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SUBJECT 45A

OUTLINE OF INVESTIGATION

FOR

Transportable and Special Purpose Portable Electric Tools

Issue Number: 1

JUNE 1, 2007

Summary of Topics

This is the first issue of the Outline of Investigation for Transportable and Special Purpose Portable Electric Tools, which covers transportable and special purpose portable electric tools rated not more than 600V, and not more than 250 V for tools employing a universal motor.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net/ulforeword.html>

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APPENDIX A

Standards for Components.....	A1
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INTRODUCTION

1 Scope

1.1 These requirements cover transportable and special purpose portable electric tools rated not more than 600 V (at not more than 250 V if the tool employs a universal motor), for use in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 In addition these requirements cover accessories and attachments for use with transportable and special purpose portable electric tools. Specific requirements are outlined in Sections 62 – 66.

1.3 These requirements do not cover fixed or stationary electric tools, flexible-shaft tools, gardening appliances, garage equipment, soldering irons or guns, painting equipment, floor-finishing machines, or other equipment covered by individual requirements.

1.4 These requirements cover double-insulated transportable and special purpose portable electric tools. Specific requirements are given in Sections 57 – 61.

1.5 For the purpose of these requirements, tools are classified into two groups:

- a) A general-use tool is considered to be a tool (usually employing a universal motor) that ordinarily is subject to a wide fluctuation of load;
- b) A special-use tool is considered to be a tool intended for a particular operation not involving a wide variation of load.

1.6 These requirements cover an accessory and an attachment:

- a) Recommended by the manufacturer;
- b) Referred to in the instruction manual for a tool; or
- c) Packed with a tool.

1.7 These requirements do not cover accessories or attachments that:

- a) Are not provided with the tool; and
- b) Are not identified by catalog number or equivalent product designation in the instruction manual for the tool.

These requirements do not cover accessories or attachments mentioned in minicatalogs or flyers even if the catalog or flyer is provided with the tool.

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2 Components

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

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 outline, or
- b) Is superseded by a requirement in this outline.

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 Undated References

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

5 Glossary

5.1 In the following text, a requirement that applies only to a specific type or types of tools is so identified by a specific reference in the requirement to the type or types of equipment involved. Absence of such specific reference or use of the term tool indicates that the requirement applies to all of the types of equipment covered by this outline unless the context indicates otherwise.

5.2 For the purposes of this outline a hand-held, hand supported, or transportable tool is denoted by the term "tool."

5.3 For the purpose of these requirements the following definitions apply.

5.4 ATTACHMENT – A device attached to the housing or other component of the tool and may or may not attach to the spindle. Attachments include tables to convert hand held tools to bench mounted types; for example, a router table.

5.5 ACCESSORY – A device that is attached only to the spindle of the tool.

5.6 FIXED (STATIONARY) TOOL – A tool for which the workpiece is moved to the tool in order to perform an operation.

5.7 SPECIAL PURPOSE PORTABLE TOOL – A tool that is moved to the workpiece in order to perform the function for which it is intended and then removed. Generally, a special purpose portable tool is hand held or hand supported.

5.8 TRANSPORTABLE TOOL – A tool such as diamond core drills, drain cleaners, magnetic drills presses, pipe threaders, and pipe benders that is not hand supported during use and which is intended to be taken to the work piece to perform its intended function.

CONSTRUCTION

6 General

6.1 A tool shall employ materials throughout that are acceptable for the particular use.

7 Frame and Enclosure

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

7.2 The minimum thickness of cast metal shall be in accordance with Table 7.1.

Table 7.1
Minimum thicknesses of cast metal

Metal	At surfaces that are reinforced by curving, ribbing, or the like (or are otherwise of a shape and/or size to provide acceptable physical strength),		At unreinforced flat surfaces,	
	inch	(mm)	inch	(mm)
Die-cast metal	3/64	(1.2)	5/64	(2.0)
Cast malleable iron	1/16	(1.6)	3/32	(2.4)
Other cast metal	3/32	(2.4)	1/8	(3.2)

7.3 An enclosure of sheet metal is to be considered with respect to its size, shape, thickness of metal, and its acceptability for the particular application, including the intended use of the complete tool.

7.4 Among the factors taken into consideration when determining the acceptability of a nonmetallic enclosure or an enclosure of magnesium is each of the following items:

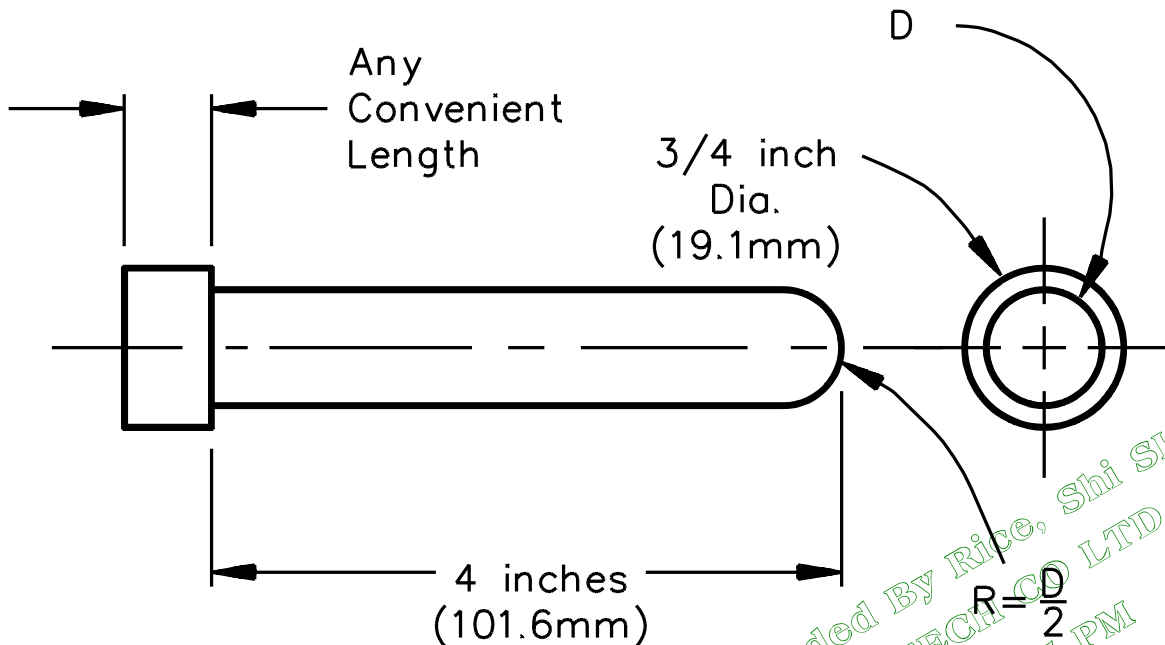
- a) Mechanical strength;
- b) Resistance to impact;
- c) Moisture-absorptive properties;
- d) Combustibility;
- e) Resistance to distortion at temperatures to which the material may be subjected under conditions of intended use and reasonably foreseeable abuse;
- f) Resistance to arcing.

7.5 Electrical parts of a tool shall be so located or enclosed that protection against unintentional contact with uninsulated live parts will be provided. Insulated brush caps do not require additional enclosure.

7.6 With reference to the requirement in 7.5, an opening in the enclosure of a tool that is hand-supported during intended use is acceptable if a probe, as illustrated in Figure 7.1, having a diameter of 3/8 in (9.5 mm) cannot be made to touch any uninsulated live part or film-coated wire when inserted through the opening. An opening in the enclosure of any other tool is acceptable in accordance with the following:

- a) An opening that will admit a 3/4 in (19.1 mm) diameter rod is acceptable if there is no uninsulated live part or film-coated wires in the space indicated in the illustration in Figure 7.2.
- b) An opening that will not admit a 3/4 in (19.1 mm) diameter rod is acceptable if:
 - 1) A probe as illustrated in Figure 7.1 having a diameter of 1/2 in (12.7 mm) cannot be made to touch film-coated wire when inserted through the opening; and
 - 2) A probe as illustrated in Figure 7.3 cannot be made to touch any uninsulated live part when inserted through the opening.

