



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

Advisory Circular

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Subject: POWERPLANT GUIDE FOR CERTIFICATION OF PART 23 AIRPLANES	Date: Initiated By: ACE-100	AC No.: 23-16A Change:
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1. WHAT IS THE PURPOSE OF THIS ADVISORY CIRCULAR?

- a. This advisory circular (AC) provides information and guidance concerning acceptable means, but not the only means of compliance with Title 14 of the Code of Federal Regulations (14 CFR) part 23, subpart E, applicable to the powerplant installation in normal, utility, acrobatic, and commuter category airplanes. This AC consolidates existing policy documents, and certain AC's that cover specific paragraphs of the regulations, into a single document. Material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation.
- b. Wherever there is no written policy or guidance material applicable to a specific paragraph, the phrase, "No specific policy is available as of December 31, 2002," is used. AC's and policy memos approved after this date may be included as reference material only.

2. WHAT IS INCORPORATED IN THIS AC AND, THEREBY, SUPERSEDED?

The following AC's and policy statements have been incorporated into this revision in whole or in part and are hereby superseded:

- a. AC 23-16, Powerplant Guide for Certification of Part 23 Airplanes, dated September 21, 1999.
- b. Policy concerning Unusable Fuel Tests and Prolonged Sideslip Maneuvers (23.959), dated November 17, 1999.
- c. PS-ACE111-2000-23.901(d)(2), issued December 14, 2000, published in the Federal Register January 5, 2001.

- d. PS-ACE111-2001-23.1093(b), issued October 23, 2001, published in the Federal Register November 7, 2001.
- e. PS-ACE111-2000-23.1155-01, issued December 22, 2000, published in the Federal Register January 12, 2001.
- f. Policy concerning Fuel Tank Outlet Strainer (§ 23.977), dated April 9, 1996.
- g. Policy concerning Confirmation of Definition of Maximum Weight in § 23.1001, dated June 24, 1999.
- h. Policy concerning Certification of Small, Single-Engine Piston or Turbopropeller Airplanes used for Special Purpose Agricultural Operations, dated December 1, 1997, pages 4 and 5, pertaining to §§ 23.954, 23.1043, 23.1093, 23.1141(e), and 23.1163(a)(1).

3. WHAT IS THE BACKGROUND FOR THIS AC AND WHAT TIME PERIOD DOES THIS AC COVER?

The AC is current through Amendment 23-55, effective February 22, 2002. Policy released prior to December 31, 2003 is included in this AC. This material spans approximately 38 years of Federal Aviation Administration (FAA) aviation history.

4. HOW SHOULD THE INFORMATION CONTAINED IN THIS AC BE APPLIED?

- a. The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration small airplane type certification engineers, and their designees.
- 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 will consider other methods 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. 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 or design changes as a basis for finding compliance.
- c. This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.
- d. If the implementing office becomes aware of reasons that an applicant's proposal that meets this guidance should not be approved, the office must coordinate its response with the office that issued the guidance.

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5. HOW IS THE INFORMATION IN THIS ADVISORY CIRCULAR ORGANIZED AND ARRANGED?

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This Advisory Circular is organized and arranged by section of 14 CFR part 23, subpart E, in a hierarchical format. This arrangement provides generally applicable information about each section under each major header and continues with information specific to each paragraph under a given section. The outline below shows the format and explains each portion of the information contained under each section heading. The advisory material is given in a question and answer format with each of the questions in bold text followed by the answer in plain text. With the exception of the section header and the CAR 3 Cross Reference, the other portions will only be shown as applicable. In general, this AC provides policy for the most recent amendment of a given section.

Section Header – Bold text banner that includes section number, section title, and current amendment level

CAR 3 Cross Reference – The CAR 3 regulation that the section was derived from

General Information – Advisory material that is generally applicable to the entire section

Related Material – Additional sources of information generally applicable to the entire section

Paragraph – The number of the paragraph under the section

Paragraph Specific Information – Advisory material that is specific to the paragraph

Related Material – Additional sources of information specific to the paragraph

6. WHAT OTHER REGULATIONS AND PUBLICATIONS ARE RELATED TO THIS AC?

- a. **Regulations:** Part 23 through Amendment 23-55. While this AC specifically addresses only those regulations in subpart E, the following additional regulations are commonly associated with the airplane powerplant:

Subpart B — Flight

§ 23.33	Propeller speed and pitch limits.
§ 23.45	Performance.
§ 23.239	Spray characteristics.

Subpart C — Structure

§ 23.307	Proof of structure.
§ 23.361	Engine torque.
§ 23.363	Side load on engine mount.

Subpart D — Design and Construction

§ 23.611	Accessibility provisions.
§ 23.771	Pilot compartment. DRAFT
§ 23.777	Cockpit controls. DRAFT
§ 23.779	Motion and effect of cockpit controls.
§ 23.781	Cockpit control knob shape.
§ 23.859	Combustion heater fire protection.
§ 23.863	Flammable fluid fire protection.
§ 23.865	Fire protection of flight controls, engine mounts, and other flight structure.
§ 23.867	Electrical bonding and protection against lightning and static electricity.

Subpart F — Equipment

§ 23.1305	Powerplant instruments.
§ 23.1309	Equipment, systems, and installations.
§ 23.1311	Electronic display instrument systems.
§ 23.1321	Arrangement and visibility.
§ 23.1322	Warning, caution, and advisory lights.
§ 23.1337	Powerplant instruments installation.
§ 23.1419	Ice protection.
§ 23.1431	Electronic equipment.
§ 23.1437	Accessories for multiengine airplanes.

Subpart G — Operating Limitations and Information

§ 23.1501	General.
§ 23.1521	Powerplant limitations.
§ 23.1522	Auxiliary power unit limitations.
§ 23.1549	Powerplant and auxiliary power unit instruments.
§ 23.1551	Oil quantity indicator.
§ 23.1553	Fuel quantity indicator.
§ 23.1555	Control markings.
§ 23.1557	Miscellaneous markings and placards.
§ 23.1583	Operating limitations.
§ 23.1585	Operating procedures.

- b. Joint Aviation Requirements (JAR):** The rules of the JAR part 23 have been harmonized with those in Title 14 of the Code of Federal Regulations (CFR) part 23 to the extent that the powerplant installation requirements are essentially the same. The numbering scheme is the same between JAR and 14 CFR part 23 so they are easily cross-referenced. With the coming of the European Aviation Safety Authority (EASA), the rules will be embodied as Certification Specifications (CS), which, in the beginning, are created directly from the JARs with the same numbering scheme.

- c. FAA Orders and Advisory Circulars:** Copies of the current FAA Orders and Advisory Circulars listed below can be obtained *at no charge* from:

U.S. Department of Transportation, Subsequent Distribution Office
 DOT Warehouse, SVC-121.23
 Ardmore East Business Center, 3341Q 75th Avenue
 Landover, MD 20785

Telephone 301-322-5377
 or by faxing your request to 301-386-5394

These documents are available for viewing via the Internet by following the aircraft certification links from the FAA homepage (www.faa.gov).

FAA Order 8100.5	Aircraft Certification Directorate Procedures
FAA Order 8110.4B	Type Certification DRAFT
AC 20-29B	Use of Aircraft Fuel Anti-icing Additives
AC 20-32B	Carbon Monoxide (CO) Contamination in Aircraft—Detection and Prevention
AC 20-43C	Aircraft Fuel Control
AC 20-53A	Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning
AC 20-66A	Vibration and Fatigue Evaluation of Airplane Propellers
AC 20-73	Aircraft Ice Protection
AC 20-88A	Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)
AC 20-100	General Guidelines for Measuring Fire-Extinguishing Agent Concentrations in Powerplant Compartments
AC 20-107A	Composite Aircraft Structure
AC 20-116	Marking Aircraft Fuel Filler Openings with Color Coded Decals
AC 20-119	Fuel Drain Valves

AC 23-16A

AC 20-122A	Anti-misfueling Devices: Their Availability and Use
AC 20-124	Water Ingestion Testing for Turbine Powered Airplanes
AC 20-128A	Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure
AC 20-135	Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria
AC 20-136	Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning
AC 20-18A	Qualification Testing of Turbojet Engine Thrust Reversers
AC 21-37	Primary Category Aircraft DRAFT
AC 21.17-3	Type Certification of Very Light Airplanes Under FAR 21.17(b)
AC 23-2	Flammability Tests
AC 23-10	Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes
AC 23-11A	14 CFR Part 23 Type Certification of an Airplane Originally Certificated to Joint Aviation Regulations – Very Light Airplane (JAR-VLA) Standards
AC 23-14	Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes
AC 23-15	Small Airplane Certification Compliance Program
AC 23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplanes
AC 23.1311-1A	Installation of Electronic Displays in Part 23 Airplanes
AC 23.1419-2B	Certification of Part 23 Airplanes for Flight in Icing Conditions
AC 23.1521-1B	Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines
AC 23.1521-2 with Change 1	Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

AC 25.939-1	Evaluating Turbine Engine Operating Characteristics
AC 33-2B	Aircraft Engine Type Certification Handbook
AC 33.28-1	Compliance Criteria for 14 CFR § 33.28 Aircraft Engines, Electrical and Electronic Engine Control Systems
AC 33.28-2	Guidance Material for 14 CFR § 33.28, Reciprocating Engine, Electrical and Electronic Engine Control Systems
AC 33.47-1	Detonation Testing in Reciprocating Aircraft Engines
AC 33.74/92-1A	Turbine Engine Continued Rotation and Rotor Locking
AC 35.37-1A	Composite Propeller Blade Fatigue Substantiation

Copies of the current Advisory Circulars listed below may be purchased from:

Superintendent of Documents
P. O. Box 371954
Pittsburgh, PA 15250–7954

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Make a check or money order payable to the Superintendent of Documents

These documents are also available for viewing via the Internet by following the aircraft certification links from the FAA homepage (www.faa.gov).

AC 23-8B Flight Test Guide for Certification of Part 23 Airplanes

AC 23-17A Systems and Equipment Guide for Certification of Part 23 Airplanes

- d. Policy Memoranda:** Copies of the current Policy Memoranda listed below can be obtained *at no charge* from the Small Airplane Directorate Regulations and Policy Branch, 901 Locust St., Room 301, Kansas City, MO 64106. These documents are available for viewing via the Internet by following the aircraft certification links from the FAA homepage (www.faa.gov).

PS-ACE100-2002-004, Diesel Engine Installation

PS-ACE100-2002-008, Propeller Testing V_d Versus V_{NE}

- e. Other Publications:** Copies of the *Design Standards for Advanced Ultra-light Aeroplanes* (DS10141) may be purchased from:

L.A.M.A.C. ~ Light Aircraft Manufacturers Association of Canada
880 St-Fereol
Les Cedres
Quebec, QC
Canada J7T 1N3
Tel.: (450) 452-4772 or 1-888-977-1447
Fax: (450) 452-2694

7. WHAT ARE THE DEFINITIONS FOR THE COMMON TERMS USED IN THIS ADVISORY CIRCULAR?

This Advisory Circular uses the definitions listed below. Some of these terms are used throughout, and will only be defined here. In some instances, the term definitions may be repeated in the relevant document section as an aid to the reader.

Aircraft Flight Manual (AFM)

The documentation detailing the operating limitations and instructions for an aircraft.

Cabin Pressurization Systems

Turbocharger used to pressurize air for airframe services.

Civil Air Regulations (CAR)

The body of rules governing aviation prior to being recodified by final rule on September 28, 1964.

CAR 3

Part 3 of the Civil Air Regulations as amended through March 25, 1964.

Instructions for Continued Airworthiness (ICA)

The documentation detailing “how to” maintenance of the airplane, engine, or propeller.

Intercooler

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A device installed in the engine air induction system that lowers the intake air charge temperature. The intercooler can be approved either as part of the engine or the engine installation.

Normal Ground Attitude

“Normal ground attitude” is defined as “the aircraft ground attitude that would normally be expected in service.” Therefore, consideration of nose wheel strut, main gear strut, variation of all landing gear tires, and the apron gradient is necessary. Use a minimum ground slope of 1 percent. An appropriate slope for seaplanes/amphibian airplanes would have to be determined from the worst-case static in-water attitude of the aircraft at the most adverse center of gravity location(s).

Turbocharger

Any engine exhaust gas-driven compressor that is a component of a Turbonormalized Engine, Turbosupercharged Engine, or Cabin Pressurization System.

Turbonormalized Engine

Turbocharger used to maintain sea level manifold pressure to a critical altitude.

Turbopropeller

A propeller driven by a turbine engine.

Turbosupercharger

A turbocharger used to provide and maintain a manifold pressure greater than sea level pressure to a critical altitude. This term has been used interchangeably with the term turbocharger.

Turbosupercharged Engine

Turbocharger used to provide and maintain a manifold pressure greater than sea level pressure to a critical altitude.

Unusable fuel

The largest total quantity of fuel remaining in the fuel system when the first evidence of engine malfunction occurs due to fuel interruption. Engine malfunction normally occurs under the most adverse fuel feed conditions. Each intended operation and flight maneuver should be checked for each fuel tank. (See Figure 3 below in this AC section.)

V_{FE}

The maximum airplane flap extended speed.

AC 23-16A

V_{so}

The airplane stalling speed or the minimum steady flight speed in the landing configuration.

DRAFT

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Aircraft Certification Service

CONTENTS

Subpart E—Powerplant

GENERAL

Section		PAGE
23.901	Installation	1
23.903	Engines	9
23.904	Automatic power reserve system	14
23.905	Propellers	17
23.907	Propeller vibration	20
23.909	Turbocharger systems	22
23.925	Propeller clearance	32
23.929	Engine installation ice protection	34
23.933	Reversing systems	36
23.934	Turbojet and turbofan engine thrust reverser systems tests	38
23.937	Turbopropeller-drag limiting systems	39
23.939	Powerplant operating characteristics	40
23.943	Negative acceleration	41

FUEL SYSTEM

23.951	General	42
23.953	Fuel system independence	44
23.954	Fuel system lightning protection	45
23.955	Fuel flow	46
23.957	Flow between interconnected tanks	58
23.959	Unusable fuel supply	59
23.961	Fuel system hot weather operation	68
23.963	Fuel tanks: General	73
23.965	Fuel tank tests	74
23.967	Fuel tank installation	75
23.969	Fuel tank expansion space	77
23.971	Fuel tank sump	78
23.973	Fuel tank filler connection	80
23.975	Fuel tank vents and carburetor vapor vents	81
23.977	Fuel tank outlet	82
23.979	Pressure fueling systems	83

FUEL SYSTEM COMPONENTS

23.991	Fuel pumps	84
23.993	Fuel system lines and fittings	86
23.994	Fuel system components	87
23.995	Fuel valves and controls	89
23.997	Fuel strainer or filter	90
23.999	Fuel system drains	92
23.1001	Fuel jettisoning system	93

OIL SYSTEM

23.1011	General	95
23.1013	Oil tanks	99
23.1015	Oil tank tests	101
23.1017	Oil lines and fittings	102
23.1019	Oil strainer or filter	103
23.1021	Oil system drains	104
23.1023	Oil radiators	105
23.1027	Propeller feathering system	106

COOLING

23.1041	General	107
23.1043	Cooling tests	108
23.1045	Cooling test procedures for turbine engine powered airplanes	110
23.1047	Cooling test procedures for reciprocating engine powered airplanes	111

LIQUID COOLING

23.1061	Installation	112
23.1063	Coolant tank tests	113

INDUCTION SYSTEM

23.1091	Air induction system	114
23.1093	Induction system icing protection	115
23.1095	Carburetor deicing fluid flow rate	126
23.1097	Carburetor deicing fluid system capacity	127
23.1099	Carburetor deicing fluid system detail design	128
23.1101	Induction air preheater design	129
23.1103	Induction system ducts	130
23.1105	Induction system screens	131

23.1107	Induction system filters	132
23.1109	Turbocharger bleed air system	133
23.1111	Turbine engine bleed air system	134

EXHAUST SYSTEM

23.1121	General	135
23.1123	Exhaust system	138
23.1125	Exhaust heat exchangers	140

POWERPLANT CONTROLS AND ACCESSORIES

23.1141	Powerplant controls: General	141
23.1142	Auxiliary power unit controls	143
23.1143	Engine controls	144
23.1145	Ignition switches	146
23.1147	Mixture controls	147
23.1149	Propeller speed and pitch controls	148
23.1153	Propeller feathering controls	149
23.1155	Turbine engine reverse thrust and propeller pitch settings below the flight regime	150
23.1157	Carburetor air temperature controls	152
23.1163	Powerplant accessories	153
23.1165	Engine ignition systems	154

POWERPLANT FIRE PROTECTION

23.1181	Designated fire zones; regions included	155
23.1182	Nacelle areas behind firewalls	156
23.1183	Lines, fittings, and components	157
23.1189	Shutoff means	159
23.1191	Firewalls	160
23.1192	Engine accessory compartment diaphragm	161
23.1193	Cowling and nacelle	162
23.1195	Fire extinguishing systems	164
23.1197	Fire extinguishing agents	166
23.1199	Extinguishing agent containers	167
23.1201	Fire extinguishing systems materials	168
23.1203	Fire detector system	169

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POWERPLANT GUIDE FOR CERTIFICATION OF PART 23 AIRPLANES**Subpart E—Powerplant****GENERAL****23.901 Installation (Amendment 23-53)**

CAR 3 Cross Reference: 3.411

What guidance is there for the certification of powerplant electronic systems installations?

Electronic systems are increasingly being used to control different airplane systems including powerplant systems. During certification of these installations, § 23.1309 must be used to determine the potential failure modes and the resulting severity of a failure event. A safety analysis is generated during the engine certification that covers engine and engine-airplane interfaces. This engine level safety analysis should be used as input to the airplane level safety analysis. Special conditions per § 11.19 may be required for powerplant systems installations to comply with the requirements of § 23.1309. These special conditions should not require re-testing of the engine or its certificated components except as part of the airplane.

What may be required by special conditions?

Examples of special condition requirements may include, but are not limited to, the following:

1. Lightning test;
2. High Intensity Radiation Fields (HIRF) testing;
3. Software level validation testing; and
4. Environmental testing.

What are some examples of powerplant electronic systems?

Examples of powerplant electronic systems may include, but are not limited to, the following:

1. Electronic Engine Controls (EEC);
2. Full Authority Digital Engine Controls (FADEC);

3. Electronic turbocharger wastegate controls; and
4. Electronic propeller speed, pitch, and feathering controls.

Related Material

AC 23.1309-1C, Equipment, Systems, and Installations in Part 23 Airplanes

AC 23.1311-1A, Installation of Electronic Displays in Part 23 Airplanes

AC 33.28-1, Compliance Criteria for 14 CFR § 33.28 Aircraft Engines, Electrical and Electronic Engine Control Systems

AC 33.28-2, Guidance Material for 14 CFR § 33.28, Reciprocating Engines, Electrical and Electronic Engine Control Systems

Policy Memorandum ANE-2001-35.31-R0, Policy for Bird Strike, Lightning, and Centrifugal Load Testing for Composite Propeller Blades and Spinners

Paragraph 23.901(a)

What components should be included in the definition of powerplant installation?

Examples of powerplant installation components may include, but are not limited to, the following:

1. Engines;
2. Propellers;
3. Gear boxes and engine driven accessories;
4. Nacelles and inlets;
5. Engine oil systems;
6. Fuel tanks, lines, manifolds, and controls;
7. Ignition system components;
8. Propulsion control and monitoring devices;
9. Exhaust nozzles, mufflers, plenums, etc.;
10. Fluid collectors and drain lines;

DRAFT

11. Pneumatic bleed valves and ducting;
12. Engine fire protection systems; and
13. Engine and propeller icing protection systems.

Components that are part of an engine or propeller type design certificated under parts 33 or 35, respectively, are considered part of the powerplant installation. As such, any findings of compliance with part 23 requirements should take maximum advantage of the relevant findings made in support of part 33 or 35.

Paragraph 23.901(b)

What are examples of potential inspection and maintenance items?

Examples of potential powerplant inspection and maintenance items may include, but are not limited to, the following:

1. Oil reservoir fill and quantity sight glasses;
2. Engine control linkages;
3. Oil, fuel, air filters;
4. Oil system chip detectors;
5. Engine mount inspections;
6. Engine exhaust system components; and
7. Firewalls.

What are the typical methods for showing compliance?

Compliance is typically shown using the following methods either alone or in combination:

1. Review of drawings, schematics, system descriptions, and safety analyses;
2. Mock-up inspections and demonstrations;
3. Laboratory and aircraft testing;
4. Comparison with the service experience on similar designs; and
5. Comparison with accepted design standards.

Related Material

AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes

Paragraph 23.901(c)

What are some of the considerations for complying with this rule?

To comply with this rule, the powerplant installation should be designed to provide access (cowling that is easily opened and closed) for the pilot to visually check the following:

1. Engine oil level;
2. Flammable fluid leaks;
3. If applicable, the exterior condition of the turbocharger and wastegate installation;
4. If applicable, tail pipe, multi-segmented V-band clamps, and firewalls;
5. Electrical wiring;
6. Fuel and oil lines and fittings; and, otherwise, make a cursory inspection of the engine installation; and
7. Other items as defined by the engine or airplane manufacturer.

For additional information refer to § 23.611, Accessibility provisions.

Paragraph 23.901(d)

What special considerations are there for turbine engine installations?

Paragraph 23.901(d) requires that carcass vibration and rain, hail, ice, and bird ingestion be considered for all turbine engine installations. This requirement ensures that the installation does not degrade the certificated capability of the engine.

What considerations and methods of compliance are typical for the vibration requirements?

Compliance with rules concerning vibration usually involves instrumentation and testing. These tests may consist of a combination of bench vibration tests and full-scale airplane tests. Analysis can be used to support the placement of instrumentation and to identify the critical test conditions.

What considerations and methods of compliance are typical for the ingestion requirements?

Compliance with the rain ingestion requirements of § 23.901(d)(2) is typically shown with design analysis that identifies areas of concern and tests for those areas of concern. Part 33 engine certification testing may be used for part 23 compliance if the engine certification testing addressed the areas of concern identified by the installation design analysis (for example, use of an installation representative test inlet system) and if specific conditions addressed in the rule were addressed during engine certification testing. For airplanes with a certification basis prior to Amendment 23-53, a test is typically required if the specific operating considerations contained in the part 23 rule were not addressed during engine certification.

