Table 29.2
Minimum acceptable primary-circuit spacings in inches (mm) at other than field-wiring terminals or
inside motors

Potential involved in volts (RMS)	Over surface ^b	Through air		
125 or less	1/16 (1.6)	1/16 (1.6)		
126—250	3/32 ^a (2.4)	3/32ª (2.4)		
^a In products employing heaters, such as sterilizers, warmers, and the like the spacings may be 1/16 inch (1.6mm) at the heating element.				
^b On printed-wiring boards, their connectors and board-mounted electrical components, wired on the load side of line filters or similar-voltage-peak-reduction networks or components or both, a minimum spacing of 0.023 inch (0.58 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over the surface and through air between uninsulated live parts and any other uninsulated conductive part (live or dead) not of the same polarity.				

29.2.4 At terminal screws and studs to which connection can be made in the field by means of wire connectors, eyelets, or the like, as indicated in 2.19, it is required that the spacings be not smaller than shown in <u>Table 29.2</u> while such connectors, eyelets, and the like are in such position that minimum spacings (opposite polarity and to dead metal) exist.

29.2.5 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 inch (0.8 mm) thick, and shall be so located or of such material that it will not be adversely affected by arcing.

Exception: Vulcanized fiber not less than 1/64 inch (0.4 mm) thick may be used in conjunction with an air spacing of not less than 50-percent of the minimum acceptable through-air spacing.

29.2.6 Insulating material having a thickness less than that specified in <u>29.2.5</u> may be used if, upon investigation, it is found to be acceptable for the particular application.

29.2.7 The barriers shall be reliably held in place by means more secure than friction between surfaces. The elasticity of tubing shall not be depended upon to hold the tubing in place, but dilated or heat-shrunk tubing is acceptable.

29.2.8 Unless protected from mechanical abuse during any user assembly or servicing and intended functioning of a product, a barrier of mica shall be 0.010 inch (0.25 mm) or more thick.

29.3 Secondary circuits

29.3.1 Primary-circuit spacings apply in all secondary circuits supplied by a transformer winding of a 200-VA or higher capacity (maximum available power) at a potential higher than 100 V. The spacings in all other secondary circuits are to be investigated on the basis of the dielectric voltage-withstand test in 51.3.1.

29.4 Spacings on printed wiring boards

29.4.1 As an alternative to the spacing requirements of <u>Table 29.1</u>, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are able to be used. The spacing requirements of UL 840 shall not be used for field wiring terminals and spacings to a dead metal enclosure.

29.4.2 The following end use factors from UL 1431 shall be applied:

a) For the applicable Overvoltage Category, see <u>Table 26.1</u>;

- b) For the applicable Material Group, see <u>Table 26.2;</u>
- c) For the applicable Pollution Degree, see <u>Table 26.3</u>.

29.4.3 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product. This voltage limiting device or system shall comply with the Standard for Surge Protective Devices, UL 1449.

29.4.4 All printed wiring boards are identified as having a minimum comparative tracking index (CTI) of 100 without further investigation, for evaluation to UL 840.

30 Grounding

30.1 All permanently connected products shall have provision for grounding all exposed dead metal parts that might become energized.

30.2 A double-insulated product shall not be provided with a means for grounding.

30.3 If a grounding means is provided on the product, whether required or not, all exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any servicing operation and that are likely to become energized shall be reliably connected to the grounding means, see Grounding Impedance Test, Section <u>53</u>.

- 30.4 The following are considered to constitute means for grounding:
 - a) In a product intended to be permanently connected an equipment-grounding terminal or lead,
 - b) In a cord-connected product an equipment-grounding conductor in the cord.
- 30.5 An equipment grounding conductor of a flexible cord shall be:
 - a) Finished to show a green color with or without one or more yellow stripes;
 - b) 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 any user servicing and that are likely to become energized. The grounding conductor shall be connected by means of a screw or other means not likely to be removed during any servicing operation not involving the power supply cord. Solder alone shall not be used for securing this conductor; and

c) Connected to the fixed grounding member of an attachment plug of the grounding type.

31 Brushes and Brush Holders

31.1 A brush cap shall be recessed, enclosed, or otherwise protected from mechanical damage that might occur during use of the product.

