors are segregated from electric light, power, Class 1 and nonpower-limited fire protection circuit conductors. The installation document shall completely detail the entry routing of all conductors into the enclosure.

b) The enclosure shall be constructed so that, with all field-installed wiring connected to the product, a minimum of 1/4 inch (6.4 mm) spacing is provided between all Class 2, Class 3, and power-limited fire protection circuit conductors, and all electric light, power, Class 1 and nonpower-limited fire protection circuit conductors. Compliance with this requirement is achieved by specific wire routing configurations detailed in the installation document. When a wire routing scheme does not maintain a separation of 1/4 inch (6.4 mm), barriers shall be used to provide separation.

Exception: The requirements in 21.2.3 (a) and (b) do not apply when all circuit conductors operate at 150 volts or less to ground and:

a) The Class 2, Class 3, and power-limited fire protection circuits are installed using CL3, CL3R, or CL3P, or substitute cable permitted by NFPA 70, and the Class 2, Class 3, and power-limited fire protection circuit conductors extending beyond the cable jacket are separated by a minimum of 1/4 inch, or by nonconductive tubing, or by a nonconductive barrier from all other conductors, or

b) The Class 2, Class 3, and power-limited fire protection circuit conductors are installed as a Class 1 or higher circuit.

22 Bonding for Grounding

22.1 All exposed dead metal parts of a product using high voltage that could become energized shall be bonded to the equipment grounding terminal connection. See Equipment Grounding Connection, Section 23.

22.2 Uninsulated dead metal parts of cabinets, electrical enclosures, motor frames and mounting brackets, controller mounting brackets, capacitors, and other electrical components shall be bonded for grounding if they may be contacted by the user or by a service person in servicing the equipment.

Exception No. 1: Adhesive-attached metal foil markings, screws, handles, and the like, which are located on the outside of enclosures or cabinets and isolated from electrical components or wiring by a grounded metal part so that they will not become energized, need not be bonded.

Exception No. 2: Isolated metal parts, such as motor controller magnet frames and armatures, small assembly screws, and the like, which are positively separated from wiring and insulated live metal parts need not be bonded.

Exception No. 3: Panels and covers which do not enclose uninsulated live parts need not be bonded if wiring is separated from the panel or cover so that it will not become energized.

Exception No. 4: Panels and covers need not be bonded if they are insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material, not less than 0.028 inch (0.71 mm) thick and secured in place.

22.3 A bonding means shall be an electrical conductor. If of ferrous metal, it shall be protected against corrosion by painting, plating, or the equivalent. The conductor shall be of an intended size. A separate bonding conductor shall be installed so that it is protected from mechanical damage.

22.4 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 materials.

22.5 A bolted or screwed connection that incorporates a star washer or serrations under the screwhead may be used for penetrating nonconductive coatings where required for compliance with 22.4.

22.6 If the bonding means depends upon screw threads, two or more screws, or two full threads of a single screw engaging metal, may be used to comply with 22.4.

22.7 Metal-to-metal hinge-bearing members for doors or covers may be used as a means for bonding the door or cover for grounding if a minimum of 2 pin-type hinges each with a minimum of 3 knuckles are used.

22.8 The size of a copper or aluminum conductor, used to bond an electrical enclosure or motor frame, shall be based on the rating of the branch-circuit overcurrent device by which the equipment will be protected. The size of the conductor shall be in accordance with Table 22.1, except the size of a bonding conductor of a component need not be larger than the conductors which supply power to the component.

Table 22.1
Bonding Wire Conductor Size

Rating of overcurrent device amperes	Size of bonding conductor[a]			
	Copper wire		Aluminum wire	
	AWG	(mm)[a]	AWG	(mm)[a]
15	14	(2.1)	12	(3.3)
20	12	(3.3)	10	(5.3)
30	10	(5.3)	8	(8.4)
40	10	(5.3)	8	(8.4)

Table 22.1 Continued on Next Page

Table 22.1 Continued

Rating of overcurrent device amperes	Size of bonding conductor[a]			
	Copper wire		Aluminum wire	
	AWG	(mm)[a]	AWG	(mm)[a]
60	10	(5.3)	8	(8.4)
100	8	(8.4)	6	(13.3)
200	6	(13.3)	4	(21.2)

[a] Or equivalent cross-sectional area.

22.9 A conductor, such as a clamp or strap, used in place of a separate wire conductor is acceptable if the minimum cross-sectional conducting area of the bonding means is not less than that of the wire indicated in Table 22.1.

22.10 Splices shall not be employed in wire connectors used for bonding.

23 Equipment Grounding Connection

23.1 The following are considered to constitute means for grounding.

a) In a product intended to be permanently connected by a metal-enclosed wiring system, a knockout or equivalent opening in the metal enclosure.

b) In a product intended to be connected by a nonmetal-enclosed wiring system, such as nonmetallic-sheathed cable or multiple-conductor cord, an equipment grounding terminal or lead.

23.2 On an equipment grounding terminal, a wire-binding screw intended for the connection of an equipment grounding conductor shall have a green-colored head that is hexagonal, slotted, or both.

23.3 A pressure wire connector intended for connection of an equipment grounding conductor shall be plainly marked "G," "GR," "GROUND," "GROUNDING," or the like, or by a marking on a wiring diagram provided on the unit. The wire-binding screw mentioned in 23.2 or pressure wire connector shall be secured to the frame or enclosure of the unit and shall be located so that it is unlikely to be removed during servicing of the unit.

23.4 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 shall be so identified.

23.5 If a multiple-conductor cord is employed, the insulation of the grounding conductor shall be green, with or without one or more yellow stripes. The grounding conductor shall be secured to the grounding terminal or lead at the enclosure and to the grounding blade or equivalent contacting member of an attachment plug. In no case shall a green-identified conductor of a cord be used as a circuit conductor. Ordinary solder alone shall not be used for securing the grounding conductor.

24 Electrical Components

24.1 Capacitors

24.1.1 A capacitor provided as a part of a capacitor motor and a capacitor connected across the line (such as a capacitor for radio-interference elimination) shall be housed within an enclosure or container that will protect the plates against mechanical damage and prevent the emission of flame or molten material resulting from impaired operation of the capacitor. Except as noted in 24.2 and 24.3, the container

shall be of sheet steel having a thickness of not less than 0.020 inch (0.51 mm) or shall be constructed so as to afford equivalent protection.

24.1.2 The container of a capacitor may be of sheet steel of thickness less than that mentioned in 24.1.1, or of other material, if the capacitor is mounted in an enclosure which houses other parts of the machine and if such a box, case, or the like is intended for the enclosure of live parts.

24.1.3 The individual enclosure of an electrolytic capacitor with means for venting is required to be such as to provide protection against mechanical damage only, and the requirement for minimum enclosure thickness does not apply. The individual enclosure of an electrolytic capacitor not provided with means for venting and with an opening more than 1/16 inch (1.6 mm) wide between the capacitor enclosure and the motor need not comply with the requirement for enclosure thickness given in 24.1.1 if it complies with the following. Several samples of the capacitor and its enclosure, with cotton placed around openings in the enclosure, are to be subjected to such overvoltage as to cause impaired operation. If the cotton ignites on impaired operation of the capacitor, the results are not acceptable.

24.2 Lampholders and lamps

24.2.1 Lampholders and lamps shall be rated for the current and voltage in the circuit in which they are used when the product is operated under intended service conditions.

24.2.2 The outer shell of each lampholder in a high-voltage circuit shall be connected to the conductor identified as the grounded conductor.

24.2.3 A lampholder shall be installed so that uninsulated high-voltage live parts other than an outer shell will not be exposed to contact by persons removing or replacing lamps.

24.3 Overcurrent protection

24.3.1 If a primary circuit breaker or fuses are provided, their rating shall be in accordance with the maximum input to the product.

24.4 Transformers, coils, and relays

24.4.1 A transformer shall be of the two-coil or insulated type.

Exception: An autotransformer may be employed if the terminal or lead common to both input and output circuits is identified, and the output circuits are located only within the enclosure containing the autotransformer. See 20.7.2.

24.4.2 A coil shall be treated with an insulating varnish, and baked or otherwise impregnated to exclude moisture.

Exception: Film-coated wire is not required to be given additional treatment to prevent moisture absorption.

24.5 Switches

24.5.1 A switch provided as part of the product shall have a current and voltage rating not less than that of the circuit which it controls when the product is operated under any condition of intended service. If the circuit controlled has a power factor less than 75 percent, the switch shall have a horsepower rating (evaluated on the basis of the ampere equivalent) or a rating of not less than 200 percent of the maximum load current.

24.6 Semiconductors

24.6.1 Semiconductors shall be rated for the intended application under all environmental conditions to which they may be exposed in service. See Performance Tests, Sections 29 – 34.

24.7 Printed-wiring boards

24.7.1 The securing of components to the board shall be made in the intended manner and the spacings between circuits shall comply with the requirements of this standard. See Spacings, Section 28. The board shall be mounted so that deflection of the board during servicing shall not result in damage to the board or in a risk of fire or electric shock. Also see 21.1.8.

25 Current-Carrying Parts

25.1 A current-carrying part shall be of silver, copper, a copper alloy, or other material which will provide equivalent performance.

