SAE Aerospace An SAE International Group	AEROSPACE STANDARD	SAE AS5692	REV. A
		Issued 2004-10 Revised 2009-12 Superseding AS5692	

(R) ARC Fault Circuit Breaker (AFCB), Aircraft, Trip-Free
Single Phase and Three Phase 115 VAC, 400 Hz - Constant Frequency

RATIONALE

Update specification to include three phase arc fault circuit breakers update requirements to comprehend three phase requirements.

FOREWORD

Thermal circuit breakers are designed to react to the heating effect of current carried by wire; and to protect the wire insulation from thermal damage. These protective devices are not designed to detect or react to the short duration of arcing faults that typically occur outside (before approaching) the defined trip region, or Time versus Current Curve, of the thermal circuit breakers.

In addition, arc impedance can reduce low voltage fault current magnitudes appreciably. AFCBs combine active arc fault detection with thermal overload protection into one package. Supplemented with the arc fault detection, the AFCB provides an equivalent level of thermal protection of existing thermal circuit breakers (typically qualified under AS58091), with the added ability to detect and react to arc fault conditions, thereby mitigating damage that will occur to the wiring system by protracted arcing events.

It is important to note that the primary purpose of the AFCB as stated above is to mitigate damage to the aircraft wiring from the circuit breaker to the first serial load element (examples: LRU, transformer, ballast, rectifier, or connected equipment, etc.). In doing so, the potential of igniting surrounding materials is reduced, but not eliminated. Use of AFCBs for hazard mitigation/prevention beyond its intended function of mitigating damage to the aircraft wiring should be carefully analyzed and evaluated.

NOTE: AS58091 was used as the base document for this AFCB specification as such the tables comprehend future amp rating expansion from ½ to 200A.

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1. SCOPE

1.1 Scope

The primary function of this specification is to cover the general requirements for manual reset trip-free arc fault/thermal circuit breakers for use in aircraft electrical systems conforming to MIL-STD-704. As a secondary function, this specification may possibly cover the general requirements for AFCBs for use in primary vehicles, other than aircraft, when mounted directly to the structure.

1.2 Classification

AFCBs shall be the Thermal Type, and classified into different styles. Variations from the basic style of each AFCB shall be indicated by the part number from the appropriate specification sheet (see 3.1).

1.2.1 Styles

AFCB styles shall consist of all part numbers covered by one Aerospace Standard or specification sheet. For example:

a. All part numbers of AS5692/1 shall be the same style.

b. All part numbers of AS5692/2 shall be the same style.

The same style classification applies to all Aerospace Standards and specification sheets covered by this specification.

1.2.2 Part Number

The part numbers for AFCBs in accordance with this specification shall conform to part number scheme below. Alphanumeric characters shall be used to designate variations from the basic style of each circuit breaker.

Example of part number scheme (amend p/n to comprehend 2A5)

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AS5692/1-DA5VL
      |      |  || || ______  Pushbutton                    (1.2.4)
      |      |  || |_______   High Vibration Capability     (1.2.6)
      |      |  || ________   Auxiliary Terminals           (1.2.5)
      |      |  | _________   Amperage Rating               (1.2.3)
      |      |___________     Random Vibration Capability   (1.2.6)
      |_________________      Basic part style AS5692/1     (1.2.1)
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When a designator for a variation is not applicable it shall be omitted from the part number. Not all letters are applicable for every specification sheet. Refer to the latest specification sheet and QPL for available and qualified configurations.

1.2.3 Amperage Ratings

The amperage rating designator shall be a number specified in each specification sheet to indicate the nominal amperage rating for overload protection.

1.2.4 Pushbuttons

The AFCB pushbutton shall be designated as follows. Standard length pushbutton, as specified in the specification sheet shall have no designator letter.

L - Extra length pushbutton (see 6.3.9)

1.2.5 Auxiliary Switch Terminals

The use of auxiliary switch terminals when allowed by the specification sheet shall be designated as follows. AFCBs with standard terminals only, as specified in the specification sheet, shall have no designator letter.

A - Auxiliary switch terminals

1.2.6 Vibration Level

The vibration level of the AFCB shall be specified in the specification sheet and shall be indicated in the part number by one or more of the following designators. Standard sine vibration capabilities shall have no designator. (see 4.7.11.2).

V - High Level sine capabilities (see 4.7.11.3).

C thru K - Random vibration capabilities (see 4.7.11.1).

1.2.7 Mounting Configurations

Unless otherwise specified, the AFCB mounting configuration shall be designated as follows. Standard bushing mounted circuit breakers shall have no designator.

P - Cover-plate mount.

2. APPLICABLE DOCUMENTS

2.1 Government Specifications, Standards and Handbooks

2.1.1 The following specifications, standards and handbooks form a part of this specification to the extent specified herein.

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

A-A-52080	Tape, Lacing and Tying, Nylon
A-A-52081	Tape, Lacing and Tying Polyester
A-A-52082	Tape, Lacing and Tying, TFE-Fluorocarbon
A-A-52083	Tape, Lacing and Tying, Glass
A-A-52084	Tape, Lacing and Tying, Aramid
MIL-I-24768/17	Insulation, Plastic, Laminated, Thermosetting, Glass-Cloth, Silicone-Resin (GSG)
MIL-DTL-81381	Wire, Electric, Polyimide Insulated, Copper or Copper Alloy
MIL-E-17555	Electronic and Electrical Equipment, Accessories, and Provisioned Items (Repair Parts); Packaging of
MIL-HDBK-454	General Guidelines for Electrical Equipment
MIL-I-24768/1	Insulation Plastic, Laminated, Thermosetting, Glass Cloth Melamine Resin
MIL-STD-104	Limit for Electrical Insulation Color
MIL-STD-1285	Marking of Electrical and Electronic Parts
MIL-STD-1916	DOD Preferred Methods for Acceptance of Product

MIL-STD-202 Test Method Standard for Electronic and Electrical Component Parts

MIL-STD-704F Aircraft Electrical Power Characteristics

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

MIL-STD-889 Dissimilar Metals

(Copies of specifications, standards, handbooks, drawings and other Government documents required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

2.2 Other Publications

ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D 635 Plastics, Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position

ASTM D 5948 Molding Compounds, Thermosetting

SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001. Tel: 977-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP4754 Certification Considerations for Highly Intergrated or Complex Aircraft Systems

ARP4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

AS4373 Test Methods for Insulated Electric Wire

AS50861 Wire, Electric, Polyvinyl Cloride Insulated, Copper or Copper Alloy

AS7928 Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For

AS22759 Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy

AS22759/34 Wire, Electrical, Fluoropolymer-Insulated, Cross-Linked Modified ETFE, Normal Weight, Tin-Coated Copper, 150°C, 600 volt

AS25036 Terminal, Lug, Crimp Style, Copper, Insulated, Ring Tongue, Bell Mouthed, Type II, Class 1 (For 105 °C Total Conductor Temperature)

AS50881 Wiring Aerospace Vehicle

AS58091 Circuit Breakers, Trip-Free, Aircraft General Specification For

AS81044 Wire, Electrical, Crosslinked Polyalkene, Crosslinked Alkane-Imide Polymer, or Polyarlyene Insulated, Copper or Copper Alloy

AS8879 Screw Threads – UNJ Profile, Inch Controlled Radius Root with Increased Minor Diameter

Other Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org

Available from American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, Tel: 800-248-1946 (United States or Canada) or +1-414-272-8575 (International), www.asq.org.

Available from Radio Technical Commission for Aeronautics, Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

AIA/NAS NASM 25027	Nut, Self-Locking, 250 deg. F, 450 deg. F, and 800 deg. F
ANSI/ASC (Z1.4)	Procedure and Tables for Inspection by Attributes
DOD/MIL-STD-100	Engineering Drawing Practices
ISO 10012-1	Calibration Laboratories and Measuring Test Equipment – General Requirement
ANSI/NCSL Z540-1	Calibration Laboratories and Measuring Test Equipment – General Requirement
RTCA/DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA/DO-178B	Software Consideration in Airborne Systems and Equipment Certification
RTCA/DO-254	Design Assurance Guidance for Electronic Hardware

2.3 Order of Precedence

In the event of a conflict between the text of this specification and the references cited herein (except for associated detailed specification sheets, specification sheets or AS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Specification Sheets

The individual item requirements shall be as specified herein and in accordance with the applicable specification sheet. In the event of any conflict between the requirements of this specification and the specification sheet, the latter shall govern.

3.2 Qualification

The AFCBs furnished under this specification shall be products that are authorized by the Qualifying Activity for Listing on the applicable Qualified Products List (see 4.5 and 6.2).

3.2.1 First Article Inspection

AFCBs furnished under this specification not covered by specification sheets or not qualified at the time of set for opening bid shall be subjected to the tests specified in 4.5.

3.3 Materials

Suitable materials shall be used that will enable the AFCBs to conform to the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guarantee of the acceptance of the finished product.

3.3.1 Fungus

Materials shall be used which are not nutrients for fungus as specified in Guideline 4 of MIL-HDBK-454. The use of fungus resistant materials is not required for sealing calibration screws, terminals or terminal barriers pending review of the qualifying activity.

3.3.2 Metal

All metals used in the construction of AFCBs shall be corrosion resistant or shall be suitably protected to resist corrosion. The use of dissimilar metals, especially contacts between brass, copper, steel and aluminum or magnesium alloys, shall be avoided. Where contact between dissimilar metals is unavoidable, the metals shall be protected against electrolytic corrosion. Dissimilar metals are defined in MIL-STD-889. When thermostatic bimetals and trimetals are used, corrosion resulting from tests specified herein shall not adversely affect the performance of the AFCB.

3.3.3 Plastics

Plastic materials used in the housing, insulator base, and any internal parts exposed to arcing or surface creepage shall conform to ASTM D 5948 or equivalent and shall not exhibit any deleterious impact on AFCB performance during normal operation or qualification testing. Other types of plastics materials may be used provided the manufacturer submits satisfactory evidence to the activity responsible for qualification.

Plastic materials used by the manufacturer must exhibit evidence of satisfactory performance that the materials are suitable for the purpose intended. The plastic materials used shall neither support combustion nor give off noxious gases when subjected to arcs, such as those caused by interrupting heavy short circuit currents (as defined on the specification sheet), or explosions of gaseous vapors to which the materials may be subjected in service. Plastic materials with cellulose fillers will not be permitted in parts that may be subjected to arcing or surface creepage. Plastic materials used shall be certified to exhibit a minimum ignition time of 90 seconds and a maximum extinguishing time of 90 seconds when tested for flammability in accordance with ASTM D 635.

3.3.4 Protective Treatment

The use of any protective coating that will crack, chip, or scale will not be permitted.

3.3.5 Selection of Materials

Specifications and standards for all materials, parts and Government certification and approval of processes and equipment, which are not specifically designated herein and which are necessary for the execution of this specification, shall be selected in accordance with MIL-STD-970.

3.3.6 Cleaning prior to final assembly

The circuit breakers shall be thoroughly cleaned of loose, spattered, or excessive solder, metal chips, and other foreign material. Burrs, sharp edges and resin flash shall be removed.

3.3.7 Electronic Components

Electronic components selected shall be such that the AFCB shall meet performance requirements and product characteristics specified herein.

3.4 Design and Construction

3.4.1 General

AFCBs shall conform to the applicable specification sheet.

3.4.2 If the design of the arc fault circuit breakers contains software or complex hardware, as a minimum, the software and hardware shall be developed in accordance with RTCA/DO-178B, level C and RTCA/DO-254, level C, respectively.

3.4.3 Mounting Means

The AFCB shall be provided with a suitable mounting means as shown on the applicable specification sheet. If self-locking nuts are used, they shall meet the performance requirements of AIA/NAS NASM 25027. AFCBs that utilize a mounting nut and lockwasher are generally supplied with the mounting nut and lockwasher. AFCBs that utilize a mounting faceplate are generally supplied without the associated mounting screw.

3.4.4 Actuator of Push-Pull AFCBs

The portion of the actuator visible when the AFCB is in the closed position shall be colored in accordance with the specification sheet and shall expose a white band when in the open or thermally tripped position. If a secondary indication for an arc fault trip condition is provided, it shall be in accordance with the specification sheet. The exterior portion of the actuator shall be insulated from all current-carrying parts. The actuator shall not work out to an intermediate position, give a false trip indication, or be removable from the AFCB. An intermediate position is a position where the white band of the actuator is partially or fully exposed yet the circuit breaker remains in the ON (closed) position. Push-Pull AFCBs shall be designed to permit manual opening of the circuit breaker by pulling out the actuator.

3.4.5 Terminals

Terminal construction shall be as specified on the applicable specification sheetand shall be designed for use with terminal lugs conforming to AS25036 and AS7928.

3.4.5.1 Terminal Hardware

Lockwashers captive to the terminal screws shall be supplied only when specified on the applicable specification sheet. AFCBs may be supplied without terminal hardware, with terminal hardware supplied in bulk, or packaged separately, according to customer instructions.

3.4.6 Housing

The AFCB mechanisms shall be enclosed in a housing securely attached to the insulator base and to the mounting plate when one is used. The housing may be integral with the insulator base.

3.4.7 Ratings

The ratings of push-pull AFCBs shall be as specified on the applicable specification sheet. Ratings of ½ amp shall be clearly indicated, i.e. 7 ½ or 7.5, not 7 (where the ½ or 0.5 would be implied) unless specified on the specification sheet.

3.4.8 Trip Indication and Reset

The AFCBs shall be so designed that when the AFCB contacts open automatically on fault condition (thermal overload or arc fault trip), the actuator shall indicate the operation by moving to the tripped position, as shown on the applicable specification sheet. The white color specified on the applicable specification sheet for the trip indicator on a push-pull shall conform to Class 1 of MIL-STD-104. AFCBs shall have an indication to distinguish between a thermal overload and an arc fault trip when required by the specification sheet.

3.4.8.1 Reset Mechanism

The reset mechanism shall be so designed that retaining the actuator in the closed position after automatic tripping occurs shall not adversely affect subsequent performance of the AFCB.

3.4.9 Arc Fault Trip Free Mechanism

If an arc fault trip indication is required by the specification sheet, the mechanism for arc fault trip indication shall be so designed that retaining the indicator in the closed position after automatic tripping occurs shall not adversely affect subsequent performance of the AFCB.

3.4.10 Position

AFCBs shall operate satisfactorily when mounted in any axis or plane.

3.4.11 Mounting Screw Clearance

The mounting screws shall be capable of being screwed into the AFCB a minimum depth, as shown on the applicable specification sheet. The mounting nuts shall be backed or provided with other means to prevent mounting screws of excess length from interfering with the operation of the circuit breaker. Screws of excess length shall not fracture the housing or the explosion-preventative seal.

3.4.12 Creepage and Clearance Distance

The minimum creepage path and the minimum clearance between current-carrying parts and any part of the current breaker other than insulating materials, and also between current-carrying parts of opposite polarity, shall be 3/16 and 1/8 inch respective.

3.4.13 Tamper-Proof Calibration

AFCBs shall be so constructed that tampering with the calibration is not possible without dismantling the device or breaking a seal.

3.4.14 Ambient Temperature

3.4.15 Unless otherwise specified (see 3.1), AFCBs shall be designed to provide thermal protection within one of the following continuous ambient temperature conditions:

Condition A-55 to 71 °C
Condition B-55 to 121 °C

The electronics of the AFCB shall comply with RTCA/DO-160 as specified herein or per the applicable specification sheet.

3.4.16 Grounding

AFCBs shall be grounded as required per the specification sheet. The AFCB shall meet all specification requirements with 2 ohms or greater resistance to ground unless otherwise specified in the applicable specification sheet.

3.4.17 Bonding

AFCBs shall provide a provision for bonding and verification as required by the specification sheet.

3.5 Interchangeability

All parts having the same manufacturer’s part number shall be functionally and dimensionally interchangeable. The drawing number requirements of DOD-STD-100 shall govern changes in the manufacturer’s part number.

3.6 Screw Threads

Screw threads on removable or replaceable threaded parts shall be as specified in MIL-S-8879. Threading of non-metallic parts is not permitted.

3.7 Performance

The AFCBs shall perform satisfactorily when subjected to tests specified in Section 4, and there shall be no breakage, malfunction, or evidence of any damage that would impair the ability of the AFCBs to meet the requirements of the specification. Although upon completion of the test there shall be no damage that degrades device basic function or performance, cosmetic damage may be deemed as acceptable

3.7.1 Examination of Product

The AFCBs shall show no evidence of defects when examined in accordance with 4.7.1.

3.7.2 Dielectric Withstanding Voltage

The AFCBs shall exhibit no evidence of breakdown or subsequent malfunction when tested in accordance with 4.7.2, 4.7.2.1, and 4.7.2.2.

3.7.3 Insulation Resistance

Unless otherwise specified, the insulation resistance of AFCBs shall not be less than 100 megohms when tested in accordance with 4.7.3.

3.7.4 Strength of Actuator

AFCB actuators shall not show evidence of breaking, cracking or jamming when tested in accordance with 4.7.4.1 or 4.7.4.2. The AFCB shall also meet the performance requirements defined when tested in accordance with 4.7.4.3.

3.7.5 Strength of Threaded Parts

The threaded parts of the AFCB shall be tested in accordance with 4.7.5. Upon completion of the test, the threaded parts of the AFCB shall not be damaged.

3.7.6 Operating Force

The force necessary for operation of the AFCB shall be within the limits specified on the applicable specification sheet when tested in accordance with 4.7.6. The minimum operating force shall not be less than 15 percent of the specified maximum value unless otherwise specified on the applicable specification sheet.

3.7.7 Calibration

The AFCB’s thermal overload and arc fault trip performance shall be within the limits specified on the applicable specification sheet, and 4.7.7, when tested and calibrated in accordance with 4.7.7

3.7.8 Endurance

The AFCB shall make and break the specified number of cycles with the current without failure as defined in the applicable specification sheet when tested in accordance with 4.7.8.

3.7.9 Overload and Arc Fault Cycling

The AFCB shall make and break the test cycles specified without failure, when tested in accordance with 4.7.9.

3.7.10 Reclosing

Manual reset AFCBs shall remain open after being tripped automatically for one hour showing no electrical continuity when tested in accordance with 4.7.10.

3.7.11 Vibration

The AFCBs shall be tested in accordance with 4.7.11 with the vibration levels and test conditions specified in the applicable specification sheet. If no vibration level is specified in the applicable specification sheet, the sine vibration with test condition A shall be performed (see 4.7.11.2). The AFCB main contacts shall not trip or show any electrical discontinuity in excess of 10 microseconds, nor shall the arc fault circuit cause a trip. Upon completion of the vibration test, AFCBs shall show no evidence of physical damage and shall meet the requirements of the 200% overload calibration test performed at 25 °C in accordance with 4.7.7.3, the guillotine test in accordance with 4.7.7.6.1, Source A, Circuit 2, and the dielectric withstanding voltage test in accordance with 4.7.2. For three phase AFCB, each phase must be tested seperately while other phases carry rated current.

3.7.12 Mechanical Shock

The AFCB main contacts shall not change state when tested in accordance with 4.7.12. Upon completion of the test, the device under test (DUT) shall meet the requirements of 200% overload calibration of 4.7.7.3 at 25 °C, and the guillotine test when tested in accordance with 4.7.7.6.1, Source A, Circuit 2. For three phase AFCB, each phase must be tested seperately while other phases carry rated current.

3.7.13 Acceleration

The AFCB main contacts shall not change state when tested in accordance with 4.7.13. Upon completion of the test, the DUT shall meet the requirements of 200% overload calibration of 4.7.7.3 at 25 °C, and the guillotine test when tested in accordance with 4.7.7.6.1, Source A, Circuit 2. For three phase AFCB, each phase must be tested seperately while other phases carry rated current.

3.7.14 Interrupting Capacity

The AFCB performance shall be as specified in the applicable specification sheet when tested in accordance with 4.7.14 and 4.7.14.1. During the interrupting capacity tests the AFCB may fail safe. For the purpose of this test, an AFCB that has failed safe is a device that is unable, because of electrical damage, to carry a continuous current or an electrical load. In addition, for an AFCB that has failed safe, with the AFCB in the closed or reset position, the leakage current between the load and line terminal(s) shall be less than 1 milliamp at 300 VAC, unless otherwise specified by the individual specification sheet. Unless the DUT enters a fail-safe condition, following the last operation of this test, the circuit breaker shall meet the requirements for dielectric withstanding voltage (4.7.2) and 200% overload calibration at 25 °C per 4.7.7.3, the allowable circuit breaker tripping time shall be within 120% of the upper limit specified in the applicable specification sheet, and there shall be no dielectric breakdown. The DUT shall also meet the requirements of the guillotine test when tested in accordance with 4.7.7.6.1, Source A, Circuit 2. NOTE: The ground connection must be restored for post testing after testing to 4.7.14.1.

3.7.14.1 Interrupting Capacity Fail Safe

In the case that an AFCB has failed safe, the design of the fail safe point cannot affect other performance characteristics, such as higher level overloads specified on the applicable specification sheet, to the extent that the device does not meet other performance requirements of this specification or the applicable specification sheet.

3.7.15 Sand and Dust

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.15. At the conclusion of this test, the circuit breaker shall be held in at 500% of rated load, thus causing the DUT to trip free. On three phase AFCB's, each phase shall be tested seperately. Failure to trip within 10 seconds shall constitute failure. The DUT shall meet the requirements for 200% overload calibration at 25 °C when tested in accordance with 4.7.7.3. The DUT shall also meet the requirements of the guillotine test when tested in accordance with 4.7.7.6.1, Source A, Circuit 2.

