42.3 EMI filter

42.3.1 The AFCI shall be installed in the following circuits. An arc test as described in Subsection 42.1 shall be introduced with a 5-A load. The AFCI shall clear the arcing fault as specified in the description for the test in 40.2.6, or in Table 40.1, or in 40.2.6 and Table 40.1, depending on the AFCI type.

a) Two EMI filters of 0.22 µF shall be installed. One filter shall be installed at one end of two resistive loads of 50 ft. (15.2 m) lengths of 12 AWG (3.3 mm^2) Type NM-B cable. Each filter shall be on the end of approximately 6 ft. (1.8 m) of 16 AWG (1.3 mm^2)Type SJT flexible cord. The arcing shall be initiated as shown in Figure 42.5.

b) An EMI filter as described in Figure 42.7 shall be installed at the end of 50 ft. (15.2 m) of 12 AWG (3.3 mm^2) Type NM-B cable. The filter shall be on the end of 6 ft. (1.8 m) of 16 AWG (1.3 mm^2) Type SJT flexible cord. The AFCI and the arcing shall be located as shown in Figure 42.6.

When testing an outlet circuit AFCI without feed through or a portable AFCI, 20 ft. (6.1 m) of 16 AWG (1.3 mm^2) Type SPT-2 flexible cord is to be substituted for the 50 ft. (15.2 m) lengths of Type NM-B cable.