25.2 Bearings, hinges, and the like shall not be used for carrying current between interrelated fixed and moving parts.

26 Insulating Material

26.1 Material for the mounting of current-carrying parts shall be porcelain, phenolic composition, cold molded composition, or equivalent material.

26.2 Polymeric materials used for the sole support of uninsulated live parts shall have mechanical strength and rigidity, dielectric withstand, resistance to heat, flame propagation, arcing, creep, moisture, and other properties equal to or exceeding the minimum level as a result of aging. See Polymeric Materials Test, Section 47.

26.3 Vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as the sole support of live parts.

26.4 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 26.1.

Table 26.1
Thickness of Flat Sheets of Insulating Material

Maximum dimension				Minimum thickness[a]	
Length or width		Area			
inch	(cm)	inch^2	(cm^2)	inch	(mm)
24	(60.9)	360	(2322)	3/8[a]	(9.5)
48	(122.0)	1152	(7432)	1/2	(12.7)
48	(122.0)	1728	(11148)	5/8	(15.9)
Over 48		Over 1728		3/4	(19.1)

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

26.5 A terminal block mounted on a metal surface 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 so as to prevent such parts and the ends of replaceable terminal screws from coming in contact with the supporting surface.

26.6 A countersunk part that is sealed 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 at not less than 65 °C (149 °F) in any case. The depth or thickness of sealing compound shall not be less than 1/8 inch (3.2 mm).

27 Motors

27.1 General

27.1.1 Each motor shall drive its maximum intended load during operation of the product without introducing a risk of electric shock or fire.

27.1.2 Each motor winding shall resist the absorption of moisture.

27.2 Overload protection

27.2.1 A continuous-duty motor in a permanently-connected product; an automatically-controlled, fractional-horsepower motor in a product; the motor of a product intended to be operated remotely or unattended; a motor whose operation or impaired operation will not be evident to the operator; and a continuous-duty, integral-horsepower motor, shall be provided with overload protection. The protection provided is to be as indicated in 27.2.3. For a multispeed motor, the protection is to be effective at all speed settings. See also 27.2.4.

27.2.2 If overloading or stalling of a motor can result from manipulation of the controls in any part of the system, the motor shall be provided with one of the following types of overload protection:

a) Thermal protection complying with UL 2111.

b) Impedance protection complying with UL 2111, when tested as used in the application.

c) Other protection that tests show is equivalent to the protection mentioned in (a).

27.2.3 A motor that drives only a blower or fan is considered to have the necessary overload protection if it is protected against locked-rotor conditions only.

27.2.4 A shaded-pole motor having a difference of 1 ampere or less between no-load and locked-rotor currents, and having a 2:1 or smaller ratio between locked-rotor and no-load currents, is considered to have the necessary overload protection if it is protected against locked-rotor conditions only.

27.2.5 Devices providing overload protection for motors shall be recognized for use on branch circuits to which the product can be connected unless recognized additional protection is provided in the product.

27.2.6 A thermal or overload protective device shall not open the circuit during intended use of the product.

27.2.7 The functioning of an overload protective device provided for a motor as part of a product, whether or not such a device is required, shall not result in a risk of fire, electric shock, or injury to persons.

27.2.8 If a product includes a motor and if the overload protection of a branch circuit to which the product can be connected does not provide protection for the motor in accordance with NFPA 70, such protection shall be included in the product.

28 Spacings

28.1 Spacings between uninsulated live parts and between uninsulated live parts and dead metal parts shall not be less than those indicated in 28.2 – 28.5.

28.2 The spacings in "To walls of enclosure" of Table 28.1 apply between an uninsulated live part and:

a) A wall or cover of a metal enclosure;

b) A fitting for conduit or metal-clad cable; and

c) A metal piece attached to a metal enclosure where deformation of the enclosure is likely to reduce spacings.

The spacings do not apply to an individual enclosure of a component part within an outer enclosure.

Table 28.1
Minimum Spacings

Point of application	Voltage range volts	Minimum spacings[a,b]			
		Through air		Over surface	
		inch	(mm)	inch	(mm)
To walls of enclosure:					
Cast metal enclosures	0 – 300	1/4	(6.4)	1/4	(6.4)
Sheet metal enclosures	0 – 50	1/4	(6.4)	1/4	(6.4)
	51 – 300	1/2	(12.7)	1/2	(12.7)
Installation wiring terminals (general application):					
With barriers	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	3/8	(9.5)	3/8	(9.5)
Rigidly clamped assemblies[c]:					
100 volt-amperes maximum[d]	0 – 30	1/32[c]	(0.8)	1/32[c]	(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)

Table 28.1 Continued on Next Page

Table 28.1 Continued

Point of application	Voltage range volts	Minimum spacings[a,b]			
		Through air		Over surface	
		inch	(mm)	inch	(mm)

[a] An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material used where spacings would otherwise be insufficient, shall not be less than 0.028 inch (0.71 mm) thick; except that a liner or barrier not less than 0.013 inch (0.33 mm) thick may be 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 will not be affected adversely by arcing. Insulating material having a thickness less than that specified may be used if it is suitable for the particular application.

[b] Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case shall the wire be smaller than 18 AWG (0.82 mm^2).

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

[d] Spacings less than those indicated, but not less than 1/64 inch (0.4 mm), may be used for the connection of integrated circuits and similar components where the spacing between adjacent connecting wires on the component is less than 1/32 inch (0.8 mm).

28.3 The spacings between an uninsulated live part and:

a) An uninsulated live part of opposite polarity;

b) An uninsulated grounded dead metal part other than the enclosure; and

c) An exposed dead metal part that is isolated (insulated)

shall not be less than that indicated in Table 28.1. See 28.5 for further specifications.

28.4 The spacings in a motor shall comply with the spacing requirements in UL 1004-1.

28.5 Film-coated wire is considered an uninsulated live part in determining compliance of a product with the spacing requirements, but film coating may be used as turn-to-turn insulation in coils.

28.6 The spacings within snap switches, lampholders, and similar wiring devices supplied as part of a device shall comply with the requirements for that component but need not comply with the requirements of Table 28.1.

28.7 To allow for the possible physical expansion of a capacitor with an internal interrupter, 1/2 inch (12.7 mm) shall be added to each of the spacing requirements of Table 28.1 for spacings between the terminals of the capacitor. The spacing shall be in line with the direction in which the terminals will expand when the interrupter operates.

PERFORMANCE – ELECTRICAL AND MECHANICAL EQUIPMENT

29 General

29.1 Unless otherwise specified, the performance of bullet-resisting equipment shall be investigated by subjecting a representative sample to the following tests.

30 Test Samples and Miscellaneous Data

30.1 Samples

30.1.1 The following samples are to be provided for testing:

a) One or more assembled products of each type.

b) Unassembled sample of any encapsulated or otherwise permanently assembled portions which otherwise could not be disassembled for examination and photographs.

c) Installation and operating instructions for each sample.

30.2 Test voltages

30.2.1 Unless otherwise specified, each test is to be conducted at the applicable potential indicated in Table 30.1.

Table 30.1
Test Voltages

Rated voltage	Normal test voltage	Input test voltage	Overvoltage	Undervoltage
110 – 120	120	Rated	132	102
200 – 208	208	Rated	229	177
220 – 240	240	Rated	264	204
Other	Rated	Rated	110 percent rated	85 percent rated

31 Input Test

31.1 The input to a product shall not be more than 110 percent of the rated current, power, or volt-ampere value when the product is operated under the condition of maximum intended load and when connected to a test voltage in accordance with the requirements in 31.2.

31.2 The test voltage for this test is to be the maximum rated voltage for the product. For a product having a single voltage, such as 115 volts, maximum rated voltage is to be that single voltage. If the voltage is given in terms of a range of voltages, such as 110 – 120 volts, the maximum rated voltage is the highest value of the range.

32 Power-Limited Circuits

32.1 General

32.1.1 All field-wiring circuits shall be classified as a power-limited or nonpower-limited circuit. A circuit shall be considered nonpower-limited unless otherwise identified in the installation documentation and marking on the product.

32.1.2 The power source (or sources) supplying a power-limited circuit shall be either:

a) Inherently limited requiring no overcurrent protection or

b) Limited by a combination of a power source and overcurrent protection devices such that a power-limited circuit has electrical characteristics described in Table 32.1 for AC circuits or Table 32.2 for DC circuits.

Table 32.1
Power Source Limitations for Alternating Current Class 2 and Class 3 Circuits

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings		Current limitations I_{max}[b] (amps)	Power limitations $(VA)_{max}$[c] (volt-amps)	Maximum overcurrent protection (amps)
		VA (volt-amps)	Current (amps)			
Inherently limited power source (overcurrent protection not required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	8.0	–	–
	over 20 to 30	100	$100/V_{max}$	8.0	–	–
	over 30 to 150	$0.005 \times V_{max}$	0.005	0.005	–	–
Class 3	over 30 to 100	100	$100/V_{max}$	$150/V_{max}$	–	–
Not inherently limited power source (overcurrent protection required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	$1000/V_{max}$	250[d]	5.0
Class 3	over 20 to 30	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 30 to 100	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 100 to 150	100	$100/V_{max}$	1.0	NA	1.0

NOTES

1 Adapted from the National Electrical Code, NFPA 70, copyright National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

2 For nonsinusoidal AC, V_{max} shall not be greater than 42.4 volts peak. Where wet contact (immersion not included) is likely to occur, Class 3 wiring methods shall be used, or V_{max} shall not be greater than 15 volts for sinusoidal AC and 21.2 volts peak for nonsinusoidal AC.