When evaluating areas of concern with the installation, consider areas where water pooling with subsequent ingestion or shed of localized “slugs” of water normally not addressed during engine certification might occur. Some examples are inlet system channels, indentations, and so forth. These are typical of turbopropeller or S-duct type inlets that have complex geometry that can allow water pooling. This consideration is usually not a concern with simple pitot style inlets typical of part 23 turbofan/jet engine installations. Part 23 turbine engine installations typically require testing since the vast majority of these are turbopropeller installations. However, if design analysis shows that the installation will not affect the water ingestion characteristics and engine certification addressed the specific conditions addressed in the part 23 rule, this analysis combined with engine certification testing may be adequate to demonstrate rain ingestion compliance. Due to the large diversity of turbine engine installations in part 23 airplanes, all installations should be evaluated to determine whether areas of concern exist. Since the rain ingestion requirements in part 33 were not added until Amendment 33-6, the airplane applicant needs to evaluate the engine's certification basis to determine whether the engine has been subjected to part 33 rain ingestion testing. If the engine does not have Amendment 33-6 or a subsequent amendment as part of the certification basis, the engine must have a safe service history of rain ingestion in similar installations, in accordance with § 23.903(a)(2)(iv).

If it is determined that testing for rain ingestion should be performed, flight test is not required. The intent of the part 23 rule is to ensure that the engine installation has not deteriorated the rain ingestion tolerance of the certificated engine. Since a ground static engine test normally demonstrates engine certification compliance, use of installation ground tests at the required power/thrust settings has been commonly accepted as a means of compliance. The applicant can use design analysis to determine critical configurations and conditions of the installation. This might reduce required installation tests to the critical configurations and conditions instead of repeating the entire part 33 test conditions. Engine certification should address the results of the critical point analysis for the engine; therefore, it is important for the engine installer to research the conditions and requirements used for engine certification.

What are some other examples of issues not addressed by engine certification that need to be addressed for installation compliance with § 23.901(d)?

Amendment 23-53 added requirements for ice, hail, and birds similar to those in part 33. Examples of installation issues normally not addressed by engine certification, but that should be addressed for installation compliance, include the following:

1. Ice build-up on areas where ice shed may be ingested by the engines (for example, ice shed from wings and airframe sources into aft mounted engines); and
2. Consideration of items such as inlet splitters, acoustic liners, and so forth, that may be damaged by impact with ice, hail, and birds.

Paragraph 23.901(e)

What instructions are typically provided under the engine and propeller type certificates?

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Sections 33.5 and 35.3 list the requirements for engine and propeller installation instruction manuals. Examples of subjects typically provided under the engine and propeller type certificates may include, but are not limited to, the following:

1. Engine and propeller operating limitations;
2. Engine and propeller mounting provisions;
3. Allowable fuel and oil specifications;
4. Allowable fuel and oil temperatures;
5. Fuel inlet pressures;
6. Allowable accessory temperature limits;
7. Vibration limits;
8. Accessibility requirements;
9. Turbine engine inlet distortion limits; and
10. Abnormal engine failure load conditions such as turbine engine fan blade failure.

It is important to identify and accommodate all engine and propeller certification dependencies with the aircraft installation to ensure compatibility of the hardware and operational limitations.

Is it possible to certificate an airplane to use a fuel other than one certificated for use on the engine?

No, the fuel used in the airplane must be certificated for use in the engine as well as the airplane to comply with § 23.901(e). Other fuels such as automobile gasoline have been certificated for use in an airplane in conjunction with a separate certification for using the fuel in the engine. All applicable sections of 14 CFR part 33 and part 23 must be considered when certificating a fuel for use in an engine and in an airplane, respectively.

Related Material

AC 23.1521-1B, Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines

AC 23.1521-2 with Change 1, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

AC 20-122A, Anti-misfueling Devices: Their Availability and Use

Paragraph 23.901(f)

What should be considered when determining the applicable parts of these regulations as applied to Auxiliary Power Units (APU)?

The typical Auxiliary Power Unit (APU) is a combustion cycle powerplant operated primarily to generate electrical, pneumatic, and hydraulic power for ground and limited flight operations and not thrust for flight. Each of the rules applicable to powerplant installations must be considered carefully relative to the design features and operating requirements for a given APU. Below are three examples.

1. APUs typically do not have propellers connected to them and, in such a case, it is obvious, that the portions of this part that apply to propellers should not be considered for such an installation.
2. APUs generally have a much smaller operating envelope than do thrust producing powerplants and, as such, due consideration should be given to the requirements in areas such as induction system icing (§ 23.1093).
3. An APU that is used to provide emergency power to meet the requirements of § 23.1351 would be considered differently than an APU intended only for ground use.

What regulations should be considered for Auxiliary Power Units using technologies other than the typical combustion cycles?

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In the future, designs using exotic technologies to produce auxiliary electrical, pneumatic, and hydraulic power, such as fuel cells, may be proposed. These designs will

require careful selection of the applicable powerplant rules and may require special conditions depending on how similar they are to the typical combustion cycle designs.

Related Material

AC 20-128A, Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure

23.903 Engines (Amendment 23-54)

CAR 3 Cross Reference: 3.415

What guidance is available for replacing a reciprocating engine with a turbine engine?

Guidance for turbine engine airplane conversions is provided in AC 23-14, Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes. This AC highlights the differences between the two engine installations that must be accounted for including, but not limited to:

1. Fuel system compatibility with turbine fuel;
2. Part 34 fuel and venting requirements for turbine engines; and
3. Inlet icing and falling and blowing snow requirements.

What guidance is available for the installation of unique types of engines?

Typical airplane engines fall into two categories: spark ignition reciprocating and turbine engines. These types account for the majority of airplanes in service today, but other types such as compression ignition reciprocating (diesel cycle) and sinusoidal cam spark ignition engines have been proposed. When certifying an airplane with engines that are different from the typical engines, the unique features of the new engines should be carefully considered relative to the rules of 14 CFR part 23. Special conditions may be necessary to account for these unique features. Appropriate guidance material will be written as necessary to capture any certification experience and other considerations relative to these installations. For example, Policy Memo PS-ACE100-2002-004, Diesel Engine Installation, was released in May 2003 in response to current engine and airplane certification projects involving diesel engines.

Related Material

AC 23-14, Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes

PS-ACE100-2002-004, Diesel Engine Installation

Paragraph 23.903(a)

Does an engine(s) require a type certificate if the airplane is to be certified under 14 CFR part 23?

Yes, the engine(s) must have an approved type certificate (per 14 CFR part 33 or CAR Part 13) for normal, utility, acrobatic, and commuter category airplanes certificated under part 23. The airplane, with the engine(s) installed, must also comply with 14 CFR part 34, § 34.11.

Is it possible to certificate an airplane under 14 CFR part 23 with an engine(s) that does not have a type certificate?

No, it is not possible to certificate an airplane under 14 CFR part 23 with an engine(s) that does not have a type certificate under 14 CFR part 33. There are rules other than part 23 that do allow engines that are not certificated under part 33. Engines may be approved as part of the airplane for airplanes originally certificated in the Primary Category under 14 CFR part 21, § 21.17(b), or airplanes certificated under Joint Aviation Requirements—Very Light Airplane (JAR-VLA), or Sport Plane (Transport Canada Design Standard TP10141E).

Related Material

AC 21.17-3, Type Certification of Very Light Airplanes under § 21.17(b)

AC 21-37, Primary Category Aircraft

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AC 23-11A, 14 CFR Part 23 Type Certification of an Airplane Originally Certificated to Joint Aviation Regulations – Very Light Airplane (JAR-VLA) Standards

Is it possible to affect the type certificate of the engine by its installation in an airplane?

This section requires compliance with the engine manufacturer’s installation drawing, installation manual, and engine specific operating instructions. Non-compliance with the engine manufacturer’s installation requirements can invalidate the type certification status of the engine, making the engine non-compliant with § 23.903(a)(1). This, in turn, would prevent certification of the airplane under part 23. Examples of engine requirements that could be affected by the airplane installation may include, but are not limited to, the following:

1. Fuel delivery flow and pressure requirements;
2. Allowable turbine engine inlet aerodynamic distortion ; and
3. Compliance with 14 CFR part 34, Fuel Venting and Exhaust Requirements for Turbine Engine Powered Airplanes.

Paragraph 23.903(b)**What is the intent of this rule?**

Airplanes with turbine engines should be designed to continue safe operation in the event of a maximum energy rotor burst (typically the energy level associated with a one-third sector of the engine rotor at the critical rotating speed) or any other uncontained turbine engine failure (i.e., fan blade) including engine case burn through. It is impossible to protect any design in an absolute sense, but good engineering judgment must be used to minimize the effects of these failures. This requires a design with features that protect structure, systems, and components from the adverse effects of heat, pressure, and loads, such as those caused by windmilling of the unbalanced engine, associated with these failures.

Airplanes using new technology materials or novel designs should be carefully evaluated for their ability to minimize the effects of engine rotor burst and case burn through. A Small Airplane Directorate policy letter dated April 7, 1989, defined the word “minimize” as used in § 23.903(b)(1) as “to reduce to a minimum, decrease to the least practical amount.” The “least practical amount” has to consider what is attainable with current technology and materials. In these cases, the de facto standard has become the existing certificated airplanes. These airplanes used discrete source damage analysis to select the most effective and appropriate design precautions and to substantiate that these precautions minimized the rotorburst hazard to the least practical amount. A typical design case minimizing the effects consists of a crown skin cut with a limit gust load that then is used as the ultimate load when analyzing the remaining structure. Advisory Circular 20-128A, in the Related Materials below, contains information on the discrete source damage analysis.

Information on engine case burn through is contained in the related material.

What compliance methods are generally acceptable?

At the most basic, a review of drawings, schematics, system descriptions, hazard assessments, and analysis along with inspections of the installation are acceptable means of compliance. Ground and flight testing to demonstrate continued safe flight with simulated failed conditions are usually also required. Design similarity and service experience can also be considered along with the means above to comply with this rule provided a clear link to the similar airplane can be established.

Related Material

AC 20-128A, Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.903(c)

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What do the words “...in at least one configuration...” mean?

The intent of this rule is to ensure that, during any one flight, any initial failure condition that could prevent the continued safe operation of one engine will not prevent the continued safe operation of the other engine(s). Compliance with this rule requires that there should be no immediate crew intervention necessary for continued safe flight.

Related Material

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

Paragraph 23.903(d)

What concerns are there with starting and stopping a piston engine?

The intent of the rule relative to starting is to ensure that the engine(s) can be started without creating a hazardous condition. Procedures and limitations must be established and documented in the Airplane Flight Manual and on appropriate airplane placards to cover all permitted conditions for starting engine. These conditions must include ground starts for all airplanes and in-flight restarts for multiengine airplanes.

The intent of the rule relative to stopping an engine is to ensure that any engine on a multiengine airplane can be stopped in flight if necessary to prevent a hazardous condition without creating an airplane hazard. Per § 23.901(d)(2), commuter category airplanes also require the stopping system components to be fire resistant. While the rule does not explicitly state any requirements for stopping an engine in normal conditions, such as ground shutdown at the end of operations, there should be no hazards associated with these conditions. Conditions that may require stopping an engine in flight include:

1. Engine compartment fires;
2. Turbocharger or exhaust system failures; and
3. Engine or accessory failures resulting in excessive vibration.

The design of the system should consider and minimize hazards during both starting and stopping, such as the following:

1. The collection of flammable liquids and vapors;

2. Any adverse affects on engine accessories from reduced rotation, starting and stopping;
3. Vibrations that adversely affect the structural integrity of the engine, its components, or aircraft structures; and
4. Any conditions that would prevent safely restarting the engine.

Paragraph 23.903(e)

What concerns are there with starting and stopping a turbine engine?

The intent of the rule relative to starting is to ensure that the engine(s) can be started without creating a hazardous condition. Procedures and limitations must be established and documented in the Airplane Flight Manual and appropriate airplane placards to cover all permitted conditions for starting the engine. These conditions include ground starts as well as in-flight restarts. Provisions and procedures for in-flight restarts must be established and documented in the Airplane Flight Manual.

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The intent of the rule relative to stopping an engine is to ensure that any engine on an airplane can be stopped in flight if necessary to prevent a hazardous condition without creating an airplane hazard. Conditions that may require stopping an engine in flight include:

1. Engine compartment fires;
2. Engine rotorburst; and
3. Engine or accessory failures resulting in excessive vibration.

The design of the system should consider and minimize hazards during both starting and stopping, such as the following:

1. The collection of flammable liquids and vapors;
2. Any adverse affects on engine accessories from windmilling;
3. Vibrations that adversely affect the structural integrity of the engine, its components, or aircraft structures; and
4. Any conditions that would prevent safely restarting the engine.

Related Material

AC 23-2, Flammability Tests

AC 33.74/92-1A, Turbine Engine Continued Rotation and Rotor Locking

Paragraph 23.903(f)

What differences are there between reciprocating and turbine engines when showing compliance with this rule?

The requirement to define the in-flight restart envelope applies to all normal, utility, acrobatic, and commuter category airplanes. A full complement of tests to define the in-flight restart envelope may or not be necessary. For example, normally aspirated reciprocating engine in-flight restart procedures typically only specify the airspeed to restart the engine. In this case, the “restart envelope” is the entire flight envelope for the selected airspeed. On the other hand, defining a turbine engine restart envelope typically requires data from a comprehensive altitude/airspeed envelope test program.

1. Airplanes powered by reciprocating engines.

The amount of in-flight restart envelope testing is dependent upon the particular design features of the engine installation. Comprehensive in-flight restart envelope testing is not usually necessary for single-engine airplanes powered by conventional reciprocating engines. The service experience of these airplanes with typical reciprocating engine installations is that a reliable in-flight engine restart can be made, provided the airplane is equipped with an adequate engine starting system. Thus, in-flight restart envelope testing has not been necessary provided a mechanically sound engine can be restarted under typical power-off flight conditions.

However, if the engine installation contains new or non-conventional design features, more extensive in-flight restart envelope testing may be necessary. This is particularly the case when the flight conditions impact the ability to restart the engine in flight. For example, consider the effects of new or unusual engine designs or operating cycles, propeller feathering systems, engine control systems, fuels or fuel system arrangements, engine starting systems, etc. Any in-flight restart envelope limitations and/or starting procedures should be defined in the appropriate areas of the Airplane Flight Manual (AFM). This information is required for compliance with § 23.1585.

As with conventional designs, extensive in-flight restart envelope testing may not be required provided the applicant can substantiate this position with respect to the new or non-conventional design features. Flight tests are generally the most appropriate means to develop this substantiating data.

2. Airplanes powered by turbine engines.

Turbine engine starting is sensitive to small differences in flight conditions, primarily pressure altitude, speed, temperature, and attitude. Therefore, it is necessary to test the engine restart envelope to ensure that turboprop or turbofan engines can be

reliably restarted in flight. These flight conditions and the associated starting procedures (windmill, starter assisted, or otherwise) should be defined in the appropriate areas of the Airplane Flight Manual (AFM). This information is required for compliance with § 23.1585.

Paragraph 23.903(g)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

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23.904 Automatic power reserve system (Amendment 23-43)

CAR 3 Cross Reference: None

No specific policy is available as of December 31, 2002.

DRAFT

23.905 Propellers (Amendment 23-43)

CAR 3 Cross Reference: 3.416

Related Material:

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

PS-ACE100-2002-008, Propeller Testing V_d Versus V_{NE}

Paragraph 23.905(a)

What regulations cover propeller certification?

Propeller certification is covered under 14 CFR part 35. These rules set the minimum requirements for propellers in a manner similar to that for engines. Installation information from the propeller manufacturer is used to comply with § 23.901(e)(1).

Do the rules in 14 CFR part 35 cover propeller blades that are constructed of composite material?

The rules in 14 CFR part 35 were written to cover wooden and metal propeller blades, and do not, by themselves, address all issues unique to blades constructed of composite materials. The following airworthiness issues are typically addressed with special conditions per § 11.19 as part of the propeller certification under part 35.

1. Safety assessment
2. Centrifugal load tests
3. Fatigue limits and evaluation
4. Bird impact
5. Lightning strike

Paragraph 23.905(b)

What should be considered when determining compliance with this rule?

Evaluate the maximum propeller power and shaft rotational speed for each airplane installation throughout its normal operational envelope. The installed limits may be below the certificated propeller power and rotational speed limits (listed on the propeller type certificate data sheet) that are typically based on static ground testing performed prior to flight test.

The applicant also needs to consider possible transient exceedances of the maximum engine power and propeller shaft rotational speed.

14 CFR part 23, § 23.33, contains additional requirements pertaining to the installed propeller speed and pitch limits.

Paragraph 23.905(c)

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No specific policy is available as of December 31, 2002.

Paragraph 23.905(d)

How do I know if a propeller blade pitch control system has been approved for use with my propeller?

The propeller Type Certificate Data Sheet (TCDS) identifies operationally compatible components of the propeller blade pitch control system that may or may not be included in the propeller type design. If the propeller blade pitch control system components are included in the propeller type design (verify this with the propeller manufacturer or the FAA office controlling the propeller type design), the components have demonstrated compliance with 14 CFR part 35, § 35.42, Blade pitch control system component test.

How do I get approval for a propeller blade pitch control system if it has not been approved as part of the propeller type certificate?

The propeller manufacturer may not have tested components that are not included in the propeller type design per § 35.42. For components that have not been previously tested, demonstrate compliance with § 35.42 either by testing or by similarity to prior approved components.

Paragraph 23.905(e)

Does the type certification of a propeller account for any foreign object damage requirements?

Propeller type certification does not include any type of foreign object damage requirements, unless accomplished with special conditions or special tests.

What foreign object damage concerns are unique for pusher propeller installations?

Most propeller installations are subject to ice being shed into them. The source of the ice for tractor propeller installations is the ice accumulated and shed from the propeller spinner. Typically, for tractor propellers, the amount of ice results in no significant propeller damage. Airplanes with pusher propellers that are very close to the fuselage and well back from the front of the airplane's nose can be subject to ice shed from the forward fuselage and from the wings. The ice from these areas may cause significant propeller damage.

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Related Material:

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

Paragraph 23.905(f)**Why are pusher propellers required to have visible markings and tractor propellers are not?**

Visibility of the propeller disk is of concern during ground operations. Because ground personnel and boarding and deplaning passengers are accustomed to tractor propellers, there is a significantly higher probability of inadvertent contact with a turning pusher propeller. Increased visibility of tractor propellers could also enhance ground operations safety. However, any additional visual distractions in the pilot's normal viewing area could adversely affect collision avoidance.

Paragraph 23.905(g)**Do the requirements for propeller certification cover engine exhaust impingement?**

Propeller type certification does not include any type of engine exhaust requirements, unless accomplished with special conditions or special tests.

What are the concerns for engine exhaust impingement on pusher propeller installations?

In most pusher propeller installations, the engine exhaust pass through the propeller disc. The affects of the exhaust temperatures and composition on the materials of the propeller are of major concern. Factors affecting the exhaust vary with the flight conditions and must be considered relative the propeller's ability to withstand them.

Paragraph 23.905(h)

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What other concerns are there for pusher propeller installations?

Similar to the concerns with ice in § 23.905(e), there is increased potential of foreign object damage because the propeller is aft of major portions of the airplane. Therefore, the design of parts like those used to meet § 23.901(c) are required to ensure that they will not separate from the airplane such that they could contact the propeller.

23.907 Propeller vibration (Amendment 23-51)

CAR 3 Cross Reference: 3.417

What should I consider when showing compliance with this rule?

For acceptable means of compliance, refer to AC 20-66A, Vibration and Fatigue Evaluation of Airplane Propellers.

The following applies to all propellers except conventional fixed-pitch wood propellers:

1. The most important part of approving a propeller installation is to demonstrate that the propeller vibration stresses do not exceed safe levels. It is often beneficial to use approved propeller type design data (contact the propeller manufacturer) to approve a propeller for use on an aircraft.
2. Some propeller TC data sheets contain a section called Note 9. This note simplifies the vibration compliance for propellers under § 23.907 for normal category, single reciprocating engine airplanes in tractor configuration. If the engine or airframe is modified such that the power of the stock engine model is increased during any phase of airplane operation, the potential exists to increase propeller stresses. Therefore, the Certificate Management Aircraft Certification Office (CMACO) should be contacted prior to using Note 9 as approval for § 23.907. Such modifications include, but are not limited to, the addition of a turbocharger or turbnormalizer, increased boost pressure, increased compression ratio, increased RPM, altered ignition timing, electronic ignition, full authority digital engine controls (FADEC), or tuned induction or exhaust.
3. Perform a flight-vibration stress survey. The stress survey should identify any operational and maintenance limitations to note in the airplane Instructions for Continued Airworthiness and/or Airplane Flight Manual (AFM). These limitations may also need to be incorporated into the propeller airworthiness limitations section. According to § 23.1521, operational limitations are to be made available to the crew by the use of appropriate placards and powerplant instrument markings (i.e., red and yellow arcs).
4. In pusher propeller installations, perform the vibration survey under the same caustic and high temperature environmental conditions identified in § 23.905(g).
5. The Airplane Instructions for Continued Airworthiness (ICA) should require regular calibration of the tachometer to ensure that the limits are not exceeded.

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Related Material:

AC 20-88A, Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)

AC 20-66A, Vibration and Fatigue Evaluation of Airplane Propellers

AC 35.37-1A, Guidance Material for Fatigue Limit Tests and Composite Blade Fatigue Substantiation

Paragraph 23.907(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.907(b)

No specific policy is available as of December 31, 2002.

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23.909 Turbocharger systems (Amendment 23-43)
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CAR 3 Cross Reference: None

What paragraphs of § 23.909 apply to a turbocharger installation that is not certificated as part of the engine under part 33?

Apply § 23.909(a) through (e) to a turbocharger system (or portions of the system) that is not certificated as part of the engine under part 33.

What paragraphs of § 23.909 apply to a turbocharger installation that is certificated as part of the engine under part 33?