Figure 42.5

EMI filter test #1

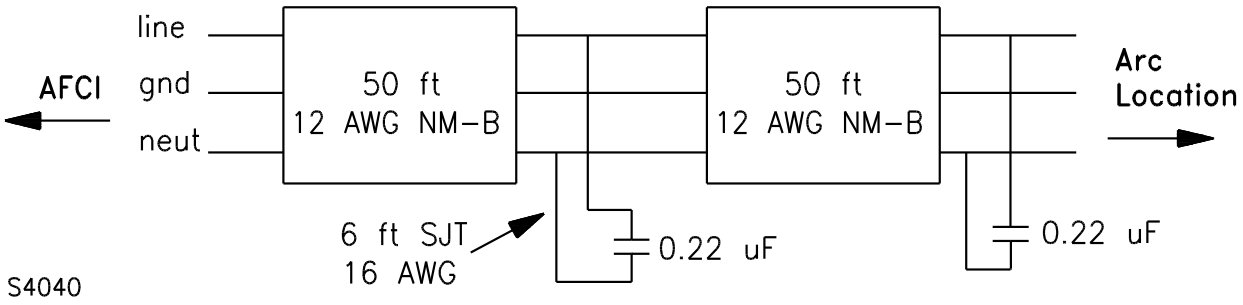


Figure 42.6

EMI filter test #2

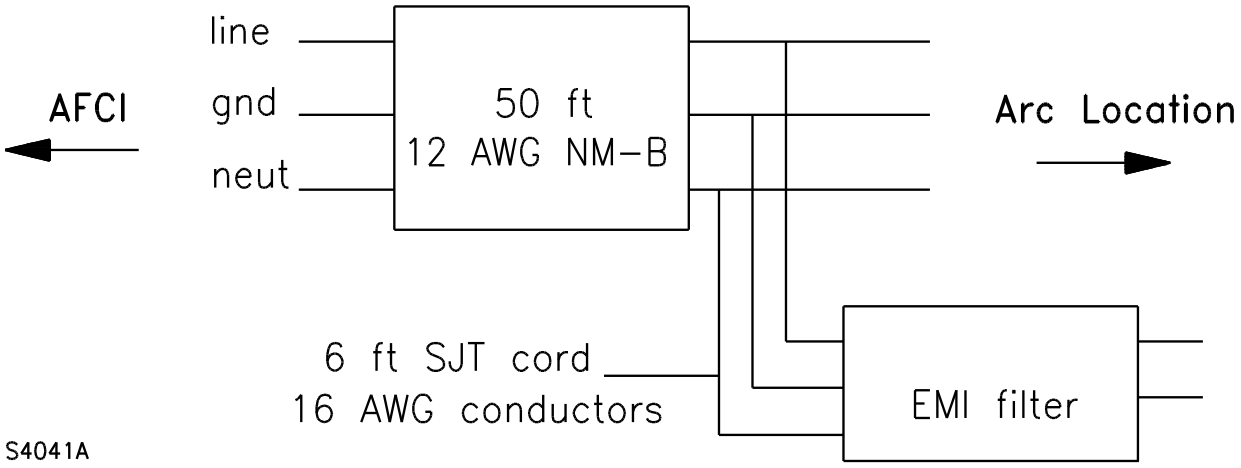
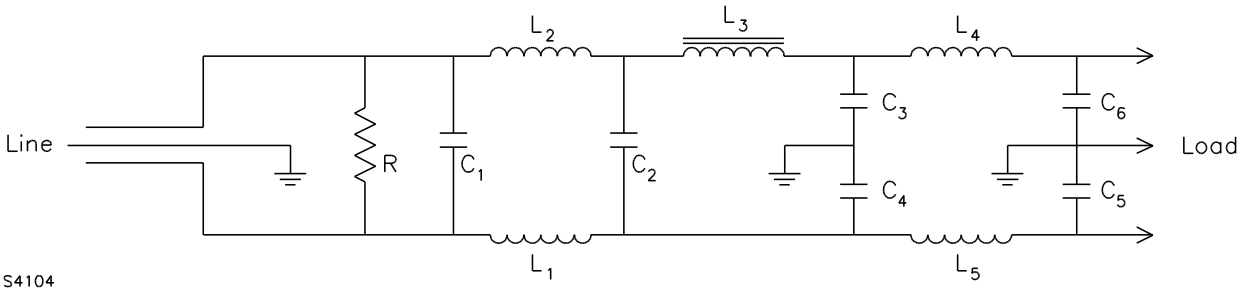


Figure 42.7

EMI filter



$L_1 = L_2 = 6.36mH$

$L_3 = 0.036mH$

$L_4 = L_5 = 1.47mH$

$C_1 = 0.47\mu F$

$C_2 = 0.27\mu F$

$C_3 = C_4 = C_5 = C_6 = 0.002\mu F$

$R = 330\ K\Omega$

42.4 Line impedance

42.4.1 The AFCI shall be installed as intended on a branch circuit, and under each of the following conditions of line impedance, the AFCI shall operate in accordance with the Point contact arcing test in 40.5, with 500 A available at the AFCI when arcing is produced at the end of the branch circuit, as modified below.

a) A branch circuit consisting of 100 ft. (30.5 m) of 14 AWG (2.1 mm^2) armored cable, 2-conductor with steel armor. The arcing shall occur from line to the grounded metal armor. See Figure 42.8; and

b) A circuit consisting of 50 ft. (15.2 m) of 14 AWG (2.1 mm^2) copper wire (single conductor) with four 90 degree bends, and 25 ft. (7.62 m) of 1/2 inch grounded steel pipe, with two 90 degree bends. The location of the arcing shall be between the wire and the steel pipe. See Figure 42.9.

c) For outlet circuit AFCIs, tests (a) and (b) shall be repeated with the power supply line source connected to the input neutral terminal and with the power-supply neutral source connected to the input line terminal. See Figure 42.10.

