



Advisory Circular

Subject: PROTECTION OF AIRCRAFT
FUEL SYSTEMS AGAINST FUEL
VAPOR IGNITION CAUSED BY
LIGHTNING

Date: 6/5/06

AC No: 20-53B

Initiated by: AIR-100

1. PURPOSE.

a. This advisory circular (AC) will show you how to gain Federal Aviation Administration (FAA) approval of your compliance with Title 14, Code of Federal Regulations (14 CFR) §§ 23.954, 25.954, 27.954, and 29.954, Fuel system lightning protection. We recommend how you can protect the aircraft's fuel system from lightning strikes that may ignite fuel vapors.

b. In establishing compliance to 14 CFR § 25.981, Fuel tank ignition prevention, this AC can also be used to supplement the guidance in AC 25.981-1, *Fuel Tank Ignition Source Prevention Guidelines*, for ignition prevention in regards to lightning.

c. This AC is not mandatory and does not constitute a regulation. It describes an acceptable means, but is not the only means, to show you how to gain certification for fuel system lightning protection. However, if you use the means described in this AC, you must follow it in all important respects.

2. SCOPE.

a. You can apply this AC to both conventional fuel systems and those using advanced composite structures or other new technologies. This AC gives you both information on, and references to, lightning effects and verification methods.

b. We address ignition hazards caused by direct effects on main and auxiliary fuel tanks, fuel tank components and plumbing, and the indirect effects (upset or damage) on analog or digital electronic and electrical systems that could lead to ignition hazards on wires or equipment such as fuel quantity probes located in a fuel tank cavity containing fuel vapor.

NOTE: For information on how lightning affects electric and electronic systems, see the current version of AC 20-136, *Protection of Aircraft Electrical / Electronic Systems Against the Indirect Effects of Lightning*.

c. You can also apply this AC when modifying fuel systems, such as adding tanks or other fuel system components. Since externally mounted tanks are often in direct lightning strike

zones, those tanks may be especially vulnerable to lightning hazards and must be adequately protected.

3. CANCELLATION. AC 20-53A, *Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning*, dated April 12, 1985, is cancelled.

4. DEFINITIONS.

- a. Attachment point:** the point where the lightning flash contacts the aircraft.
- b. Corona:** luminous discharge caused by an electrical potential difference between the aircraft and the surrounding atmosphere.
- c. Charge center:** area of high potential of opposite charge.
- d. Direct effect:** physical damage caused by lightning attaching to the system's hardware or components. Examples are arcing, sparking, or puncturing in the fuel tank skin.
- e. Indirect effects:** electrical transients caused by lightning strikes.
- f. Lightning flash:** the total lightning event consisting of one or more lightning strokes, plus intermediate or continuing currents.
- g. Lightning strike:** attachment of the lightning flash to the aircraft.
- h. Lightning strike zones:** aircraft surface areas and structures that are susceptible to lightning attachment, dwell time, and current conduction.
- i. Lightning stroke:** current surge occurring when lightning makes contact with the ground or another charge center.
- j. Streamering:** branch-like ionized path caused by a direct lightning stroke or lightning strokes that are imminent.
- k. Upset:** permanent or momentary degradation to the fuel system's performance.

5. LIGHTNING EFFECTS ON FUEL SYSTEMS.

- a.** Lightning may strike aircraft flying in or near thunderstorms, and nearby lightning flashes may produce corona and streamer formations on the aircraft. Lightning can be a hazard to aircraft fuel systems if those systems are not properly designed, built, and maintained.
- b.** The effects of lightning on aircraft can range from seemingly insignificant sparking at fasteners or joints to severe damage. If sparking occurs in a fuel vapor environment, it may ignite the fuel vapor, damaging the aircraft.
- c.** All or some of the lightning current may be conducted through fuel tanks or fuel system components. It is important to determine where the current flows through the aircraft to allow for adequate design measures to protect the fuel system.
- d.** Aircraft skin and fuel tanks are constructed of metals, low electrical conductivity composite materials, and electrically insulating materials, all of which react differently when

subjected to a lightning strike. Metals and carbon fiber composite materials (CFC) offer a high degree of electric field shielding and some magnetic field shielding. Electrically insulating materials, however, offer little or no electric or magnetic field shielding. Because of this, lightning does not have to come into direct contact with fuel systems to pose a hazard. Lightning-induced arcing, sparking, or corona may be sufficient to ignite fuel.

