U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Engine Fire Protection § 33.17 | **Date:** 8/3/09 | **AC No:** 33.17-1A
Initiated by: ANE-111

1. PURPOSE. This advisory circular (AC) provides definitions, guidance, and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the engine fire protection requirements of Title 14 Code of Federal Regulations (14 CFR 33.17). The guidance provided in this AC supersedes information contained in AC 33-2B titled "Aircraft Engine Type Certification Handbook" (Chapter 3, Section 22, titled "Section 33.17, Fire Prevention").

2. APPLICABILITY.

a. The guidance provided in this document is directed to the applicant engine manufacturer or modifier.

b. This material 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 Federal Aviation Administration (FAA) will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as "should," "shall," "may," and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if 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 as the basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from existing regulatory requirements.

3. DEFINITIONS. For the purposes of this AC, the following definitions apply:

a. Hazardous Quantity: An amount of flammable fluid, vapor or other material which could sustain a fire of sufficient severity and duration to significantly increase the overall fire hazard or result in a hazardous condition.

b. External Lines, Fittings, and Other Components: Engine parts conveying flammable fluids that are external to the main engine casings, frames, and other major structure. These parts include, but are not limited to, fuel or oil lines, accessory gearbox, pumps, heat exchangers, valves, and engine fuel control units.

c. Fireproof: The capability of a part or component to withstand, as well as or better than steel, a 2000 ^{0}F average flame temperature (± 150^0 F individual thermocouple tolerance) for a minimum of 15 minutes, while still performing those functions intended to be performed when exposed to a fire.

d. Fire Resistant: The capability of a part or component to perform those functions intended to be performed while exposed to the heat and other conditions that are likely to occur at the particular location, and to withstand a 2000^0 F average flame temperature (± 150^0 F individual thermocouple tolerance) for a minimum of 5 minutes.

e. Hazardous Condition: Any hazardous engine effect listed in § 33.75(g)(2), or any other result of exposure to fire which would prevent the continued safe operation or shutdown of the engine.

f. Fire Hazard: The unintentional release or collection of flammable fluids; vapor or other materials; a failure or malfunction which results in an unintentional ignition source within a fire zone; the potential for a hazardous condition as the result of exposure to a fire, or a sustained or non-self extinguishing fire.

4. GENERAL.

a. Intent and Objective: The overall intent of § 33.17 is to ensure the design, materials, and construction methods used will minimize the occurrence and spread of a fire. The primary objectives are to contain, isolate and withstand a fire; prevent any source of flammable material from feeding an existing fire; perform those engine functions intended to be performed in the case of fire, and not result in a hazardous condition.

b. Test Article: The test article should be type design or equivalent. Care should be taken to assure that installation side connections are also type design or equivalent.

c. Fire Protection Capability - Determination of Fireproof vs. Fire Resistant: Section 33.17(b) requires all flammable fluid conveying parts or components be fire resistant or fireproof, as applicable, while § 33.17(c) generally requires flammable fluid tanks and associated shutoff means to be fireproof. Therefore, it must be determined which level of fire protection capability must be shown for each component requiring a fire protection evaluation. A fire resistant standard is generally applied to components that are required to provide certain function(s) for the first five minutes of a fire in order to give the flight crew time to detect the fire and safely shutdown the engine. Controls whose failure or malfunction could contribute to the spread of fire after engine shutdown must be fireproof.

(1) In general, components which convey flammable fluids can be evaluated to a fire resistant standard, provided the normal supply of flammable fluid can be stopped by a shutoff feature (also refer to § 33.71(c)(8)). For example, the fire resistant criteria has been applied to engine fuel system components because the 5 minute exposure provides a reasonable time period for the flight crew to recognize a fire condition, close the appropriate fuel shutoff valve(s), and shut down the appropriate engine, thereby cutting off the fuel source.

(2) However, oil system components of turbine engines may continue to flow oil after the engine has been shutdown due to continued rotation (windmilling). These effects include the rotation of gearbox mounted oil pump(s), and subsequent oil flow through the lubrication system. The supply of oil to the fire might exist for as long as the continued rotation effects are present, or until the oil supply is depleted. Therefore, oil system components need to be evaluated from a fire hazard perspective (for example, quantity, pressure, flow rate, etc.) to determine whether the fire resistant or fire proof standard should apply. Historically, it should be noted that most oil system components have been evaluated to a fireproof standard.