[a] V_{max} : Maximum output voltage regardless of load with rated input applied.

[b] I_{max} : Maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed, when used. When a transformer limits the output current, I_{max} limits apply after 1 minute of operation. Where a current limiting impedance is used in combination with a nonpower-limited transformer or a stored energy source, such as a storage battery, in order to limit the output current, I_{max} limits apply after 5 seconds.

[c] $(VA)_{max}$: Maximum volt-ampere output after 1 minute of operation regardless of load, and with overcurrent protection bypassed, when used.

[d] When the power source is a transformer, $(VA)_{max}$ is 350 volt-amperes or less where V_{max} is 15 volts or less.

Table 32.2
Power Source Limitations for Direct Current Class 2 and Class 3 Circuits

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings		Current limitations I_{max}[b] (amps)	Power limitations $(VA)_{max}$[c] (volt-amps)	Maximum overcurrent protection (amps)
		VA (volt-amps)	Current (amps)			
Inherently limited power source (overcurrent protection not required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	8.0	–	–
	over 20 to 30	100	$100/V_{max}$	8.0	–	–
	over 30 to 60	100	$100/V_{max}$	$150/V_{max}$	–	–
	over 60 to 150	$0.005 \times V_{max}$	0.005	0.005	–	–

Table 32.2 Continued on Next Page

Table 32.2 Continued

	Circuit voltage V_{max}[a] (volts)	Power source maximum nameplate ratings		Current limitations I_{max}[b] (amps)	Power limitations $(VA)_{max}$[c] (volt-amps)	Maximum overcurrent protection (amps)
		VA (volt-amps)	Current (amps)			
Class 3	over 60 to 100	100	$100/V_{max}$	$150/V_{max}$	–	–
Not inherently limited power source (overcurrent protection required)						
Class 2	0 to 20	$5.0 \times V_{max}$	5.0	$1000/V_{max}$	250[d]	5.0
Class 3	over 20 to 60	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 60 to 100	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
	over 100 to 150	100	$100/V_{max}$	1.0	N/A	1.0

NOTES

1 Adapted from the National Electrical Code, NFPA 70, copyright National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

2 A dry cell battery shall be considered an inherently limited power source, when the voltage is 30 volts or less and the capacity is equal to or less than that available from series connected No. 6 carbon zinc cells.

3 For DC interrupted at a rate of 10 to 200 hertz, V_{max} shall not be greater than 24.8 volts. Where wet contact (immersion not included) is likely to occur, Class 3 wiring methods shall be used, or V_{max} shall not be greater than 30 volts for continuous DC and 12.4 volts for DC that is interrupted at a rate of 10 to 200 hertz.

[a] V_{max} : Maximum output voltage regardless of load with rated input applied.

[b] I_{max} : Maximum output current under any noncapacitive load, including short circuit, and with overcurrent protection bypassed, when used. When a transformer limits the output current, I_{max} limits apply after 1 minute of operation. Where a current limiting impedance is used in combination with a nonpower-limited transformer or a stored-energy source, such as a storage battery, in order to limit the output current, I_{max} limits apply after 5 seconds.

[c] $(VA)_{max}$: Maximum volt-ampere output after 1 minute of operation regardless of load, and with overcurrent protection bypassed, when used.

[d] When the power source is a transformer, $(VA)_{max}$ is 350 volt-amperes or less where V_{max} is 15 volts or less.

32.1.3 With regard to 32.1.2, acceptable means for current limiting include:

a) Transformer winding impedance;

b) A thermal link embedded within the winding overwrap of a transformer;

c) Circuit components (resistors, regulators, transistors, and similar components) that comply with the Temperature Test, Section 43, under I_{max} condition; and

d) Current limiting impedances determined to be suitable for the application (positive temperature coefficient varistor or similar component).

Circuit component burnout, permanent (by soldered means or similar method) or replaceable fuses, opening of conductors on printed-wiring boards, or opening of internal wiring conductors shall not be used as a means of current limiting.

32.1.4 The overcurrent protection device specified in 32.1.2 shall be of the noninterchangeable type such that it is incapable of being renewed in the field with an overcurrent device having a higher current rating.

32.1.5 When measuring the I_{max} and VA_{max}, all overcurrent protection devices of the control unit shall be short-circuited. However, current limiting devices shall not be bypassed and shall remain functional.

32.2 Maximum voltage

32.2.1 With the circuit energized only from its rated primary power source, the output voltage of the circuit under test is to be measured while the circuit is connected to full rated load and under open circuit conditions. The maximum voltage under these two conditions shall be considered V_{max}.

32.3 Maximum current

32.3.1 In order to determine compliance with the I_{max} limitation, a variable load resistor is to be connected across the circuit. While monitoring the current through the load resistor, the load resistor shall be adjusted from open circuit to short circuit as quickly as possible and the highest current noted. The load resistor is then to be readjusted to produce the highest current obtained and the current through the load resistor is to be measured after 1 minute or after 5 seconds as determined by Table 32.1 or Table 32.2.

32.3.2 When the maximum current through the load resistor is unable to be maintained for 5 seconds due to current-limiting devices (opening of thermal link, power supply foldback, PTC varistor effect, and similar methods), the circuit load resistor is to be adjusted to a value that produces a current just above the I_{max} value indicated in Table 32.1 or Table 32.2. The results are in compliance when the I_{max} value stated in Table 32.1 or Table 32.2 is unable to be maintained for more than 5 seconds.

32.3.3 When a transformer limits the value of I_{max}, and when I_{max} is unable to be maintained for 1 minute due to transformer burnout, a plot of current versus time is to be generated and the graph extrapolated to 1 minute. The results are in compliance when the extrapolated value of I_{max} at 1 minute does not exceed the I_{max} limitations as indicated in Table 32.1 or Table 32.2.

32.4 VA_{max} (Not inherently limited circuits only)

32.4.1 The circuit is to be energized from a rated source of supply and then the circuit under test is to be open-circuited. A variable load resistor, initially set to draw rated circuit current, is then to be connected across the circuit. The circuit voltage and current are to be recorded and the load is to be removed. The resistance of the load shall then be decreased, momentarily reconnected across the circuit while recording the voltage and current, and then removed. This procedure is to be repeated until the load resistance has been reduced to a short circuit. Using the recorded voltage and current, the maximum volt-ampere, VA_{max}, output under each load condition is to be calculated. The load resistor is then to be adjusted to that value which produced the maximum volt-ampere, VA_{max}; calculated; and then connected to the circuit. After 1 minute, the voltage and current are again to be measured. The results of this test are in compliance when the calculated volt-ampere, VA, output of the circuit does not exceed the values specified in Table 32.1 or Table 32.2, after 1 minute.

33 Starting Current Test

33.1 A unit shall start and operate as intended on a circuit protected by an ordinary (not time-delay) fuse having a current rating corresponding to that of the branch circuit to which, in accordance with NFPA 70, the unit shall be connected.

33.2 To determine compliance with 33.2 the unit is to be started three times, with the device at room temperature at the beginning of the test. Each start is to be made under conditions representing the beginning of intended operation (the beginning of the normal operating cycle, in the case of any automatic product), and the motor is to be allowed to come to rest between successive starts. The performance is unacceptable if the fuse is blown. Tripping of an overload protector provided as part of the unit is also considered to constitute impaired operation.

34 Voltage Variations Test

34.1 A product shall function at 85 – 110 percent of test voltage without readjustment. The product may not operate as intended, but its bullet resistance shall not be affected, and a risk of fire or electric shock shall not be created.

35 Variable Ambient Temperature Test

35.1 When tested as described in 35.2, the bullet resistance of the product shall not be affected and a risk of fire or electric shock shall not be created, but the product need not operate as intended.

35.2 The product is to be maintained at the applicable temperature indicated in (a) – (c) for a length of time sufficient to reach thermal equilibrium (at least 4 hours) and then tested at that temperature for intended operation while connected to a source of rated voltage and frequency.

a) A product intended for indoor use is to be exposed to temperatures of 0 and 49 °C (32 and 120 °F).

b) If intended for outdoor use, the product or the part of the product intended to be exposed to outdoor conditions is to be subjected to temperatures of ambient air at minus 35 and plus 66 °C (minus 30 and plus 150 °F).

c) A product that is to be used indoors during business hours only is to be exposed to temperatures of 13 and 35 °C (55 and 95 °F).

36 Humidity Test

36.1 When tested as described in 36.2, the bullet resistance of the product shall not be affected, and a risk of fire or electric shock shall not be created. The product need not operate as intended.

36.2 Bullet-resisting equipment is to be exposed for 24 hours to air having a relative humidity of 85 ±5 percent at a temperature of 30 ±2 °C (86 ±3 °F).

36.3 In addition, leakage current measurements are to be recorded for cord-connected products powered from a high-voltage source following the 24-hour exposure to the humid environment in accordance with the Leakage Current Test for Cord-Connected Products, Section 37.