Figure 7.1
Probe for film-coated wire



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Figure 7.2
Opening in enclosure
 Proportions exaggerated for clarity

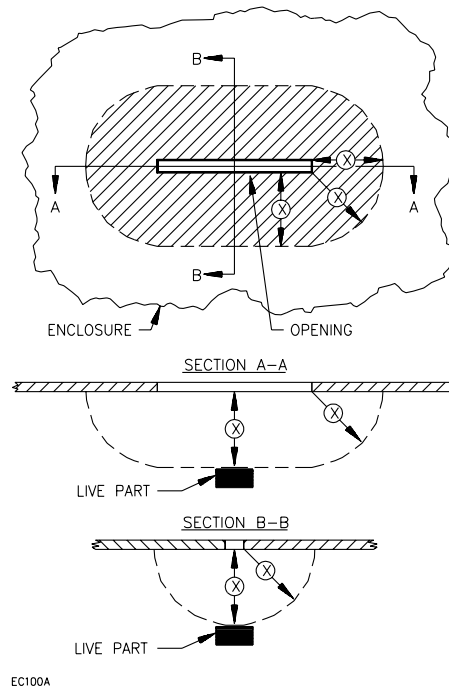
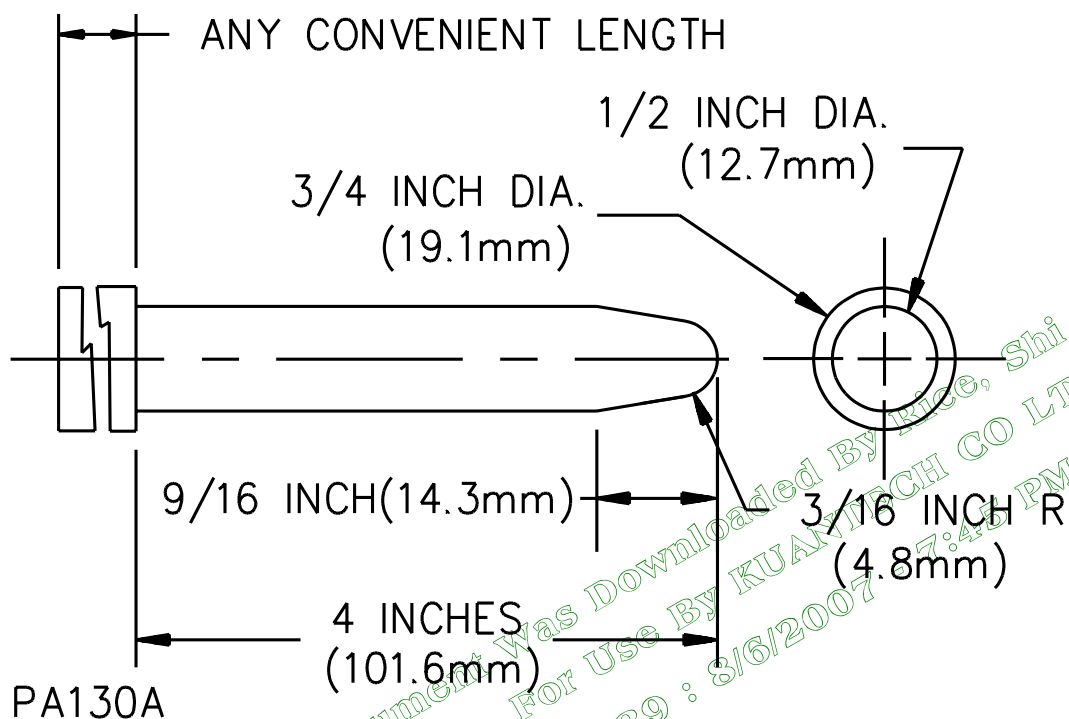


Figure 7.3
Probe for uninsulated live part



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7.7 An opening that has a minor dimension of 1 in (25.4 mm) or more in an enclosure as illustrated in Figure 7.2 is acceptable if, within the enclosure, there is no uninsulated live part or film-coated wire less than:

- a) R distance from the inside edge of the perimeter of the opening; and
- b) X distance from the plane of the opening.

T equals the enclosure thickness, R equals X minus T, and X equals five times the diameter of the largest round rod that can be inserted through the opening but not less than 6-1/16 in (154 mm). In evaluating an opening, any barrier located within the volume is to be ignored unless it intersects the boundaries of the volume in a continuous, closed line.

7.8 During examination of a tool in connection with 7.6, a part of the outer enclosure that is intended to be removed, without the use of tools, by the user of the tool (for the attachment of accessories, access to means for making operating adjustments, or other reasons) is to be disregarded – that is, such a part is not considered to reduce the risk of electric shock.

7.9 The enclosure of a tool or of a control unit or auxiliary component, such as a rheostat or a rectifier, that is not integral with the tool proper shall exclude foreign matter – abrasive or electrically conductive particles and the like – likely to be present during operation that might adversely affect electrical insulation or otherwise result in risk of fire, electric shock, or injury to persons.

8 Mechanical Assembly

8.1 A tool shall be so assembled that it will not be affected adversely by the vibration of intended operation.

8.2 A brush cap shall be tightly threaded or otherwise constructed so that it does not loosen.

8.3 A switch, an attachment-plug receptacle, and a plug connector shall be mounted securely and shall be prevented, by means other than friction between surfaces, from turning or shifting to the extent of:

- a) Reducing spacings below the minimum acceptable values;
- b) Applying stress to connections; or
- c) Flexing leads.

8.4 A properly applied lock washer is acceptable as a means to prevent turning of a switch or other device having single-hole mounting means.

8.5 A tool shall be so constructed that user-maintenance can be accomplished without the likelihood of:

- a) Pinching leads;
- b) Reducing spacings to values less than those indicated in Table 19.1;
- c) Mislocating or damaging the means for accomplishing strain relief; and
- d) Mislocating or damaging a guard or other similar device.

8.6 User-maintenance is considered to consist of inspection of or replacement of motor brushes or fuses and other service that is recommended in the instruction manual to be performed by the user. It does not include maintenance that the instruction manual recommends be done by authorized service personnel.

8.7 Compliance with the requirement in 8.5 may be accomplished by routing of wires, provision of wire channels, provision of locating wells for components, use of barriers, use of restraints, securing of components, and other means.

8.8 Routing as mentioned in 8.7 is acceptable if the construction is such that after the wire has been put into the intended position preparatory to the reassembling of the tool, that the reassembly procedure will not result in the wire contacting a moving part or being pinched. This does not mean that the wire must be of such length or so clamped that it cannot reach the pinch point or the moving part.

8.9 A tool employing a soft rubber, neoprene, or polyvinyl chloride pressure pad to hold down or maintain permanent position of an electrical part, such as a motor, to provide for intended functioning of the tool shall be tested in accordance with 41.1. If the pressure pad is exposed to grease, it shall also be tested in accordance with 41.2.

Exception: The test is not required if a risk of fire or electric shock does not result from deterioration of the pad as determined by an abnormal operation test in which the tool is operated without the pressure pad.

9 Protection Against Corrosion

9.1 Except as noted in 9.2, iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means if deterioration or breakage of such parts would be likely to result in a risk of fire, electric shock, or injury to persons.

9.2 If the oxidation of iron or steel due to the exposure of the metal to air and moisture is not likely to be appreciable – thickness of metal and temperature also being factors – the surfaces of sheet steel and cast-iron parts in an enclosure may not be required to be protected against corrosion. The requirement in 9.1 does not apply to bearings, laminations, and minor parts of iron or steel, such as washers, screws, and the like.

10 Power Supply Cords

10.1 Cords and plugs

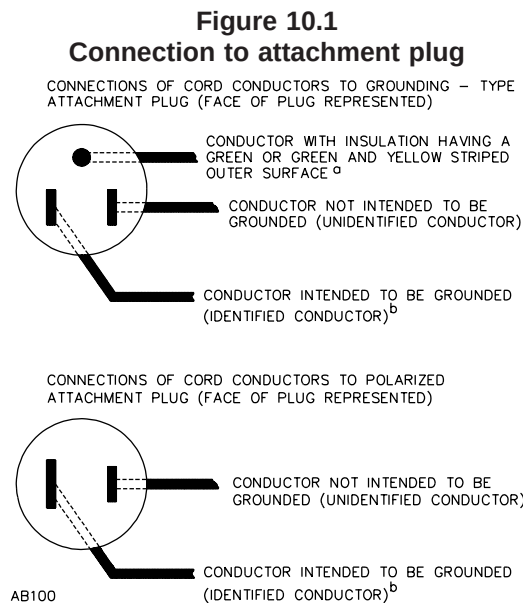
10.1.1 A tool shall be provided with flexible cord, permanently attached to the tool, and with an attachment plug, which may be of the locking type, for connection to the power-supply circuit.