e. Damage from lightning strikes to non-conducting materials, such as fiberglass and aramid reinforced composites, can be more severe than damage to metal surfaces. A lightning strike can penetrate non-conducting materials easier, and directly ignite fuel vapors.

6. FUEL SYSTEM LIGHTNING PROTECTION

a. To protect fuel systems from lightning, you should do one, or a combination, of the following:

(1) Rid the fuel tank and fuel system of ignition sources. This is the preferred approach. To do this, you must specifically design for ignition source prevention, because thousands of amperes of current are conducted, and a spark of only about two-tenths of a millijoule released inside a fuel tank can start a fire or explosion.

(2) Reduce fuel tank flammability to ensure the fuel tank atmosphere will not support combustion, or,

(3) Design the fuel tank so that fuel tank pressures do not exceed structural design limits if fuel ignition occurs.

NOTE: FAA reports DOT/FAA/CT-83/3, *Users Manual for AC 20-53A Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning*, and DOT/FAA/CT-89/22, *Aircraft Lightning Protection Handbook*, provide detailed fuel system lightning protection techniques.

b. When designing the fuel system lightning protection, consider the following factors:

(1) Flammable fuel vapor may exist in any part of the fuel system.

(2) Streamering or direct lightning strikes may ignite flammable vapors in vent outlets.

(3) Streamers or corona can contain enough energy to serve as an ignition source.

(4) Strike attachment to poorly conducting parts may contain enough energy to induce sparking inside the fuel tank, and could ignite flammable vapors.

(5) Strike attachments may puncture the skin, heat fuel tank skins, or cause arcing in fuel tank structures.

(6) Lightning currents flowing in the internal components of the fuel system (such as fuel and vent lines, conduits, or internal structural parts) may produce electrical sparks and ignite flammable vapors.

(7) Lightning currents flowing in the airframe produce voltage differences between adjacent parts or structure. The lightning electromagnetic fields can induce transient voltage and current in the electrical wiring and components of the fuel system.

(8) Strike attachment may weaken adhesives/structural bonds or mechanical fasteners enough to affect the integrity of the fuel tank.

c. Composite materials such as CFC have lower electrical conductivity than aluminum. When used to construct fuel systems, CFC often require design features different from those required on metallic structures to provide an equivalent level of protection. Using adhesive bonding in the construction of CFC to build fuel systems may decrease lightning current conductivity. Decreased conductivity affects both metallic and non-metallic structures such as rubber or fiberglass. Also, indirect effects in composite structures, such as lightning-induced voltages in electrical wiring in the fuel system and other electrically-conducting parts, may be higher and have different waveforms than conventional aluminum airframes.

d. Parts of the fuel system are typically found throughout much of an aircraft, and occupy considerable volume. These parts include the fuel tanks themselves, and other areas that may contain fuel vapors. Protect all the following parts from lightning strikes when designing the aircraft:

- Vent outlets,
- Metal fittings inside fuel tanks,
- Fuel filler caps and access doors,
- Drain plugs,
- Tank skins,
- Fuel transfer lines inside and outside the tanks,
- Electrical bonding jumpers between components in a tank,
- Mechanical fasteners inside tanks, and
- Electrical and electronic fuel system components and wiring.

7. STEPS TO SHOWING COMPLIANCE. You may demonstrate compliance with the applicable certification requirements by following the steps below:

a. **Create a certification plan.** Describe the fuel system lightning protection approach and analytical procedures or qualification tests planned to show the protection effectiveness of your proposed aircraft fuel lightning protection. Where designs consist of unique characteristics or materials, we may impose special conditions, issue papers, or other regulations to show compliance with the certification requirements.

b. **Determine the Lightning Strike Zones.** Determine the aircraft surfaces, or zones, where lightning strike attachment will likely occur to your particular design, and the portions of the airframe through which currents may flow between these attachment points.

c. **Determine the Lightning Environment.** Identify the particular aircraft components that will be in each lightning strike zone, and determine whether certain components should be located elsewhere.