3.7.16 Corrosion

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.16. At the conclusion of this test, the DUT shall be held in at 500% of rated load, thus causing the DUT to trip free. On three phase AFCB's, each phase shall be tested seperately. Failure to trip within 10 seconds shall constitute failure. The DUT shall then meet the requirements for 200% overload calibration, per 4.7.7.3, at 25 °C, except that the tripping time shall be within 80% of the lower limit and 120% of the upper limit specified. All hardware shall be removable without damage to the DUT or hardware. The DUT shall also meet the requirements of the guillotine test when tested in accordance with 4.7.7.6.1, Source A, Circuit 2.

3.7.17 Moisture Resistance

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.17.

3.7.18 Explosion

Ignition of the explosive mixture outside the AFCB shall constitute failure when tested in accordance with 4.7.18.

3.7.19 Voltage Drop

Voltage drop across the AFCB greater than that specified on the applicable specification sheet shall constitute failure when tested in accordance with 4.7.19. Voltage drop shown on the specification sheet is a beginning of life value, unless otherwise indicated on the specification sheet.

3.7.20 Transit Drop

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.20. Upon completion of the test there shall be no damage to the DUT through handling and manipulation of the breaker as detected by visual inspection that compromises device performance (including but not limited to chips or cracks in the circuit breaker housing; while cosmetic damage may be deemed as acceptable). In addition, each DUT shall be tested in accordance with and meet the requirements of 4.7.2, 200% overload calibration at 25 °C of 4.7.7.3, and guillotine testing per 4.7.7.6.1, Source A, Circuit 2, of this specification.

3.7.21 Temperature and Pressure

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.21.1, 4.7.21.2, 4.7.21.3 and 4.7.21.4.

3.7.22 Magnetic Effect

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.22.

3.7.23 Electromagnetic Compatibility

The AFCB shall not trip or otherwise malfunction when tested in accordance with 4.7.23. After signal injection, but prior to first removal of power, each DUT shall be tested in accordance with and meet the requirements of guillotine testing per 4.7.7.6.1, Source A, Circuit 2.

3.7.24 Maximum Power

The AFCB performance shall be within the limits specified on the applicable specification sheet when tested in accordance with 4.7.24.

3.7.25 Power Quality and Interruptions

The AFCB performance shall be as specified in this specification when tested in accordance with 4.7.25.

3.7.26 Reverse Installation

The AFCB performance shall be as specified in the applicable specification sheet when tested in accordance with 4.7.26.

3.8 Markings

All AFCBs shall be permanently and legibly marked as shown on the applicable specification sheet. The markings shall remain legible during and after all the tests specified in this specification.

3.8.1 Push-Pull Actuators

3.8.2 The exposed end of the push-pull actuator shall be marked with a white, raised or depressed, number indicating the applicable current rating of the AFCB as shown on the applicable specification sheet.

3.8.3 Terminals

The line and load terminals shall be clearly and permanently marked or identified "LINE" or "1," and "LOAD" or "2," adjacent to the terminals, when shown on the applicable specification sheet. A ground point or ground connection shall be clearly and permanently marked or identified "GND" or neutral identified "N." Refer to the specification sheet for other detailed terminal marking instructions.

3.8.4 Multi-phase breakers

Primary terminal identification shall be the same as for single phase breakers, as identified above, except that for the phase identification shall be identified by a letter prefix reading consecutively from right to left as defined in the specification sheet.

3.9 Identification of Product

Each AFCB shall be permanently and legibly marked for identification as follows:

- Part No. (see 1.2.2)
- Manufacturer's name or trademark
- Date code (YYWW) (0212 = week 12 of 2002)

3.10 Workmanship

The AFCB, including all parts and accessories, shall be constructed and finished in a careful and workmanlike manner in accordance with good design and sound practice. Particular attention shall be given to neatness and thoroughness of soldering, wiring, impregnation of coils, marking of parts and assemblies, and freedom of parts from burrs and sharp edges (see 4.7.1).

4. QUALITY ASSURANCE PROVISIONS:

Throughout this section, Device Under Test (DUT) refers to a single phase or three phase 115 VAC, 400 Hz AFCB.

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use their own or another facilities' equipment suitable for the performance of the inspection requirements specified herein, unless disapproved by the qualification authority. The qualification authority reserves the right to perform any of the inspections set forth in the specification where such inspections deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for Compliance

All items must meet all requirements of Sections 3 and 5. The inspection set forth in this specification shall become a part of the manufacturer's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the manufacturer of the responsibility of assuring that all products or supplies submitted to the qualification authority for acceptance comply with all requirements of the specification. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the qualification authority to accept defective material.

4.1.2 Test Equipment and Inspection Facilities

The manufacturer shall establish and maintain a calibration system in accordance with ISO 10012-1, ANSI/NCSL Z540-1.

4.2 Classification of Inspections

The inspections specified herein are classified as follows:

- Materials inspection (4.3)
- Qualification (4.5)
- Quality conformance inspection (4.6)

4.3 Materials Inspection

Material inspection shall consist of certification that the materials are in accordance with the requirements of 3.3.

4.4 Inspection Conditions

Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in the General Requirements of MIL-STD-202. If the temperature tolerance is not specified in test conditions, the tolerance shall be ±5 °C. Room temperature is defined as 25 °C ± 2 °C.

4.4.1 Calibration

Calibration tests shall be performed at a temperature specified on the applicable specification sheets with the temperature maintained at a constant value. Test sample units with leads and terminals attached shall be maintained at the specified ambient temperature for 1 hour prior to application of the specified current during all calibration tests. Test circuit may be in accordance with Figure 1. Calibration tests shall be conducted at all voltages and frequencies shown on the specification sheet where applicable. (Refer to Table 1 for test set up)

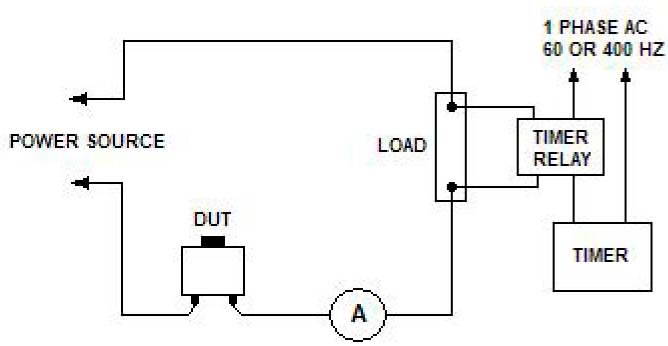

FIGURE 1 – CALIBRATION TEST CIRCUIT

4.4.1.1 Production Calibration

For calibration tests performed during production only (not for qualification or quality conformance tests), it will be permissible to use test methods so designed as to expedite calibration testing, provided the manufacturer can demonstrate that the results are comparable to the calibration tests specified herein.

4.4.2 Thermal Overload

Tests of the thermal overload may be conducted using alternating current at commercial frequencies.

4.5 Qualification Inspection

Qualification inspection shall be performed at a laboratory acceptable to the qualification authority (6.2) on sample units produced with equipment and procedures normally used in production.

4.5.1 Sample Size

Thirty-three single phase or 23 three phase AFCB specimens as defined in any one specific detail specification shall constitute a sample size. The combination of specimens to be tested shall be determined by the qualifying activity based upon the manufacturer's desired listing. The qualifying activity reserves the right to request additional untested samples to be submitted with the qualification test report.

4.5.2 Test Routine

The qualification and test samples for one and three phase AFCB's shall be subjected to the tests specified in Table 2 and 2A, respectively. All sample units shall be subjected to Test Group I then divided as indicated into the various remaining test groups. At the option of the qualifying activity, the environmental tests consisting of vibration, mechanical, shock, acceleration, sand and dust, corrosion and moisture resistance (4.7.11, 4.7.12, 4.7.13, 4.7.15, 4.7.16, and 4.7.17) may be omitted when qualifying additional ratings under a specification sheet provided that two amperage ratings of the same sample style have previously completed these tests satisfactorily. Qualification of additional circuit breaker styles or amperage ratings by similarity to circuit breakers previously qualified may be determined by the qualifying activity.

NOTE: 36 inches minimum of appropriate gauge wire with lugs per Table 1 shall extend from each terminal of the DUT.

TABLE 1 – CALIBRATION TEST CIRCUIT COMPONENTS

(a) AFCB capacity (amperes)	Wire Size (AWG designation)	(b)Insulated terminal lug (MS Part Number)
1 and below	20	AS25036-103
2 to 6 included	18	AS25036-103
7 to 10 included	16	AS25036-108
11 to 15 included	14	AS25036-108
16 to 20 included	12	AS25036-112
21 to 25 included	10	AS25036-112
26 to 40 included	8	AS25036-115
41 to 50 included	6	AS25036-119
51 to 60 included	6	AS25036-121
61 to 90 included	4	AS25036-124
91 to 120 included	2	AS25036-127
121 to 150 included	0	AS25036-133
151 to 200 included	00	AS25036-136

NOTE: Test wires shall conform to AS22759, AS81044, MIL-DTL-81381, or AS5086. Test terminals shall conform to AS7928. Ammeter: Accuracy within 0.5% at full scale.

(a) For a DUT with nominal amperage ratings between steps of the above Table 1, use the wire of the next large physical wire size.

(b) For Group A or B quality conformance test terminal lead lugs may be spade or electrical spring clamp type provided the electrical resistivity and thermal conductivity are equivalent to AS25036 ring type terminals.

TABLE 2 – SINGLE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX

Tests and Sample 33 Units	Requirement Paragraph	Test Paragraph
Test Group I – 33 sample units		
Examination of product	3.7.1	4.7.1
Dielectric withstanding voltage	3.7.2	4.7.2
Insulation resistance	3.7.3	4.7.3
Minimum limit of ultimate trip	3.7.7	4.7.7.1
Maximum limit of ultimate trip	3.7.7	4.7.7.2
Overload calibration	3.7.7	4.7.7.3
Guillotine-Source A, Circuit 2	3.7.7	4.7.7.6.1
Test Group II – 1 sample unit		
Voltage drop	3.7.19	4.7.19
Temperature/altitude dielectric strength	3.7.2	4.7.2.2
Trip-free calibration	3.7.7	4.7.7.4
Strength of threaded parts	3.7.5	4.7.5
Mechanical cycling (endurance)	3.7.8	4.7.8.3
Operating force	3.7.6	4.7.6
Test Group III – 1 sample unit		
Voltage drop	3.7.19	4.7.19
Reclosing	3.7.10	4.7.10
Overload & arc fault cycling	3.7.9	4.7.9
Vibration	3.7.11	4.7.11
Corrosion	3.7.16	4.7.16
Test Group IV – 1 sample unit		
Ambient effect on calibration	3.7.7	4.7.7.5
Trip-free calibration	3.7.7	4.7.7.4
Acceleration	3.7.13	4.7.13
Sand and dust	3.7.15	4.7.15
Test Group V – 1 sample unit		
Magnetic Effects	3.7.22	4.7.22
Endurance – Inductive Load (ac)	3.7.8	4.7.8.1.1
Operating force	3.7.6	4.7.6
Test Group VI – 1 sample unit		
Endurance – Resistive load (ac)	3.7.8	4.7.8.1.2
Operating force	3.7.6	4.7.6
Test Group VII – 1 sample unit		
Mechanical shock	3.7.12	4.7.12
Moisture resistance	3.7.17	4.7.17
Operating force	3.7.6	4.7.6
Impact force on push button	3.7.4	4.7.4.3
Strength of actuator	3.7.4	4.7.4
Test Group VIII – 1 sample unit		
Interrupting capacity (available current short circuit ac)	3.7.14	4.7.14 Table VII-A
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group IX – 1 sample unit		
Interrupting capacity (available current close-in ac)	3.7.14	4.7.14 Table VII-B
Dielectric withstanding voltage	3.7.2	4.7.2

TABLE 2 – SINGLE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX (CONT.)

Tests and Sample 33 Units	Requirement Paragraph	Test Paragraph
Test Group X – 1 sample unit		
Interrupting capacity (available intermediate current interrupting ac)	3.7.14	4.7.14 Table VII-C
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group XI – 8 sample unit*		
Unwanted Tripping & Operation Inhibition	3.7.7	4.7.7.7
Transit Drop Test	3.7.20	4.7.20
Test Group XII – 1 sample unit		
Interrupting capacity (available current close-in ac)	3.7.14	4.7.14 Table VII-B
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group XIII – 3 sample units		
Strength of actuator	3.7.4	4.7.4
Impact force on push button	3.7.4	4.7.4.3
Test Group XIV – 3 sample unit*		
Reverse Installation	3.7.26	4.7.26
Loose Terminal	3.7.7	4.7.7.6.3
Inductively Coupled Cross Talk Immunity	3.7.7	4.7.7.8
Common Source Feedback Imunity	3.7.7	4.7.7.9
Temperature Pressure Circuit Functionality	3.7.21	4.7.21
Electromagnetic Compatability	3.7.23	4.7.23
Maximum Power	3.7.24	4.7.24
Power Quality	3.7.25	4.7.25
Test Group XV – 2 sample unit*		
Guillotine-Source B, Circuit 2	3.7.7	4.7.7.6.1
Guillotine-Source A, Circuit 1	3.7.7	4.7.7.6.1
Guillotine-Source B, Circuit 1	3.7.7	4.7.7.6.1
Test Group XVI – 2 sample unit		
Wet Arc Source A, Circuit 2	3.7.7	4.7.7.6.2
Wet Arc Source B, Circuit 1	3.7.7	4.7.7.6.2
Test Group XVII – 1 sample unit*		
Interrupt Capacity – Under Loss of Ground (available intermediate current interrupting ac)	3.7.14	4.7.14.1 Table VII-C
Test Group XVIII – 2 sample units		
Explosion (ac)	3.7.18	4.7.18.1
Test Group XIX – 1 sample units*		
Interrupt Capacity – under loss of ground (available current short circuit ac)	3.7.14	4.7.14.1 Table VII-A
Test Group XX – 1 sample unit		
Interrupt capacity – under loss of ground (available current close-in ac)	3.7.14	4.7.14.1 Table VII-B

TABLE 2 – SINGLE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX (CONT.)

Tests and Sample 33 Units	Requirement Paragraph	Test Paragraph
Test Group XXI – extra sample units These AFCBs may be used for repetition of any tests considered advisable by the qualification activity		

TABLE 2A – THREE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX

Tests and Sample Units	Requirement Paragraph	Test Paragraph
Test Group I – 23 sample units		
Examination of product	3.7.1	4.7.1
Dielectric withstanding voltage	3.7.2	4.7.2
Insulation resistance	3.7.3	4.7.3
Minimum limit of ultimate trip	3.7.7	4.7.7.1
Maximum limit of ultimate trip	3.7.7	4.7.7.2
Overload calibration	3.7.7	4.7.7.3
Guillotine-Source A, Circuit 2	3.7.7	4.7.7.6.1
Test Group II – 1 sample unit		
Voltage drop	3.7.19	4.7.19
Temperature/altitude dielectric strength	3.7.2	4.7.2.2
Trip-free calibration	3.7.7	4.7.7.4
Strength of threaded parts	3.7.5	4.7.5
Mechanical cycling (endurance)	3.7.8	4.7.8.3
Operating force	3.7.6	4.7.6
Test Group III – 1 sample unit		
Voltage drop	3.7.19	4.7.19
Reclosing	3.7.10	4.7.10
Overload & arc fault cycling	3.7.9	4.7.9
Vibration	3.7.11	4.7.11
Corrosion	3.7.16	4.7.16
Test Group IV – 1 sample unit		
Ambient effect on calibration	3.7.7	4.7.7.5
Trip-free calibration	3.7.7	4.7.7.4
Acceleration	3.7.13	4.7.13
Sand and dust	3.7.15	4.7.15
Test Group V – 1 sample unit		
Magnetic Effects	3.7.22	4.7.22
Endurance – Inductive Load (ac)	3.7.8	4.7.8.1.1
Operating force	3.7.6	4.7.6
Test Group VI – 1 sample unit		
Endurance – Resistive load (ac)	3.7.8	4.7.8.1.2
Operating force	3.7.6	4.7.6

TABLE 2A – THREE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX (CONT.)

Tests and Sample Units	Requirement Paragraph	Test Paragraph
Test Group VII – 1 sample unit		
Mechanical shock	3.7.12	4.7.12
Moisture resistance	3.7.17	4.7.17
Operating force	3.7.6	4.7.6
Strength of actuator	3.7.4	4.7.4
Impact force on push button	3.7.4	4.7.4.3
Test Group VIII – 1 sample unit		
Interrupting capacity (available current short circuit ac)	3.7.14	4.7.14 Table VII-D
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group IX – 1 sample unit		
Interrupting capacity (available current close-in ac)	3.7.14	4.7.14 Table VII-E
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group X – 1 sample unit		
Interrupting capacity – under loss of ground (available current short circuit ac)	3.7.14	4.7.14 Table VII-D
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group XI – 1 sample unit		
Interrupting capacity – under loss of ground (available current close-in ac)	3.7.14	4.7.14 Table VII-E
Dielectric withstanding voltage	3.7.2	4.7.2
Test Group XII – 8 sample units		
Transit Drop Test	3.7.20	4.7.20
Test Group XIII – 3 sample units		
Unwanted Tripping & Operation Inhibition	3.7.7	4.7.7.7
Test Group XIV – 1 sample unit		
Reverse Installation	3.7.26	4.7.26
Loose Terminal	3.7.7	4.7.7.6.3
Inductively Coupled Cross Talk Immunity	3.7.7	4.7.7.8
Common Source Feedback Immunity	3.7.7	4.7.7.9
Temperature Pressure Circuit Functionality	3.7.21	4.7.21
Electromagnetic Compatibility	3.7.23	4.7.23
Maximum Power	3.7.24	4.7.24
Power Quality	3.7.25	4.7.25
Test Group XV – 1 sample unit		
Guillotine-Source B, Circuit 2	3.7.7	4.7.7.6.1
Guillotine-Source A, Circuit 1	3.7.7	4.7.7.6.1
Guillotine-Source B, Circuit 1	3.7.7	4.7.7.6.1

TABLE 2A – THREE PHASE REQUIREMENTS TEST TRACEABILITY MATRIX (CONT.)

Tests and Sample Units	Requirement Paragraph	Test Paragraph
Test Group XVI – 1 sample unit		
Wet Arc Source A, Circuit 2	3.7.7	4.7.7.6.2
Wet Arc Source B, Circuit 1	3.7.7	4.7.7.6.2

4.5.3 Retention of Qualification

To retain qualification, the manufacturer shall forward at 36 month intervals to the qualifying activity a summary report of the results of Group A and B tests, indicating as a minimum the number of lots which passed and the number of lots which failed, however a complete test report of Group C tests, including the number and type of failures is required by the qualifying activity. The summary shall include those tests performed during the 36-month period. If the summary of the test results indicate nonconformance with the specification requirements, action shall be taken to remove the failing product from the Qualified Products List. Failure to submit the summary shall result in loss of qualification for that product. In addition to the periodic submission of inspection data, the supplier shall immediately notify the qualifying activity, through the local Government representative, at any time during the 36-month period that the inspection data indicates failure of the qualified product to meet the requirements of the specification. In the event that no production occurred during the reporting period, a report shall be submitted certifying that the company still has the capabilities and facilities necessary to produce the item. If there has been no production during the next reporting period the manufacturer may be required by the qualifying activity to perform Group C testing in accordance with 4.6.6.2 on the products.

4.6 Quality Conformance Inspection

4.6.1 Inspection of Product for Delivery

Inspection of product for delivery shall consist of Group A inspection. Except as specified in 4.6.2, delivery of product that has passed Group A inspection shall not be delayed pending results of Group B and C inspection.

4.6.1.1 Inspection Lot

An inspection lot shall consist of all the circuit breakers covered by a single style (see 1.2.1) offered for inspection at one time.

4.6.1.1.1 Group A Inspection

Group A inspection shall consist of the examinations and tests specified in Table 3 and shall be made on the same set of sample units.

4.6.1.1.1.1 Sampling Plan

Statistical sampling and inspection shall be in accordance with MIL-STD-1916 for general inspection Level II. The acceptable quality level (AQL) shall be as specified in Table 3. Critical, major, and minor defects shall be as specified in MIL-STD-1916.

4.6.1.1.1.2 Rejected Lots

If an inspection lot is rejected, the manufacturer may rework it to correct the defective units, and resubmit for reinspection. Resubmitted lots shall be inspected using tightened inspection. Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots.

TABLE 3 - ACCEPTANCE TESTS

Test	Inspection Level	Requirement Paragraph	Test Paragraph	AQL Percent Defective		
				Critical	Major	Minor
Product Examination	II	3.7.1	4.7.1	.25	.65	4.0
Dielectric withstanding Voltage	II	3.7.2	4.7.2	N/A	1.0	N/A
Calibration (overload at Minimum and maximum Limit of ultimate trip and 200% rated current only at room temperature)	II	3.7.7	4.7.7	N/A	1.0	N/A
Guillotine test	II	3.7.7.6.1	4.7.7.6.1	N/A	1.0	N/A

NOTE: At the manufacturer's discretion, equivalent test methods may be used to demonstrate performance to the guillotine test requirements in Table 3 based on demonstration and acceptance of equivalency by the qualifying activity.

