



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

Advisory Circular

Subject: Engine Fuel Systems

Date: MM/DD/YYYY **AC No:** Draft AC
Initiated By: AIR-624 33.67

1. **PURPOSE.**

This advisory circular (AC) provides guidance for demonstrating compliance with the requirements of Title 14, Code of Federal Regulations (14 CFR) Section 33.67, *Fuel system*. This AC addresses turbine aircraft engine compliance methods, failure modes, § 33.67 lessons learned, and references to associated aircraft-level guidance. It does not address aircraft-level fuel system icing effects or compliance.

2. **APPLICABILITY.**

2.1 The guidance in this AC is for aircraft engine manufacturers, modifiers, Federal Aviation Administration (FAA) engine type-certification engineers, and FAA designees.

2.2 The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. The document is intended only to provide information to the public regarding existing requirements under the law or agency policies. This AC is not mandatory and does not constitute a regulation. This AC describes an acceptable means, but not the only means, to show compliance to § 33.67. However, if you use the means described in the AC, you must follow it in all important respects. When the method of compliance in this AC is used, terms such as “should,” “may,” and “must” are used only in the sense of ensuring applicability to this particular method of compliance. The FAA will consider other means of showing 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, the FAA becomes aware of circumstances that convince us that following this AC would not result in compliance with the applicable

This document does not represent final agency action on this matter and should not be viewed as a guarantee that any final action will follow in this or any other form.

regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as a basis for finding compliance.

- 2.3 This 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. **RELATED READING MATERIAL.**

The following materials are referenced in this document. Unless otherwise indicated, you should use the current edition if following the method of compliance set forth in this AC.

3.1 **Title 14, Code of Federal Regulations (CFRs).**

- Section 23.2430, *Fuel systems.*
- Section 25.951, *Fuel System--General.*
- Section 25.952, *Fuel system analysis and test.*
- Section 25.955, *Fuel flow.*
- Section 25.1305, *Powerplant instruments.*
- Section 25.1337, *Powerplant Instruments.*
- Section 27.955, *Fuel flow.*
- Section 27.1337, *Powerplant Instruments.*
- Section 29.955, *Fuel flow.*
- Section 29.1337, *Powerplant Instruments.*
- Section 33.5, *Instruction manual for installing and operating the engine.*
- Section 33.7, *Engine ratings and operating limitations.*
- Section 33.17, *Fire protection.*
- Section 33.67, *Fuel system.*
- Section 33.75, *Safety analysis.*
- Section 33.89, *Operation test.*

3.2 **FAA Documents.**

- AC 20-24D, *Approval of Propulsion Fuels, Additives, and Lubricating Oils.*
- AC 20-29B, *Use of Aircraft Fuel Anti-icing Additives.*

- AC 20.135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria.*
- AC 25.1309-1A, *System Design and Analysis.*
- AC 33-2C, *General Type Certification Guidelines for Turbine Engines.*
- AC 33.7-1, *Ratings And Operating Limitations for Turbine Engines.*
- AC 33.17-1A, *Engine Fire Protection.*

3.3 **Other US Government Publications.**

- Military Specification MIL-E-5007D, *Engines, Aircraft, Turbojet and Turbofan, General Specification For, Table X, Fuel Contaminants*, dated October 15, 1973.

3.4 **Foreign Authority Publications.**

- Air Accident Investigation Branch (AAIB), United Kingdom, Department for Transport, *Aircraft Accident Report 1/2010- Boeing 777-236ER, G-YMMM, 17 January 2008: Report on the accident to Boeing 777-236ER, G-YMMM, at London Heathrow Airport on 17 January 2008*, dated December 10, 2014.

3.5 **Industry Publications.**

- SAE International, SAE Aerospace Informational Report AIR4246D, *Contaminants for Aircraft Turbine Engine Fuel System Component Testing*, dated September 27, 2017.

4. **DEFINITIONS.**

The following terms and definitions apply to this AC.

