UL 1699 重要条款

1.2 AFCIs have a maximum rating of 20 A and are intended for use in 120-V ac, 60-HZ circuits. Cord AFCIs are rated up to 30 A.
（220V 系统一般应为 10A，最大不超过 16A）
1.3 These devices are not intended to detect glowing connections.
不用于检测连接发热。（用压降判定－4%）

1.5 An AFCI that is also intended to perform other functions, such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable Standard or Standards that cover devices that provide those functions.
AFCI 还可包括其他功能，例如：过负荷保护、接地故障、断路开关、浪涌抑制及类似功能，或这些功能的组合，其功能符合相关标准。

2.2 ARCING – A luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.
飞弧——一种跨越绝缘介质的明亮的电气放电，通常伴随部分电极物质的挥发。

2.3 ARCING FAULT – An unintentional arcing condition in a circuit.
飞弧故障——电路中一种非故意的飞弧情况。

2.4 ARC-FAULT CIRCUIT-INTERRUPTER (AFCI) – A device intended to mitigate the effects of arcing faults by functioning to deenergize the circuit when an arc-fault is detected.
电弧故障断路器 AFCI——一种在检测到电弧故障时通过切断电路来减轻故障影响的装置。

2.5 BRANCH/FEEDER ARC-FAULT CIRCUIT-INTERRUPTER – A device intended to be installed at the origin of a branch circuit or feeder, such as at a panelboard. It is intended to provide protection of the branch circuit wiring, feeder wiring, or both, against unwanted effects of arcing. This device also provides limited protection to branch circuit extension wiring. It may be a circuit-breaker type device or a device in its own enclosure mounted at or near a panelboard.
分支/电源电弧故障断路器——一种安装在分支电路或电源入口处（如：配电盘）的装置，提供对分支电路和（或）电源线路的保护，以防止电弧造成的不良影响。此装置还可对分支电路的延长部分提供保护。装置可以是断路器形式或在配电盘内或附近单独安装的封闭装置。
2.6 CARBONIZED PATH – A conductive carbon path formed through or over the surface of a normally insulating material.
碳化通道——形成在正常绝缘材料之中或之上的碳化导电通路

2.7 COMBINATION ARC-FAULT CIRCUIT-INTERRUPTER – An AFCI which complies with the requirements for both branch/feeder and outlet circuit AFCIs. It is intended to protect downstream branch circuit wiring and cord sets and power-supply cords.
组合式电弧故障断路器——满足分支/电源线路以及插座回路电弧保护要求的断路器，用以保护下游分支回路、电源引线及设备电源线。

2.8 CORD ARC-FAULT CIRCUIT-INTERRUPTER – A plug-in device intended to be connected to a receptacle outlet. It is intended to provide protection to the power-supply cord connected to it against the unwanted effects of arcing. The cord may be integral to the device. The device has no additional outlets.
插头引线式 AFCI——用于连接插座的插头式装置，用于对连接其上的电源引线提供保护，防止电弧故障造成的不利影响。引线与装置为一整体，装置不再提供其他插座。

2.9 OPERATION INHIBITION – Denotes the concealment of an arcing fault by the normal operation of certain circuit components.
禁止操作——通过对某线路元件的正常操作，指出电弧故障的隐藏位置。

2.10 OUTLET CIRCUIT ARC-FAULT CIRCUIT-INTERRUPTER – A device intended to be installed at a branch circuit outlet, such as at an outlet box. It is intended to provide protection of cord sets and power-supply cords connected to it (when provided with receptacle outlets) against the unwanted effects of arcing. This device may provide feed-through protection of the cord sets and power-supply cords connected to downstream receptacles.
插座式 AFCI——安装在分支线路的插座处，例如插座盒内，用以保护连接其上的电源引线，防止电弧故障造成的不利影响。此装置可以通过引线对所连接的下游插座进行保护。

2.11 PORTABLE ARC-FAULT CIRCUIT-INTERRUPTER – A plug-in device intended to be connected to a receptacle outlet and provided with one or more outlets. It is intended to provide protection to connected cord sets and power-supply cords against the unwanted effects of arcing.
(便携)插线板式 AFCI——用于连接插座的插头式装置并提供一个或多个插座。保护连接其上电源引线，防止电弧故障造成的不利影响。

2.12 UNWANTED TRIP – A tripping function in response to a condition that is not an arcing fault but a condition that occurs as part of the normal or anticipated operation of circuit components.
误触发（误脱扣）——对线路元件进行正常或预期操作而非电弧故障时，出现的脱扣动作。

10 Internal Wiring
10.1 The gauge and insulation of wires shall withstand the mechanical and electrical stresses of service. Wires smaller than 24 AWG (0.21 mm^2) shall be investigated for the application.

12.6 When applying the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the environment for a printed wiring board assembly within an arc fault circuit-interrupter is considered to be:
a) Pollution degree 3 for an assembly without a conformal coating;
b) Pollution degree 2 for
1) An assembly with a coating,
2) An assembly without a coating when the printed wiring board is contained in a sealed housing that complies with the Dust Test, Section 57, or
c) Pollution degree 1 for an assembly with a conformal coating complying with the Printed Wiring Board Coating Performance Test, in UL 840.

12.7 For Clearance B (controlled overvoltage) requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the applicable overvoltage category for line-voltage circuits is Category III for branch/feeder and outlet circuit AFCIs and Category II for portable and cord AFCIs. Category I is applicable to low-voltage circuits if short circuit between the parts involved may result in operation of the controlled equipment that increases the risk of fire or electric shock. Any overvoltage protection device needed to achieve these categories shall be provided as an integral part of the arc fault circuit-interrupter.