31.2 A brush cap that is accessible to the user without the removal of a guard or enclosure shall be provided with a positive means so that it will not disengage from the brush-holder assembly. Screw threads only on the brush cap are not considered a positive means.

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31.3 A brush-holder 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 will be retained to the degree necessary to reduce the likelihood of accessible dead-metal parts becoming energized and live parts becoming accessible.

32 Double Insulation

32.1 A product constructed with double insulation and marked as such shall comply with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097, in addition to requirements contained here. Where requirements supersede requirements in the standard, the more severe would apply.

PROTECTION AGAINST INJURY TO PERSONS

33 General

33.1 If the operation and maintenance of a product by the user involves the risk of injury to persons, protection shall be provided to reduce the risk.

33.2 When investigating a product with respect to the requirement in 33.1, consideration shall be given to reasonably foreseeable misuse of the product.

33.3 The adequacy of a guard, a release, an interlock, and the like, and whether such a device is required, are to be determined from an investigation of the complete product, its operating characteristics, and the likelihood of a risk of injury to persons resulting from a cause other than gross negligence. The investigation is to include consideration of the results of breakdown or malfunction of any one component; but not more than one component at a time, unless one event contributes to another. If the investigation shows the breakdown or malfunction of a particular component can result in a risk of injury to persons, that component is to be investigated for reliability.

33.4 Specific constructions, tests, markings, guards, and the like are detailed for some common constructions. Specific features and products not covered herein are to be given appropriate consideration. See the requirements for marking in Details, Section <u>68</u>.

34 Sharp Edges

34.1 Each edge, projection, and corner of an enclosure, opening, frame, guard, knob, handle, or the like of a product shall be smooth and shall not cause injury to persons during intended use or during operator maintenance of the product.

34.2 For edges whose acceptability cannot be determined by inspection, compliance with the requirements in 34.1 is to be investigated by the test procedure in the Standard for Determination of Sharpness of Edges in Electrical Equipment, UL 1439.

35 Enclosures and Guards

35.1 A moving part that may cause risk of injury to persons shall be enclosed, guarded, located, or otherwise arranged to reduce the likelihood of unintentional contact.

Exception: A part or portion of a part that is necessarily exposed to perform the work function need not be enclosed but, when necessary, guarding shall be provided. See <u>35.3</u>.

35.2 A moving part that may involve a risk of injury to persons shall be located or enclosed to reduce the risk of unintentional contact by persons. Such a part shall be considered with respect to

- a) The degree of exposure necessary to perform the intended function,
- 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 a part of the body or clothing would be endangered by the moving part.

These factors are to be considered with respect to both intended operation of the product and reasonably foreseeable misuse.

35.3 Some guards are required to be of the self-restoring type. Other features of guards that are to be considered include:

- a) Removability without the use of tools;
- b) Removability for servicing;
- c) Strength and rigidity;
- d) Completeness;

e) Creation of additional risk of injury to persons such as pinch points, and the necessity for additional handling because of the increased need for servicing, such as for cleaning, unjamming, and the like.

35.4 An enclosure or guard over a rotating part shall retain a part that, because of breakage or other reasons, may become loose or may separate from a rotating part, and retain a foreign object that may be struck and propelled by the rotating part.

36 Materials

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

36.2 The requirement in <u>36.1</u> applies to those portions of a part adjusted to a moving part considered to involve a risk of injury to persons.

37 Surface Temperatures

37.1 During the normal temperature test described in Temperature Test, Section <u>50</u>, the temperature of a surface that may be contacted by the user shall not be more than the maximum acceptable value specified in <u>Table 37.1</u>.

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	Composition of surface ^a		
Location	Metallic	Nonmetallic	
A handle or knob that is grasped for lifting, carrying or holding	50°C (122°F)	60°C (140°F)	
A handle or knob that is contacted but does not involve lifting, carrying, or holding and other surfaces subject to contact in operation and user maintenance	60°C (140°F)	85°C (185°F)	
A surface subject to casual contact	70° (158°F)	95°C (203°F)	
^a A handle, knob or the like made of a material other than metal, that is plated or clad with metal having a thickness of 0.005 inch (0.13 mm) or less is evaluated as a nonmetallic part.			