- **Sticky range.** As identified by test, a fuel temperature range between -5°C and -20°C, at which slushy ice can accumulate in the fuel feed system.
- **Minimum engine inlet fuel pressure.** The minimum aircraft fuel pressure required for the engine fuel pump to operate, in case the aircraft pressurization means fails. This pressure is also known as “suction feed” pressure.

5. **BACKGROUND.**

This AC provides guidance for demonstrating compliance with § 33.67, *Fuel system*, which provides that the engine must function properly under each operating condition required by part 33 with fuel supplied to the engine at the flow and pressure specified by the applicant. This AC also provides guidance on addressing failure modes recently observed in service, that relate to specific requirements of § 33.67. In addition, this AC includes information on aircraft-level regulations (listed in paragraph 6.2.1) that may also impact engine design.

6. GUIDANCE.

6.1 Minimum Engine Fuel Inlet Pressure.

With fuel supplied to the engine at the flow and pressure specified by the applicant, § 33.67(a) requires that the engine must function properly under each operating condition required by part 33. The engine applicant should:

- Determine the minimum engine inlet fuel pressure the engine requires for proper operation.
- Consider the condition in which the aircraft's means of fuel pressurization fails (also known as "suction feed") and consult with the aircraft manufacturer to determine any other operations in which aircraft-level fuel pressurization is lost.

Include any related engine limitations in the installation instructions required by § 33.5.

Fuel pressure at the engine fuel inlet is also a requirement of § 33.7(c)(6)(i). Detailed guidance is provided in AC 33.7-1, paragraph 15, and summarized here. The minimum and maximum fuel inlet pressures will be incorporated in the engine type certificate data sheet. The installation manual should also include any maintenance actions required if the engine has operated with the aircraft fuel pump in a degraded or failed condition. Findings of compliance should consider all fuel types proposed under § 33.7(c)(2).

6.2 Fuel Filtration Limits and Bypass Flightdeck Indication.

6.2.1 Any operational fuel filtration limitations must be specified as required by § 33.7(c)(9) and included in the approved instructions for installing and operating the engine as required by § 33.5. The applicant should also be aware of aircraft-level requirements that require engine provision for flightdeck indication of filter, strainer, or other fuel bypass systems. These include:

Section 23.2430, *Fuel systems*,
Section 25.951, *Fuel System (General)*,
Section 25.952, *Fuel system analysis and test*,
Section 25.955, *Fuel flow*,
Section 25.997, *Fuel strainer or filter*,
Section 25.1305, *Powerplant instruments*,
Section 25.1337, *Powerplant instruments*,
Section 27.955, *Fuel flow*,
Section 27.1337, *Powerplant instruments*,
Section 29.955, *Fuel flow*, and
Section 29.1337, *Powerplant instruments*,

The applicant should coordinate with the aircraft manufacturer to determine which bypass systems require flightdeck indication. In addition to the required fuel filter,

engine fuel systems commonly include additional filters and screens to prevent clogging and damage to engine components in the fuel system, such as screens that have been installed downstream of the engine-driven pump to prevent debris from contaminating downstream components. Additional indications for these features may be needed to support aircraft-level requirements. The aircraft manufacturer will assess these features as part of the engine and aircraft fuel system analysis. Fuel oil heat exchangers (FOHE) may clog and restrict oil cooling and cause shutdown or failure of the engine or other critical engine components. Section 25.1305(c)(7) outlines the aircraft-level requirement for the indication. Section 25.1309(c) states, “Warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors which could create additional hazards.” General guidance on 25.1309(c) can be found in AC 25.1309-1A.