Apply § 23.909(b) through (e) to a turbocharger system (or portions of the system) that is certificated as part of the engine under part 33.

Related Material:

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

AC 23.1521-2 with Change 1, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

AC 33-2B, Aircraft Engine Type Certification Handbook

AC 33.47-1, Detonation Testing in Reciprocating Aircraft Engines

What are the definitions of some of the common terms used relative to turbocharger systems?

Turbocharger System

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Includes the following:

1. The turbocharger;
2. All components necessary to control the turbocharger and the associated engine/installation connections;
3. All ducting, heat exchangers, and other plumbing between the turbocharger to the engine intake and exhaust interface points;
4. All plumbing and control devices between the turbocharger and the aircraft; and

5. Mounting provisions for these components.

Turbocharger

Any engine exhaust gas-driven compressor that is a component of one or more of the following systems:

1. **Turbonormalized Engine:** Turbocharger used to maintain sea level manifold pressure to a critical altitude.
2. **Turbosupercharged Engine:** Turbocharger used to provide and maintain a manifold pressure greater than sea level pressure to a critical altitude.
3. **Cabin Pressurization Systems:** Turbocharger used to pressurize air for airframe services.

Intercooler

A device installed in the engine air induction system that lowers the intake air charge temperature. The intercooler can be approved either as part of the engine or the engine installation.

Paragraph 23.909(a)

What engine affects should be considered when adding a turbocharger to a normally aspirated engine?

Adding a turbocharger to a normally aspirated engine will have the following affects on the engine.

1. A turbocharged engine will have different endurance and reliability characteristics than the non-turbocharged engine.
2. A turbocharged engine will have different overhaul characteristics and intervals than the non-turbocharged engine.
3. A turbocharged engine will have different detonation characteristics than the non-turbocharged engines. Detonation margin is affected by the following:
 - a. Induction air temperature and pressure;
 - b. Exhaust back pressure;
 - c. Ignition timing;
 - d. Fuel grade and flow;

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- e. Carburetor or injector metering characteristics;
 - f. Compression ratio;
 - g. Cooling; and
 - h. Exhaust gas temperature.
4. A turbocharger has high speed rotating components similar to a turbine engine. Consider the effects of low-cycle fatigue on turbocharger rotor integrity and durability. The installation should be designed to minimize the effects of an uncontained turbocharger rotor burst event.
 5. Expect higher temperatures with a turbocharged engine's induction system due to the heat generated in compressing induction air, as well as positive internal pressure instead of suction by the engine.
 6. Expect higher rates of oil consumption, contamination, and deterioration due to the more severe operating environment. These items may shorten oil change intervals.
 7. Expect higher flow rates of hot exhaust gas with a turbocharged engine's exhaust system, which will increase the temperature of the metal and raise internal pressure. Consequently, the durability of the exhaust system components is important. Increased or mandatory inspections of the exhaust system components may be necessary.
 8. Both the engine and propeller vibration characteristics of the turbocharged engine installation might be altered by changes in horsepower and by changes in horsepower-to-altitude relations. Readdress the propeller vibration compatibility per § 23.907 or determine if propeller recertification is necessary.

What are the typical means of compliance with § 23.909(a)?

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Turbochargers certificated as part of the engine may use the findings of compliance from the engine certification.

Turbochargers that have not been certificated as part of the engine require analysis and testing. Endurance tests should be conducted to meet the reliability standards established by the 150-hour endurance test under § 33.49 for the engine and turbocharger combination. In addition, the engine and turbocharger combination should be tested to determine the effects on the service life of the engine and engine components as required by § 33.7. Any component of the engine and turbocharger installation not substantiated by endurance testing as capable of operating in all normally anticipated flight and atmospheric conditions should be subjected to additional tests or investigations to substantiate this capability as required by § 33.53.

Affects of low-cycle fatigue on turbocharger rotor integrity and durability: A rotor without prior service history should be subjected to a 1,000-cycle start-stop test under the most adverse operating conditions to provide a basis for establishing initial service life.

The applicant should provide instructions for the installation, operation, service, maintenance, repair, and overhaul of the turbocharger and related items as required by § 33.4, Instructions for continued airworthiness, and § 33.5, Instruction manual for installing and operating the engine. Particular attention should be given to component life limits for both the engine and turbocharger.

The exhaust system and supports should be capable of withstanding all vibration and inertia loads at the higher temperatures and pressures to which they are subjected by the turbocharger installation as required by § 23.1123, Exhaust system. Tests or investigations, as necessary, should be conducted to substantiate that the exhaust system meets the standards of airworthiness established by the basic engine 150-hour endurance test as required by § 33.49.

Turbocharger mounts and supporting structure should withstand all vibration and inertia loads to which they are subjected in operation as required by § 23.307, Proof of structure.

Conduct calibration tests and investigations to establish the sea level and altitude power characteristics of the engine and turbocharger combination.

Conduct flight tests to demonstrate that the engine operates throughout its anticipated operating range without exceeding detonation limits at limit temperatures and fuel flow, using the minimum-grade fuel. If necessary, establish the minimum fuel flow required for proper operation. Also, consider the limitations specified in the installer's instructions and as required by § 33.47, Detonation test.

Turbocharger and engine mount provisions should have sufficient strength to withstand loads arising from the conditions prescribed in § 33.23, Engine mounting attachments and structure. Because of relative motion and fire concerns in the event of a failure, experience has shown that turbochargers should not be remotely mounted on the firewall.

Paragraph 23.909(b)

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What should be considered when certificating the turbocharger control system?

A turbocharged engine requires additional systems necessary to control the turbocharger, such as the wastegate and wastegate controller. The effects of cold oil on the operating characteristics of the turbocharger wastegate and any oil-operated flow control devices should be considered when certificating the turbocharger control system.

The design of the turbocharger control devices should be such that any probable failure does not result in engine or turbocharger limits being exceeded, which should preclude damage to the turbocharger compressor or turbine.

Guidance for electronic wastegate controllers is contained in AC 33.28-2.

Related Material

AC 33.28-2, Guidance Material for 14 CFR § 33.28, Reciprocating Engines, Electrical and Electronic Engine Control Systems

Paragraph 23.909(c)

What guidance is available when determining compliance with § 23.909(c)?

A turbocharger has high speed rotating components similar to a turbine engine. Consider the possibility of damage from turbine or compressor rotor failure.

If the turbocharger case alone has not demonstrated compliance with § 23.909(c), then the installer may provide additional containment shielding to preclude damage due to rotor failure.

No additional containment shielding is required for turbochargers approved with the engine provided the following conditions are both met. Information concerning the testing for part 33 certification should be obtained from the engine manufacturer.

1. Containment has been demonstrated during part 33 certification.
2. The containment testing was performed at operating conditions appropriate to the airplane and its engine installation.

Related Material

AC 20-128A, Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure

Paragraph 23.909(d)

What affect does a turbocharger have on the engine induction air temperature at altitude?

A turbocharged engine has higher induction air temperatures at altitude because of the increased compression required to maintain engine manifold pressure. Turbocharger speed and compressor discharge temperature increase up to critical altitude.

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NOTE. Critical altitude is defined as pressure altitude on an International Standard Atmospheric (ISA) day.

What should be considered relative to the turbocharger system discharge?

Turbochargers on engines with carburetors produce combustible mixtures (at elevated pressure and temperature) in portions of the induction system. Induction system leaks should be minimized. Consider the relation of the turbocharger to the point of fuel introduction into the induction system. For turbocharged engines with carburetors, a combustible mixture at elevated pressure and temperature exists in portions of the induction system and should require special precautions. Consider that engine backfire combined with combustible mixtures in the induction system might produce fire in the system.

What methods of compliance are typical for § 23.909(d)?

Demonstrate the strength of the intercooler and mounting provisions as required by § 33.23.

Evaluate the intercooler installation for adequacy of:

1. The intercooler and mounting provisions;
2. Vibration response;
3. Engine cooling;
4. Additional instrumentation required for the intercooler to ensure that the engine ratings are not exceeded; and
5. Any cowling or airframe protrusions located in front of the firewall for fire resistance.

Demonstrate that the induction system can withstand pressure differentials (positive and negative) and temperature levels resulting from the turbocharger under the most critical operating conditions expected.

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If a filter is installed in the induction system, provide an alternate air source.

Determine the effect of turbocharger installation on ice accretion characteristics of the induction system per § 33.35(b). The induction system should meet the requirements of § 23.1091 and incorporate means to prevent and eliminate ice accumulation within the engine and turbocharger induction system, as required by § 23.1093. Associated heat rise requirements should also be evaluated.

Paragraph 23.909(e)

What methods of compliance are typical for § 23.909(e)?

It is difficult to thermodynamically match a turbocharger to an engine by analysis alone. A combination of test data and analysis is required for performance predictions and correction factors.

Power (Performance)

For airplanes required to comply with the performance requirements of § 23.45, Amendment 23-21, establish the actual calibrated power available at all altitudes. If performance information is required per § 23.45, Amendment 23-50, determine the actual engine power at altitude.

Investigate each engine installation at all operating points to ensure engine power output at the specified manifold pressure.

On intercooled installations, evaluate the effects the intercooler has on the engine approved limits. For example, increased engine horsepower output at the same manifold pressure and engine speed would require a method of limiting engine horsepower.

The Maintenance Manual should identify any turbocharger control system calibration checks required to ensure that the engine is maintaining the approved power output. This is especially important on installations with automatic turbocharger control systems.

Cooling

If turbocharger lubrication is provided by the engine oil system, the capacity of that system should be adequate to serve the engine and turbocharger under the most adverse combination of oil temperature and bearing clearances.

External lines and fittings containing flammable fluids as part of the turbocharger installation should comply with §§ 23.1017 and 23.863.

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If the turbocharger oil system is self-contained, the capacity should be adequate to provide lubrication and cooling under the most adverse conditions of turbocharger oil temperature and bearing clearance.

Powerplant cooling provisions should be capable of maintaining the temperature of all powerplant components, parts, and fluids at or below the maximum established safe values under all ground and flight operating conditions as required by § 23.1047.

All portions of the engine exhaust system and turbocharger should be isolated from lines or components carrying flammable fluids, the accessory section, and primary structure by firewalls and shrouds, or by adequate separation as required by § 23.1121. Where

required, adequate cooling air should be provided so that there is no adverse change in service life or failure rate of adjacent components.

Any ducting that bypasses the firewall and/or cowling should be fireproof.

Operating Limits

Define all operating limitations or instructions in the AFM and revise placards as required.

Demonstrate, using an engine conforming to type design data, that the approved power is not exceeded at any altitude.

Demonstrate through test that engine and turbocharger limits are not exceeded under any intended operating condition. In particular, establish that the turbocharger is operating within its speed and turbine inlet temperature limits.

Establish turbocharger oil temperature and pressure limits per § 33.39, Lubrication system.

Specify temperature limits for any components requiring special cooling as required by § 33.21, Engine cooling.

Determine whether propeller blade, crankshaft, and prop shaft stresses are within acceptable limits. The applicant should readdress the propeller vibration compatibility per § 23.907. Additionally, propeller recertification may be required.

Demonstrate compliance with § 23.955 if the maximum fuel flow has increased or the operating condition where maximum fuel flow is required has changed.

Operating Procedures

Demonstrate compliance with § 23.939(b), which includes a demonstration that the engine installation is free from compressor surge at all operating points.

Investigate the in-flight restart characteristics of the turbocharged engine. Demonstrate engine in-flight restart procedures.

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The fuel system should be free from vapor lock throughout the flight envelope as required by § 23.961.

Because additional moisture might be introduced into the engine crankcase, demonstrate that the engine crankcase breather is adequately protected from ice blockage.

If the turbocharger provides airplane cabin pressurization, a failure of the installation should not contaminate the cabin air. Refer to § 23.831 for cabin Carbon Monoxide (CO)

contamination levels and § 23.1121(a) for design requirements to prevent engine exhaust leaks that would allow CO to enter into the cabin area.

Evaluate the propeller-engine-airplane vibration characteristics at altitude to provide continued compliance with § 23.907. Additionally, demonstrate that the engine crankshaft torsion characteristics are within the original engine certificated limits or other safe operational limits.

If the turbocharger installation can affect the windshield defogging system, demonstrate continued compliance with § 23.773(b).

What engine cooling conditions should be considered for a turbocharged engine?

The peak temperature for a turbocharged engine normally occurs at the sea level power output condition at a specified altitude. Cooling air is less effective at altitude due to its lower density. As a general rule, design the engine cooling capacity for the sea level power output, then check the flight envelope cooling capacity at various altitudes. The applicant should investigate enough of the operating envelope to ensure that engine cooling is adequate. The simplest means to determine compliance is by performing a cooling climb test.

What should be considered relative to the turbocharger effect on the engine fuel system?

The increased heating of the induction system for turbocharged engines can affect the vapor lock potential for the engine. In addition, diaphragm-type fuel pumps might be inadequate to supply fuel to the turbocharged engine under all operating conditions. It might become necessary to add a fuel boost pump or make other changes to the pumping system to ensure freedom from vapor lock. The critical conditions should be determined by test, and acceptable fuel system vapor lock characteristics should be demonstrated under all desired operating conditions.

What should be considered if the turbocharger is used to supply pressurized cabin air?

The possibility of contamination of the cabin air during normal operation and after a failure in the system should be considered.

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Can the turbocharger lubrication system use pressurized engine oil?

Turbocharger lubrication systems may be self-contained or require oil from an external source. If pressurized engine oil is used, the following effects should be considered:

1. The additional oil requirements should not exceed the capacity of the engine oil pump.

2. Heat rejected by the turbocharger to the oil should not exceed the engine oil system cooling provisions.
3. Air entrained in the turbocharger scavenge oil should not exceed the capability of the engine breather or scavenge systems.

What should be considered relative to turbocharger failures?

The operating procedures to minimize the potential hazards relating to fire and/or loss of engine power due to a turbocharger failure should be specified in the AFM. In particular, the in-flight restart characteristics of the engine with a failed turbocharger should be considered.

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23.925 Propeller clearance (Amendment 23-51)**CAR 3 Cross Reference:** 3.422**Paragraph 23.925(a)****What is the basis for the minimum clearances specified for ground clearance?**

The clearances of seven and nine inches have been in the rules since the 1930's and are probably based on experience. The primary purpose of these minimums is to provide enough clearance to limit the amount of foreign object damage from debris kicked up from the runway surfaces by the propeller wash and no propeller strike probability. The rule sets out the minimums as well as the airplane and propeller configurations to limit the number of potential test conditions required to demonstrate compliance.

What is the purpose of the positive clearance at the end of the rule if the minimums are met?

The minimums are for normal operational conditions whereas the positive clearance portion of the rule applies with the critical tire deflated and deflected struts. This portion of the rule is used to ensure that in such a condition the propeller will not strike the runway surface. Although tire is singular, the intent of the rule is that the airplane be in the most critical condition necessary to prevent a propeller strike. Thus, for airplanes with more than one critical tire, the interpretation is that tire could be plural.

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Paragraph 23.925(b)**If the positive ground clearance from § 23.925(a) is met, why are there additional requirements for aft-mounted propellers?**

The positive ground clearance in § 23.925(a) is for a condition with a deflated tire, whereas this rule is used for normal takeoffs and landings. Propellers mounted aft of the center of gravity of the airplane will be naturally closer to the ground with the airplane nose pitched up as for takeoff and landing. Thus, this rule is used to ensure that aft-mounted propellers will not contact the runway surface during these conditions. Compliance with this paragraph is required in addition to § 23.925(a).

Paragraph 23.925(c)**What is the basis for the minimum clearances specified for water clearance?**

The eighteen-inch clearance has been in the rules since the 1930's and is probably based on experience. The primary purpose of these minimums is to provide enough clearance to limit the spray kicked up from the water by the propeller wash. The rule sets out the

minimum to limit the number of potential test conditions required to demonstrate compliance with § 23.925(c) and § 23.239.

Paragraph 23.925(d)

What is the basis for the minimum clearances specified for structural clearance?

These minimum clearances have been in the rules since the 1930's and are probably based on experience. The purpose of these minimums is to provide enough clearance to prevent the propeller from striking any other part of the airplane during operations and to limit propeller induced fuselage fatigue. These are considered the minimums, but care should be taken to identify any propeller or structural vibration modes that occur during operations that may lead to propeller strikes.

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23.929 Engine installation ice protection (Amendment 23-51)
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CAR 3 Cross Reference: None

What components of the engine installation does this apply to?

This section applies to propellers, and cooling inlets for oil, generators and other components, when the applicant has requested certification with the ice protection provisions of § 23.1419. This section does not apply to engine induction system icing protection, which is covered under § 23.1093.

Who is responsible for engine installation ice protection certification?

Ice protection is the responsibility of the type certificate applicant. Propeller type certification requirements do not include any type of propeller ice protection requirements, unless accomplished with special conditions or special tests. In most instances, the propeller ice protection components are not included in the propeller type design.

Since the ice protection equipment is normally mounted on the propeller, include the propeller manufacturer in the process of assuring that the installation or failure of ice protection equipment will not harm the propeller. For example, an electrical short on a deicing boot could burn a hole in a composite blade or locally change the heat treatment of an aluminum blade. The resulting damage could make the propeller un-airworthy.

Can a deicing system that is certificated as part of the propeller be used to show compliance with § 23.929?

Deicing systems that are certificated per the requirements of 14 CFR part 35 do not fully meet the requirements of § 23.929. Part 35 requirements address only propeller structural and vibration characteristics and require that the system functions. System failure modes are not addressed with part 35 certification of deicing systems.

The typical analysis report from the deicing boot manufacturer is not sufficient by itself to show compliance to § 23.929. The typical report calculates intercycle ice thicknesses for various flight and icing conditions, but it does not calculate the effect on propeller efficiency, which must be done to show no appreciable loss of thrust. It would be acceptable to show that intercycle ice is equal to or less than the accretions obtained on the same propeller on an airplane that was flight-tested in icing conditions and shown to have no appreciable loss in thrust.

The typical deicing boot manufacturer report also contains a caveat that it does not address propeller runback ice. Similarity to another propeller that was flight tested in icing conditions is usually done to address runback. Similarity would include propeller

DRAFT

and deicing boot aerodynamic and thermal similarity, deicing timer, propeller RPM, and flight conditions. Note that metal and composite propellers have different thermal masses.

As a final qualitative check for both intercycle and runback ice on new airplane programs, airplane performance is checked during flight tests in icing conditions.

Related Material

AC 20-73, Aircraft Ice Protection

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

AC 23-1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

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23.933 Reversing systems (Amendment 23-51)

CAR 3 Cross Reference: None

What are the origins of this rule?

This rule reads exactly the same as § 25.933, which was developed in response to uncommanded, in-flight deployments of thrust reversing systems in turbine powered transport airplanes.

Paragraph 23.933(a)

If the reversing system can be restored to forward thrust, why must the airplane be capable of continued safe flight with the reverser in any possible position?

During uncommanded reversing system deployment, there is a possibility of damage to the system due to the dynamic nature of the deployment that might prevent the system from being restored to forward thrust. The nature of this damage is considered unpredictable, and it is necessary that the airplane be capable of continued safe flight in such an event.

Paragraph 23.933(b)

Is propeller reversing system certification covered as part of the propeller certification?

The requirement of 14 CFR part 35, § 35.21, applies to components of the propeller reversing system. If the reversing system components are included in the propeller type design (this can be verified with the propeller manufacturer or the FAA office controlling the propeller type design), the components have demonstrated compliance with § 35.21. The compliance data used to certify the propeller may be used to support the demonstration of compliance with § 23.933(b).

Components that are not included in the propeller type design may or may not have demonstrated compliance with § 35.21. Those components that have not been certificated as part of the propeller are covered under and must show compliance with § 23.933(b).

Are there other rules in 14 CFR part 23 that are related to § 23.933?

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Requirements related to the operation of propeller reversing systems are contained in 14 CFR part 23, § 23.1155.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

23.934 Turbojet and turbofan engine thrust reverser systems tests (Amendment 23-43)

CAR 3 Cross Reference: None

Are there other rules in 14 CFR part 23 that are related to § 23.934?

Requirements related to the operation of thrust reverser systems are contained in 14 CFR part 23, § 23.1155.

Related Material

AC 20-18A, Qualification Testing of Turbojet Engine Thrust Reversers

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23.937 Turbopropeller-drag limiting systems (Amendment 23-43)

CAR 3 Cross Reference: None

Paragraph 23.937(a)

Is a failure probability analysis an acceptable means of showing compliance to § 23.937?

A failure probability analysis may be used to show compliance with this paragraph. Show that the probability of an accident occurring because of any failure of a propeller drag limiting system (either automatic or manual) is extremely improbable.

Related Material

AC 23.1309-1C, Equipment, Systems, and Installations in Part 23 Airplanes

Paragraph 23.937(b)

Is there any policy available for compliance with § 23.937(b)?

This paragraph was added at Amendment 23-43 in 1993 to define a propeller drag limiting system as manual or automatic devices that, when actuated after engine power loss, can move the propeller blades toward the feather position to reduce windmilling drag to a safe level. This does not include negative torque sensing systems. Prior to this, there was confusion as to whether these systems included negative torque sensing systems or only propeller feathering systems.

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23.939 Powerplant operating characteristics (Amendment 23-42)

CAR 3 Cross Reference: None

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

AC 25.939-1, Evaluating Turbine Engine Operating Characteristics

Paragraph 23.939(a)

Is it possible to extrapolate engine operability compliance for airfields at higher elevations than those tested when showing compliance with § 23.939(a)?

There currently are no extrapolation procedures for showing compliance with the requirements of § 23.939(a) for airplanes certificated to part 23. Traditionally, testing up to the field elevation for which the airplane is to be approved has been used to show compliance. This is the most desirable method since it does not require parameter variation analysis to account for the higher airfield elevations. Extrapolations have been used for part 25 airplanes, and the same considerations may be used for part 23 airplanes.

When considering extrapolation for compliance with § 23.939(a), data must be presented that substantiates the proposed extrapolation procedures. This data should include supportive flight test and engine operations data. The applicant should determine, understand, and substantiate the critical operating modes of the engine including a determination and quantification of the effects the installation and variations in ambient conditions have on these modes. Advisory Circular 25.939-1 may be used for turbine engines to determine and evaluate the engine critical operating modes. If the proposal is appropriately substantiated, the extrapolation of the engine data for compliance with the operability requirements of § 23.939(a) may be performed up to a maximum of 3,000 feet above the airfield elevation tested.