(3) Other flammable fluid conveying components, such as those part of hydraulic and thrust augmentation systems, must be evaluated in a similar manner as described in paragraphs 4.c. and 4.c.(1) and (2) of this AC. However, flammable fluid tanks generally must be fireproof in accordance with § 33.17(c). Fluid tanks are discussed in paragraph 7.a. of this AC.

(4) Section 33.17(e) requires all engine control system components be fire resistant or fireproof, as applicable. Similar to § 33.17(b), it must be determined which level of fire protection capability must be demonstrated for the affected components. The requirement does not differentiate between control technologies, such as electronic, mechanical or fiber-optic components. However, if the component is flammable fluid conveying, then § 33.17(b) would apply. For other non-flammable fluid conveying control components, a fire resistant or fireproof standard is determined as described in paragraph 4.c. of this AC. Therefore, the function of the component must be considered when making this determination. Control components include, but are not limited to, electronic controllers, electro-mechanical metering devices, electrical harnesses, valves, fiber optic devices, etc.

(5) Note that §§ 23.1189(a), 25.1189 (a), and 29.1189(a) require a shutoff valve in all flammable fluid conveying components flowing into, within or through designated fire zones. However, shutoff means are not required for oil systems for turbine engine installations in which all components of the system in a designated fire zone, including oil tanks, are fireproof or located in areas not subject to engine fire conditions.

d. Fire Test Pass/Fail Criteria: In general, the following fire test criteria have been applied and found to be acceptable:

(1) Maintain the ability to perform those functions intended to be provided in the case of fire. The functions intended to be provided in the case of fire will be determined on a case by case basis. The following examples are included only to illustrate the case by case nature of making this determination. The applicant, along with the appropriate FAA Aircraft Certification Office (ACO) should coordinate early in the program in this regard.

(a) Engine fuel control components must not cause a hazardous condition while continuing to operate, but must allow (or may cause) a safe shutdown of the engine at any time within the required exposure time period. A safe engine shutdown at any time during the fire test is an acceptable outcome for this type of component, provided the safe shutdown is maintained until the end of the fire test period.

(b) For a shutoff valve which must be fireproof, the valve must be operable to the closed position after 5 minutes fire exposure, or should default closed, and be capable of maintaining this position without leakage of a hazardous quantity for the full 15 minute fireproof test.

(2) No leakage of hazardous quantities of flammable fluids, vapors or other materials. At no time during, or at the end of the test, should the test article leak a hazardous quantity of flammable fluid in any manner. Pressurized lines should remain pressurized during and following the test. Observation of the test article for a period after the test flame is removed, and with the test article still pressurized, is generally needed to determine if leakage has occurred and to what extent. Hazardous quantity is defined in paragraph 3. of this AC.

(3) No support of an existing fire event by the constituent material of the test article or by flammable fluid or material leaking from the test article.

(4) No residual fire. For example, a rapid self-extinguishing flame and no re-ignition after test flame removal is generally acceptable. However, consideration must be given to fires that continue to burn after removal of the test flame. This type of event could be either combustion of the constituent material of the test article, or combustion of flammable fluid leaking from the component (firewalls are not considered in either case). In general, these events are cause for failure of the test, unless it can be shown the residual fire will not significantly increase the overall fire hazard. The acceptability of such a test result will be determined on a case by case basis, and will consider the type and function of the component under test.

(5) No failure of a firewall. See paragraph 7(e) of this AC for further discussion of firewalls.

(6) No other hazardous condition should result. At no time during, or at the end of the test, should a hazardous condition result. A hazardous condition is defined in paragraph 3. of this AC.