4.6.2 Periodic Inspection

Periodic inspection shall consist of Group B and C inspection.

4.6.2.1 Group B Inspection

AFCBs shall be tested as specified in Table 4 in the order shown.

TABLE 4 - GROUP B INSPECTION

Test	Requirement Paragraph	Test Paragraph
Insulation resistance	3.7.3	4.7.3
Trip-free calibration 200% (at room temperature)	3.7.7	4.7.7.4
Operating force (at room temperature)	3.7.6	4.7.6

4.6.2.1.1 Sampling Plan

Three sample units shall be selected at random out of every 1000 units or every three months, whichever occurs first, from each style (1.2.2) manufactured. Group B inspection shall be performed on sample units which have passed Group A inspection, unless the qualification authority considers it more practical to select a separate sample.

4.6.2.1.2 Failures

If one or more sample units fail to pass Group B inspection, the sample shall be considered to have failed.

4.6.2.1.3 Disposition of Sample Units

Sample units that have passed Group B inspection may be delivered against open purchase orders.

4.6.2.2 Group C Inspection

AFCBs shall be tested as specified in Table 5 in the order shown.

TABLE 5 - SAMPLING PLAN C TESTS

Sample Group	Sample No. of Units		Tests	Requirement Paragraph	Test Paragraph
	Single Phase	Three Phase			
1	3	1	Ambient effect on calibration Mechanical cycling (endurance)	3.7.7 3.7.8	4.7.7.5 4.7.8.2
2	3	1	Voltage drop Endurance – Inductive	3.7.19 3.7.8	4.7.19 4.7.8.1.1
3	3	1	Interrupting capacity (1)	3.7.14	4.7.14 Table VII-A
4	3	1	Interrupting capacity (1)	3.7.14	4.7.14 Table VII-B
5	3	1	Strength of threaded parts Strength of actuator Moisture resistance	3.7.5 3.7.4 3.7.17	4.7.5 4.7.4 4.7.17
6	3	1	Reclosing Overload and arc fault cycling	3.7.10 3.7.9	4.7.10 4.7.9
7	3	1	Temperature-altitude Dielectric withstanding voltage Corrosion	3.7.2 3.7.16	4.7.2.2 4.7.16
8	3	1	Unwanted tripping and operation inhibition Loose terminal Wet Arc Souce A Circuit 2 Wet Arc Source B Circuit 1	3.7.7 3.7.7 3.7.7 3.7.7	4.7.7.7 4.7.7.6.3 4.7.7.6.2 4.7.7.6.2
9	3	1	Guillotine Source B Circuit 1	3.7.7	4.7.7.6.1

(1) This test is to be run at one-half of the maximum fault current level specified on the applicable specification sheet for interrupting capacity test designations (A) and (B) or at a level of 500 amperes, whichever is less.

4.6.2.2.1 Sampling Plan

For sampling plan C tests (see Table 5) 27 single phase AFCBs representative of each style (see 1.2.1) and 9 three phase shall be selected at random each year to be tested in the 36 month interval as authorized by the qualifying activity. Sample units that have been subjected to and have passed sampling plans A and B tests shall be used, unless the qualifying activity considers it more practical to select separate sample units.

4.6.2.2.2 Failures

If one or more sample units fails to pass Group C inspection, the sample shall be considered to have failed. The qualifying activity must be notified of the failure immediatley.

4.6.2.2.3 Disposition of Sample Units

Sample units that have been subjected to Group C inspection are considered to have undergone destructive testing and shall not be delivered against any purchase orders.

4.6.2.3 Noncompliance

If a sample fails to pass Group B or C inspection the manufacturer shall take corrective action on the materials or processes, or both, as warranted, and on all units or processes which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials, processes, etc., and which are considered subject to the same failures. Acceptance of the product shall be discontinued until the corrective action; acceptable to the qualifying activity has been taken. After the corrective action has been taken, Group B or C inspection shall be repeated on additional sample units (all inspection, or the inspection which the original sample failed, at the option of the qualifying activity). Group A inspection may be reinstituted; however, final acceptance shall be withheld until the Group B or C reinspection has shown that the corrective action was successful. In the event of a failure after reinspection, information concerning the failure and the corrective action taken shall be furnished to the cognizant inspection activity and the qualifying activity.

4.6.3 Inspection of Preparation for Delivery

Sample packages or packs and the inspection of the preservation, packaging, packing and marking for shipment and storage shall be in accordance with the requirements of Section 5.

4.7 Inspection

4.7.1 Examination of Product

Each AFCB shall be inspected to verify that the materials, design, construction, weight, physical dimensions, marking, and workmanship conform to the applicable requirements.

4.7.2 Dielectric Withstanding Voltage

Each DUT shall be tested in accordance with the following:

a. Magnitude of Test Voltage: 1000 volts (rms) plus twice the maximum rated voltage AC at commercial frequencies (1500 volts (rms) minimum).

b. The potential shall be applied at a maximum rate of increase of 250 volts per second, until the test potential is reached, and shall be maintained for 1 minute during qualification tests.

c. Nature of Potential: AC.

d. Points of Application: Between mutually insulated parts.

NOTE: If the line or load terminal and one or more grounding location(s) on the DUT are electrically interconnected through a solid-state module, they must be shorted together during test.

e. Measurement During Test: The DUT shall show no evidence of breakdown, flashover, or current flow in excess of 1.0 milliamperes.

f. During normal quality conformance tests, a potential equal to 120% of the above values may be applied for a duration of 5 seconds.

4.7.2.1 Dielectric Withstanding Voltage Following Another Test

Where the dielectric withstanding voltage is called for following another test, the dielectric test voltage shall be reduced to 75% of the value specified.

4.7.2.2 Temperature-Altitude Dielectric Withstanding Voltage

Sample units shall be subjected to the dielectric withstanding voltage test in accordance with 4.7.2 at the maximum operating altitude and temperature as defined in this specification, or on the applicable specification sheet. The potential applied shall be 500 volts (rms). The temperature and altitude conditions shall be maintained prior to and during application of the test potential.

4.7.3 Insulation Resistance

Each DUT shall be tested in accordance with Method 302 of MIL-STD-202. The following details shall apply:

a. Test condition letter B

b. Points of measurement – between mutually insulated metal parts

NOTE: If the line or load terminal and one or more grounding location(s) on the DUT are electrically interconnected through a solid-state module, they must be shorted together during test.

4.7.4 Strength of Actuator

The DUT shall be tested per 4.7.4.1 or 4.7.4.2, as applicable, and 4.7.4.3 to meet requirements identified in 3.7.4.

4.7.4.1 Actuating Lever Pivot and Lever Stop Strength

a. The lever pivot and stop shall be subjected to a 25-pound load applied for 1 minute to the tip of the actuating lever, as follows:

b. Perpendicular to the lever axis and parallel to the line of lever travel at each end position of the lever.

c. Same as the condition a., but in both directions perpendicular to the line of travel at each position of the lever.

d. Coaxial with the lever axis toward the lever pivot throughout the entire range of travel of the lever.

e. Coaxial with the lever axis away from the lever pivot throughout the entire range of travel of the lever.

4.7.4.2 Strength of Push Button

4.7.4.3 A 25 pound force shall be applied for 1 minute in both directions, along the line of push button travel. With the push button in the fully extended position, a force of 25 pounds shall be applied at the end of the push button for 1 minute in two mutually perpendicular directions, each normal to the line of push button travel.

4.7.4.4 Impact Force on Push Button

The DUT shall be subjected to an impact force of 3 pounds from a height of 5 inches.

a. With the push button in the closed or reset position, the circuit breaker shall be mounted by its normal mounting means to a rigid panel with the push button in the upright or longitudinal direction. The impact force shall be applied by dropping a 3 pound weight from 5 inches (±0.1 inches) onto the extremity of the push button. The DUT shall receive three impacts.

b. When similarity of the design actuators and latching systems exists, five sample units shall be tested. AFCBs with the highest and lowest ampere ratings must be 2 of the 5 sample units selected to qualify all the other amperage ratings by similarity.

c. During or after the impact tests the DUT shall be tested in accordance with and meet the requirements of 200% overload calibration test requirements at 25 °C of 4.7.7.3, guillotine testing per 4.7.7.6.1, Source A, Circuit 2, and operating forces per 4.7.6; or the DUT may fail in a safe manner. A failsafe AFCB in this application is defined as a circuit breaker with a broken or jammed push button (a jammed push button is a push button exhibiting high pull-out or reset forces in excess of the specification limits) in either the open or closed position with the contacts either in the open position or unable to carry current, or in the closed position capable of being tripped to the open position by a 200% overload condition within the prescribed time limits shown on the applicable specification sheet. A failsafe AFCB must also satisfy the dielectric withstanding voltage test requirements of 4.7.2.1.

4.7.5 Strength of Threaded Parts

Unless otherwise specified, the force levels shown in Table 6 shall be applied to the nuts and screws or bolts for the terminals and mounting means. If terminals are tested with lead lugs, the lugs shall conform to the type described in Table 1.

TABLE 6 - STRENGTH OF THREADED PARTS

Terminals		
Stud or screw Size	Tensile load (pounds)	Torque (inch-pounds)
No. 6	25	10
No. 8	25	15
¼ inch	50	60
5/16	70	80
M4	25	15
M8	70	80
Mounting Means		
Stud or screw Size	Axial loads (pounds)	Torque (inch-pounds)
No. 6	30	10
No. 8	35	20
7/16 inch	N/A	40
15/32 inch	N/A	50
M4	35	20
M12	N/A	50

4.7.5.1 Strength of Terminals

The tensile load as specified in Table 6 shall be applied to each terminal successively, in a direction most likely to cause failure, for a period of 1 minute; then the torque value as specified in Table 6 shall be applied to the screw head about the thread axis for 1 minute.

4.7.5.2 Strength of Mounting Means

The axial load as specified in Table 6 shall be applied for 1 minute after which the specified torque shall be applied to the screw head about the thread axis for 1 minute.

4.7.6 Operating Force

The force shall be applied parallel to the line of travel of the actuator. The forces required for operation of the DUT during or as a result of the tests shall be as specified on the applicable specification sheet. The specified operating force shall be applicable with the DUT at room ambient temperature conditions.

4.7.7 Calibration

Each DUT shall be subjected to calibration tests specified in 4.7.7.1 through 4.7.7.5. Minimum limit of ultimate trip tests (see 4.7.7.1) and maximum limit of ultimate trip tests (see 4.7.7.2) shall be treated as separate tests. Each DUT shall be stabilized at room ambient temperature while carrying no current for a minimum 1 hour before proceeding to the next test. Each section of multiphase AFCB's shall be subjected to the calibration current speciifed with the remaining phase or phases passing no current. Multiphase AFCB's shall also be subjected to tests in which each of the phases is is carrying the specified current simultaneously.

4.7.7.1 Thermal Minimum Limit of Ultimate Trip

The DUT shall be subjected to the minimum limit of ultimate trip current for the time specified on the applicable specification sheet. For qualification tests only, the temperature rise of the DUT terminals shall be measured at the terminals outside but adjacent to the DUT case. The DUT shall be monitored to determine that it does not trip and unless otherwise specified (see 3.1), the temperature rise shall be measured at the terminals for a rise not to exceed 75 °C, or the value specified in the applicable specification sheet. Each phase of the multiphase AFCB shall be tested with each of the phases carrying the current specified in the specification sheet.

4.7.7.2 Thermal Maximum Limit of Ultimate Trip

The DUT shall be subjected to the maximum limit of ultimate trip current for the time specified on the applicable specification sheet and shall be monitored for tripping within the time limits specified. Each phase of the AFCB shall be tested with each of the phases carrying the current specified in the specification sheet.

4.7.7.3 Thermal Overload Calibration

The DUT shall be subjected to the overload calibration shown on the applicable specification sheet, and shall be monitored for operation within the limits specified. Each of the phases of the AFCB shall be tested seperately with the remaining phase or phases carrying zero current.

4.7.7.4 Trip-Free Calibration

The external actuator of the DUT shall be held in the closed position and subjected to the calibration test at maximum ultimate trip current per applicable specification sheet. The test shall be repeated using the values of overload calibration current shown on the applicable specification sheet and arc fault guillotine test method Source A, Circuit 2 per 4.7.7.6.1. The external actuator and a mechanical arc fault trip indicator (if so equipped) shall be held in the closed position for 5 minutes after tripping occurs. When released, the appropriate trip indicator shall be displayed. For a recycling trip-free DUT, the DUT may close momentarily during this waiting period, but subsequent performance shall not be adversely affected. The DUT shall be monitored for automatic tripping within the specified limits and for adverse performance in subsequent testing.

4.7.7.5 Ambient Effect on Thermal Calibration

The DUT shall be tested at the ambient temperatures and loads specified on the applicable specification sheet, and shall be monitored for operation within the time limits specified. Tests shall be performed in chambers with the airflow adjusted to the still air environment specified in 4.7.7.5.1.

4.7.7.5.1 Still Air Environment

Still air environment is the area surrounding the DUT within a given chamber where any reduction in air velocity within the area of the DUT would cause a maximum 2 °C rise in temperature. The still air environment for temperature chambers 4 cubic feet and larger shall be obtained by using the fixture shown on Figure 2. Fixture dimensions are shown on Figures 2, 3, and 4. The test fixture shall be placed in the temperature chamber so that the rear lead port of the fixture is facing away from the direct air flow created by the chamber circulating fan. A typical chamber installation is shown in Figure 5. The distance of the rear lead port from the chamber wall shall be determined by first placing a fully loaded fixture beginning at 1 inch from the chamber wall and performing the minimum limit of ultimate trip test at both temperature extremes. The temperature rise inside the fixture shall be monitored during the test. If the internal temperature exceeds the 2 °C limit, the test shall be stopped and the fixture moved away from the chamber wall in small increments, and the procedure repeated, until the fixture internal temperature maintains the temperature gradient of +2 °C within the area of the fixture. During the performance of all calibration tests, a minimum of 18 inches of lead length shall be kept inside the chamber to cancel any of the effects of heat conduction from the circuit breakers through the leads. Alternate means of obtaining the still air environment must be approved by the Qualifying Activity.

For chambers that are less than 4 cubic feet in volume, the fixture dimensions (stated for the chambers that are 4 cubic feet and larger) can be modified and the DUT quantity that can be tested at one time can be reduced in order to meet the still air requirements.

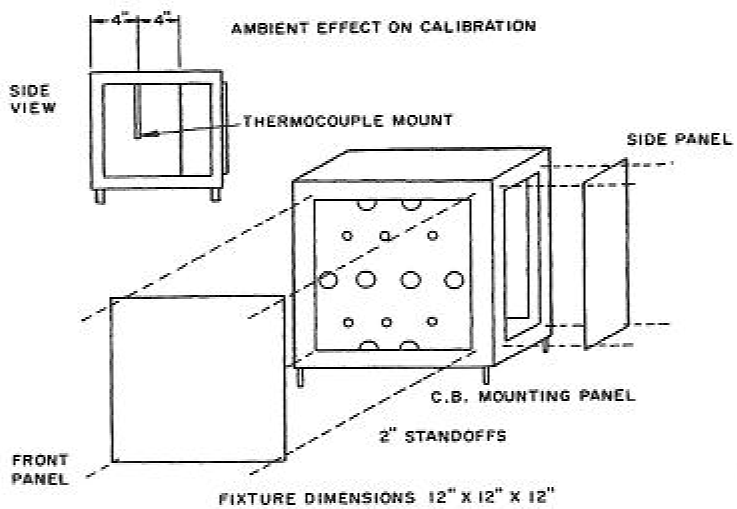

FIGURE 2 - SAMPLE FIXTURE

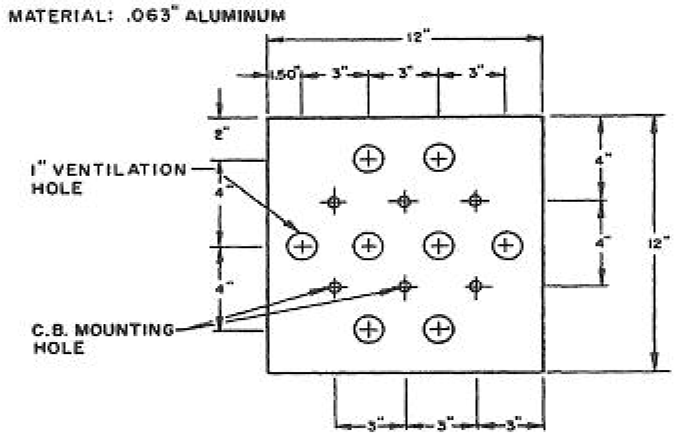

FIGURE 3 - MOUNTING PANEL

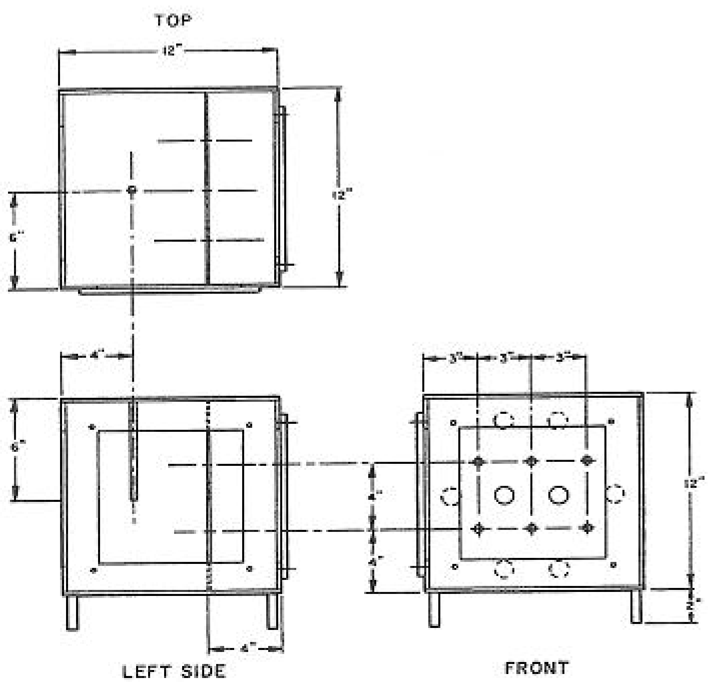

FIGURE 4 - FIXTURE DIMENSIONS

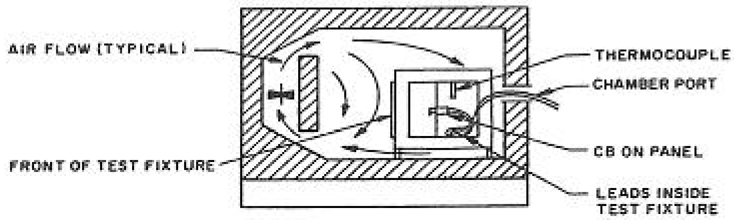

FIGURE 5 - TYPICAL CHAMBER INSTALLATION

4.7.7.6 Arc Fault Detection

All testing is to be conducted with 2 ohms ± 0.1 ohm of resistance between the DUT ground connection and the actual ground reference unless otherwise specified. Each of the phases of the three phase AFCB shall be tested seperately and shall meet the criteria for a single phase AFCB with the remaining two phases connected to power with zero current running through them.

4.7.7.6.1 Guillotine Test

There are two main portions to the set up of the test for guillotine arc testing. The first portion of the set up is targeted towards simulating a range of power sources. The second portion is targeted at simulating different lengths of wire. Each load set up will be run with each source equipment set up, resulting in four tests conducted on each device of each amp rating to be tested.

Two source equipment set-ups will be conducted per Figure 6 below.

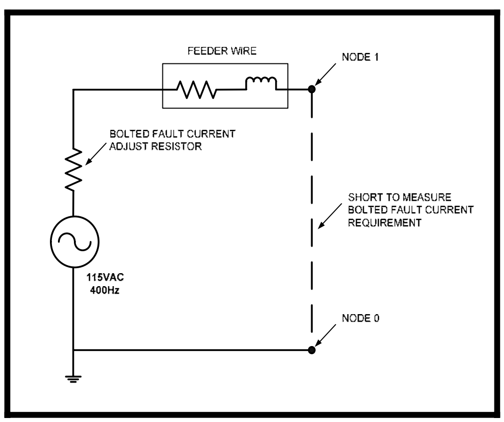

FIGURE 6 - SOURCE SET-UP CIRCUIT

A source equipment set up shall be defined as a combination of a suitable rotary generator, an appropriate length of feeder wire to ease in set up, and an adjustable resistance that will be used to achieve the bolted fault current required by that particular source equipment set up. The bolted fault current shall be measured when connections node 0 & 1 shown in Figure 6 are electrically shorted together. For example, the feeder wire will be physically flexible enough to connect the nodes 0 & 1 together without adding another resistive member. Two source equipment set-ups, Source A and Source B: are required as defined below.

Source A: This source equipment shall be set up to achieve no more than the maximum bolted fault transient current per the Table 7 below:

Source B: This source equipment test shall be set up to achieve no less than the minimum bolted fault sub transient current per Table 7. The bolted fault sub transient current will differ based on the amp rating of the device being tested.