13.2 A device that has tripped in accordance with the provisions of arcing fault interruption shall not be capable of automatic reclosure.（不可自动闭合）
13.3 Except for an AFCI that is intended to be mounted in a panelboard, an AFCI shall operate to open both the ungrounded and grounded（应理解为 N、L?） circuit conductors in the event of a fault.
除了安装在配电盘内的 AFCI，其他类型的 AFCI 要能切断 N，L。
注 :*如果根据 17.2.2 The insulation of lead type terminals shall be rated for the application and be of a color that conforms with the requirements of the NEC, that is white or gray for the grounded conductor and green or green with a yellow stripe for the grounding conductor.*
17.2.2 revised February 28, 2007
“grounded conductor ”应理解为中性线。

13.4 An AFCI device that contains separate line and load terminals, intended for mounting in an outlet box, and that is powered through its load terminals, shall not reset and supply power to its line terminals. See Reverse Line – Load Miswire Test, Section 59.
13.4 effective February 10, 2008
入线与出线分开的 AFCI，由其负载端供电时，不应复位且不应使其入线端带电。

14.3 The risks to be considered for the Risk Analysis portion of UL 1998 include the following scenarios:风险分析
a) Unwanted tripping;误脱扣动作
b) Failure to trip under conditions where tripping should occur; and 不脱扣动作
c) Failure of test circuit to complete evaluation.不能通过测试（按钮）进行评估

14.5 All tools used in the design, implementation, and verification of software shall be documented. The documentation shall include:
设计、实施、软件验证文档应包括：
a) The name of the tool supplier or developer; 工具提供者或研发者的名称
b) The model, application, or trade name of the tool;工具型号、用途、商标
c) The tool version identification; 工具识别版本
d) A description of the purpose for which the tool is used; and 工具使用目的
e) A list of known errors, faults or failures of the tool performance, such as a ＂bug list＂.已知错误明细表、工具使用故障，例如：错误（bug）清单。

15.1 An AFCI shall be provided with a test circuit that simulates an arc such that the arc detection

circuit or software is caused to detect the simulated arc. An AFCI that also incorporates features of other devices that require a supervisory circuit, such as GFCIs, shall be provided with one or more test circuits that simulate the arc detection portion of the device as described in this Section, and comply with the test or supervisory circuit requirements for the additional device or features provided with the AFCI.
15.1 effective July 15, 2007

15.2 Operation of the test circuit shall cause the contacts of the device to open. The results of the test shall be made known to the user by a positive visual indication.

25.1 An outlet provided with a portable AFCI shall be either of the grounding or non-grounding type but in any case shall have the same configuration as the attachment plug of the AFCI. When the outlet is of the grounding type, the grounding terminal shall be conductively connected to the grounding circuit.
插座式 AFCI 应既有接地型也有非接地型，两种类型都应有相同的 AFCI 插头。接地型插座的保护线应与接地线连通。

25.3 The ampere rating of an outlet of a cord-connected portable AFCI shall not exceed the rating of the attachment plug.

25.4 The ampere rating of the outlet of a portable (direct plug-in or cord-connected) AFCI that has only a single outlet shall be equal to the ampere rating of the attachment plug.

30.3 A cord AFCI shall provide protection in the event that the grounded conductor （中性线 N，见“注”）becomes open circuited.
Exception: A cord AFCI constructed with arc fault protection circuitry integral to the attachment plug and intended for a dedicated（专门的）load need not comply with the requirements of 30.3.

注：*如果根据 17.2.2 The insulation of lead type terminals shall be rated for the application and be of a color that conforms with the requirements of the NEC, that is white or gray for the grounded conductor and green or green with a yellow stripe for the grounding conductor.*
17.2.2 revised February 28, 2007
“grounded conductor ”应理解为中性线。

32.1 The accessible conductive parts and the equipment grounding conductor of a cord AFCI provided with a cord shall be conductively connected to the grounding contacts of the attachment plug.

表 34.1 Test Sequence 测试顺序

测试项目	条件/环境	过载/耐久性	其他
条件实验			
冲击实验 Impact	●		
跌落实验 Drop	●		
潮湿 Humidity	●		
漏电 Leakage	●		
浪涌电压 Voltage Surge	●		
环境顺序实验	●		
电弧故障探测 Arc fault detection	●		
误脱扣动作(<8 个或>8 个？) Unwanted Tripping			●
抑制 Inhibition			●
温度			●
过压		●	
过载		●	
耐久性		●	
绝缘强度 Dielectric withstand	●	●	●
异常 Abnormal			●
短路			●
碾压 Crushing			●
应变消除 Strain relief			●
机械性能			●

表 34.2 电弧故障探测测试表

测试项目	分支/电源型 AFCI	组合型 AFCI	插座式 AFCI feed	插座式 AFCI without feed	插线板 AFCI	电源线插头 AFCI
碳化通道电弧燃烧测试 40.2 切断 NM-B 导体	●	●				
碳化通道电弧燃烧测试 40.3 切断 SPT-2 绝缘 切断 NM-B 绝缘	●	●				
碳化通道电弧清除时间 40.4 切断 SPT-2 绝缘		●	●	●	●	●
点接触电弧测试 40.5 切断 SPT-2 绝缘	●	●	●	●	●	●
点接触电弧测试 40.5 切断 NM-B 绝缘	●	●				
41 误脱扣测试						
41.2 负载条件 I 冲击电流	●	●	●	●	●	●
41.3 负载条件 II 正常操作电弧 条件 a—c	●	●	●	●	●	●

正常操作电弧 条件 d－g	●	●	●			
41.4 负载条件 III 非正弦波	●	●	●	●	●	●
41.5 负载条件 IV-串扰	●	●	●			
41.6 负载条件 V-多负载	●	●	●	●	●	
41.7 负载条件 VI-灯丝断	●	●	●			
42 操作抑制						
42.2 遮蔽罩	●	●	●	●	●	●
42.3EMI 滤波器	●	●	●	●	●	
42.4 线路阻抗	●	●	●			

38.1.2 The arc-fault circuit-interrupter is to be connected to a supply of rated voltage. The grounding lead or terminal of the arc-fault circuit-interrupter is to be connected to the supply conductor serving as the neutral. The arc-fault circuit-interrupter is to be in the ″on″ condition with no load connected.