Paragraph 23.939(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.939(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.943 Negative acceleration (Amendment 23-43)

CAR 3 Cross Reference: None

What methods of compliance are acceptable?

This requirement can be satisfied by flight test demonstrations that consider critical airplane, engine, and APU configurations (for an APU approved for use in flight). Guidance concerning these tests is included in AC 23-8B. The durations of the tests specified in chapter 196 of AC 23-8B are intended to represent anticipated abnormal operational events such as atmospheric upsets and collision avoidance maneuvers. Fuel, oil lubrication, and electrical systems are typically monitored during these tests. Fuel tanks should not be more than half full to allow room for fuel to lift and uncover fuel line inlets and boost pump pickups during the negative accelerations.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

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FUEL SYSTEM

23.951 Fuel System General (Amendment 23-43)

CAR 3 Cross Reference: 3.429, 3.430

Related Material

AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes

AC 23.1521-2 with Change 1, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

Paragraph 23.951(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.951(b)

Under what conditions can fuel be drawn from more than one tank at a time?

Section 23.951(b) allows fuel (for the purpose of direct engine feed) to be drawn from more than one tank at a time provided:

1. There are means to prevent introducing air into the fuel system; and
2. The pilot has a means to draw fuel from a single tank.

What are some of the considerations for such systems?

Fuel systems that supply engine fuel from more than one tank at a time do not consume fuel at the same rate from both tanks. This is attributable to differences in vents, filter condition, line losses, pumps, fuel return flow, fuel consumption rates (multiengine airplanes), etc. It is probable that one tank will run out of usable fuel while there is still usable fuel on board. To prevent air being drawn into the engine fuel supply line, use a method to seal the fuel tank outlets whenever the tank is out of usable fuel.

Substantiation tests are required for systems that draw fuel from more than one tank demonstrating that air is not drawn into the fuel system.

A series of fuel tanks can be interconnected to function as a single tank. For example, two left-handed wing tanks using gravity to feed from one to the other with interconnected vent lines function as a single tank provided that fuel is drawn from only

DRAFT

one location. For the purposes of this discussion, these tanks may be treated as a single tank.

Interconnecting the vent lines on two independent tanks (i.e., left-hand and right-hand wing tanks feeding to a common fuel selector valve) does not cause the tanks to function as a single tank. As above, this configuration may allow air into the fuel system when either independent tank has consumed its usable fuel unless there is a means to prevent the introduction of air.

(Many in-service airplanes were certified under the Civil Air Regulations (CAR). For background, CAR § 3.430, which preceded § 23.951(b), required the fuel system arrangement to “permit any one fuel pump to draw fuel from only one tank at a time.” In the past, this has sometimes been interpreted (incorrectly) as “a fuel pump may only draw fuel from one tank at a time.” The CAR regulation is actually more permissive than § 23.951(b) as it did not address the possibility of introducing air into the fuel system.)

Paragraph 23.951(c)

Is the use of fuel anti-icing additives an acceptable means of compliance for § 23.951(c)?

Yes, the fuel icing requirements of § 23.951(c) may be satisfied by using the anti-icing additives as specified in AC 20-29B, Use of Aircraft Fuel Anti-icing Additives.

Related Material

AC 20-29B, Use of Aircraft Fuel Anti-icing Additives

Paragraph 23.951(d)

Is this requirement covered under § 23.903(a)(1)?

The portion of the fuel system that is certificated with the engine is covered under § 23.903(a)(1). The remainder of the airplane fuel system, including the tanks, pumps, fuel lines, and firewall shutoff valves, is covered under § 23.951(b).

DRAFT

23.953 Fuel system independence (Amendment 23-43)

CAR 3 Cross Reference: 3.431

What parts of the fuel supply system should be considered when assessing its independence for each engine?

The independence of a fuel supply system for each engine should be assessed starting at the fuel supply pickup point within the tank and continue to the fuel inlet at the engine.

Related Material

AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes

Paragraph 23.953(a)

What is the intent of requiring no immediate action by the pilot to prevent the loss of thrust to more than one engine?

In the event a multiengine airplane experiences a loss of thrust on one engine as a result of a fuel system failure, the pilot will be occupied with flying the airplane in the new thrust configuration, as well as trouble shooting the problem engine. The intent of § 23.953(a) is that the system should be designed such that, in this event, the remaining engine(s) will not be affected by the failure so the pilot will not be required to deal with another engine thrust loss during this time of increased workload.

Paragraph 23.953(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.954 Fuel system lightning protection (Amendment 23-7)

CAR 3 Cross Reference: None

Is it possible to comply with § 23.954 with operational limitations only?

Operational limitations only are not acceptable means of compliance for standard category airplanes. However, this has been allowed for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis. A limitation in the Airplane Flight Manual, such as “Operation of the airplane in and around thunderstorms is prohibited,” has been determined to be sufficient to address this regulation.

Related Material

AC 20-53A, Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning

AC 23-15, Small Airplane Certification Compliance Program

AC 23.1521-2 with Change 1, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

Paragraph 23.954(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.954(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.954(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.955 Fuel flow (Amendment 23-51)

CAR 3 Cross Reference: 3.433, 3.434, 3.435, 3.436, 3.437(e)

Paragraph 23.955(a)

What are the acceptable means for showing compliance with § 23.955(a)?

Demonstrate fuel-flow characteristics with the entire fuel system installed in the airplane during the airplane type certification program. A suitable mock-up of the fuel system can also be used to demonstrate fuel-flow capacity. Analysis may be used to reduce the tests required, provided the analysis has been validated through appropriate tests.

Some applicants may modify their airplanes in such a way as to affect the original fuel system. Changes in the type of fuel used are also considered a change to the fuel system. In these cases, additional fuel-flow testing may be required to substantiate continued compliance of the fuel system with applicable regulations and engine manufacturer's requirements.

In-service fuel that has the correct physical properties and octane ratings should flow at the rate specified by regulation and at the pressure established in compliance with 14 CFR part 33, § 33.7, Engine ratings and operating limitations.

As stated in § 23.955(d), the test conditions and tests provided in this section are also applicable to auxiliary fuel systems and their associated fuel transfer systems.

What test conditions should be considered?

1. Airplane Attitude

DRAFT

Flow tests should be conducted at the critical attitude for the airplane. The critical attitude may be determined with the use of an inclinometer by flying the airplane at critical weight.

Conventional tractor airplanes normally have fuel tanks aft of the carburetor or engine injector inlet. Conditions grow less favorable for fuel flow as the airplane rotates in the “nose-up” attitude. Likewise, pusher airplanes normally have the fuel tanks forward of the carburetor or engine injector inlet making conditions less favorable for fuel flow as the airplane rotates in the “nose-down” attitude.

2. Minimum Inlet Pressure

The engine manufacturer usually establishes the minimum and maximum fuel pressure limits necessary to obtain acceptable engine operation. These limits are on the applicable FAA Engine Type Certificate Data Sheet (TCDS).

The fuel pressure limits are shown in a number of different ways:

- a. Minus or plus “x” pounds per square inch (psi);
- b. “y” psi above true vapor pressure; and
- c. “z” inches fuel head differential between carburetor fuel inlet fitting and float bowl chamber.

Most of these inlet pressure limits require no conversions. Some turbine engine manufacturers specify either the minimum inlet fuel pressure as “x” psi above the true vapor pressure of the fuel used with a Vapor/Liquid (V/L) ratio of zero, or as the maximum V/L ratio for emergency use that should not exceed a specific value. These fuel pressure limits will require an analysis of the fuel to determine true vapor pressure of the fuel with the corresponding V/L. Alternatively, a laboratory test may be conducted to determine the engine minimum fuel inlet pressure.

3. Supercharged Engine Fuel System Inlet Pressure

This applies to engines using either a mechanical or an exhaust-driven (turbocharger) device to pressurize the intake air charge.

The required fuel pressure at the carburetor or injector inlet is stated on the engine TCDS and is normally referenced to the engine inlet air (manifold) pressure. The manifold pressure is an absolute pressure and is typically stated in inches of mercury (Hg). Be sure to use compatible units when calculating the (carburetor or injector) fuel pressure minimum limit.

The inlet air (or upper deck) pressure is maintained up to the critical altitude, while the fuel tank pressure decreases with increasing altitude. This usually results in the greatest difference between the fuel tank pressure and the inlet air pressure at the critical altitude. Therefore, conduct pressure and flow tests at conditions that account for the difference between the tank pressure at the actual test altitude and the critical altitude. The pressure and flow tests may be done in two ways:

- a. Reduce the fuel tank pressure, or
- b. Add the difference to the pressure that the engine TCDS indicates the pump is required to deliver to the carburetor or injector.

DRAFT

How can the minimum inlet fuel pressure for reciprocating engines be determined if it is not available from the engine manufacturer?

Should the minimum carburetor or injector-inlet fuel-pressure figure not be available from the engine manufacturer, the following process may be used to determine the acceptable inlet pressure:

1. Connect a gravity flow fuel tank that can be varied in height in relation to the carburetor inlet. Large tubing may be used to minimize the effects of fluid friction;
2. With the airplane in the ground attitude, run the engine at full takeoff r.p.m. and manifold pressure. Consider using a propeller that will allow full takeoff r.p.m. and satisfactorily cool the engine;
3. Start with the fuel tank high enough to permit proper operation of the engine. Vary the fuel level by lowering the tank until the first evidence of engine malfunction occurs, then measure and record the fuel head available to the engine. This measurement is to be made from the carburetor fuel inlet to the top of the fuel level in the tank;
4. Engine malfunction may be detected by use of an exhaust gas temperature indicator, which will indicate change in the fuel-air mixture. Any change in fuel-air mixture will result in an exhaust gas temperature change and impending engine malfunction. Also, any noticeable change in engine r.p.m. or manifold pressure will indicate a change in engine horsepower; and
5. Establish the minimum fuel pressure 10 percent above the measured fuel pressure (at the carburetor inlet) required for acceptable engine operation.

DRAFT

Are there any special considerations?

If a fuel flowmeter is installed, block the flowmeter during the flow test and measure the fuel flow through the bypass per § 23.955(a)(2).

If a fuel filter with bypass provisions is installed, block the fuel filter during the flow test and measure the fuel flow through the bypass.

For engines operating on kerosene (jet) or diesel fuels, evaluate the effects of fuel density, low temperature, altitude, attitude, and water saturation.

Paragraph 23.955(b)**How can I demonstrate the fuel flow rate compliance for a gravity fed fuel system?**

This method is applicable only to airplanes with reciprocating engines. Use this method only if the airplane is being certificated without the use of airplane supplied fuel pumps for normal operation. The airplane may be equipped with *optional* auxiliary or emergency pumps provided they are installed but not used during this test.

This test demonstrates the adequacy of the engine fuel supply under the most adverse operating condition. Measure the flow directly at the carburetor inlet (for example, if a reducing nipple is used at the carburetor inlet, measure the fuel flow through the nipple).

Position the airplane on the ground with the thrust or fuselage level line at the most critical attitude for fuel flow. A bench test using the pertinent fuel system components located at relative elevations to represent actual airplane critical attitudes may be used. If the airplane is tested in the level flight attitude, determine the appropriate fuel head for the critical attitude by analysis and test, and add this fuel head to the fuel system in the level flight attitude.

Reduce the fuel pressure to the minimum operating pressure for an acceptable takeoff power mixture as recommended by the carburetor and engine manufacturer. An acceptable method of simulating the minimum pressure required at the carburetor inlet is to disconnect the fuel-feed line at the carburetor and raise the end of the line above the carburetor a distance equal to that of the required minimum operating pressure in inches of fuel.

Compensate for the differential pressure (calculated as shown below under Normally Aspirated, Carbureted, Reciprocating Engine Fuel System Pressure Differential), by subtracting it from the required minimum carburetor inlet pressure. For example, if the minimum permissible fuel inlet pressure is 19 inches of fuel and a system pressure differential is 7 inches (produced between the fuel tank vent space and the carburetor float bowl airspace), then run the test with the fuel line assembly raised 12 inches above the fuel inlet fitting of the carburetor. (The pressure, in psi, can be estimated at approximately one psi for each 40 inches head of fuel.)

Alternatively, compute the sum of the head pressure associated with best rate-of-climb and carburetor inlet requirements, and demonstrate (with the fuel restricted by a valve installed at the engine-end of the system to simulate this pressure) that fuel flow is at least equal to the regulatory minimum.

Completely drain the fuel system before beginning the test. Set the system to feed from one tank only. Slowly add fuel to the tank until a steady flow is established at the inlet to the carburetor or fuel injector unit. Steady flow should be established when approximately the usable fuel supply has been added. When steady flow has been

DRAFT

established, add an additional gallon (or the fuel quantity necessary to complete the flow test) to the tank.

Record the time in seconds for at least one gallon of fuel to flow from the feed line. The time for one gallon of fuel to flow should not be more than the figure computed from the following equations:

1. For reciprocating engine powered airplanes, certificated under Part 3 of the CAR or 14 CFR part 23, at the rate of 150 percent of the actual fuel flow to the engine at maximum takeoff power:

$$\text{Seconds per gallon} = 14,400/(\text{SFC})(\text{TOHP})$$

Where SFC = Engine Specific Fuel Consumption (SFC)
(at Takeoff Power (TOPH)) expressed in (lb./bhp/hr.)

TOHP = Engine brake horsepower (bhp) at takeoff

2. For reciprocating engine powered airplanes certificated under Part 04a of the CAR, at the rate of double the normal flow required for takeoff engine power:

$$\text{Seconds per gallon} = 10,800/(\text{SFC})(\text{TOHP})$$

NOTE. For the purpose of this discussion, engine fuel flow has been defined by the calculated term (SFC)(TOHP). If the engine manufacturer has specified a higher maximum fuel flow rate, then use that fuel flow rate in place of the calculated term. These calculations are based upon a fuel density of 6 lbs. per U.S. gallon.

NOTE. The fuel flow for airplanes powered by a turbine engine(s) under part 23 should meet the requirements discussed under **Fuel Flow Rate for Pressure Regulated Systems** below.

How do I account for the Normally Aspirated, Carbureted, Reciprocating Engine Fuel System Pressure Differential?

A pressure differential normally exists between the fuel tank airspace and the carburetor float bowl airspace at various climb attitudes and climb speeds. Account for this pressure differential when calculating the minimum fuel head for conducting fuel-flow tests. One way to determine the fuel system pressure differential is as follows:

DRAFT

1. Connect a calibrated airspeed indicator between the fuel tank vent and the carburetor float bowl airspace. Connect the pitot pressure connection to the fuel tank vent airspace and the static connection to the carburetor float bowl airspace. Use a liquid trap on each side of the airspeed indicator. The carburetor float bowl should be vented to the atmosphere at the normal carburetor air passage during the test.

2. With the airspeed indicator installed as described above, fly the airplane at critical weight (using the regular airspeed indicator) at the best angle-of-climb airspeed (V_Y) with the carburetor inlet air heat off and a full rich mixture setting (if mixture is controllable). Record the airspeed indicated on the instrument connected between the fuel tank and the carburetor.
3. Calculate the pressure differential (ΔH) between the fuel tank vent airspace and the carburetor float bowl using this equation:

$$\Delta H = 6.81 (V/100)^2$$

Where ΔH = Pressure differential in inches of fuel

V = Airspeed indicator reading in miles per hour

- The ΔH obtained may be subtracted from the minimum carburetor inlet pressure specified by the engine manufacturer to determine the minimum pressure to be substantiated by the fuel flow tests. (See Figure 1 below in this AC section.)

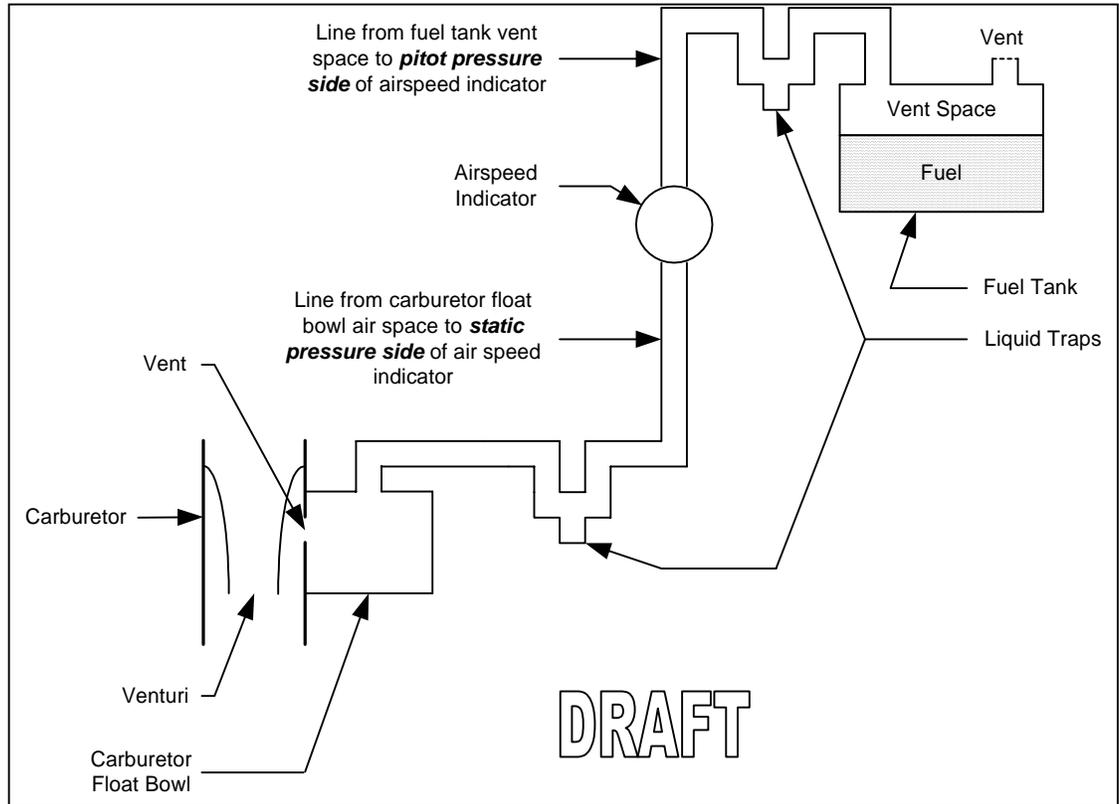


FIGURE 1

5. A U-tube manometer (see Figure 2 below in this AC section) containing actual fuel or any other appropriate fluid may be used instead of the airspeed indicator to determine the pressure differential. Use of the manometer allows reading pressure differential directly in inches of fuel or the chosen fluid. If some other fluid is used, correct the differential height for the specific gravity of the test fluid. A U-tube manometer is generally commercially available or can be constructed of clear plastic or glass tubing.

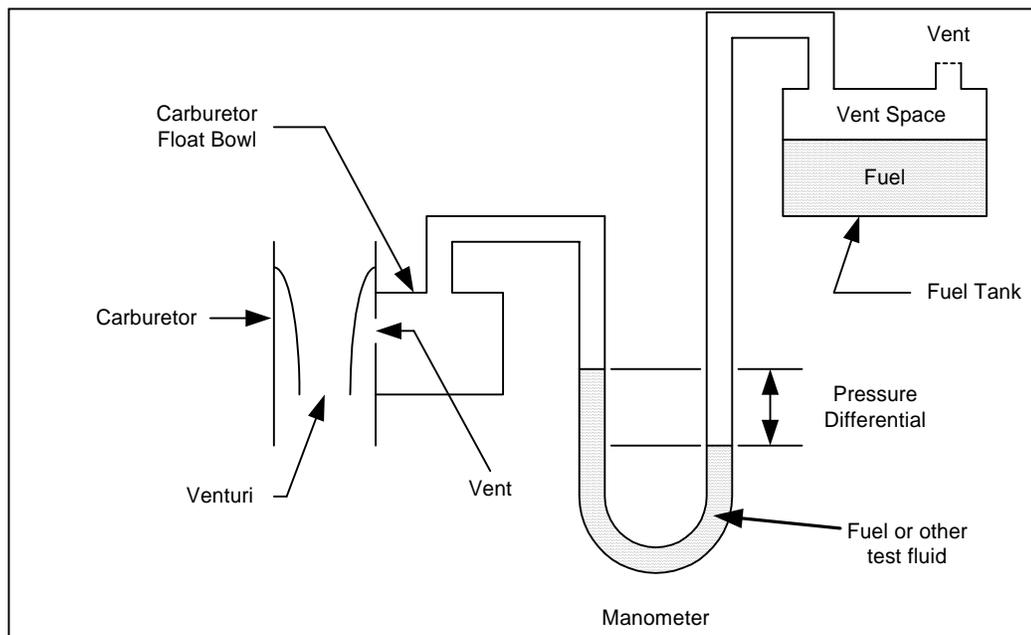


FIGURE 2

6. Installation of a U-tube manometer, containing fuel, in the cabin can be hazardous; therefore, take special precautions to prevent damage or spillage. Incorporate provisions to collect and drain any fuel spillage overboard.

Paragraph 23.955(c)

DRAFT

How can I demonstrate the fuel flow rate compliance for a pump fed fuel system?

These tests are required to demonstrate that the airplane fuel system can deliver an adequate fuel supply to the engine.

1. Fuel Flow Rate for Pressure Regulated Systems

Conduct these fuel-flow rate tests by placing the airplane in the same attitude as outlined in the procedure for gravity-feed fuel system tests. Operate the fuel pump either driven by the engine with the pump mounted on the regular engine-fuel pump drive pad or driven by a separate external power source.

If conducted with the pump mounted on the engine, use a separate source of fuel, external to the airplane, to operate the engine at takeoff r.p.m.

If an external power source is used to drive the fuel pump, conduct the test with the pump operating at the same speed as the pump operates when the engine is running at takeoff r.p.m. Mount the pump at the same height as it would be if mounted on the fuel pump pad on the engine.

In either case, measure the pump discharge flow rate using a calibrated flowmeter and correct for inlet condition if necessary.