Table 37.1 Surface temperatures

37.2 All values for temperatures specified in <u>Table 37.1</u> are based on a 25° C (77° F) ambient temperature; however, tests may be conducted at any ambient temperature within the range of $10 - 40^{\circ}$ C (50 - 104°F) and corrected to 25°C (77°F). See <u>50.1.3</u> - <u>50.1.8</u>.

38 Stability

38.1 Overturning of a portable or free-standing product, one not secured in place, when it is tested as described in <u>38.2</u> and <u>38.3</u>, shall not result in a risk of injury to persons.

Exception: A product that is completely hand supported in use need not be tested.

38.2 The product is not to be energized during the stability test. The test is to be conducted under conditions most likely to cause the product to overturn. The following conditions are to be such as to result in the least stability:

a) The position of all doors, drawers, casters, and other movable or adjustable parts, including that of the supply cord resting on the surface supporting the product;

b) Connection or omission of any attachment made available or recommended by the manufacturer;

c) Provision or omission of any intended load if the product is intended to contain a liquid or other mechanical load; and

d) Direction in which the product is tipped or the supporting surface is inclined. See <u>38.3</u>.

- 38.3 In conducting the stability test, the product is to be:
 - a) Placed on a plane inclined at an angle of 10 degrees from the horizontal; or
 - b) Tipped through an angle of 10 degrees from an at rest position on a horizontal plane.

39 Strength of Handles

39.1 A handle used to completely support or carry a product during use shall withstand a force of four times the weight of the product without damage – to the handle, its securing means, or that portion of the enclosure to which the handle is attached – that will affect the performance of the handle or the product.

39.2 To determine whether a product complies with the requirements in <u>39.1</u>, the weight of the product plus a force of three times its weight are to be used. The load is to be uniformly applied over a 3 inch (76.2 mm) width at the center of the handle without clamping. The load is to be started at zero and gradually increased so that the test value will be reached in 5 to 10 seconds and is to be maintained for 1 minute. If more than one handle is furnished on a product, and the product cannot be carried by one handle, the force is to be distributed between the handles. The distribution of force is to be determined by measuring the percentage of the product weight sustained by each handle with the product in the normal carrying position. If a product is furnished with more than one handle and can be carried by only one handle, each handle is to sustain the total force.

40 Rotating or Moving Members

40.1 A rotating member, the breakage of which might create a risk of injury to persons, shall be constructed so as to reduce the likelihood of its breakage, or the release or loosening of a part that could become a risk of injury to persons.

40.2 To determine whether a product employing a series motor complies with the requirement in 40.1, it is to be tested as described in 40.3. A part that can become a risk of injury to persons shall not work loose as a result of the test.

40.3 For the test referenced in <u>40.2</u>, a product employing a series motor is to be operated for 1 minute at the no-load speed resulting from application of 1.3 times rated voltage.

40.4 A product with a user-removable rotating part, secured by threaded hardware - such as a nut - shall be constructed so that the direction of rotation tends to tighten the nut that secures the rotating part in place.

40.5 Unless secured as described in <u>40.4</u>, 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 equivalent means.

41 Parts Subject to Pressure

41.1 A part of a product that is subjected to air or vapor pressure during normal or anticipated abnormal operation shall withstand, without rupture, a pressure corresponding to five times:

a) The relief-valve pressure setting provided in the system,

b) The maximum pressure that can be developed in the system – but not greater than the relief valve setting, or

c) The marked maximum pressure to which the system may be exposed by an external pressure source.

Exception: A section of a pressure system constructed of continuous tubing or of lengths of tubing connected by conventional tubing fittings or hard-soldered, brazed, or welded joints if study and analysis indicate that the strength of the part is adequate for the purpose.

41.2 If a test is necessary to determine whether a part complies with the requirement in 41.1, two samples of the part are to be subjected to the hydrostatic strength test and withstand without rupture for one minute a hydrostatic pressure per 41.1. The results are not acceptable if either sample bursts.

41.3 With reference to the requirements in 41.2 the test is to be conducted by filling the part with water so as to exclude all air, connecting the pressure vessel to a hydraulic pump, gradually increasing the pressure to the specified test value, and holding it at that value for 1 minute.

42 Pressure-Relief Devices

42.1 A means for relieving pressure shall be provided for a part in which pressure might be generated by an external source of heat.