5. MATERIALS DESIGN ASSESSMENT. When showing compliance with § 33.17(a), the applicant should conduct a design assessment of materials. Experience has shown that when using certain materials (for example, magnesium and titanium alloys), appropriate design precautions may be required to prevent an unacceptable fire hazard. Consideration should be given to the possibility of fire if certain materials rub or contact hot gases. Any materials used for abradable linings need to be assessed to ensure that fire or explosion hazards are avoided.

a. Use of Titanium: Many titanium alloys used in the manufacture of engine components will ignite and sustain combustion under certain conditions. In general, titanium fires burn very fast and are extremely intense. The molten particles in titanium fires generate highly erosive hot sprays that have burned through compressor casings with resulting radial expulsion of molten or incandescent metal. When showing compliance with § 33.17(a), the applicant should assess the overall design for vulnerability to titanium fires. If this assessment cannot rule out the possibility of a sustained fire, then it should be shown that a titanium fire does not result in a hazardous condition. Additional information on the use of titanium parts in aircraft engines can be found in AC 33-4, titled "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines" (see Appendix 1, reference number 3 of this AC).

b. Use of Magnesium: Many magnesium alloys used in the manufacture of engine components are highly combustible when in finely divided form, such as chips or powder. Therefore, magnesium use should be carefully evaluated when used in thin sections, or where rubbing or high scrubbing speeds will be a consideration. Additional information on the use of magnesium parts in aircraft engines can be found in FAA Report No.FAA-ADS-14, titled "A Study of the Flammability of Magnesium" (see Appendix 1, reference number 9 of this AC).. When showing compliance with § 33.17(a), the applicant should assess the overall design for vulnerability to magnesium fires. If this assessment cannot rule out the possibility of a sustained fire, then it should be shown that a magnesium fire will not result in a hazardous condition.

c. Abradable Linings: Many fan, compressor, and turbine modules have abradable linings between rotating blade tips and stator casings, and in certain seal applications. Depending upon the material used in the abradable lining, experience has shown that a fire or explosion can occur in the presence of an ignition source if a significant amount of lining is removed during rubs between the rotor and stator, or in labyrinth seals. Under certain conditions, auto-ignition can occur in the mixture of small abradable particles and hot flowpath gases or in bearing compartments. These situations should be evaluated by the applicant for each fan, compressor, and turbine stage with abradable linings, and for other rotating seal applications.

d. Absorbent Materials: If absorbent materials are used in close proximity to flammable fluid system components, they must be treated or covered to prevent the absorption of a hazardous quantity of flammable fluid.

e. Fiber and Resin Materials: Certain fiber and resin materials, such as aramid fiber (for example, kevlar fabric) or carbon/graphite composites may be combustible under certain circumstances. In engines, aramid fabric is typically used as part of fan rotor containment systems. Carbon/graphite composites have also been used for fan blades, thrust reverser components, and other parts. When showing compliance with § 33.17(a), the applicant should assess the overall design for vulnerability to fires supported by these materials. If the assessment cannot rule out the possibility of these components supporting a sustained fire, then it should be shown that such a fire will not result in a hazardous condition.

6. CONDUCT OF FIRE TESTS.

a Test Equipment: Guidance on acceptable burner types, burner configurations, and other test hardware can be found in AC 20-135, titled "Powerplant Installation and Propulsion System Component Fire Protection Methods, Standards, and Criteria", and FAA Report No. 3A, titled "Standard Fire Test Apparatus and Procedures" (see Appendix 1, reference numbers 1 and 2 of this AC). Pre and post test calibrations of burner equipment are generally required. Measured burner flame temperature fluctuations during the test are acceptable only when the pre and post test calibrations are within the prescribed limits, and test burner controlling parameters are constant during the test. Experience has shown the measured temperature of the flame could be affected by the presence of the component under test.

b. Flame Impingement Location: The FAA has accepted the following methods for determining fire test flame impingement locations:

(1) General Method: The test flame should be applied to the test article feature(s), which are determined by analysis or test, to be critical with respect to surviving the effects of the fire. For this approach, determination of the flame impingement location(s) should consider, as a minimum, the following potential factors:

- Materials;
- Geometry;
- Part critical features;
- Local torching effects;
- Vibration;
- Internal fluid level/pressure/flow rate;
- Surface coatings;
- Fire protection features;
- Wetting; and
- Other factors not listed may also apply.