Completely drain the fuel system before beginning the test. Set the system to feed from one tank only. Slowly add fuel to the tank until a steady flow is established at the inlet to the carburetor or fuel injector unit. Steady flow should be established when approximately the usable fuel supply has been added. When steady flow has been established, add an additional gallon of fuel to the tank. The fuel-flow tests should be made on the main fuel-pump system followed by a test on the emergency fuel-pump system with the main pump inoperative in the critical mode for fuel delivery.

Part 23 airplanes using aviation or automobile gasoline

For airplanes certified under part 23 using aviation or automobile gasoline, the time for one gallon to flow should be less than or equal to the smaller of the following:

- a. At the rate of 0.9 pounds for each TOHP:

$$\text{Seconds per gallon} = 24,000/\text{TOHP}$$

DRAFT

- b. At the rate of 125 percent of the actual fuel flow to the engine at maximum takeoff power:

$$\text{Seconds per gallon} = 17,280/(\text{SFC})(\text{TOHP})$$

Airplanes using jet or diesel fuel

For airplanes using jet or diesel fuels, the time for one gallon to flow should be less than or equal to the following at each intended operating condition and maneuver:

At the rate of 100 percent fuel flow:

$$\begin{aligned} \text{Seconds per gallon} &= 24,480 \text{ (JP-5)/(SFC)(bhp or lb. thrust)} \\ &23,400 \text{ (JP-4, Jet B)/(SFC)(bhp or lb. thrust)} \\ &23,760 \text{ (JP-7)/(SFC)(bhp or lb. thrust)} \\ &24120 \text{ (JP-8, Jet A, Jet A-1)/(SFC)(bhp or lb. thrust)} \end{aligned}$$

NOTE. For the purpose of this discussion, engine fuel flow has been defined by the calculated term (SFC)(TOHP) or (SFC)(bhp or lb. thrust). If the engine manufacturer has specified a higher maximum fuel flow rate, then use that fuel flow rate in place of the calculated term.

NOTE. Jet fuels vary considerably in density. For example, at 60 °F:

$$\begin{aligned} \text{JP-4, Jet B range is } &6.27 \text{ to } 6.69 \text{ lbs./U.S. gallon} \\ \text{JP-5 range is } &6.58 \text{ to } 7.05 \text{ lbs./U.S. gallon} \\ \text{JP-7 range is } &6.50 \text{ to } 6.73 \text{ lbs./U.S. gallon} \\ \text{JP-8, Jet A, Jet A-1 range is } &6.47 \text{ to } 7.01 \text{ lbs./U.S. gallon} \end{aligned}$$

Since the flow rates for turbine-powered airplanes are 100 percent, account for the effects of cold fuel, blocked filters, altitude, attitude, maneuvers, acceleration, etc.

Part 04a airplanes using aviation or automobile gasoline

For airplanes certified under Part 04a of the CAR using aviation or automobile gasoline, the time for one gallon to flow should be less than or equal to the following:

At the rate of double the normal flow required for takeoff engine power:

$$\text{Seconds per gallon} = 10,800 / (\text{SFC})(\text{TOHP})$$

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2. Fuel Flow Rate for Unregulated Fuel Injection Pump Systems

Some fuel injection systems utilize an integral speed-sensing pump, approved as part of the engine type design, that delivers fuel at an unregulated pressure proportional to engine speed. A fuel injection system with an integral speed sensing pressure pump (refer to AC section on § 23.991) is normally capable of suction lift at the inlet to the pump; therefore, an emergency pump may not be required. Use care in selecting and operating emergency pumps with these types of systems as engine malfunction (as defined in the AC section on § 23.959) can also occur due to excess fuel when operating under high fuel pressure.

Conduct these fuel-flow rate tests by placing the airplane in the same attitude as outlined in the procedure for gravity-feed fuel system tests, with the following exceptions or additions:

- a. The fuel-injector system normally has an engine-driven fuel-injector pump that is approved as part of the engine. It is necessary to show that the fuel system, excluding the injector pump, complies with the applicable regulations. Therefore, any fuel pump capable of providing the flow capacity may be used to conduct the fuel-flow tests. Pressure indicators installed in the fuel lines will be necessary to determine that the system will maintain the pressure specified by the engine manufacturer.
- b. Some engine fuel injector systems have a bypass or return-flow fuel system. These systems may be evaluated by determining that the system can conduct fuel back to the tank at the required flow rate without exceeding the back pressure established by the engine manufacturer at the bypass exit port.
- c. When conducting the fuel flow test with a separate fuel pump, the fuel flow requirements of the main fuel system should include the quantity of fuel consumed by the engine plus the quantity returned to the fuel tank.

Airplanes equipped with engine-driven integral speed-sensing pressure pumps can experience engine misfire, stall, or other engine malfunction attributable to excess fuel should the optional emergency fuel pump produce too high an output pressure. In these cases, the optional fuel pumps are not required by the regulation as emergency pumps but are used to supply fuel pressure at the engine-driven injector pump inlet for engine starting, vapor suppression, and, in some cases, maintaining engine power after an engine-driven fuel injector pump failure. These optional pumps may have a sufficiently high fuel output pressure to adversely affect engine operation when the pump is turned on with the engine-driven pump operating normally. To ensure that the optional fuel pump operates within the maximum allowed fuel pressure limit at the inlet to an engine-driven injector fuel pump, an in-flight evaluation with both pumps operating or a ground pressure check is recommended as follows:

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- a. Block the engine-driven fuel pump outlet line and operate the airplane's electric fuel pump under a no-flow condition, then
- b. Take a pressure reading to ascertain that the fuel pressure falls within the pressure limits specified for the engine at the inlet to the fuel injector or compare the pump manufacturer's no-flow performance pressure with the injector pump's inlet limit.

Is it possible to certify component changes without a full fuel system test?

Changes in components, such as an engine-driven fuel pump or a wobble pump, can often be substantiated by comparative tests of the components themselves without testing the entire airplane system. For example, a replacement fuel pump should be capable of delivering at least the same flow as the original pump when operating at the same speed, suction lift, and delivery pressure.

Paragraph 23.955(d)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes

Paragraph 23.955(e)

No specific policy is available as of December 31, 2002.

Related Material

AC 23.1521-1B, Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines

AC 23.1521-2 with Change 1, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines

Paragraph 23.955(f)

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No specific policy is available as of December 31, 2002.

23.957 Flow between interconnected tanks (Amendment 23-43)

CAR 3 Cross Reference: 3.439

Paragraph 23.957(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.957(b)

Can fuel tank vent lines be used to transfer fuel between tanks?

It is not advisable to use the fuel tank vent lines to transfer fuel between tanks as a normal procedure because this will prevent the vent lines from venting and expose the tanks and lines to higher pressures.

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23.959 Unusable fuel supply (Amendment 23-51)

CAR 3 Cross Reference: 3.437

Paragraph 23.959(a)

What is the definition of unusable fuel supply?

The following definitions are for terms used throughout this section.

Unusable fuel is the largest total quantity of fuel remaining in the fuel system when the first evidence of engine malfunction occurs due to fuel interruption. Engine malfunction normally occurs under the most adverse fuel feed conditions depending on such things as tank geometry, fuel system geometry and operating characteristics, and operating maneuvers. Each intended ground operation and flight maneuver should be checked for each fuel tank. See Figure 3 below in this AC section for common fuel tank configuration definitions relative to unusable fuel.

V_{FE} is the maximum airplane flap extended speed.

V_{SO} is the airplane stalling speed or the minimum steady flight speed in the landing configuration.

V_X is the best angle-of-climb speed.

V_{YSE} is the best rate-of-climb speed with one engine inoperative.

A tank that is not used in all flight regimes need only be tested in the flight regime where it is used (e.g., cruise conditions). Tests for this kind of tank should include slips and skids to simulate turbulence. Provide limitations on the conditions under which the tank may be used in a placard or in the Airplane Flight Manual (AFM).

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What operating maneuvers are typically critical?

The following maneuvers are typically critical and should be considered:

1. Level Flight with maximum recommended cruise power:
 - a. Straight coordinated flight;
 - b. Turbulent air;
 - c. Skidding turn; and
 - d. Full rudder sideslip.
2. Climb with maximum climb power at best angle-of-climb speed, V_X :
 - a. Straight coordinated flight;
 - b. Turbulent air; and
 - c. Skidding turn.
3. One-Engine-Inoperative Climb with maximum climb power at one-engine-inoperative best-rate-of-climb speed, V_{YSE} .
4. Descent and Approach:
 - a. Emergency or rapid descent;
 - b. Continuous power-off glide at $1.3 V_{SO}$;
 - c. Transition from power-off glide;
 - d. Sideslip on approach; and
 - e. Sideslip on approach with balked landing.

What are the general guidelines for testing?

The following should be considered as general guidelines for testing

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1. Conduct usable fuel tests under flight conditions and attitudes that are critical with respect to unusable fuel quantity. Likewise, evaluate any ground maneuvers such as taxi turns and turning takeoffs that may also be critical.
2. Choose the minimum fuel quantity sufficient to perform the maneuvers described below. A minimum fuel quantity is most important as repeated maneuvers may result in the fuel refilling some bays or tanks.
3. Conduct all tests at the minimum practical weight or at a weight determined to be critical for the airplane being tested. When testing an airplane with a single-engine fuel tank, use a separate temporary fuel system to supply the engine after fuel interruption occurs.

What criteria should be used to determine engine malfunction due to fuel interruption during the testing?

For the purpose of these tests, only malfunctions attributable to fuel flow interruption are considered. Some examples are the following:

1. Engine roughness;
2. Partial or total loss of power;
3. Fuel pressure reduced below minimum; or
4. Fuel flow fluctuations.

To ensure the most conservative unusable fuel supply value for each tank, another fuel tank should be selected at the first indication of engine malfunction due to fuel interruption. The fuel remaining in the test tank at the time of malfunction is the unusable fuel. If header tanks (small tanks that accumulate fuel from one or more fuel tanks and supply the engine directly) are utilized, the fuel remaining in the header tank should be added to the unusable fuel, but it is not shown on the fuel gauge marking.

How should the flight test maneuvers be conducted to determine the unusable fuel quantity?

The following tests should be performed as applicable to determine the unusable fuel supply at the most critical condition during flight. The unusable fuel quantity is the largest quantity of fuel necessary to accomplish the critical maneuvers. This quantity should be used to set the fuel gauge zero mark.

1. Level Flight: Maximum Recommended Cruise Power

NOTE. If the airplane manufacturer does not specify Maximum Recommended Cruise Power, then operate engine at the maximum allowable power for continuous operation.

Condition a.—Straight coordinated flight. Perform the following until the first indication of interrupted fuel flow is observed:

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Maintain straight coordinated flight (bank angles not exceeding 5°).

Condition b.—Turbulent Air. Perform the following until the first indication of interrupted fuel flow is observed:

Simulate turbulent air with +/- half-ball width oscillations at approximately the natural yawing frequency of the airplane in pitch, roll, and yaw.

Condition c.—Skidding turn in the direction most critical with respect to fuel feed. Repeat the following until the first indication of interrupted fuel flow is observed:

Maintain a skidding turn with 1-ball width skid for 30 seconds and return to coordinated flight for 1 minute.

Condition d.—Full rudder sideslip.

Consider all possible flight conditions together with the fuel system design to determine the critical flight conditions for testing in order to determine the unusable fuel supply. Some fuel system designs may be susceptible to uncovering the fuel pickups during maneuvers such as sideslips. Designs that lack tank baffles and/or collector cans are potentially susceptible. In one airplane, the fuel system design was such that the engine experienced fuel starvation in prolonged full deflection rudder slips with the tank three-quarters full.

An example of an additional procedure developed to test an airplane's critical condition is full rudder sideslip for 30 seconds with full flap at power for level flight. An extended duration 1/2 to 2/3 ball sideslip has also been used. In both cases, the direction of sideslip was in the direction most critical with respect to fuel feed.

2. Climb: Maximum Climb Power at Best Angle-of-Climb Speed, V_X

NOTE. If the airplane manufacturer does not specify Maximum Climb Power, then operate engine at either the maximum allowable power for takeoff operation (maximum airplane weight over 6,000 lbs.) or maximum allowable power for continuous operation (maximum airplane weight 6,000 lbs. or less).

Condition a.—Straight coordinated flight. Perform the following until the first indication of interrupted fuel flow is observed:

Maintain straight coordinated flight (bank angles not exceeding 5°).

Condition b.—Turbulent air. Perform the following until the first indication of interrupted fuel flow is observed:

Simulate turbulent air with +/- half-ball width oscillations at approximately the natural frequency of the airplane.

Condition c.—Skidding turn in the direction most critical with respect to fuel feed. Repeat the following until the first indication of interrupted fuel flow is observed:

Maintain a skidding turn with 1-ball width skid (or full rudder if 1-ball width cannot be obtained) for 30 seconds and return to coordinated flight for 1 minute.

3. **One-Engine-Inoperative Climb: Maximum Climb Power at One-Engine-Inoperative Best Rate-of-Climb Speed, V_{YSE}**

NOTE. If the AFM does not specify Maximum Climb Power, then operate engine at either the maximum allowable power for takeoff operation (maximum airplane weight over 6,000 lbs.) or maximum allowable power for continuous operation (maximum airplane weight 6,000 lbs. or less).

DRAFT

Set the critical engine to zero thrust to simulate a critical engine-out condition (do not shut down the critical engine). Conduct a straight climb at the best rate-of-climb speed for one engine inoperative (V_{YSE}). Utilize the bank angle and ball displacement used in determining single-engine performance. Continue climb until a malfunction occurs.

4. **Descent and Approach**

Condition a.—Emergency descent or rapid descent. Perform the following until the first indication of interrupted fuel flow is observed:

Make a continuous power-off straight descent at V_{FE} with gear and flaps down or follow emergency descent procedures contained in the AFM.

Condition b.—Perform the following until the first indication of interrupted fuel flow is observed:

Make a continuous power-off glide at 1.3 V_{SO} . Simulate turbulent air or smooth condition, whichever is most critical.

Condition c.—Transition from power-off glide.

Starting from the most critical condition established in condition b above, verify that there is no interruption of fuel flow when making a simultaneous application of Maximum Continuous Power (MCP) and a transition to best rate-of-climb speed, V_Y , from a power-off glide at $1.3 V_{SO}$.

Condition d.—Sideslip on approach. Perform the following for 30 seconds or until the first indication of interrupted fuel flow is observed, whichever comes first:

Establish a $1.3 V_{SO}$ descent in a landing configuration. Maintain a $1\frac{1}{2}$ -ball sideslip in the direction most critical for the fuel feed system. (Use the maximum sideslip anticipated for the airplane if it is less than $1\frac{1}{2}$ -ball.) Maintain a constant heading using sufficient aileron.

Condition e.—Sideslip on approach with balked landing. Perform the following test.

Establish a $1.3 V_{SO}$ descent in a landing configuration. Maintain a $1\frac{1}{2}$ -ball sideslip in the direction most critical for the fuel feed system for 30 seconds. (Use the maximum sideslip anticipated for the airplane if it is less than $1\frac{1}{2}$ -ball.) followed by a maximum power straight ahead balked landing climb for 1 minute. Maintain a constant heading using sufficient aileron.

Are there other tests to perform after determining the unusable fuel supply using the tests above?

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After determining the unusable fuel supply using the tests above, perform the following tests to determine the need for additional fuel gauge markings and restrictions.

1. Taxi Turns and Turning Takeoffs

Choose the minimum fuel quantity sufficient to perform the maneuvers described below. This quantity should not exceed the flight unusable fuel supply plus 30 minutes of fuel supply at MCP (see **NOTE** below). Turns should be in the direction most adverse for the tank being used. Load the airplane to the approximate minimum flying weight or its critical weight. Any engine malfunction due to fuel interruption during this test sequence is not acceptable.

Make a maximum lateral gravity (g 's) 90° turn rolling takeoff. (The maximum lateral g 's turn is where lateral skidding is evident.) Immediately follow the takeoff with a 3-minute climb at best angle-of-climb speed for single-engine airplanes or speed determined under § 23.51 for multiengine airplanes. Follow normal flight procedures and maintain operating conditions necessary for safe operations (i.e., proper engine cooling).

Make a 360° clearing turn at a rate appropriate to the airplane, immediately followed by a takeoff and a 3-minute straight climb at best rate-of-climb speed for single-engine airplanes or the speed determined under § 23.51 for multiengine airplanes. Follow normal flight procedures and maintain operating conditions necessary for safe operations (i.e., proper engine cooling).

DRAFT

Make a 180° turn at normal taxi speed, immediately followed by a takeoff and a 3-minute climb at best rate-of-climb speed for single-engine airplanes or a speed determined under § 23.51 for multiengine airplanes. Follow normal flight procedures and maintain operating conditions necessary for safe operations (i.e., proper engine cooling).

NOTE. If the initial fuel quantity used during the above tests exceeds the 30-minute fuel supply at MCP, take the following actions:

- a. Mark the fuel quantity gauge with a yellow arc (appropriately placarded) from the unusable fuel (“zero” level) to a level corresponding to the amount of fuel used in the above tests.
- b. Add an AFM limitation restricting takeoff with the fuel quantity less than the top of the yellow arc.

2. Level Flight Attitude

If the level flight attitude conditions are found to be critical flight conditions, perform the following test:

Verify (with the specified unusable fuel quantity) that no interruption of fuel flow will occur when performing a full rudder sideslip for 90 seconds with appropriate flaps, airspeed, and power for level flight. The direction of sideslip should be in the direction most critical with respect to fuel feed.

Should fuel flow interruption occur during this additional test at fuel quantities higher than those determined as unusable, verify a return to normal operation during coordinated flight with fuel quantities at or above minimum usable fuel. Determine the highest fuel quantity where the interruption occurs. The following method using a yellow arc may be used to address this fuel system issue while retaining the lower unusable fuel quantity.

- a. Mark and placard the fuel gauge with a yellow arc extending to this higher fuel quantity from the unusable fuel (“zero” level).
- b. Limit the allowable airplane maneuvers in the Airplane Flight Manual (AFM) for operating at these fuel quantities provided the limitations are operationally acceptable for the likely flight conditions when operating at these fuel quantities.

Related Material

AC 20-88A, Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)

Paragraph 23.959(b)

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Does compliance with § 23.959(b) require fuel quantity indicator markings?

The preamble to Amendment 23-51 states paragraph (b) requires that, “The effect of any fuel pump failure on the unusable fuel supply be established. This change would not require any change in the fuel quantity indicator marking required by § 23.1553.”

23.961 Fuel system hot weather operation (Amendment 23-43)

CAR 3 Cross Reference: 3.438

What is the primary concern with fuel systems hot weather operation?

The primary concern is vapor formation resulting in vapor lock in the fuel system. Vapor lock occurs most frequently with hot fuel. Evaluate airplanes using aviation gasoline at the fuel's critical temperature with respect to vapor formation. Evaluate airplanes using jet or diesel fuel at the more critical temperature with respect to vapor formation of 110 °F (-0, +5°) or the airplane's maximum allowable outside air temperature.

Procedures for conducting hot weather fuel tests on airplanes using automobile gasoline (autogas) are contained in AC 23.1521-1B, Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines.

Test results referred to in this section were made at the William J. Hughes Technical Center in Atlantic City, New Jersey.

What considerations are applicable to evaluating hot weather performance for airplane fuel systems?

Several factors are involved in the evaluation of an airplane fuel system for hot weather. The applicant should consider at least the following:

1. Fuel System Design

Fuel system designs should be in compliance with 14 CFR part 23. In particular, do not route fuel lines close to hot exhaust systems as that may cause increased fuel temperature in the fuel lines.

Any fuel system (including gravity feed systems) using aviation or automobile fuels is conducive to vapor formation. Systems using a fuel pump with suction lift are highly susceptible to vapor formation.

2. Determination of Critical Fuel Temperature

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The likelihood of vapor formation and subsequent interruption of engine power increases with elevated fuel temperature up to 110 °F. The temperature value of 110 °F was derived from the distillation data pertinent to aviation and turbine fuels.

The tendency of various fuels to form vapor is different. Fuels such as automobile gasoline (autogas) have an initial boiling point of approximately 85 °F, whereas some turbine fuels have an initial boiling point of approximately 120 °F.

The distillation data for any other fuel should be analyzed and the appropriate test temperature chosen. If, for example, an applicant wanted to test an airplane with liquid hydrogen fuel, it would not be reasonable to require the fuel to be heated to 110 °F since the boiling point is -423 °F at one atmosphere pressure. The same logic should apply, regardless of what alternate fuel is being tested.

Distillation data, provided from the National Institute for Petroleum and Energy Research (NIPER), using the ASTM D-86 distillation method for ASTM D-910 aviation gasoline and winter-grade automotive gasoline, revealed autogas heated to 110 °F in a vented vessel (i.e., an airplane fuel tank) will boil off approximately 18 percent of its mass in the form of non-recoverable vapors. These lost constituents are primarily the highly volatile fractions, mainly pentane and butane, the fuel constituents that can cause vapor lock problems. In contrast, aviation gasoline will boil off approximately 1 percent of its mass when heated to 110 °F.

Since the initial boiling point is a vapor temperature, the actual fuel temperature for the initial boiling point is greater than the vapor temperature. The tendency to form vapor may be related to Reid Vapor Pressure (RVP) with the higher values being more conducive to vapor formation.

3. Test Requirements for Demonstrating Compliance

A flight test is required for the initial certification of an airplane to complete the hot weather operation tests at the critical operating conditions, including the following: maximum fuel flow, highest angle-of-attack (for tractor propeller aircraft), maximum fuel temperature, etc. Supplemental ground testing should closely simulate flight conditions. Derivative models of an airplane may use ground testing and analysis using the original flight test data to demonstrate compliance.

In the case of small airplanes with shallow depth fuel tanks, the actual fuel level in the tanks has little affect on hot weather test results.

4. Other

Fuel temperatures will be significantly higher than the ambient air temperature if the airplane has been parked in direct sunlight.

What are the definitions of common terms used when talking about fuel?

Initial boiling point

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The vapor temperature at which the first drop of liquid fuel is observed after passing vapor through a distillation test apparatus.

