U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: FAA Approval of Electrical Firing Cartridge Components in an Aircraft Fire Extinguishing or Suppression System

Date: 10/11/2018

Initiated By: AIR-670

AC No: 20-144A

This advisory circular (AC) provides acceptable means for showing compliance with the requirements of title 14, Code of Federal Regulations (14 CFR) 23.1301, amendment 23-62 or earlier, 25.1301, 27.1301, and 29.1301 (herein, collectively, 2X.1301), *Function and installation*, with regard to fire extinguishing or suppression systems that contain electrical firing cartridge components.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

For/

Dr. Michael C. Romanowski
Director, Policy and Innovation Division
Aircraft Certification Service

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1 PURPOSE.

1.1 This AC provides acceptable means for showing compliance with the requirements of 14 CFR 2X.1301, *Function and installation*, with regard to fire extinguishing or suppression systems that contain electrical firing cartridge components. Airplanes having to comply with part 23 rules using amendment 23-64, effective August 30, 2017, must show compliance with § 23.2505, *Function and installation*.

1.2 This AC also includes the various aspects that should be considered by applicants seeking approval from the Federal Aviation Administration (FAA) of fire extinguishing or suppression systems that contain electrical firing cartridge components manufactured under a production certificate (PC), components to be approved under the part manufacturer approval (PMA) process, or design changes to components originally approved by either method. Since each environment and installation may differ, the applicant should select those portions of this document necessary to show compliance and coordinate it with the responsible FAA engineer, inspector, or their designee. This AC does not address other firex components or the complete aircraft system installation. There may be airframe installation requirements and boundary conditions that should be met prior to installation approval.

2 APPLICABILITY.

The guidance in this AC is for applicants requesting a PC or PMA, or a new, or amended, or supplemental type certificate (STC). This guidance is also for aircraft manufacturers, modifiers, foreign regulatory authorities, FAA aircraft type certification engineers, FAA manufacturing inspectors, and the Administrator's designees.

2.1 The material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other means of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. If, however, we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

2.2 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

3 CANCELLATION.

This AC cancels AC 20-144, *Recommended Method for FAA Approval of Aircraft Fire Extinguishing System Components*, dated September 22, 2000.

4 SUMMARY OF CHANGES.

This AC revision removes the sections that had been reserved for later inclusion of specifications for fire extinguishing or suppression system components other than firing cartridge components: precision burst discs, fill/change fittings, pressure indicators, and discharge head assemblies. The revised title of this AC reflects that change by specifying electrical firing cartridge components. This AC adds “or suppression” to “fire extinguishing or suppression system.” In addition, this AC adds and updates references and definitions, and deletes the “Engineering Design Test Schedule,” referring the reader instead to MIL-DTL-23659F, *General Design Specifications for Electrical Initiators*, for the current version. Compliance with MIL-DTL-23659F and this AC satisfies the requirements of § 2X.1301.

5 RELATED DOCUMENTS.

5.1 Regulations.

5.1.1 The following 14 CFR regulations are related to this AC. You can download the full text of these regulations at the U.S. Government Printing Office e-CFR website. You can order a paper copy by sending a request to the U.S. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-0001; by calling telephone number (202) 512-1800; or by sending a request by facsimile to (202) 512-2250.

- Section 21.1, *Applicability, and definitions*.
- Section 21.137, *Quality System.*
- Section 21.303, *Application*.
- Part 21, subpart G, *Production Certificates*.
- Part 21, subpart K, *Parts Manufacturer Approvals*.
- Section 25.851, *Fire extinguishers*.
- Section 25.855, *Cargo or baggage compartments*.
- Section 25.857, *Cargo compartment classification*.
- Section 25.901, *Installation*.
- Section 25.1195, *Fire extinguishing systems*.
- Section 25.1197, *Fire extinguishing agents*.
- Section 25.1199, *Extinguishing agent containers*.
- Section 25.1201, *Fire extinguishing system materials*.
- Section 25.1301, *Function and installation*.
- Section 25.1529, *Instructions for Continued Airworthiness.*
- Section 27.859, *Heating systems*.

- Section 27.1301, *Function and installation*.
- Section 27.1529, *Instructions for Continued Airworthiness.*
- Section 29.851, *Fire extinguishers*.
- Section 29.859, *Combustion heater fire protection*.
- Section 29.1195, *Fire extinguishing systems*.
- Section 29.1197, *Fire extinguishing agents*.
- Section 29.1199, *Extinguishing agent containers*.
- Section 29.1201, *Fire extinguishing system materials*.
- Section 29.1301, *Fire and installation*.
- Section 29.1529, *Instructions for Continued Airworthiness.*

5.1.2 In addition to the part 21 requirements in paragraph 5.1.1 above, airplanes having to comply with part 23 rules prior to amendment 23-64, effective August 30, 2017, must meet:

- Section 23.1195, *Fire extinguishing systems*.
- Section 23.1197, *Fire extinguishing agents*.
- Section 23.1199, *Fire extinguishing containers*.
- Section 23.1201, *Fire extinguishing systems materials*.
- Section 23.1301, *Function and installation*.