Figure 42.8

Line impedance test with armored cable

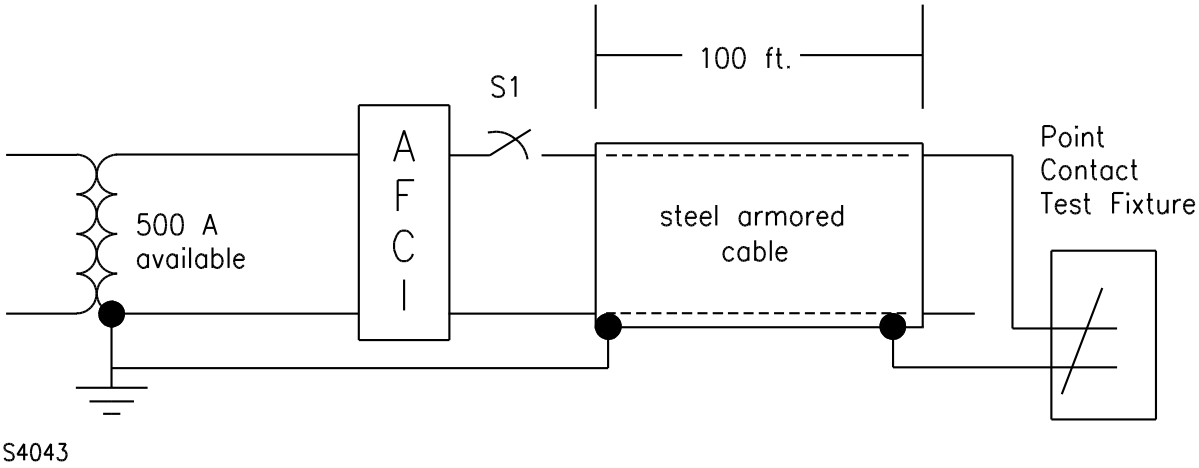


Figure 42.9

Line impedance test with steel pipe

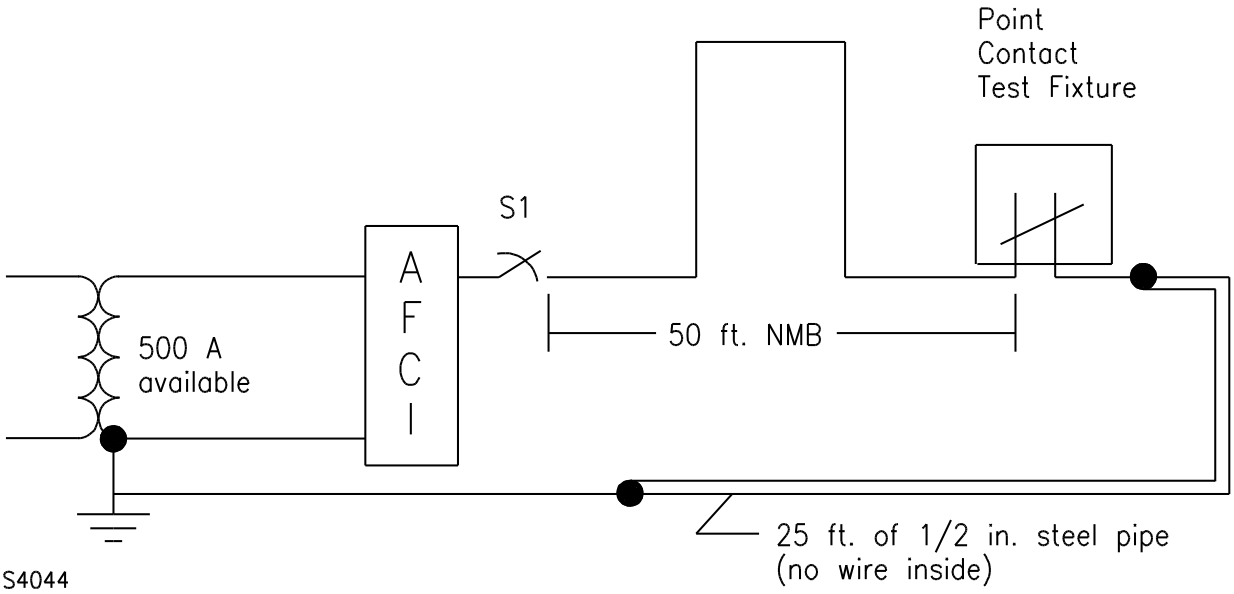
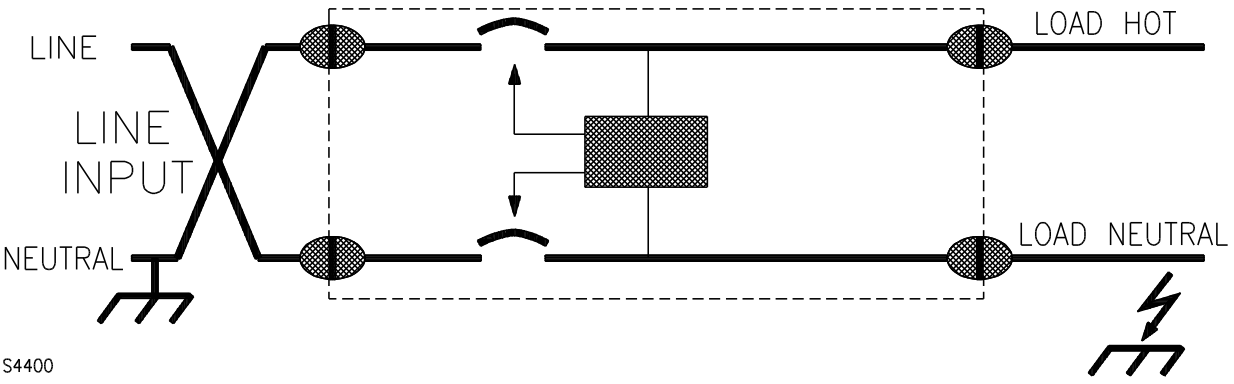