10.1.2 Except as noted in 10.1.3, the flexible cord on all other tools shall be at least 5 ft (1.5 m) long.

10.1.3 A tool may be provided with less than 5 ft (1.5 m) of permanently attached flexible cord (see 10.1.5) or with a motor attachment plug if:

- a) The manufacturer makes an acceptable extension cord available, and if a statement indicating the availability of such extension cord is marked on the tool or is included in the instruction book or the like regularly furnished with the tool; or
- b) The manufacturer furnishes an acceptable detachable cord set, 5 ft (1.5 m) or more in length, with the tool. If several tools are packaged and marked together, only one cord set need be furnished with the group of tools.

10.1.4 If a 3-wire grounding type attachment plug or a 2-wire polarized attachment plug is provided, the attachment plug connections shall be as shown in Figure 10.1. See 10.1.1.



^a The blade to which the green conductor is connected may have a U-shaped or circular cross section.

^b Signifies a conductor identified in accordance with Table 10.1.

Table 10.1
Polarity identification of flexible cords

Method of identification	Acceptable combinations	
	Wire intended to be grounded ^a	All other wires
Color of braids on individual conductors	A Solid white or gray – without tracer	Solid color other than white or gray – without tracer
	B Color other than white or gray, with tracer in braid	Solid color other than white or gray – without tracer
Color of insulation on individual conductors	C Solid white or gray	Solid color other than white or gray
	C1 Light blue	Solid color other than light blue, white, or gray
^a A wire finished to show a green color with or without one or more yellow stripes or tracers is to be used as an equipment grounding conductor.		

10.1.5 The power supply cord mentioned in 10.1.3 shall be of such length that it cannot be damaged or impaired by any cutting edges, blades, belts, or rotating parts, and shall not be more than 18 in (457 mm) in length in any case.

10.1.6 A three-to-two wire grounding-type adapter shall not be provided with a tool employing a short cord as described in 10.1.4 unless an acceptable 3-wire grounding-type extension cord set is also provided with the tools.

10.1.7 Except as noted in 10.1.8, the flexible cord shall be hard-service cord, such as Type SJ, or extra-hard-service cord, such as Type S.

10.1.8 A light weight hand-held sharpening tool, such as a chain saw sharpener, may employ Type SVT or SV, or equivalent jacketed cord having 36 AWG (0.0127 mm²) individual strands.

10.1.9 If a lamp having a separate power supply cord is provided as a part of a tool, the cord for the lamp shall be the same type as that specified for the tool.

10.1.10 The flexible cord shall be rated for use at a voltage not less than the rated voltage of the tool, and shall have an ampacity, as given in the National Electrical Code, ANSI/NFPA 70, not less than the current rating of the tool.

10.1.11 The attachment plug shall be acceptable for use with a current not less than the rated current, and at the rated voltage of the tool. If the tool is adaptable for use on two or more different values of voltage by field alteration of internal connections, the attachment plug provided with the tool shall be rated for the voltage for which the tool is connected when shipped from the factory. See 52.8.

10.1.12 A tool intended for use with a detachable power supply cord shall not be provided with terminal pins that will accommodate a standard flatiron or appliance plug.

10.1.13 If a tool incorporates a disconnecting means, such as a cord connector in the power supply cord, the arrangement shall be such that no live parts will be exposed under any normal conditions.

10.2 Strain relief

10.2.1 Strain relief shall be provided to prevent a mechanical stress on a flexible cord from being transmitted to terminals, splices, or internal wiring.

10.2.2 A metal strain relief clamp or band is acceptable with a Type SP-2, SPE2, SPT2, SVT, SVTO, or SVTOO cord only if auxiliary nonconductive protection is provided over the cord. A metal strain relief clamp or band without auxiliary protection is acceptable for other cord types.

10.2.3 Means shall be provided to prevent the flexible cord from being pushed into the tool through the cord-entry hole if such displacement may expose the cord to mechanical damage or to a temperature higher than that for which the cord is rated, or is likely to reduce spacings, such as to a metal strain relief clamp, below the minimum acceptable values.

10.2.4 If a knot in a flexible cord serves as strain relief, the surface against which the knot may bear or with which it may come in contact shall be free from projections, sharp edges, burrs, fins, and the like, that may cause abrasion of the cord jacket or the insulation on the conductors.

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10.2.5 The strain relief provided on the power supply cord shall be independent of any rubber cord guard unless the guard is molded on the cord or has been determined to be acceptable for the particular application.

10.3 Bushings

10.3.1 At a point at which a flexible cord passes through an opening in a wall, barrier, or enclosing case, there shall be a bushing or the equivalent that shall be acceptably constructed and secured in place, and shall have a smooth, round surface on which the cord may bear. If Type SP-2 or SPT-2 cord is employed and if the wall or barrier is of metal, an insulating bushing shall be provided.

10.3.2 If the cord-entry hole is in porcelain, phenolic composition, or other equivalent insulating material, a smooth, round surface is considered to be equivalent to a bushing.

10.3.3 Ceramic materials and some molded compositions are acceptable generally for insulating bushings; but separate bushings of wood or of so-called hot-molded shellac and tar compositions are not acceptable.

10.3.4 Vulcanized fiber may be employed if the bushing is not less than 3/64 in (1.2 mm) thick, and if it is so formed and secured in place that it will not be affected adversely by conditions of ordinary moisture.

10.3.5 An acceptable separate soft-rubber, neoprene, or polyvinyl chloride bushing may be employed in the frame of a motor or in the enclosure of a capacitor attached to a motor (but not elsewhere in the tool, except as noted in 10.3.6), if:

- a) The bushing is not less than 1/16 in (1.6 mm) thick; and
- b) The bushing is so located that it will not be exposed to oil, grease, oily vapor, or any other substance having a deleterious effect on the compound employed.

10.3.6 A bushing of any of the materials mentioned in 10.3.5 may be employed at any point in a tool if used with cord of a type for which an insulating bushing is not required. See 10.3.1.

10.3.7 If a bushing of one of the materials mentioned in 10.3.5 is used, the edges of the hole in which the bushing is mounted shall be smooth and free from fins, burrs, and the like, regardless of the type of cord involved.

10.3.8 At any point in a tool, a bushing of the same material as, and molded integrally with, the supply cord is acceptable on a Type SP-2 or heavier cord if the built-up section is not less than 1/16 in (1.6 mm) thick at the point where the cord passes through the enclosure. An insulating metal grommet may be accepted in place of an insulated bushing if the insulating material used is not less than 1/32 in (0.8 mm) thick and completely fills the space between the grommet and the metal in which it is mounted.

11 Live Parts

11.1 Metal employed for a current-carrying part shall be silver, copper, a copper alloy, or other metal that is acceptable for the particular application.

11.2 Iron or steel with a corrosion-resistant coating may be used for a current-carrying part:

- a) If permitted in accordance with Section 2; or
- b) Within a motor or associated governor.

The use of unprotected iron or steel for current-carrying parts elsewhere in a tool is not acceptable.

11.3 An uninsulated live part shall be so secured to the surface on which it is mounted, and supporting insulating materials shall be so secured in place, that it will be prevented from turning or shifting in position, if such motion may result in a reduction of spacing below the minimum acceptable values. A brushholder connector shall be acceptably captivated independently of the brush.

11.4 Friction between surfaces is not acceptable as a means to prevent turning or shifting of uninsulated live parts; but a lock washer, properly applied, is acceptable for this purpose.

12 Internal Wiring

12.1 The wiring and the connections between parts of a tool shall be protected or enclosed, except that a length of flexible cord may be employed for external interconnection between components if flexibility is essential.

12.2 With reference to exposure of internal wiring through an opening in the enclosure of a tool, the protection of the wiring required by 12.1 is considered to exist if, when considered as though it were film-coated wire, the wiring would be acceptable according to 7.6. Internal wiring not so protected may be acceptable if it is so secured within the enclosure that it is unlikely to be subjected to stress or mechanical damage.

12.3 Internal wiring of a tool shall consist of wires that are acceptable for the particular application when considered with respect to:

- a) The temperature and voltage to which the wire is likely to be subjected;
- b) Exposure to oil, grease, or other substances likely to have a deleterious effect; and
- c) Other conditions of service to which it is likely to be subjected.

12.4 Thermoplastic-insulated, or neoprene-insulated wire, used for internal wiring shall be standard building wire or appliance wiring material and shall comply with Table 12.1.

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Table 12.1
Characteristics of internal wiring

Insulation	Nominal wall thickness of insulation,		Braid or jacket required	Nominal thickness of braid or jacket,	
	Inch	(mm)		Inch	(mm)
Thermoplastic or neoprene	0.030 ^a	(0.76)	No ^a	—	
Cross-linked synthetic polymer	0.015	(0.38)	No	—	
^a The wall thickness may not be less than 0.015 in (0.38 mm) if the wire is provided with a braid or jacket not less than 0.015 in (0.38 mm) thick.					