注：试验时，PE 与 N 共同接在电源 PE 线？

Table 38.1
Surge impulse test levels

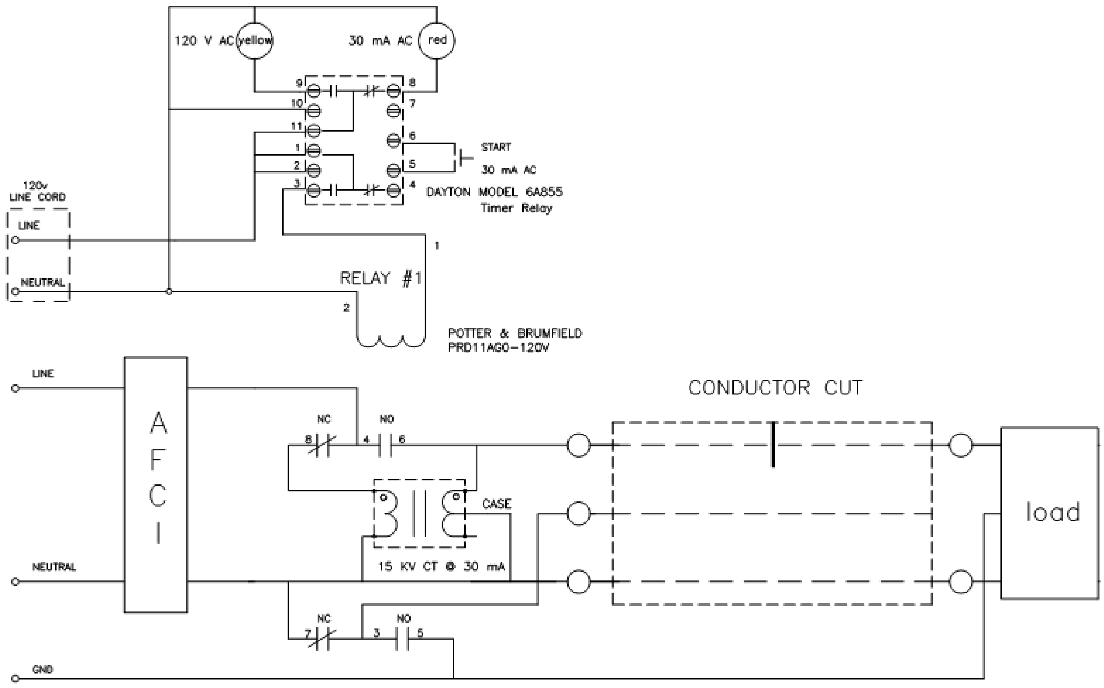
Impulse[a]	
Peak voltage (KV p)	Peak current (KA p)
4	2

[a] Combination 1.2/50 μs, 8/20 μs Voltage/Current surge waveform. For specifications and tolerances, refer to the IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits (ANSI/IEEE), IEEE C62.41.

38.3.5 The AFCI is permitted to trip during surge immunity testing. If the AFCI trips, it is to be reset prior to the next surge application.

40.2.3 The schematic for the Carbonized Path Arc-Fault Tester is shown in Figure 40.1. A 10 seconds ON and 10 seconds OFF timer is used to control a contactor. Two form A contacts are wired in series as shown. A 15 kV ±10 percent center tapped gas tube sign transformer is used to provide a 30 mA current source for creating a carbonized conductive path across the insulation of the cable specimens.

Figure 40.1
Carbonized path tester – arc ignition test (load deenergized)



40.2.4 串型弧 The test is initiated by energizing the transformer through the normally closed relay contacts. The transformer's 30 mA secondary current flows through the gap in the cable specimens (caused by the cut wire) and load. The cable specimen's input terminal voltage becomes impressed across the gap in the cable plus the voltage across the load with 30 mA flowing in the test circuit. After 10 seconds the relay is energized, de-energizing the transformer, allowing the 120 VAC input voltage to be applied to the cable specimen's line-to-neutral terminals through the relay's normally opened contacts. After another 10 seconds the relay is opened and the 30 mA high voltage cycle is repeated. These 10 second cycles of high voltage and rated voltage are to be repeated until the device opens. Interruption of the electric circuit during the high voltage cycle does not count as meeting the intent of the test. An oscilloscope is to be utilized to determine the moment of interruption. It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.
40.2.4 revised August 29, 2008

40.2.6 The test apparatus is to be located between the AFCI and a resistive load. The taped area of the prepared conductor specimen is to be loosely wrapped with surgical cotton. The load resistance is to be adjusted for 5 A. The test is to be conducted until the AFCI trips or the cotton ignites, except that a test need not be continued if either result is not achieved within a period of 5 minutes. In this case the test is considered to be indeterminate and is to be repeated with a new conductor specimen prepared in accordance with 40.2.7. The test is to be repeated with the load adjusted for 10 A, rated current, and 150 percent of rated current RMS without the presence of a series arc. For each test a new conductor specimen is to be used.

40.2.7 The conductor specimens are to be prepared as follows:

a) A minimum 8-inch (203-mm) length of cable is to be stripped of insulation 1 inch (25.4 mm) from each end.
b) The ungrounded circuit conductor is to be cut as indicated in Figure 40.1 without damaging insulation on the other conductor.
c) The cut is to be wrapped with two layers of electrical grade black PVC tape and overwrapped with two layers of fiberglass tape. The tape is to be centered on the cut and wrapped completely around the cable specimen.

40.3.1 As a result of being tested as described in this Subsection, an AFCI shall clear the arcing fault if 8 half-cycles of arcing occur within a period of 0.5 seconds. For the purposes of these requirements, an arcing half-cycle is considered to be all of the current traces occurring within a period of 8.3 ms (for a device rated 60 Hz). Within that time period there may be current flow for some but not all of the time. Prior to and following each period of current flow, there may be a period of no current or very reduced current. Very reduced current is considered to be current with an amplitude less than 5 percent of the available current or current that continues for not more than 0.42 ms. This may last for either a portion of a half cycle or for several half cycles. A complete sinusoidal half cycle of current flow is not considered to be an arcing half cycle.