TABLE 7 - BOLTED FAULT TRANSIENT CURRENTS

Circuit Breaker Rating (Amps)	Source A Low Power Generator (maximum transient fault rms current	Source B High Power Generator Sub (minimum sub transient fault rms current)
½ - 10	220	390
11 – 20	330	390
21 – 25	330	2000% ($20I_n$)
26 – 40	440	2000% ($20I_n$)
41 – 60	660	2000% ($20I_n$)

The proper test current shall be determined by the following method.

1. From an oscillograph measurement of the bolted fault, measure the peak-to-peak current of the first or second full cycle.

2. Divide the number attained in method 1 above by 2.

3. Divide the number attained in method 2 above by 1.414 to obtain an rms value of sub-transient fault current. This number should be compared to the required value in Table 7, for the appropriate source set-up.

NOTE: Due to possible DC components in the three phases, the absolute magnitude of sub-transient fault current may exceed the AC rms value. The DC component that causes this increase in absolute current magnitude is not to be considered in the above measurement method.

Load setup: Two load circuit set-ups will be conducted per Figure 7 below.

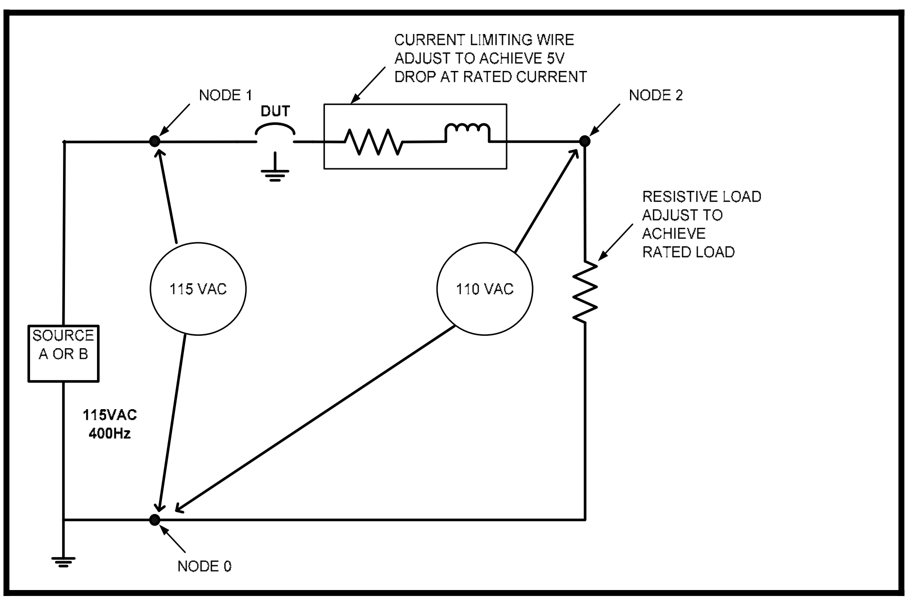

FIGURE 7 - LOAD SET UP CIRCUIT

A load set up shall be defined as a length of AS22759/34, laid out in a non-inductively coupled manner. Two load circuit set-ups, Circuit 1 and Circuit 2, are required as defined below.

Circuit 1: Use 3 feet ± 3 inches of the proper gauge wire for the amp rating of the DUT.

Circuit 2: A wire length of the proper gauge wire for the amp rating of the DUT, or equivalent, that results in a 5 ± ½ volt drop when a resistive load is applied at rated current. For example when open circuit voltage is 115 ± 5 VAC the voltage drop across the resistive load shall be 110 VAC at rated current, see diagram.

The four test combinations required shall be configured in accordance with Figure 8.

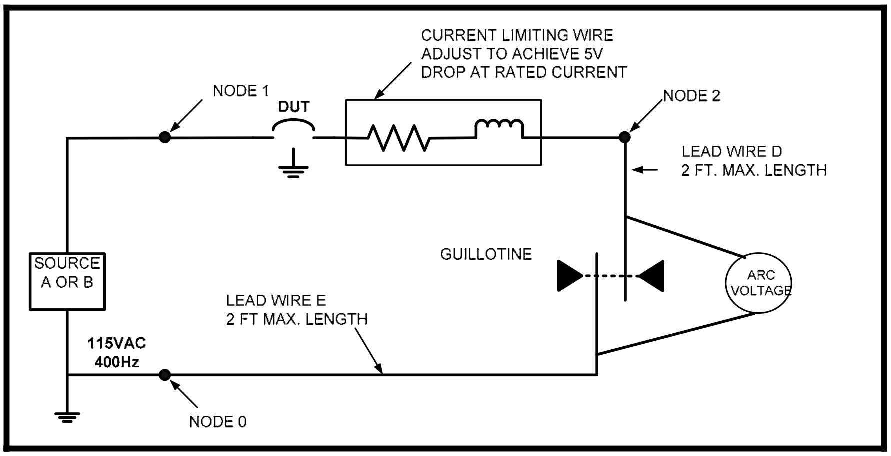

FIGURE 8 - TEST CIRCUIT

The open circuit voltage before application of the fault current shall be 115 ± 5 VAC, or as specified in the applicable specification. Power will be applied to the DUT for a minimum period of 1minute before introducing the fault.

To introduce the fault, a sharp razor blade will be used to cut through the insulation of wire D and E, see Figure 8, and Figure 10. The circuit shall be closed and a slow steady force shall be applied to the lever arm so as to allow the blade to cut through the insulation of the conductor specimen under test. The cutting action should not result in a cut of the conductors.

Records of current, voltage, and time shall be obtained. The DUT shall be subjected to the guillotine tests as specified above unless otherwise specified on the applicable specification sheet and shall clear the fault. After the DUT has been exposed to arcing the records of the test must be evaluated to determine if the DUT identified and reacted to an arc within the requirements of this specification, the applicable specification sheet, and the definition for an arcing half cycle.

Figure 9 below defines the results of the guillotine test once the test record has been analyzed, unless otherwise specified in the applicable specification sheet.

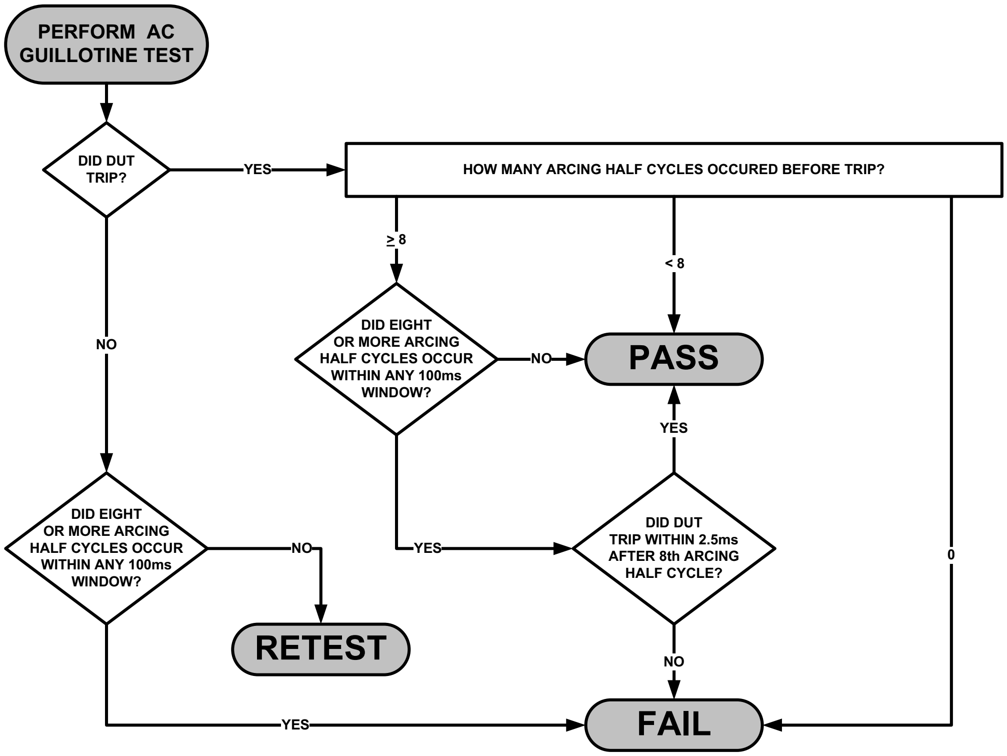

FIGURE 9 - TEST FLOW CHART

Apparatus Example

The test apparatus for the guillotine test can be as shown in Figure 10. A sharp razor blade can be used. The blade shall be replaced as necessary. The blade may be sharpened and reused. The blade shall be attached to a lever arm as shown in Figure 10. The exact dimensions of the tester may vary, however, the required effect must be maintained. As an alternative, a single wire apparatus may be used with the blade of the apparatus at ground and the wire at line voltage. When using the single wire apparatus the blade shall be at frame ground reference within 2.5 milliohms.

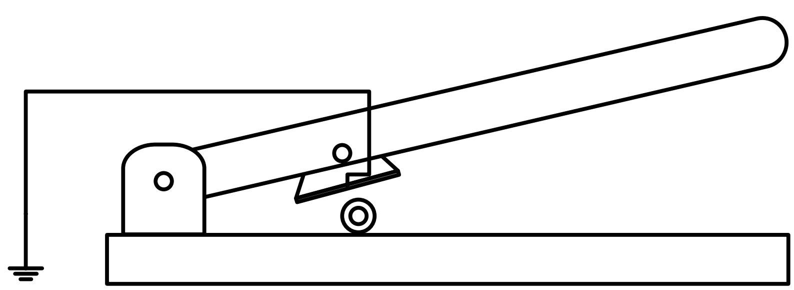

FIGURE 10 -– TWO WIRE GUILLOTINE TEST APPARATUS AND OPTIONAL SINGLE WIRE GUILLOTINE

Definitions Specific to This Test

Arcing Half Cycle: The trace for the actual current and arc voltage must be analyzed to determine if an arcing half cycle has occurred. An arcing half cycle has occurred if the arc voltage is above 15 volts over at least 5% of the time of the half cycle (0.0625 milliseconds for 400 Hz), and current flow is present at or above 1 amp. A complete sinusoidal half cycle of current flow is not considered to be an arcing half cycle.

Arcing Time Duration & Maximum Arcing Half Cycles

The arcing time duration is used to define an arcing event that rises to a level that requires clearing. An arcing event that rises to a level that requires clearing is defined as the accumulation of a number of arcing half cycles that occur within a predetermined period of time. The predetermined period of time is the Arcing Time Duration. The number of arcing half cycles, which must occur before the event is deemed requisite of being cleared, is the Maximum Arcing Half Cycles.

4.7.7.6.2 Wet Arc Track

Simulating a parallel arcing event with a Wet Arc Generation Test Description: This arc fault propagation test is similar to the SAE AS4373 Method 509 Wet arc propagation resistance used for testing wire insulation. For Arc Fault Circuit Interrupters this describes the procedure for simulating a conducting fluid bridging the gap between adjacent damaged wires.

Procedure Overview

The test apparatus for the wet arc track test is derived from SAE AS4373 Method 509 wet arc propagation test. This procedure uses a seven-wire bundle that has been prepared with non-concurrent insulation breaches. Power is applied to selected wires by a three-phase 115 ± 5 VAC 400 Hz source. A continual salt-water drip is used to bridge the gap between the insulation breaches; and the AFCB units shall interrupt the circuit. The DUT should interrupt the circuit prior to the damage propagating from the “prepared/damaged” wires to the other wires in the bundle. The integrity of the other wires in the bundle will be evaluated by using a wet dielectric test. For single phase breakers refer to Figure 12A set up. For three phase breakers refer to Figure 12B, 12C, and 12D set ups. Three test must be run by testing each of the phases of the three phase breaker as shown.

Equipment

1. A variable speed, peristaltic pump and hypodermic needle or burette. The apparatus should be able to deliver the electrolyte solution at a rate of 100 mg ± 10 mg (0.0035 ounces ± 0.00035 ounces) per minute (8 to 10 drops of 3% sodium chloride solution) to the test specimen. An alternative means of delivery is acceptable.

2. A mechanical device for supporting the test bundle in free air in a horizontal position.

3. An electrolyte solution made by dissolving 3% ± 0.5% by weight of sodium chloride (NaCl) in distilled water.

4. A three phase wye connected representative source supply, grounded at wye, derived from rotary machine or solid state power source of not less than the 20 KVA or that required for specific test described in Table 7 and “Source Equipment Set Up” described below, delivering 200 volts ± 10 volts line-to-line at 400 Hz.

5. An AFCB and appropriately sized thermal protective circuit breakers.

6. A-A-52080 through A-A-52084 (Type V) lacing tape, or equivalent.

7. MIL-DTL-81381/11 wire (polyimide insulation) of the appropriate gauge for the DUT sizes listed in Table 1. The conductor samples shall consist of bundles composed of seven wires approximately 8 to 16 inches (20.3 to 40.6 centimeters) in length.

Procedure

1. The conductor bundles shall be prepared as follows. Conduct a 2500 volt Wet Dielectric test on 100% of the wire in accordance with the Wet Dielectric test procedure described in SAE AS4373 Method 510 before the arc-propagation resistance test is performed. Discard any failed sections of the wire.

2. Cut seven wire segments 8 to 16 inches (20.3 to 40.6 centimeters) in length for each of the bundles. Clean the cut wires using a cloth saturated with isopropyl alcohol or similar cleaning solvent. Strip both ends of two of the seven wire segments. Use these stripped ends for making electrical connections. These two wire segments will be called “Active Wires”. The five unstripped wire segments will be called “Passive Wires”.

3. Using a sharp blade, cut a square groove completely around (360°) the insulation of the active wires at their midpoints to expose the conductors. The width of the exposed conductor should be between 0.020 and 0.040 inch (0.5 and 1.0 millimeter).

4. Form the bundle by laying the seven wires segments straight and geometrically parallel. Assemble the wires to form a six-around-one configuration shown in Figure 11. The two pre-damaged wires should be placed in the A1 and B1 position and care should be taken to ensure that there is a longitudinal distance of 0.24 to 0.25 inches (6.0 to 6.5 millimeters) as measured between the stripped windows on the two exposed conductors. The five passive wires correspond to the B2, C1, A2, D1 and D2 components shown in Figure 11.

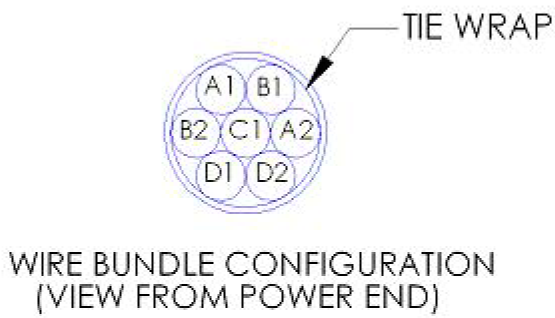

FIGURE 11 - WET ARC TRACKING WIRE BUNDLE

5. Use A-A-52080 through A-A-52084 lacing tapes, or equivalent, to hold the test bundle together. Clean the assembled bundle using a cloth saturated with isopropyl alcohol or similar cleaning solvent prior to installation in the fixture.

6. Connect the test bundle to the power source using the schematic circuit shown in Figure 12. Connect one end of each active wire to the appropriate phase of the power supply as described in Table 8. The source ground will also need to be connected to the DUT in a manner that is suitable to the manufacturer.

7. Typical Test Current is to be set at 1 amp or 15% of the rating of the DUT, whichever is less.

NOTE: Tester may remove power immediately upon opening of the DUT to eliminate further collateral damage to the wires. This will eliminate the chance of current flowing from B1 to load side of A1 through the established arcing track path, then to ground. Any additional flow of current after the DUT trips may cause further damage to A2, B2, C1, D1 and D2 potentially resulting in erroneous test results.

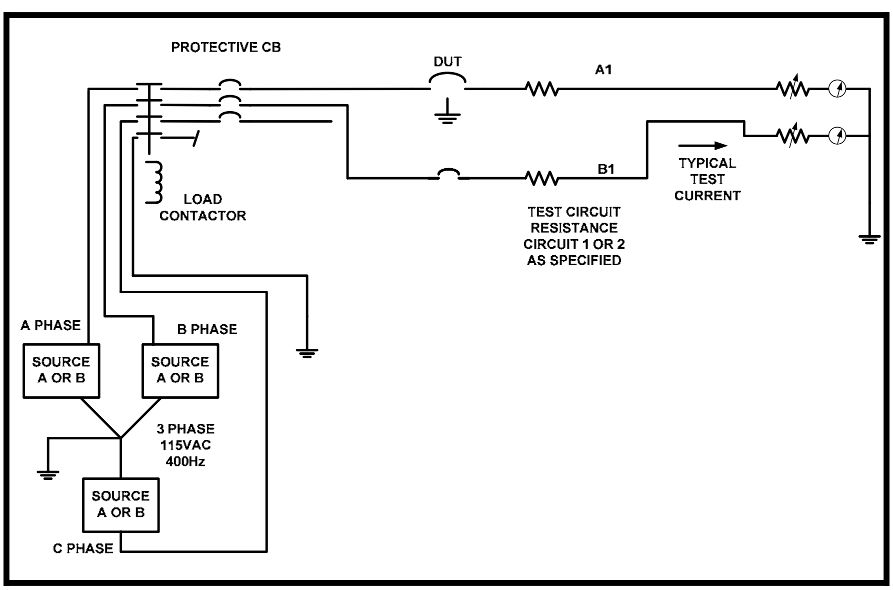

FIGURE 12A – SINGLE PHASE WET ARC TRACK CURRENT PATH

TABLE 8A - CONNECTION TABLE

Wire Identification	Power Supply	Layer
A1	Phase A	Top
B1	Phase B	Top
C1	None	Middle
A2	None	Middle
B2	None	Middle
D1	None	Lowest
D2	None	Lowest

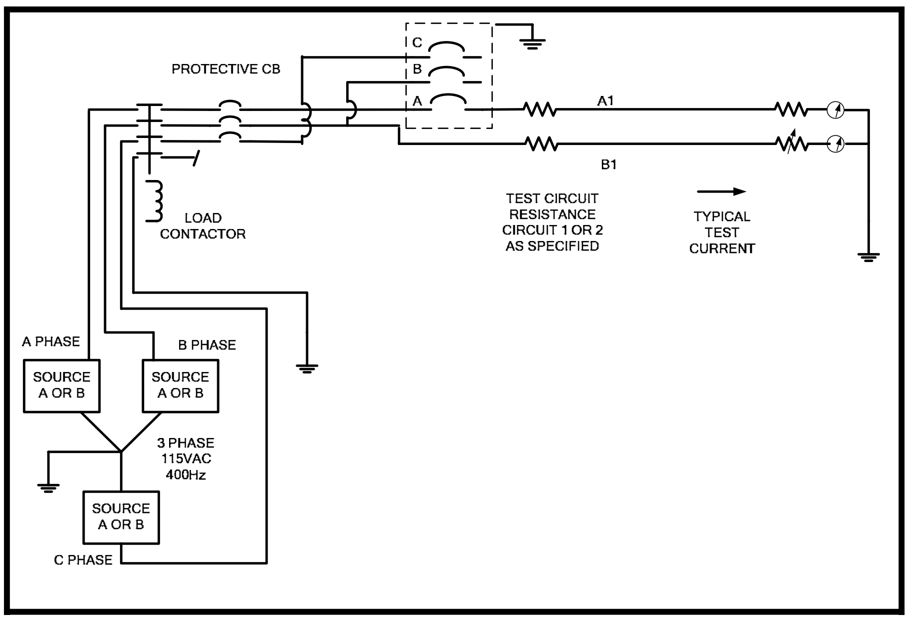

FIGURE 12B – THREE PHASE WET ARC-TRACK CURRENT PATH

TABLE 8B - CONNECTION TABLE

Wire Identification	Power Supply	Layer
A1	Phase A	Top
B1	Phase B	Top
C1	None	Middle
A2	None	Middle
B2	None	Middle
D1	None	Lowest
D2	None	Lowest

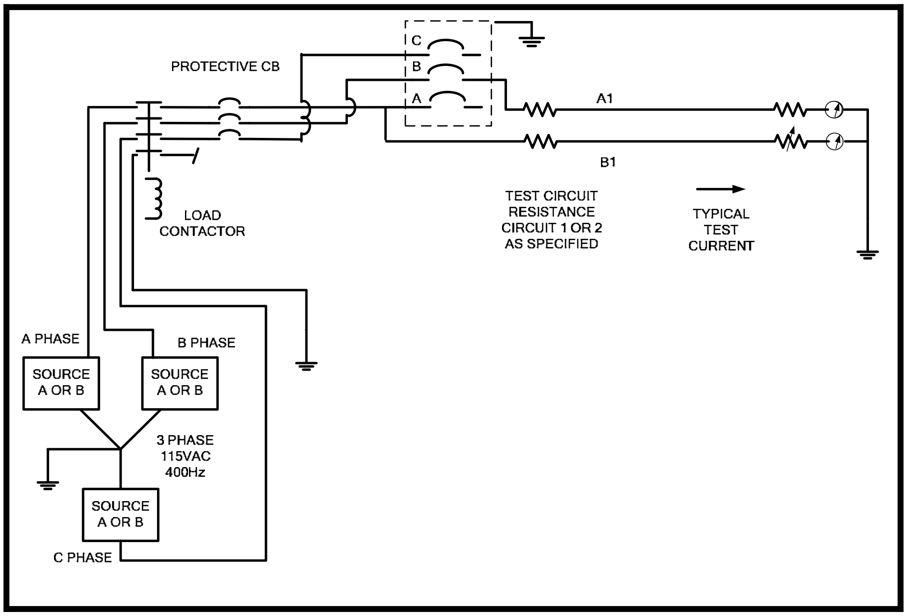

FIGURE 12C – THREE PHASE WET ARC-TRACK CURRENT PATH

TABLE 8C - CONNECTION TABLE

Wire Identification	Power Supply	Layer
A1	Phase B	Top
B1	Phase A	Top
C1	None	Middle
A2	None	Middle
B2	None	Middle
D1	None	Lowes t
D2	None	Lowes t

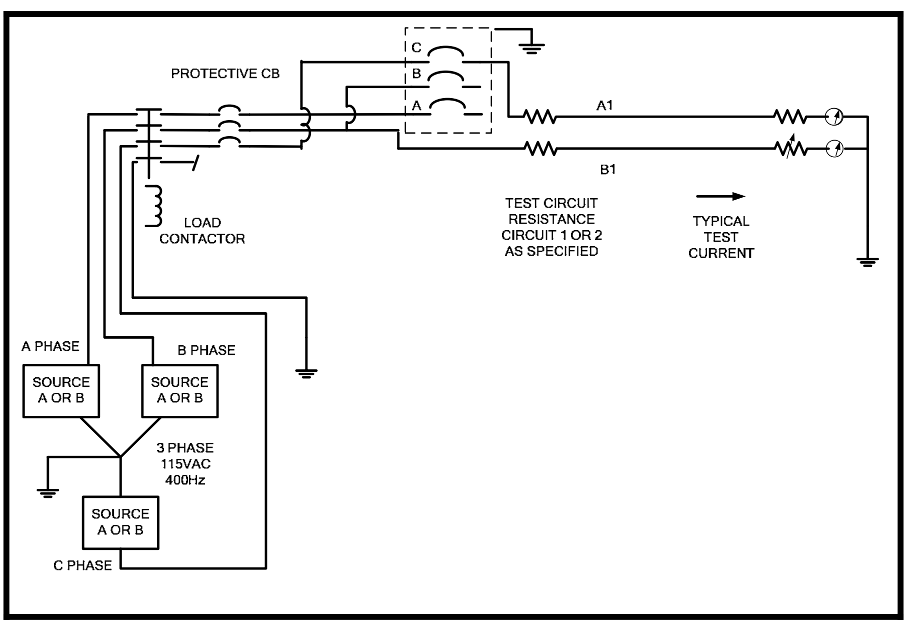

FIGURE 12D – THREE PHASE WET ARC-TRACK CURRENT PATH

TABLE 8D - CONNECTION TABLE

Wire Identification	Power Supply	Layer
A1	Phase C	Top
B1	Phase B	Top
C1	None	Middle
A2	None	Middle
B2	None	Middle
D1	None	Lowes t
D2	None	Lowes t

8. Testing will be conducted under two of the test conditions described in the guillotine test, see 4.7.7.6.1:

   a. Source B & Circuit 1.

   b. Source A & Circuit 2.