12.5 Insulating tubing employed instead of wire insulation shall be acceptable for the application and shall have a wall thickness of not less than 1/32 in (0.8 mm).

12.6 Wiring shall be protected from sharp edges (including screw threads), burrs, moving parts, and other agencies that might cause abrasion of the insulation of conductors.

12.7 A hole through which insulated wires pass in a sheet-metal wall within the overall enclosure of a tool shall be provided with a smooth, rounded bushing or shall have smooth, well-rounded surfaces upon which the wires may bear to prevent abrasion of the insulation. A flexible cord used for external interconnection as mentioned in 12.1 shall be provided with a bushing and strain relief in accordance with 10.2.1 – 10.3.8 and Section 39 unless the construction is such that the cord will be protected from stress and motion.

12.8 Insulated wires may be bunched and passed through a single opening in a metal wall within the enclosure of a tool.

12.9 Film-coated wire employed as a jumper between a coil and a brush holder or switch shall be secured in place unless there is no likelihood of its contacting other live parts or dead metal parts if breakage occurs as a result of vibration.

12.10 All splices and connections shall be mechanically secure and shall provide acceptable electrical contact. A soldered connection shall be made mechanically secure before being soldered.

12.11 A tool shall be so constructed that if a wire breaks, loosens, or otherwise becomes free to move at a switch termination the enclosure will not be made live and no live part will project from the enclosure.

12.12 Compliance with the requirement in 12.11 may be accomplished by use of barriers, by relative placement of parts, by mechanical restraint of the conductor in addition to that resulting from its electrical connections, or by other equivalent means.

12.13 On a tool in which excessive vibration is likely to occur (such as an impact tool), the requirements in 12.10 necessitate the use of lock washers or other acceptable means to prevent wire-binding screws and nuts from becoming loosened.

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12.14 An open-end spade lug is not acceptable unless additional means (such as upturned ends on the lug, bosses, shoulders, and the like) are provided to hold the lug in place should the wire-binding screw or nut become slightly loosened.

12.15 A wire-binding screw shall thread into metal.

12.16 A splice shall be provided with insulation if permanence of spacings between the splice and other metal parts may not be maintained.

12.17 The thickness of insulation on a splice shall be 1/32 in (0.8 mm) or more. In determining if splice insulation consisting of coated fabric, thermoplastic, or other tubing is acceptable, consideration is given to such factors as its dielectric properties, heat-resistant and moisture-resistant characteristics, and the like. Thermoplastic tape wrapped over a sharp edge is not acceptable.

12.18 Stranded internal wiring shall be so connected to a wire-binding screw that loose strands of wire will be prevented from contacting other uninsulated live parts not always of the same polarity as the wire, and from contacting dead metal parts. This may be accomplished by use of pressure terminal connectors, crimped eyelets, soldering all strands of the wire together, or other equivalent means.

12.19 In a hammer, impact wrench, or other tool, the intended use of which causes severe vibration, a splicing device of the thread-on or setscrew type shall be additionally secured by wrapping the wires and the connector with friction tape or by other equivalent means.

Exception: This requirement does not apply to double-insulated tools.

13 Insulating Material

13.1 Material for the mounting of uninsulated live parts shall be phenolic composition, cold molded composition, or other material that is acceptable for the particular application.

13.2 Vulcanized fiber may be used for insulating bushings, washers, separators, brushholder liners, and barriers, but not as the sole support for uninsulated live parts where shrinkage, current leakage, or warpage may introduce a condition likely to result in a risk of fire or electric shock. Thermoplastic materials may be employed for sole support of uninsulated live parts only if found to have mechanical strength and rigidity, resistance to heat, resistance to flame propagation, dielectric properties, resistance to arc tracking, and other properties that are acceptable for the application.

13.3 A molded part shall be so constructed that it will have mechanical strength and rigidity to withstand stresses likely to occur in service. A brush cap shall be protected from mechanical damage, by recessing or other means, that might occur unless the part has the strength necessary to withstand the abuses to which it is likely to be subjected.

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14 Motors

14.1 The motor of a tool shall drive the maximum intended load of the tool without introducing a risk of fire, electric shock, or injury to persons.

14.2 A motor winding shall resist the absorption of moisture and shall be formed and assembled in a workmanlike manner.

14.3 A brushholder assembly shall be constructed so that when a brush is worn out – no longer capable of performing its function – the brush, spring, and other parts of the assembly shall be retained to the degree necessary so that:

- a) An accessible dead metal part does not become energized; and
- b) A live part does not become accessible.

15 Switches and Controls

15.1 A switch or other control device shall be acceptable for the application, with a voltage rating and an ampacity not less than the corresponding values of the load that it controls.

15.2 A tool shall not employ a through-cord switch.

15.3 A single-pole switch employed in a tool having a nominal rating of 120 V shall be connected in the ungrounded conductor circuit.

16 Lampholders

16.1 If a tool is intended to be connected to the grounded conductor of the power-supply circuit, a lampholder comprising part of the tool shall be so wired that the screw shell will be connected to that conductor.

17 Thermal Cutoffs

17.1 If a thermal cutoff is used as noted in 59.7.1.2, it shall comply with the requirements applicable to such a device in addition to the applicable requirements in this standard. A thermal cutoff shall comply with the applicable requirements in this standard and those in the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

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18 Capacitors

18.1 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 or power-factor correction, shall be housed within an enclosure or a container that will protect the plates against mechanical damage and will contain the emission of flame or molten material resulting from malfunction of the capacitor. The container shall be of metal providing strength and protection not less than that of uncoated steel having a thickness of 0.020 in (0.51 mm). Sheet metal having a thickness less than 0.026 in (0.66 mm) is not recommended.

18.2 The individual container of a capacitor may be of sheet metal thinner than that mentioned in 18.1 or may be of material other than metal if the capacitor is mounted in an enclosure that houses other parts of the tool and if such a box, case, or the like, is acceptable for the enclosure of live parts.

18.3 The total capacitance of capacitors connected from one side of the line to the frame or enclosure of a tool shall not be such as to permit the flow of more than 0.5 mA in the grounding conductor when the frame or enclosure is connected to ground. See also 31.1.

19 Spacings

19.1 Except as noted in 19.2, the spacing between uninsulated live parts of opposite polarity, and between an uninsulated live part and a dead metal part, shall not be less than the value indicated in Table 19.1. If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the spacing will not be reduced to less than the minimum acceptable value.

Table 19.1
Minimum spacings

Potential involved, volts	Motor diameter 7 in (178 mm) or less ^c				Motor diameter more than 7 in (178 mm) ^c			
	Over surface		Through air		Over surface		Through air	
	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)
0 – 125	3/32	(2.4)	3/32	(2.4)	1/4 ^{a,b}	(6.4)	1/8 ^{a,b}	(3.2)
126 – 250	3/32	(2.4)	3/32	(2.4)	1/4 ^{a,b}	(6.4)	1/4 ^{a,b}	(6.4)
251 – 600	1/2	(12.7)	3/8 ^b	(9.5)	1/2 ^b	(12.7)	3/8 ^b	(9.5)

^a Spacings of not less than 3/32 in (2.4 mm) are acceptable throughout a universal motor.

^b Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 in (2.4 mm) – over surface and through air – between film-coated wire, rigidly supported and held in place on a coil, and a dead metal part is acceptable.

^c This is the diameter, measured in the plane of a lamination, of the circle circumscribing the stator frame excluding lugs, boxes, and the like used solely for motor mounting, assembly, or connection.

19.2 The spacing requirements given in Table 19.1 do not apply to the inherent spacings of a component of the tool, such as a snap switch; such spacings are considered on the basis of the requirements covering the component in question. For a repulsion motor, a repulsion-induction motor, or a repulsion-start induction motor the spacing requirements do not apply to the commutator, the brush assembly, and the jumpers that short-circuit the brushes. Any uninsulated conductor of the rotor circuit is regarded as a dead metal part with respect to the stator circuit, and the appropriate spacing is required between uninsulated rotor and stator conductors.

19.3 In the application of Table 19.1 to the motor not rated in horsepower, use is to be made of the appropriate table in the National Electrical Code, ANSI/NFPA 70, that gives the relationships between horsepower and full-load currents for motors. The table applying to single-phase alternating-current motors is to be used for a universal motor.