(2) Installation Analysis Method: For this method, the test plan may consider all potential sources of fire in the intended installation when determining the test flame impingement location requirements. The intent is to identify locations or features that cannot be directly impinged by fire, and evaluate the critical features at locations that can be directly impinged. If the applicant chooses this installation analysis approach, it should be based on the actual intended installation, and should consider, as a minimum, the potential factors noted above, and specifically the following potential installation factors:

- Cowling and nacelle structure;
- Adjacent structure shielding;
- Undercowl airflow;
- Aircraft engine build up (EBU) hardware;
- Fuel sources;
- Air sources; and
- Other factors not listed may also apply.

Such installation analyses should avoid simple generalities, such as "the most likely flame direction is vertical assuming fuel collects at the bottom of the cowl," and should generally be coordinated with the installer before the test plan is submitted. If this approach is used, each new installation will need to be re-evaluated against the original fire protection substantiation to confirm its applicability to the new installation. A notation in the installation instructions may be necessary to explain this limitation. Lastly, due consideration should be given to fire protection features such as fire shields, fire protective coatings, or other methods, so as to not discourage or invalidate their use for fire prevention purposes.

c. Operating Parameters for Test Articles: The operating characteristics and parameters of the test article should be consistent, but conservative, relative to the conditions that might occur during an actual fire situation in the type design product. For example, where a high internal fluid flow increases the heat sink effect, and is less conservative with respect to fire susceptibility, a minimum flow condition should be specified for the test. The same is true for examples relating to internal fluid temperatures, quantity, or other parameters. This evaluation primarily concerns critical inflight operating conditions, including continued rotation (windmilling and propeller feathering) after shutdown. Consideration of engine basic failure states (for example, mechanically damaged component, or locked main rotor) are not generally under consideration when evaluating test conditions. In addition, any facility slave hardware used to establish boundary conditions for the test (for example, simulated engine heat exchanger) must do so in a manner representing type design operation.

d. Other Guidance: Other guidance on acceptable methods of conducting fire tests can be found in AC 20-135, and FAA Report No. 3A (see Appendix 1, reference numbers 1 and 2 of this AC).

7. OTHER CONSIDERATIONS.

a. Flammable Fluid Tanks:

(1) Flame Impingement Location: In the absence of an acceptable installation assessment, the fire test flame should be applied to the tank location(s) or feature(s) that have been determined, by analysis or test, to be critical regarding surviving the effects of the fire (that is, the location(s) or feature(s) least likely to survive the test conditions or meet the test pass/fail criteria). In selecting the flame application location(s), all features of the tank assembly must be considered. Typical tank installation features include, but are not limited to:

- Tank body;
- Inlet and outlet assemblies;
- Sight-gauge;
- Drain plug;
- Magnetic chip detector;
- Quantity sender assembly;
- Vent line assembly;
- Fill cap and scupper;
- Mounts;
- Shutoff valve;
- Temperature sensor; and
- Air/fluid separator assembly.

Tanks can be designed and manufactured with any combination of the above features, or other features not listed, and of varying materials. Therefore, in some instances, compliance with § 33.17 may need to be supported by data from other fire tests, multiple location testing, subcomponent level tests, or service experience, to cover all tank assembly features. Also, other aspects of determining impingement location should be considered, such as vent system performance (for example, oil tank fire tests have failed due to high internal pressure and inadequate venting), the lack of heat sink effect for tank features at or above the operating level (that is, the water line) of the tanks fluid contents; and the affect of any special protective features (for example, shields, coatings, feature placement, etc.) incorporated into the design when developing the fire test plan.

(2) Other Test Parameters: With respect to fluid quantity, the tank quantity at the start of the test should be no greater than the minimum dispatchable quantity minus the normal gulping volume, unless a greater quantity is more severe. Relative to flow rate, the first five minutes of the test should be conducted at the most critical operating condition (typically a minimum flight idle flow rate), and the subsequent 10 minutes should be conducted at an engine shutdown flow rate (continued rotation considered). The test may be run, at the applicant's option, for 15 minutes at the most critical condition (worst case of engine operating or inflight shutdown conditions).

(3) Fluid temperature should be at its maximum value (greater of steady-state or transient limit established under § 33.7) at the start of the test, unless a lower temperature is more severe. The tank internal pressure should be the normal working pressure for the operating conditions at the start of the test. It is understood these values may change due to the test conditions.