5.1.3 In addition to the part 21 requirements in paragraph 5.1.1 above, airplanes having to comply with part 23 rules using amendment 23-64, effective August 30, 2017, must meet:

- Section 23.2250(a), *Design and construction principles.*
- Section 23.2400(c) and (d), *Powerplant installation.*
- Section 23.2440(c) and (f), *Powerplant fire protection*.
- Section 23.2500, *Airplane level systems requirements.*
- Section 23.2505, *Function and installation.*

5.2 **Advisory Circulars.**

AC 21.303-4, *Application for Parts Manufacturer Approval via Tests and Computations or Identicality*, dated March 21, 2014, is related to the guidance in this AC. If AC 21.303-4 is revised after publication of this AC, you should refer to the latest version for guidance, which can be downloaded from the Internet at http://www.faa.gov/regulations_policies/advisory_circulars/.

5.3 Orders.

The following FAA orders are related to the guidance in this AC. The latest version of each order at the time of publication of this AC is identified below. If any order is revised after publication of this AC, you should refer to the latest version for guidance, which can be downloaded from the Internet at http://www.faa.gov/regulations_policies/orders_notices/.

- Order 8110.42D, Parts Manufacturer Approval Procedures, dated March 21, 2014.
- Order 8120.16A, Suspected Unapproved Parts Program, dated June 3, 2016.
- Order 8120.22A, Production Approval Procedures, dated January 11, 2016.

5.4 Other Documents.

The following documents are related to this AC. If any of these documents are revised after publication of this AC, you should refer to the latest version.

- MIL-DTL-23659F NOT 1, *Initiators, Electrical, General Design Specifications for*, dated March 18, 2015, ASSIST (DoD Specs and Standards).
- AIAA-S-113A-2016/A1-2018, *Criteria for Explosive Systems and Devices on Space and Launch Vehicles*, dated 2018, https://aiaa.org.
- MIL-C-22284A(1) NOT 1 (AS), Revision A, Notice 1, *Container, Aircraft Fire Extinguishing System, Bromotrifluoromethane, CF3BR*, dated September 18, 1996, ASSIST (DoD Specs and Standards).
- RTCA/DO-160G, Change 1, *Environmental Conditions and Test Procedures for Airborne Equipment*, dated December 16, 2014, https://www.rtca.org/.
- SAE AIR5060A, *Electronic Engine Control Design Guide for Electromagnetic Environmental Effects*, dated August 11, 2011, https://www.sae.org/.

6 DEFINITIONS.

For the purpose of this document, the following definitions apply:

6.1 All-Fire and No-Fire Reliability Conditions.

"All-fire" and "no-fire" are minima and maxima conditions for different cartridges under specific operating conditions. Refer to MIL-DTL-23659F.

6.2 Backshell.

Metal shell connecting circuit shields or overbraid to an electrical connector.

6.3 Burst Disc.

Diaphragm that ruptures to allow extinguishing agent to escape.

6.4 Cartridge.

Device used for discharging pressurized extinguishing agent. These are sometimes referred to as firing cartridges and initiators. These components meet definition of critical component under FAA Order 8110.42D, appendix K.

6.5 Discharge Head.

Device that houses cartridges and interfaces between the pressure vessel and the agent distribution system. This is sometimes referred to as the cartridge body or header assembly.

6.6 Firex.

Any fire extinguishing or suppression system that consists of the extinguishing agent container (vessel) and all attached components.

6.7 Pressure Indicator.

Device to indicate pressure or status of pressure vessel.

6.8 Production Approval Holder (PAH).

The holder of a production certificate, parts manufacturer approval, or technical standard order authorization who controls the design and quality of a product or part.

7 SCOPE.

7.1 A fire extinguishing or suppression (firex) system is required by subpart E of parts 23, 25, 27, and 29, among other part 2X provisions (for example, §§ 2X.851, 2X.854, 2X.855, 2X.857, 2X.901, 2X.1195, 2X.1197, 2X.1199, 2X.1201, 2X.1301, and 2X.1309). A firex system is composed of many components that are critical for the proper operation of the system when installed in an aircraft. One such component may be an electrical firing cartridge component. While there are no specific regulatory requirements on the design, production, or testing of an electrical firing cartridge, § 2X.901(b)(2) requires that components of the installation be constructed, arranged, and installed to ensure their continued safe operation between normal inspections and overhauls. Additionally, § 2X.1301(a)(1) and (4) requires that each item of installed equipment must be of a kind and design appropriate to its intended function and operate properly when installed. This AC does not address other firex components or the complete aircraft system installation. There may be airframe installation requirements and boundary conditions that should be met prior to installation approval.