Figure 42.10

Test for line-side miswiring



43 Dielectric Voltage-Withstand Test

43.1 In a device, except as described in 43.2, the insulation and spacings between:

a) Line and load; and

b) Line and parts that are grounded

shall withstand without breakdown the following test potentials. The functional insulation and spacings of other circuits too shall withstand without breakdown the application of 1000 V + twice rated voltage, except that where the potential does not exceed 70 V peak in normal service, the test potential is to be 500 V.

43.2 The test voltage across the dielectric of a capacitor shall be 900 volts.

43.3 Basic insulation and spacings inherent in a component need not withstand the test potentials mentioned in 43.1 if the component in question complies with the requirements applicable to the component.

43.4 In order to determine compliance with the provisions of 43.1, the insulation and spacings are to be subjected to 60 Hz essentially sinusoidal potentials increased from zero to the values specified and maintained for a period of one minute. The increase in the applied potential is to be at a substantially uniform rate and as rapid as is consistent with the value of the applied potential being correctly indicated by the voltmeter.

43.5 Where the construction of the device is such as to deny access to the insulation to be tested, suitable subassemblies may be employed.

43.6 In the application of test potentials to insulating surfaces, metal foil may be used providing that care is taken to avoid flashover at the edge of the insulation.

44 Resistance to Environmental Noise Test

44.1 General

44.1.1 A device shall demonstrate immunity from false operation when exposed to the conditions described in this Section. The levels for immunity specified in this Section represent those that could be expected in a typical domestic/commercial electromagnetic environment. The intent of this Section is to configure the device under test as shown in Section 40.5 using the point contact arc test apparatus to induce the arc fault and determine that the device functions as intended after exposure to the electromagnetic environment specified herein.

44.1.2 The same representative device shall be tested for all of the tests described in 44.2, 44.3, 44.4, 44.5, 44.6, and 44.7.

44.1.3 The device is to be tested as described in each section, and shall not trip as a result of the electromagnetic event.

44.1.4 After all of the tests involving the electromagnetic events, the representative device shall be tested in accordance with 40.5 using wire Type SPT-2 and any two of the currents specified in 40.5.3, and shall trip as required.

44.2 Electrostatic discharge immunity

44.2.1 The Standard for Electromagnetic compatibility (EMC) Part 4; Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication, IEC 61000-4-2, is to be used as the reference for testing and measuring techniques. The test limits are:

a) 4kV, positive and negative polarity, for direct contact discharge; and

b) 8kV, positive and negative polarity, for air discharge.

44.3 Radiated electromagnetic field immunity

44.3.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 3: Radiated, radio frequency, electromagnetic field immunity test, IEC 61000-4-3, is to be the test measurement reference. The frequency range to be investigated is to be from 80 MHz to 1 GHz. The exposure is to be level 2, 3 V/m modulated with 80 percent AM modulation at 1 kHz. The protective device shall not false trip when exposed to these fields. The frequencies to be used encompass the standard broadcast frequency ranges for commercial and amateur ("ham") radio and television. The step size for the test frequency ranges is to be 1 percent of fundamental. In addition the device should be exposed to radiated electromagnetic fields that simulate those generated by digital radio telephones (commonly known as "cell phones"). This test consists of exposure to 3 V/m field using a 200 Hz digital modulation technique with a 50 percent duty cycle on one frequency between 895 MHz and 905 MHz. Other frequency ranges that are used in the United States are to be considered.