37 Leakage Current Test for Cord-Connected Products

37.1 The leakage current of a high-voltage, cord-connected product intended to be located in an area accessible to contact by a person or one which is interconnected to a product accessible to contact by a person, shall not exceed the values shown in Table 37.1 when tested in accordance with 37.7 and 37.8 after exposure to the Humidity Test, Section 36.

Exception: A product that incorporates a loss-of-ground detector that opens the live conductors is exempted from these requirements.

Table 37.1
Maximum Leakage Current

Type of product	Maximum leakage current, mA
Two-wire cord-connected product	0.50
Three-wire (including grounding conductor) cord-connected, portable product	0.50
Three-wire (including grounding conductor) cord-connected stationary or fixed product	0.75

37.2 The test is to be conducted as soon as possible after the completion of the Humidity Test, Section 36, and with the supply voltage adjusted to the test voltage. For this test, the product is to be de-energized, removed from the humidity environment, placed on a dry insulating surface, and immediately reenergized from a rated source of supply. The leakage measurement is then to be made with the product in the ready-to-serve and operating conditions.

37.3 "Leakage current" refers to all currents, including capacitively coupled currents, which may be conveyed between exposed conductive surfaces and ground or other exposed conductive surfaces.

37.4 All exposed conductive surfaces are to be tested for leakage currents. Parts are to be considered exposed surfaces unless guarded by an enclosure that provides protection against risk of electric shock. Leakage currents from simultaneously accessible surfaces are to be measured to the grounded supply conductor individually, as well as collectively, and from one surface to another. Surfaces are to be considered simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock.

37.5 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using metal foil having dimensions of 10 by 20 centimeters (3.9 by 7.8 inches) in contact with the surface. Where the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the product.

37.6 The measurement circuit for leakage current is to be as shown in Figure 37.1. The measurement instrument is defined in (a) – (c). The meter used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all of the attributes of the defined instrument.

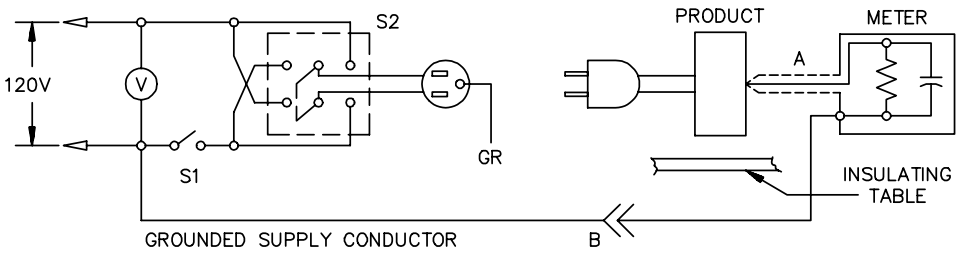
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) equal to the ratio of the impedance of a 1500 ohm resistor shunted by a 0.15 microfarad capacitor to 1500 ohms. At indications of 0.5 and 0.75 milliampere, the measurement is to have an error of not more than 5 percent at 60 hertz.

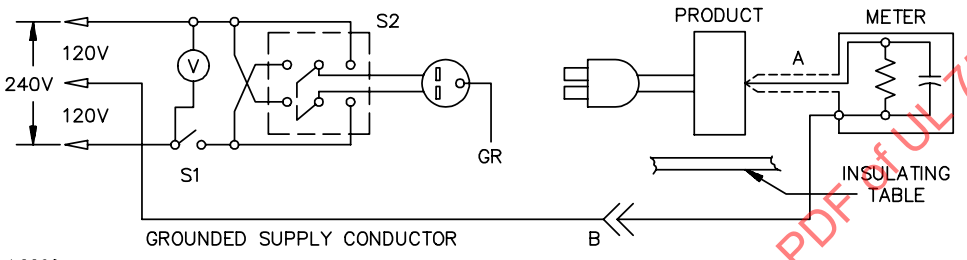
Figure 37.1

Leakage Current Measurement Circuits



LC100

Product intended for connection to a 120 volt power supply.



LC200

Product intended for connection to 3-wire grounded-neutral power supply.

A. Probe with shielded lead – Under some circumstances where higher frequency components are present, shielding of measuring instrument and its leads may be necessary.

B. Separated and used as clip when measuring currents from one part of a product to another.

37.7 A sample of the product is to be prepared and conditioned for leakage current measurement as follows:

a) The sample is to be representative of the wiring methods, routing, component location and installation, and the like, of the product.

b) The grounding conductor is to be open at the attachment plug and the test product isolated from ground.

c) The sample is to be conditioned as described in 36.2.

37.8 The leakage current test sequence, with reference to the measuring circuit in Figure 37.1, is to be as follows:

a) With switch S1 open, the product is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2. All manual switching devices then are to be operated in their intended manner and leakage currents measured using both positions of switch S2.

b) With the product switching devices in their operating positions, switch S1 then is to be closed, energizing the product and within a period of 5 seconds the leakage current is to be measured using both positions of switch S2. All manual switching devices then are to be operated in their intended manner, and leakage currents measured using both positions of switch S2.

c) The product switching devices are then to be returned to their operating positions and the product allowed to operate until thermal equilibrium is obtained. Leakage current is to be monitored continuously. For this test, thermal equilibrium is defined as that condition where leakage current is found to be constant or decreasing in value. Both positions of switch S2 are to be used in determining this measurement.

d) Immediately following the test, any single-pole switch on the product is to be opened, and the leakage current monitored until constant or decreasing values are recorded. Readings are to be taken in both positions of switch S2.

38 Electric Shock Current Test

38.1 If the open circuit potential between any part that is exposed only during operator servicing and either:

a) Earth ground; or

b) Any other exposed accessible part,

exceeds 42.4 volts peak, the part shall comply with the requirements in 38.2 – 38.4, as applicable.

38.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 38.1 when the resistor is connected between any part that is exposed only during operator servicing and either:

a) Earth ground; or

b) Any other exposed accessible part.

Table 38.1
Maximum Current During Operator Servicing

Frequency, hertz[a]	Maximum 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 current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

38.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 38.2 shall not exceed:

a) 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, and

b) 809 milliamperes, regardless of duration.

The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. Typical calculated values of maximum transient current duration are shown in Table 38.2.

Table 38.2
Maximum Transient Current Duration

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
7.1	7.26 seconds
8.5	5.58
10.0	4.42
12.5	3.21

Table 38.2 Continued on Next Page

Table 38.2 Continued

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	919 milliseconds
40.0	609
50.0	443
60.0	341
70.0	274
80.0	226
90.0	191
100.0	164
150.0	92
200.0	61
250.0	44
300.0	34
350.0	27
400.0	23
450.0	19
500.0	16
600.0	12
700.0	10
809.0	8.3

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

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

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

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. Typical calculated values of maximum capacitance are shown in Table 38.3.

Table 38.3
Electric Shock – Stored Energy

Potential in volts, across capacitance prior to discharge	Maximum capacitance in microfarads
1000	0.868
900	1.02
800	1.22
700	1.50
600	1.90
500	2.52
400	3.55
380	3.86
360	4.22
340	4.64
320	5.13
300	5.71
280	6.40
260	7.24
240	8.27
220	9.56
200	11.2
180	13.4
160	16.3
140	20.5
120	26.6
100	36.5
90	43.8
80	53.8
70	68.0
60	89.4
50	124.0
45	150.0
42.4	169.0

38.5 With reference to the requirements of 38.2 and 38.3, the current is to be measured while the resistor is connected between ground and:

a) Each accessible part individually, and

b) All accessible parts collectively if the parts are simultaneously accessible.

The current also is to be measured while the resistor is connected between one part or group of parts and another part or group of parts, if the parts are simultaneously accessible.

38.6 With reference to the requirements of 38.5, parts are considered to be simultaneously accessible if they can be contacted by one or both hands of a person at the same time. For the purpose of these requirements, one hand is to be considered to be able to contact parts simultaneously if the parts are

within a 4 by 8 inch (102 by 203 mm) rectangle; and two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 feet (1.8 m) apart.

38.7 Electric shock current refers to all currents, including capacitively coupled currents.

38.8 If the product has a direct-current rating, measurements are to be made with the product connected in turn to each side of a 3-wire, direct-current supply circuit.

38.9 Current measurements are to be made:

a) With any operating control, or adjustable control that is subject to user operation, in all operating positions; and

b) Either with or without a vacuum tube, separable connector, or similar component in place.

These measurements are to be made with controls placed in the position that causes maximum current flow.

39 Overload Test

39.1 Electrically-operated bullet-resisting equipment shall operate as intended for each of its major functions when tested as described in 39.2 – 39.4.

Exception: Impaired operation is acceptable if the bullet resistance is not affected and a risk of fire or electric shock is not created.

39.2 The product is to be operated for 50 cycles of operation with the supply circuit at 115 percent of test voltage and at rated frequency. Each cycle is to consist of:

a) The product energized in the "ready to serve" mode;

b) "Normal service" operation; and

c) Restoration to the ready-to-serve mode.

39.3 A current-interrupting device intended to control loads that are not connected to the product supply terminals and require a separate supply circuit is to be tested with an overload current of 150 percent of its ampere rating and at the maximum test voltage for 50 cycles.