7.2 The applicant should evaluate the firex system and establish minimum reliability standards for the components of the system so the overall system can meet the requirements of subparts E and F of parts 23, 25, 27, and 29. In accordance with § 2X.1529, the maintenance instructions should also be provided. These instructions should include required service after discharge.

7.3 The applicant should design and qualify components to meet specific operating performance, service life, and reliability requirements of the firex system established at the time of type design approval.

7.4 The FAA recommends that PAH and PMA applicants demonstrate that their candidate components meet or exceed these criteria. This document describes the critical parameters involved with the design, production, and testing of the electrical firing cartridge component.

8 FIREX SYSTEM FUNCTIONAL OVERVIEW.

8.1 There are generally three, cartridge-activated, firex systems onboard commercial aircraft. These systems provide fire extinguishment or suppression for engines, auxiliary power units (APUs), and cargo compartments. The extinguishing agent is contained in a pressurized vessel that is sealed with a precision burst disc. A discharge head, containing a cartridge and strainer, is attached to the pressure vessel.

8.2 When a fire is detected, an electrical pulse to the firing cartridge activates the firex system (activation may be automatic or commanded by a flightcrew member). The aircraft electrical system supplies the pulse, and the agent is discharged into the fire zone through a distribution system of piping and nozzles.

8.3 Most firex systems are designed to use a firing cartridge. In some types, when the firex cartridge activates, it produces a controlled shock wave that fractures the burst disc on the pressurized container, allowing the agent to escape.

8.4 In other types, the firex cartridge, upon activation, either propels a slug into the burst disc and discharges the agent, or supplies a pressurizing force to drive a piston that, in turn, moves a cutter knife that pierces the burst disc and allows the agent to disperse.

8.5 The opening in the burst disc is dependent on the application—high-rate discharge for engine or APU, or a combination of high-rated and flow-metered discharge for cargo compartments. In either case, the opening of the burst disc diaphragm should meet critical performance characteristics. A proper size opening should ensure the correct flow rate of agent to the desired destination.

8.6 A firex system may use a system of diverter valves, components of the flow metering, and filters to control where the agent travels for some cargo compartment applications.

9 FIREX CARTRIDGE PERFORMANCE PARAMETERS OVERVIEW.

9.1 General.

A firex cartridge is an explosive component of an aircraft firex system. The applicant is responsible for ensuring that the design and qualification of firex cartridges meet the specific operating performance, service life, and reliability requirements of aircraft firex system designs. This section discusses parameters for the design, production, testing, and approval process. To comply with § 2X.1301, the applicant should verify that these parameters are appropriate for the installation and perform analysis and qualification testing to validate the cartridge. These analyses and tests are discussed in paragraphs 9.4, 9.5, 9.7, and 9.9.2 of this AC.

9.2 Design Parameters.

9.2.1 Physical Parameters.

Physical parameters include all information related to how the cartridge interfaces with the aircraft firex system. These include, but are not limited to:

- Length dimensions (e.g., threads, output cup, overall, connector).
- Diameter dimensions (e.g., threads, output cup).
- Concentricity of dimensions.
- Tolerances.
- Thread size.
- Thread type.
- Electrical connector specification.
- Mounting features (e.g., relationship of cartridge output cup to pressure vessel burst disc).

9.2.2 Electrical Parameters.

Electrical parameters include the electrical signal required to initiate the cartridge in a proper and reliable manner. Of equal importance are the electrical requirements that ensure the cartridge will not inadvertently fire. The cartridge electrical parameters should be compatible with the applicable aircraft electrical system requirements, limitations, and tolerances. The following is a list of electrical parameters:

9.2.2.1 Minimum Firing Current.[1]

The applicant should establish the minimum firing current required to initiate the cartridge in a reliable manner. This is typically expressed with a current level and time duration such as 3.5-ampere pulse for 10 to 50 milliseconds.

9.2.2.2 Firing Circuit.[1]

Each type of cartridge has a different firing circuit. The type and number of circuits are related to the connector specified for the particular aircraft. The identification and proper orientation of the pins on the cartridge are critical for correct functioning of the firex system. The circuit diagram identifies each pin on the cartridge, typically by a letter or number. In

[1] Values may depend on the installation requirements.

addition, the applicant should specify the circuit resistance, typically 1.0 ohm for each unit.

9.2.2.3 No-Fire Current.[1]

The no-fire current is the maximum current at which the device will not fire or degrade, typically 1 amp or 1 watt for five minutes.

9.2.2.4 Electrostatic Discharge.[1]

The cartridge should not fire when exposed to an electrostatic discharge pulse. An electrostatic discharge is typically 25,000 volts from a 500 picofarad capacitor through a 5,000 ohm resistor shorted pin(s)-to-case.