44.4 Electrical fast transient immunity

44.4.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – Basic EMC publication, IEC 61000-4-4, is to be the standard for testing methods and to specify multiple levels of limits based on installation environment. Level 2 is to be the test limit.

44.5 Voltage surge

44.5.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 5: Surge immunity test – Basic EMC publication, IEC 61000-4-5, is to be the standard for testing methods and to specify multiple levels of limits based on installation environment. The test limit is to be level 3 at 2 kV line-to-ground and level 2 at 1kV line-to-line and line-to-neutral.

44.6 Immunity to conducted disturbances, induced by RF fields

44.6.1 The test method described in the Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Section 6, Immunity to conducted disturbances, induced by radio-frequency fields, IEC 61000-4-6, are to be followed. The representative product is to be subjected to a conducted disturbance at 3 V over a frequency range of 150 kHZ to 80 MHz.

44.7 Voltage dips, short interruptions and voltage variations immunity

44.7.1 The Standard for Electromagnetic compatibility (EMC) Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variations immunity tests, IEC 61000-4-11, is to be the standard for testing methods. The protective aspects of the device are not to be compromised under the following power line conditions:

a) 100 percent voltage dip for 10 mS;

b) 60 percent voltage dip for 200 mS; or

c) 30 percent voltage dip for 1 S.

44.7.2 A protective device turning OFF during the disturbances specified in 44.7.1 meets the intent of the requirement provided:

a) The power to the protected unit is removed, and

b) Operation is automatically restored when input power is restored to at least 85 percent of rated voltage.

45 Normal Temperature Test

45.1 When carrying rated current and with rated voltage applied, a device shall not attain a temperature at any point that is sufficiently high to:

a) Constitute an increased risk of fire;

b) Affect injuriously any materials used in the device; or

c) Exhibit greater rises in temperature at specific points than indicated in Table 45.1, based on an assumed average ambient temperature in normal service of 25°C (77°F).

45.2 Coil or winding temperatures are to be measured by thermocouples unless access cannot be gained for mounting a thermocouple (for example, a coil enclosed in sealing compound) or unless the coil wrap includes thermal insulation or more than two layers (1/32 inch or 0.8 mm maximum) of cotton, paper, rayon, or the like. At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by means of a thermocouple may be 10°C (18°F) more than the indicated maximum, provided that the temperature rise of the coil, as measured by the resistance method is no more than that specified in Table 45.1.

Table 45.1
Maximum acceptable temperature rises

Material and components	°C	°F
Wire insulation or insulating tubing	35	63
Electrical tape	55	99
Varnish-cloth insulation	60	108
Fiber employed as electrical insulation	65	117
Phenolic composition or melamine[a]	125	198
Urea composition[a]	75	108
Other insulating materials[a]	–	–

[a] The acceptability of insulating materials shall be determined with respect to properties – such as flammability, arc resistance, relative or generic temperature indices, and the like – based on the temperature rise plus 25°C (45°F).

45.3 Except at coils, temperature readings are to be obtained by means of thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2), and 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 5-minute intervals, indicate no change. When thermocouples are used in the determination of temperatures in connection with the heating of electrical devices, it is common practice to employ thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a potentiometer type of indicating instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

45.4 Ambient air is to be at any convenient temperature within the range of 20 – 30°C (68 – 86°F).

45.5 The thermocouples and related instruments are to be accurate and calibrated in accordance with accepted laboratory practice. The thermocouple wire is to conform with the requirements specified in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

46 Overvoltage Test

46.1 A device shall operate continuously while connected to a supply set at 110 percent of rated voltage. The test shall continue for 4 hours or until thermal equilibrium is reached. During the 4 hours, the device shall not trip or become inoperative, and shall be in condition to continue the sequence at the end of the 4 hours.

47 Overload

47.1 A device shall have necessary interrupting capacity.

47.2 In order to determine compliance with the provisions of 47.1, a device that may be required to open a load circuit is to be caused to switch an inductive impedance adjusted for a value of load current equal to six times the ampere rating of the device and a power factor within the range of 0.45 – 0.50.