Fuel volatility

The fuel's tendency to evaporate (change to a vapor from a fluid).

Vapor lock

Vapor lock is the tendency of a liquid to form vapor in fuel lines, pumps, etc., that would restrict liquid fuel flow to the engine and interrupt combustion.

True vapor pressure

True vapor pressure is the pressure exerted by its vapor in equilibrium with the liquid at a specific temperature with the absence of air over the fuel.

Weathering

Weathering is the reduction of fuel volatility when given sufficient time, agitation, temperature cycles, and/or pressure changes.

What are the requirements for running hot weather compliance tests?

Perform hot weather operation tests only with outside air temperatures at 85 °F or higher measured at 4 feet to 6 feet above the runway surface.

Conduct the tests with the fuel system operating normally per the Airplane Flight Manual (AFM). Do not operate the emergency fuel pumps if they are being considered for use as backup pumps. This test may be used to establish the maximum pressure altitude for operation with the pumps off.

Do not allow the test fuel to weather, which includes exposure to the atmosphere overnight, as this may have a significant effect on the RVP. This ensures that the fuel has the maximum RVP. Take fuel samples just prior to the test to establish that the fuel's vapor pressure is correct.

Set the airplane weight with critical fuel level in the critical fuel tank, minimum crew necessary for safe operation, and the ballast necessary to maintain the center of gravity within allowable limits. If the critical fuel tank cannot be positively identified, then the hot weather operation tests should be repeated for the other tank(s). The critical fuel level in most cases would be low fuel; however, full fuel can be critical.

DRAFT

If required, heat the fuel in the shortest time period possible without causing excessive local temperature conditions at the heat exchanger, optimally less than 90 minutes but not to exceed 180 minutes. The temperature of the fuel during this time period should not exceed the critical values below. Exceeding this temperature will “weather” the fuel by driving off the volatile elements. This will make the fuel less susceptible to vapor lock and defeat the purpose of this test. It is not necessary to provide additional heat to the

fuel system after this initial heating is completed. Raise the temperature of the fuel to the critical value with respect to vapor formation as follows:

1. For aviation gasoline, 110 °F (-0 to +5 °F), and
2. For turbine fuel, 110 °F (-0 to +5 °F).

There are several methods of heating the fuel such as the following:

1. Circulating hot water or steam through a heat exchanger placed in the fuel tank to increase the fuel temperature, or
2. Placing black plastic or other material on the fuel tanks in bright sunlight, or
3. Blowing hot air over the fuel tank.

NOTE. Do not agitate or excessively handle the fuel during the heating process.

CAUTION: Heating and handling fuel at elevated temperatures is hazardous to ground and flight personnel; therefore, every safety precaution should be taken.

If the outside ambient conditions interfere with the ability to conduct a valid test, it may be necessary to insulate fuel tank surfaces, fuel lines, and other fuel system components.

Perform the following as soon as possible after the fuel in the tank reaches the required test temperature:

1. Perform a maximum power takeoff and climb. (This ensures maximum fuel flow rates.)
2. Use the same climb airspeed used in demonstrating the requirements specified in § 23.65.
3. Continue the climb to the maximum operating altitude approved for the airplane.

NOTE. It is not necessary for the engine oil temperature to be at maximum, although it should be at least the minimum recommended for takeoff.

Record the following data, at minimum, throughout the test:

1. Fuel temperature in the tank;
2. Fuel pressure at the start of the test and continuously during climb, noting any loss of pressure, fluctuation, or variations;
3. Main and emergency fuel pump operation, as applicable;

DRAFT

4. Pressure altitude;
5. Ambient air temperature, total or static as applicable;
6. Airspeed;
7. Engine power (i.e., engine pressure ratio, gas generator speed, torque, r.p.m.), turbine inlet temperature, exhaust gas temperature, manifold pressure, and fuel flow, as appropriate;
8. Comments on engine operation;
9. Fuel quantity in the fuel tank(s) during takeoff;
10. Fuel vapor pressure for autogas only, determined prior to test; and
11. Fuel grade or designation, determined prior to test.

The test is passed if:

1. The fuel pressure is at or above the minimum prescribed by the engine manufacturer;
2. The fuel pressure does not fluctuate excessively; and
3. There is no engine malfunction due to fuel interruption throughout the test.

If fuel pressure fluctuations occur, but the test is otherwise passed, consider additional testing requirements to determine that pressure failure may not occur during any expected operating mode. Also, evaluate the fuel system for vapor formation during cruise flight at maximum approved altitude in smooth air at low to moderate power setting, and at low fuel flow and idling approach to landing.

Document instructions for proper fuel pump use during hot weather operation in the AFM. Also, document any limitations on the outside air temperature in the AFM.

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23.963 Fuel tanks: General (Amendment 23-51)

CAR 3 Cross Reference: 3.440

Paragraph 23.963(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.963(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.963(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.963(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.963(e)

No specific policy is available as of December 31, 2002.

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23.965 Fuel tank tests (Amendment 23-51)

CAR 3 Cross Reference: 3.441

Paragraph 23.965(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.965(b)

When is the vibration testing in § 23.965(b) required?

The vibration tests are necessary for any tank with a capacity of more than 10 gallons constructed in a wide flat shape with no baffles. It is acceptable to test the portion of the wing encompassing the tank(s) with a suitable amount of structure extending on all sides provided the support is representative. If there are several tanks spanwise, it may be desirable to test the entire wing, thus substantiating all tanks at the same time. If the entire wing span is wet, then test the entire structure.

The tests *may not* be required if:

1. The tanks include internal baffles (not exceeding 15 inches apart in length and width); or
2. The tank is constructed of a .050 inch or more thick aluminum alloy and the tank uses “suitable” joints. Joining methods can be determined “suitable” based upon design characteristics and relevant service experience.

The tests *are necessary*, even if the above are met, if any permanent set is observed in the baffles or their attachments during the pressure test.

Refer to AC 23-15, Small Airplane Certification Compliance Program, for fuel tanks with less than a 10-gallon capacity.

Paragraph 23.965(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.965(d)

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No specific policy is available as of December 31, 2002.

23.967 Fuel tank installation (Amendment 23-43)

CAR 3 Cross Reference: 3.442

Paragraph 23.967(a)**What should be considered when determining if the tanks are sufficiently supported?**

Consideration should be given to installed fuel system components such as fuel quantity capacitance probes, fuel level floats, fuel lines, and any other components that could induce concentrated loads on primary structure or tank liner attach points during the slosh and vibration test in § 23.965.

What is the definition of minor spillage?

Minor spillage applies to ground operation only. The definition of *minor* is “upon removal of the filler cap, no fuel makes it from the filler opening to the surface upon which the airplane is resting.”

What operations does this rule apply to?

Current policy on § 23.967(a)(6) applies the prohibition against fuel siphoning only to bladder (flexible) fuel tanks. A legal review of the regulation has concluded that the intent of this paragraph is to prevent the fuel loss and associated fuel quantity measuring inaccuracies in collapsed bladder cells due to filler openings being left uncovered. This policy applies to ground and flight operations.

Paragraph 23.967(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.967(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.967(d)

No specific policy is available as of December 31, 2002.

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Paragraph 23.967(e)

What are acceptable means of compliance with § 23.967(e)(1)?

Compliance with § 23.967(e)(1) may be demonstrated by analysis alone, provided sufficient margin can be shown to ensure that fuel leakage is such that no hazard to occupants results.

Related Material

AC 20-107A, Composite Aircraft Structure

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23.969 Fuel tank expansion space (Original)

CAR 3 Cross Reference: 3.443

Does this apply to a pressure refueling system?

Yes, these requirements are applicable, and are related to compliance with § 23.979(b).

NOTE. Fuel tank expansion space is illustrated in Figure 3 of this AC under section 23.959.

DRAFT

23.971 Fuel tank sump (Amendment 23-43)

CAR 3 Cross Reference: 3.441

Paragraph 23.971(a)

What is the purpose of the fuel tank sump?

The fuel tank sump functions as an operational trap for contaminants. The fuel tank sump may be located either within the fuel tank, or outside of the fuel tank, provided the tank is drainable to the sump.

A single fuel tank sump may serve multiple fuel tanks provided:

1. The fuel tanks are interconnected to function as a single tank, and
2. The fuel tanks are completely drainable to one tank.

While part 23 does not require fuel cross-feed capabilities, airplanes with fuel cross-feed systems should also incorporate fuel tank sumps to prevent contaminated fuel from entering the engine.

Paragraph 23.971(b)

Is there guidance as to the time it should take for water to migrate from any part of the fuel tank to its sump?

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Design each fuel tank to allow drainage of any “hazardous” quantity of water from any part of the fuel tank to its sump, with the airplane in the “normal ground attitude” within a reasonable period of time. The amount of time it takes for water in a fuel tank to migrate to the tank sump is dependent on many different factors, including temperature and size and design of the tank. Because of this, a time limit cannot be assigned. The fuel tanks should be designed to provide the most direct path from the different areas of the tank to the sump.

What is a hazardous quantity of water?

A hazardous quantity of water is generally taken to be the amount necessary to affect engine operation if it were taken up into the fuel system and made its way to the engine. Coordination with the engine manufacturer may be required to determine the quantity of water. The term “hazardous” was incorporated by Amendment 23-43 (55 FR 40598, October 3, 1990) based on service experience that reciprocating engine airplane fuel systems are susceptible to water collecting in the fuel tanks. Prior to Amendment 23-43, tank sumps or a sediment bowl/chamber arrangement could be approved that does not

always prevent water from reaching the engine, especially in tank configurations with flexible liners.

Related Material

AC 20-43C, Aircraft Fuel Control

AC 20-116, Marking Aircraft Fuel Filler Openings with Color Coded Decals

Paragraph 23.971(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.971(d)

No specific policy is available as of December 31, 2002.

DRAFT

23.973 Fuel tank filler connection (Amendment 23-51)

CAR 3 Cross Reference: 3.445

Paragraph 23.973(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.973(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.973(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.973(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.973(e)

Why are there fuel-filler opening dimensional restrictions?

The fuel-filler opening dimensional restrictions specified in § 23.973(e) and (f) were incorporated by Amendment 23-43 (55 FR 40598, October 3, 1990) to prevent turbine fuel from being put into tanks of airplanes that operate only on gasoline. The dimensions were established through discussions with airplane manufacturers, fuel suppliers, and pertinent industry associations. In addition, airplanes in production at that time were found to comply with the proposed dimensions.

Related Material

AC 20-122A, Anti-misfueling Devices: Their Availability and Use

Paragraph 23.973(f)

See paragraph (e) above.

DRAFT

23.975 Fuel tank vents and carburetor vapor vents (Amendment 23-51)

CAR 3 Cross Reference: 3.446

What other sections of this document are pertinent to § 23.975?

Some general information on this subject is found in this AC under sections 23.951, 23.955, and 23.959 of this document.

Paragraph 23.975(a)

What is considered excessive pressure as mentioned in § 23.975(a)(3)?

Section 23.975(a)(3) refers to excessive pressure differences between the interior and exterior of the fuel tank. The characteristics and consequences of excessive difference in pressure will depend on the type and material of the tank. For instance, excessive differences in pressure for a bladder-type tank would result in deformation in the bladder resulting in an erroneous fuel quantity indication. Adequate positive pressure should remain within the bladder tank. For an integral tank system, excessive difference in pressure may result in collapse or structural failure of the tank and supporting structure.

What are acceptable means of compliance to § 23.975(a)?

Compliance with the requirements of § 23.975(a) is typically accomplished through a combination of design review and testing (both ground and flight testing).

Paragraph 23.975(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.975(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.977 Fuel tank outlet (Amendment 23-43)

CAR 3 Cross Reference: 3.448

Paragraph 23.977(a)

Why are the requirements different for reciprocating and turbine engine powered airplanes?

The requirement in § 23.977(a)(1) is that the strainer have 8 to 16 meshes per inch. This requirement was introduced with Civil Air Regulations (CAR) 3 in 1945, and the mesh size was found desirable by field service experience. Section 25.977 has the same requirement. The § 23.977(a)(2) requirement for turbine engines is different because field experience showed that this mesh size produced strainer icing problems with turbine engine fuel. Turbine engine fuels have a greater affinity for water than aviation gasolines, and there is a greater chance for entrained water to enter turbine engine fuel systems. The strainer mesh size for turbine engines and turbine fuel is typically larger (4 meshes per inch) than for aviation gasoline. Sections 23.951(c), 23.955, 23.997, 23.1305(b)(4), and 23.1305(c)(8) contain related applicable requirements. For example, the requirements of § 23.997, Fuel Strainer or Filter, are in addition to § 23.977 and must be considered.

Paragraph 23.977(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.977(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.977(d)

No specific policy is available as of December 31, 2002.

DRAFT

23.979 Pressure fueling systems (Amendment 23-51)

CAR 3 Cross Reference: None

Paragraph 23.979(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.979(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.979(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.979(d)

No specific policy is available as of December 31, 2002.

DRAFT

FUEL SYSTEM COMPONENTS**23.991 Fuel pumps (Amendment 23-43)**

CAR 3 Cross Reference: None

Paragraph 23.991(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.991(b)**How are § 23.991(b) and § 23.991(c) related?**

Paragraphs (b) and (c) are interrelated, and the interpretation of § 23.991(c) should consider § 23.991(b).

Both the main and emergency fuel pumps may operate continuously (simultaneously) provided there is a means to immediately indicate to the crew (in-flight) a malfunction of either pump.

A main fuel pump(s) supplies sufficient fuel to sustain the engine(s) during normal operations. An emergency fuel pump can sustain engine operation at full power in the event the engine-driven fuel-injector pump fails. An auxiliary fuel pump can provide some fuel flow during emergency operations but not enough to sustain engine operation at full power. Its function is to aid in priming the engine and suppressing fuel vapors.

Some fuel injection system designs utilize an integral speed-sensing pump, approved as part of the engine type design that delivers fuel at a (unregulated) pressure proportional to engine speed. Such systems have fuel lift capability that enables the system to function with a negative inlet pump pressure within specific limits as indicated by the engine type certificate data sheet (TCDS). For these types of fuel systems, an emergency fuel pump is not required when the injection pump is approved as part of the engine under § 23.991(b).

Other fuel injection system designs require an essentially constant (regulated) fuel pressure to the fuel-injector inlet. The acceptable pressure limits are specified on the engine TCDS. In these systems, the engine-driven fuel pump is functionally independent of the engine and not tied to the type design (regardless of the fuel pump supplier). Consequently, these systems do require an emergency pump (per 14 CFR part 23, § 23.991(b)) to ensure engine operation is sustained should the engine-driven pump fail.

Paragraph 23.991(c)

See paragraph (b) above.

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Paragraph 23.991(d)

No specific policy is available as of December 31, 2002.

DRAFT

23.993 Fuel system lines and fittings (Amendment 23-43)

CAR 3 Cross Reference: 3.550

Related Material:

AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes

Paragraph 23.993(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.993(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.993(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.993(d)

What does the term suitable for a particular application mean?

The term “suitable for a particular application” was incorporated by Amendment 23-43 (55 FR 40598, October 3, 1990) to remove the words “must be approved or.” This wording made § 23.993(d) more restrictive. All components are “approved” if they are installed on a certificated airplane; however, this in itself does not guarantee suitability. For example, fuel hoses could be “approved” through the Technical Standard Order (TSO) system but still not be “suitable” for the environment of a particular installation.

Paragraph 23.993(e)

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How is § 23.993(e) related to the powerplant cooling requirements?

Section § 23.1041 specified that there be provisions for maintaining the temperatures of powerplant components and fluids within their limits during various operations including shutdown. One such provision, as specified in § 23.993(e), is to not locate these items in areas exposed to unacceptable temperatures.

23.994 Fuel system components (Amendment 23-29)
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CAR 3 Cross Reference: None

What is considered a hazardous quantity of fuel in § 23.994?

For the purpose of this section, “hazardous quantity” is defined as one quart, except a greater amount may escape if that greater amount can be substantiated as non-hazardous.

What other sections of the regulations are related to § 23.994?

The following sections are related to § 23.994 and may help determine the acceptability of the design.

§ 23.561 Emergency Landing Conditions, General

§ 23.721 Landing Gear, General

§ 23.863 Flammable fluid fire protection

§ 23.967(e) Fuel tank installation

§ 23.1189 Shutoff means

DRAFT

What are some typical methods used in complying with this rule?

The release of fuel from damaged fuel system components is the most likely cause of fire during a wheels-up landing on a paved runway. Therefore, the location and routing of fuel system components in the engine nacelle(s) and fuselage should be evaluated with respect to runway scraping and the resultant structural deformation. Particular attention should be paid to the release of fuel in areas with possible ignition sources such as electrical arcing and hot components. The following guidelines should be considered.

1. Design the fuel system to minimize the spilling or leaking of fuel and migration of the fuel into areas with like ignition sources.
2. Locate and route the fuel system components as far as practicable from likely impact areas and areas where structural deformation may cause crushing, severing, punctures, rupture of frangible fittings, or high tensile loads in the lines.
3. Construct fuel lines to protect their integrity during and after a wheels-up landing. The lines should allow stretching or movement with the deformed structure.

4. Isolate, separate, and route fuel lines and electrical wiring to the maximum extent practicable to minimize hazardous fuel spillage in these potential ignition source areas.
5. Shield and drain areas of potential fuel spillage away from potential ignition source areas.
6. Locate fuel shutoff valves outside areas of potential damage, such as engine nacelles, and design the valve support structures to maintain their integrity during and after the event.
7. Install auxiliary fuel tanks and systems based on the guidance in AC 23-10, Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes.

DRAFT

23.995 Fuel valves and controls (Amendment 23-29)

CAR 3 Cross Reference: 3.551

What rules are related to § 23.995?

See § 23.1189 Powerplant Fire Protection, Shutoff Means.

Paragraph 23.995(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.995(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.995(c)

What is a typical means of compliance for § 23.995(c)?

Compliance with this rule is usually accomplished by designing the fuel valve installation such that the valve is supported by primary or secondary airframe structure.

Paragraph 23.995(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.995(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.995(f)

DRAFT

No specific policy is available as of December 31, 2002.

Paragraph 23.995(g)

No specific policy is available as of December 31, 2002.

23.997 Fuel strainer or filter (Amendment 23-43)

CAR 3 Cross Reference: 3.552

Does the powerplant installation require a fuel filter if the engine has one per its type certificate?

Turbine engines certificated to 14 CFR part 33, § 33.67, Fuel system, Amendment 33-6 or subsequent, will include a fuel filter complying with § 23.997, and no airframe-supplied filter is required. Turbine engines certificated prior to § 33.67, Amendment 33-6, may require an airframe-supplied filter.

Reciprocating engines certificated to 14 CFR part 33, § 33.35 are not required to have a fuel filter as part of their certificated fuel system. The engine manufacturer is required only to specify the degree of filtering necessary and to verify that particles passing through the specified filter will not adversely affect the engine fuel system operation. Because of this, an engine with a fuel filter certified to § 33.35 is not sufficient to meet all the requirements of § 23.997. To show compliance to § 23.997 for an engine with a filter, an airplane manufacturer would have to coordinate with the engine manufacturer on the filter installation to provide compliance data or add an airframe filter.

Paragraph 23.997(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.997(b)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-15, Small Airplane Certification Compliance Program

Paragraph 23.997(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.997(d)

Is there any requirement for a pilot indication system relative to the fuel filter?

Section 23.1305 requires fuel flow indicators for both reciprocating and turbine-powered airplanes and a means to warn the pilot of fuel strainer or filter blockage before it reaches the capacity specified in § 23.997(d).

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Paragraph 23.997(e)

No specific policy is available as of December 31, 2002.

Related Material

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

23.999 Fuel system drains (Amendment 23-43)

CAR 3 Cross Reference: 3.553

Paragraph 23.999(a)

Where are drains typically located?

Usually more than one drain valve is required to drain the entire fuel system. These are typically located in fuel tank sumps, fuel line low spots, and in fuel filter/strainers.

Paragraph 23.999(b)

May a spring-loaded drain valve be used to comply with § 23.999(b)?

Spring-loaded drain valves may be used to comply with the positive locking provision of this paragraph in any region of positive fuel pressure. If a spring-loaded valve is located in a negative fuel pressure region (e.g., upstream of an engine-drive fuel pump providing suction lift), substantiate the installation by a test.

Related Material:

AC 20-119 Fuel Drain Valves

DRAFT

23.1001 Fuel jettisoning system (Amendment 23-51)

CAR 3 Cross Reference: None

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1001(a)

What is the definition of maximum weight as used in § 23.1001(a)?

The maximum weight to be used in calculating the fuel jettison rate is the maximum takeoff weight of the airplane. This is supported by Amendment 23-7, which, for the most part, used the requirements of § 25.1001 as a new § 23.1001. At the time, § 25.1001 stated that the calculation was to use maximum takeoff weight.

Paragraph 23.1001(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1001(c)

What methods are typically used to show compliance with § 23.1001(c)?

Colored fuel or a surface treatment that changes appearance upon contact with fuel or fuel vapor has been used to detect surface impingement. Combustible mixture detectors, scent, or visual inspections have been used to detect fuel or fuel vapor entering portions of the airplane.

Paragraph 23.1001(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1001(e)

DRAFT

No specific policy is available as of December 31, 2002.

Paragraph 23.1001(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1001(g)

No specific policy is available as of December 31, 2002.

Paragraph 23.1001(h)

No specific policy is available as of December 31, 2002.

DRAFT

OIL SYSTEM**23.1011 General (Amendment 23-43)****CAR 3 Cross Reference:** None**Paragraph 23.1011(a)****Can the part 33 certification of oil system components be used to show compliance with § 23.1011?**

Oil systems and components certified with the engine may or may not be suitable for use in a specific airplane installation, depending upon the test/analysis performed at the time. Also, engines may be originally certified with the intention of being installed in different airplanes than where they are eventually used. Consequently, oil systems and components approved during engine type certification are only acceptable for use without further substantiation when they complied with standards that are equal or more stringent than those in this subpart.

Evaluate each pertinent item in the installation to assess the airplane requirements versus the requirements demonstrated during engine certification. Verify the latter with the engine manufacturer or the FAA office controlling the engine type design.