39.4 The product may be cycled at any rate up to 15 cycles per minute.

40 Endurance Test

40.1 The Overload Test, Section 39, is to be conducted prior to the Endurance Test.

40.2 A unit that is intended to be operated once a day shall operate as intended (at test voltage if electrically operated) for 6000 cycles of complete operation.

40.3 A unit that is intended to be operated several times a day, such as a teller's deal tray, shall operate as intended (at test voltage if electrically operated) for 100,000 cycles of complete operation.

41 Rain Test

41.1 The section of electrically-operated bullet-resisting equipment exposed to weather shall withstand a rain exposure for 1 hour without creating a risk of electric shock or affecting its bullet resistance. After each exposure, the insulation resistance between live parts and dead metal parts of the product shall be at least 50,000 ohms.

41.2 All electrical components are to be energized and the product tested under the conditions that could cause the entrance of water into or onto electrical components. It may be necessary to operate the product under various modes of operation or to de-energize the product if more water entry could result. Each exposure is to be for 1 hour, and if more than one exposure is required, the product is to be prepared for test as indicated in 41.5 before repeating the test.

41.3 Deal trays, package passers, and the like, that are opened to receive or return items, are to be operated in their intended manner 15 times during the 1-hour exposure at a rate of one operation every 4 minutes. Each operation is to consist of opening the product to its maximum, holding that position for 5 seconds and then closing the product.

41.4 Field wiring connections are to be made in accordance with the wiring method specified for the product. Openings intended to terminate conduit are to be sealed. Openings intended for the entry of a conductor(s) for a low-voltage circuit are not sealed unless seals are provided as a part of the product.

41.5 The product is to be examined to determine that all electrical parts, including motor windings, are not wetted and that there is no accumulation of water within the enclosures of electrical parts prior to rain exposure. See 41.6 for further specifications.

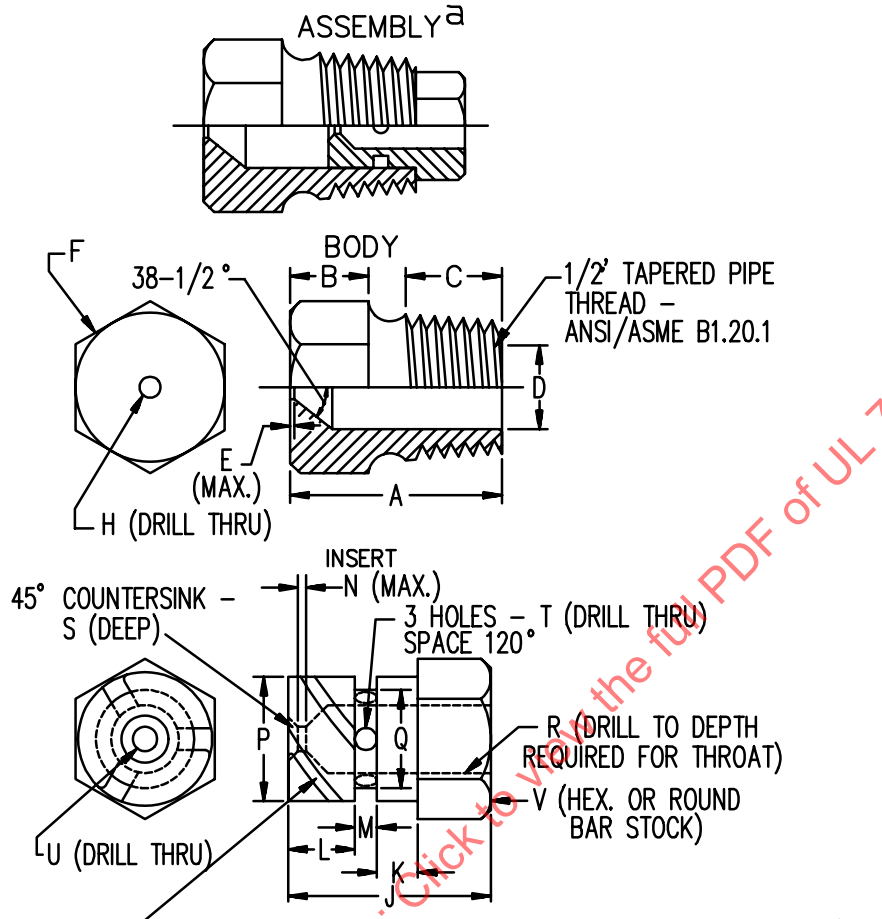
41.6 Drying of the product prior to the second or subsequent exposure is not required if, without such preparation, the product complies with the requirement in 41.1.

41.7 The insulation resistance is measured 1 minute after application of the voltage obtained by using the series-voltmeter method, or equivalent means, and a DC circuit. After measurement of the insulation resistance, the complete product is to be subjected to the Dielectric Voltage-Withstand Test, Section 42.

41.8 The rain test apparatus is to consist of three spray heads mounted in a water supply rack as shown in Figure 41.1. Spray heads are to be constructed in accordance with Figure 41.2. The water pressure for all tests is to be maintained at 5 psi (34.5 kPa) at each spray head. The product is to be brought into the focal area of the three spray heads in such position and under such conditions that the greatest quantity of water will enter the product. The spray is to be directed at an angle of 45° to the vertical toward the louvers or other openings closest to live parts.

Figure 41.1

Rain-Test Spray Head



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

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

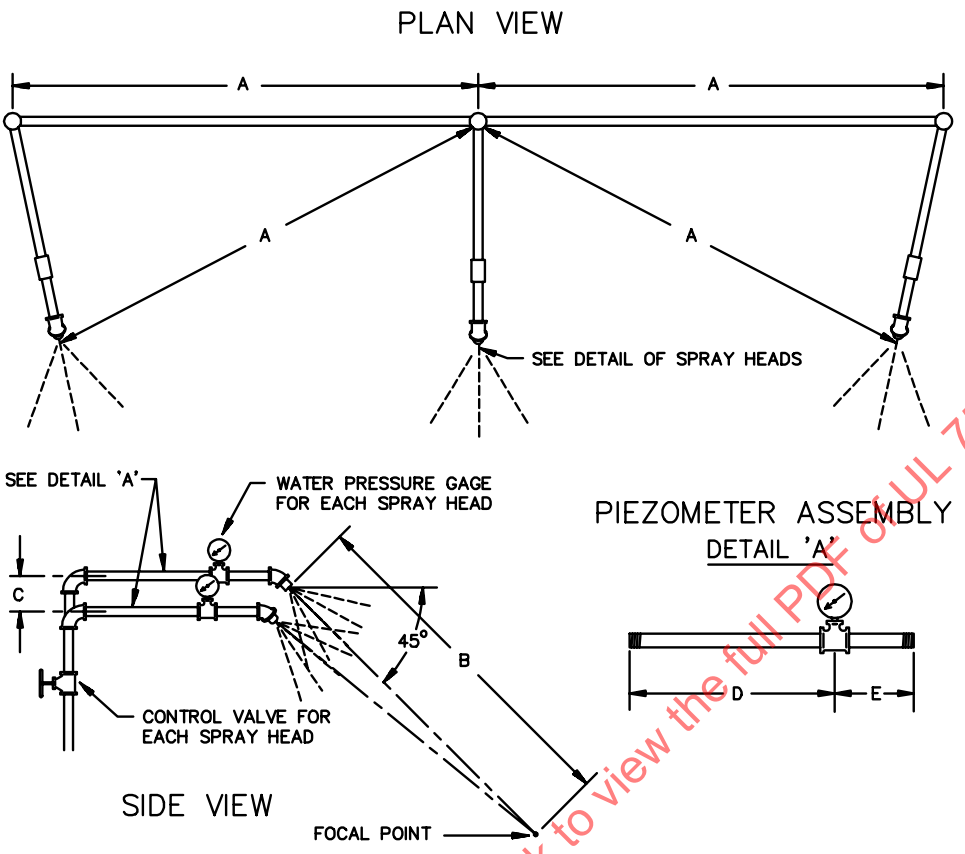
[b] ANSI B94.11M Drill Size

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

RT100E

Figure 41.2

Rain-Test Spray Head Piping



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

RT101D

41.9 The test is not to result in the entrance of water into enclosures above the lowest electrical component other than insulated wire or in wetting live parts.

Exception No. 1: Motor windings may be evaluated on the basis of the insulation resistance and by the Dielectric Voltage-Withstand Test, Section 42, if the motor is within the cabinet and is shielded from openings in the top of the cabinet.

Exception No. 2: Water may enter an enclosure above the lowest electrical component if the point of entrance is not in proximity to live parts and live parts are not wetted during the test.

42 Dielectric Voltage-Withstand Test

42.1 A product shall withstand for 1 minute, without breakdown, the application of an essentially sinusoidal AC potential of a frequency within the range of 40 – 70 hertz, or a DC potential, between live parts and the enclosure, between live parts and exposed dead metal parts, and between live parts of circuits operating at different potentials or frequencies. The test potential is to be as indicated in Table 42.1.

