

44 Static Load Test

44.1 A mounting means for a fixed power unit shall withstand the Static Load Test, Section 71 without permanent deformation, breakage, or cracking of the mounting supports.

45 Strength of Handles

45.1 A handle used to support or carry a unit shall comply with the Strength of Handles Test, Section 72.

PERFORMANCE

46 General

46.1 A representative sample of a unit is to be subjected to the tests described in Sections 47 – 72. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 46.1.

Exception: A test voltage of not less than 90 percent of the values specified in Table 46.1 is acceptable when the unit delivers rated output power at the reduced test voltage.

Table 46.1
Values of test voltages

Rated voltage	Test voltage
Less than 110	Rated voltage ^a
110 – 120	120
121 – 219	Rated voltage ^a
220 – 240	240
241 – 253	Rated voltage ^a
254 – 277	277
278 – 439	Rated voltage ^a
440 – 480	480
481 – 525	Rated voltage ^a
526 – 600	600

^a A unit marked with an operating voltage range shall comply with the requirements in Sections 47 – 72 while connected to a source of voltage adjusted to any value within the specified range.

46.2 A unit marked with one frequency rating is to be tested at that frequency. For a unit marked with a dual frequency rating such as 50/60 hertz or a frequency range such as 50 – 60 hertz, tests are to be conducted at any frequency covered by the marking.

Exception: For a unit marked with a dual frequency rating or a frequency range, Power Input (Section 49), Temperature (Section 50), and Transformer Burnout Tests (53.2.1 – 53.2.3) are to be conducted at the lowest frequency.

47 Leakage Current Test

47.1 A cord-connected unit rated for a nominal 250-volt or less supply shall be tested in accordance with 47.2 – 47.8. Leakage current shall not be more than:

- a) 0.5 MIU for a two-wire cord- and plug-connected unit,
- b) 0.5 MIU for a three-wire (including grounding conductor) cord- and plug-connected portable unit, and
- c) 0.75 MIU for a three-wire (including grounding conductor) cord- and plug-connected fixed appliance.

Exception No. 1: Conductive parts of a unit that complies with the following conditions and that have a leakage current greater than specified in (a), (b), or (c) shall have a leakage current from simultaneously accessible parts to the grounded supply conductor no greater than 3.5 MIU. The leakage current between simultaneously accessible parts shall not exceed 0.5 MIU.

- a) The unit requires electromagnetic interference (EMI) suppression filtering for compliance with other requirements, such as Federal Communications Commission (FCC) Regulations;*
- b) The unit is equipped with a grounding type supply cord and plug;*
- c) There is a low probability that a path for available current through the body exists in the expected environment. When the available current flows to ground, this involves the probability that the user is grounded during the use of the unit;*
- d) There is a low probability that high leakage conductive parts are contacted during normal use of the unit;*
- e) The probability of injury resulting from an involuntary reaction is small.*

Exception No. 2: For a unit that upon loss-of grounding, dependably disconnects all sources that produce leakage current, the leakage current to ground shall not exceed 5 MIU with the grounding conductor open and with the loss-of-grounding circuit disabled. The leakage current between simultaneously accessible parts on the unit shall not be more than 5 MIU.

47.2 All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 47.1. Where surfaces are simultaneously accessible, they are to be tested:

- a) Individually,
- b) Collectively (connected together) with the combined current measured to ground, and
- c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.

Surfaces are simultaneously accessible when they are capable of being touched by one or both hands of a person at the same time. Accessible parts within a 4 by 8 inches (100 by 200 mm) rectangle are simultaneously accessible to one hand. The rectangle shall be flexed or bent to closely conform to the surface of the device. Accessible parts that are capable of being touched at the same time by the ends of a string 6 ft (1.8 m) in length are simultaneously accessible to both hands. The grounding pin, blade, or contact of an attachment plug is an accessible part.

47.3 When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 4 by 8 inches (100 by 200 mm) in contact with the surface. Where the conductive surface has an area less than 4 by 8 inches (100 by 200 mm) the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface and is not to remain in place long enough to affect the temperature of the unit.