40.3.2 The cord and cable specimens shall be 16 AWG (1.3 mm^2) two-conductor Type SPT-2 flexible cord and nonmetallic sheathed cable (Type NM-B copper) of rated ampacity for the AFCI being tested.

40.3.6 并型弧 The test is initiated by energizing the transformer through the normally closed relay contacts. The transformer’s secondary current flows from one conductor of the specimen to the adjacent conductor or conductors (through the cut in the insulation). The cable specimen’s input terminal voltage becomes impressed across the space between conductors. After 10 seconds the relay is energized, de-energizing the transformer, allowing the 120 VAC input voltage to be applied to the cable specimen’s line-to-neutral terminals through the relay’s normally opened contacts. After another 10 seconds the relay is opened and the high voltage cycle is repeated. These 10 second cycles of high voltage and rated voltage are to be repeated until the device opens. Interruption of the electric circuit during the high voltage cycle does not count as meeting the intent of the test. It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.
40.3.6 revised August 29, 2008

Table 40.1
Arc test clearing times

Test current, Amperes[c]	15 Amp AFCI	20 Amp AFCI	30 Amp AFCI
5	1 sec	1 sec	1 sec
10	0.4 sec	0.4 sec	0.4 sec
Rated current	0.28 sec	0.20 sec	0.14 sec
150 percent rated current	0.16 sec[a] 0.19 sec[b]	0.11 sec[a] 0.14 sec[b]	0.1 sec

[a] Required clearing time when the switch is closed on the load side of the AFCI. See 40.4.6.
[b] Required clearing time when the AFCI is closed on the fault. See 40.4.6.
[c] Tests at 120 V are also applicable to cord AFCIs rated 120 V/240 V.

41.2.1 （inrush current） Loading condition I is as follows:

负载条件 I

a) A 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs. With the AFCI closed, the load shall be energized by using a controlled switch closing the circuit at 30, 60 and 90 degrees on the voltage waveform or 60 times with random closing. The switch is to be on the load side of the AFCI. The maximum peak inrush shall not be less than 100 A, when measured at a 90 degree closing angle. The lamps are to cool for one minute between each energization.

- 1000W 阻性负载（4*150W+4*100W 灯泡)
- 在电压波形的 30、60、90 度闭合开关，或随机闭合开关 60 次
- 90 度闭合角时，最大冲击电流峰值不小于 100A？（如何达到 100A？）
- 每次通电之间，灯泡冷却 1 分钟。

b) A capacitor start (air compressor type) motor with a peak inrush current of 130 A ±10 percent is to be started under load (compressor operating without any air pressure in the air tank) and operated for one minute then switched off. The test shall be repeated five times. The motor is allowed to come to rest after each "off" operation. The air tank is to be empty at the start of each test.

- 容性负载（空压机，储气罐无压力时启动），冲击电流峰值 130 A ±10%，工作 1 分钟，断电。
- 测试重复 5 次，断电后电机允许冷却。
- 每次测试前，储气罐排空。

41.3.1（normal operation arcing） Loading condition II is as follows:

负载条件 II

a) A vacuum cleaner rated at 10.8 – 12 A full load having a universal motor shall be started and run for one minute and then switched off using the switch on the appliance. This test is to be repeated 5 times. The vacuum cleaner shall then be started by plugging the vacuum into a wall receptacle to start the motor and run for one minute then unplugging the motor from the wall receptacle. This test is to be repeated five times. The motor is allowed to come to rest after each off operation.

- 10.8 – 12 A 真空吸尘器（220V 下，6A－6.5A？）满载启动，
- 运行 1 分钟后用电器上的开关断电，测试重复 5 次
- 将吸尘器通过接入墙壁插座启动，运行 1 分钟，通过拔下插头断电，测试重复 5 次
- 断电后电机允许冷却

b) A bi- metallic appliance (such as flat iron, skillet, or similar appliance) rated 1200 W ±10 percent and having slow-make slow-break thermostatically controlled contacts for temperature regulation as follows:

双金属片控温电器（熨斗、煎锅等慢合慢开热稳态控制电器）额定功率 1200 W ±10%

1) The appliance shall be operated for 4 hours continuously during which the thermostat contacts are to open and close at least 25 times.

电器应连续运行 4 小时，温控开关至少开合 25 次

2) During a 1-minute period the appliance shall be rapidly moved and jolted and then placed into the normal rest position 10 times.
1 分钟周期内，电器应被快速移动和摆动，之后放置在正常位置，10 次

c) A 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs shall be controlled by a general-use snap switch. The load shall be energized ″on″ and ″off″ for 10 cycles using normal force and care. The test is to be performed at a rate of 6–10 operations per minute. The bulbs need not be allowed to cool.
1000W 灯泡，用通常的按钮开关，开合 10 次。每分钟测试 6-10 次，灯泡不允许冷却。

d) The test in 41.3.1(c) is to be repeated with a general-use snap switch that complies with the Standard for General-Use Snap Switches, UL 20, and has been conditioned by cycling for 30,000 operations under rated load conditions of 15 A, 120 V, with 10,000 operations of resistive load, 10,000 operations with a load power factor of 75 – 80 percent, and 10,000 operations with a tungsten lamp load.
重复 41.3.1(c)试验
15 A, 120 V 负载下执行 30，000 次开合，其中：
10，000 次阻性负载
10，000 次功率因数为 75%－80%
10，000 次钨丝灯泡负载

e) An electronic variable-speed electric hand-held shop tool rated 5–7A that has been conditioned by undergoing 24 hours of continuous operation under a no-load condition at maximum speed. The speed shall be evenly varied from minimum to maximum and again to minimum every 10 seconds for one minute under a no-load condition.
电子调速电动手持工具，额定负载 5–7A，工具应能空载最高速情况下连续工作 24 小时。工具空载条件下，转速从最小到最大再到最小，每 10 秒平稳调整 1 次循环。

