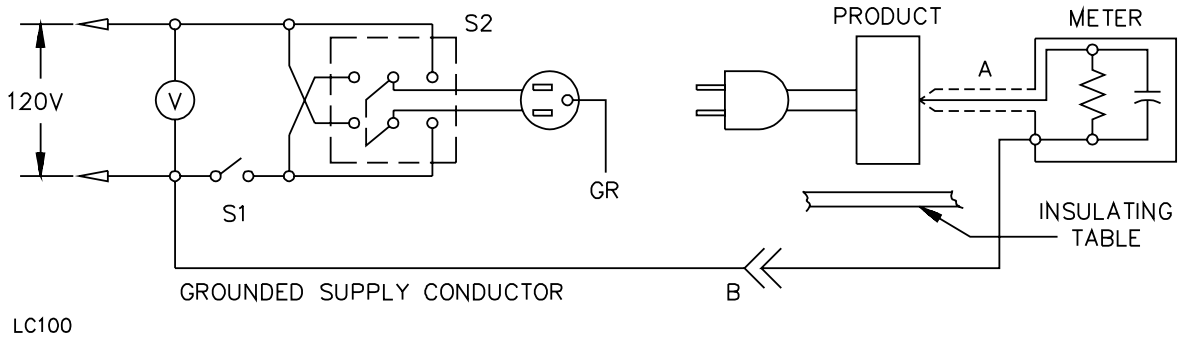
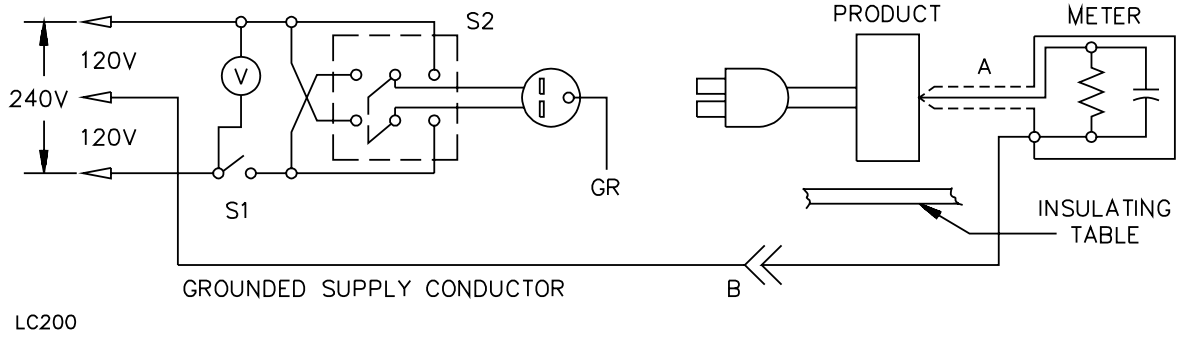
Figure 24.1
Leakage-current measurement circuit

Figure 24.1 revised September 25, 1998



LC100

Unit intended for connection to a 120-volt supply.



LC200

Unit intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

A. PROBE WITH SHIELDED LEAD.

B. SEPARATED AND USED AS CLIP WHEN MEASURING CURRENTS FROM ONE PART OF DEVICE TO ANOTHER.

25 Leakage Current Test and Dielectric Voltage Withstand Test After Humidity Exposure

25.1 A unit shall comply with the Leakage Current Test, Section 24, and Dielectric Voltage Withstand Test, Section 32, following exposure for 48 hours to air having a relative humidity of 88 ±2.0 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F).

25.2 To determine whether a unit complies with the requirement in 25.1, a sample of the unit at a temperature just above 34.0°C (93.2°F) is to be conditioned for 48 hours in a humidity chamber maintained as specified in 25.1. Following the conditioning, the sample is to be tested unenergized as described in 24.7(a), and then energized and tested as described in 24.7(b) and 24.7(c). The test is to be discontinued when the leakage current stabilizes or decreases. The sample is then to be subjected to the Dielectric Voltage Withstand Test, Section 32.