NOTE: AC 20-155, *SAE Documents to Support Aircraft Lightning Protection Certification*, offers methods you can use in determining lightning strike zones and the aircraft lightning environment.

d. Identify Possible Ignition Sources. Identify systems and components that might ignite fuel vapor.

e. Set Protection Criteria. Set lightning protection pass/fail criteria for items you are evaluating.

f. Verify Protection Adequacy. To verify the adequacy of the protection designs, perform simulated lightning tests, perform analysis, or compare the protection design with previously proven protection designs. When analyzing protection designs, you should also identify margins to account for assumptions made in the analytical techniques. When your intended means of compliance includes tests, you should do the following:

(1) Describe, in your test plans:

- The production or test articles,
- Production or test article drawings as required,
- Installation procedures for the product,
- Applicable lightning zones,
- Test voltage or current waveforms used for your lightning simulations,
- Spark detection methods,
- Pass/fail criteria, and
- Schedules and locations of proposed tests.

(2) Get FAA acceptance of your test plan.

(3) Get FAA conformity of the test articles, and installation conformity of applicable portions of the test setup.

(4) Schedule dates for FAA to witness tests.

(5) Submit test reports describing all results for FAA review and approval.

8. MAINTAINING FUEL SYSTEM LIGHTNING PROTECTION.

a. Some fuel systems or equipment require dedicated protection devices or specific techniques to protect them. For these fuel systems and equipment, you should define requirements for maintaining and monitoring the lightning protection devices or techniques to ensure their integrity remains intact. You should also define the aircraft dispatch requirements, limitations, or both when a protection device has degraded.

b. Some fuel system components may be protected through the use of shield and connector electrical bonding, sealing materials, grounding jumpers, and structural foil shield liners. When using those types of devices, you must specify in the instructions for continued airworthiness

manual, procedures to prevent these protection items from remaining on the aircraft in a degraded condition, or how to prevent their accidental removal during normal aircraft maintenance. Degradation or removal of these items could cause the system to lose its designed protection integrity.

c. Where possible, do not use devices susceptible to corrosion, fretting, flexing cycles, or other life-limiting design features. However, when using those types of devices, you must publish their replacement cycles in your instructions for continued airworthiness manual. When using devices such as surge protectors to protect against direct and indirect effects, you must identify the number of lightning strikes each device can encounter before it must be replaced.

d. Define the inspection techniques and intervals necessary to ensure the continued integrity of the lightning protection features. Examples of inspection techniques include built-in test equipment, resistance measurements, or continuity checks of the entire system.

9. RELATED DOCUMENTS AND HOW TO GET THEM.

a. 14 CFR. Order copies of the 14 CFR sections referenced in this AC from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325. Telephone 202-512-1800; fax 202-512-2250. You can also get copies from the Government Printing Office (GPO) electronic CFR Internet website at www.gpoaccess.gov/cfr/.

b. FAA ACs. Order copies of AC 20-136, AC 20-155, and AC 25.981-1 from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20795. Telephone 301-322-5377, fax 301-386-5394. You can also get copies from our Regulatory and Guidance library (RGL) at www.airweb.faa.gov/rgl. On the RGL website, select “Advisory Circulars,” then select “By Number.”

c. FAA Reports. Order DOT/FAA/CT-83/3, *Users Manual for AC 20-53A Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning*, and DOT/FAA/CT-89/22, *Aircraft Lightning Protection Handbook*, from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Telephone 703-605-6000, fax 703-605-6900, website www.ntis.gov: You can also get copies from the FAA’s William J. Hughes Technical Center Reference and Research Library at <http://actlibrary.tc.faa.gov/>. On the website, select “Search Library Catalog,” then input the report number.

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