Table 42.1
Dielectric Voltage-Withstand Test Potential

Product rating	Test potential,	
	AC	DC
30 volts AC rms (42.4 volts DC or AC peak) or less	500 volts	707 volts
Between 31 and 250 volts AC rms	1000 volts	1414 volts
More than 250 volts AC rms	1000 volts plus twice the rated voltage	1414 volts plus 2.828 times the rated AC rms voltage

42.2 For the application of a potential between live parts of circuits operating at different potentials or frequencies, the voltage is to be the applicable value specified in Table 42.1, based on the highest voltage of the circuits under test instead of the rated voltage of the product. Electrical connections between the circuits are to be disconnected before the test potential is applied.

42.3 Exposed dead metal parts referred to 42.1 are noncurrent-carrying metal parts that are likely to become energized and accessible from outside of the enclosure of a unit during intended operation.

42.4 If an autotransformer is in the circuit, the primary of the transformer is to be disconnected and an AC test potential in accordance with 42.1 is to be applied directly to all wiring involving more than 250 volts.

42.5 If the charging current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is sufficient to prevent maintenance of the specified AC test potential, the capacitor or filter is to be tested using a DC test potential in accordance with 42.1.

42.6 The test potential may be obtained from any convenient source having sufficient capacity to maintain the specified voltage. The output voltage of the test apparatus is to be monitored. Starting at zero, the potential is to be increased at a rate of approximately 200 volts per minute until the required test value is reached and is to be held at that value for 1 minute.

42.7 A printed wiring assembly or other electronic circuit component that would be damaged, or would short-circuit, by the application of the test potential, is to be removed, disconnected, or otherwise rendered inoperative before the test. A representative subassembly may be tested instead of an entire product.

Rectifier diodes in the power supply may be individually shunted before the test to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.

43 Temperature Test

43.1 The materials used in the construction of electrically-operated bullet-resisting equipment shall not attain temperature rises greater than the applicable value specified in Table 43.1 under any condition of intended operation. A thermal or overcurrent-protective device shall not open the circuit during the test.

Table 43.1
Maximum Temperature Rises

Materials and components	Ready-to-serve °C	Ready-to-serve (°F)	Normal service °C	Normal service (°F)
A. MOTORS[a,b]				
1. Class A insulation systems on coil windings of alternating-current motors 7 inches (178 mm) or less in diameter (not including universal motors):				
a) In open motors:				
Thermocouple or resistance method	75	(135)	75	(135)
b) In totally enclosed motors:				
Thermocouple or resistance method	80	(144)	80	(144)
2. Class A insulation systems on coil windings of alternating-current motors more than 7 inches (178 mm) in diameter and of direct-current and universal motors:				
a) In open motors:				
Thermocouple method	65	(117)	65	(117)
Resistance method	75	(135)	75	(135)
b) In totally enclosed motors:				
Thermocouple method	70	(126)	70	(126)
Resistance method	80	(144)	80	(144)
3. Class B insulation systems on coil windings of alternating-current motors 7 inches (178 mm) or less in diameter (not including universal motors):				
a) In open motors:				
Thermocouple or resistance method	95	(171)	95	(171)
b) In totally enclosed motors:				
Thermocouple or resistance method	100	(180)	100	(180)
4. Class B insulation systems on coil windings of alternating-current motors more than 7 inches (178 mm) in diameter and of direct-current and universal motors):				
a) In open motors:				
Thermocouple method	85	(153)	85	(153)
Resistance method	95	(171)	95	(171)
b) In totally enclosed motors:				
Thermocouple method	90	(162)	90	(162)
Resistance method	100	(180)	100	(180)
B. COMPONENTS				
1. Capacitors:[c,d]				
a) Electrolytic types	25	(45)	40	(72)

Table 43.1 Continued on Next Page

Table 43.1 Continued

Materials and components	Ready-to-serve °C	Ready-to-serve (°F)	Normal service °C	Normal service (°F)
b) Other types	25	(45)	65	(117)
2. Rectifiers – at any point				
a) Germanium	25	(45)	50	(90)
b) Selenium	25	(45)	50	(90)
c) Silicon				
1) Maximum 60 percent of rated volts	50	(90)	75	(135)
2) 61 percent or more of rated volts	25	(45)	75	(135)
3. Relay, solenoid, transformer and other coils with:				
a) Class 105 insulation system:				
Thermocouple method	25	(45)	65	(117)
Resistance method	35	(63)	85	(153)
b) Class 130 insulation system:				
Thermocouple method	45	(81)	85	(153)
Resistance method	55	(99)	105	(189)
c) Class 155 insulation system:				
1) Class 2 transformers:				
Thermocouple method	95	(171)	95	(171)
Resistance method	115	(207)	115	(207)
2) Power transformers:				
Thermocouple method	110	(198)	110	(198)
Resistance method	115	(207)	115	(207)
d) Class 180 insulation system:				
1) Class 2 transformers:				
Thermocouple method	115	(207)	115	(207)
Resistance method	135	(243)	135	(243)
2) Power transformers:				
Thermocouple method	125	(225)	125	(225)
Resistance method	135	(243)	135	(243)
4. Resistors:[e]				
a) Carbon	25	(45)	50	(90)
b) Wire wound	50	(90)	125	(225)
c) Other	25	(45)	50	(90)
5. Solid-state devices	See note f			
6. Other components and materials:				
a) Fiber used as electrical insulation or cord bushings	25	(45)	65	(117)
b) Varnished cloth insulation	25	(45)	60	(108)
c) Thermoplastic materials	Rise based on temperature limits of the material			
d) Phenolic composition used as electrical insulation or as parts where deterioration will result in a risk of fire or electric shock[g]	25	(45)	125	(225)

Table 43.1 Continued on Next Page

Table 43.1 Continued

Materials and components	Ready-to-serve °C	Ready-to-serve (°F)	Normal service °C	Normal service (°F)
e) Wood or other combustibles	25	(45)	65	(117)
f) Sealing compound	15 °C (27 °F) less than the melting point			
g) Fuses	25	(45)	65	(117)
C. CONDUCTORS				
1. Appliance wiring material[h]	25 °C (45 °F) less than the temperature limit of the wire			
2. Flexible cord (for example, SJO, SJT)	35	(63)	35	(63)
3. Conductors of field-wired circuits to be permanently connected to the product	35	(63)	35	(63)
D. GENERAL				
1. All surfaces of the product and surfaces adjacent to or upon which the product may be mounted	25	(45)	65	(117)
2. Surfaces intended to be contacted by the user in operating the unit (control knobs, push buttons, levers, and the like):				
a) Metal	35	(63)	35	(63)
b) Nonmetallic	60	(108)	60	(108)
3. Surfaces subjected to casual contact by the user (enclosure, customer access panels, and the like):				
a) Metal	45	(81)	45	(81)
b) Nonmetallic	65	(117)	65	(117)

[a] The motor diameter is to be measured in the plane of the laminations of the circle circumscribing the stator frame, excluding lugs, boxes, and the like, used solely for motor cooling, mounting, assembly, or connection.

[b] Coil or winding temperatures are to be measured by the thermocouples unless the coil is inaccessible for mounting of these devices (for example, a coil immersed in sealing compound) or unless the coil wrap includes thermal insulation such as more than two layers, 1/32 inch (0.8 mm) maximum, of cotton, paper, rayon, or the like. For a thermocouple measured temperature of a coil of an alternating-current motor having a diameter of 7 inches (178 mm) or less, the thermocouple is to be mounted on the integrally applied insulation on the conductor. At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by a thermocouple may exceed the indicated maximum, if the temperature rise of the coil, as measured by the resistance method, is not more than that specified in this table.

1) 5 °C (9 °F) for Class A insulation on coil windings of alternating-current motors having a diameter of 7 inches or less, open type.

2) 10 °C (18 °F) for Class B insulation on coil windings of alternating-current motors having a diameter of 7 inches or less, open type.

3) 15 °C (27 °F) for Class A insulation on coil windings of alternating-current motors having a diameter of more than 7 inches, open type.

4) 20 °C (36 °F) for Class B insulation on coil windings of alternating-current motors having a diameter of more than 7 inches, open type.

[c] For an electrolytic capacitor that is physically integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure may not be more than 65 °C (117 °F).

[d] A capacitor which operates at a temperature higher than a 65 °C (117 °F) rise may be evaluated on the basis of its marked manufacturer's rating.

[e] The temperature rise of a resistor may exceed the values shown if the power dissipation is 50 percent or less of the manufacturer's rating.

[f] The temperature of a solid-state device (for example, transistor, SCR, integrated circuits) shall not exceed 50 percent of its rating during the Ready-to-Serve Condition; and 75 percent of its rated temperature under Normal Service or any other condition of operation which produces the maximum temperature dissipation of its components. For reference purposes 0 °C (32 °F) shall be considered as 0 percent. For integrated circuits the loading factor shall not exceed 50 percent of its rating under the normal standby condition; and 75 percent under any other condition of operation. Both solid-state devices and integrated circuits may be operated up to the maximum ratings under any one of the following conditions:

Table 43.1 Continued on Next Page

Table 43.1 Continued

Materials and components	Ready-to-serve °C	Ready-to-serve (°F)	Normal service °C	Normal service (°F)
1) The component complies with the requirements of MIL-STD-750F.				
2) A quality-control program is established by the manufacturer consisting of an inspection stress test followed by operation of 100 percent of all components, either on an individual basis, as part of a subassembly, or equivalent.				
3) Each assembled production unit is subjected to a burn-in test, under the condition which results in the maximum temperatures, for 24 hours while connected to a source of rated voltage and frequency in an ambient of at least 49 °C (120 °F).				
[g] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds that have been investigated and determined to have special heat-resistant properties.				
[h] For standard insulated conductors other than those mentioned, reference should be made to NFPA 70. The maximum allowable temperature rise in any case is 25 °C (45 °F) less than the temperature limit of the wire in question.				