47.3 Reactive components of the impedance in the AC test circuit mentioned in 47.2 may be paralleled with each other if they are of the air-core type. An air-core reactor is to be paralleled with resistance adjusted to dissipate approximately one percent of the total power dissipated in the impedance without such resistance.

47.4 The value of paralleled resistance R in ohms mentioned in 47.3 may be obtained by calculation from the following equation:

$$R = \frac{163E}{I}$$

in which:

E is the closed-circuit voltage at the load, and

I is the load current in amperes, without resistance R.

47.5 The supply circuit for the test mentioned in 47.2 is to have the capacity to provide a closed-circuit voltage not less than 85 percent of the rated voltage of the device. Except when a higher value is agreed to by those concerned, the open-circuit voltage is to be in the range of 100 – 105 percent of the rated voltage of the device. A 1-A fuse is to be connected between the grounded conductor of a grounded supply circuit and accessible conductive parts of the device. This fuse shall not operate to open the circuit.

47.6 In performing the test mentioned in 47.2 the device is to be switched "on" and, after not less than one period duration of a 60 Hz line voltage waveform, switched "off". Each cycle of on/off operation is to be repeated for a total of 50 cycles of operation, at the rate of six cycles of operation per minute.

Exception: If the device operation will not permit these cycle times, times as close as possible to these are to be used.

48 Endurance Test

48.1 A device shall have the necessary capacity for normal operation.

48.2 In order to determine compliance with 48.1, a device is to be caused to switch an inductive load adjusted for a value of load current equal to the ampere rating of the device and a power factor within the range of 0.75 – 0.80.

48.3 In performing the test described in 48.2, the device is to be switched "on" and, after one second, switched "off" at a rate of approximately 6 cycles of operation per minute for 3000 cycles and switched "on" and, after one second "tripped" off by using the test switch for 3000 cycles. Ten percent of the latter 3000 operations shall be performed with the supply voltage reduced to 85 percent of rated voltage.

Exception: When the device under test has no ON/OFF switch, the initial 3000 cycles are not required.

48.4 Reactive components of the load mentioned in 48.2 may be paralleled with each other if they are of the air-core type. An air-core reactor is to be paralleled with resistance adjusted to dissipate approximately one percent of the total power dissipated in the load without such resistance.

48.5 The value of paralleled resistance R in ohms mentioned in 48.4 may be obtained by calculation from the following equation:

$$R = \frac{52E}{I}$$

in which:

E is the closed-circuit voltage at the load, and

I is the load current in amperes, without resistance R.

48.6 In performing the test described in 48.2, the capacity of the supply circuit is to be such as to allow a closed-circuit voltage not less than 97.5 percent of the rated voltage of the device. Except when a higher value is agreed to by those concerned, the open-circuit voltage is to be in the range of 100 – 105 percent of the rated voltage of the AFCI. A 1-A fuse is to be connected between the grounded conductor of a grounded supply circuit and accessible conductive parts of the device. This fuse shall not operate to open the circuit.

49 Abnormal Operations Test

49.1 A device shall not become a risk of fire or shock when operating while in an abnormal condition, such as with a short-circuited or open-circuited component.

49.2 A single layer of cheesecloth is to be loosely draped over the device. In addition, a portable or cord AFCI is to rest on white tissue paper supported by a softwood surface. A 1-A fuse is to be connected between the grounded supply conductor and accessible conductive parts of the device.

49.3 The cheesecloth mentioned in 49.2 is to be bleached cheesecloth running 14 – 15 square yards per pound mass (approximately 26 – 28 square meters per kilogram mass) 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 (for any square centimeter, 13 threads in one direction and 11 in the other direction).

49.4 A device operating under abnormal conditions will be considered to have become a risk of injury if:

a) There is glowing or flaming of the cheesecloth or tissue paper mentioned in 49.2;

b) There is emission of molten metal;

c) The fuse mentioned in 49.2 operates to open the circuit;

d) Except if the device is likely to be removed from service, there is dielectric failure (see 49.5 and 49.6);

e) It is possible to touch a part with the articulated probe shown in Figure 7.1 while there is a risk of shock at that part; or

f) There is any other evidence of a risk of injury.