47.4 Typical measurement circuits for leakage current with the ground connection open are illustrated in Figures 47.1 and 47.2. The measurement instrument is defined in Figure 47.3. The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:

- a) The measured ratio V_1/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_1/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 47.3.
- b) The measured ratio V_3/I_1 with sinusoidal voltages is to be as close as feasible to the ratio V_3/I_1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 47.3. V_3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts is converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1,000. The mathematic equivalent is to multiply the RMS voltage reading by 2.

Figure 47.1

Leakage current measurement circuit used for devices intended for connection to 120 V circuits

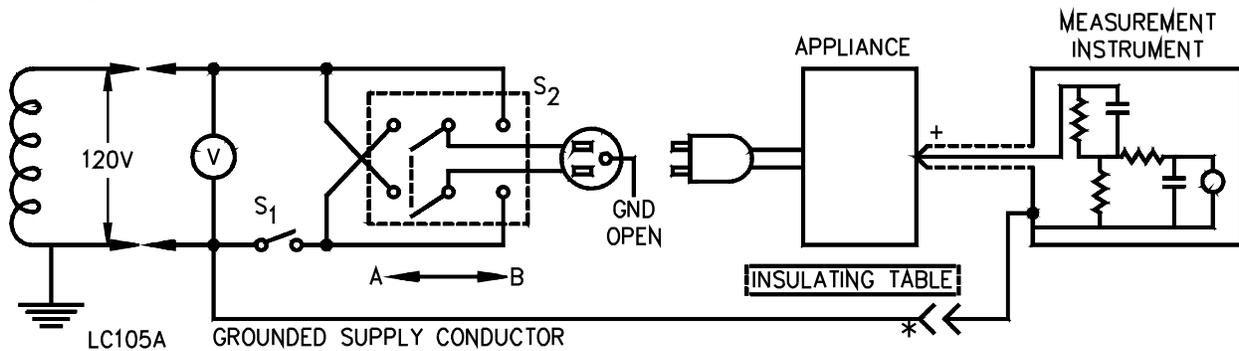
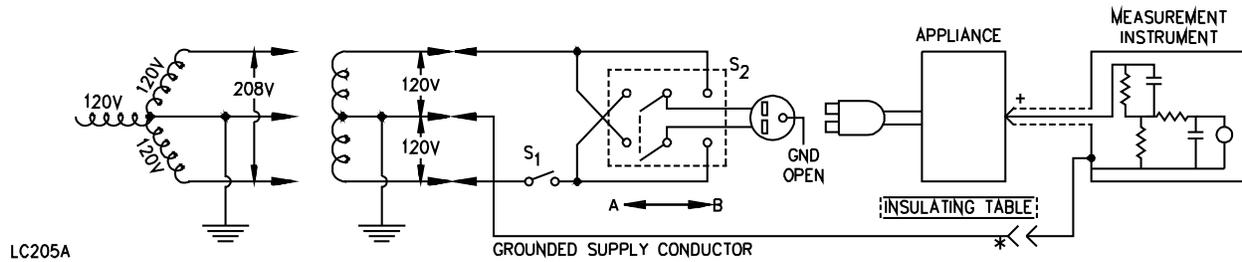


Figure 47.2
Leakage current measurement circuit used for grounded or ungrounded 208 V or 240 V devices
intended for connection to 3-wire neutral grounded circuits