9. Use an appropriately rated DUT on A1; the other powered wires will be protected by thermal circuit breakers of the same amp rating or higher amp rating as the DUT, generator kVA and wire length as specified in item 8 above, in making this connection.

10. The test circuit shall be protected with AS58091 qualified or equivalent circuit breakers, (of approximately two times higher rating than the DUT), connected on the supply side of the test setup.

11. The tests shall be conducted at the rated voltage of the DUT and at the test conditions specified in step 7. The test will be conducted three times. Each wire bundle shall only be used for one test.

12. Using the mechanical supports, mount the test bundle in a draft-free location so that the wires with the exposed conductor are upper most.

13. Close all circuit breakers. Set up the flow of the electrolyte to 8 to 10 drops per minute. Position the hypodermic needle to drop the electrolyte into the grove between the wires with the exposed conductor. Position the tip of the needle so that the vertical distance of the tip is 6 inches ± 0.5 inch above the specimen. Position the protective screen to shield the operator from ejecting objects or UV radiation. Apply three-phase 400 Hz power within 1 minute of first electrolyte contact. Allow the electrolyte to flow.

14. Use one of the following conditions to conduct and complete the test.

   a. If the circuit breaker in B1 trips at any time during the test, disconnect the power. Conduct a 1000 volt Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet Dielectric procedure of SAE AS4373 Method 510. If any of these wires fail the wet dielectric test it is considered a DUT failure. If these wires pass, redo the wet arc test with a new wire bundle.

   b. If the DUT trips at any time during the test, disconnect the power. Conduct a 1000 volt Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet Dielectric procedure of SAE AS4373 Method 510. If any of these wires fail the wet dielectric test it is considered a DUT failure. If there is no dielectric breakdown per AS4373 the DUT is considered a pass.

4.7.7.6.2.1 Cold Startup Time Test: Prepare test in accordance with 4.7.7.6.2 Wet Arc Track Test. Run the Wet Arc Track Test in accordance with the procedures, until the sample arc tracks and the DUT opens. Remove power from the line side of all breakers. Continue the solution drip over the wire samples. Close all the breakers. Apply power to the line side of all breakers after at least 5 minutes. The DUT shall open and provide protection in accordance with the requirements of 4.7.7.6.2.

4.7.7.6.3 Intermittent Connection – Vibration Test

Prepare wire jumpers using 12 inch lengths of wire as specified in Table 1 terminated on both ends with the appropriate wire size terminal to achieve a gap measurement 0.020 +/-0.010 inches as shown in Figure 14B. Install one stud into a conductive surface, separate this surface from the shaker table with a nonconductive material. Loop the wire jumper from stud to terminal in the manner shown in Figure 13 producing a series connection from one end of the fixture to the other. Tighten a self-locking nut on the stud only until the locking mechanism on the nut fully engages (this nut is only used to ensure that the wire terminal does not vibrate off the stud). DO NOT TIGHTEN ANY FURTHER. The wire terminal must remain free to vibrate while making intermittent contact with the stud and self locking nut.

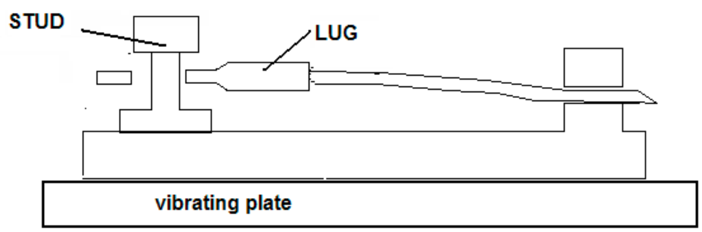

FIGURE 13 - SHAKER TABLE WITH LOOSE TERMINALS

Procedure:

1) Apply a resistive load to the system to ensure that the current is at 80 +-10% of rated current of the DUT and monitor the voltage across stud and lug with a data recorder as shown in Figure 14C.

2) Vibrate the shaker table using the profile defined in Figure 14A.

3) After the shaker has reached the programmed spectral level, apply power to the system and verify current flow and arcing. If arcing is not visible, shut down the shaker table, remove power, reset the wire jumper (ensuring free movement of the wire terminal on the stud), vibrate the shaker table, reapply power, and verify arcing. To minimize further damage to the test fixture, each test shall not exceed 1 minute.

4) Pass/fail criterion: Pass- The DUT must trip within 1 minute after the application of power. If the DUT does not trip within one minute, review the data and check the evaluation criteria.

Evaluation criteria

Series arcing event definition

An arcing event is defined as being an event where the voltage between stud and lug goes above 100 volts for 20% of a half cycle minimum and the rest of the time (with the exception of about 40us before and after the zero cross) between 15 and 60 volts (series arc voltage).

Satisfactory test data includes:

a) at least 10 series arcing events in a 100 msec sliding window (called an arcing period)

b) at least 2 consecutive arcing periods in a 2 second sliding window (called a confirmed arcing period)

c) at least one confirmed arcing period in each 10 sec interval of of the test

The DUT is considered a failure if the three criteria are present in the data and the DUT did not trip in one minute. Should the three criteria not be present the test shall be rerun.

freq	PSD
10	0.012
28	0.012
31	0.012
40	0.012
51.7	0.02
100	0.02
200	0.02
250	0.02
500	0.02
2000	0.00126

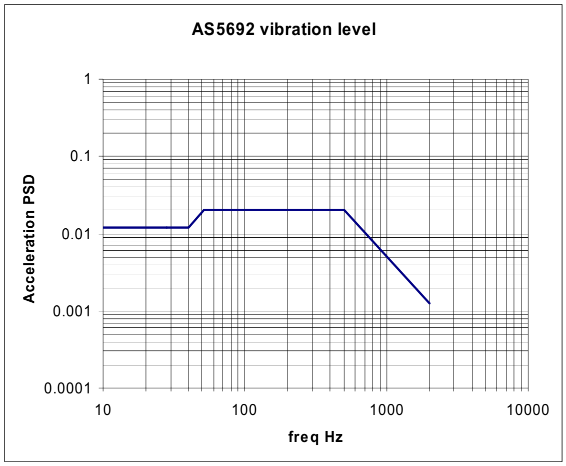

FIGURE 14 A - VIBRATION PROFILE (TOLERANCE IS ±3 DB) - DO160E, CATEGORY R, CURVE C

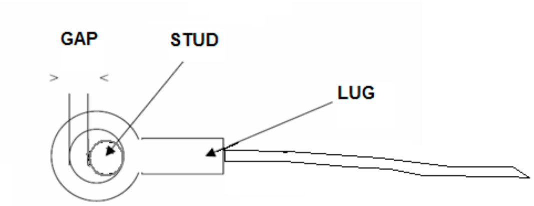

FIGURE 14B – GAP MEASUREMENT

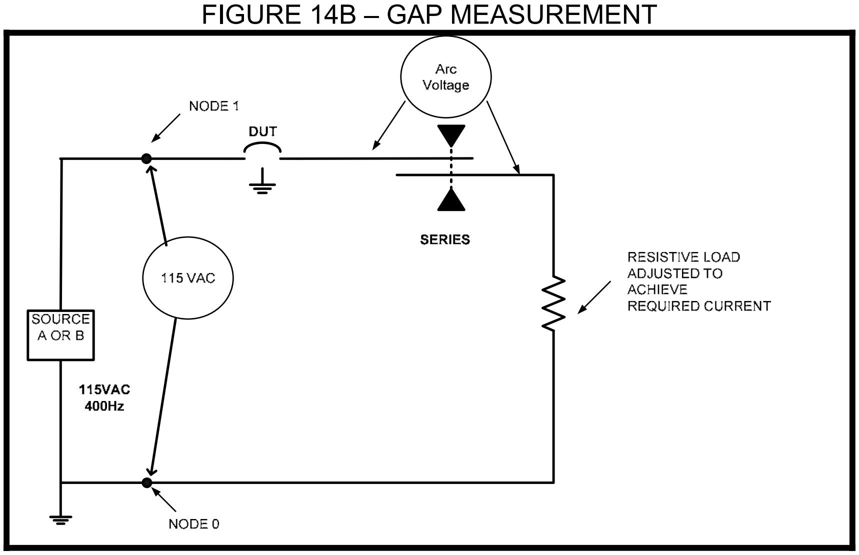

FIGURE 14 C – TEST CIRCUIT

4.7.7.7 Nuisance Tripping and Operation Inhibition

Compatibility of the AFCB with normal; aircraft loads will be demonstrated by conducting testing in accordance with 4.7.7.7.1 or 4.7.7.7.2 or per ARD5568.

Source B generator (refer to 4.7.7.6.1) shall supply power to an AC load, as shown in Figure 15.

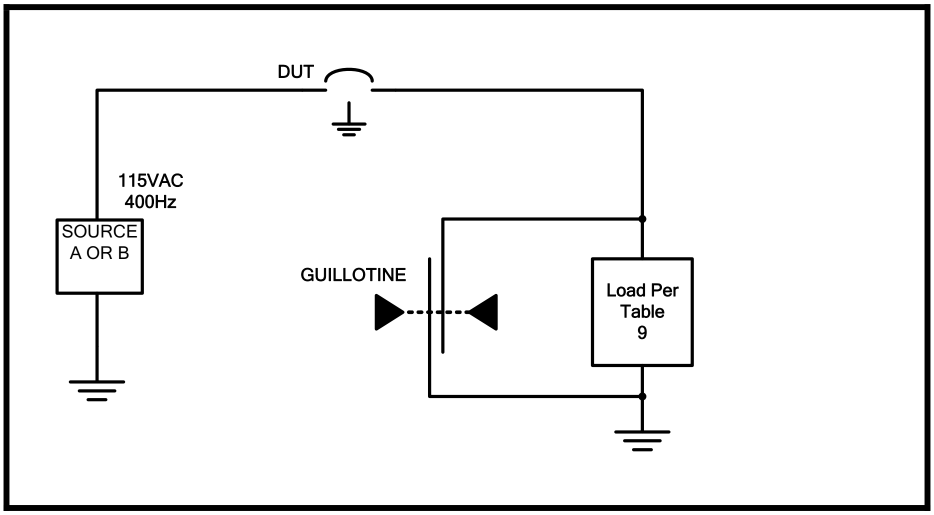

FIGURE 15 - AC LOAD TEST SETUP

4.7.7.7.1 For each load listed in Table 9A, the following tests shall be performed:

a. With the DUT open, energize the system and allow it to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

b. The DUT shall be closed into the load listed in Table 9A and the load shall run for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

c. The load shall then be turned off, or power shall be removed from the load on the load side of the DUT, and the system shall be allowed to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

d. The load shall then be turned on, or power shall be returned to the load on the load side of the DUT, and the system shall be allowed to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

   Loads with multiple settings shall be exposed to each setting.

   Loads with specified turn on sequences shall be exposed to the full turn on sequence at this point during the test.

e. Repeat steps “c” and “d” five times.

f. Perform the guillotine test per 4.7.7.6.1 Circuit 2.

g. The DUT shall meet the requirements specified in 4.7.7.6.1.

TABLE 9A – SINGLE PHASE TEST LOADS

Load Category	Example Load(2)	Amp Ratings	Suggested Manufacturer & Part Number(1)	Load Characterization
Avionics Switching Power Supply	Air Data Computer	2	Honeywell Model HG180	Large inrush, harmonics; (5X <Inrush < 10X / Duration <20 cycles).
Inductive Load – Incandescent	Left Landing Light Auto Transformer/l Landing Lamp	7½	Oeco or Electrocube: p/n 310-13569-01 or FT1140 310-13569-02 GE or Sylvania: p/n Q4559X	Large peak/short duration inrushes; (5X Inrush <10X / Duration < 10 cycles).
Motor load	Pilot Seat or Motorized Foot Rest	5	813500-415 Weber Aircraft Inc.	Large peak/long duration inrushes; (5X < 10X / 1s < Duration < 4s).
Resistive	Auxiliary Pitot Heater	5	Goodrich Sensor Systems: P/n 851CM-2	Periodicity
Resistive - thermostat controlled	Window Heat	5	Honeywell: G1-1-1 (4)	Switching charateristics of of thermostat
Resistive – SCR controlled (window heater)		25	Cox 2915-5 (4)	Switching charateristics of SCR controller Conduction angle shifts
Fluorescent Load	Left Ceiling Light	15-25	Avtech: p/n 978-1 (11 ballast)	Large inrushes, harmonics, random variation in dim settings.
Strobe Lamps	Beacon	2 – 71/2	Grimes p/n 60-3368-7	Periodicity, large inrush, modulation.
Switching power supply/IFE	Computer power supply	15- 25	Powertech Electronic Co., Power Tronic Switching Power Supply PK-6145DT3 (3)	Large inrush, harmonics; (5X <Inrush < 10X / Duration <20 cycles).
Linear actuated valve	Anti-Ice Valve	5	Whittaker Controls: p/n's 127055, 129475, 128775, 229165, 129525	Random inrushes as motors are reversed midstream

(1) Equivalent loads may be used for similarity.
(2) Prior to running the first or subsequent tests the load must be stabilized in a non-energized state.
(3) Six power supplies shall be sequentially turned on within 15 seconds (1-3 seconds between each supply turn on)
(4) Window heater element shall be simulated with 8-12 ohm resistive load

4.7.7.7.2 Three Phase Nuisance Tripping and Operation Inhibition

A three phase source with each phase per Source B generator (refer to 4.7.7.6.1) shall supply power to a three phase AC load , as shown in Figure 16.

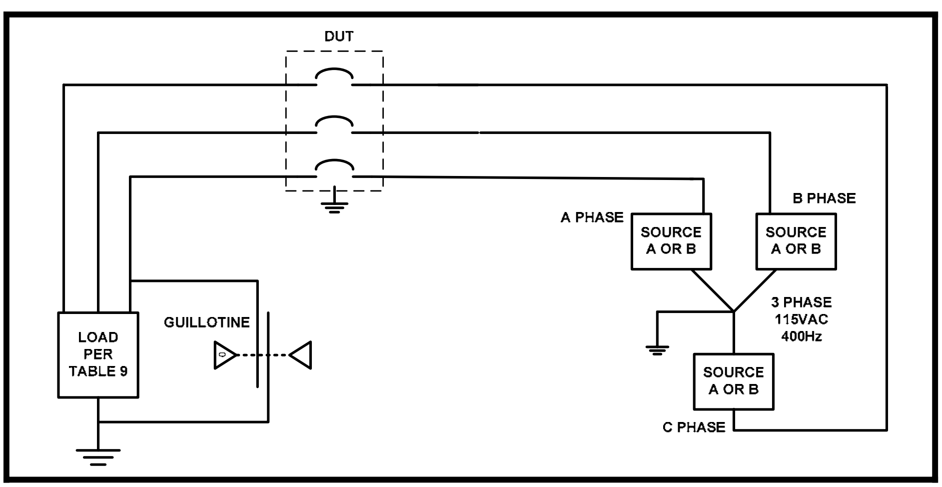

FIGURE 16 – THREE PHASE AC LOAD TEST SETUP

For each load listed in Table 9B, the following tests shall be performed:

a. With the DUT open, energize the system and allow it to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

b. The DUT shall be closed into the three phase load listed in Table 9B and the load shall run for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

c. The load shall then be turned off, or power shall be removed from the load on the load side of the DUT, and the system shall be allowed to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

d. The load shall then be turned on, or power shall be returned to the load on the load side of the DUT, and the system shall be allowed to stabilize for 5 seconds after it reaches a steady state condition, or for a minimum of 30 seconds.

   Loads with multiple settings shall be exposed to each setting.
   Loads with specified turn on sequences shall be exposed to the full turn on sequence at this point during the test.

e. Repeat steps “c” and “d” five times.

f. Perform the guillotine test per 4.7.7.6.1 Circuit 2 for each phase of the DUT, figure 16 shows the diagram for testing phase A only, the guillotine shall be applied to all three phases of the DUT.

g. Each phase of the three phase DUT shall meet the requirements specified in 4.7.7.6.1.

TABLE 9B – THREE PHASE TEST LOADS

Amp Rating	Equipment	Part Number	Supplier	Boeing Reference
5	Door Area Heater	116817-3	Electrofilm Inc	S210W004-5
7.5	Galley Heater	24E508322G01	B.F.Goodrich	S210W004-2
10	Cooling Exchange Fan	4101054	Sundstrand Aerospace	S210N701-38
10	Fuel Boost Pump	5006003C	Sundstrand Aviation	S343T001-14
10	Flap Elec Drive	126762-9	Honeywell Engines Systems	60B80042-37
10	Door Area Heater	2831-37	Cox and Company Inc	--
10	TRU	080-20705-01	OECO LLC	10-3257-6
15	TRU	60B00177-6	Crane Eldec Corp	60B00177-6
15	Flight Control Stab Trim Actuator	10-62233-5	Vickers Electromechanical or Eaton	10-62233-5
15	Recirculation Fan	4100945A	Sundstrand Aerospace	S210W003-5

4.7.7.8 Cross Talk Immunity Test

The DUT shall be designed not to trip as a result of faults on adjacent circuits due to coupling. When tested by the procedure below, the DUT shall not trip at any time. Any trip during the test shall be considered a failure. Wire for use in this testing shall be proper gauge of SAE AS22759/34. Each of the phases of the three phase AFCB shall be tested seperately and shall meet the criteria for a single phase AFCB with the other two phases connected to power with the wire for the phase under test being twisted with the faulted circuit for each test, and the load terminal for the other two phases disconnected.

Sample AFCBs of the highest and lowest rating of each basic product type or family will be tested. They shall be connected between one phase of the generator and a length of 80 feet of wire of the appropriate gauge for the rating of the DUT. The DUT shall be terminated in a resistive load at 85 to 90% of the breaker rating.

A 20 amp or greater thermal-only breaker shall be connected between a second phase of the generator and a capacitor load, C, and to a similar length (80 feet) of #16 AWG wire. The test sequence specified below will be repeated at the following capacitive (C) settings: 0 and 5 µF.

- The two wires are to be twisted together at a spacing of approximately 1 turn per foot.
- The resulting twisted pair is to be mounted during the test so as to be electrically similar to a wire bundle in an airframe.
- Coupling is twisted pair, with one loop, 2 inches ± 0.5 inch from the ground plane, and no less than 4 inches separation between loopbacks.
- The return path to the generator feeder connection should consist of an electrical equivalent to an aluminum airframe or a 6 foot maximum length of wire greater in size than the rated wire.
- The wire gauge shall be selected based on the appropriate CB rating (Table 1) and is to be subjected to three guillotine tests for each breaker rating and capacitive rating for a total of 6 tests per test condition. Refer to figure 17 for circuit schematic.
- The DUT shall not trip in the adjacent circuit for three tests which each produce a minimum arcing of 8 half cycles in 100 ms.
- Except as noted in this test procedure, conduct guillotine test in accordance with 4.7.7.6.1, Source B, Circuit 1.