f) A ceiling fan speed control (capacitive type with a rotary switch) rated 1.5 A controlling a ceiling fan. The speed shall be varied from the ″off″ position to maximum and again to the ″off″ position every 10 seconds for one minute.
吊扇调速（电容式+旋转开关）额定 1.5A。从“关”位置到最大转速，再回到“关”，每 10 秒 1 次循环，持续 1 分钟。

g) An air purifier (a model employing electrostatic forces to move air and containing UV lamp to provide germicidal protection) shall be started by plugging the purifier into a wall receptacle to start the air moving and run for one minute, then unplugging the device from the wall receptacle. The device should have the following settings:
空气净化器（采用静电移动空气并含紫外线杀菌灯），直接通过插头接通墙壁插座开启设备电源并运行 1 分钟，之后拔下插头。
1) Power control switch – in the highest air movement position. 开关置于最大空气流量档
2) Mode control switch – in “ON/GP” position (power + UV light). The test is to be repeated 20

times. 电源+紫外灯都开启，测试 20 次。
The test also should be conducted 20 times with the mode control switch in “OFF” position (no power and no UV light). 只开紫外灯，测试 20 次。
41.3.1 effective February 10, 2008

41.4.1 （non-sinusoidal waveform）Loading condition III is as follows:
非正弦波负载条件 III

a) A 1000-W electronic lamp dimmer (thyristor type) with a filtering coil controlling a 1000-W tungsten load consisting of four 150-W bulbs and four 100-W bulbs. The dimmer is to be turned on for 1 minute each with the dimmer preset at full on, conduction angles of 60, 90, and 120 degrees, and at the minimum setting that causes the lamps to ignite. The lamps are to cool for one minute between each energization. The test is to be repeated with a 600-W dimmer without a filtering coil controlling a 600-W tungsten load consisting of two 150-W bulbs and three 100-W bulbs.
1000W 可控硅调光灯（滤波线圈），分别在全亮、导通角 60、90、120 度，以及灯泡刚刚点亮的情况下各开灯 1 分钟，每种情况各冷却 1 分钟。在没有滤波器的 600W 灯泡负载上重复测试。

b) A previously unconditioned electronic variable-speed electric hand-held shop tool rated 5–7A. The speed shall be evenly varied from minimum to maximum and again to minimum every 10 seconds for one minute under a no-load condition. A tool that has been used for a previous test, but not conditioned for 24 hours, is capable of being used as an unconditioned tool.
c) An electronic switching mode power supply (or power supplies), having a total load current at 120 V of at least 5 A with a minimum Total Harmonic Distortion (THD) of 100 percent, and individual minimum current harmonics of 75 percent at the 3rd, 50 percent at the 5th, and 25 percent at the 7th. The power supply (or power supplies) shall be turned on for one minute and then turned off.
d) Two 40-W fluorescent lamps plus an additional 5-A resistive load. The lamps are to be initiated from a cold start and operate for at least 10 seconds.
41.4.1 revised February 28, 2007

41.5.1 （cross talk） Loading condition IV is as follows:
a) Two branch circuits connected to the same ungrounded conductor of the source circuit, one with AFCI protection and one without AFCI protection (but with conventional overcurrent protection) shall be installed using 14 AWG (2.1 mm2) copper Type THHN conductors in the same EMT 1/2 inch trade size metal raceway. The conduit shall be 25 ft. (7.62 m) long and grounded, and serves to maintain the conductors in close proximity. With arcing produced using the method in 40.5, except only at 150 A, in the circuit without the AFCI, the AFCI protected circuit shall not trip.
b) Two branch circuits connected to the same ungrounded conductor of the source circuit, one with AFCI protection and one without AFCI protection (but with conventional overcurrent protection) shall be installed using 14 AWG (2.1 mm2) copper Type NM-B cables. Each cable shall be 25 ft. (7.62 m) long, with the cables secured under a common staple every 4 ft. (1.22

m). With arcing produced using the method in 40.5 except only at 150 A, in the circuit without the AFCI, the AFCI protected circuit shall not trip.

41.6.1 （multiple load） The tests in 41.4.1 (b) 调速电机 and (d)荧光灯 are to be repeated with the total AFCI load current equal to the AFCI
rating. The additional load necessary to reach rated current shall be resistive.

41.7.1 （lamp burnout）As a result of being tested as described in this Section, the AFCI shall not trip.
41.7.2 A Type A incandescent, 100-W lamp is to be installed in the lampholder as shown in Figure 41.1
and energized in a circuit as described in PERFORMANCE, General, Section 34 that is protected by the
AFCI. The lever arm is to be raised to approximately a 20 degree angle and allowed to drop. This is to be
repeated until the lamp burns out. Preconditioning of the lamp for a few minutes at greater than rated
voltage is permitted to help promote lamp burnout at rated voltage.
41.7.3 The test apparatus is shown in Figure 41.1. The base and lever arm are to be approximately 48
inches (1.22 m) in length and constructed of wood or similar material. The lampholder is to be secured to
the lever arm approximately 30 inches (762 mm) from the hinged end of the apparatus.

44.2 Electrostatic discharge immunity
44.3 Radiated electromagnetic field immunity
44.4 Electrical fast transient immunity
44.5 Voltage surge
44.6 Immunity to conducted disturbances, induced by RF fields
44.7 Voltage dips, short interruptions and voltage variations immunity
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.

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).

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.

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.

59 Reverse Line – Load Miswire Test

59.1 A previously untested arc-fault circuit-interrupter intended for mounting in an outlet box shall interrupt the electric circuit to the line terminals when a supply circuit is wired to the load terminals of the

device.

59.1 effective February 10, 2008

59.2 Under the conditions described in 59.3 and 59.4 the arc-fault circuit-interrupter shall interrupt the electric circuit to the line terminals or not permit power to be applied to the line terminals when the power is first applied to the load terminals, and each time the reset is operated.