19.4 At terminal screws and studs to which connection may be made in the field by wire connectors, eyelets, and the like, and at garter springs of brushes, the spacings shall not be less than those shown in Table 19.1 when such connectors, eyelets, and similar parts are in such position that minimum spacings (opposite polarity and to dead metal) exist.

19.5 An insulating liner or barrier of vulcanized fiber or similar material employed where a spacing would otherwise be less than the minimum acceptable value shall not be less than 1/32 in (0.8 mm) thick, and shall be so located or of such material that it will not be affected adversely by arcing; except that vulcanized fiber not less than 1/64 in (0.4 mm) thick may be used in conjunction with an air spacing of not less than 50 percent of the spacing required for air alone.

19.6 A printed wiring board with spacings between circuits of opposite polarity and potentials less than those required is acceptable provided that the spacings:

a) Are located on a portion of the printed wiring board provided with a conformal coating which complies with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; and:

- 1) Applied at no less than the required thickness; and
- 2) Complies with the dielectric voltage withstand test in 35.7;

b) Are located on a portion of the printed wiring board provided with an epoxy coating not less than 1/32 in thick and:

- 1) Having a minimum spacing of not less than 1/32 in; and
- 2) Complying with the dielectric voltage withstand test in 35.7; or

c) Are connected to the load side of a resistor where a short circuit at that point does not result in the resistor wattage exceeding the resistor rating.

Exception: Spacings on a printed wiring board may alternatively be evaluated to the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, in accordance with 19.7.

19.7 For the purpose of determining suitability of spacings in accordance with the exception to 19.6, a tool is considered to operate in a pollution degree 3 environment. For a tool employing a conformal coating to comply with pollution degree 1 criteria or a solder mask or unevaluated conformal coating used to achieve a Pollution Degree 2 level shall be used according to the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the conformal coatings shall be used in accordance with its ratings, and applied in accordance with the coating manufacturer's instructions.

20 Grounding

20.1 The power supply cord of a tool shall include an equipment-grounding conductor.

20.2 An equipment-grounding conductor in a flexible cord shall be:

- a) Finished to show a green color with or without one or more yellow stripes;
- b) Connected to the grounding member of an attachment plug of the grounding type; and
- c) Conductively connected to:
 - 1) All exposed dead metal parts that are likely to become energized; and
 - 2) All dead metal parts within the enclosure that are exposed to contact during user servicing and that are likely to become energized.

The grounding conductor shall be connected by means of a screw or equivalent means not likely to be removed during any servicing operation; solder alone shall not be used for securing this conductor.

20.3 The screw mentioned in 20.2(c) shall be of corrosion-resistant metal or shall be protected against corrosion. A lock washer or other equivalent means shall be employed to prevent the screw from being loosened by vibration.

20.4 The grounding member of the attachment plug mentioned in 20.2(b) shall be fixed in position with respect to the plug unless the tool is hand-supported.

21 Insulating Surfaces

21.1 Tools likely to cut into live wiring in a wall or their own cords, shall have an insulating handle of a type that will make it convenient to use the tool grasping this handle, and shall be marked as described in 52.25. If the tool is not double insulated, the switch trigger shall be of insulating material or have double insulation between the trigger and live parts of the switch. The switch shall either be a double pole switch or a single pole switch that opens the ungrounded conductor, and used in combination with a polarized or grounding type attachment plug. The switch shall be located in the handle with an outer surface of non-conductive material.

Exception: A low voltage battery-operated portable tool need not be provided with a double pole switch.

21.2 A drain cleaner shall have insulated surfaces for the two surfaces most likely to be grasped during operation of the tool, unless it is convenient to use the tool using a single insulated grasping surface only, as specified in 21.1.

21.3 All auxiliary type handles on the tools mentioned in 21.1 and 21.2 shall have insulating material on the outer surfaces for at least the area that is intended to be grasped or touched during operation. Examples of auxiliary handles include: spade type handles, "D" shaped handles, pipe handles, or stick type handles.

21.4 A stick type auxiliary handle, that is required to be insulated, and that is provided as a grasping area, shall be:

- a) Provided with a flange of insulating material located on the tool side of the grasping surface with a height not less than 3/4 in (19 mm) above any point around the circumference of the handle at the flange base, unless the tool housing serves as an insulating flange; and
- b) Insulated along the full length of the grasping surface to the flanges or housing.

21.5 A bolt, screw, or other mounting hardware in an area likely to be grasped during operation that secures a covering of insulating material to a metal enclosure and threads into a metal enclosure containing electrical components or into a metal enclosure that contacts another metal enclosure containing electrical components shall be one of the following:

- a) Of insulating material;
- b) Provided with a layer of insulation between the hardware and the metal enclosure equivalent to supplementary (protecting) insulation;
- c) Inaccessible to the probe illustrated in Figure 7.1, having a diameter of 3/8 in (9.5 mm), when inserted to a depth of 1 in (25.4 mm); or
- d) Recessed not less than 1/8 in (3.2 mm) below the outer surfaces of the insulating material if the opening will not admit a 3/8 in (9.5 mm) diameter cylinder rod.

21.6 As described in 21.1 – 21.5, the outer surface of a handle or other area likely to be grasped may be of electrically conductive material provided it is:

- a) Separated from internal live parts by at least two separate insulating systems;
- b) Spaced not less than 3/32 in (2.4 mm) from any dead metal part insulated from a live part by basic insulation only; and
- c) For a tool likely to cut into wiring in a wall or its own cord, isolated from the cutting tool.

21.7 As described in 21.1 – 21.6, the insulating material on the outer surface of a handle or in an area likely to be grasped shall be acceptable for its intended application.

21.8 If the insulating material mentioned in 21.1 – 21.7 overlies dead metal, the material shall be tested as described in 45.3.1.

21.9 Tools not likely to cut into wiring or its own cord as described in 21.1 need not have an outer surface of insulating material if it has:

- a) A switch with a trigger of insulating material; or
- b) A switch with double insulation or reinforced insulation between the trigger and the live parts of the switch.

PROTECTION AGAINST INJURY TO PERSONS

22 Scope

22.1 This section gives the requirements for tools covered by this outline the operation of which may involve an injury to the operator or a bystander in the work area.

22.2 During examination of a tool with respect to risk of injury to persons, the general requirements for such features as materials, enclosures, guards, and the like will be applied, along with appropriate requirements for tests, construction, markings, guards, and the like, that apply to that tool. The requirements given in Sections 23 – 28 apply to tools of common constructions, and specific features of tools that are not contemplated herein will be given consideration. A specific requirement pertaining to a particular tool takes precedence over the requirement specified in the general section.

22.3 To determine the SFPM for peripheral surface, the following formula may be employed:

$$SFPM = \frac{3.1416 \times D \times RPM}{12}$$

in which:

SFPM is surface ft/min,

D is diameter in inches, and

RPM is revolutions/min.

23 Accessories and Attachments

23.1 Operation of a tool with an accessory or an attachment, see 1.6, 1.7 and 5.2, shall not increase the risk of injury to persons. See Sections 62 – 66 for specific requirements regarding accessories and attachments.

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24 Materials

24.1 The material of a part such as an enclosure, a frame, or a guard, the breakdown of which might result in a risk of injury to persons shall have such properties as to meet the demand of expected loading conditions.

25 Rotating Members

25.1 A tool employing a user-removable rotating part secured by a threaded member, such as a blade or a grinding wheel, shall be so constructed that the direction of rotation tends to tighten the nut that secures the rotating part in place.

25.2 Unless secured as described in 25.1, a removable rotating part not intended to be removed by the user shall be secured by a keyed nut, a jam nut, a nut locked in place with a pin, or other positive means.

26 Enclosures and Guards

26.1 A moving part shall be so enclosed or guarded as to acceptably reduce the likelihood of injury to persons, except only as such part is necessarily exposed during intended operation of the tool.

26.2 Among the factors to be considered in determining the acceptability of an exposed moving part are:

- a) The degree of exposure;
- b) The sharpness of the moving part;
- c) The likelihood of unintentional contact therewith;
- d) The speed of the moving part; and
- e) The likelihood that fingers, arms, feet, or clothing would be endangered by the moving part.

These factors are to be considered with respect to the intended operation of the tool and also during setting of any adjustment or replacement of any tool.

26.3 Some guards provided over moving parts are required to be of the self-restoring type. Other features of guards that will be considered include each of the following:

- a) Removability of the guard without the use of tools;
- b) Removability for servicing and the need for replacement;
- c) Strength and rigidity;
- d) Completeness; and
- e) Creation of additional risks, such as pinch points, and the necessity for additional handling because of increased need for servicing, such as cleaning and unjamming.