26 Maximum Output Voltage Test

26.1 The maximum output voltage under any load condition (including no load) between any two output terminations of a unit shall not be more than the peak voltages specified in 14.2.2 when the primary is connected to the supply circuit. The Exception to 14.2.2 does not apply to this requirement. See 26.3.

26.2 If a unit has more then one pair of output terminations, the output voltage mentioned in 26.1 is to be measured with any combination of interconnections of the output terminations.

26.3 The maximum voltage between output terminations of a multiple output unit may exceed the values specified in 26.1 when the output terminations are interconnected, if the following conditions are met:

a) The maximum output voltage between any two terminations is not more than the values indicated in 26.1 when no connections are made between the output terminations, and

b) The unit is marked in accordance with 49.2.10.

27 Maximum Input Test

27.1 The primary input of a unit shall not be more than 660 watts when the unit is connected to the supply circuit with any condition of secondary load, including the short-circuiting of any combination of outputs.

27.2 To determine compliance with 27.1, one sample of the unit is to be connected to the load specified in Table 23.3, and the loads are to be adjusted to cause maximum input to the sample. The supply circuit is then to be de-energized and the sample is to be allowed to cool to room temperature. The supply circuit is then to be energized a second time and the input power measured within 15 seconds after application of voltage to the primary windings.

28 Output Current and Power Test

28.1 General

28.1.1 The maximum output current and output volt-amperes specified in 28.2 and 28.3 are to be determined using a current meter and a watt meter. A resistive load is to be adjusted to result in maximum reading of the meters. With no further adjustment of the load, the sample is to be de-energized and cooled to room temperature. The sample is then to be energized and maximum current and wattage measurements are to be taken at the time specified in 28.2.

Exception: An inherently limited or a not inherently limited Class 2 transformer that complies with the requirements in UL 1585, Standard for Class 2 and Class 3 Transformers, is not required to be tested in accordance with 28.2 or 28.3.

28.1.1 revised August 2, 1996

28.2 Inherently limited

28.2.1 Under any condition of resistive loading – including short-circuit and interconnection of outputs when not prohibited by marking – the maximum output current shall not exceed the value specified in Table 28.1 and the maximum output volt-amperes shall not be more than 100 volt-amperes, except as indicated in 28.2.3 and 28.3.1, for the following conditions, as applicable:

a) For a unit which employs a transformer with no form of protection, the measurement is to be made 60 seconds after the unit is connected to the source of supply.

b) For a unit which employs a transformer and an energy limiting impedance or energy limiting circuit (a resistor, a PTC device, or similar circuitry) required for the purpose (See 2.7), the measurement is to be made five seconds after the unit is connected to the source of supply.

c) For a unit which employs a transformer and either a thermal cutoff, a fuse, or both, the all protection is to be defeated during the test and the measurement made 60 seconds after the unit is connected to the source of supply.

d) For a unit that employs a transformer and a combination of a limiting impedance or circuit required for the purpose, and a protective device (such as a thermal cutoff, a fuse, or both), all protective devices are to be defeated and the measurement is to be made five seconds after the unit is connected to the source of supply.

e) For a unit that employs a dc input, in accordance with 1.1, and a combination of a limiting impedance or circuit required for the purpose, and a protective device (i.e. thermal cutoff, fuse, or both), the protective device is to be defeated and the measurement is to be made five seconds after the unit is connected to the source of supply.

28.2.1 revised August 2, 1996

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Table 28.1
Maximum output current for inherently limited units

Circuit voltage (V_{max})[a,b] ac or dc Volts	Maximum nameplate ratings		Maximum output current (I_{max})[c], Amperes
	Volt-Amperes	Amperes	
0 – 20	5.0 X V_{max}	5.0	8.0
Over 20 to 30	100	$100/V_{max}$	8.0
Over 30 to 60, dc only	100	$100/V_{max}$	$150/V_{max}$

[a] V_{max} : Maximum output voltage regardless of load with rated input voltage applied.
[b] Voltage ranges shown are for sinusoidal alternating current and continuous direct current. For nonsinusoidal alternating current, maximum voltage shall not be greater than 42.4 volts peak. For direct current interrupted at a rate of 10 – 200 hertz, maximum voltage shall not be greater than 24.8 volts.
[c] I_{max} is maximum output current regardless of load.