(4) The tank design and its intended application should be reviewed, and provide reasonable assurance the test set-up reflects the most critical flame impingement orientation and operating conditions for the intended application. The aircraft requirements of parts 23, 25, 27, and 29 rely heavily on the fire prevention findings of part 33. Failure to adequately test may result in aircraft installation issues.

b. Air Sources: In accordance with § 33.17(a), the applicant should evaluate the effect of fire on components conveying bleed air, and evaluate whether failure of such components could further increase the severity or duration of a fire within a fire zone.

c. Engine Mounts: The fire protection requirements for engine mount systems (including engine type design) are governed by the aircraft regulations, and compliance is shown as part of the aircraft certification. The engine manufacturer should coordinate with the installer to minimize the possibility of installation issues affecting aircraft certification.

d. Hot Surface Ignition (HSI): Information concerning hot surface ignition is available in SAE Report No. 690436, titled "Ignition of Aircraft Fluids on High Temperature Engine Surfaces", and FAA Report No. FAA-RD-75-155, titled "Ignition and Propagation Rates for Flames in a Fuel Mist" (see Appendix 1, reference numbers 7 and 8 of this AC).

e. Firewalls (§ 33.17(d)): If a component's primary function is that of a firewall, and is part of the engine type design, then it must comply with the requirements of § 33.17(d). For test demonstrations, at no time during or at the end of a fire test should the firewall component fail to contain the fire within the intended zone or area. Acceptable evidence that the fire is contained would be if the firewall component does not develop a burn through hole, does not fail at any attachment or fire seal point around its periphery, does not cause backside ignition, and does not continue to burn after the test flame is removed. Also, in no case should a hazardous quantity of fuel or fuel/air mixture leak around or pass through the firewall. In addition, the firewall should contain the fire without resulting in a hazardous condition. The effects of pressure and mechanical loading on the firewall structure and associated seals must be considered when evaluating overall firewall capability and testing under § 33.17. AC 20-135 provides additional guidance for the testing and evaluation of firewalls and fire seals (see Appendix 1, reference number 1 and of this AC). Also, firewall components will also be evaluated at the aircraft level (for example, §§ 1191 and 1193 of parts 23, 25, 27, and 29). Lastly, firewalls must be protected against corrosion as required by § 33.17(d)(3).

f. Shielding (§ 33.17(b)): The overall intent of the § 33.17(b) requirement concerning the shielding and location of components, is to minimize the possibility of leaking flammable fluids contacting ignition sources and igniting. Ignition sources include hot surfaces with temperatures at or above the typical auto-ignition temperature for aviation fuels, oils, and hydraulic fluids, or any component that produces an electrical discharge. Compliance with this requirement has been shown by installation of drainage shrouds around flammable fluid lines or fittings; installation of spray shields to deflect leaking fuel away from ignition sources; and general component location on the engine which minimizes the possibility of starting and supporting a fire. Therefore, the overall substantiation should show that leaked flammable fluid would not likely impinge on an ignition source to the extent of starting and supporting a fire. For kerosene type fuels, an auto-ignition temperature of 450^0 F has been accepted, although fuel/air ratio, nacelle venting and other factors may play a role in determining whether hot surface ignition is a hazard for a given design. Information concerning hot surface ignition is available in SAE Report No. 690436, and FAA Report No. FAA-RD-75-155 (see Appendix 1, reference numbers 7 and 8 of this AC).

g. Drains and Vent Systems (§ 33.17(b) and (f)): Certain drain and vent systems may be exempt from the requirements of § 33.17(b) if it can be shown they do not typically contain or convey flammable fluids during normal engine operation. In this context, normal operation is the taxi and flight portions of a typical flight. An example of a drain line that might be exempt is a combustor drain line that typically drains off residual fuel after an aborted engine start. An example of a tube or line which would not be exempt is a shrouded fuel manifold. Such a line is considered a single assembly that cannot be separated into its main fuel line and its outer drain line (which would flow if the main manifold failed). In the case of a drain and vent system line that would flow a hazardous quantity of flammable fluid during continued rotation, then a fireproof standard may be appropriate. A drain collection reservoir that stores a hazardous amount of flammable fluid would likely be evaluated against a fireproof standard. The function of each drain or vent system component should be carefully reviewed in making these determinations. Lastly, a drain and vent system flow capacity should be equal to the maximum flow rate that the drain or vent line may need to convey.