26.4 Except for an opening for the cutting edge of a tool, an opening in a guard or enclosure around a moving part capable of causing injury, such as a cutting tool, fan, pulley or gear, shall have a baffle to prevent contact with that part or the opening shall have a minor dimension less than 1 in (25.4 mm).

26.5 The unobstructed distance from the opening to the moving part mentioned in 26.4 shall not be less than $8D-1.5$ in ($8D-38.1$ mm), in which D is the minor dimension of the opening in inches (mm), except that a fan is considered to be acceptably guarded if it cannot be contacted with the probe described in Figure 7.3 having a diameter of $1/2$ in (12.7 mm).

26.6 The enclosure or guard around a rotating member shall be complete from the standpoint of number and size of the openings provided, and shall have such strength as to contain a member or part of a member, such as a grinding wheel, or a carbide-tipped saw blade, that, because of breakage or other reason, might become loose or separate from the rotating member and strike the guard.

27 Switches and Controls

27.1 A device that automatically starts a tool, such as a timer, an automatically reset overload protective device, or the like, shall not be employed unless it can be demonstrated that automatic starting will not result in a risk of injury to persons.

27.2 An on-off switch or control shall be provided on a tool.

27.3 If unintentional operation of a switch, including a reversing switch, can result in risk of injury to persons, the switch shall be so located or guarded that such operation is unlikely.

27.4 A switch, other than a momentary-contact switch, that controls the motor of a tool shall have a marked off position if the tool, when energized, has moving parts that are likely to cause injury to persons.

27.5 A maintained-contact on-off switch or a momentary-contact switch that can be locked in the on position shall not be provided on a tool if a risk of injury to persons is likely to result if the tool is energized while unattended. See 27.6 – 27.10.

27.6 A combination tool shall be provided with a momentary-contact switch with no provision for being locked in the on position:

Exception: A combination tool may be provided with a maintained contact on-off switch or with a momentary-contact switch having a means for locking the on-off switch in the on position, if all functions of the tools are functions for which the type of switch used would be acceptable.

27.7 An on-off switch may be provided with a means for locking the switch in the on position if the switch can be unlocked with a single motion of the same finger or fingers that turns it on.

27.8 A lock-on device mentioned in 27.7 shall be located outside the grasping area or designed such that it is not likely to be unintentionally locked on by the user's hand during intended left or right handed operation.

27.9 Compliance with the requirement in 27.8 can be accomplished by recessing the lock-on button or by placement outside the grasping area of the lock-on device. If located within the grasping surface area, the lock-on device shall not be actuated by a straight-edge utensil when the utensil is made to pass back and forth across the device in any direction. The straight-edge utensil is to be of any convenient length sufficient to bridge the surface of the lock-on device and any surface adjacent to the lock-on device.

27.10 When the power-supply cord of a tool is plugged in, unexpected operation can result in a risk of injury to persons. Consideration is to be given to risks that may occur if an unattended tool is energized with the cutting tool or abrading surface in contact with the supporting surface.

28 Combination Tools

28.1 A motor unit intended to be used with an attachment provided by the unit manufacturer shall be guarded against risk of injury to persons with and without the attachment applied to the motor unit.

28.2 A guard required on an individual tool shall be integral with the tool or shall be permanently attached. Each attachment shall be provided with its own guard, or a universal guard may be provided on the basic tool if it provides protection for each attachment to be used with the tool.

28.3 If a tool is converted by an attachment to a combination that falls within the scope of another standard, the combination shall comply with the appropriate guarding requirements therefore.

PERFORMANCE

29 General

29.1 If the tool has a single frequency rating, the test is to be made at that frequency. A tool rated alternating current/direct current, or direct current - 60 Hz, is to be tested on direct current or on 60 Hz alternating current, whichever results in higher temperatures. A tool rated 25 – 60 Hz or 50 – 60 Hz is to be tested on 60-Hz alternating current.

29.2 Except as indicated in 29.3, a fuse or other protective device shall not operate during tests. See 28.1. For all other tests, unless otherwise indicated, a fuse or other protective device is to be shorted.

29.3 During the abnormal tests described in 47.4.2 and 48.7.1, and Sections 43 and 44, the tool is to be connected in series with a nontime-delay fuse of the maximum size branch circuit device that the equipment is likely to be connected, (but no less than 30A). Opening of the fuse before a risk of fire, electric shock, or injury to persons results is an acceptable conclusion of a test.

29.4 An alternate magnet wire coating used in a tool motor subject to tests in Section 44 or 59.7.1.1 – 59.7.3.3 and 59.8.1 – 59.8.8, shall:

- a) Be an investigated magnet wire of the same ANSI grade designation or generic material type and construction with the same temperature rating as the original magnet wire tested; or
- b) Be tested as indicated in Section 44 or 59.7.1.1 – 59.7.3.3 and 59.8.1 – 59.8.8 as appropriate.

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30 Loads for Tests

30.1 A tool shall be operated under the condition of maximum normal load when connected to a supply circuit of maximum rated voltage and rated frequency. For tests on a tool, maximum normal load is considered to be the load that approximates as closely as possible the most severe conditions of normal use, operated continuously or marked duty cycle. It is not a deliberate overload except as the conditions of actual use are likely to be somewhat more severe than the maximum load conditions that are recommended by the manufacturer of the tool.

30.2 A tool intended to perform two or more different operations is to be tested with the load that results in maximum temperatures. The tool is to be subjected to an input test while operating with the attachment or accessory if any accessory or attachment is:

- a) Provided with a tool;
- b) Recommended for use with a tool; or
- c) Referred to in the instruction manual of a tool.

30.3 Unless indicated otherwise, the temperature test is to be continued until constant temperatures are attained.

31 Leakage Current Test

31.1 The leakage current of a tool rated for a nominal 240-V or 120-V supply when tested in accordance with 31.3 – 31.6, shall not be more than 0.5 mA.

31.2 Leakage current refers to all currents, including capacitively coupled currents that may be conveyed between exposed conductive surfaces of a tool and ground or other exposed conductive surfaces of the tool.

31.3 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible and from one surface to another if simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered acceptable for protection against risk of electric shock. Surfaces are considered to be 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 considered to be acceptable.

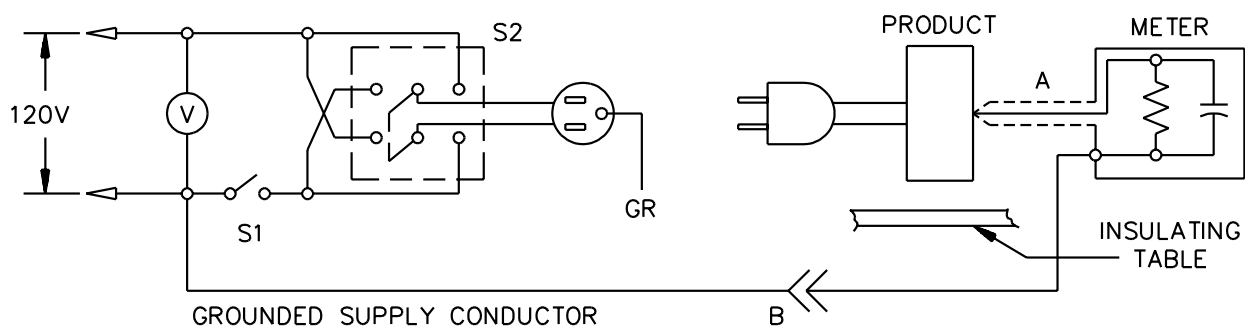
31.4 If a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 cm in contact with the surface. When the surface is less than 10 by 20 cm, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the tool.

31.5 The measurement circuit for leakage current is to be as shown in Figure 31.1. The measurement instrument is defined in (a) – (d). The meter that is actually 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 the attributes of the defined instrument.

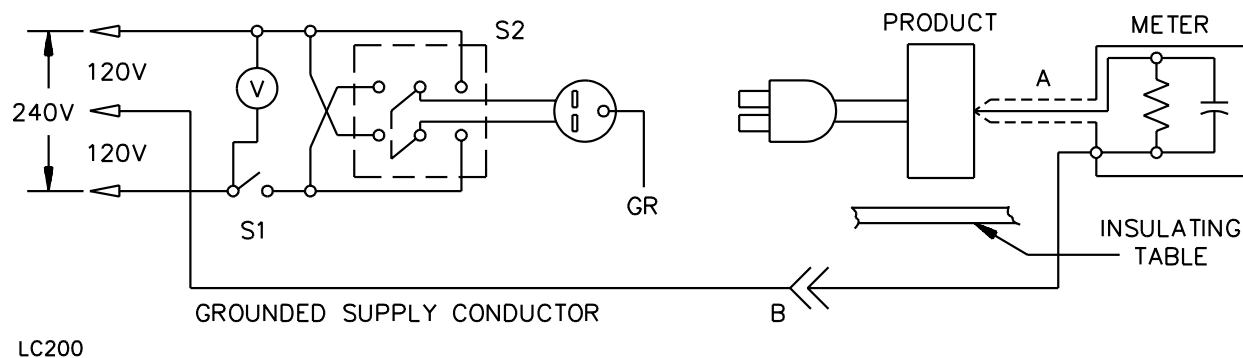
- a) The meter is to have an input impedance of $1500\ \Omega$ resistive shunted by a capacitance of $0.15\ \mu\text{F}$.