9.2.2.5 Electromagnetic Interference (EMI).

Applicants should use RTCA/DO-160G as a standard and should determine limitations on the aircraft. The cartridge should not fire when exposed to various electromagnetic fields. Radar and communication systems generally produce these types of fields. The applicant should establish EMI protection criteria based on aircraft system EMI limitations.

9.2.2.6 Insulation Resistance/Dielectric Withstanding Voltage.[1]

The applicant should use insulation resistance of typically 100 megohms at 500 volts DC to prevent the loss of a fire pulse due to internal shorting or arcing.

9.2.2.7 Dielectric Strength.[1]

The cartridge should typically have a dielectric strength of 1000 volts AC root mean square (RMS) shorted pin(s)-to-case, and the leakage rate should not be greater than 0.1 milliamps for 60 seconds.

9.2.3 Functional Parameters.

Upon initiation, the cartridge should provide sufficient energy to open the burst disc effectively, but not enough energy to cause a failure of the firex system or aircraft.

9.2.3.1 Installed Air Gap.

The installed air gap is the distance between the end of the cartridge and the surface of the ruptured state of the disc. The applicant should establish the installed air gap with the approved burst disc(s), considering all system installation variables and tolerances, and accounting for repair limits for the bottle burst disc assembly, to determine the minimum and maximum gap conditions. The applicant should use the minimum and maximum gap for system level testing.

9.2.3.2 Burst Disc Opening.

The applicant should identify the opening size of the burst disc for the applicable installation, which is a critical performance characteristic, and evaluate the proper size opening to ensure the adequate flow rate of agent to the desired destination. The size of the required opening may be different for an engine or APU versus cargo compartment installations. The applicant should establish burst disc opening with the pyrotechnic charge and electrical energy specifications at their minimum tolerance and the minimum and maximum temperatures established for the system. This disc opening should be equal to or greater than the minimum flow area of the discharge head. It is essential that the applicant establish an adequate margin of safety.

9.2.4 Environmental Parameters.

According to § 2X.1301, the cartridge should function properly for its intended function, which means it should function normally after exposure to all the environmental conditions it is expected to operate in. The applicant should consider the additional environmental parameters in RTCA/DO-160G, or equivalent specifications. Examples include:

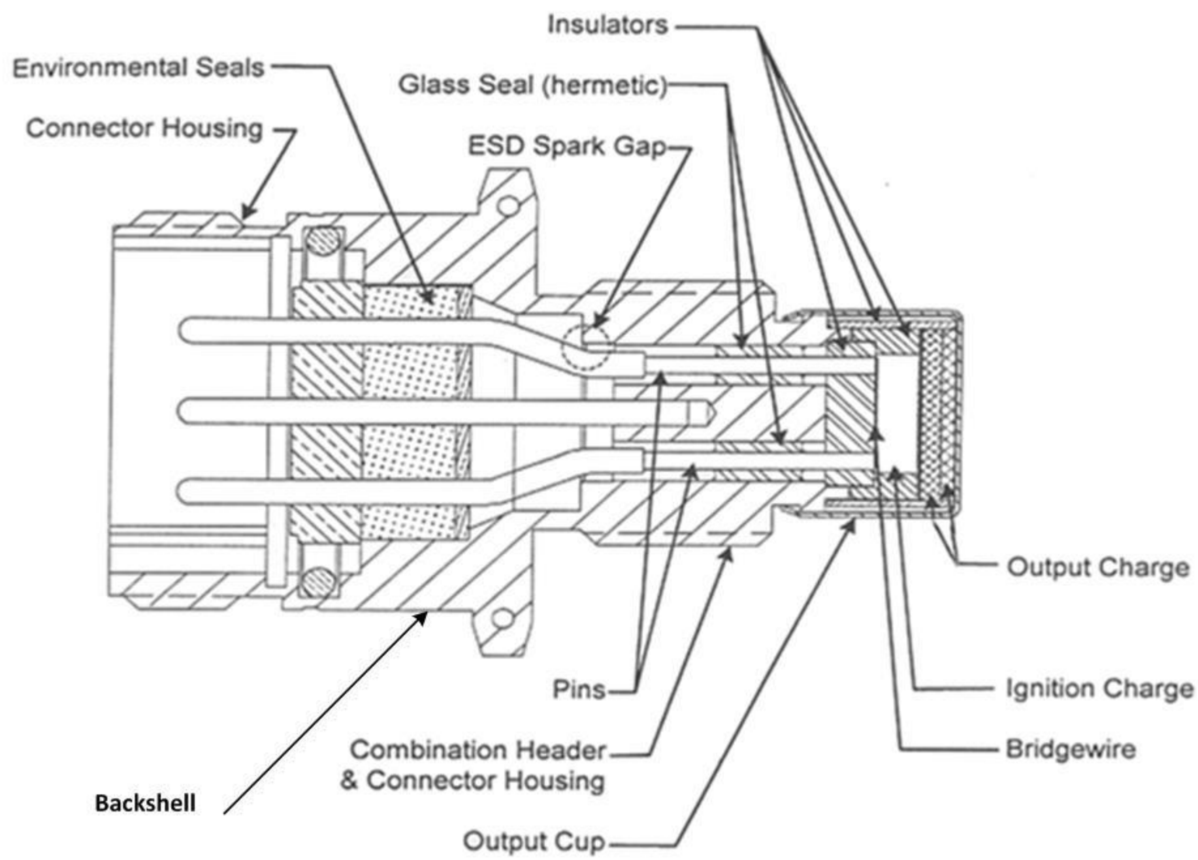
- High temperature (200 ºF).[2]
- Low temperature (-65 ºF).[2]
- Temperature shock/humidity/altitude cycling.[2]
- Vibration.[2]
- Shock.[2]
- Drop test (6 feet).
- Drop test (40 feet).[3]