6.3 **Prevention of Hazardous Engine Effects from Fuel Line Failures.**

Section 33.67(b)(3) requires that any fuel strainer or filter must be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the strainer or filter, unless adequate strength margins under all loading conditions are provided in the lines and connections. Other regulations also include requirements that may affect the fuel system design. Section 33.75, *Safety analysis*, paragraph (a)(3) states, in pertinent part, “The applicant must show that hazardous engine effects are predicted to occur at a rate not in excess of that defined as extremely remote (probability range of 10^{-7} to 10^{-9} per engine flight hour).” Section 33.75 (g)(2)(iv) states that an uncontrolled fire is considered a hazardous engine effect. Applicants should show that the chance of uncontrolled fire from failures of fuel lines is extremely remote. Section 33.17, Fire protection includes requirements on uncontrolled fire prevention and protection. Refer to AC 20-135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria*, and AC 33.17-1A, *Engine Fire Protection* for further guidance. Also, engine manufacturers should be aware that aircraft airworthiness standards (§§ 23.1337, 25.1337, 27.1337 and 29.1337) specifically call out requirements for instrumentation lines carrying flammable fluids under pressure to have restricting orifices or other safety devices at the source of pressure to prevent the escape of excessive fluid if the line fails. One means of limiting the fluid loss in a pipe failure is to include a restricting feature near each fuel pressure connection provided for instrumentation.

6.4 **Fuel Contamination.**

6.4.1 Fuel contamination guidance.

For § 33.67(b)(5) compliance, one-half the average predicted mission flight time has been considered to be a period acceptable to the Administrator for the demonstration time period. Test demonstrations should be conducted at fuel flows most critical to the mission. Refer to Table X of Military Specification MIL-E-5007D, “*Engines, Aircraft*,

Turbojet and Turbofan, General Specification For” for examples of fuel contaminants, particle sizes, and quantities to be considered. SAE International, SAE Aerospace Informational Report AIR 4246D, *Contaminants for Aircraft Turbine Engine Fuel System Component Testing* contains additional information on potential contaminants. If the engine is intended for use in Extended Operations (ETOPS), the mission time for calculating the amount of fuel contamination should not be less than the approved ETOPS diversion capability, plus 15 minutes.

6.5 Hazards from Water and Ice in Fuel.

6.5.1 Several types of hazards can result from water in the fuel.

Section 33.67(b)(4)(ii) requires that the fuel system is capable of sustained operation throughout its flow and pressure range with the fuel initially saturated with water at 80°F (27°C) and having 0.025 fluid ounces per gallon (0.20 milliliters per liter) of free water added and cooled to the most critical condition for icing likely to be encountered in operation. Fuel is hydrophilic and will absorb water from the atmosphere over time. This absorption can be mitigated but not eliminated by the use of ground refueling water filtration systems. Therefore, applicants should expect water to be absorbed by fuel in service.

6.5.2 Engine operation with water in the fuel.

Applicants must ensure that their engine will operate satisfactorily throughout the flight envelope, in accordance with § 33.65, *Surge and stall characteristics* and § 33.89(b), *Operation test*, with the concentration of liquid water required by § 33.67(4)(ii). In addition, applicants should ensure that operation with the amounts of water specified will not result in engine damage that could lead to a hazardous engine effect or failure.

6.5.3 Ice from aircraft fuel system (also known as slug/slush/snow shower).

One accident, described below, and at least three in-flight incidents have been attributed to engine power interruption due to restriction in fuel flow to the engine caused by the release of ice from aircraft fuel tubing.

6.5.3.1 **Engine Fuel Restriction or Blockage Caused by Ice.**

On January 17, 2008, an accident occurred when a transport airplane powered by two large turbofan engines operating from Beijing, China to London, England, crash-landed short of London Heathrow Airport runway 27L. The United Kingdom, Department for Transport, Air Accident Investigation Branch (AAIB), December 10, 2014, Aircraft Accident Report 1/2010- Boeing 777-236ER, G-YMMM, 17 January 2008: *Report on the accident to Boeing 777-236ER, G-YMMM, at London Heathrow Airport on 17 January 2008* (“AAIB report”), identified the following probable causal factors that led to the fuel flow restrictions:

- Ice had formed within the fuel system, from water that occurred naturally in the fuel, while the aircraft operated with low fuel flows

and lower fuel velocities in the fuel lines over a long period, and the localized fuel temperatures were in an area described as the “sticky range.”

- When the throttle was increased, which increased the fuel demand, accreted ice from within the aircraft and engine fuel system released, causing a restriction to the engine fuel flow at the face of the FOHE on both of the engines.
- The FOHE, although it had shown compliance to the applicable certification requirements, was susceptible to restriction when presented with soft ice in a high concentration, with a fuel temperature that is below -10°C and a fuel flow above flight idle.