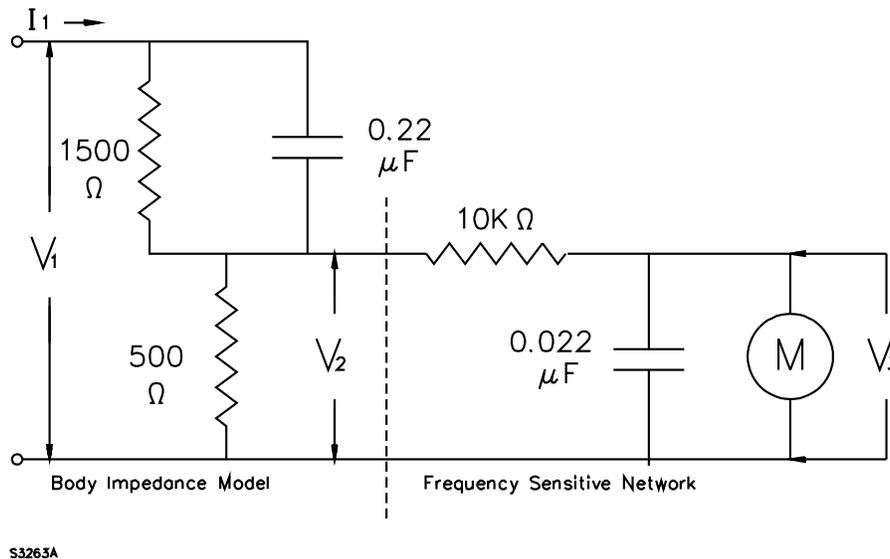
* Separated and used as clip when measuring currents from one part of the device to another.

+ Probe with shielded lead

NOTES –

- 1) All voltages shown in Figures 47.1 and 47.2 are nominal.
- 2) When it is not feasible to isolate the device from ground, the supply circuit shall be isolated from ground. It is then also sometimes required to reverse the leads of the measurement instrument.

Figure 47.3
Measurement instrument for reaction (leakage) current



Note – Detailed specifications and guidance for the calibration of this instrument are given in the Standard for Leakage Current for Appliances, UL 101.

47.5 Unless the measurement instrument is being used to measure leakage current from one part of a unit to another, it is to be connected between accessible parts and the supply conductor connected to ground (the grounded or grounding conductor) that has the least extraneous voltages introduced from other equipment operated on the same supply. For products rated 120 volts or 240 volts, with one supply conductor grounded, this is likely to be the grounded supply conductor.

47.6 When there is no grounded conductor connected to the unit under test (for example, a 240-volt, 2-conductor product supplied by a 120/240 volt source), then the instrument return lead is not prohibited from being connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.

47.7 A sample of a unit is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage.

The test sequence is to be as follows, with reference to Figures 47.1 and 47.2

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

- b) Switch S1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the product switching devices in all their normal operating positions.
- c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.
- d) The leakage current is also to be monitored with switch S1 open while the unit is at operating temperature and while cooling.

47.8 A sample is to be subjected to the entire leakage current test, as specified in 47.7, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.

48 Leakage Current Test Following Humidity Conditioning

48.1 A portable unit rated 250 volts or less shall comply with the requirements for leakage current in 47.1, following exposure to air having a relative humidity of 88 ± 2 percent at a temperature of $32 \pm 2^{\circ}\text{C}$ ($90 \pm 4^{\circ}\text{F}$).

48.2 To determine whether a unit complies with the requirement in 48.1, a sample of the unit is to be heated to a temperature just above 34°C (93°F) to reduce the risk of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 48.1. Immediately following the conditioning, the sample is to be removed from the humidity chamber and tested unenergized as described in 47.7 (a). The sample is then to be energized and tested as described in 47.7 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

49 Power Input Test

49.1 The input current and power factor to a unit is to be measured with the unit operating while connected to the maximum rated load (see 49.2 – 49.4). The current input shall not be more than 110 percent of the rated value.

49.2 A unit is to be tested with:

- a) A resistive-capacitive (rc) load having capacitance of 200,000 microfarads and a parallel resistance adjusted to draw rated output current;
- b) A battery supplemented with a resistive load bank; or
- c) A battery as specified by the manufacturer.

49.3 With reference to 49.2(c), when a unit is to be tested using batteries as the load, batteries are to be of the intended size. The batteries are to be discharged to 1.70 volts per cell at a rate not exceeding the discharge rate assigned by the battery manufacturer, and not exceeding one-sixth of the ampere-hour capacity of the battery.

49.4 Output current measurements of either half-wave or full-wave rectified circuits are to be based on the average current.

50 Temperature Test

50.1 Under the conditions specified in 49.1, the unit shall not reach a temperature at any point high enough to cause a risk of fire, damage any material used, cause a protective device to operate, or exceed the temperature limits specified in Table 50.1. During this test, the ambient temperature is to be as specified in 50.11.