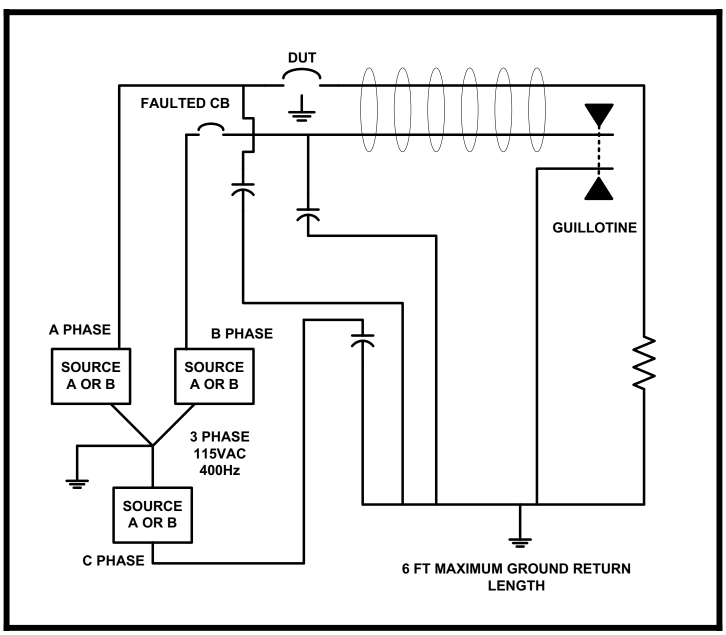

FIGURE 17 - CROSSTALK CIRCUIT DIAGRAM

4.7.7.9 Feedback Immunity Resistance Test

The Guillotine test procedure will be used to generate an arcing fault in a simulated aircraft system to determine if the DUT will inadvertently interrupt a circuit because of an arcing fault on another circuit on the same electrical phase.

Procedure Overview

The DUT shall not nuisance trip as a result of an arcing fault on another circuit on the same phase (both protective devices operating from a common source). Using a setup representative of typical applications, as noted in Figure 18, a guillotine arcing fault will be initiated on a circuit that is not coupled to the circuit protected by the DUT.

The highest and lowest rating of each basic type or family of arc fault circuit interrupter will be tested with a faulted breaker of equal or higher amp rating. Wire for use in this testing shall be the proper gage of SAE AS22759/34 as specified in 4.5.2. Two tests are to be run per condition. In addition, each of the phases of the three phase AFCB shall be tested seperately and shall meet the criteria for a single phase AFCB with the other two phases connected to power, and the load terminal for the other two phases disconnected.

Equipment

1. Guillotine Test Apparatus similar to that described in 4.7.7.6.1.

2. Conductors sized to the DUT will be used as outlined in 4.5.2 (see Table 1). The insulation type will be of SAE AS22759/34. The test circuit shall be connected to a supply that meets the normally accepted levels of performance. The supply shall be maintained at the rated voltage of 115 VAC ± 5 VAC, 400 Hz. The test shall be run at the highest fault current condition (large source with a short added wire length). This is depicted in the “Source Equipment Set up” description in 4.7.7.6.2.

3. A representative load, commonly a light, may be used in the circuit to readily indicate that the test circuit is energized.

4. Two units of the highest and lowest rating of each basic type or family of arc fault circuit interrupter.

5. Faulted breakers of quantity and rating necessary to perform the testing.

6. An oscilloscope or similar data acquisition equipment capable of monitoring the arcing event and analyzing the test results.

Procedure

1. A 115 VAC ± 5 VAC 400 Hz source capable of sourcing the current specified, protected by a circuit breaker, with a current rating larger than either the breaker under test or faulted thermal breaker will be connected to the line side of a DUT. The source ground will also need to be connected to the DUT in a manner that is suitable to the manufacturer.

2. Source B Circuit 1, as defined in 4.7.7.6.1 test conditions will be setup.

3. A resistive load shall be applied to the DUT equal to 85 to 90% of its current rating.

4. Wiring of length and size as specified in 4.7.7.6.1 connected to the load side of the Faulted Breaker shall be subjected to the guillotine test outlined in 4.7.7.6.1.

5. After visible arcing has occurred on the guillotine test for approximately 1 second the test may be terminated. A minimum of 8 half cycles of arcing current within 100 ms shall occur. If less than 8 half cycles of arcing occur, the test will be repeated.

6. The DUT shall not trip. This test shall be conducted a total of three times.

7. Repeat steps 3 to 6 with Source A Circuit 1.

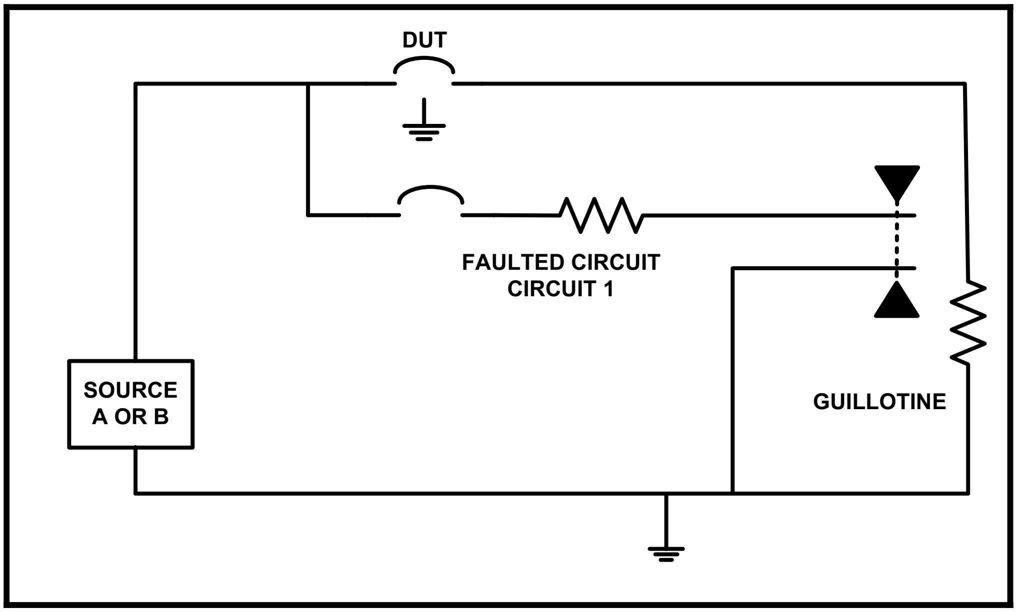

FIGURE 18 - FEEDBACK TEST SCHEMATIC

4.7.8 Endurance

The DUT shall be subjected to the number of cycles of make-and-break operation specified in the applicable specification sheet, and shall make and break the specified current throughout the cycling period. One operating cycle is defined as the mechanical opening and closing of the DUT. At the option of the manufacturer, testing shall be performed at a minimum rate of 2 operating cycles per minute (cpm) or at a faster rate, and the ON time to OFF time ratio shall be approximately 1 to 5. The mechanical operation shall simulate manual operation, including over travel. Each phase of the multiphase AFCB's shall be simultaneously subjected to the required load tests. The test for operating forces shall be performed at the approximate testing midpoint and again at the completion of the test. The DUT shall calibrate within the limits of 90% of the specified minimum ultimate trip current and 110% of the maximum ultimate trip current (see 4.7.7). Upon completion of endurance cycling, the DUT shall pass the dielectric withstanding voltage test (see 4.7.2), guillotine test, per 4.7.7.6.1, Source A, Circuit 2, and end of life voltage drop (only in the instance that a voltage drop specifically designated as an end of life voltage drop is listed on the applicable specification sheet). In addition, the auxiliary switch contact (if present) shall make and break as specified in the applicable specification sheet.

4.7.8.1 Alternating Current

During the alternating current endurance tests defined in 4.7.8.1.1 and 4.7.8.1.2, the voltage and frequency shall be as specified on the applicable specification sheet.

4.7.8.1.1 Inductive Load

The power factor during this test shall be between 0.6 and 0.7 lag unless otherwise specified by the applicable specification sheet. The load shall be the rating of the DUT unless otherwise specified by the applicable specification sheet.

4.7.8.1.2 Resistive Load

Resistive operation shall be accomplished at rated load with a power factor between 0.9 and unity.

4.7.8.2 Mechanical Cycling (no load)

The DUT shall be subjected to the number of cycles of opening and closing specified on the applicable specification sheet. The rate of cycling shall be 6 to 7 cpm.

4.7.9 Overload Cycling

At 200% of rated current resistive load, the DUT shall be subjected to manual make and automatic break applied as follows: The DUT shall be subjected to 50 cycles of normal trip-outs from the closed position and 50 cycles of trip-free trip-outs while the reset actuator is held in the closed position. Three phase AFCB's shall be subjected to 25 cylces of normal tripouts from a balanced three phase overload. Each phase of the AFCB shall then be individually subjected to 25 trip free tripouts. These tests shall be run at a manually controlled cycling rate of 2 to 3 minutes per operation. A single failure to trip automatically within the maximum time limit specified on the applicable specification sheet throughout the test shall constitute DUT failure. Following this test, the DUT shall meet the requirements of the minimum and maximum ultimate trip of 4.7.7.1 and 4.7.7.2. The DUT shall also meet the 200% calibration requirement of 4.7.7.3 at 25 °C, and shall be tested in accordance with and meet the requirements of the guillotine test section 4.7.7.6.1 Source A, Circuit 2 (For three phase AFCB's, each phase must be tested separately).

4.7.9.1 Arc Fault Circuitry Cycling

Using any of the three arc fault tests specified in this document, cycle the DUT through 50 arc fault cycles and 50 trip-free arc fault cycles. Three phase AFCB's shall be subjected to 25 cycles of normal tripouts. Each phase of the AFCB shall then be individually subjected to 25 trip free tripouts. The performance of each device shall be validated by conducting a guillotine test in accordance with 4.7.7.6.1 Source A, Circuit 2 at the completion of the 100 cycles. The DUT shall also meet the 200% calibration requirements of 4.7.7.3 at 25 °C. (For three phase AFCB's, each phase must be tested separately).

4.7.10 Reclosing

Manual reset arc fault circuit breakers shall remain open after being tripped automatically and subjected to the maximum and minimum ambient temperature specified on the applicable specification sheet for 1 hour. Continuity shall be checked with open ground during both of these exposures. This test may be waived by the qualifying authority if the design of the arc fault circuit breaker precludes automatic closing.

4.7.11 Vibration

Each DUT shall be tested in accordance with one or more of the test paragraphs listed below. The following details shall apply for all vibration tests:

a. Mounting: Each DUT shall be mounted as designed in normal application.

b. Electrical Load: Unless otherwise specified, each DUT shall carry rated current load in the (ON) position at room ambient temperature.

c. Measurements: DUT main contacts and auxiliary contacts (if present) shall be continuously monitored by a continuity tester capable of detecting electrical discontinuities of 10 microseconds or less.

d. Post Test Measurements: Following vibration testing, each DUT shall be visually examined for physical damage, then subjected to 200% overload calibration at 25 °C per 4.7.7.3, the dielectric withstanding voltage test per 4.7.2 and the guillotine test using the Source A, Circuit 2 per 4.7.7.6.1.

4.7.11.1 Random Vibration

When listed on the applicable specification sheet, each DUT shall be subjected to random vibration per test method 214 of MIL-STD-202, and/or to other random vibration conditions as specified. Test conditions C through K pertain to vibration levels in test method 214 of MIL-STD-202. Each DUT shall be vibrated 3 hours in each of three perpendicular axes. During the first 1½ hours of vibration in each axis, the circuit breaker shall be monitored for discontinuity. During the remaining time, the circuit breakers shall be monitored for tripping only.

4.7.11.2 Sine Vibration

Each DUT shall be subjected to the vibration test method 204, test condition A, of MIL-STD-202.

4.7.11.3 High Level Sine Vibration

Each DUT shall be subjected to the vibration test Method 204 of MIL-STD-202. The following test conditions shall apply:

a. Test Condition B – No Electrical Load

b. Test Condition C – Rated Electrical Load

4.7.12 Mechanical Shock

Each DUT shall be tested in accordance with Method 213 of MIL-STD-202. The following details and exceptions shall apply:

a. Mounting – by normal means.

b. Test Condition Letter A, or as specified on specification sheet.

c. Electrical load conditions.

Three separate shocks shall be applied to each of the three principle axes with the DUT contacts in the closed position, and three separate shocks shall be applied to each of the axes with the DUT contacts in the open position. All sections of the DUT shall be carrying rated current. A device capable of detecting momentary opening or closing periods not exceeding ½ (0.5) millisecond duration shall be used to determine that the DUT contacts in the closed position remain closed, and the circuit breaker contacts in the open position remain open.

4.7.13 Acceleration

The DUT shall be mounted by its normal means on a centrifuge in a position most likely to cause malfunctioning. The centrifuge shall be brought up to the radial speed required to produce a radial acceleration of 10 g. The rates of centrifuge acceleration and deceleration shall be controlled so that the vector components (radial and tangential) or their vector sum do not exceed 10 g. Once the specified radial acceleration is obtained, it shall be stabilized and maintained for a period of not less than 1 minute. All phases of the DUT shall be carrying rated current during, and for 30 minutes prior, to test. The test shall be repeated with the DUT contacts in the open position. Suitable instrumentation shall be used to determine the ability of the DUT contacts to remain in the open position. There shall be no opening or closing of contacts and there shall be no damage caused by acceleration.

4.7.14 Interrupting Capacity

For the interrupting capacity tests, the circuit breaker shall be so connected to the power source that currents specified on the applicable specification sheet are provided at the circuit breaker terminals. The test circuit of Figure 19 may be used. The open circuit voltage before application of the interrupting current shall be as specified on the applicable specification sheet. The open circuit recovery voltage shall be the value specified on the applicable specification sheet. Records of current, voltage, and time shall be obtained. The DUT shall be subjected to the interrupting capacity tests of Table 10 as specified on the applicable specification sheet, and shall close on and open with the interrupting currents and voltages specified. When the specification sheet lists multiple current levels under test condition "C", tests shall be conducted consecutively at listed current levels "a" then "b", then "c", in accordance with the applicable specification sheet. After each interruption, the open circuit voltage specified by the applicable specification sheet shall be maintained across the circuit breaker for a minimum of 5 seconds. There shall be sufficient time to permit proper cooling and reset between each cycle of operation. Failure of the DUT to reset after 10 minutes shall be cause for rejection unless it meets the requirements of fail-safe condition. Interrupting tests shall not be repeated within 5 minutes of the previous test. Each phase of a multiphase AFCB in turn shall be subjected to this test while the other phase or phases are carrying rated current. For multiphase AFCB'S, one operation shall be performed for each test altitude specified. Upon completion, the DUT shall again be subjected to this test while each of the phases is simultaneously carring 60 +10/-0 percent of the single phase fault current specified on the applicable AS or specification sheet.

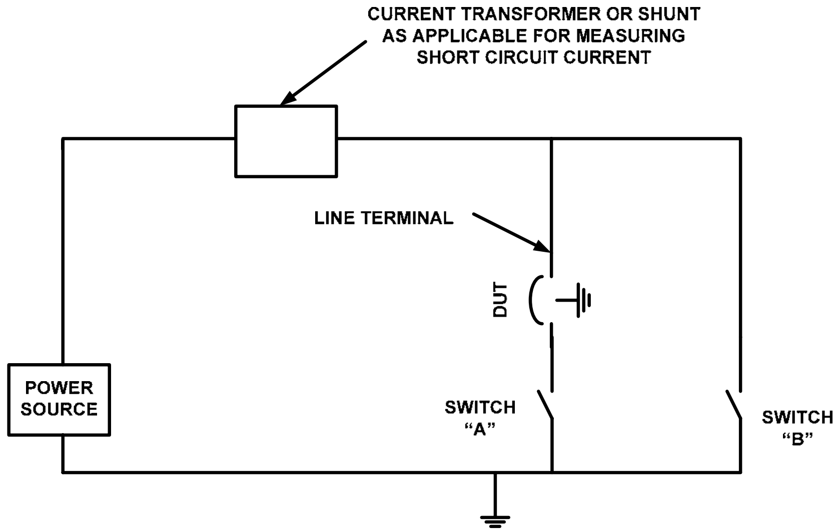

FIGURE 19 - TEST CIRCUIT

AC SHORT CIRCUIT INTERRUPT TEST

1. Open DUT and switch “A”.

2. Close switch “B” and adjust current in accordance with applicable AS requirement.

3. Open switch “B”.

4. Close DUT.

5. Close switch “A”.

AC CLOSE-IN INTERRUPT TEST

1. Open DUT and switch “A”.

2. Close switch “”B” and adjust current in accordance with applicable AS requirement.

3. Open switch “B”.

4. Close switch “A”.

5. Close DUT.

Interrupting current shall be measured by a current transformers or shunt as indicted and suitable recording instrument. The voltage across the DUT shall be recorded simultaneously with interrupting current and at the point indicated.

TABLE 10 - INTERRUPTING CAPACITY TESTS

Test Desig-Nation	Test Description	Operations[1]	System	Open Circuit Voltage	Calibrated Fault Current Amperes	Transient rms Voltage After Calibrated Fault Current Interruption
A	Available current short circuit interruption (ac)	2 CO[2] SL 2 CO Alt	"Y" connected 400 Hz 115 +/-5 / 200 +/-10 volts	120+5	Current specified on applicable specification sheet in 10 to 25 cycles after fault initiation	120 within 3 cycles 150 within 6 cycles 165 maximum
B	Available current close-in interrup-tion (ac)	2 OCO[3] SL 2 OCO Alt				
C	Available inter-mediate current interruption	1 CO Alt 1 OCO SL For each value of current specified on applicable AS			Current as specified on applicable specification	
D	Available current short circuit interruption (ac) for 3-phase circuit breakers only	1 CO SL 1OCO ALT	"Y" connected 400 Hz 115 +/-5 / 200 +/-10 volts	Single phase 120+5	Current as specified on applicable specification	120 within 3 cycles 150 within 6 cycles 165 maximum
		1 CO SL 1OCO ALT		3-phase 205+5		205 within 3 cycles 255 within 6 cycles 280 maximum
E	Available current close-in interrup-tion (ac) for 3-phase circuit breakers only	1 CO SL 1OCO ALT		Single phase 120+5		120 within 3 cycles 150 within 6 cycles 165 maximum
		1 CO SL 1OCO ALT		3-phase 205+5		205 within 3 cycles 255 within 6 cycles 280 maximum

Alt = Altitude   SL = Sea Level

(1) Current and maximum operating altitude are specified on applicable specification sheet.
(2) CO is an operation in which the circuit breaker is closed before initiation of the fault.
(3) OCO is an operation in which the fault is initiated, and the DUT is closed to complete the fault.

4.7.14.1 Interrupt Capacity – Under Loss of Ground

All of the testing requirements of 4.7.14 and the applicable specification sheet shall be performed with the ground connection for the detection circuit disconnected, to preclude the arc fault detection and actuation mechanisms from assisting the DUT to clear the short circuit current.

4.7.15 Sand and Dust

While in the closed (ON) position and mounted on a dummy panel, the DUT shall be subjected to the sand and dust test, Method 110, Test Condition A, of MIL-STD-202 with no evidence of mechanical or electrical failure.

4.7.16 Corrosion

Each DUT shall be mounted in the closed (ON) position with all hardware shown on the applicable specification sheet, and installed finger tight. Each DUT should be mounted such that DUT mounting orientations higher on the panel do not adversely affect any DUT mounted below them (i.e., dripping or concentrating the salt solution on any DUT resulting in these samples being subjected to a more severe test condition than specified). Each DUT shall be subjected to the salt spray test Method 101, Test Condition B, of MIL-STD-202 with a 5% salt solution. Within 10 minutes after the test, each DUT shall be washed for 5 minutes under running water not warmer than 37.8 °C accompanied by a slight brushing, and dried for 6 hours in a forced draft oven at approximately 57 °C.

4.7.17 Moisture Resistance

Three AFCBs shall be mounted in the closed (ON) position with all hardware shown on the applicable AS or specification sheet installed finger tight. The three DUTs shall be designated as test sample units 1, 2 and 3, and subjected to the moisture resistance test of Method 106 of MIL-STD-202, except that no vibration is required during step 7b, and distilled, demineralized, or deionized water having a pH of between 6.5 and 7.2 at 25 °C shall be used to obtain the desired humidity. Prior to subjecting sample units 2 and 3 to this test, the contact resistance of each sample unit shall be determined as specified in 4.7.17.1. Before, during and after the moisture resistance test, the contacts shall be maintained in the closed position. On removal from the chamber, each DUT shall be manually shaken to remove excess water and then permitted to stabilize at room temperature for 45 minutes. The following operations shall be performed on the three sample units as indicated:

For sample unit 1:

a. Conduct a normal trip test with 500% rated load on each phase separately with the remaining phase or phases carrying zero current. Failure to trip within 10 seconds shall constitute failure.

b. Stabilize for 1 hour at room temperature.

c. Conduct a trip-free test with 300% rated load on each phase separately, with the remaining phases carrying zero current .

d. Stabilize for 2 hours at room temperature.

e. Conduct the specified overload calibration trip test of 4.7.7.3 with 200% rated load on each phase separately with the remaining phase or phases carrying zero current except that the tripping time may vary within ±10% of the specified limits.

f. Stabilize for 4 hours at room temperature.

g. Conduct the dielectric withstanding voltage test of 4.7.2. The DUT must pass this test and shall show no evidence of breaking, cracking, spalling, excessive corrosion, or loosening of terminals. All hardware shall be removable without damage.

h. The DUT shall then be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1 Source A, Circuit 2.