28.2.2 If the value of current and power cannot be obtained due to operation of a protective device, damage to the transformer, or the like:

a) The values are to be extrapolated, if feasible, from the values measured earlier in the time period, or

b) A protective device may be shunted to obtain the required data.

28.2.3 The current between output terminations of a multioutput unit is not required to comply with the requirement in 28.2.1 when output terminations are interconnected if the following conditions are met:

a) The output current between any two terminations is not more than the limit specified in 28.2.1 when no connections are made between output terminations of separate outputs,

b) The unit is marked in accordance with 49.2.10, and

c) There is no emission of flame or molten metal from the unit enclosure and no other evidence of a risk of fire or electric shock.

28.2.3 revised April 4, 2000

28.3 Not inherently limited

28.3.1 When the unit includes means to automatically de-energize the output circuit (see 9.10), the values of the output current and volt-amperes specified in 28.2.1 shall not exceed those specified in Table 28.2.

28.3.1 revised April 4, 2000

28.3.2 To determine if a unit complies with the requirement in 28.3.1, the unit is to be allowed to deliver the test current to a resistance load, with the primary connected to a source of supply. The unit is to be draped with a double layer of cheesecloth conforming to the device outline. Charring, glowing, or flaming of the cheesecloth is unacceptable.

28.3.2 revised April 4, 2000

Table 28.2
Maximum output current and volt-amperes for not inherently limited units

Table 28.2 revised July 7, 1995

Circuit voltage (V_{max})[a,b] ac or dc, volts	Maximum nameplate ratings		Maximum output (I_{max})[c], amperes	Maximum output volt-amperes, (VA_{max})[d]	Maximum overcurrent protection rating, amperes
	Volt-amperes	Amperes			
0 – 20	5.0 X V_{max}	5.0	$1000/V_{max}$	250[e]	5.0
Over 20 to 30	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$
Over 30 to 60, dc only	100	$100/V_{max}$	$1000/V_{max}$	250	$100/V_{max}$

[a] V_{max} is the maximum output voltage regardless of load with rated input voltage applied.

[b] Voltage ranges shown are for sinusoidal alternating current and continuous direct current. For nonsinusoidal alternating current, maximum voltage shall be greater than 42.4 volts peak. For direct current interrupted at a rate of 10 – 200 hertz, maximum voltage shall not be greater than 24.8 volts.

[c] I_{max} is maximum ampere output regardless of load after operation as specified in 28.2.1.

[d] VA_{max} is maximum volt-ampere output regardless of load after operation as specified in 28.2.1.

[e] Maximum volt-amperes is 350 if maximum circuit voltage is 15 or less.

29 Calibration of Overcurrent Protection Devices Test

29.1 A protective device provided as a part of a not inherently limited unit shall operate in not more than the time indicated in Table 29.1 when the unit is delivering the specified secondary current. There shall be no emission of flame or molten metal from the enclosure, and no evidence of a risk of fire or electric shock as described in 38.1.2. The unit shall withstand the dielectric voltage withstand test as specified in 32.1.1(a), applied between the primary winding and secondary windings, and between the primary and exposed dead metal parts.

Exception: This test need not be conducted if a suitably rated (see Table 28.2) and calibrated fuse is provided in the output circuit.

29.2 During the test, the grounding means is to be connected to ground through a 3-ampere nontime-delay fuse and the unit is to be draped with a double layer of cheesecloth conforming to the outline of the unit.