[2] Values can depend on the installation requirements.
[3] The cartridge does not have to function properly after a 40-foot drop but should remain safe, i.e., not explode or burst.

9.3 Cartridge Design.

Figure 1 below shows an example of a firex cartridge.

Figure 1. Cross-Section View of a Typical Firex Cartridge.



9.3.1 Backshell.

9.3.1.1 The backshell is typically a stainless steel housing with pins imbedded in a high-pressure hermetic seal. The pins provide the electrical connections from the external wiring or connector to the bridgewire. The environmental and glass seals are critical in providing a high-pressure hermetic seal before and after firing. They provide:

- Pressure and shock barrier between the explosive output and the electrical connections.
- Hermetic moisture seal to protect the explosive charges.
- Mechanical retention of the pins.
- Electrical isolation of the pins.

9.3.1.2 Cracked or poor seals, due to design or quality issues, can cause failures because the header pins could be explosively dislodged from the cartridge, resulting in agent leakage through the cartridge backshell. Also, cracked or poor seals can allow moisture to infiltrate and degrade the explosive charges during the environment exposure cycles of aircraft operation. This will degrade performance as well as the effective service life of the cartridge. The applicant should define the method of verifying the integrity of the seal (typically using a helium leak test).

9.3.2 Bridgewire.

The bridgewire initiates the detonation by heating the ignition charge to its ignition temperature. The specific bridgewire size and material should be selected to meet the required all-fire and no-fire reliability. See paragraphs 9.2.2.1 and 9.2.2.3 of this AC for the definitions of minimum firing current and no-fire current.

9.3.3 Explosive Charges.

The typical cartridge contains a minimum of two types of explosive charges: an ignition charge and an output charge. These charges initiate sequentially in the cartridge to generate the required energy output to rupture the firex system burst disc. The bridgewire initiates the cartridge by heating the ignition charge to its ignition temperature.

9.3.3.1 Ignition Charge**.**

The ignition temperature and thermal conductivity characteristics of the ignition charge have a significant effect on the all-fire and no-fire reliability and performance of the cartridge.

9.3.3.2 Output Charge**.**

When initiated, the output charge provides the energy focused to open the burst disc effectively without causing other damage to the firex system or aircraft.

9.3.4 Part Labeling.

To comply with § 2X.1301, firing cartridge components should be labeled. The labeling should include the applicable “manufactured on” date or “life-limited date.”

9.3.5 Shorting Springs and Shunts.

Firing cartridge components are often shipped using a shorting spring or shunt mounted on the cartridge electrical connector. There have been instances where shunts were left installed inadvertently on the cartridge connector during installation. This effectively disables the firex system. When these cases were detected, the FAA released airworthiness directives (ADs) to correct the condition. To comply with § 2X.1301 and prevent future ADs, firing cartridge components should be designed to ensure that cartridges may not be installed with such devices in place. Alternatively, where this is impractical, the device should be distinctively marked with instructions to ensure correct installation.

9.4 Cartridge Validation.

To validate compliance to § 2X.1301, the all-fire and no-fire condition tests may consist of firing a group or groups of cartridges at various current levels and noting the performance characteristics of the cartridge. The applicant should establish specific quantities of specimens for testing to be statistically significant and provide the desired confidence levels. The current levels should be statistically selected and the results analyzed to provide no-fire and all-fire current ratings at various required reliability and confidence levels (0.99 reliability at 95 percent confidence) with reference to the engineering design test schedule in MIL-DTL-23659F.

9.5 Basic Qualification.

The FAA recommends that the applicant qualify each cartridge design to meet and address the items listed in the engineering design test schedule in MIL-DTL-23659F, plus an additional test sequence to ensure open disc performance (pursuant to paragraph 9.2.3.2 of this AC) at high and low temperature extremes. The test should use a representative bottle and burst disc charged to the minimum allowable pressure using 7 bottle/disc test units per high and low temperature condition for a total of 14 firings. (See MIL-DTL-23659F.)