50.2 For a fixed unit, the ampacity of the conductors connected to the field wiring terminals or leads shall be in accordance with the value determined by the requirement described in 11.1.1.3.

50.3 With reference to 50.1, a unit having voltage adjustment taps for intended use shall operate within the temperature limits at the setting representing the most severe loading condition as determined by an analysis of the circuit.

50.4 A unit intended for mounting or support in more than one position, or in a confined location, is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch thick trade-size soft-pine boards.

Table 50.1
Temperature limits

Materials and Components		Degrees	
		C	F
A.	MOTORS		
1.	Class A insulation systems on coil windings of motors having a diameter of more than 7 inches (178 mm)		
a.	In an open motor:		
	Thermocouple method	90 ^a	194 ^a
	Resistance method	100	212
b.	In a totally enclosed motor:		
	Thermocouple method	95	203
	Resistance method	105	221
2.	Class A insulation systems on coil windings of motors having a diameter of 7 inches (178 mm) or less		
a.	In an open motor:		
	Thermocouple or resistance method	100	212
b.	In a totally enclosed motor:		
	Thermocouple or resistance method	105	221
3.	Class B insulation systems on coil windings of motors having a diameter of more than 7 inches (178 mm)		
a.	In an open motor:		
	Thermocouple method	110 ^a	230 ^a
	Resistance method	120	248
b.	In a totally enclosed motor:		
	Thermocouple method	120	248
	Resistance method	125	257
4.	Class B insulation systems on coil windings of motors having a diameter of 7 inches (178 mm) or less		
a.	In an open motor:		

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Table 50.1 Continued

Materials and Components		Degrees	
		C	F
	Thermocouple or resistance method	120	248
b.	In a totally enclosed motor:		
	Thermocouple or resistance method	125	257
B.	COMPONENTS		
1.	Capacitors:		
a.	Electrolytic types	65 ^b	149 ^b
b.	Other than electrolytic	90 ^b	194 ^b
2.	Reserved		
3.	Field wiring Terminals	75 ^c	167 ^c
4.	Vulcanized fiber employed as electric insulation	90	194
5.	Plated bus bar	90 ^d	194 ^d
6.	Unplated bus bar and a joint	75 ^d	167 ^d
7.	Relays, solenoids, and similar devices		
a.	Class 105 coil insulation systems:		
	Thermocouple method	90 ^a	194 ^a
	Resistance method	110	203
b.	Class 130 coil insulation systems:		
	Thermocouple method	110 ^a	230 ^a
	Resistance method	120	248
8.	Transformer insulation systems:		
a.	Class 105:		
	Thermocouple method	90 ^a	194 ^a
	Resistance method	95	203
b.	Class 130:		
	Thermocouple method	110 ^a	230 ^a
	Resistance method	120	248
c.	Class 155:		
	Thermocouple method	135 ^a	275 ^a
	Resistance method	140	284
d.	Class 180:		
	Thermocouple method	150 ^a	302 ^a
	Resistance method	160	320
e.	Class 200:		
	Thermocouple method	165 ^a	329 ^a
	Resistance method	175	347
f.	Class 220:		
	Thermocouple method	180 ^a	356 ^a
	Resistance method	190	374
9.	Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock	150 ^e	302 ^e
10.	Wood and other combustible material	90	194
11.	Rubber- or thermoplastic-insulated wire and cord	60 ^{e,f}	140 ^{e,f}
12.	Other types of insulated wires	g	g
13.	A surface upon which a portable unit is mounted in service, and surfaces that are adjacent to the unit when so mounted	90	194
14.	Any point on or within a terminal box or compartment of a fixed unit on which field-installed conductors rests	60 ^c	140 ^c
15.	Thermoplastic sealing compound	i	i

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Table 50.1 Continued

Materials and Components		Degrees	
		C	F
16.	Selenium rectifier	75 ^{e,i}	167
17.	Power semiconductor	j	j
18.	Printed-wiring board	k	k

^a At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple is not prohibited from being 5°C (9°F) higher than that specified when the temperature of the coil as measured by the resistance method is not more than that specified.