For sample units 2 and 3:

Without disturbing the contacts, the samples shall be subjected to the storage test (4.7.17.2).

4.7.17.1 Contact Resistance

The purpose of this test is to establish a level of contact resistance before and after the tests on moisture resistance (4.7.17) and storage (4.7.17.2). No specific absolute value of contact resistance is required. The parameter desired is comparison of contact resistance before and after 4.7.17 and 4.7.17.2. The DUT contacts (sample units 2 and 3) shall be manually operated to successfully interrupt and make a test circuit having a dc resistance load on one-half the current rating (0.5 In) on the circuit breaker or 200 milliamperes, whichever is less, at 26 volts ± 2 volts. The contact resistance (specified as millivolt drop) shall be computed by averaging the results of ten measurements. Each measurement shall be taken after a consecutive contact closure. All measurements shall be made across the DUT external electrical terminals.

4.7.17.2 Storage Test

Within 24 hours of completing prior applicable tests, each DUT shall then be stored, in an area free from chemicals that give off vapors known to be reactive with metals, for 10 days at a minimum temperature of 20 °C and a relative humidity of not less than 40%. Throughout the above test, DUT contacts shall be maintained in the closed position. Upon completion of 10 days, each DUT shall be subjected to the contact resistance 4.7.17.1. The contact resistance shall not exceed the initial contact resistance by more than 250 millivolts. All measurements shall be made across the DUT external electrical terminals. Each DUT shall be submitted to and pass the test requirements for calibration at room ambient with 200% rated current, except that the tripping time shall be within 80% of the lower limit and 120% of the upper limit specified. All hardware shall be removable without damage. The DUT shall then be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1 Source A, Circuit 2.

4.7.18 Explosion

The DUT shall be subjected to explosion test, Method 109 of MIL-STD-202, except that the test shall be conducted only at sea level. Each DUT shall be subjected to operations required for the interrupting capacity tests of Table 10 unless otherwise specified in the applicable slash sheet. One sample unit shall be subjected to test A and one sample unit to test C.

4.7.19 Voltage Drop

The voltage drop of the DUT from terminal to terminal shall be measured while subjected to rated current. This test shall be performed after the DUT has been carrying its rated current for at least 30 minutes.

4.7.20 Transit Drop

The intent of this test is to determine the structural and functional integrity of the DUT to a transit drop. All packaging shall be removed from the DUT during transit drop tests. Perform all tests with the drop tester (see Figure 20), or equivalent set up as approved by the qualifying activity. A total of eight units will be subjected to three random drops per unit. Each drop will be from a height of 48 inches ± 3 inches onto a concrete surface. DUT toppling following impact will occur in the field, therefore, DUT toppling following initial impact should not be restrained as long as the DUT does not leave the required drop surface. All drops will be performed at room ambient temperature unless otherwise specified.

The following steps will be performed, at 25 °C: Perform a visual inspection of each unit and record.

Place the eight AFCB’s onto the drop tester. The units shall be set in random directions, and on random faces, and be evenly spaced along the edge of the drop tester.

Raise the drop tester and allow the AFCB’s to drop onto the concrete surface.

Repeat steps 1 to 3 for an additional two drops.

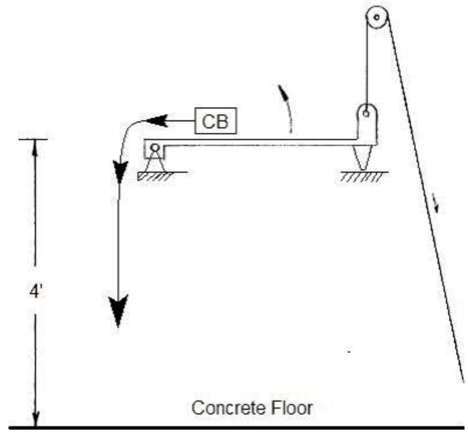

FIGURE 20 - DROP TEST SET UP

4.7.21 Temperature/Pressure Circuit Functionality

4.7.21.1 Temperature Circuit Survivability

The DUT shall be tested in accordance with RTCA/DO-160 Section 4.0 paragraphs 4.5.1, 4.5.2, 4.5.3, and 4.5.4 Category E1. The DUT shall carry the minimum limit of ultimate trip current at 71 °C, for testing at the operating high temperature, paragraph 4.5.4. The test shall be modified to include a short-time operating high temperature of 85 °C, and operating high temperature of 71 °C. At the end of each operating cycle, the DUT shall be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1, Source A, Circuit 2.

4.7.21.2 Altitude

The DUT shall be subjected to the altitude test in accordance with RTCA/DO-160 Section 4.0 paragraph 4.6.1 Category E1. At the end of each operating cycle the DUT shall be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1, Source A, Circuit 2.

4.7.21.3 Decompression

The DUT shall be subjected to the decompression test in accordance with RTCA/DO-160 Section 4.0 paragraph 4.6.2, Category A1. At the end of each operating cycle the DUT shall be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1, Source A, Circuit 2.

4.7.21.4 Overpressure

The DUT shall be subjected to the overpressure test in accordance with RTCA/DO-160 Section 4.0 paragraphs 4.6.3, Category A1 with the additional requirement to conduct the testing with the circuit breaker operating. At the end of each operating cycle the DUT shall be tested in accordance with and meet the requirements of the guillotine test per 4.7.7.6.1, Source A, Circuit 2.

4.7.22 Magnetic Effects

The DUT shall be subjected to the magnetic effects test in accordance with RTCA/DO-160 Section 15.0 Category Z.

4.7.23 Electromagnetic Compatibility

The DUT shall be tested under resistive load, under no load condition, and then again at 85% to 90% of rated current.

4.7.23.1 Audio Frequency Conducted Susceptibility

The DUT shall be subjected to the audio frequency conducted susceptibility test in accordance with RTCA/DO-160 Section 18.0 Category A (CF) or as specified in the specification sheet.

4.7.23.2 Induced Signal Susceptibility

The DUT shall be subjected to the induced signal susceptibility test in accordance with RTCA/DO-160 Section 19.0 Category C or as specified in the specification sheet.

4.7.23.3 Radio Frequency Susceptibility

The DUT shall be subjected to the radio frequency susceptibility test in accordance with RTCA/DO-160 Section 20.0 Category W and R (radiated susceptibility pulse test) or as specified in the specification sheet.

4.7.23.4 Emission of Radio Frequency Energy

The DUT shall be subjected to the emission of radio frequency energy test in accordance with RTCA/DO-160 Section 21.0 Category M or as specified in the specification sheet.

4.7.23.5 Lightning Induced Transient Susceptibility

The DUT shall be subjected to the lightning induced transient susceptibility test in accordance with RTCA/DO-160 Section 22.0 Category XXG33 as specified in the specification sheet.

4.7.23.6 Electrostatic Discharge

The DUT shall be subjected to the electrostatic discharge test in accordance with RTCA/DO-160 Section 25.0 Category A or as specified in the specification sheet.

4.7.24 Maximum Power

4.7.24.1 Quiescent Power During Normal Operation

With the DUT in the open position and stabilized at 25 °C ambient temperature, apply the specified voltage per the specification sheet after 5 minutes measure the current to the ground connection. Close the circuit breaker on rated current and measure current to ground connection after 30 minutes at rated current. Utilizing this current and voltage information measure the real power dissipation. It shall not exceed 1.2 watts, or as specified in the specification sheet.

4.7.24.2 Current Value and Duration During Arc Fault Trip

With the DUT stabilized at 25 °C ambient temperature and at 100% rated current conditions for 30 minutes, the quiescent current through the DUT shall be measured. The DUT shall be subjected to the guillotine test per 4.7.7.6.1 Source A Circuit 2 and the current drawn through the ground connection shall not exceed 3.5 A peak current or the requirements of the specification sheet. The duration of the increase above the quiescent current to the ground connection shall not exceed 50 ms unless otherwise specified in the specification sheet.

4.7.25 Power Quality

4.7.25.1 Power Input

The DUT shall be subjected to the ac power input tests in accordance with MIL-STD-704A (the requirements of Rev.A of MIL-STD-704 must be met), or as specified in the specification sheet.

4.7.25.2 Voltage Spike

The DUT shall be subjected to the voltage spike test in accordance with RTCA/DO-160 Section 17.0 Category A or as specified in the specification sheet. The DUT shall not trip or otherwise malfunction. Following signal injection, but prior to first removal of power, each DUT must be subjected to and meet the requirements of the guillotine test per 4.7.7.6.1, Source A, Circuit 2. The DUT shall also meet the calibration test requirements for 200% overload at 25 °C, as specified in section 4.7.7.3.

4.7.26 Reverse Installation

The DUT must satisfy one of the following three performance criteria:

1. The DUT shall provide full functionality in a bi-directional fashion for both thermal and arc fault protection functions. This shall be verified through performance of the following tests:

    a. Connect the DUT with line power supplied to the load terminal; perform a 200% overload test in accordance with 4.7.7.3, the DUT shall meet all performance requirements of this test.

    b. Perform a guillotine test in accordance with 4.7.7.6.1, Source A, Circuit 2, the DUT shall meet all performance requirements of this test.

    c. Connect the DUT with line power supplied to the line terminal (reversing the connections); perform a 200% overload test in accordance with 4.7.7.3, the DUT shall meet all performance requirements of this test.

    d. Perform a guillotine test in accordance with 4.7.7.6.1, Source A, Circuit 2, the DUT shall meet all performance requirements of this test.

2. The DUT shall provide full functionality in a bi-directional fashion for the thermal protection function, and a visible indication of an inactive arc fault protection function per the specification sheet, if installed incorrectly. This visible indication can be satisfied with coding (as defined in the specification sheet) as well as with a more active method. This shall be verified through performance of the following tests:

    a. Connect the DUT with line power supplied to the load terminal; perform a 200% overload test in accordance with 4.7.7.3, the DUT shall meet all performance requirements of that test. Subject the DUT to an arc fault condition per 4.7.7.6.1, Source A, Circuit 2. The DUT must experience a minimum of 8 half cycles of arcing within a 100 ms window, per 4.7.7.6.1, however, it is not required that the DUT clear the fault. In the case where the DUT does not experience a minimum of 8 half cycles of arcing within a 100 ms window, the DUT shall be retested until 8 half cycles of arcing are achieved within a 100 ms window.

    b. Connect the DUT with line power supplied to the line terminal (reversing the connections); perform a 200% overload test in accordance with 4.7.7.3, the DUT shall meet all performance requirements of this test.

    c. Perform a guillotine test in accordance with 4.7.7.6.1, Source A, Circuit 2, the DUT shall meet all the requirements of 4.7.7.6.1.

3. The DUT shall open on reverse power application. This shall be verified through performance of the following tests:

    a. Connect the DUT with line power supplied to the load terminal, apply 115 VAC and the DUT shall open.

    b. Connect the DUT with line power supplied to the line terminal (reversing the connections); perform a 200% overload test in accordance with 4.7.7.3, the DUT shall meet all performance requirements of this test.

    c. Perform a guillotine test in accordance with 4.7.7.6.1, the DUT shall meet all performance requirements of this test.

5. PREPARATION FOR DELIVERY

Preservation, Packaging, Packing and Marking: AFCBs shall be preserved and packaged in accordance with Level A or C of MIL-E-17555 (no commercial equivalent), as specified. They shall be packed in accordance with Level A, B, or C, as specified and marked in accordance with MIL-E-17555.

6. NOTES

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

6.1 Intended Use

The trip-free AFCBs defined herein are intended for use in aircraft circuits as noted on the applicable specification sheet. SAE AS5692 AFCBs are not generally designed to be used as switches and should not be used as such per MIL-HDBK-454.

6.2 Qualification

The activity responsible for the QPL is the Department of the Navy, Naval Air Systems Command, Electrical Power System Air 4.4.4.3, 22229 Elmer Road, Building 2360, Patuxent, River MD 20670. Copies of “Provisions Governing Qualification” may be obtained upon application to Commanding Officer, DODSSP Standardization Documents Order Desk, 700 Robbins Avenue, Bldg, 4D, Philadelphia, PA 19111-5094.

6.3 Definitions

6.3.1 Ultimate Trip Current:

For overload protection, ultimate trip current is the smallest value of current that will cause tripping of the AFCB under a given set of ambient conditions.

6.3.1.1 Ultimate Trip Limits

For overload protection, the specified limits of ultimate trip current are maximum ultimate trip current and minimum ultimate trip current. At the maximum specified ultimate trip current, the AFCB will open within the specified time. At the minimum specified ultimate trip current, the AFCB will not open.

6.3.2 Line Terminal

The terminal attached to the isolated stationary contact, with the AFCB in the open or tripped position, is considered as the line terminal. When both contacts of a circuit are isolated, only one terminal shall be designated the line terminal.

6.3.3 Push-Pull

Push-pull AFCBs are those which can be manually actuated by an actuator moving in a direction perpendicular to the plane of the mounting surface or plate.

6.3.4 Multiphase AFCB

A multiphase AFCB has two or more phases controlled by a single actuating member. Separately operable AFCB’s in a common case will not be condered as multiphase breakers, but will be treated throughout as a single phase AFCB.

6.3.5 Trip-Free

An AFCB so designed that the circuit cannot be maintained closed and cannot be held closed against a fault when carrying overload currents that would automatically trip the AFCB to the open position.

6.3.6 Recycling Trip-Free

An AFCB so designed that the circuit will automatically recycle, open and momentarily close, as long as the actuator is maintained in the closed position.

6.3.6.1 Non-recycling Trip-Free

An AFCB so designed that after tripping with the actuator held in a closed position, the AFCB will not automatically reset.

6.3.7 Interrupting Capacity

Former revisions referred to this parameter as “Rupture capacity”. For overload protection, interrupting capacity is the maximum potential short circuit current at rated voltage that an AFCB is required to interrupt under the operating duty specified and with a normal frequency recovery voltage not less than rated voltage.

6.3.8 Available Short Circuit and Close in Interrupting Capacity Tests

For overload protection, these tests use a voltage regulated circuit in which the calibrated fault current is obtained after the regulator has provided the maximum excitation.

6.3.9 Extra-Length Pushbutton

Unless otherwise specified, a push-pull actuated AFCB with a pushbutton nominally 0.375 inches longer than the standard length pushbutton is designated as an extra-length pushbutton AFCB. The standard and extra length of pushbutton for each style AFCB is shown on the specification sheet.

6.3.10 Separable Link

A mechanism shall be able to open a circuit under current overload condition if the normal tripping mechanism malfunctions.

6.3.11 Arc Fault

An electrical arc fault is a sustained luminous discharge of electricity across a gap in a circuit or between conductors. Arc impedance can reduce low voltage fault current magnitudes appreciably.

6.3.12 Parallel Arc Fault

An arc fault condition in which arcing occurs in a circuit from line-to-line or line-to-ground and not through any load(s). Only the arc impedance and the system current impedance limit the magnitude of the arc fault current.

6.3.13 Series Arc Fault

An arc fault condition in which the current passes through the arc and each circuit load. The load equipment limits the magnitude of the arc fault current.

6.3.14 International Standardization Agreement

Certain provisions (1.1) of this specification are the subject of international standardization agreement ASCC 12/3. When amendment, revision or cancellation of this specification is provided which will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels including departmental standardization offices, if required.

6.4 Nuisance Load Traces

Traces are provided to allow the developer of an AFCB, or applicant for qualification, a snap shot of the characteristics of a select few of the loads required for qualification. The traces are not a performance requirement, or a complete definition of the loads that can be used to determine equivalency in and of themselves. They are provided for reference only. The AFCB manufacturer, or applicant for qualification, must determine the requirements for equivalency based on their knowledge of their algorithm and hardware, and the load requirements. The qualifying activity must approve an application for equivalency.

6.4.1 Strobe Light Trace

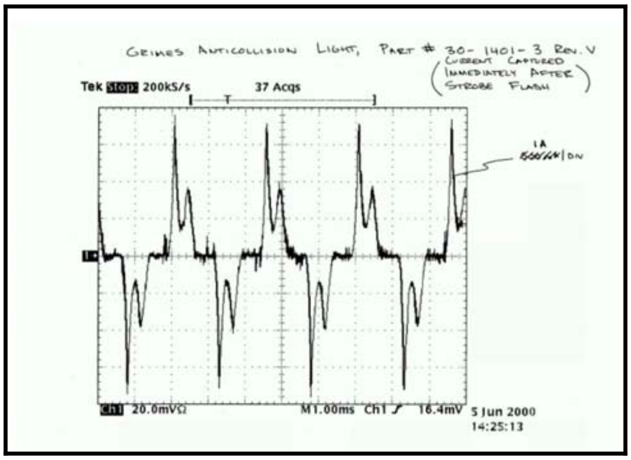

FIGURE 21

6.4.2 In Flight Entertainment Overall Trace

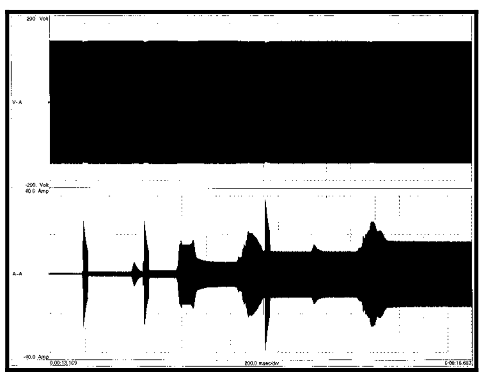

FIGURE 22

6.4.3 Switching Power Supply Start Up Trace

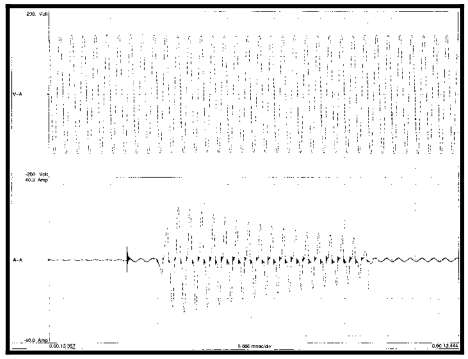

FIGURE 23

6.4.4 SCR Controlled Window Heat (747) Trace

6.4.4.1 SCR Controlled Window Heat Start Up Trace

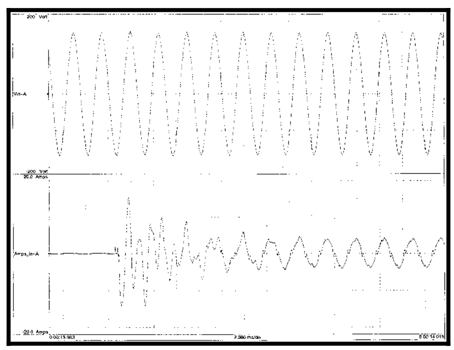

FIGURE 24

6.4.4.2 SCR Controlled Window Heat Shut Down Trace

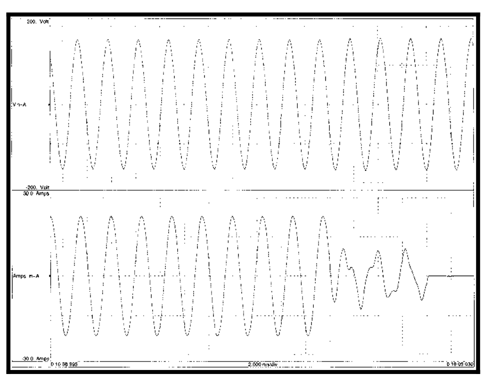

FIGURE 25

APPENDIX A
AS5692 SPECIFICATION – BACKGROUND INFORMATION

A.1 BACKGROUND

The AE8B1 subcommittee provides this section to capture some of the thought processes relative to the performance requirements detailed in this specification. As such, it is intended to facilitate the incorporation of specification sheets and subsequent revisions to AS5692 by providing insight into the intent of the requirements.

A.1.1 SAE recommended practices ARP4754 and ARP4761 should be reviewed and considered in the development of AFCBs.

A.1.2 Design General

The subcommittee felt strongly that any software or complex hardware, invoking the requirements of RTCA/DO-178B, and RTCA/DO-254, should be to level C at a minimum, and that specification sheets that would allow for lower levels should not be accepted. The committee also felt that level A would be required for many applications, and that new products should be designed to level A to avoid potentially expensive upgrade efforts later in the developments cycle. However, level C was specified to allow for a less costly device to be manufactured for commercial applications with less stringent requirements.

A.1.3 Grounding (3.4.15)

The 2-ohm requirement specified in this paragraph was chosen by the subcommittee as a value that would significantly exceed the resistance of standard bonding operations after a considerable period of time in the application. The intention of the subcommittee was to avoid the need for specialized bonding operations to facilitate the broadest practical retrofit.