9.6 Pre-Production Design and Quality Control.

The FAA will review the applicant’s quality system to ensure the inspection system that is required by part 21 is in place. The applicant should ensure that the cartridge design, development, qualified baseline, and quality aspects are maintained throughout the production life cycle and meet the requirements in §§ 21.1, 21.137, 21.303, and Orders 8110.42D and 8120.22A.

9.6.1 Manufacturing Processes.

The applicant should use a documented and controlled system to ensure that cartridge components are manufactured or procured from a qualified source that provides closed-loop controls to ensure material acceptability. One example of the importance of this documented and controlled system is to ensure the quality of the seal in the cartridge body (header assembly), which is a critical component. Poorly manufactured seals may result in failure, as the header pins could be explosively dislodged from the cartridge, causing agent to leak through the cartridge or backshell, or allowing air or moisture contamination of the pyrotechnic mixture. The manufacturing processes that the applicant should address are identified and described below:

9.6.1.1 Bonding Assemblies**.**

Bonding of the assemblies is critical to ensure the cartridge meets all electrical requirements. Failure to achieve complete and proper bonded assemblies may cause failure in dielectric strength, insulation resistance, or electrostatic discharge capability. This may result in inadvertent firing of the cartridge during electrical surges from sources such as lightning, or failure to fire if the cartridge is electrically shorted. Bonding processes include, but are not limited to:

- Proper mix ratio definition.
- Cure temperature and time definition.
- Cleanliness of bonded surfaces definition.
- Coverage of bonded surfaces definition.
- Bridgewire material selection.

9.6.1.2 Bridgewire Welding**.**

Bridgewire welding is critical to ensure that the proper electrical energy is transferred to the explosive material, which is achieved through the bridgewire. Typically, the bridgewire is resistance-welded to the header pins and is process-sensitive. Poor bridgewire welds may result in the cartridge failing to fire as the bridge circuit may open during normal temperature cycling, shock, and vibration. Welding parameters include, but are not limited to:

- Length of the bridgewire.
- Location of the bridgewire weld on the header pins.
- Strength of the bridgewire welds.
- Resistance values.
- Bridgewire material.

9.6.1.3 Powder Preparation.

The applicant should use documented procedures to control critical processes. These procedures should ensure handling safety, ingredient consistency, and consistency from production lot to production lot. Each powder blend should be characterized and tested for performance and accepted prior to use in production cartridges. Typically, testing includes caloric content, particle size, thermal analysis, and performance analysis. Steps include, but are not limited to:

- Use of controlled and approved procedures.
- Acceptance testing of powder prior to use in production cartridges.
- Documentation and approval of raw materials.
- Storing and handling.
- Verification of moisture content.

9.6.1.4 Powder Loading.

Powder loading is critical to the functional performance of the cartridge. The applicant should verify moisture content, hygroscopic capability, and volatility of the powder to ensure proper ignition and output of the explosive. Proper density of the powder should be achieved to ensure all-fire and no-fire capability. Failure to ensure moisture, volatility content, and proper pack density will typically result in failure to fire or inadvertent firing from stray voltages. Processes include, but are not limited to, control of the:

- Process environment.
- Consolidation force of the explosive into the cartridge.
- Length of time the consolidation force is applied.
- Accuracy of the powder quantity to be loaded.

9.6.1.5 Hermetic Sealing.

Environmentally sealing the cartridge by a hermetic seal ensures the cartridge meets the prescribed life requirements. Failure to achieve a hermetic seal will reduce service life as the explosive material degrades through normal environment conditions. The applicant should verify the integrity by testing 100 percent for leakage (e.g., 1×10^{-6} standard cubic centimeter per second of helium at one atmosphere).

9.6.2 The FAA or its delegates will not allow deviation to the approved manufacturing procedures at any level of assembly, unless the applicant evaluates the deviation under an FAA-approved process.

9.7 **Quality Verification.**

To comply with § 2X.1301, the cartridge design or changes to cartridge design, manufacture, or processes of cartridge testing should encompass the entire spectrum of criteria from cartridge design, development, qualification, and production and storage prior to installation. The performance elements of the cartridge at the firex system level that are typically used to develop the test and validation methods are:

9.7.1 Design Development.

During development, the cartridge design requirements are dictated by the firex system performance requirements. The applicant can correlate these results with other non-system-level function tests (e.g., agent flow, function time, and environments) and use the results to determine how to test the cartridge based on the engineering design test schedule in MIL-DTL-23659F, and the addition of disc opening performance tests in paragraph 9.5 of this AC.

9.7.2 Design Change Control.

The applicant should have a process for design changes in a method acceptable to the FAA. The applicant should validate all design changes to the firex system performance and reliability requirements.

9.7.3 Design Qualification and Validation.

System qualification testing should ensure that the cartridge:

- Performs the required functions at the system level.
- Can effectively open the burst disc, allowing correct agent flow under all operating and expected environmental conditions.
- Does not cause any peripheral degradation of the firex system as the result of the explosive event occurring.