43.2 The values for temperature rises specified in Table 43.1 are based on an assumed ambient temperature of 25 ±15 °C (77 ±27 °F), and tests are to be conducted at an ambient temperature within that range. A temperature is considered to be constant when three successive readings indicate no change when taken at intervals of 10 percent of the previously elapsed duration of the test, but at not less than 5-minute intervals.

43.3 Temperature measurements on a product intended for recessed mounting are to be made with the product installed in an enclosure of 3/4-inch (19.1-mm) plywood having clearances of 2 inches (50.8 mm) on the top, sides, and rear, and the front extended to be flush with the cover of the product. If other clearances are specified in installation instructions, they are to be used.

43.4 A temperature measurement by either the thermocouple or resistance method is acceptable, except that the thermocouple method is not to be used for a temperature measurement at any point where supplementary thermal insulation is employed.

43.5 Thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2)are to be used whenever temperature measurements by thermocouples are made. Thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer-type indicating instrument are to be used whenever referee temperature measurements by thermocouples are necessary.

43.6 The temperature of a coil winding may be determined by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature by means of the formula:

$$\Delta t = \frac{R_2}{R_1}(k + t_1) - (k + t_2)$$

in which:

Δt is the temperature rise in °C;

R_2 is the resistance in ohms at end of test;

R_1 is the resistance in ohms at beginning of test;

k is 234.5 for copper, or 225 for electrical conductor grade aluminum;

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

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

43.7 The product is to be connected to a supply circuit of rated voltage and frequency (see 30.2.1) and operated continuously under representative service conditions that are likely to produce the highest temperature.

43.8 The circuit of a current-regulating resistor or reactor provided as a part of a unit is to be adjusted for the maximum resistance or reactance at its intended current.

43.9 The duration of the test operating condition is not to be less than:

a) Ready-To-Service – (7 hours– Constant temperatures.)

b) Normal Service, Maximum Normal Load – (1 hour – Constant temperature.)

43.10 "Normal Service" is to be the repeated operation of the product at a rate of one operation every 2 minutes, or at its fastest possible rate if a complete cycle is longer than 2 minutes. The open position is to be held for 5 seconds during each operation.

44 Abnormal Operation Test

44.1 Electrically-operated bullet-resisting equipment energized in any condition of intended operation shall not result in a risk of fire or electric shock when under abnormal (fault) conditions. There shall be no emission of flame or molten metal, or any other manifestation of a risk of fire, or dielectric breakdown when tested in accordance with the Dielectric Voltage-Withstand Test, Section 42, after the Abnormal Operation Test, Section 44. Also see Motor Overload Test, Section 46.

44.2 To determine compliance with the requirement of 44.1, the product is to be operated under the most severe abnormal circuit fault conditions that could be encountered in service while connected to a source of supply in accordance with 30.2.1.

44.3 In determining compliance with the requirement with regard to circuit-fault conditions, the fault condition is to be maintained continuously until constant temperatures are attained, or until burnout occurs, if the fault does not result in the operation of an overload protective device. Shorting of the secondary of the power supply transformer and shorting of an electrolytic capacitor would represent typical fault conditions.

45 Solenoid Burnout Test

45.1 A solenoid employed as part of a unit shall be subjected to a burnout test. There shall be no emission of flame or molten metal when the armature is blocked in the de-energized position and energized continuously at rated frequency and at rated voltage from a circuit fused at least ten times the current input rating of the solenoid.

46 Motor Overload Test

46.1 A motor having a thermal protector or impedance protection complying with the requirements for such protection is considered to comply with the requirements in 46.2 – 46.7.

46.2 A product employing a motor rated at 1 horsepower (746 W output) or less shall incorporate thermal or overcurrent protection that will prevent the motor from attaining temperatures higher than those indicated in 46.3 and 46.4. The motor shall not burn out, nor shall there be other evidence of a risk of fire as a result of these tests.

46.3 When the motor is running under the maximum overload condition which it can carry without causing the protective device to operate, the temperature shall not exceed 140 °C (284 °F) on a Class A

insulated motor winding or 165 °C (329 °F) on a Class B insulated motor winding; except that this consideration does not apply to the motor of a fan or blower intended to move air only.

46.4 When the rotor of the motor is locked, the maximum acceptable temperature is 200 °C (392 °F) for a Class A insulated motor winding and 225 °C (437 °F) for a Class B insulated motor winding during the first hour of operation and is 175 °C (347 °F) for Class A and 200 °C for Class B thereafter. After the first hour of operation, the average temperature, found by taking the arithmetic mean of the maximum temperatures and the arithmetic mean of the minimum temperatures, shall not be more than 150 °C (302 °F) for Class A and 175 °C for Class B.

46.5 Temperatures are to be measured by thermocouples on the surface of coils of the motor. The test on a manual-reset device is to be continued for four operations of the protective device, with the device being reset as quickly as possible after it has opened. For an automatic-reset device, the locked-rotor test is to be continued for 72 hours. During the test, the motor is to be connected to a supply circuit of rated voltage. See 30.2.1.

46.6 An automatic-reset thermal protector of a motor shall perform successfully when operated for 360 hours (15 days) with the rotor of the motor locked, and with the motor connected to a supply circuit having a voltage of 100 – 110 percent of the rated voltage of the motor. There shall not be permanent damage to the motor, including excessive deterioration of the insulation. If the device permanently opens the circuit, it shall do so without grounding to the motor frame, damage to the motor, or introduction of a risk of fire. A manual-reset thermal protector of a motor shall interrupt the locked-rotor current of the motor for 50 operations, without damage to itself.

46.7 There shall not be ignition of cotton surrounding the enclosure of a thermal protector of a motor when three samples of the device are subjected to limited short-circuited currents. For a motor rated at 1/2 horsepower (373 W output) or less and 250 volts or less, the current is to be 200 amperes. For a motor having other ratings [and not more than 1 horsepower (746 W output) or more than 600 volts], it is to be 1000 amperes. The power factor of the test circuit is to be 0.9 – 1.0, and the circuit capacity is to be measured without the device in the circuit. A nonrenewable cartridge fuse is to be connected in series with the device under test. The fuse rating is not to be less than four times the rated current of the device; except that the fuse rating is not to be less than 20 amperes for a product rated 150 volts or less, and is not to be less than 15 amperes for a product rated more than 150 volts but not more than 600 volts. The test on one sample is to be made by closing the device on the short circuit.

46.8 The functioning of a motor-protective device provided as part of the unit (whether such device is required or not) shall not result in a risk of fire, electric shock, or injury to persons due to unintentional contact with hazardous moving parts.

46.9 Impedance protection is acceptable for motors, if it is determined that the motor will not overheat under locked-rotor conditions or other performance requirements in this standard.

47 Polymeric Materials Test

47.1 Polymeric materials used as an enclosure or for the support of current-carrying parts shall comply with the applicable portion of UL 746C.

48 Strain Relief Test

48.1 General

48.1.1 The strain relief means provided on a flexible cord shall be tested as described in 48.1.2. The strain relief is not to be used if, at the point of disconnection of the conductors, there is such movement of the cord as to indicate that stress would have resulted on the connections.

48.1.2 The strain relief means provided on a flexible cord is to be subjected to a pull of 35 pounds-force (156 N) applied to the cord with the connections within the product disconnected for 1 minute. To apply the force, a 35-pound (15.9 kg) weight is to be suspended on the cord and supported by the product so that the strain relief means will be stressed from any angle which the construction of the product permits.

48.2 Field-wiring leads

48.2.1 Each lead employed for field connections shall withstand for 1 minute a pull of 10 pounds (44.5 N) without any evidence of damage or of transmitting the stress to internal connections.

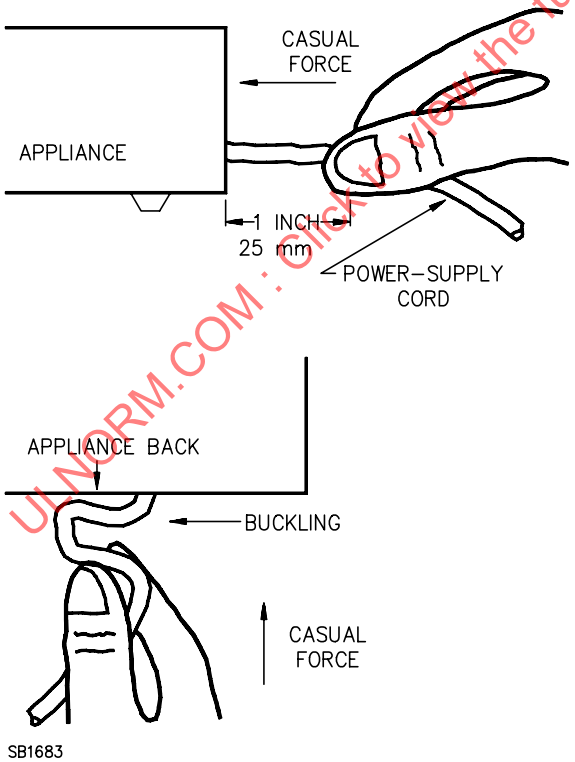
48.3 Push-back test

48.3.1 To determine compliance with 20.8.6, a product shall be tested in accordance with 48.3.2 without occurrence of any of the conditions specified in 20.8.6.