59.2 effective February 10, 2008

59.3 For this test:

a) The supply line voltage is to be set at 85 percent of the rated voltage.

b) The arc-fault circuit-interrupter is to be switched on unless it is shipped from the manufacturer in the tripped condition and cannot be reset until properly installed. If shipped in the tripped condition, to verify the arc-fault circuit-interrupter cannot be reset until properly installed, attempt to engage reset by first pressing the reset button and then by pressing the test and reset buttons simultaneously. This is to be performed before and after load terminals are connected to supply voltage.

c) Power is to be applied to the load terminals, and the reset shall be operated ten times in rapid succession.

59.3 effective February 10, 2008

59.4 The test described in 59.2 is to be repeated on the same device, with the supply line voltage set at
110 percent of the rated voltage.

59.4 effective February 10, 2008

61.1 An AFCI shall be rated 120 V and 60 Hz. A branch/feeder or outlet circuit AFCI shall be rated 15 or
20 A. A portable or cord AFCI shall be rated 20 A maximum.

61.2 The load capacity of a portable or cord AFCI shall also be rated in watts.

62.1 An arc-fault circuit-interrupter shall be marked with the manufacturer’s name, trademark, or other
suitable means of identification, a type or catalog designation, and the electrical ratings in voltage, frequency, and load capacity in amperes.

62.2 An arc-fault circuit-interrupter shall be legibly and permanently marked with the date or other dating
period of manufacture not exceeding any three consecutive months.

Exception: The date of manufacture may be abbreviated, or may be in a nationally accepted conventional code, or in a code affirmed by the manufacturer, provided that the code:

a) Does not repeat in less than 20 years; and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured

62.4 An arc-fault circuit-interrupter shall be marked ″Arc-Fault Circuit-Interrupter″ or ″AFCI″, and with the
specific device name or respective abbreviation noted in Sections 64 – 66.

62.5 A device that is required to be mounted in a specific orientation shall be marked to identify that orientation.

62.6 Controls on an arc-fault circuit-interrupter such as those provided for Test and Reset of the device shall be identified.

64 Branch/Feeder Arc-Fault Circuit-Interrupter

64A Combination Arc-Fault Circuit-Interrupter

65 Outlet Circuit Arc-Fault Circuit-Interrupter

66 Portable and Cord Arc-Fault Circuit-Interrupters

Figure SA7.1

Carbonized path tester – arc ignition test (load deenergized)

Figure SA8.1

Carbonized path tester – arc interruption test, insulation only cut

SA9 Carbonized Path Arc Clearing Time Test
SA10 Point Contact Arc Test
SA11.1 Loading condition I – inrush current
SA11.2 Loading condition II – normal operation arcing
SA11.3 Loading condition IV – cross talk
SA12 Operation Inhibition Tests
Figure SA12.1
Carbonized path tester – arc ignition (load energized)
Figure SA12.2
Carbonized path tester – arc ignition (load energized, cut grounded circuit conductor)
SA12.3 Short circuit current test
SA13 Ratings
SA13.1 An AFCI that is intended to open two ungrounded conductors shall be rated 120/240 V and 60HZ.

http://www.unplggd.com/unplggd/safety-security/3-fire-dangers-hidden-inside-your-walls-131633

Old Wiring

Electrical systems get outdated *fast* and are only designed to last 30 or 40 years. Older fuses were set up to handle about 30 amps of power, while many homes now have up to 200 amps.
How to spot it: If your house is more than 40 years old, look out for circuit breakers that trip and fuses that blow repeatedly.
How to fix it: Every case is different, so call an electrician to survey the situation in your home. He'll reccomend the past plan of action to bring your wiring up to code.

Aluminum Wiring

Back in the 1960s and 1970s, aluminum wiring was the standard. But we know now that it oxidizes and corrodes more easily than today's copper wiring and aluminum wires are linked to many electrical fires.
How to spot it: If your home was built (or an addition added) in the '60s or '70s, be on the lookout. You can check for a brand name or the word "aluminum" printed or embossed anywhere there's exposed wiring, like an attic or electric panel, but an electrician can check thoroughly for the wiring itself.
How to fix it: An electrician can keep problems at bay by installing copper connectors called "pigtails" at receptacles and breakers.

Arc Faults

Have you ever seen a spark jump through the air? Well that kind of thing can happen inside your walls and cause a fire. Any damaged wiring—whether from age or something like drilling into the wall—could create an arc fault and send an electrical current off its intended path.
How to spot it: It's tough. Like, nearly impossible.
How to fix it: We can't *fix* what we can't see. But the good news is that arc faults are easy to prevent against. An electrician can upgrade standard circuit breakers to arc-fault circuit interrupters (AFCI), which can sense the electrical abnormalities that arc faults create and shut down circuits before they overheat.

http://www.iaei.org/magazine/?p=4454

New: 406.4(D)(4) Replacements – Arc-Fault Circuit Interrupters
This proposal would require AFCI protection in existing locations where a replacement receptacle is installed in a location where AFCI protection would be required in new installations. The existing requirement in 406.3(D)(2) requires GFCI-protected receptacles where replacements are installed at receptacle outlets that are required to be so protected elsewhere in the NEC. The benefits of AFCI protection have been well substantiated over the last few NEC code cycles. There is no practical reason to limit the level of safety provided by an AFCI to new homes only. This proposal will provide AFCI protection for older homes by requiring the gradual replacement of non-AFCI-protected receptacles with new AFCI-protected ones.

IAEI MAGAZINE (http://www.iaei.org/magazine/?p=2651)

Arc-fault Circuit Interrupters – A Critical NEC 2005 Issue

[0] Published: November 2003 | Author: Brendan Foley

During 2003, many AFCI articles and comments have appeared in IAEI News. This publication activity is associated with the actions taken by code-making panel 2 on the more than 60 proposals received relative to Section 210.12 of the NEC. In particular, CMP-2 has proposed a revision that would require protection by a combination AFCI. This would effectively obsolete the field-proven branch/feeder AFCI and replace it with a combination AFCI that is not even commercially available. The present paper expands on an Eaton Electrical comment in the IAEI News, September/October, AFCI Forum.1 This paper expands on the forum comment and supports the Eaton Electrical viewpoint that the existing code language should not be changed to reference a specific type of AFCI. In particular, the present code language is non-exclusionary and presently permits either type of device.