- 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 kHz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) that is equal to the ratio of the impedance of 1500- Ω resistor shunted by a 15-uF capacitor to 1500 Ω . At an indication of 0.5 mA, the measurement is to have an error of not more than 5 percent.
- d) Unless the meter is being used to measure leakage from one part of a tool to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

Figure 31.1
Leakage-current measurement circuits



LC100



A: Probe with shielded lead.

B: Separated and used as clip when measuring currents from one part of device to another

31.6 A sample of the tool is to be tested for leakage current starting with the as received condition (as received being without prior energization, except as may occur as part of the production line testing), but with its grounding conductor, if any, open at the attachment plug. The supply voltage is to be adjusted to 120 V or 240 V, depending upon the rating of the tool. The test sequence, with reference to the measuring circuit (Figure 31.1) is to be as follows:

- With switch S1 open, the tool is to be connected to the measuring circuit. Leakage current is to be measured using both positions of S2, and with the tool switching devices in all their normal operating positions.
- Switch S1 is then to be closed, energizing the tool, and within a period of 5 s, the leakage current is to be measured using both positions of switch S2, and with the tool switching devices in all their normal operating positions.
- Leakage current is then to be monitored under the no load condition until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement.

32 Starting Current Test

32.1 A tool shall start and operate normally on a circuit protected by an ordinary (not time-delay) fuse having a current rating corresponding to that of the branch circuit of minimum rating to which, in accordance with the National Electrical Code, ANSI/NFPA 70, the tool may be connected.

32.2 In a test to determine whether a tool complies with the requirement in 32.1, it is to be started three times with the tool at room temperature at the beginning of the test. Each start of the motor is to be made under conditions representing the beginning of normal operation and the tool is to be given time to come to rest between successive starts. Opening of the fuse or tripping of an overload protector provided as part of the tool is considered to be unacceptable.

33 Current Input Test

33.1 The current input to a tool that is connected to a circuit of rated frequency and maximum rated voltage and loaded in accordance with 29.1 shall be:

- a) Not more than 150 percent of the rated value for a general-use tool in which, during intended operation, the no-load or off periods are relatively long;
- b) Not more than 120 percent of the rated value for a general-use tool in which, during intended operation, the no-load or off periods are relatively short; and

Exception: Not more than 150 percent of the rated value for a tool when using any accessory or attachment that is:

- 1) *Provided with the tool;*
- 2) *Recommended for use with the tool; or*
- 3) *Referred to in the instruction manual of the tool.*

c) The maximum normal load as indicated in 30.1 shall be 90 – 110 percent of the rated value for a special-use tool.

Exception: The lower limit does not apply to operation or loading other than the maximum normal load or if the temperature test is conducted with the tool so loaded that it draws rated input current.

33.2 On a tool provided with means for controlling the speed, the input test is to be performed at the maximum-speed setting. It is then to be repeated with the tool operated in accordance with the manufacturer's recommendations as to speeds, drill bits, saw blade, or other accessory to be acceptable for use with the tool, and work stock, such as steel, wood, concrete, and the like.

33.3 The means for controlling the speed mentioned in 33.2 and 34.2 – 34.6 includes a controller having a number of discrete settings, as well as a controller having an infinite number of settings.

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33.4 During the current-input test, the no-load speed of a tool having a rotating output means shall not exceed the marked value by more than 20 percent when measured at the maximum speed setting.

Exception: The above does not apply to:

- a) Drain cleaners; and
- b) Tools with predominantly linear work function motion.

33.5 If a tool has more than one frequency rating, the requirements given in 33.1 for current input apply when the tool is tested at each of the frequencies indicated in 29.1.

34 Temperature Test

34.1 When tested under the conditions described in 34.2 – 34.7, a tool shall not attain a temperature at any point sufficiently high to constitute a risk of fire or to damage any materials employed in the tool, nor show temperature rises at specific points more than those indicated in Table 34.1. See also 34.11 – 34.18.

Table 34.1
Maximum temperature rises

Materials and Components		°C	°F
1.	Varnished-cloth insulation	60	108
2.	Fuses	65	117
3.	Fiber employed as electrical insulation	65	117
4.	Wood and other similar material	65	117
5.	Class E insulation systems on coil windings and core laminations		
	Thermocouple method	75	135
	Resistance method	85	153
6.	Class A insulation systems on coil windings of an a-c motor having a diameter of more than 7 in (178 mm), of a d-c motor, and of a universal motor ^{a,f} :		
	A. In an open motor:		
	Thermocouple method	65	117
	Resistance method	75	135
	B. In a totally enclosed motor:		
	Thermocouple method	70	126
	Resistance method	80	144
7.	Class A insulation systems on coil windings of an a-c motor having a diameter of 7 in (178 mm) or less (not including a universal motor) and on a vibrator coil ^{a,f} :		
	A. In an open motor and on a vibrator coil:		
	Thermocouple or resistance method	75	135
	B. In a totally enclosed motor:		
	Thermocouple or resistance method	80	144
8.	Class 105 insulation on windings of a relay, a solenoid, and the like:		
	Thermocouple method	65	117
	Resistance method	85	153
9.	Phenolic composition employed as electrical insulation or relied upon to prevent a risk of electric shock or fire	125 ^c	225 ^c
10.	Rubber or thermoplastic-insulated wire and cord	35 ^{b,c}	63 ^{b,c}

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Table 34.1 Continued on Next Page



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Table 34.1 Continued

Materials and Components		°C	°F
11.	Capacitor:		
	Electrolytic	40 ^e	72 ^e
	Other types	65 ^d	117 ^d
12.	Sealing compound (This is a maximum temperature, not temperature rise)	40°C (140°F) less than melting point	
13.	Class B insulation systems on coil windings of an a-c motor having a diameter of more than 7 in (178 mm), of a d-c motor, and a universal motor ^{a,f} :		
	A. In an open motor:		
	Thermocouple method	85	153
	Resistance method	95	171
	B. In a totally enclosed motor:		
	Thermocouple method	90	162
	Resistance method	100	180
14.	Class B insulation systems on coil windings of an a-c motor having a diameter of 7 in (178 mm) or less (not including a universal motor) and on a vibrator coil ^{a,f} :		
	A. In an open motor and on a vibrator coil:		
	Thermocouple or resistance method	95	171
	B. In a totally enclosed motor:		
	Thermocouple or resistance method	100	180
15.	Class 130 insulation on windings of a relay, a solenoid, and the like:		
	Thermocouple method	85	153
	Resistance method	105	189
16.	Handle or knob grasped for lifting, carrying, or holding:		
	A. Metallic	25 ^g	45 ^g
	B. Nonmetallic	35 ^g	63 ^g
17.	Handle, knob, or surface of the enclosure intended to be contacted during intended use but not requiring continuous holding:		
	A. Metallic	35 ^g	63 ^g
	B. Nonmetallic	60 ^g	108 ^g
18.	Surface subjected to casual contact:		
	A. Metallic	45 ^{g,h}	81 ^{g,h}
	B. Nonmetallic	70 ^{g,h}	126 ^{g,h}
^a See 34.12. ^b Rubber-insulated conductors within a motor having Class A insulation systems, rubber-insulated leads, and a rubber-insulated flexible cord entering a motor may be subjected to a temperature rise of more than 35°C (63°F) if an acceptable braid is employed on the conductor of other than a flexible cord. However, this does not apply to thermoplastic-insulated wires or cords. See 34.16. ^c The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds that have been found to have heat-resistant properties. ^d A capacitor that operates at a temperature rise of more than 65°C (117°F) may be considered on the basis of its marked temperature limit. ^e 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). ^f See note c to Table 19.1. ^g These temperatures do not apply to the cutting tool. ^h These temperatures do not apply to a hammer, including the rotary type.			

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34.2 When loaded as described in 34.3, a general-use tool is to be operated continuously until constant temperatures are obtained.