49.5 Failure to comply with the provisions of 43.1 will be considered to be dielectric failure.

49.6 A device that is no longer able to complete the electric circuit to the load will be considered likely to be removed from service.

50 Surge Current Test

50.1 General

50.1.1 All AFCIs when subjected to the Surge Current test in 50.3.1 – 50.4.1, shall comply with the requirements in 50.1.2.

50.1.2 During and following the Surge Current Test the following conditions shall not result:

a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth.

c) Ignition of the enclosure.

d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Energized Parts, Section 13.

50.1.3 Three previously untested representative devices of the AFCI are to be subjected to the test.

50.2 Mounting and installation

50.2.1 A AFCI shall be placed on a softwood surface covered with a double layer of white tissue paper. Each AFCI is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

50.3 Surge parameters

50.3.1 A plug-in type arc-fault circuit-interrupter is to be subjected to a surge of 6 kV at 3 kA. A permanently-connected arc-fault circuit-interrupter is to be subjected to a minimum surge of 6 kV at 10 kA. The surge shall be a combination 1.2/50μs, 8/20μs voltage/current surge waveform.

50.4 Surge polarity

50.4.1 The polarity of the impulses shall be one positive applied at a phase angle of 90 degrees (+0, -15), one negative applied at a phase angle of 90 degrees (+0, -15).

51 Abnormal Overvoltage Tests

51.1 General

51.1.1 The test described in Full Phase Voltage-High Current Abnormal Overvoltage Test, 51.2, and Limited Current Abnormal Overvoltage Test, 51.3, shall not result in any of the following conditions:

a) Emission of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test in the product);

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth;

c) Ignition of the enclosure; and

d) Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with Accessibility of Energized Parts, Section 7.

51.1.2 The representative devices used for each of the tests described in 51.2.1 – 51.3.2 are to be previously untested.

51.1.3 The representative AFCI's shall be placed on a softwood surface covered with a double layer of white tissue paper. The orientation of the representative device shall be such as to create the most severe conditions representative of normal installation. Each representative AFCI is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, receptacle openings, ventilation openings and any other similar openings) where flame, molten metal, or other particles may be expelled as a result of the test. However, the cheesecloth shall not be deliberately pushed into openings.

51.1.4 Portable and cord arc-fault circuit-interrupter types intended for connection to common outlet boxes shall be tested in accordance with Limited Current Abnormal Overvoltage Test, 51.3, in both normal and reversed polarity.

51.1.5 When agreed upon by all concerned parties, fewer representative arc-fault circuit-interrupters than those specified in 51.2.1 – 51.3.2 shall be used for testing.

51.1.6 Following the tests described in the Full Phase Voltage – High Current Abnormal Overvoltage Test, 51.2, and the Limited Current Abnormal Overvoltage Test, 51.3, the same representative devices are to be subjected to and comply with the Leakage Current Measurement, Section 37, for cord-connected and direct plug-in AFCIs, and comply with requirements for Grounding, Sections 19, 23, 28, and 32 for branch/feeder, outlet circuit, portable, and cord AFCIs, respectively, as appropriate. The leakage current test shall be conducted within five minutes of the end of the abnormal overvoltage tests.

51.1.7 Operation of the ac-power-line circuit breaker, fuse internal or external to the arc-fault circuit-interrupter, or operation of an acceptable overcurrent or overtemperature protective device provided as part of the arc-fault circuit-interrupter is considered acceptable.

51.2 Full phase voltage – high current abnormal overvoltage test

51.2.1 The test described in this section shall not result in any of the conditions described in 51.1.1. One previously untested arc-fault circuit-interrupter, for each combination of conductor pairs that were tested in accordance with the Voltage Surge Test, Section 38, is to be subjected to the application of the test voltage as specified in Table 51.1 with a power factor as specified in Table 51.3. The ac power source shall have an available short-circuit (fault) current (I_{sc}) as specified in Table 51.2. For each representative device, the overvoltage is to be applied for 7 hours, or until current to, or temperatures within the AFCI attain equilibrium, or until the AFCI becomes disconnected from the ac supply (due, for example, to open circuiting of a thermal or overcurrent protective device). See Figure 51.1.