A.1.4 Guillotine Test (4.7.7.6.1)

All types of wiring can be chafed and cut by aircraft vibration on structures, clamps and avionics boxes. Also, wiring can be chafed, pinched or cut during maintenance on doors and avionics boxes. After the wire insulation is cut, pinched or chafed, electrical arcing occurs. The reality of damaged wiring required testing that was experienced on aircraft. The guillotine test provides realistic representation of arcing events on aircraft wiring. The team desired to be considerably more conservative and selected 8 half-cycles in the duration of 100 ms as the criteria for this test based on the number of half-cycles in UL1699. This represents a much more rapid clearing time than UL1699 due to the higher operating frequency of the aerospace electrical system. The example apparatus shown in this section pinches the sample wires between the cutting blade and the base plate. Another embodiment of the guillotine test apparatus would have a trough parallel to the cutting blade below the wires. This type of scissors action has been found to provide more consecutive half cycles of arcing in some cases.

A.1.5 Wet Arc Test (4.7.7.6.2)

Polyimide wire insulation can become brittle and crack in the presence of water. This can lead to water intrusion that creates an electrical path from wire-to-ground or wire-to-wire which can then arc. The wire is presently widely used in commercial and military aircraft so wet arc tests based on AS50881 and MIL-W-5086 were included.

A.1.6 Cold Startup (4.7.7.6.2.1)

This represents an event where all power is removed from the AFCB for a sufficient time for all internal capacitors or other energy storage elements to be discharged. This test allows for one reclosure and it is required, after these two arc fault tests, that the wiring adjacent to the arc fault is not damaged to the point that its insulation integrity is compromised. The Cold Startup test requires that the time from the initial wet arc fault trip event to the reclosure of the AFCB be at least 5 minutes and that during this time the line side power of the AFCB be removed. Upon reapplication of power to the AFCB, its power supply and any storage element included to power the arc fault trip device must go through their startup. The subcommittee did not include a test for Hot Re-close. The hot reclose test was considered early in the development of the specification because it is expected that the cockpit crew may need to reclose a breaker even though standard practice dictates that a circuit breaker should not be closed in flight unless completely necessary after a trip has occurred. This test and the “Arc Fault Circuit Breaker Cold Startup Time Test” allow for one reclosure and it is required, after the two arc fault tests, that the wiring adjacent to the arc fault is not damaged to the point that its insulation integrity is compromised. The Hot Re-close Wet Arc test requires that the time from the initial wet arc fault trip event to the reclosure of the AFCB be 2 seconds or less. This represents an event where the AFCB is re-closed very quickly after the trip event. AFCB design approaches that require the charging of an energy storage element for actuation of the trip solenoid are addressed with this test. The subcommittee decided not to include the hot reclose test because it was determined that the cold start test was a more stringent test, and that it would be extremely unlikely for an AFCB to fail the hot reclose test after passing the cold startup test, making the hot reclose test unnecessary.

A.1.7 Loose Terminal (4.7.7.6.3)

Prior to the introduction of this test methodology, the accepted method for creating “series” type arcing events was the opposed carbon rod tester in UL 1699. This method utilizes one carbon and one copper rod in physical contact with one another. Current is allowed to flow through the rods while one of the rods is slowly drawn away, creating a very clean and reproducible “series” type arcing event. Opponents of this test argued that the arcing was too “sterile” and unrepresentative of what actually occurs on an aircraft.

To address these concerns, a loose terminal connection test method was proposed. To mimic the conditions on an aircraft as closely as possible, vibration was required as well as a deliberate wire clamping means. The test was originally conducted on a portable random shaker table, but this approach allowed for uncontrolled variability from test setup to test setup. To aid in reproducibility, a standard commercial aircraft equipment vibration profile was eventually agreed upon. To maximize the intermittency of the electrical connection, the wire jumpers were clamped independently of the terminal strip, and a larger gauge wire was used such that the flexibility of the wire did not considerably dampen the wire terminal to terminal stud displacement during vibration tests.

Empirically, a single loose terminal produced very little arcing, except when meticulous care was taken at setup to properly align the wire terminal on the terminal stud. To minimize the setup time and increase the probability of achieving consistent results, multiple loose terminals were connected in series. Typically, the arcing associated with this test setup is still localized to one or two of the weakest link terminals, rather than the entire strip. Standard wiring practices allow for a maximum of four wire terminals per post.

The pass/fail criteria for this test relies heavily upon the amount of damage allowed prior to interrupting the circuit. Due to the limited energies associated with “series” type arcing events, the response time of the circuit breaker to “series” events is much longer than for “parallel” type events. Originally, the overall response time was specified at 10 minutes, but subsequent testing demonstrated that hazardous insulation damage can occur between 5 to 10 minutes. Therefore, the maximum response time for the circuit breaker was changed to 5 minutes, and was later changed to 1 minute with the change to a single terminal test.

The committee eventually proposed a single terminal test with the addition of an arcing content requirement. The “Evaluation Criteria” section of the loose terminal paragraph, 4.7.7.6.3 contains the definition of the arcing content required for a DUT to trip. It should be noted that the “Evaluation Criteria” are only examined in the event that a DUT does not trip within 1 minute of the application of power. So the evaluation criteria are only used to determine if a DUT has failed a test or if the DUT requires retest. The first step taken after a DUT has not tripped within 1 minute of the application of power is to divide the current trace of the first 60 seconds of power into 10 second intervals. If each of these 6 intervals contains at least one “confirmed arcing period” the DUT has failed the test. If, at least one of these intervals does not contain at least one “confirmed arcing period”, the DUT must be retested. Note that a “confirmed arcing period” is not an “arcing period”. These two terms refer to different occurrences. There are three terms defined in the “Evaluation Criteria” section of 4.7.7.6.3. The three terms are: “arcing event”, “arcing period”, and “confirmed arcing period”.

A.1.8 Nuisance Tripping and Operation Inhibition

Originally tItled as Unwanted Tripping and Operation Inhibition testing and was initially two separate sections of the specification. However, the subcommittee decided that the two sections should be merged. This section also examines, to some extent, the effects of bus transfers, and load sharing and shedding events common to the environment of the aircraft electrical system. The loads for this section were chosen, mainly from the FAA 737 and 747 ground-operation-only platforms at the Hughes Technical Center in Atlantic City, NJ.

The operation inhibition testing, commonly referred to as masking testing, verifies performance to check for two main considerations. It ensures that the algorithm of the DUT does not employ special case recognition methods that would prevent the logic of the DUT from tripping when an arc occurs while a load is powered. It also ensures that the DUT does not rely on arc information that is attenuated by reactions with the load, to such an extent that the DUT cannot pick up the arcing signal. An inability to detect arcs in the presence of normal aircraft loads would obviously negate AFCB installation benefits.

The AE8-B1 committee recognized that verification of nuisance load performance was an extremely important part of the AS5692 specification.

The committee discussed waveform based electronic testing. Waveform testing captures current and voltage traces from nuisance load events performed in the application or in the lab. These traces are then replicated with a waveform generator and applied to the DUT.

Some of the advantages of this type of testing are as follows:

- It lends itself to quick and easy test setups.
- It allows a variety of performance parameters to be tested with one piece of equipment.
- Its greatest strength is reduced variability.
- It can be used on the full device with full current and voltage, or it can be used to inject lower level signals into portions of the arc detection circuit.

Some of the disadvantages of waveform testing are as follows:

- It would require relatively large file sizes necessary to properly characterize the load.
- The method of control (e.g., configuration management, distribution, data, accuracy of data) of this electronic data is not currently available.
- There were technical concerns that even higher resolution data collection will not adequately capture the challenging characteristics of nuisance loads.

The committee then turned its focus toward live testing, where actual loads would be specified, following the precedent set by the residential industry in UL1699. Some of the advantages of this method are as follows:

- The DUT is exposed to all of the characteristics of the nuisance load; there is no opportunity for signal aliasing due to digitization.
- Live testing is much easier to specify than wave form testing; the load type, a representative part number, and any important characteristics are all that are needed.
- Live testing offers some natural variability from run to run that is similar to variability in aircraft load installations.

There are however, some disadvantages to this type of testing that the committee considered. Some of these disadvantages are as follows:

- It is a cumbersome test to setup.
- It is fairly inflexible; once you have a load, or group of loads, you are confined to the characteristics of the loads obtained.
- Its variability can also mask performance changes.
- The purchase of aerospace loads makes live testing potentially expensive.

Weighing all of these considerations, the committee reached consensus that there were far too many barriers to specifying the nuisance load requirements of AFCBs with waveform testing for the initial release of this specification, so live testing of loads were required.

Once this decision was made, the loads had to be determined and specified, amp rating specific considerations had to be made, and some considerations had to be outlined relative to equivalent load use. The AE8-B1 committee characterized loads and gathered part numbers on the FAA Hughes Technical Center, Atlantic City maintained Boeing 727, 737[1], and 747[1]. The committee decided to specify loads by manufacturer part numbers, allowing the AFCB manufacturer to run equivalent loads. The AFCB manufacturer must determine the requirements for equivalency based on their knowledge of their algorithm and hardware. However, the committee did use the specification to communicate the characteristics of each load that resulted in its inclusion as a nuisance load candidate. These characteristics are communicated in two ways. The first is a verbal description of the characteristics of each load, such as “landing lamp” on incandescent loads, and “cabin light” on fluorescent lighting ballasts. The second is a diagram of the representative current trace for each load, which is included in 6.5 of AS5692. The specification also requires that the DUT endure bus transfers and load shedding and sharing on a common source for each load without nuisance tripping.

[1]FAA 737 and 747 set for ground operation only

A.1.9 Cross talk (4.7.7.7.2)

Aircraft have Electromagnetic Interference (EMI) requirements under which they operate. These requirements cause avionics to incorporate EMI filter capacitors. These capacitors with the generator and wire inductance can change the current and voltage waveform characteristics of acing faults. The two capacitance values chosen were 0 and 5 microfarads. The 0 microfarads represents an aircraft with no loads turned on and 5 uF represents the typical capacitance incorporated on aircraft. The AFCB must function in both conditions.

a. Impedance of a single supply line where an arc can occur. Aircraft have EMI requirements under which they operate. These requirements cause aircraft loads to incorporate EMI filters, essentially capacitors (chokes or coils are less significant). The wire inductance is low because of the characteristics of the short runs of 12-22-gauge wire. Thus the main variability encountered in the impedance of a single supply line is capacitive. The experience of NAVAIR is that the capacitance on a line can go from 0 to 5 microfarads. Zero microfarads representing an aircraft with no loads turned on and 5 uF represents the maximum capacitance experienced on aircraft. As the loads are generally balanced, the most representative values are 3 times 5 microfarads (one on each line A, B, and C) or 3 times nothing (0 microfarad on each line).

b. Cross talk between 2 lines: The above rationale is valid when the lines are far from one another, but generally, wires are confined in a bundle and are very close to one another. An arc can generate quick variations of voltage and current. These variations will be transmitted to adjacent wires by capacitive or inductive coupling. The purpose of the test is to insure that an arc appearing on line B will not induce a trip on the AFCB on line A. The test is therefore done to reproduce the maximum cross talk (inductive or capacitive) expected on an aircraft wiring. An inductive cross talk between 2 wires will be most effective if the wires are very close together (this is the reason for the twisted pair). The inductive cross talk will be enhanced by a capacitor on line B (the instantaneous inrush due to the arcing current will be increased on line B -> high di/dt -> high H (magnetic induction field) -> high induced di/dt in line A). Having 0 microfarad on line A, B, and C, or 5 microfarad capacitors on line A, B, and C, represents the minimum and maximum values of the impedance existing on balanced aircraft wiring.

c. Line to neutral coupling: Another coupling is often present on aircrafts: line to neutral. Most of the time, the wire bundles are connected close to the aircraft chassis. The chassis (frame) is used as the return path (neutral). The ground plane has been introduced to simulate this coupling (between line A and B and the aircraft frame). The height of 2½ inches represents the average distance of an aircraft bundle to the aircraft frame. The 4 inches minimum between the loop backs is to reduce the inductive behavior of the wiring: the intention is to avoid the introduction of inductive behavior in the lab that does not exist on an airplane and we still want a relatively small test apparatus. The 80 feet twisted pair can be laid down in an “S” shape and be fixed above a 1.5 x 1.5 meter aluminum panel. Source B and circuit 1 is the combination that enables the highest current and represents the worst case.

A.1.10 Feedback Immunity Resistance Test Background (4.7.7.9)

Multiple breakers are fed from a given phase of the three-phase power source. Of these multiple breakers, some may be AFCB's while others will remain conventional thermal CB's. This test is setup to verify that if an arc fault occurs on any breaker connected to the phase, it will not cause the tripping of any of the arc fault breakers connected to the phase. This test it is run with a conventional thermal CB on the circuit with the arc fault, as this is considered worst-case condition.

A.1.11 Overload cycling (4.7.9)

The overload testing description was pulled directly from MIL-C-5809, and addresses the thermal functionality of the combined arc fault thermal circuit breaker governed by this specification. Paragraph 4.7.9.1 was added to test the endurance of the mechanisms used during arc fault detection. The AE8-B1 committee adopted the philosophy that arc fault tripping is analogous to thermal tripping from the perspective of frequency of occurrence in the application. As such the committee made the arc fault trip cycling requirements the same as the overload cycle requirements. If a BIT is required by an applicable specification sheet, the author of that specification sheet should consider overriding the 100 cycles currently required by 4.7.9.1, as even a moderate monthly BIT check will add up to thousands of cycles over the lifetime of the device under test.

A.1.12 Transit Drop (4.7.20)

The test requirements were derived from MIL-STD-810F, Method 516.5, Procedure IV - Transit Drop. This test is conducted in order to provide a degree of confidence that the AFCB can physically and functionally withstand the relatively infrequent, non-repetitive shocks that may be encountered during handling of the AFCB in the field. Transit drop test was not a MIL-C-5809 requirement for thermal circuit breakers. It was added to AS5692 primarily to provide assurance that the electronics can withstand the shock effects related to an occasional drop of the product during the handling process. Secondly, it also provides assurance that the mechanical parts that have been minimized in size and mass to meet the very demanding packaging requirements of AFCBs can withstand transit drop occurrences. The effects of such shocks may be:

a. Material failure as a result of increased or decreased friction between parts, or general interference between parts.

b. Changes in material dielectric strength, loss of insulation resistance, variations in magnetic and electrostatic field strength.

c. Material electronic circuit card malfunction, electronic circuit card damage, and/or electronic connector failure.

d. Permanent mechanical deformation of the material as a result of over-stress of material structural and non-structural members.

e. Collapse of mechanical elements of the material as a result of the ultimate strength of the component being exceeded.

f. Material failure as a result of cracks in fracturing crystals, ceramics, epoxies, or glass envelopes.

MIL-STD-810 requires 26 drops of a test item, which may be divided among up to five samples. The 26 drops are to be set up to impact 6 faces, 8 corners, and 12 edges. The AE8-B1 committee discussed typical handling of a circuit breaker, and determined that from the point of issue to the installation into the aircraft, no drops of the breaker are normally encountered. Certainly no more than three drops would be expected for any given breaker. The breakers are not typically removed for maintenance or repair activity. Based upon this, the committee agreed that each unit under test would be subjected to three drops. The random orientation of the units on the drop tester assures that the units will impact the test surface at many different axes and points - similar to what will be experienced in the field. A drop height of 4 feet is specified in MIL-STD-810 and is considered reasonable in this application.

NOTE: The subcommittee conducted drop tests of the thermal CBs to verify that this new requirement did not result in damage to the breakers; result - no damage to the breakers that were dropped.

A.1.13 Temperature/Pressure Circuit Functionality and EMC (4.7.21- 4.7.23) RTCA/DO160 Testing

All of the RTCA/DO160 testing contained in these paragraphs was the result of aviation industry standards recommended by the FAA. All of the tests and levels were discussed and agreed by the SAE-AE8B1 subcommittee members. Temperatures were chosen to approach the MIL-C-5809 levels without requiring specialized electronic components in the AFCB. The following table was used as a reference by the subcommittee to summarize portions of the requirements of RTCA/DO-160D section 4, it is included in this section only as a reference.

TABLE 11

Ground survival high temperature	RTCA/DO-160 Section 4.0 paragraphs 4.5.2	85C	3 hours
Short-time operating high temperature	RTCA/DO-160 Section 4.0 paragraphs 4.5.2	85C	30 minutes
Operating high temperature	RTCA/DO-160 Section 4.0 paragraphs 4.5.3	71C	continuous
Ground survival low temperature	RTCA/DO-160 Section 4.0 paragraphs 4.5.1	-55C	3 hours
Operating low temperature	RTCA/DO-160 Section 4.0 paragraphs 4.5.1	-55C	30 minutes

Selection of 85 to 90% of rated current for temperature circuit functionality testing (4.7.21): The trip curves of existing thermal circuit breakers drifts with temperature. Depending on the specific breaker, at 71 °C, the maximum hold current rating could drop to 85% rated current. Therefore, to avoid THERMAL nuisance tripping, standard aircraft design practices (attempt to) limit the actual current draw of each circuit breaker to 85% rated current.

Selection of XXG33 in 4.7.23.5 was based on the minimum reasonable level suggested by the FAA for aluminum paneled aircraft. Equipment intended for use in severe electromagnetic environments such as composite paneled aircraft should evaluate and adjust the category designations as appropriate for the application. Equipment in applications susceptible to pin injection exposure should also evaluate and adjust the category designations as appropriate for the application.

A.1.14 Maximum Steady-State Power (4.7.24.1)

The arc fault circuit breaker is continuously monitoring current for arc fault signatures. The electronics for detecting the fault are energized continuously, as long as the AFCB is closed. Over 100 circuit breakers are co-located in and around the cockpit area on most commercial and military aircraft. In order to limit the heat in the cockpit area, 10 milliamps per breaker was chosen, balanced with the requirement to detect arcing faults in the circuit breaker. As a point of reference, the maximum continuous current for today's relays is 100 milliamps.

A.1.15 Maximum Peak Current (4.7.24.2)

The maximum peak current required, to open an actuator of the AFCB is determined by the force needed and the actuator available. Based on today's technology 3.5 amps maximum is required to operate the actuator. The 50-millisecond time was set to allow operating time to open the mechanical actuation for AFCB. The current level was balanced with the fact that the ground return through panel should be as low as possible.

A.1.16 Power Quality (4.7.25)

MIL-STD-704A vs RTCA/DO-160 - Electrical power requirements fall into two categories: steady-state and transient. MIL-STD-704A has both requirements and is utilized in older aircraft designs and will comprehend today's aircraft. (i.e., if the AFCB will work with MIL-STD-704A it will work on all subsequent revisions of MIL-STD-704 and RTCA/DO-160). Since MIL-STD-704A steady-state and transient limits are wider than RTCA/DO-160, this requirement ensures that AFCBs will operate on legacy aircraft.

A.1.17 Reverse Installation (4.7.26)

The reverse installation test is targeted at accomplishing two things. First and foremost, the committee wanted to ensure that units installed in a reversed fashion would not compromise the thermal protection. Second, the committee wanted to minimize the likelihood of a latent failure of the arc fault functionality.

This test requires that the AFCB demonstrate performance to one of three performance modes. Each of the three possible modes of demonstrating performance requires the AFCB under test to demonstrate thermal protection while installed with reversed polarity. Each performance mode was considered acceptable to the members of the AE8-B1 committee. The mode to which a candidate would qualify would be dictated by the applicable specification sheet, the competitive market environment, or by the candidate for qualification. This is not to imply that the committee felt that all of the performance verification modes were equivalent. There was a clear consensus that the first mode was the preferable mode. In this mode the AFCB would perform the same regardless of polarity of installation.

The second mode ensures that reverse installation of the AFCB is detectable by the installer, and that the reverse installation does not damage the AFCB to the extent that it would not operate properly when installed correctly after previously being powered up installed in a reverse polarity fashion. The committee agreed that indication of reverse installation could be as simple as coding on the side of the AFCB indicating the correct connections, to provide a least-cost manufacturing solution. A fully defined coding convention, contained in the applicable specification sheets, or amended to the body of AS5692, would be required for any device using the code only type of indication for reverse installation. NAVAIR input has indicated that the coding must be common among AFCB manufacturers for qualification to be granted from NAVAIR. Further, the coding definition should be contained in this specification to best foster this commonality. However, the committee also felt that a more active indication would be preferable, and likely a lower total cost solution. More active indication would also include any type of LED or audible indication. Exposure to a guillotine style test was added to this mode to reveal a design that is vulnerable to a latent failure when the arc fault detection actuation mechanism is exercised in the reverse installed condition. Specifically, the subcommittee considered the load side powered AFCB without design controls in place to limit the time period over which the actuation mechanism is energized, particularly susceptible to this type of latent failure.

The third mode specifies a mode of active indication deemed acceptable by the committee. This mode requires the DUT to detect reverse installation and open itself upon application of power, and cannot be maintained in the closed position until un-powered and installed correctly. Special procedures may need to be developed for any loads that are not energized until in flight.

A.1.18 BIT

The committee did not mandate built in test (BIT) functionality in the base specification, as it was decided that an AFCB without BIT would still add a step function improvement in the safety of the circuits in which they are installed above thermal only circuit breakers. Additionally, the committee decided that the form and function would be as varied as the applications and end users that will be using it. As an example some end users would want an interface for maintenance personnel behind the panel only, while others would want their maintenance personnel to be able to access a BIT function with the panel closed. Some may want a specialized maintenance tool, while others might want a simple button. The subcommittee decided that such details must be defined in the applicable specification sheet.