AFCI Enhanced Protection

AFCIs were added to the NEC because of the dire U.S. electrical fire statistics. A recent National Fire Protection Association (NFPA) report2 shows that the electrical fire statistics are worse than was believed at the time of the original adoption of AFCIs into the Code. The average annual number of fires in one- and two-family dwellings in the U.S. caused by electrical arcing is over 60,000, and result in nearly 500 deaths annually and property damage of almost $1 billion. AFCIs were designed to provide enhanced protection against these electrical arcing faults, and to reduce the number of electrical fires.

Reviewing the UL Standard for AFCIs sheds some light on the protective features of AFCIs. The standard for AFCIs is UL 1699.3 The standard defines five different types of AFCIs. The types are: branch/feeder, combination, outlet circuit, portable and cord.

Branch/feeder AFCIs have been commercially available for over six years. It is important to note that only the branch/feeder and the combination type (if it were commercially available) would meet the NEC requirement of providing protection for the entire branch circuit. The outlet circuit, portable and cord types are specific-use to protect only the downstream connected cords or devices. Since this article relates to the NEC, we will limit further discussion to the branch/feeder and combination types.

There has been confusion over the types of faults that AFCIs detect. To understand the protection that AFCIs provide, a common understanding of the types of faults is important.

Parallel Arcing Fault 4

This is an across-the-line fault at which arcing occurs.

In our experience, parallel arcing faults result from an insulation fault between an ungrounded circuit conductor and either (1) a grounded circuit conductor, or (2) ground. The amount of current available in a parallel fault is determined by the available short-circuit current at the point of the fault. Here we note that the fault current levels used for the UL 1699 standard are 75 amps and above. The 75-A level was chosen because a UL report 5 of available short-circuit currents concluded that 100 percent of all residential circuits have at least 75 amps of available fault current at the receptacle location. At these current levels, arcs have high power dissipation, large diameters, and are associated with electrode (copper) melting with ejection of heated electrode material. This results in a large spatial region where ignition is probable.

Series Arcing Fault 4

A series fault at which arcing occurs.

[A series (continuity) fault 4 is a partial or total local failure in the intended continuity of a conductor characterized by either infinite resistance (a completely severed conductor) or by resistance that alternates between infinite resistance and high or normal resistance such as intermittent connection at a loose wiring terminal or splice. Note: A series fault may contribute to an insulation fault.]

With respect to series arcing faults, we note that, since the fault is only in one of the circuit conductors, the load determines the amount of current that is conducted. These low current arcs have low power dissipation and small diameter. Consequently, the spatial region for ignition is small.

High Resistance Series Fault 4

A series fault characterized by the presence of abnormally high resistance (high resistance in comparison to the normal resistance of the normal conductor but not high comparison to the infinite resistance of a completely severed conductor) in a wire, at a wire termination, or wire splice, resulting in a reduction of ampacity and an excess of heat dissipation at the fault. Examples are a partially severed stranded conductor with only a small percentage of the strands intact and a corroded wire terminal or splice.

In our experience, these high resistance series faults result from a build-up of copper or aluminum oxide that creates a high resistance “glowing contact.”6 This high-resistance point can become extremely hot with temperatures exceeding 600° F causing insulation failure that can result in a damaging high-power parallel arcing fault or ground fault. Glowing contacts can develop at virtually any electrical connection conducting current. The current in the high resistance fault, like the series arcing fault, is limited to the current being drawn by the load—until the insulation degrades to the point where this type of fault becomes a parallel arcing fault or causes leakage current to ground.

All of today’s branch/feeder AFCIs combine the thermal and magnetic protection of a standard circuit breaker with arc-fault detection circuitry to sense high-power parallel arcing faults. As pointed out in the AFCI Forum comment,1 the commercially available branch/feeder AFCIs also contain earth leakage protection that provides protection against ground faults. As a consequence, commercially available branch/feeder AFCIs provide complete protection to the commonly used branch-circuit installation wire (NM-B plus ground), protection against all arcing faults between two conductors (parallel faults) in 2-wire cords and protection via ground fault against all arcs-to-ground of 30 mA and above at any point in the circuit. Significant protection is also provided against glowing connections7 via ground fault and parallel arc detection.

SUMMARY OF BRANCH/FEEDER PROTECTION		
Location: Behind the wall		
Wiring Hazard	Type	Comment
1. Metallic bridging in Install wiring (NM-B)	High power parallel arc	Line-to-neutral (for ground) parallel arcing fault.
2. Glowing contact with copper wire	High resistance series fault at a receptacle terminal.	Caused by loose connection. Leads to parallel arcing or ground faults due to insulation failure and ground fault tracking due to heat.
3. Glowing wire nut	High resistance series fault at a loose wire nut.	" "
4. Back-wired push-in receptacle	High resistance series fault at a receptacle push-in terminal.	" "
5. "Hot" plug	High resistance series fault at a receptacle-to-plug connection	" "
6. Aluminum branch wiring	High resistance series fault due to flow and oxidation of aluminum.	" "
7. Shared Neutral	Multiple line conductors with a single neutral.	Overheats neutral, but is detected and protected by ground fault circuitry.
Location: In-the-room		
Wiring Hazard	Type	Comment
8. Metallic bridging of lamp cord	High power parallel arc	Line-to-neutral parallel arcing fault
9. Broken conductor in lamp cord	High resistance series fault as the result of a wire break with reconnection.	Leads to parallel arcing due to insulation heatin heating and failure
10. Overheated cord-plug connection	High resistance series fault due to a poor crimped wire-to-plug connection.	" "
11. Overheated extension cord	Overloaded line & neutral conductors, for example cord under a rug.	" "

Table 1. Summary of branch/feeder protection

Table 1 summarizes the protective features of the branch/feeder AFCI relative to eleven recognized home wiring fault hazards. Seven of these are "behind-the-wall" faults and four are "in-the-room" faults. Seven of them start as high resistance series faults while two start as parallel faults. Two are related to current overload. With respect to parallel faults, the same UL study that was used as the basis of the 75-ampere threshold, and direct experience, shows it unlikely that a standard circuit breaker would respond to many of these situations.5 All of these hazards are mitigated by the currently available branch/feeder AFCIs.