42.2 A means for relieving pressure – a pressure-relief device, a fusible plug, a soldered joint, nonmetallic tubing, or other equivalent means – shall be employed to comply with the requirement in $\frac{42.1}{1.1}$.

42.3 A pressure-relief device is considered to be a pressure-actuated valve or rupture member designed to relieve excessive pressures automatically.

42.4 There shall be no shutoff valve between the pressure-relief means and the parts that it is intended to protect.

42.5 A vessel having an inside diameter of more than 3 inches (76 mm) and subject to air or stream pressure generated or stored within the product shall be protected by a pressure-relief device.

42.6 The start-to-discharge pressure setting of a pressure-relief device shall not be higher than the marked working pressure. The discharge rate of the device shall be adequate to relieve the pressure.

42.7 A pressure-relief device shall:

a) Be connected as close as possible to the part of the product that it is intended to protect;

b) Be installed so that it is readily accessible for inspection and repair, and cannot be readily rendered inoperative so that it will not perform its intended function; and

c) Have its discharge opening located and directed so that:

1) Operation of the device will not deposit moisture on bare live parts or on insulation or components detrimentally affected by moisture, and

2) The likelihood of scalding persons is reduced.

42.8 A pressure-relief device having an adjustable setting is determined on the basis of the maximum setting unless the adjusting means is reliably sealed at a lower setting.

42.9 If a pressure-relief device is required in accordance with 42.5, a control depended upon to limit the pressure in a vessel shall:

a) Comply with <u>3.6.5</u> and shall have a maximum pressure setting of not more than 90 percent of the rating of the pressure-relief device, or

b) Operate so that the pressure-relief device described in $\frac{42.7}{10}$ does not operate during or after the test described in $\frac{42.10}{10}$.

42.10 A pressure-limiting control shall perform under rated load for 30,000 cycles of operation with no shift in calibration greater than 5 percent above the initial calibration pressure setting. An adjustable control is to be tested at its highest pressure setting unless the adjusting means is reliably sealed at a lower setting.

43 Switches, Controls, and Interlocks

43.1 A product shall be constructed so that unexpected operation will not occur that may cause injury to persons, such as from moving parts, hot liquids, and the like.

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

43.3 The actuator of a switch may be guarded by recessing, ribs, barriers, or the like.

43.4 A device that automatically starts a product, such as a pressure control, timer, an automatically reset overload-protective device, or the like, shall not be employed unless it can be demonstrated that automatic starting will not present a risk of injury to persons.

43.5 The requirement in <u>43.4</u> will necessitate the use of an interlock if moving parts or the like could result in a risk of injury to persons upon the automatic starting or restarting of the motor.

43.6 The actuator of an interlock switch shall be located so that unintentional operation is unlikely. See <u>43.3</u>.

43.7 Operation of an interlock during use shall not inconvenience the operator so as to encourage deliberate defeat of the interlock.

43.8 An interlock shall not be likely to be defeated by materials that could accumulate during use of the product.

43.9 An interlock shall be such that it can be defeated readily only by:

- a) Damaging the product,
- b) Making wiring connections or alterations, or
- c) Using materials that are not readily available.

43.10 If an interlock is actuated by movement of a guard, the arrangement shall be such that the guard is in place when the interlock is in the position that permits operation of the parts being guarded. With the guard removed, the interlock shall comply with the requirement in 43.6.

43.11 A product that is provided with a maintained contact switch or a switch that can be locked on shall not create a risk of injury to persons when the product is in an at rest position and connected to the source of supply with the switch on.

43.12 For a product that is partially or completely hand-supported, the requirement in <u>43.11</u> will necessitate a means to keep the product from traveling more than 6 inches (152 mm) in any one direction in 15 seconds when the product is placed on a hardwood surface while energized.

43.13 The off position of a switch other than a momentary-contact switch shall be such that the operator can determine by visual inspection that the product is off.

PERFORMANCE

44 General

44.1 The sample used for the Temperature Test, Section 50, shall be employed in the dielectricwithstand test, see 51.2.1 - 51.3.4.

44.2 Unless otherwise noted in the individual requirements, all tests are to be conducted with the product connected to a supply circuit of rated frequency, and having a potential of:

- a) For a product rated from 110 V to 120 V, inclusive, 120 V;
- b) For a product rated from 220 V to 240 V, inclusive, 240 V; and
- c) For a product other than as mentioned in (a) or (b), the maximum rated voltage of the product.