Table 29.1
Maximum acceptable time for protection device operation

Rated secondary potential, volts	Secondary test current, amperes	Maximum time for protective device to operate, minutes
20 or less	10[a]	2
20 or less	6.75[b]	60
Over 20 to 30	$200/V_{max}$[a,c]	2
Over 20 to 30	$135/V_{max}$[b,c]	60
Over 30 to 60, dc only	$200/V_{max}$[a,c]	2
Over 30 to 60, dc only	$135/V_{max}$[b,c]	60

[a] The load is to be adjusted continuously to maintain the test current value shown.
[b] After 15 minutes of operation, the load is to be readjusted to return the output current value shown.
[c] V_{max} is the maximum output voltage regardless of load with rated input.

30 Full-Load Output Current Test

30.1 A unit shall deliver its rated full-load secondary current continuously.

30.2 To determine compliance with the requirement in 30.1, one sample is to be tested as follows. With a variable load as specified in Table 23.3 and an ammeter connected to the output, the primary is to be connected to the supply circuit. The load is to be adjusted to draw rated output current. After 15 minutes of operation, the resistance is to be readjusted, if necessary, to return the current to that value. The test is then to be continued for 1 hour without further adjustment. At the end of 1 hour, the output current shall not be less than 90 percent of the rated load current. An overtemperature- or overcurrent-protective device shall not function during this test.

30.3 If a unit has its output rated in volt-amperes or watts, the rated output current is to be determined by dividing the rated output voltage into the rated output volt-amperes or watts.

31 Normal Temperature Test

31.1 The temperature rises on various materials and parts shall not exceed the limits specified in Table 31.1 when the unit is operated as specified in 31.2 – 31.5. Upon completion of this test, the unit shall comply with the Dielectric Voltage Withstand Test, Section 32.

31.2 For a direct plug-in unit, this test is to be conducted in both the horizontal and vertical positions. For a cord-connected unit, this test is to be conducted in all likely mounting positions. A sample is to be operated with the primary energized from a circuit as specified in 23.3 and 23.4. Each output is to be loaded as specified in 23.8. A battery charger which is likely to be used for consecutive charging of batteries is to be tested as specified in 31.5 and 31.6.

Table 31.1
Maximum acceptable temperature rises

Table 31.1 revised October 22, 2001

Materials and components			°C	°F
A.	COMPONENTS			
	1.	*Deleted*		
	2.	Rubber- or thermoplastic-insulated conductors[a]	35	63
	3.	Silicon components[b]	75	135
B.	ELECTRICAL INSULATION – GENERAL			
	1.	Class 105 insulation systems:		
		Resistance method	75	135
		Thermocouple method	65	117
	2.	Class 130 insulation systems:		
		Resistance method	95	171
		Thermocouple method	85	153
	3.	Fiber employed as electrical insulation	65	117
	4.	Phenolic composition[a]	125	225
	5.	Varnish-cloth insulation	60	108
C.	SURFACES			
	1.	Surface temperature, metal[c,d]	30	54
	2.	Surface temperature, nonmetallic[c,e]	50	90
	3.	Wood or similar material	65	117

[a] The limitation on phenolic composition, rubber and thermoplastic insulation does not apply to compounds that have been investigated and found to be acceptable for use at a higher temperature. The maximum acceptable temperature rise in any case is 25°C (77°F) less than the acceptable temperature limit in question.

[b] Does not apply to a material that has been investigated and found acceptable for a higher temperature.

[c] A material having a coefficient of thermal conductivity greater than 2.419 Btu per hour per square foot per foot per degree Fahrenheit (0.01 c/s/cm^2 /cm/°C) is considered to be metal. See 31.7.

[d] 45°C (81°F) rise for semipermanent mounted units marked as required by 49.2.5.

[e] 65°C (117°F) rise for semipermanent mounted units marked as required by 49.2.5.

31.3 If the load mentioned in 31.2 and specified in 23.8 includes a variable resistance, the load is to be adjusted after 15 minutes of operation, if necessary, to return the output to the original value. If the load consists of a battery, the battery shall be discharged as specified in 23.10, 23.11, or 23.12, as applicable.