9.7.4 Testing.

9.7.4.1 During cartridge qualification and validation, the applicant should perform system level tests to demonstrate the capability of a cartridge design to meet the burst disc rupture requirements. A typical number of tests at the system level is seven according to MIL-C-22284A. Cartridge qualification and validation also involve non-system-level testing where key design elements are evaluated (see the engineering design test schedule in MIL-DTL-23659F). This combined test series establishes baseline reliability and performance parameters.

9.7.4.2 After design validation, the applicant should correlate the results with other non-system-level function tests to develop criteria for suitable production lot acceptance tests. Such testing can effectively indicate manufacturing process control issues in a validated design. However, the applicant should not use the results of the testing to demonstrate the suitability of a new design for a given system. Using non-system-level test methods to demonstrate similar performance of a new design to a qualified design does not validate the suitability of a new design to work properly in an installed firex system. The applicant should substantiate the use of non-system-level tests and analysis to show equivalence as installed on the actual firex system.

9.7.4.3 The applicant should verify proper storage and handling procedures are in place to ensure that firing cartridges function properly in support of §§ 2X.1301 and 2X.1309 requirements.

9.7.5 Production Lot Acceptance Testing.

Cartridge sample lot acceptance testing is a means of assessing the manufacturing process to ensure nothing has changed that might have affected cartridge performance. After cartridge qualification, the applicant should develop test methods and criteria to ensure production cartridges conform to the performance requirements of the qualified design. This demonstrates that the production cartridges have not changed with respect to the qualified design. Production lot acceptance tests should include, for example:

- Bridgewire resistance on 100 percent of the lot.
- Dielectric strength on 100 percent of the lot.
- Insulation resistance on 100 percent of the lot.
- Leakage on 100 percent of the lot.
- Radiographic on 100 percent of the lot.
- Electrostatic discharge on 100 percent of the lot (if applicable).
- No-fire on a lot sample.
- All-fire on a lot sample.
- Functional performance on a lot sample.

9.8 **Service Life Issues.**

9.8.1 The firex system is a safety system that is exposed to repeated cycles of temperature, altitude, and vibration. This system remains dormant, until it is needed, and then should perform flawlessly. Compromising on the long-term quality when approving new, modified, or replacement cartridges could result in catastrophic loss of the airplane. For example, cracked seals and poor welds can be patched with potting to pass helium leak tests during production lot acceptance. However, this low-quality fix may not survive the entire rated service life. Repeated cycles of temperature and altitude can force moisture into the explosive charges. As previously discussed, this can cause cartridge failure resulting in non-actuation of the firex system, which would compromise safety of the airplane. Section 2X.1301 requires that the systems function properly when installed.

9.8.2 To comply with § 2X.1301, the applicant should identify the method to validate the proposed service life of the cartridge. Accelerated life testing should reference AIAA S-113A-2016, section 5.5.1, *Age Surveillance of Explosive Components*, or equivalent, except for the following:

Note: Prior to initial approval, the applicant should complete this validation and evaluate the aircraft installation environment with respect to the service life test plan to ensure compatibility with the proposed service life of the cartridge.

1. An additional performance discharge sequence for the non-system-level function testing identified in paragraph 9.7.4.2 of this AC should be conducted in accordance with AIAA S-113A-2016.

2. When performing accelerated age testing as listed in AIAA S-113A-2016, section 5.5.1, *Age Surveillance of Explosive Components*, establish the temperature and time using the method referenced in the National Institute of Standards and Technology, NIST/SEMATECH e-handbook of Statistical Methods: http://www.itl.nist.gov/div898/handbook/apr/section1/apr151.htm.

9.8.3 Determining accelerated age test temperature and time using in-service temperature and time: Most aircraft installations do not have a uniform environmental temperature where the cartridges are installed. Some cargo installations are in a location that are environmentally controlled when the aircraft is in operation, but see temperature variations when the aircraft is not in use. Other cartridges are installed outside the pressure vessel of the aircraft in the same compartments as engine bleed ducting; these see large variations in temperature between ground operation and in-flight conditions (some may be as high as 160 ºF and as low as -80 ºF).

The number of collisions that can cause reactions increases exponentially with temperature. This can sometimes double with an increase of as little as 10 ºC. It may not be correct to use the average or mean installed temperature when determining the installed temperature used in the accelerated age testing calculation. Using a lower average temperature would ignore the detrimental effects that occurs at even relatively short periods of time at the highest temperatures. Using the maximum installed temperature would conservatively cover the in-service environment but would not take credit for the time spent at the lower temperatures. The applicant must propose a method found acceptable to the FAA to determine the usage temperature to be used in the accelerated temperature life testing.