44.3 A product having a single frequency rating is to be tested at that frequency. A product rated ac/dc or dc-60 Hz is to be tested on direct current or 60-Hz alternating current, whichever results in the most severe condition. A product rated 25 - 60 Hz or 50 - 60 Hz is to be tested on 60-Hz alternating current.

44.4 Wherever cloth is mentioned in the abnormal tests, the cloth is to be bleached cheesecloth, running $14 - 15 \text{ yd}^2/\text{lb}$ (approximately $26 - 28 \text{ m}^2/\text{kg}$) and having what is known in the trade as a "count of 32 by 28," that is, for any square inch 32 threads in one direction and 28 threads in the other direction – or any square centimeter, 13 threads in one direction and 11 in the other direction.

45 Operational Test

45.1 Operation of a product as described in <u>45.2</u> shall not increase the risk of fire, electric shock, or injury to persons.

45.2 With reference to 45.1, an as-received sample of the product is to be set up or installed in accordance with the manufacturer's instructions. The sample is to be operated in — accordance with the manufacturer's instructions with respect to – the intended uses of the product, including maintenance and cleaning recommended by the manufacturer and lack of such maintenance and cleaning; and with all accessories recommended by the manufacturer for use with the product. The product is to be manipulated as it would be in actual use, including manipulation of all controls and operation under the various loading conditions that can be expected. The product is to be operated for a sufficient length of time or through a sufficient number of cycles so that all reasonably foreseeable complications are revealed.

46 Leakage Current Test

46.1 The leakage current of a cord- and plug-connected product when tested in accordance with $\frac{46.3}{46.7}$ shall be no more than 0.5 mA.

Exception No. 1: For a grounded (3-wire) product, fastened in place, the leakage current shall not be more than 0.75 mA.

Exception No. 2: For a grounded (3-wire) product, intended for use in a dedicated location, see <u>11.1.1.3</u>, the leakage current shall not be more than 0.75 mA.

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

46.3 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 where simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered as protection against electric shock as defined in Frame and Enclosure, Section <u>8</u>. Surfaces are considered to be simultaneously accessible when 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 considered not to present a risk of electric shock.

46.4 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 having an area of 10 by 20 cm in contact with the surface. Where 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 product.

46.5 The measurement circuit for leakage current is to be as shown in <u>Figure 46.1</u>. The measurement instrument is defined in (a) – (d). The meter 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 ohms resistive shunted by a capacitance of 0.15 uf.

b) The meter is to indicate 1.11 times the average of the full wave rectified composite waveform of the 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) equal to the ratio of the impedance of a 1500 ohm resistor shunted by a 0.15 uf capacitor to 1500 ohms. At an indication of 0.5 or 0.75 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 product to another, the meter is to be connected between an accessible part and the grounded supply conductor.

46.6 A sample of the product is to be tested for leakage current starting with the "as received" condition, but with its grounding conductor, if any, open at the attachment plug (open at receptacle as shown in Figure 46.1). The "as received" condition is without prior energization, other than that which may have occurred as part of the production line testing. The supply voltage is to be adjusted to 120 or 240 V depending on the rating. Thermostats are to be closed. The test sequence, with reference to the measuring circuit (Figure 46.1) is to be as follows:

a) With switch S1 open, the product is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the product switching devices in all their normal operating positions.

b) Switch S1 is then 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, and with the product operated at the maximum heat setting of controls.

c) Leakage current is to be monitored until thermal stabilization under the maximum heat conditions, Both positions of switch S2 are to be used. The equivalent of thermal stabilization is considered to be obtained as in the normal temperature test, if any temperature-regulating thermostat does not cycle at the maximum setting, the setting is to be lowered until the thermostat does cycle before the final measurements at thermal stabilization are taken. Measurements are to be made with the thermostat, if any, open and closed. Upon evidence of stabilizing readings, monitoring periods may be increased.

d) If the product employs a single pole switch or a thermostat with an off position, monitoring of leakage current is to continue until the leakage current stabilizes or decreases after the product is turned off. Both positions of switch S2 are to be used.

UL 1431



Leakage current measurement circuits



NOTES -

A - Probe with shielded lead.

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