31.4 If a battery charger which is not likely to be used for consecutive charging of batteries is tested with a battery load, the test is to be continued until temperatures peak. The load is to be replaced by a second discharged battery. The test is terminated when temperatures peak during the second load condition.

31.5 A battery charger which is likely to be used for consecutive charging of batteries is to be tested with the intended battery load. The test is to be conducted in accordance with 31.6.

31.6 With respect to 31.5, a charger is to be tested in accordance with the following:

a) For a charger with no charge status indicator, the test is to be continued until temperatures peak. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

b) For a charger with a visual charge status indicator, the test is to be continued until the visual indicator indicates that the charge cycle is complete. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

c) For a charger with a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

d) For a charger with both a visual charge status indicator and a charge time marking or instruction, the test is to be continued until the specified charge time has elapsed or until the visual indicator indicates that the charge cycle is complete, whichever occurs first. The load is to be replaced with another discharged battery. This sequence is to be repeated until maximum temperatures are obtained.

31.7 With reference to footnote c to Table 31.1, the thermal conductivity of a material can be obtained by comparison with materials that have known thermal conductivities. Samples of materials with known values of the constant and a sample of the material for which the value is unknown are to be fixed to a heated metal plate. All samples are to be of the size used in the unit. The temperatures of the faces of the reference samples opposite the heated metal plate are to be plotted as a function of the constant. The constant of the material for which the value is unknown is derived from the curve by reading off the value corresponding to the temperature attained by the sample under investigation.

31.8 All values in Table 31.1 are based on an assumed ambient temperature of 25°C (77°F), but a test may be conducted at any ambient temperature within the range specified in 23.7.

31.9 A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no further increase.

31.10 Except when it is specifically stated that the temperature determinations are to be made by the resistance method, temperatures are to be measured by means of thermocouples. The junction of the thermocouple is to be secured in intimate contact with the point of the surface at which the temperature is to be measured.

31.11 Thermocouples are to consist of wires not larger than No. 24 AWG (0.21 mm^2) and not smaller than No. 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of No. 30 AWG iron and constantan wire and a potentiometer-type instrument; and such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with accepted laboratory practice. The thermocouple wire is to comply with the requirements listed in the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1.

31.11 revised April 4, 2000

31.12 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except the resistance method is to be used for a coil that is inaccessible for mounting of these devices such as a coil:

a) Immersed in sealing compound,

b) Wrapped with thermal insulation, or

c) Wrapped with a material, such as cotton, paper, or rayon more than 1/32 inch (0.8 mm) thick.

31.13 The temperature rise of a copper 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:

$$\Delta t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

Δt *is the temperature rise;*

R is the resistance of the coil at the end of the test in ohms (see 31.14);

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

k is 234.5 for copper;

t_1 *is the room temperature in degrees C at the beginning of the tests; and*

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

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

31.14 Because it is generally necessary to de-energize the winding before measuring R, the value of R at shutdown may be determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values against time may be plotted and extrapolated to give the value of R at shutdown. Instrumentation by which R can be measured while the coil is energized may be used.

31.15 For manufacturers who choose to declare an operating ambient above 25°C, the following formulas can be used to determine compliance when testing in a normal room temperature environment:

$$\text{if } T_{MAX} \text{ is specified: } (T - T_{AMB}) \leq (T_{MAX} - T_{MRA})$$

$$\text{if } \Delta T \text{ is specified: } (T - T_{AMB}) \leq (\Delta T_{MAX} + 25 - T_{MRA})$$

where:

T = the temperature of the given part measured under prescribed test conditions; and

T_{MRA} = the maximum room ambient temperature permitted by the manufacturer's specification or 25°C, whichever is greater.

31.15 added September 25, 2001

32 Dielectric Voltage Withstand Test

32.1 General

32.1.1 One minute after the applicable test, the unit shall withstand for 1 minute without breakdown the application of a potential. The test potential shall be:

a) One thousand volts ac plus twice the maximum rated voltage between

1) The primary circuit and accessible dead metal parts, and

2) The primary and secondary circuit or circuits.

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