^b A capacitor that operates at a temperature of more than 65°C (149°F) for electrolytic and more than 90°C (194°F) for other types is not prohibited from being judged on the basis of its marked temperature limit.

^c The temperature observed on the terminals and at points within a terminal box of a unit shall not attain a temperature higher than the temperature marking required in items p and o of 76.2.

^d For a bus bar having a current density in accordance with 19.2.9, it is not required to measure the temperature since it has characteristics which result in temperatures not exceeding the indicated values.

^e The temperature limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

^f A short length of rubber- or thermoplastic-insulated cord inside the unit is exposed to a temperature of more than 60°C (140°F) when supplementary insulation on each individual conductor is rated for the measured temperature and has dielectric properties in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, and the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

^g The temperature is not to exceed the temperature limit of the wire except as noted in note f.

^h The sealing compound temperature limit is 15°C (27°F) less than the softening point of the compound as determined in accordance with the Test Method for Vicat Softening Temperature of Plastics, ASTM D1525.

ⁱ A temperature limit of 85°C (185°F) meets the intent of the requirement when the stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 150°C (302°F).

^j For a power-switching semiconductor and similar components the temperature limit on the case is the maximum case temperature specified by the semiconductor manufacturer.

^k For a printed wiring board, the temperature limit is the specified limit of the board.

50.5 Unless investigated and found to meet the intent of the requirement, see the exception to 7.3 and 83.2.1, a supporting means formed of rubber or neoprene material is to be removed prior to the test. Where the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the unit supported by the metal insert. At the request of the manufacturer, it is not prohibited to conduct the test without any means of support.

50.6 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in good thermal contact with the surface of which the temperature is being measured. Usually, good thermal contact results from securely taping or cementing the thermocouple in place. Where a metal surface is involved, brazing or soldering the thermocouple to the metal is to be done when required for good thermal contact.

50.7 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method is an alternate method for a coil that is inaccessible for mounting thermocouples, such as a coil immersed in sealing compound, wrapped with thermal insulation, or wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32 inch (0.8 mm) thick. In a motor, the thermocouple is to be mounted on the integrally applied insulation of the coil wire.

50.8 The temperature of a winding is determined by the resistance method by comparing the resistance of the winding at a temperature to be determined with the resistance at a known temperature according to the formula:

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

in which:

T is the temperature of the winding in degrees C;

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

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

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

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined.

The winding is to be at room temperature at the start of the test.

50.9 All temperature limit values in Table 50.1 are based on an ambient temperature of 104°F (40°C) for units intended to be installed outdoors or on-board an EV and 77°F (25°C) for all other units. However, with correction of temperature measurements, tests conducted in other ambients as described in Table 50.2 are allowed.

Table 50.2
Temperature measurement correction

Ambient temperature rating of unit	Test ambient temperature	Correction of observed temperature
1. 25°C (77°F)	Range of 10 – 40°C (50 – 104°F)	See note a, item 1
2. Range of 25 – 40°C (77 – 104°F)	Range of 20 – 40°C (68 – 104°F)	See note a, item 2
3. Above 40°C (104°F)	Rated ambient See note b	c
<p>^a Correction of temperature, as determined by item A or B below, shall not exceed the temperature limit specified in Table 50.1:</p> <p>1) An observed temperature is to be corrected by addition (when the test ambient temperature is lower than the rated ambient temperature) or by subtraction (when the test ambient temperature is higher than the rated ambient temperature) of the difference between the rated ambient temperature and the test ambient temperature.</p> <p>2) An observed temperature is to be corrected by addition (when the test ambient temperature is lower than the rated ambient temperature) or by subtraction (when the test ambient temperature is higher than the rated ambient temperature) of the difference between the rated ambient temperature and the test ambient temperature.</p> <p>^b Allowable tolerances are: Minus – not less than 5°C (9°F) below rated ambient. Plus – not specified.</p> <p>^c When the test ambient temperature equals rated ambient, no correction is to be made, and an observed temperature shall not exceed the temperature limit specified in Table 50.1. When the test ambient temperature is other than rated ambient, correction is to be made as described in item 2 of note a.</p>		