Note: The investigation team discovered no abnormal water concentrations in the fuel system and subsequent analysis of fuel samples showed the fuel met all applicable standards, including for water content.

6.5.3.2 **Sudden Release of Ice and Water.**

In some aircraft designs, under certain conditions, water and ice can accumulate and suddenly release. Those conditions include operation at very low ambient temperatures for long periods, followed by warmer ambient conditions. This can occur even though bulk fuel water concentrations are consistent with § 33.67(b)(4)(ii). Soft and compactable ice can cause flow blockage around entries to narrow passages of the FOHE, filter elements, or strainers. This fuel icing behavior has become better understood as a result of investigations and should be addressed when showing compliance to § 33.67(b)(4)(ii).

6.5.3.3 **Analysis of Sudden Release of Ice and Water.**

To address the sudden release of ice and water into the engine fuel system, aircraft fuel system analysis is necessary to establish both the amount and physical state of ice and water that could threaten the engine during the longest flight under conditions with the lowest expected temperature. When setting the aircraft threat, the engine manufacturer should work with the aircraft manufacturer to establish the maximum amount of ice in the fuel released from the aircraft fuel system that the engine may encounter in service. Afterward, each fuel system component should be evaluated under its most critical condition for fuel icing regarding fuel temperature, fuel properties, water content, and potential continuous exposure to ice accumulation and release in the fuel system. Test experience has shown difficulty in consistently forming ice under laboratory conditions that can replicate the ice formation observed in actual installations. The applicant should consider factors that affect the formation and possible release of ice in the aircraft fuel system, such as temperature ranges that influence the

creation, collection, and release of the ice, such as the sticky temperature range described in the AAIB report, and the influences of contaminants other than water in the fuel. Critical icing temperature and component features that could contribute to the formation and possible release of ice in the fuel system should be reexamined for derivative engine models and new applications of existing engines.

6.5.3.4 **Ice Proportions.**

The applicant should determine the amount of ice the engine fuel system can tolerate and still function correctly in accordance with § 33.67(a). The analysis should consider each area in the engine fuel system vulnerable to ice accretion. Adverse operation includes power interruption or power loss. The engine must properly function when exposed to the maximum amount of ice that may be released from the aircraft into the engine, or up to the limit defined by the engine manufacturer, given the concentrations of water in § 33.67(b)(4)(ii). Ice slug release may not cause any thrust loss; § 33.67(b)(4)(ii) requires that the fuel system is capable of sustained operation throughout its flow and pressure range, with the fuel initially saturated with water and cooled to the most critical condition for icing likely to be encountered in operation.

6.5.3.5 **Compliance Demonstration.**

During the compliance demonstration of the cooled, water-saturated fuel portion of § 33.67(b)(4)(ii), the applicant may either:

1. Define the maximum amount of ice that may be released from the aircraft to the engine.

Engine manufacturers should work with the engine installer or airframer to define the maximum amount of ice that can be released at once by the aircraft's fuel system. The maximum amount of ice should be declared in the engine installation instructions. Then, the engine manufacturer should show through component or engine test that the turbine engine and its components (e.g., engine or generator FOHEs, fuel filter, engine-driven pump, or fuel control), will not be adversely affected by that amount of ice, or

2. Define the maximum water or ice slug that will not affect the engine.

An engine manufacturer may show, independent of the installer through component or engine test, the maximum ice amount that will not adversely affect engine operation. In this case, the applicant should include an engine limitation within the installation instructions required by § 33.5, the maximum amount of ice that will not adversely affect engine operation.

6.5.3.6 High Concentrations of Water.

Another hazard related to ice formation in the aircraft fuel system involves releasing transiently high water concentrations into the engine fuel system. Water concentrations much higher than the amount in § 33.67(b)(4)(ii) can be released into the engine when ice forms in the aircraft fuel system and then melts, either before reaching the engine or upon contact with the first engine component it encounters. Failure modes may happen that are different from those associated with solid ice in the fuel.