Paragraph 23.1011(b)**What are the requirements for continued safe operation of the engine(s)?**

The engine requirements for oil quantities and temperatures are established by the engine manufacturer and may be found on the Type Certification Data Sheet or in the engine installation manual. The airplane installation must not cause the engine limits to be exceeded under normal operations.

Paragraph 23.1011(c)**DRAFT****How much oil must the system contain?**

Paragraph 23.1011(c) requires that, “The usable oil tank capacity may not be less than the product of the endurance of the airplane under critical operating conditions and the maximum oil consumption of the engine under the same conditions, plus a suitable margin to ensure adequate circulation and cooling.” In other words, there needs to be enough oil (usable supply) to allow the engine to consume the usable fuel. This should be substantiated by a quantitative analysis.

In addition, a suitable oil quantity margin for system circulation is necessary for all engine installations. The oil system should be capable of maintaining the engine within

its operating limitations (i.e., oil temperature with the minimum oil quantity provided for circulation). Cooling tests do not need to be performed with a low usable oil supply provided the oil is properly cooled at all oil levels.

What are the definitions of some of the terms used to determine the required oil quantity?

Usable Oil

Usable oil is defined as the quantity of oil in the oil tank (or sump in the case of wet sump engines) in excess of the minimum quantity of oil required to keep the oil pump inlet feed covered under the most adverse operating condition.

In the absence of any other data, the most severe of the following two conditions may be used as the most adverse operating condition (in both cases, with the airplane at a zero-degree roll angle):

1. The nose-up pitch angle required for the sea level best rate-of-climb speed with maximum continuous power, or
2. The nose-down pitch angle required for the 1.3 V_{SO} power-off landing configuration.

For most wet sump engines, the usable oil quantity for various pitch angles is listed on the appropriate engine Type Certificate Data Sheet (TCDS). This quantity may be used instead of a determination of usable oil as described above. If the usable quantity is not listed, it may be determined by contacting the engine manufacturer or conducting a usable oil test with the critical operating conditions.

Usable Fuel

The usable quantity of fuel established under § 23.959.

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Specific Oil Consumption (SOC)

The SOC is the maximum oil consumption rates established by the engine's manufacturer, expressed in pounds per brake horsepower per hour (lb./bhp/hr.). If such a maximum oil consumption rate is not available, use 0.012 lb./bhp/hr. for reciprocating engines. There is no similar "default" maximum oil consumption rate for turbine engines.

You can also establish an oil consumption rate by the following:

1. **Statistical analysis of actual in-service oil consumption rates.** The analysis should include observed data on the actual oil consumption from statistically valid sample engines of the same model. These data should be obtained from

high time engines or those with high oil consumption just prior to removal for overhaul.

2. **Testing per an FAA-approved test plan.** Testing for a lower oil consumption rate should include a positive demonstration that a lower oil consumption rate will not jeopardize the airworthiness of the engine.

Specific Fuel Consumption (SFC)

SFC is the fuel consumption established for the engine based on available engine power expressed in pounds per brake horsepower per hour.

What are the acceptable means of compliance for § 23.1011(c)?

Single-engine Installations

Determine the **minimum** allowable usable oil capacity from the airplane's endurance (~total fuel capacity divided by the minimum SFC) and the maximum allowable oil consumption rate. For either wet or dry sump engines, this is expressed mathematically as follows:

$$[\text{Minimum Usable Oil Capacity (lbs.)}] = \frac{[\text{Maximum Usable Fuel Capacity (lbs.)}] \times [\text{Maximum SOC (lb./bhp/hr.)}]}{[\text{Minimum Obtainable SFC (lb./bhp/hr.)}]}$$

A usable oil capacity greater than or equal to the calculated number above is acceptable.

Multiengine Installations

Calculate the minimum usable oil capacity for a multiengine aircraft as above, except modify as follows:

Account for the additional usable fuel if the airplane has a fuel cross-feed system or common fuel tank in the event of an engine shutdown. Allocate 50 percent of the maximum usable fuel capacity attributable to the shutdown engine as available to the other engine(s). For example, for a twin-engine airplane with 1,000 pounds of maximum usable fuel, 500 pounds of which is attributed to the shutdown engine, add 50 percent of that (250 pounds) to the available fuel.

In addition, adjust the fuel consumption of the remaining engine(s) to reflect any power or mixture setting changes made to complete the flight safely.

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Paragraph 23.1011(d)

What oil quantity should be used in finding compliance with § 23.1011(d)?

A conventional system (no transfer system provided) should only consider the usable oil tank or sump capacity in the determination of the usable oil supply. Do not consider the quantity of oil in the engine oil lines, in the oil radiator, oil filter, propeller feathering reserve, etc. If the airplane manufacturer elects to operate the engine with less than total oil capacity, the lower oil level should be used in the analysis.

Paragraph 23.1011(e)

Is it possible to consider oil in transfer lines as part of the usable oil?

When an oil reserve system is installed, additional oil may be available. The system is often configured so the transfer pump can pump oil into the main engine oil tank(s) from the transfer lines. In this case, include the quantity of oil that would be pumped to the main engine oil tank(s) in the determination of the usable oil supply.

DRAFT

23.1013 Oil tanks (Amendment 23-51)

CAR 3 Cross Reference: None

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

NOTE. In the event of differences between AC 20-135 and AC 23-2 (see below for AC title), the applicant may choose whichever advisory circular is most applicable and/or advantageous.

Paragraph 23.1013(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1013(b)

What is the difference between the expansion space requirements in § 33.71(c) and § 23.1013(b)?

The requirements of § 33.71(c) and § 23.1013(b) are similar, and both the engine manufacturer and the installer must show compliance to the oil tank expansion space requirement. When showing compliance with § 23.1013(b), data from the certification of the engine to § 33.71(c) may be used. Compliance with the installation requirements should account for any installation affects including wing dihedral, installed engine droop, and yaw angles. This could require ground test of both a left and right wing engine if adequate data is not available from the part 33 compliance demonstration.

In some cases, the oil quantity in the tank may change with changing engine operating conditions such as engine rotation. This condition can result in overfilling the engine oil tank resulting in less than the required expansion space if the tank is serviced soon after engine shutdown. If conditions like this exist, they can be handled by oil system servicing limitations in the appropriate manuals with placards near the fill port.

Paragraph 23.1013(c)

No specific policy is available as of December 31, 2002.

DRAFT

Paragraph 23.1013(d)

No specific policy is available as of December 31, 2002.

AC 23-16A

Paragraph 23.1013(e)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

Paragraph 23.1013(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1013(g)

No specific policy is available as of December 31, 2002.

DRAFT

23.1015 Oil tank tests (Amendment 23-15)

CAR 3 Cross Reference: None

What guidance is available for compliance with § 23.1015?

The requirements in § 23.1013 provide detailed specifications for compliance and no additional guidance has been developed.

Paragraph 23.1015(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1015(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1015(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.1017 Oil lines and fittings (Amendment 23-14)

CAR 3 Cross Reference: 3.570, 3.575

Paragraph 23.1017(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1017(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1019 Oil strainer or filter (Amendment 23-43)

CAR 3 Cross Reference: 3.573

Paragraph 23.1019(a)**Can the engine oil pressure indicator be used to comply with § 23.1019(a)(3)?**

The engine oil pressure indication may be used as a method of detecting oil filter/strainer contamination provided the applicant demonstrates a procedure that does the following:

1. Identifies the oil strainer/filter contamination, and
2. Isolates the contamination as the sole cause of an indicated oil pressure change.

The procedure used to comply with § 23.1019(a)(3) should be documented in the Airplane Flight Manual.

Can a red warning light be use to comply with § 23.1019(a)(5)?

A red warning light is one means of complying with § 23.1019(a)(5).

Paragraph 23.1019(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1021 Oil system drains (Amendment 23-43)

CAR 3 Cross Reference: 3.574

Paragraph 23.1021(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1021(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1021(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.1023 Oil radiators (Original)

CAR 3 Cross Reference: 3.572

No specific policy is available as of December 31, 2002.

DRAFT

23.1027 Propeller feathering system (Amendment 23-43)

CAR 3 Cross Reference: None

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1027(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1027(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1027(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1027(d)

No specific policy is available as of December 31, 2002.

DRAFT

COOLING**23.1041 General (Amendment 23-51)**

CAR 3 Cross Reference: 3.581

What altitudes are typically used for demonstrating compliance with the cooling requirements for reciprocating engine powered airplanes?

For reciprocating engines, cooling climb tests are typically commenced at pressure altitudes below 5,000 feet. The applicant should choose test conditions that are the most adverse with respect to demonstrating engine and engine component cooling for the installation.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

DRAFT

23.1043 Cooling tests (Amendment 23-51)

CAR 3 Cross Reference: 3.582, 3.583, 3.584, 3.585

Paragraph 23.1043(a)**What are the typical means of complying with § 23.1043?**

In general, the demonstration of compliance with this section requires analysis to identify areas of concern and instrumentation requirements and flight tests to demonstrate compliance. The applicant must identify all critical components (electronic components, actuators, etc.), fluids (engine oil, hydraulic fluid, etc.), and structures that have temperature limits. The limits are typically based on component qualification testing. Each limit may be expressed in terms of a fluid temperature, surface temperature, or environmental temperature and may have associated time limits. Instrumentation should be installed to provide data needed to show that the corrected temperature for each critical component, fluid, and structure remains below the identified limit.

Are there any special considerations for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis?

For these aircraft, conduct engine cooling test per AC 23-8B, except as follows: After the temperature has stabilized for the pre-takeoff holding condition on the taxiway, feather the propeller and record the data until the temperatures stabilize. **NOTE:** This simulates normal agricultural operational engine running loading conditions. These criteria can be disregarded if the propeller is not feathered during normal agricultural operations on the ground.

Are there any special considerations for certificating winterization kits?

Winterization kits modify an airplane for operation in cold weather environments. These kits typically block or baffle air inlets to decrease the mixing of cold air in the engine compartments and keep the temperatures of fluids and components from falling below operating range. These kits can allow certification to lower ambient temperature operations than the standard 38 °C (100 °F). These limits must be reflected in the Airplane Flight Manual and placards on the equipment to indicate when the equipment should be removed. Additional guidance is available in paragraph 246 of AC 23-8B.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1043(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1043 (c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1043 (d)

DRAFT

No specific policy is available as of December 31, 2002.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

DRAFT

23.1045 Cooling test procedures for turbine engine powered airplanes (Amendment 23-51)

CAR 3 Cross Reference: None

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1045(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1045(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1045(c)

No specific policy is available as of December 31, 2002.

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**23.1047 Cooling test procedures for reciprocating engine powered airplanes
(Amendment 23-51)**

CAR 3 Cross Reference: 3.587

No specific policy is available as of December 31, 2002.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

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LIQUID COOLING

23.1061 Installation (Amendment 23-43)

CAR 3 Cross Reference: None

Paragraph 23.1061(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1061(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1061(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1061(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1061(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.1061(f)

No specific policy is available as of December 31, 2002.

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23.1063 Coolant tank tests (Original)

CAR 3 Cross Reference: None

Paragraph 23.1063(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1063(b)

No specific policy is available as of December 31, 2002.

DRAFT

INDUCTION SYSTEM

23.1091 Air induction system (Amendment 23-51)

CAR 3 Cross Reference: 3.605

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1091(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1091(b)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

Paragraph 23.1091(c)

What is considered a hazardous quantity in § 23.1095?

A hazardous quantity is defined as one that if ingested into the engine inlet would cause the engine to exceed its operational limitations, cause a significant loss of power, or otherwise cause the engine to operate in an unsafe condition.

Related Material

AC 20-124, Water Ingestion Testing for Turbine Powered Airplanes

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23.1093 Induction system icing protection (Amendment 23-51)
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CAR 3 Cross Reference: 3.606

Is an airplane required to comply with § 23.1093 if it is not being certified to fly in icing conditions?

Yes, compliance with § 23.1093(b) for induction system icing protection is required for all normal, utility, acrobatic, and commuter category airplanes certificated under part 23 even if the airplane is *not* being certificated for flight in icing conditions (§ 23.1419 compliance). Service experience has shown that airplanes encounter icing conditions even if the airplane is not approved for flight into icing conditions. This is particularly true for turbine engine powered airplanes, which typically have a greater operating flight envelope than reciprocating engine powered airplanes. These requirements are in addition to those demonstrated during engine certification (reference 14 CFR part 33, subpart E, § 33.68, Induction system icing, for turbine aircraft engines).

What other icing related sections of 14 CFR part 23 cover the propulsion systems?

Sections 23.901(d)(2), 23.929, and 23.975(a)(1) address engine ice ingestion capability, engine installations including propellers, and fuel tank venting, respectively.

Are all icing related sections of 14 CFR part 23 that cover the propulsion systems required for airplanes not being certificated to fly in icing conditions?

Airplanes not being certified for flight into icing conditions per § 23.1419 do not have to demonstrate compliance with § 23.929.

Are there any special considerations for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis?

An exemption to the requirements of § 23.1093 is possible for single-engine piston or turbopropeller airplanes certificated under the provisions of 14 CFR part 21, § 21.25(a), for special purpose agricultural operations. A limitation in the Airplane Flight Manual, such as “Operation of the airplane in visible moisture below 40 °F is prohibited,” will be sufficient to address this regulation.

What methods can be used to show compliance with § 23.1093?

Compliance with § 23.1093 can be shown using an appropriate combination of the methods listed and described below.

1. Compliance with part 33 icing requirements

2. Similarity and service experience
3. Analysis
4. Ground testing
5. Flight testing with an airborne icing tanker
6. Flight testing in natural icing conditions

How can the part 33 engine certification be used to demonstrate compliance?

Engine certification to part 33 does not fully address all the part 23 engine installation requirements. For example, part 33 engine certification does not address snow ingestion. It is the responsibility of the airplane applicant and not the engine manufacturer to show compliance with the part 23 induction system ice protection requirements.

An applicant seeking airplane certification should coordinate the installation of an engine with the engine manufacturer. The engine manufacturer should be able to identify critical points, conditions, and operational requirements that may need to be addressed when showing compliance with the installation requirements. Typically, part 33 engine certification programs do not fully address all the part 23 engine installation requirements. Engine type certification data can be used as the basis for reducing design risk, analysis, and testing. When showing compliance with § 23.1093, the airplane applicant should evaluate the engine type certification data and demonstrate how the data is applicable to the particular installation. For example, the use of an inlet system recommended by the engine manufacturer would still require installation substantiation to show compliance with part 23 requirements.

How can similarity and service experience be used for compliance?

The use of similarity and service experience is appropriate to lessen the design risk associated with an installation. Once an applicant has developed data on an installation, the applicant may then use this data, when suitable, for substantiation on later projects with similar installations. It is common and proper for an applicant to base analytical methods and test point definitions on experience and testing from previous, similar certification programs performed by the applicant. Certification is based on the analysis and testing of an airplane's type design. Because of this, it is difficult to show similarity to an airplane configuration certified by another applicant without direct access to the type design data used for that certification.

Even if previous experience and data are used, each inlet/engine installation and the associated operating characteristics can be different and should be considered individually. Therefore, it is not appropriate to use similarity or service experience by itself for the purpose of demonstrating compliance to the § 23.1093 requirements.

Rather, such means as similarity or service experience should be supplemented with either analysis, even if only basic design analysis to substantiate similarity, or testing, or a combination of both.

Can compliance with § 23.1093 be accomplished with analysis alone?

No, analysis alone is not sufficient to show compliance. Testing is normally required to demonstrate compliance as analytical methods have been difficult to validate. It is possible, for airplanes not being certified to § 23.1419, that flight testing will not be required given analysis that is backed by similarity to and service experience of other certified installations.

How can ground testing be used to show compliance?

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Artificial icing conditions can be generated in icing tunnel facilities. Artificial icing for compliance to ground ice fog requirements can also be generated with an icing spray rig set up in front of the airplane. The icing conditions are very dependent on the calibration of the nozzles. SAE ARP 5905 contains calibration guidelines for icing tunnels. The personnel operating icing spray rigs should be familiar with the calibration of icing nozzles.

Artificial snow can be generated in some ground facilities to supplement natural snow testing. Considerations are provided in the discussion under § 23.1093(b).

How can tunnel test data be used for compliance?

An area where there has been much discussion has been the use of tunnel test data instead of full-scale, airplane flight test data for showing compliance with § 23.1093. The use of tunnel test data is a common, appropriate, and often efficient means to reduce the amount of testing required by the applicant for showing compliance. However, the extent that this data can be used for compliance is dependent upon how representative the test article and test conditions are to the installation and airplane operating conditions.

It is not uncommon for tunnel testing to be performed on a prototype or test inlet that often has design differences from the production inlet used by an installer. When using tunnel test data, or any test data for that matter, as a basis for testing or certification, the applicant must address the differences and the impact of the differences. Three areas of difference usually addressed include the following:

1. Heated versus non-heated inlets;
2. Inlets with movable or variable internal devices (for example, movable vanes used to select bypass modes on a number of turbopropeller inlets) versus fixed inlets; and
3. Differences in geometry even if the inlet type (fixed versus variable) is the same.

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As an example, if tunnel testing is performed with a heated inlet and an applicant incorporates a non-heated inlet, ice runback/refreeze may be reduced, but items such as ice accretion characteristics will be different.

It must be ensured that the tunnel tests were performed at the critical points. Advisory Circular 20-73, Aircraft Ice Protection, provides guidance on critical points determination.

How can testing with airborne icing tankers be used for compliance?

Tanker icing tests are not used as a sole means of compliance, but may be used:

1. To verify analyses or scaled icing tunnel tests
2. To obtain data at the limits of the Appendix C icing envelopes
3. To evaluate ice shedding characteristics

SAE ARP 5904 provides useful information on icing tanker testing.

One limitation of icing tankers in the past has been their inability to generate droplet sizes at the low end of the Appendix C envelope, which may be critical for inlets with curves and bends, such as some turboprop inertial separation inlets.

How can flight test in natural icing conditions be used for compliance?

Airplanes being certified for flight into icing conditions per § 23.1419 will require flight test into natural icing conditions. The results of this testing can be used to show compliance with § 23.1093.

Airplanes not being certified for flight into icing conditions per § 23.1419 do not necessarily require flight test into natural icing conditions to show compliance with § 23.1093. It is acceptable to use analysis backed with sufficient similarity and service experience to show compliance.

Related Material

AC 20-73, Aircraft Ice Protection

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

AC 23.1521-1B, Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines

SAE ARP 5904, Airborne Icing Tankers

DRAFT

SAE ARP 5905, Calibration and Acceptance of Icing Wind Tunnels

Paragraph 23.1093(a)**What does the term preheat mean and how is it different from heat rise?**

Current interpretation of the term preheat as written in § 23.1093(a)(4) and § 23.1093(a)(6) is that it is a change in temperature above the ambient requirements stated in the regulation. Thus, it is interpreted as interchangeable with the term heat rise.

The regulation is written to provide rules of compliance that can be reasonably demonstrated without testing over the whole range of the icing and engine power envelopes. Per Appendix C of part 25, the icing temperature envelope extends down to -22 °F, a condition that is difficult to attain during a normal flight test program. The interpretation of § 23.1093(a)(6) is that a “preheat of 60 °F” requires a change of 60 °F above the 30 °F ambient baseline temperature. This interpretation ensures that the system will always provide sufficiently heated air to prevent icing even if the airplane encounters the worse case scenario with -22 °F temperatures and the engines at idle as with a descent to landing.

Related Material

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

Paragraph 23.1093(b)**Why are the falling and blowing snow requirements separate from the icing and water ingestion requirements?**

The falling and blowing snow requirement was incorporated separately from the icing and water ingestion requirements due to the unique characteristics of snow. The requirement contained in § 23.1093(b)(1)(ii), incorporated initially by Amendment 23-15, is to evaluate the installed powerplant system to ensure that no hazardous effects are encountered when operating in falling and blowing snow. A hazardous effect could be unacceptable engine operating characteristics (for example, adverse power loss, surges, and so forth) due to inlet blockage or engine damage resulting from conditions such as snow, which may accumulate, melt, refreeze, shed, and then be ingested by the engine. Therefore, compliance with engine induction system icing requirements does not show compliance with the snow requirements in § 23.1093(b)(1)(ii).

What should be considered relative to complying with the falling and blowing snow requirements?

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The effect of ingesting snow during ground operations and critical in-flight operations should be evaluated. Service experience has demonstrated that engine damage can occur as a result of prolonged ground operations in falling and blowing snow. Also, in-flight

service experience has shown that snow, which has melted and refrozen, can shed from engine, inlet, or airplane accumulation sites, resulting in adverse engine operability or engine damage. The critical snow environment is a "wet, sticky snow," which accumulates on unheated exterior and interior surfaces subject to impingement.

When showing compliance with § 23.1093(b)(1)(ii), the installation should be reviewed to identify potential inlet, engine, and airframe sites where snow accumulation and shedding is possible. The airplane ground and in-flight operational envelope should be reviewed to determine critical conditions that should be addressed. The information from these reviews should be used to identify the critical conditions to evaluate compliance. The following differences between turbopropeller and turbofan/jet installations should be considered:

1. Typical turbopropeller installations have inlets that incorporate complex geometry with features such as particle separators, plenum chambers, screens, oil coolers, and so forth, where hazardous snow accumulations may occur. Turbopropeller installations normally require testing in operationally representative conditions.
2. Typical turbofan/jet installations, using simple pitot (straight duct) inlets, have minimal, if any, areas for snow accumulation. For these inlets, in-flight icing tests have generally been found to be more critical than snow tests. Turbofan/jet installation may be found acceptable by inlet design and airplane operation analysis. Care should be taken to identify potential airplane accumulation sites that could shed into the engine(s), such as in the case of aft-mounted engines. Atypical installations with S-type inlet geometries should be treated like the turbopropeller installations when finding compliance with § 23.1093(b)(1)(ii).

What operationally representative condition should be considered?

When evaluating the conditions for showing compliance, the following airplane operations should be considered:

1. Takeoff power after static operation with the engine at idle for 30 minutes.

This condition is considered critical due to the operational consideration of idling an engine on the ground with minimal ability for de-ice/anti-ice. The primary concern is the loss of power at takeoff roll.