From a standard's standpoint, the difference between the branch/feeder and combination types is that the latter must pass low current arc detection tests: namely to detect arcs down to 5-amperes in 2-wire cords. Thus the combination AFCI must clear low current arcs within the times specified in Table 56.1 of UL 1699.

Figure 1. Circuit diagram for carbonized path arc clearing time test

In a 20-amp circuit, for example, a 30-amp arc (150% rating) must be detected and interrupted within 0.11 seconds (13 arcing half cycles) and a 5-amp arc within 1 second (120 arcing half cycles). But in our experience, when a copper conductor breaks in a 120-volt circuit, low-current arcs of these durations are highly unlikely. This is to be expected because, from Paschen's curve,8 the minimum breakdown voltage for flat parallel copper electrodes in air exceeds 300 volts. The circuit voltage is too low for arc re-ignition at the AC current zero. Thus the UL Standard (UL 1699) contains long duration low-current arcing tests, but these are performed using either a parallel cut across conditioned SPT-2 conductors (see figure 1), or with the separation of a copper rod from an opposing carbon-graphite rod during current conduction. Here sustained arcing is possible because high temperature carbon emits electrons and this emission facilitates arc reignition in 120-volt circuits.

These UL 1699 conditions certainly result in long-duration low-current arcing, but the conditions are rarely encountered in residential circuits.

Experience with Branch/feeder AFCIs

Branch/feeder AFCIs have been UL listed for four manufacturers, Siemens, GE, Square D, and Cutler-Hammer, for several years. Not only are they listed; they have been commercially available since 1997 with more than 5 million installed. In total these devices have been operating in residences for approximately 20 billion hours and can no longer be regarded as "new products."

As AFCIs became a requirement in a given area, there was a learning curve associated with wiring practices. Some of the early troubles encountered by electricians were related to the fact that most were unaware that all commercially available branch/feeder AFCIs have an earth leakage element as part of the enhanced protective functions. This ground-fault element (most are set at approximately 30 mA) provides rapid response to insulation damage in the commonly used branch-circuit installation wire (NM-B plus ground) where a break in the neutral or hot conductor will result in current flow to the bare ground wire. As with the installation of ground-fault devices, the neutrals of AFCI-protected circuits must be kept isolated from the neutrals of other circuits and from ground wires. Following this installation learning curve, unwanted tripping has not been a problem.

Experience with Combination AFCIs

Combination AFCIs have been UL listed by three companies, Pass & Seymour Legrand, HETKO and Square D. The Pass & Seymour Legrand device was listed in 1999,9 the HETKO device was listed in the first quarter of 2003, and the Square D AFCI was listed in August/September of 2003. None are commercially available. It must be noted that the detection of low current arcs by combination AFCIs necessitates technology that is capable of distinguishing, on a continuous basis, between damaging arcs and the safe arcs and transient waveforms associated with everyday circuits. Thus there are safe arcs associated with motor brushes (for example, vacuum cleaners), with switches (for example, light controls, hairdryers, etc.), with bi-metal temperature controls of household appliances (for example, irons). Further, there are chopped waveforms associated, for example, with electronic power supplies (computers, lamp ballasts, etc.).

Combination AFCIs, if mandated exclusively, will be installed in millions of homes; each with appliances and circuit loads of varying age and characteristics. Further, these AFCIs will be installed for the life of the home and will have to handle the switching events and electronic waveforms of the future. In Eaton Electrical's opinion, combination AFCIs must be commercially available, and installed in tens of thousands of homes, before their ability to discriminate between low current damaging arcs on the one hand, and normal arcs plus chopped wave forms on the other hand, can be judged a success. In our experience, the public will not tolerate unwanted, nuisance tripping with the associated power-interruption inconvenience and, in particular, the implication of fire hazards.

Code Proposals — Cause for Alarm

Of particular concern are (1) proposal 2-146 that CMP-2 has "”accepted in principle”" and the associated panel proposal 2-134A. These proposals would change the wording of 210.12(B) to require protection by "a listed arc-fault circuit interrupter, combination type, installed to provide protection of the entire branch circuit." There is cause for alarm because the change would effectively obsolete the field-proven branch/feeder AFCI and replace it with a combination device that is not even commercially available. Here it is noted that the present Code language is inclusive in that it mandates "an arc-fault circuit interrupter listed to provide protection of the entire branch circuit." This language permits either the currently available branch/feeder AFCIs or combination AFCIs.

Conclusion

Eaton Electrical advises that the code language should not be changed to reference a specific type of AFCI. The code panel could certainly revisit this subject in future code cycles when combination AFCIs have become commercially available, and if practical field experience indicates superior fire protection capabilities without unwanted tripping. However, in the interests of continued fire safety and consumer choice, the present code language should be retained.

References

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7 UL Special Services Investigation for Cutler-Hammer entitled “Branch/Feeder Arc-Fault Circuit Interrupter Incorporating Equipment Ground-fault Protection,” File E45310, May 31, 2001.

8 *Electrical Contacts. Principle and Application*. Published by Marcell Dekker, Inc., Edited by P. G. Slade, 1999.

8 Proposal 2-108 submitted in 1999 by Pass & Seymour Legrand for the 2002 NEC (NFPA 70, May 2001 ROP, page 130).

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Earl W. Roberts, PE< is president of REPTEC, a consulting engineering firm in Mystic, CT. He retired from GE in 1986 and has been involved in the electrical industry since 1946. He was a member of the National Electrical Code Correlating Committee and served as Chairman and as a member representing NEMA of NEC Panel 2 for many years. He was a member of the NEMA Codes and Standards Committee. He served as Chairman of the Electrical Section of NFPA and is a Life Member of NFPA and a member of IAEI. He is a graduate of Brown University and is a retired Lt. Commander in the U.S. Naval Air Reserve.