6.5.3.7 Engine Power Loss.

Engine manufacturers should consider power loss from high concentrations of water saturating the engine fuel filter or filters. If one filter becomes saturated by water, a fuel bypass valve may be triggered (see paragraphs 6.2 and 6.4). If further high concentrations of water are released after the initial fuel filter bypass is triggered, downstream fuel filters may also become saturated, resulting in fuel pressure reduction and potential power or thrust loss.

6.5.3.8 Other Failure Modes.

There are other failure modes caused by the ingestion of melted ice in the fuel to consider. Depending on the engine design, the water concentration and the total amount of water released can cause failures such as flameout or fuel system damage. Applicants should consider these additional failure modes when evaluating the potential effects of ice in the fuel.

6.5.4 Anti-icing additives.

In accordance with § 33.67(b)(4)(ii), the prevention of engine failures caused by solid ice in the fuel can be shown by demonstrating the effectiveness of specified, approved fuel anti-icing additives. Alternatively, this prevention of engine failures can be shown by demonstrating that the engine fuel system will maintain the fuel temperature at the fuel strainer or other critical fuel system components and the fuel inlet at temperatures above 32°F (0°C) under the most critical conditions.

6.5.4.1 Guidance for Fuel Anti-Icing Additives.

AC 20-29C, *Use of Aircraft Fuel Anti-icing Additives*, provides guidance on the use of anti-icing additives PFA-55MB and MIL-I-27686 in turbine aircraft fuel systems. Applicants should coordinate the use of anti-icing additives with the aircraft manufacturer since an engine requirement to use anti-icing additives will become a limitation in the Aircraft Flight Manual.

6.5.4.2 Fuel Anti-Icing Additives.

If an applicant elects to comply with § 33.67(b)(4)(ii) by means of fuel anti-icing additives, an operating limitation must be specified in accordance with § 33.7 and included in the installation instructions

required by § 33.5. The applicant must also include appropriate engine operating information on the use of fuel anti-icing additives in the § 33.5 operating instructions. Information will be included in the engine type design data sheet if fuel anti-icing additives are used to comply with § 33.67(b)(4)(ii).

6.6 **Fluid Injection.**

When complying with § 33.67(c), the applicant must show for each fluid injection (other than fuel) system and its controls that the flow of the injected fluid is adequately controlled. Fluid injection (other than fuel) refers to any fluid (for example, water) injected into the airstream. The requirements of § 33.67(c) apply irrespective of the location of fluid injection into the engine.

6.7 **Communicating the Certification Plan and Results.**

The engine applicant should coordinate with the aircraft manufacturer to ensure that engine characteristics, limitations, or requirements that may affect aircraft certification are properly documented and communicated. As a minimum, any engine limitations must be included in the operating instruction required by § 33.5(b)(1). Issues to coordinate may consist of:

- Fuel anti-icing additives required or allowed to be used.
- The maximum limit of allowable ice in the fuel that the engine can accept and still function properly in accordance with § 33.67(a). If the engine applicant has determined the amount of ice that the engine can accept and still properly function independent of an aircraft manufacturer, the applicant should include a limitation in the operating instructions.
- Minimum fuel pressure requirements with and without operating aircraft fuel pumps and any maintenance requirements resulting from engine operation with a failed aircraft fuel pump.
- Fuel transfer back to the aircraft fuel tank if a fuel-return circuit is included in the engine design. If the engine has a system that sends excess fuel back to the aircraft fuel tank, the applicant should coordinate with the aircraft manufacturer about necessary information on the amount of fuel returned. This information should include return fuel flow rate requirements to ensure proper engine function, the temperature of the returned fuel, and the amount of heat expected to be added to the aircraft fuel tank.

7. **SUGGESTIONS FOR IMPROVING THIS AC.**

If you have suggestions for improving this AC, you may use the [Advisory Circular Feedback Form](#) at the end of this AC.

END

FAA Form 1320-73 to be added (<https://www.faa.gov/documentLibrary/media/Form/FAA1320-73.pdf>)

This document does not represent final agency action on this matter and should not be viewed as a guarantee that any final action will follow in this or any other form.