34.3 For the temperature test, a general-use tool is to be loaded by an eddy-current brake, dynamometer, or the like as follows:

- a) A single-speed tool with a universal motor is to be operated loaded to rated current.
- b) A tool with an induction motor is to be operated at rated voltage and loaded to obtain rated current. The input wattage is to be measured. If the tool is intended for use on a nominal 120 V or a 240 V supply, the load is to be increased until the initial wattage is obtained at 120 V or 240 V.
- c) A variable-speed tool with a universal motor, and discrete speed setting is to be operated when loaded to rated current at highest and lowest speed settings and may be operated at intermediate speed settings.
- d) An infinitely variable-speed tool with a universal motor, without feedback, is to be operated as follows:
 - 1) At the maximum-speed setting, while loaded to rated current; and
 - 2) At the no-load speed setting equal to 25 percent of the no-load maximum speed and then loaded to obtain 25 percent of the maximum speed obtained with rated current.

Exception: For an infinitely variable speed tool having a pre-determined low speed, the low speed test shall be performed at the speed (N_L) determined by the following equation:

$$N_L = \frac{N_F \times N_{\min}}{N_{\max}}$$

in which:

N_L is the low speed;

N_F is speed at full load current;

$N_{\max}$ is maximum speed at no load current; and

$N_{\min}$ is minimum speed at no load current.

- e) An infinitely variable-speed tool with feedback is to be operated as follows:

- 1) At the maximum-speed setting while loaded to obtain rated current; and
- 2) At a no load speed setting equal to 25 percent of the maximum no load speed and then loaded to obtain rated current.

Exception: If a tool with feedback employs circuits to limit the current at low speed, so that rated current cannot be obtained at 25 percent of no load speed, then the load is to be adjusted to result in the maximum current obtainable at 25 percent of the maximum no load speed.

34.4 With reference to feedback as mentioned in 34.3 (d) and (e), a tool is considered to have feedback if the rated current is exceeded when making the adjustment described in 34.3(e)(2).

34.5 The temperature test on a special-use tool not provided with means for controlling the speed is to be conducted in accordance with 30.1.

34.6 The temperature test on a special-use tool provided with means of controlling the speed is to consist of operation in accordance with 30.1 at the maximum-speed setting. The test is then to be repeated at lower speeds, and the requirements in 34.1 and Table 34.1 apply at these lower speeds. During these tests at lower speeds, the duty cycle described in 30.1 is to be followed, and the test is to be conducted in accordance with the manufacturer's recommendations as to the accessory acceptable for use with the tool, and the work stock.

34.7 For temperature tests during which the unit is cycled on and off, the temperatures shall be recorded until constant or for specified duty cycles. Only temperatures measured during the on portion of the test cycle are to be used to determine compliance with 34.1.

34.8 A tool when operated as described in 34.10 shall not attain a temperature of more than 125°C (257°F) on any exterior surface of the tool that may be laid on combustible material or against which combustible material may be laid. There shall not be emission of smoke, flame, or molten material from the tool. See 34.9.

Exception: This requirement does not apply to a tool equipped with a momentary-contact switch if the switch is:

- a) Not provided with means for being locked in the on position; and*
- b) So located that the tool will not become and remain energized, regardless of the position in which it is laid down.*

34.9 A tool is considered to comply with the requirement in 34.8 if, during the temperature test, it was operated until constant temperatures were attained.

34.10 To determine whether a tool complies with the requirements of 34.8, it is to be operated at the voltage and frequency indicated in 29.1 and 34.12 until constant temperatures are attained. The tool may be stationary in a rest position during the test and simulation of conditions of actual use need not be attempted.

34.11 For the temperature test, the tool is to be connected to a power supply circuit of the voltage indicated below. If the voltage rating of the tool is nominally 115 V, it is to be tested on a circuit of 115 V if direct current, and 120 V if alternating current. If the nominal rating is 230 V, the tool is to be tested on a circuit of 230 V if direct current, and 240 V if alternating current. For a tool having rating other than those indicated above, the voltage of the power supply circuit for the test is to equal the maximum rated voltage of the tool.

34.12 The coil or winding temperature is to be measured by thermocouples mounted on the coil surface unless the coil is inaccessible for mounting of the thermocouples (for example, a coil immersed in sealing compound) or unless the coil wrap includes thermal insulation, such as asbestos, or more than two layers of cotton, paper, rayon, or the like. The change in resistance method is then to be employed, see 34.14, or the thermocouples are to be applied to the coil magnet wire coating under the wrap if feasible.

34.13 For a coil of an alternating current motor, other than a universal motor, having a diameter of 7 in (178 mm) or less (Items 7 and 14 in Table 34.1) the thermocouple is to be applied to the coil magnet wire coating.

34.14 The temperature of a winding may be determined by the resistance method by comparing the resistance of the winding at the temperature determined with the resistance at a known temperature according to the equation:

$$T = R/r (k + t_1) - (k + t_2)$$

in which:

T is the temperature rise;

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

r is the resistance of the coil at the beginning of the test;

*t*₁ is the room temperature in degrees C at the beginning of the test;

*t*₂ is the room temperature in degrees C at the end of the test; and

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum.

Values of the constant for other grades must be determined.

34.15 All values for temperature rises in Table 34.1 are based on an assumed ambient temperature of 25°C (77°F). Tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). Tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F).

34.16 A short length of rubber or thermoplastic-insulated flexible cord exposed to a temperature of more than 60°C (140°F), such as at terminals, is acceptable if supplementary heat-resistant insulation of acceptable dielectric strength is employed on the individual conductors of the cord to safeguard the tool against deterioration of the conductor insulation and if the strain relief means is not dependent on that portion of the insulation subjected to the excessive temperature.

34.17 In a test in which constant temperatures are to be obtained, thermal equilibrium is considered to exist when three successive readings, taken at intervals of 10 percent of the previous duration of the test, but not less than 5-min intervals, indicate no change. Temperatures are not to be measured after final shutdown; however, they are to be observed during the off or idling intervals if the loading during the test is of a cyclic nature. Thermocouples are to consist of wires no larger than 24 AWG (0.21 mm²).

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34.18 When thermocouples are used in the determination of temperatures in connection with the heating of electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG (0.05 mm²) iron and constantan wires and a temperature indicating instrument. 30 AWG iron and constantan wire is to be used whenever referee temperature measurements by thermocouples are necessary.

35 Dielectric Voltage Withstand Test

35.1 A tool shall withstand for 1 min, without an indication of unacceptable performance, the application of a potential of 1000 V plus twice the rated voltage applied, except as indicated in 35.2, between live parts and dead metal parts, with the tool at the temperature reached during the temperature test.

35.2 For a tool employing an induction motor rated 1/2 hp (373 W output) or less and 250 V or less, the potential for the motor (but not for the remainder of the tool) is to be 1000 V.

35.3 A line bypass capacitor, or a capacitor connected across the line or provided for power-factor correction shall withstand for 1 min, without an indication of unacceptable performance, the application of a sinusoidal potential of 1000 V plus twice the rated voltage of the tool between terminals of the capacitor.

Exception: To distinguish between capacitor leakage and unacceptable performance, the test instrument may use a dc potential of 1414 V plus 2.828 times the rated voltage of the tool. This dc potential is to be maintained for 1 min without an indication of unacceptable performance. The capacitor is to be disconnected from the circuit for this test.

35.4 To determine whether a tool complies with the requirements in 35.1 – 35.3, the test potential is to be applied as described in 34.6 by means of test equipment having the characteristics outlined in 35.5.

35.5 The test equipment for conducting the dielectric voltage withstand test is to have the following features and characteristics:

a) A means for indicating the test voltage that is being applied to the tool under test. This may be accomplished by sensing the voltage at the test leads or by an equivalent means.

b) An output voltage that:

- 1) Has a sinusoidal waveform;
- 2) Has a frequency that is within the range of 40 – 70 Hz; and
- 3) Has a peak value of the waveform that is not less than 1.3 and not more than 1.5 times the root-mean-square value.

c) A sensitivity of the test equipment that is such that when a resistor of 120,000 Ω is connected across the output, the test equipment does not indicate unacceptable performance for any output voltage less than the specified test voltage, and the test equipment does indicate unacceptable performance for any output voltage equal to or greater than the specified test value. The resistance of the calibrating resistor is to be adjusted as close to 120,000 Ω as instrumentation accuracy can provide, but never more than 120,000 Ω .

Exception: The sensitivity of the test equipment may be increased and a higher value of calibrating resistance may be used, if agreeable to those concerned.

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