48.3.2 The supply cord or leads are to be held 1 inch (25.4 mm) from the point where the cord emerges from the product and is then to be pushed back with casual force as shown in Figure 48.1. The force is to be applied until the cord is buckled and in no case shall the force exceed 6 pounds-force (26.7 N).

Figure 48.1

Supply Cord or Lead Push-Back/Strain Relief Evaluation



49 Ignition Through Bottom-Panel Openings Tests

49.1 General

49.1.1 Both of the bottom-panel constructions described in 16.2.4 are not required to be tested. Other constructions are capable of being used when they pass the test described in 49.2.1 – 49.2.4.

Exception: This test does not apply to low-voltage, power-limited products or to products in which an internal fault does not produce flame, molten metal, flaming or glowing particles, or flaming drops.

49.2 Hot, flaming oil

49.2.1 Openings in a bottom panel shall be arranged and sufficiently small in size and few in number so that hot, flaming No. 2 furnace oil poured three times onto the openings from a position above the panel is extinguished as it passes through the openings.

49.2.2 A sample of the complete, finished bottom panel is to be securely supported in a horizontal position several inches above a horizontal surface under a hood or in another area that is well ventilated but free from significant drafts. One layer of bleached cheesecloth running 14 – 15 square yards to the pound (25.75 – 27.54 m^2/kg) and having a count of 32 by 28 is to be draped over a shallow, flat-bottomed pan that is of sufficient size and shape to cover completely the pattern of openings in the panel but is not large enough to catch any of the oil that runs over the edge of the panel or otherwise does not pass through the openings. The pan is to be centered under the pattern or openings in the panel. The center of the cheesecloth is to be 2 inches (51 mm) below the openings. Use of a metal screen or wired-glass enclosure surrounding the test area is recommended to prevent injury and other damage due to splattering of the oil.

49.2.3 A small metal ladle [preferably not more than 2-1/2 inches (63.5 mm) in diameter] with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring is to be partially filled with 10 milliliters of No. 2 furnace oil, that is a medium-volatile distillate having:

a) An API gravity of 32 – 36°;

b) A flash point of 44 – 73 °C (110 – 190 °F); and

c) An average calorific value of 136,900 Btu per gallon (39.7 MJ/liter) (see ASTM D396-97).

The ladle containing the oil is to be heated and the oil ignited and allowed to burn for 1 minute, at which time all of the hot, flaming oil is to be poured at a rate of approximately but not less than one milliliter per second in a steady stream onto the center of the pattern of openings from a position 4 inches (102 mm) above the openings.

49.2.4 Five minutes after completion of the pouring of the oil, the cheesecloth is to be replaced with a clean piece and a second 10 milliliters of hot, flaming oil is to be poured from the ladle onto the openings. Five minutes later, a third identical pouring is to be made. The openings are not to be used if the cheesecloth is ignited during any of the three pourings.

50 Mechanical Strength Tests for Enclosures

50.1 The external enclosure of a product using high-voltage and/or nonpower limited energy shall withstand the tests described in 50.2 and 50.3 without permanent distortion to the extent that spacings are reduced below the values specified in Spacings, Section 28, or transient distortion which results in contact with live parts, and without causing openings that would expose uninsulated live parts that involve risk of electric shock. Any openings that occur as a result of these tests are to be evaluated under the requirements in 16.2.2 and 16.2.3.

50.2 For the first test specified in 50.1, a force of 25 pounds (111 N) is to be applied to the enclosure for 1 minute. The force is to be applied by means of a 1/2-inch (12.7-mm) diameter hemisphere.

50.3 For the second test specified in 50.1, an impact of 5 foot-pounds (6.78 J) is to be applied to the enclosure. The impact is to be applied by means of a solid, smooth, steel sphere 2 inches (50.8 mm) in

diameter and weighing approximately 1.18 pounds (0.54 kg). The sphere is to fall freely from rest through a vertical distance of 51 inches (1.3 m).

50.4 The force described in 50.2 is to be 10 pounds (44 N) and the impact described in 50.3 is to be 2 foot-pounds (2.7 J) for products using low-voltage and power-limited energy.

51 Tests on Special Terminal Assemblies

51.1 General

51.1.1 For determination of its use as a field-wiring connection under 20.5.1 and 20.5.2, representative samples of the terminal assembly shall comply with the tests in 51.2.1 – 51.6.2.

Exception: Terminals complying with the requirements in any of the standards specified in 20.4.2 are not required to be subjected to these tests.

51.2 Disconnection and reconnection

51.2.1 If a wire is to be disconnected for testing or routine servicing and then reconnected, each terminal is to be subjected to 20 disconnections and 20 reconnections prior to the tests of 51.3.1 – 51.6.2.

51.3 Mechanical secureness

51.3.1 A terminal connection shall withstand the application of a straight pull of 5 pounds-force (22.2 N), applied for 1 minute to the wire in the direction which would most likely result in pullout, without separating from the wire.

51.3.2 Six samples of the terminals are to be connected to the intended wire sizes in accordance with the manufacturer's instructions. If a special tool is required it is to be used to assemble the connection. Each sample is to be subjected to a gradually increasing pull on the wire until the test force of 5 pounds (22.2 N) is reached.

51.4 Flexing test

51.4.1 The wire attached to a terminal shall withstand five right angle bends without breaking.

51.4.2 Twelve terminal assemblies prepared as described in 51.5.2 are to be subjected to this test. The terminal is to be rigidly secured so as to prevent any movement. With the wire subjected to a tension of 3 pounds-force (13.3 N) and held at a point 3 inches (76.2 mm) from the terminal-to-wire juncture, the wire is to be bent at a right angle from the nominal wire position. The tension on the wire is to hold the wire in a rigid position during the flexing trials.

51.5 Millivolt drop test

51.5.1 The millivolt drop across a terminal connection using the maximum and minimum wire sizes intended to be used with the terminals connected in series shall not be greater than 300 millivolts with the maximum current of the circuit flowing through the terminal connection at the rated voltage of the circuit.

51.5.2 Six terminal assemblies using the maximum wire sizes and six assemblies using the minimum wire sizes are to be tested. The wires are to be assembled to the terminals, using any special tool, if required, according to the manufacturer's instructions. The millivolt drop is then to be measured using a high impedance millivoltmeter with the maximum current, as specified by the manufacturer, flowing through the connection.

51.6 Temperature test

51.6.1 The maximum temperature rise on a terminal junction with the maximum and minimum wire sizes with which the terminal is used, connected in turn, shall not be greater than 30 °C (54 °F) based on an ambient temperature of 25 °C (77 °F).

51.6.2 Twelve terminal assemblies prepared as described in 51.5.2 are to be subjected to this test. The maximum current is then to be passed through the terminal connection to which the wire will be subjected in service. The maximum temperature rise is then to be measured by the thermocouple method in accordance with the Temperature Test, Section 43, after temperatures have stabilized.

MANUFACTURING AND PRODUCTION TESTS

52 General

52.1 To determine compliance with these requirements in production, the manufacturer shall provide the necessary production control, inspection, and tests. The program shall include at least the following tests. A record of accepted bullet-resisting equipment and the product serial number or equivalent is to be maintained.

53 Dielectric Voltage-Withstand Test

53.1 Each product rated at more than 30 volts AC rms (42.4 volts DC or AC peak) shall withstand, without breakdown, as a routine production-line test, the application of an essentially sinusoidal AC potential of a frequency within the range of 40 – 70 hertz, or a DC potential, between high-voltage live parts and the enclosure, between high-voltage live parts and exposed dead metal parts, and between live parts of circuits operating at different potentials or frequencies. The test potential is to be as indicated in Table 53.1.

Table 53.1
Production-Line Test Potentials

Product rating	Test potential			
	60 second test		1 second test	
	volts DC[a]	volts AC	volts DC[a]	volts AC
250 volts or less	1414	1000	1697	1200
More than 250 volts	1414 + 2.828V[b]	1000 + 2V[b]	1697 + 3.394V[b]	1200 + 2.4V[b]

[a] Peak DC voltage

[b] V = Rated AC rms voltage

53.2 If the product employs high-voltage and low-voltage circuits, the test is to be conducted with the low-voltage circuit connected to the cabinet, chassis, or other dead metal parts so that the potential which is applied between the high-voltage live parts and dead metal parts will simultaneously be applied between high-voltage live parts and low-voltage circuits.

53.3 A printed wiring assembly or other electronic circuit component that would be damaged by the application of, or would short-circuit, the test potential is to be removed, disconnected, or otherwise rendered inoperative before the test. A representative subassembly may be tested instead of an entire product. Rectifier diodes in the power supply may be individually shunted before the test to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits.