multiple secondary windings, all measurements on one secondary-winding circuit are to be made with all other windings unloaded.

35.1.14 The acceptability of spacings between live and dead metal parts connected to the enclosure within an instrument shall be judged by conducting the applicable dielectric voltage-withstand test described in Section 43, Dielectric Voltage-Withstand Test.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panel Board Types, UL 1437, is not required to be subjected to a Dielectric Voltage-Withstand Test.

35.2 Alternative Spacings

35.2.1 With reference to 35.1.1 Exception No. 8, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used. The spacing requirements of UL 840 shall not be used for field wiring terminals or for spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be evaluated and is able to modify those characteristics given in 35.2.2 and 35.2.3.

35.2.2 The level of pollution expected or controlled for indoor use equipment is pollution degree 2. For outdoor use equipment, pollution degree 3 is expected. Hermetically sealed or encapsulated enclosures, or coated printing wiring boards in compliance with the Printed Wiring Board Coating Performance Test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are pollution degree 1.

35.2.3 It is anticipated the equipment is rated overvoltage category II and overvoltage category I as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

35.2.4 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.

35.2.5 For the purpose of applying this alternative, all printed wiring boards are evaluated as having a minimum comparative tracking index of 100 without further investigation.

35.3 Insulation liners and barriers

35.3.1 An insulating liner or barrier of material such as vulcanized fiber or thermoplastic used in lieu of required spacings specified in Exception No. 1 to 35.1.1 shall not be less than 0.028 inch (0.71 mm) thick. The material shall not be used as the sole support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current. Other insulating materials used as a barrier or as either direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical-energy/high current shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: Vulcanized fiber not less than 0.013 inch (0.33 mm) thick is capable of being used:

> *a) In conjunction with an air spacing of not less than 50 percent of the minimum required through air spacing; and*
>
> *b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.*

Exception No. 2: A generic material as noted in 35.3.5 and Table 35.3 is capable of being used as an insulating liner when the material:

a) Does not serve as sole support of live parts; and

b) Is not subject to inadvertent mechanical stresses by a user or a field installer.

Exception No. 3: An insulating material having a thickness less than that specified is capable of being used when, upon investigation, it is found to be capable of being used for the application and has a dielectric breakdown strength of not less than 5000 volts or 2500 volts in the thickness used for equivalency to 0.028 inch or 0.013 inch thick vulcanized fiber, respectively, as determined by the equivalent insulation test described in Tests of Insulating Material, Section 44.

35.3.2 Other than as indicated in 35.3.3, insulating tubing complying with the requirements in the Standard for Extruded Insulating Tubing, UL 224, may be used as insulation of:

a) A conductor including bus bars in lieu of the minimum required spacings; and

b) A capacitor case in lieu of bonding the case for grounding, providing that the following conditions are met:

1) The conductor is not subjected to compression, repeated flexure, or sharp bends;

2) The conductor or case covered with the tubing is well rounded and free from sharp edges;

3) The tubing is used in accordance with the manufacturer's instructions; and

4) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

35.3.3 Insulating tubing complying with the Standard for Extruded Insulating Tubing, UL 224, shall not be used as insulation over parts subject to maintenance, such as bolts that are periodically tightened.

35.3.4 A wrap of thermoplastic tape, complying with the requirements in the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510, may be used when all of the following conditions are met:

a) The wrap is not less than 0.013 inch (0.33 mm) thick, is applied in two or more layers, and is used in conjunction with not less than one-half the required through air spacing;

b) The wrap is not less than 0.028 inch (0.71 mm) thick when used in conjunction with less than one-half the required through air spacing;

c) Its temperature rating is not less than the maximum temperature observed during the Temperature Test of Section 42;

d) The tape is not subject to compression;

e) The tape is not wrapped over a sharp edge; and

f) The tape is not wrapped over parts subject to maintenance, such as bolts that are periodically tightened.

35.3.5 With reference to Exception No. 2 of 35.3.1, and notes (c) and (g) of Table 26.1, insulation of a generic material type specified in Table 35.3, is capable of being used where the layer(s) of each generic material is of a minimum thickness such that all layers collectively are greater than, or equal to, the minimum thickness required (T):

$$T \leq A_1(EF_1) + A_2(EF_2) + A_3(EF_3)...$$

in which:

A_1, A_2, and A_3 denote the total thickness of each generic material type;

EF_1, EF_2, and EF_3 denote the equivalency factor specified in Table 35.3 for the generic material type corresponding to A_1, A_2, and A_3; and

T is the thickness requirement for vulcanized fiber.

Table 35.3
Equivalency factors for insulation materials

Generic material	Equivalency factor (EF)
Electrical grade paper, fiber, or pressboard	1
Impregnated rag paper	1.3
Acetate sheet	1.5
Polyvinyl chloride (PVC)	1.3
Silicone rubber (SIR)	0.5
Impregnated glass or acetate cloth	1.2
Polyester	b
Polyethylene terephthalate (PETP)	b
Fluorinated ethylene propylene (FEP)	3
Polytetrafluoroethylene (PTFE)	3
Aramid paper	c
Polyamide (PI)	6
Mica[a]	4.7

NOTE – See 35.3.5.

[a] EF applies when not subject to mechanical damage.

[b] To determine equivalence to 0.028 inch (0.71 mm) thick vulcanized fiber, EF = 4; to determine equivalence to 0.013 inch (0.33 mm) thick vulcanized fiber, EF = 2.

[c] To determine equivalence to 0.028 inch thick vulcanized fiber, EF = 3.3; to determine equivalence to 0.013 inch thick vulcanized fiber, EF = 1.5.

36 Control Circuits

36.1 An LVLE circuit as described in 6.15, or a limited-energy circuit as described in 6.13 is able to be connected to the frame of the unit.

36.2 When the frame is used as a current-carrying part of a secondary circuit, a hinge or other movable part shall not be relied upon to carry current.

36.3 Except as indicated in 36.4, an LVLE circuit (see 6.15) is not required to be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that are required for the application. See 22.1.1 and 34.1.

36.4 Safety circuits shall comply with the requirements for primary circuits.

36.5 A control circuit, including associated electronic components on printed-wiring boards, that does not extend out of the unit is not required to be investigated when the maximum voltage and current are limited as specified in (a) and (b):

a) A voltage limit of 42.4 volts peak for ac, 60 volts for dc; and

b) 8 amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 36.6.

Printed-wiring boards, insulated wires, and motors used in such circuits shall be types that are required for the application. See 22.1.1, 25.1, 25.2, and 34.1.

Exception: The current is able to exceed the value specified in (b) when the circuit includes an overcurrent protection device as described in 36.9 and 36.10.

36.6 With reference to the current specified in 36.5(b), the maximum current is to be measured under any condition of loading, including short circuit. This is to be accomplished using a resistor that is continuously readjusted during the 1-minute period to maintain maximum load current. This current shall not exceed the value indicated in 36.5(b).

36.7 With reference to the voltage limit specified in 36.5(a), measurement is to be made with the unit connected to the voltage specified in 39.1 and with all loading circuits disconnected. When a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

36.8 When the control circuit specified in 36.5 is not limited as to available short-circuit current by the construction of a transformer, and the circuit includes either one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network (see 36.12), the circuits in which the current is limited, in accordance with 36.9, 36.10, or 36.11, is not required to be investigated.

36.9 A fuse or circuit-protective device provided in the control circuit used to limit the current in accordance with 36.8 shall be rated or set at not more than the values specified in Table 36.1.

Table 36.1
Rating for secondary fuse or circuit protector

Circuit voltage (volts, rms)	Maximum overcurrent protection (amperes)
20 or less	5
More than 20 and not greater than 60	$100/V^a$
[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with 39.1.	

36.10 A fuse or circuit-protective device is able to be connected in the primary of a transformer to limit the current, in accordance with 36.8, when the protection is equivalent to that specified in 36.9. This shall be determined by conducting the Overcurrent Protection Calibration Test, Section 52.

36.11 One or more resistors, or a regulating network, used to limit the current in accordance with 36.8 shall be such that the current under any condition of load, including short circuit, does not exceed the values indicated in 36.5(b).

36.12 When a regulating network is used to limit the voltage or current, in accordance with 36.5 – 36.11, and the performance is affected by malfunction, either short circuit or open circuit, of any single component – excluding a resistor – the network shall comply with the following:

a) The environmental tests specified in 36.14 are to be performed; and

b) Critical components shall be derated in accordance with the Electronic Reliability Design Handbook, Military Handbook Number 338-1A.

36.13 In a circuit of the type described in 36.8, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited, shall be evaluated to the applicable requirements in this standard.

36.14 When it is determined that environmental tests in accordance with 36.12 (a) are required, the control is to be subjected to the following tests, in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991:

a) Transient Overvoltage Test;

b) Ramp Voltage Test;

c) Electromagnetic Susceptibility Tests;

d) Electrostatic Discharge Test;

e) Thermal Cycling Test;

f) Humidity Test for a unit intended for a general environment; and

g) Effects of Shipping and Storage Test.

Before and after each test, the control is to be checked for normal operation. See 36.15.

36.15 The following test parameters are to be used in the investigation of the control covered by 36.14 for compliance with the Standard for Tests for Safety-Related Controls Employing Solid State Devices, UL 991:

a) Critical components are able to be electrically supervised;

b) Audibility is capable of being used as a trouble indicator for an electrical supervision circuit;

c) A field strength of 3 volts per meter (0.91 volts per foot) is to be used for the Radiated EMI Test; and

d) Exposure Class H5 is to be used for the Humidity Test.

37 Accessible Signal Circuits

37.1 The requirements in 37.2 and 37.3 apply to accessible signal circuits having provision for external connections such as RS232 communication ports and similar equipment.

37.2 A signal circuit that extends out of a unit shall be isolated from internal circuits having a voltage involving a risk of electric shock by any of the following or the equivalent:

a) An optical isolator having an isolation voltage rating of not less than the dielectric voltage-withstand test potential required in 43.1.1 and complying with the requirements in the Standard for Optical Isolators, UL 1577;

b) An isolation transformer complying with the requirements in the Standard for Class 2 Power Units, UL 1310, or the Standards for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3;

c) An isolation transformer complying with the requirements in 26.1.4 – 26.2.4;

d) An electro-mechanical relay complying with the requirements in the Standard for Industrial Control Equipment, UL 508; or

e) A voltage regulating network when:

1) The voltage being isolated is not derived from the ac input circuit; and

2) The network does not show a risk of electric shock at the external signal circuits as a result of a failure mode and effect analysis, in accordance with the method described in the Standard for Tests for Safety Related Controls Employing Solid-State Devices, UL 991.

37.3 The maximum voltage and current available from an accessible signal circuit shall comply with the requirements in 36.5 – 36.12.

37.4 The maximum power available from an accessible signal circuit that employs an overcurrent protection device to limit the current, as described in the Exception to 36.5, shall not exceed the values specified in Table 37.1.

Table 37.1
Maximum power of accessible signal circuits

Circuit voltage volts, rms	Maximum power, volt-amperes
15 or less	350
More than 15 and not greater than 60	250

38 Class 2 and Class 3 Output Circuits

38.1 When an output is marked or otherwise identified as being Class 2, that output shall comply with the construction, performance, and marking requirements described in the Standard for Class 2 Power Units, UL 1310.

38.2 When an output is marked or otherwise identified as being Class 3, and the output is ac supplied from a linear transformer, that output shall comply with the construction, performance, and marking requirements described in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3. When the output is dc or supplied from other than a linear transformer, that output shall comply with the requirements in Sections 79 – 87.

PERFORMANCE

39 General

39.1 A representative sample of a power unit shall be subjected to the tests described in 39.4 and Sections 40 – 57. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 39.1, and at rated frequency. A power unit rated 50 – 60 hertz is to be tested at 60 hertz. A power unit marked with an operating voltage range shall comply with the requirements in this Section while connected to a source of voltage adjusted to any value within the specified range.

Table 39.1
Values of test voltages

Rated voltage	Test voltage
110 – 120	120
121 – 219	Rated voltage
220 – 240	240
241 – 253	Rated voltage
254 – 277	277
278 – 439	Rated voltage
440 – 480	480
481 – 525	Rated voltage
550 – 600	600

39.2 The tests of a power unit having an output for a utilization appliance, other specific equipment, or for charging storage batteries shall, if necessary, include consideration of the output voltage and current wave forms under all likely loading conditions.

39.3 Output current measurements of either half-wave or full-wave rectifier circuits are to be based on the average current reading.

39.4 In addition to the applicable performance tests specified in Sections 40 – 57, a polymeric enclosure (see 7.1.5) shall be evaluated to the following tests in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C:

a) Mold Stress Relief Distortion;

b) Resistance to Impact; and

c) Strain Relief Test after Mold Stress Relief Distortion.

40 Leakage Current Test

40.1 The leakage current of a cord-connected power unit when tested in accordance with 40.2 – 40.6 shall not be more than:

a) 0.5 milliampere for a portable power unit; or

b) 0.75 milliampere for a stationary power unit.

Exception: A unit that is required to have primary-circuit filtering to meet the applicable electromagnetic compatibility (EMC) regulations may have higher leakage current levels at accessible parts provided that the unit complies with the following:

a) Leakage current does not exceed 5.0 milliampere and the unit complies with the grounding requirements in Section 16, Grounding Connections; or

b) Leakage current does not exceed 5 percent of the input current determined in accordance with Section 41, Power Input Test, and all of the following conditions are met:

1) The unit complies with the grounding requirements in Section 16, Grounding Connections;

2) The unit is not supplied through a standard configuration 125 volt, 15 amp nor 125 volt, 20 amp non-locking type plug;

3) Provision is made for connecting together and earth-grounding all the metal frames of the unit in the system; and

4) The installation instructions comply with the requirements in 62.1.9.

40.2 All exposed conductive surfaces shall 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 to reduce the risk of electric shock as defined in 8.1. 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 output terminals operating at voltages less than 30 volts rms (42.4 volts peak) or 60 volts dc. If all accessible surfaces are bonded together and connected to the grounding conductor of the power supply cord, the leakage current may be measured between the grounding conductor and the grounded supply conductor.

40.3 If a conductive surface other than metal is used for the enclosure or a part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 centimeters (3.9 by 7.9 inches) in contact with the surface. If the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the power unit.

40.4 The circuit for the leakage current measurement is to be as illustrated in Figure 40.1. 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. The measurement instrument is to comply with the following:

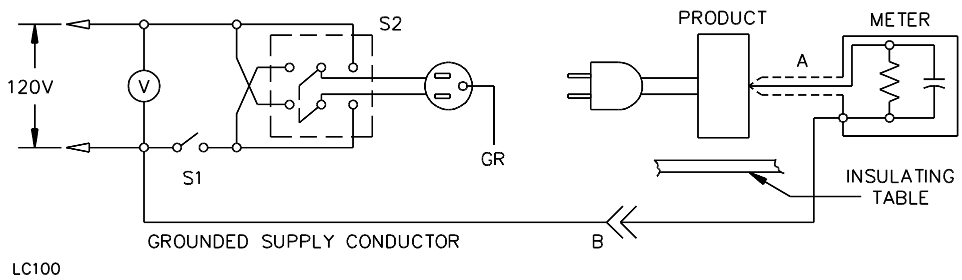
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

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

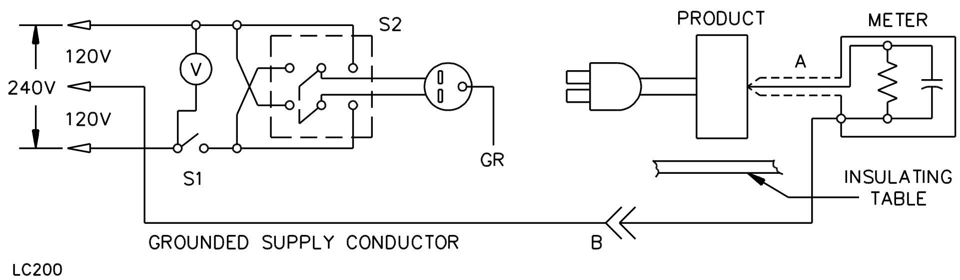
c) Over a frequency range of 0 – 100 kilohertz, the measurement circuit is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.5 or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

Figure 40.1

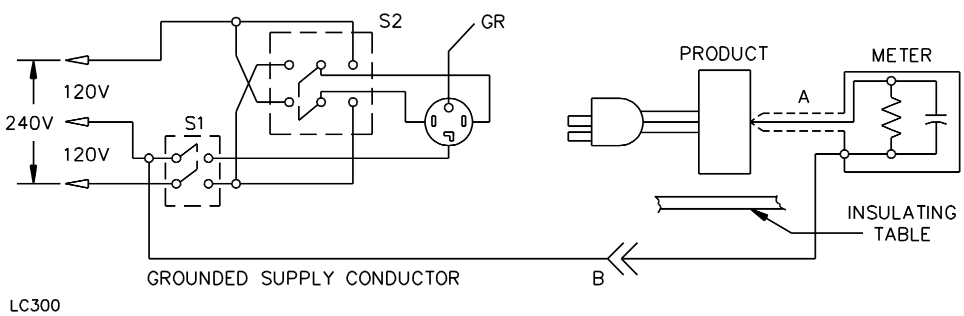
Leakage current measurement circuit



A. Appliance intended for connection to a 120-volt power supply.



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



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

Note:

A. Probe with shielded lead.

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

40.5 Unless the meter is being used to measure leakage from one part of a power unit to another, the meter is to be connected between an accessible part and the grounded supply conductor.

40.6 A sample of the power unit is to be tested for leakage current starting with the as-received condition – the as-received condition is without prior energization except as may occur as part of the production-line testing – but with the grounding conductor, if any, open at the attachment plug. The supply voltage is to be adjusted to the test voltage specified in Table 39.1. The test sequence, with reference to the measuring circuit, Figure 40.1, is to be as follows:

a) With switch S1 open, the power unit is to be without load and connected to the measuring circuit. The leakage current is to be measured using both positions of switch S2 and with the power unit switching devices in all their operating positions.

b) Switch S1 is then to be closed energizing the power unit, and within 5 seconds the leakage current is to be measured using both positions of switch S2, and with the power unit switching devices in all their operating positions.

c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in making this measurement. Thermal stabilization is considered to be obtained by operation as in the normal temperature test.

40.7 In general, the complete leakage current test program as described in 40.6 is to be conducted without interruption for other tests. With the concurrence of those concerned, the leakage current tests may be interrupted to conduct other nondestructive tests.

41 Power Input Test

41.1 The current or watts input to a power unit, when connected to a supply adjusted to the test voltage specified in Table 39.1 and supplying rated output into a load as described in Table 41.1 shall not be more than 110 percent of the rated value when temperatures stabilize (see 42.15).

Table 41.1
Unit output loading

Type of output current	Intended use	Load for test
Alternating current or rectified	Unspecified	Variable resistor adjusted to result in rated output.
Rectified	Battery charger rated ≤ 20A	Variable resistor in parallel with a 100,000 microfarad capacitor adjusted to result in rated output.[a,b]
	Battery charger rated > 20A	Variable resistor in parallel with a 185,000 microfarad capacitor adjusted to result in rated output.[a,b]

[a] For a power unit having a capacitive filter in the output circuit, only a variable resistor is to be used.

[b] If appropriate, the power unit may be tested with a battery supplemented with a resistive load, or the battery intended to be charged by the power unit (see 41.4 and 41.5).

41.2 A battery charger intended for use with a specific battery pack shall be tested using the battery pack as its intended load.

41.3 If a power unit intended to charge batteries is to be tested using a lead-acid battery or batteries as the load, each battery is to be discharged to 1.75 volts per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer, but in any case, the rate of the discharge is not to exceed one-sixth of the ampere-hour capacity of the battery. See Table 41.1.

41.4 If a battery charger is to be tested with a typical 1.2 volt per cell nickel-cadmium battery or batteries as the load, each battery is to be discharged to 0.9 volts per cell – measured with the load connected – at a rate not to exceed the discharge rate assigned by the battery manufacturer.

41.5 If a battery charger is to be tested with a battery or batteries other than those specified in 41.3 and 41.4, the battery is to be discharged in accordance with the battery manufacturers maximum recommended discharge rate to an appropriate discharge voltage.

42 Temperature Test

42.1 The power unit shall be mounted as in intended service and connected as described in 41.1. With the power unit operating at its maximum marked duty cycle, the power unit shall not reach a temperature at any point high enough to cause a risk of fire, to damage any material used, or to exceed the temperature limits specified in Table 42.1.

Table 42.1
Maximum temperature limits

Materials and components	°C	(°F)
1. A surface upon which a stationary power unit may be mounted in service, and surfaces that may be adjacent to the unit when so mounted	90	(194)
2. Any point on or within a terminal box or compartment of a fixed power unit on which field-installed conductors to be connected may rest	60[a]	(140)[a]
3. Field wiring terminals	75[a]	167[a]
4. Class 105 coil insulation systems of a relay, a solenoid, or the like		
Thermocouple method	90[b]	(194)[b]
Resistance method	110	(230)
5. Class 130 coil insulation systems of a relay, a solenoid, or the like		
Thermocouple method	110[b]	(230)[b]
Resistance method	120	(248)
6. Class 105 transformer insulation systems:		
Thermocouple method	90[b]	(194)[b]
Resistance method	95	(203)
7. Class 130 transformer insulation systems		
Thermocouple method	110[b]	(230)[b]
Resistance method	120	(248)
8. Class 155 transformer insulation systems		
Thermocouple method	135	(275)
Resistance method	140	(284)
9. Class 180 transformer insulation systems		
Thermocouple method	150	(302)
Resistance method	160	(320)
10. Class 200 transformer insulation systems		
Thermocouple method	165	(329)
Resistance method	175	(347)
11. Class 220 transformer insulation systems		

Table 42.1 Continued on Next Page