9.9 **Final Approval Process.**

9.9.1 Qualification Document Package.

The applicant should include the following:

- An overall certification plan.
- Detailed drawings on the proposed item.
- Manufacturing and quality procedures and processes.
- Engineering change orders for the proposed item and configuration control.
- Statement of differences between the proposed item and the baseline item.
- Approved plan to address the testing specified in the engineering design test schedule in MIL-DTL-23659F.
- Data/report showing successful completion of all proposed component level tests on the proposed item.
- Approved qualification test plan on the applicant's and PAH's items.
- Data/report showing successful completion of approved qualification test plan.
- Data/report showing approved system-level test.

- Data/report showing successful completion of all system-level tests in the system-level test plan.
- Approved production functional test methods to be used on both items with an explanation of the pass/fail criteria.
- Approved service life test plan.
- Data/report showing successful completion of the service life testing according to the approved life test plan.
- Approved production quality screening plan (lot acceptance).

9.9.2 Final Qualification.

The qualification is performed by conducting adequate analyses and testing to verify that the components will function properly when installed in the installation environment with the required reliability. With respect to appropriate testing in RTCA/DO-160G, qualification provides an accepted means for testing components in various environments. Qualification can be done to support an application for a type certificate (TC), an amended TC, or an STC. The applicant should submit a qualification test plan to the FAA or its authorized designee. The results of the qualification should be provided for approval in a qualification test report to the FAA or its designee. Additionally, applicants may produce after-market components with a PMA.

9.9.2.1 There are three ways to receive a PMA. They are identicality, identicality by licensing agreement, and by test and computation. Sections 21.301 through 21.320 and Order 8110.42D describe the responsibilities of the FAA aircraft certification offices (ACOs) and manufacturing inspection district offices (MIDOs) and applicants, and the process for approving replacement and modification articles for installation on type-certificated products when issuing a PMA. The associated procedures for the FAA (MIDO) and manufacturing personnel are in Order 8120.22A. Applicant guidance is in AC 21.303-4. When applying these procedures to firex cartridges, the applicant should address the following items:

9.9.2.1.1 PMA Approval by Identicality.

Engineering drawings and specifications of the proposed cartridge should contain adequate detailed information to define the cartridge assembly and its components accurately, item by item, to show identicality to approved parts. The applicant must obtain FAA approval for any significant differences with the original approved cartridges under the test and computation method. Examples of significant differences are charge material changes, loading changes, process changes, changes in supplier or manufacturer, and physical configuration differences.

9.9.2.1.2 PMA Approval by Licensing Agreement.

According to § 21.303(a)(4), if the applicant obtains the design of the electrical firing cartridge by a licensing agreement, the applicant must provide evidence of that agreement.

9.9.2.1.3 PMA Approval by Test and Computation.

Test and computation requires a PMA applicant to conduct analyses and tests necessary to show they produce an electrical firing cartridge that meets the performance and reliability of the production version. The test method is to fire the cartridge in charged bottles under operational conditions. RTCA DO-160 (latest revision) provides guidance for component testing in the appropriate environment. Typically, the firex system-level tests are coordinated with the FAA. They are performed during the development and qualification of a new design and should establish system performance of replacement parts.

9.9.2.2 For parts determined to be critical or life-limited, the FAA may require the applicant to perform inspections and tests and submit the results to the FAA. These test results are necessary to show airworthiness of parts produced in conformity with the proposed design to obtain design approval. If the application is based on identicality, no testing is normally required. If the application is based on test and computation, or an STC, the applicant should submit both design and qualification test results.

9.9.2.3 The applicant should address all sections of this AC in a certification plan per part 21, subpart G, and obtain FAA approval for the certification plan prior to beginning qualification activities.

9.9.2.4 The applicant should address any aspect that might degrade:

- Safety.
- Performance.
- Soundness of mechanical design.
- Resistance to environment.
- Service life.

9.9.2.5 The FAA considers all cartridges in aircraft fire extinguishing and suppression systems as critical components and therefore requires the applicant to define performance testing requirements and conduct such tests.

9.9.2.6 The FAA considers all subsequent changes to the design under the definition provided in § 21.93. The applicant should not ship any parts that are of any major change configuration prior to receiving FAA approval of that change. The applicant may need to seek guidance as to whether its proposed change should be considered major or minor. Parts shipped prior to FAA approval of any major change may be subject to the suspected unapproved parts reporting requirements of Order 8120.16A.

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR-DMO@faa.gov, or (2) faxing it to (202) 267-1813.

Subject: AC 20-144A Date: Click here to enter text.

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph Click here to enter text. on page Click here to enter text..

☐ Recommend paragraph Click here to enter text. on page Click here to enter text. be changed as follows:

Click here to enter text.

☐ In a future change to this AC, please cover the following subject: *(Briefly describe what you want added.)*

Click here to enter text.

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☐ I would like to discuss the above. Please contact me.

Submitted by: ______________________________ Date: ________________________