h. Electrical Bonding (§ 33.17(g)): Electrical bonding is a means to protect against the effects of unintentional electrical discharges or fault currents. Specifically, bonding can help minimize the risk of the ignition of flammable materials from static electrical discharges. Components, modules or equipment that may cause, or are susceptible to such effects must be electrically bonded (grounded) to the main engine reference. Conductive parts are considered to be bonded when they are mechanically interconnected to maintain a common electrical potential. This may be shown by an examination of the type design drawings, electrical continuity checks, and physical inspection of a representative engine. An additional benefit of good electrical bonding of engine components is the minimization of electromagnetic interference of electrical equipment, especially controls.

i. Powerplant Designated Fire Zones: Powerplant fire zones are designated regions of a powerplant installation as identified in parts 23, 25 and 29, specifically § 1181 in each part. A generic definition of fire zone is a flammable fluid leakage zone that contains a nominal ignition source. Aircraft areas outside power-plant installations can also be a fire zone.

8. TEST PLANS.

a. Certification test plans should include, but are not limited to, the following information:

- Component name(s);
- Part number(s);
- Part detail drawing(s) or sketches (for example, denote critical features);
- Installation drawing(s) or sketches (for example, describe installation in an engine);
- Description of component operation;
- Hardware reconciliation to type design (test article and installation connections);
- Definition and range of component operating parameters;
- Flame direction/impingement analysis;
- Fireproof/fire resistant analysis;
- Test equipment, test set-up, calibrations, and test fluids;
- Test methods and procedures;
- Test pass/fail criteria;
- Data recording methods;
- Applicable regulations; and
- Time and place of test.

b. The proposed certification test plan should contain as a minimum; the information described in paragraph 8.a. of this AC, and should be submitted to the applicable FAA ACO for coordination and approval before conducting the fire testing.

c. The cognizant ACO and engine manufacturer should review the part 33 compliance plan, ensuring the fire prevention intent and objective of each part 33 section is met. Regarding the aircraft requirements of parts 23, 25, 27, and 29 listed in AC 20-135, the applicant should be encouraged to review these sections with the installer early in the program to minimize potential installation problems after engine certification.

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APPENDIX 1

REFERENCES

1. U.S. Department of Transportation. Federal Aviation Administration. Advisory Circular 20-135 *Powerplant Installation and Propulsion System Component Fire Protection Methods, Standards, and Criteria*, dated February 6, 1990.

2. U.S. Department of Transportation. Federal Aviation Administration. Powerplant Engineering Report No. 3A *Standard Fire Test Apparatus and Procedures*, Revised March 1978.

3. U.S. Department of Transportation. Federal Aviation Administration. Advisory Circular 33-4 *Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines*, dated July 28, 1983.

4. U.S. Department of Transportation. Federal Aviation Administration. Report No. SAE AS1055D *Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components*, dated August 2007.

5. U.S. Department of Transportation. Federal Aviation Administration. Report No. SAE AIR 1377 *Fire Test Equipment for Flexible Hose and Tube Assemblies*, dated January 1980.

6. U.S. Department of Transportation. Federal Aviation Administration. Report No. FAA-RD-76-213 *Re-evaluation of Burner Characteristics for Fire Resistance Tests*, dated January 1977.

7. U.S. Department of Transportation. Federal Aviation Administration. SAE Report No. 690436 *Ignition of Aircraft Fluids on High Temperature Engine Surfaces*, by W.T. Westfield of the FAA.

8. U.S. Department of Transportation. Federal Aviation Administration. Report No. FAA-RD-75-155 *Ignition and Propagation Rates for Flames in a Fuel Mist*, dated October 1975, by C.E. Polymeropoulos.

9. U.S. Department of Transportation. Federal Aviation Administration. Report No. FAA-ADS-14 *A Study of the Flammability of Magnesium*, by Paul Boris, Systems Research and Development Service, FAA dated April 1964.