It is acceptable to incorporate engine run-up to higher power settings during the 30 minute period for the purposes of ice/snow shed, provided the procedure does not create any hazards. A potential hazard could be the airplane sliding toward other airplanes due to the higher power settings required. If run-ups are performed during compliance demonstration, these procedures should be incorporated as limitations in the flight manual.

2. Higher power settings

Higher power settings, which could result in increased snow ingestion, associated with taxi/hold ground operations.

3. Takeoff run to takeoff speed

Airplanes with identified sites of possible hazardous snow accumulation and all inlets with bypass ducts (for example, typical turbopropeller inlets), should consider a takeoff run to takeoff speed. This condition is considered critical since—

- a. Accumulated snow may come loose and the engine can ingest it in this condition; and
- b. The static, idle point will not provide the ram effects that create bypass flow for bypass ducts.

DRAFT

4. Takeoff climb

Airplanes with identified sites of possible hazardous snow accumulation should consider a takeoff climb. This condition is considered critical because accumulated snow may come loose and the engine can ingest it in this condition.

5. Extended in-flight operations

Conditions such as holding patterns should be considered.

6. Operation when engine rotor speeds are low

Operations with low engine rotor speeds, such as during descent from high altitudes, should be considered. An engine is highly susceptible to snow/ice accretion during this condition.

Is a flight test required for all these operational conditions?

The preceding conditions are operational considerations and not meant to require flight test at all the conditions. Each installation may have different critical operational considerations and only the critical conditions may need flight testing.

When appropriately substantiated by the applicant, some of the conditions can be, and have been, simulated and accepted by the FAA. For example, for a turbopropeller engine that incorporates an inlet screen that precludes the ingestion of hazardous quantities of materials, the critical concern may only be the effect of snow accumulation and release from the inlet and screen. In this case, the inlet, bypass duct, inlet screen, and so forth, could be blocked to simulate snow accumulation on an identified area of concern. Since accumulation during dynamic operation would be simulated, the effects of snow

ingestion could be determined through ground tests (for example, effects of operability on items such as reverse flow). Such methodologies need to be substantiated by means such as design analysis, operational review, tunnel tests, icing tests, and so forth, and coordinated early with the FAA.

How is the actual snow amount quantified for testing?

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When testing in "falling and blowing snow" the actual snow amount is often difficult to quantify. The FAA Aeronautical Information Manual (AIM), an official FAA guide to basic flight information and air traffic control procedures, may be used as guidance for what constitutes falling and blowing snow. Per the AIM, paragraph 7-1-18, heavy snow, which is representative of what may be expected in operation, is defined as visibility of 1/4 mile or less as limited by snow (not snow and fog). These conditions are usually indicative of the wet snow environment necessary for test. When using the 1/4 mile or less visibility for test, including flight tests, this value can be determined using ground conditions. Useful information on snow characterization can also be found in FAA Report DOT/FAA/AR-97/66, Snow and Ice Particle Sizes and Mass Concentrations at Altitudes Up to 9 km (30,000 ft.). Advisory Circular 29-2C (Certification of Transport Category Rotorcraft), section AC 29.1093, paragraph c(4)(iv), also provides information on snow quantification, including desired snow concentration, which is acceptable for use on part 23 airplanes. Whatever method is used to characterize the snow, as mentioned earlier, the design consideration that has been found to be critical is snow that accumulates on surfaces subject to impingement. Therefore, the applicant should address this consideration when choosing the appropriate snow environment.

What temperatures are considered appropriate for testing?

The applicant is responsible for defining the critical ambient temperatures for snow tests. The primary consideration is to demonstrate operability in a snow environment that is critical as far as snow accumulation on exterior and interior areas of impingement (for example, wet, sticky snow). However, for a snow environment indicative of a representative concentration expected for the airplane, temperature is also an important consideration. The applicant is responsible for defining the critical ambient temperatures for snow tests.

Typically, in natural conditions, a temperature range between 25 and 34 degrees Fahrenheit has been found conducive to the heavy snow environment. However, colder temperatures may be critical to some configurations. For example, in some installations, colder exterior surfaces may be by-passed, with snow crystals sticking to partially heated interior inlet surfaces, leading to melting and refreeze. Company developmental tests or experience with similar induction systems may be used to determine critical conditions.

Is it difficult to locate and maintain the desired conditions for the test?

Snow concentration corresponding to the visibility prescribed is often extremely difficult to locate naturally and it is often difficult to maintain the desired concentrations for the

duration of testing. Because of this, it is likely that exact target test conditions will not be achieved for all possible test conditions. Those involved in certification must exercise reasonable engineering judgment in accepting critical test conditions and alternate approaches, with early coordination between the applicant and the FAA addressing these realities.

Is it possible to use artificially produced snow for the test?

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Artificially produced snow is an excellent developmental tool and has been used successfully to show potential problem areas and critical test points. When the desired natural snow concentration is not found, artificial means may be used to supplement the snow amount. However, when snow testing is required, the use of simulated snow is normally not used as the sole means of compliance. The desired heavy snow environment produces "wet, sticky snow," which accumulates on unheated exterior and interior surfaces subject to impingement. Most artificial means (for example snow blowers) produce snow pellets that are dissimilar to the snowflakes associated with "wet, sticky snow." Also, simulated snow produced indoors does not accumulate moisture from snowfall as seen in naturally created snow, with critical temperatures for simulated snow varying significantly from natural snow. Therefore, quantification of artificially produced snow for critical conditions can be difficult and subjective. If artificial means is proposed as a means of compliance, the applicant should provide data and substantiation on how the artificial means will effectively simulate the critical, desired operational consideration.

What is the difference between falling and blowing snow?

The concentration of snow entering the inlet in blowing snow will normally exceed the amount in falling snow; hence, the need to address "blowing snow." The location of the inlets should be considered to determine critical directions of blowing snow in relation to snow accumulation on impingement surfaces. Snow blowing in excess of 15 knots is the appropriate compliance condition. Means such as use of another airplane's propeller, taxiing the airplane in excess of 15 knots, and so forth, may be used to simulate blowing.

Is it possible to use flight manual limitations to comply with § 23.1093(b)(1)(ii)?

The only possible flight manual limitation that may be acceptable would be prohibitions for ground operations such as taxi, takeoff, engine runs, and so forth. As with all environmental considerations, such as rain, ice, hail, lightning, and so forth, operation in snow is considered an unavoidable, meteorological hazard that must be addressed including flying into snow after deployment.

What should be considered relative to complying with the § 23.1093(b)(2) requirements?

The requirement of § 23.1093(b)(2), incorporated by Amendment 23-15, addresses running the engine in an atmospheric condition commonly referred to as "ice fog." The

DRAFT

engine is run at idle power in this condition to ensure no ice build-up that produces adverse engine operational characteristics (for example, no surges or adverse power losses). The § 23.1093(b)(2) requirement is as an extension of the 14 CFR part 25, Appendix C, icing envelope addressed in §§ 23.1093(b)(1)(i) and 23.1419. Therefore, the methodologies and analysis used for compliance with § 23.1093(b)(1)(i) can be extended for § 23.1093(b)(2) compliance.

It is often difficult to encounter all the ambient conditions required by § 23.1093(b)(2); therefore, when testing, one or more of the conditions is typically simulated. For example, a common and acceptable method of compliance is using water spray devices to simulate the water conditions required while testing at the required ambient temperature conditions. Other manufacturers have used thermal analysis combined with dry air tests using ice shapes/simulated blockage to demonstrate compliance, which is also acceptable if properly substantiated.

The rule allows an engine run-up periodically to higher power settings to shed ice. As with snow testing, if run-ups are performed during compliance demonstration, then these procedures should be incorporated as limitations in the flight manual. Also, before run-ups are accepted, the practicality of the procedures should be evaluated.

Related Material

FAA Aeronautical Information Manual (AIM)

FAA Report DOT/FAA/AR-97/66, Snow and Ice Particle Sizes and Mass Concentrations at Altitudes Up to 9 km (30,000 ft.)

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

AC 20-73, Aircraft Ice Protection

AC 29-2C, Certification of Transport Category Rotorcraft

Paragraph 23.1093(c)

DRAFT

No specific policy is available as of December 31, 2002.

23.1095 Carburetor deicing fluid flow rate (Original)

CAR 3 Cross Reference: None

Paragraph 23.1095(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1095(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1097 Carburetor deicing fluid system capacity (Original)

CAR 3 Cross Reference: None

Paragraph 23.1097(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1097(b)

No specific policy is available as of December 31, 2002.

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23.1099 Carburetor deicing fluid system detail design (Original)

CAR 3 Cross Reference: None

No specific policy is available as of December 31, 2002.

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23.1101 Induction air preheater design (Amendment 23-43)

CAR 3 Cross Reference: 3.610

What is the purpose of the induction air preheater?

Some carburetor and fuel injection system designs do not experience icing. Designs that are susceptible to icing typically incorporate a means to preheat the air supply entering the system. The purpose of this system is to add sufficient heat to replace the heat lost due to vaporization of the fuel such that the mixing chamber temperature cannot drop to the freezing point of water. This is typically accomplished with a system consisting of an engine exhaust heated jacket surrounding the induction duct, which serves to preheat the inducted air. There is a control installed in the flight deck for adjusting the preheater valve such that the system may be operated only when required to prevent ice formation.

Paragraph 23.1101(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1101(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1101(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.1103 Induction system ducts (Amendment 23-43)

CAR 3 Cross Reference: 3.611

Paragraph 23.1103(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1103(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1103(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1103(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1103(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.1103(f)

No specific policy is available as of December 31, 2002.

DRAFT

23.1105 Induction system screens (Amendment 23-51)

CAR 3 Cross Reference: 3.612

Paragraph 23.1105(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1105(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1105(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1105(d)

No specific policy is available as of December 31, 2002.

DRAFT

23.1107 Induction system filters (Amendment 23-51)

CAR 3 Cross Reference: None

Paragraph 23.1107(a)

What should be considered in the design of induction system filters to comply with § 23.1107?

The filter media should be resistant to fuel, oil, water, cleaning materials, and other engine/airplane fluids in the powerplant installation. It should also be flame resistant. In addition, gasket material and adhesives should be resistant to fuel, oil, water, normally used cleaning materials, and other engine/airplane fluids in the powerplant installation. They should not deteriorate from exposure to engine compartment temperatures.

Paragraph 23.1107(b)

What design features should be considered for filter installations?

Design the filter installation to preclude the release of pieces of the filter and/or gasket material into the intake airstream. These failures are critical as they can result in a power loss. One methodology is to provide screens or other restraints to prevent failed pieces from moving downstream and interfering with the fuel metering components.

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23.1109 Turbocharger bleed air system (Amendment 23-42)

CAR 3 Cross Reference: None

Paragraph 23.1109(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1109(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1111 Turbine engine bleed air system (Amendment 23-17)

CAR 3 Cross Reference: None

Paragraph 23.1111(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1111(b)

How can the bleed air effects on the engine and airplane be established?

The engine manufacturer provides information on the engine bleed air limits. This information should be used as a starting point for determining the effects on the installed engine and the airplane that are usually established through testing. It is important not to exceed the certificated engine limits as this could invalidate the engine certification for the installation required in § 23.903(a)(1).

Paragraph 23.1111(c)

No specific policy is available as of December 31, 2002.

DRAFT

EXHAUST SYSTEM

23.1121 General (Amendment 23-51)

CAR 3 Cross Reference: 3.615

Are there any general guidelines for exhaust system installations?

Use the following guidelines for exhaust system installations:

1. Provide sufficient clearance and/or heat shielding between exhaust components and spark plugs, plug leads, mount isolators, induction systems, engine controls, fuel systems, and other heat-sensitive airframe components.
2. The exhaust system should be accessible for inspections. Adequately support all exhaust components such as tail pipes, heat exchangers, and mufflers.
3. Provide slip joints or other suitable components in the exhaust system to address thermal expansion and engine movement. Locate any such components so minor leakage does not impinge on components or contaminate the cabin air.

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1121(a)

DRAFT

What are acceptable means of compliance with § 23.1121(a)?

Compliance with § 23.1121(a) should be demonstrated through testing using any acceptable carbon monoxide detection method. The test should be conducted with the airplane's heater system in operation if there is any possibility of the system containing carbon monoxide and with aircraft thermal deicing systems, if installed, in full operation. The effect of different airplane configurations and flight and ground conditions on the induction of carbon monoxide into the passenger cabin should be considered in establishing the test procedures. Flight test guidance is provided in chapter 166 of AC 23-8B.

Is a system that employs a carbon monoxide (CO) detector to warn the pilot of unsafe concentrations during normal operations acceptable to show compliance with § 23.1121(a)?

No, a system with a CO detector to warn the pilot of unsafe concentrations is not sufficient to show compliance. Section 23.1121(a) requires that the system be designed to prevent CO contamination of the personnel compartment in the first place.

Related Material

AC 20-32B, Carbon Monoxide (CO) Contamination in Aircraft—Detection and Prevention

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1121(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(c)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

AC 20-107A, Composite Aircraft Structure

Paragraph 23.1121(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(g)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(h)

No specific policy is available as of December 31, 2002.

Paragraph 23.1121(i)

No specific policy is available as of December 31, 2002.

DRAFT

23.1123 Exhaust system (Amendment 23-43)

CAR 3 Cross Reference: 3.616

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1123(a)

What are the general considerations relative to compliance with § 23.1123(a)?

Exhaust components are typically constructed of stainless steel or steel alloys of appropriate wall thickness to withstand the highly corrosive high temperature exhaust gases in order to comply with § 23.1123(a). Proper material selection and corrosion protective design should be performed and validated during certification. Analysis and validation tests are done to ensure thermal and structural integrity and to ensure thermal expansion does not cause structural overload, failure, unintentional contact of adjacent components, or hazardous heating of surrounding components. The thermal expansion analysis and test should be done at the maximum in-service temperature excursions expected for the installation.

Related Material

AC 23-2, Flammability Tests

Paragraph 23.1123(b)

What loading cases are typically considered?

Typically, the worst-case static design load conditions are either the inertia loads from an emergency impact, such as that specified in § 23.561, or combined loading from thermal expansion, in-flight deflections, and internal exhaust gas flow. The exhaust system components should be designed and supported to avoid critical frequencies and to minimize the effects of the vibration environment. Flight test vibration surveys may be necessary to properly define or validate the critical modes and vibration environment. In addition, the strength reduction in the system materials at the operating and worst-case temperatures should be properly accounted for during the design and structural substantiation.

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Paragraph 23.1123(c)

What should be considered in the design of an exhaust system with components having relative motion between them?

Section 23.1123(c) requires that exhaust system components with relative motion between them have a means for flexibility. This is typically provided by different types of flexible joints employing metal bellows, metal rings, or carbon rings. These components typically have limited lives because of the high temperatures and corrosive nature of the exhaust gases. For this reason, experience has shown that it is good to design the system to avoid relative motion between components to eliminate the use of these failure prone components.

23.1125 Exhaust heat exchangers (Amendment 23-17)

CAR 3 Cross Reference: 3.617, 3.618

Paragraph 23.1125(a)

Does the heat exchanger require constant cooling airflow?

Yes, the intent of § 23.1125(a)(3) is to require cooling airflow when and where the exhaust gasses are in contact with the heat exchanger.

Paragraph 23.1125(b)

No specific policy is available as of December 31, 2002.

DRAFT

POWERPLANT CONTROLS AND ACCESSORIES

23.1141 Powerplant controls: General (Amendment 23-51)

CAR 3 Cross Reference: 3.627

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

Paragraph 23.1141(a)

Do single-lever power controls comply with § 23.1141?

Airplanes may be equipped with single-lever power controls (a control arrangement allowing the engine throttle, propeller pitch control, and possibly mixture control to operate via one lever) where the propeller pitch varies with engine r.p.m. by means of a mechanical cam or slider device as a function of throttle position. Any such propeller control system must be shown to have the level of integrity and reliability of a typical installation with independent propeller and throttle controls. Specific guidance for this is contained in the related material listed below under § 23.777.

Related Material

AC 23-17A, Systems and Equipment Guide for Certification of Part 23 Airplanes

Paragraph 23.1141(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1141(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1141(d)

No specific policy is available as of December 31, 2002.

DRAFT

Paragraph 23.1141(e)

Are there any special considerations for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis?

It is acceptable for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis to delete the phrase “or probable combination thereof” when demonstrating compliance with the rule as restated below.

This regulation currently reads as follows:

For turbine engine powered airplanes, no single failure or malfunction, or probable combination thereof, in any powerplant control system, may cause the failure of any powerplant function necessary for safety.

Paragraph 23.1141(f)

No specific policy is available as of December 31, 2002.

Related Material:

AC 23-2, Flammability Tests

Paragraph 23.1141(g)

No specific policy is available as of December 31, 2002.

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23.1142 Auxiliary power unit controls (Amendment 23-43)

CAR 3 Cross Reference: None

No specific policy is available as of December 31, 2002.

DRAFT

23.1143 Engine controls (Amendment 23-51)

CAR 3 Cross Reference: 3.628

Paragraph 23.1143(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1143(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1143(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1143(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1143(e)

No specific policy is available as of December 31, 2002.

Related Material:

AC 20-136, Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning

Paragraph 23.1143(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1143(g)

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What is the origin of this requirement?

This regulation was introduced with Amendment 23-43 on May 10, 1993, and originated as a proposal in response to the Small Airplane Airworthiness Review conducted in 1983 and 1984. This proposal was forwarded by the National Transportation Safety Board as a response to a study of single-engine aircraft accidents involving separation of the throttle linkages with subsequent loss of propulsive power. The original wording of the proposal stated the following:

“(f) A means must be provided to assure that if throttle linkage separation occurs in a single engine airplane, the fuel control will be automatically positioned at:

- (1) The full throttle position for agricultural airplanes.
- (2) An intermediate throttle position for other airplanes which will allow the pilot to maintain level flight in the cruise configuration.”

A review of the minutes of the Small Airplane Airworthiness Review Conference held in St. Louis, Missouri on October 22-26, 1984, reveals that the discussion was centered around the appropriate settings for different airplane classifications.

The rule as proposed and subsequently accepted in Amendment 23-43 states the following:

“(g) For reciprocating single-engine airplanes, each power or thrust control must be designed so that if the control separates at the engine fuel metering device, the airplane is capable of continued safe flight and landing.”

The generally accepted definition of “engine fuel metering device” is a device that controls the amount of fuel flow (fuel control in the original proposal) to the engine based on throttle position. The throttle refers to the device the pilot uses to set the desired engine power level.

The intent of the rule is to keep the engine supplied with a sufficient amount of fuel to allow continued safe flight and landing in the event of a control system failure that prevents the pilot from setting the appropriate power level (i.e., fuel flow rate).

Can a design that maintains positive retention of the linkage be used to show compliance with § 23.1143(g)?

A number of Equivalent Level of Safety (ELOS) findings have been issued that have allowed linkage designs incorporating positive retention means when complying with § 23.1143(g). These ELOS findings have required a higher level of attachment reliability, establishment of mandatory inspection intervals, inspection procedures, and replacement criteria for the attachments.

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23.1145 Ignition switches (Amendment 23-43)

CAR 3 Cross Reference: 3.629

Paragraph 23.1145(a)

Does § 23.1145 apply to turbine and reciprocating engines?

This paragraph applies to both turbine and reciprocating engines. The required ignition switch may be used to select any position such as continuous, automatic, on, or off.

Paragraph 23.1145(b)

Is it possible to integrate the required shutoff switch with the engine power lever?

On turbine engines incorporating an auto-relight system, one acceptable means of complying with the shutoff provision would be to have the shutoff switch activated by the power lever. Adequate instruction should be available to the pilot.

Paragraph 23.1145(c)

No specific policy is available as of December 31, 2002.

DRAFT

23.1147 Mixture controls (Amendment 23-43)

CAR 3 Cross Reference: 3.630

Paragraph 23.1147(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1147(b)

No specific policy is available as of December 31, 2002.

Can a design that maintains positive retention of the linkage be used to show compliance with § 23.1147(b)?

A number of Equivalent Level of Safety (ELOS) findings have been issued that have allowed linkage designs incorporating positive retention means when complying with § 23.1147(b). These ELOS findings have required a higher level of attachment reliability, establishment of mandatory inspection intervals, inspection procedures, and replacement criteria for the attachments.

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23.1149 Propeller speed and pitch controls (Original)

CAR 3 Cross Reference: None

Paragraph 23.1149(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1149(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1153 Propeller feathering controls (Amendment 23-51)

CAR 3 Cross Reference: None

No specific policy is available as of December 31, 2002.

Related Material

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

DRAFT

**23.1155 Turbine engine reverse thrust and propeller pitch settings below the flight regime
(Amendment 23-7)**

CAR 3 Cross Reference: None

What is the history of this requirement?

The FAA has long recognized the hazard of inadvertent operation of propeller reversing systems. Prior to the commercial use of turbine-powered airplanes, a few reciprocating engine powered airplane designs included propeller-reversing systems and were addressed by Civil Air Regulations (CAR) paragraph 4b. Section 23.1155 was added to part 23 with Amendment 23-7 (1969) and applied to turbine-powered airplanes only. In the event of a part 23 reciprocating engine powered airplane using propeller-reversing systems, special conditions should be developed.

If the possibility of inadvertent operation can be shown to be remote, does it comply with § 23.1155?

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No, the intent is to prevent inadvertent operation in the beta mode, even if the possibility of inadvertent operation is remote. If an operation or feature of the design can allow in-flight, inadvertent placement of the control below the flight regime, the design does not comply with the regulation. The design should be evaluated considering the types of operations that will be seen in service, and it should consider items such as hardware wear modes or maintenance issues that may cause the control to be unintentionally placed or creep into the beta regime over time.

Amendment 23-7 added § 23.1155 requiring that operations of the propeller controls at pitch settings below the flight regime have a means to prevent inadvertent operation. For airplanes with a certification basis before Amendment 23-7 that are modified to add in-flight beta capability, the provisions of § 21.101(b) should be used to evaluate the possible unsafe nature of inadvertent operation of propellers in the beta regime. If it is determined that such operation is unsafe, the issue may be addressed by showing compliance with § 23.1155.

What is an acceptable means of compliance with § 23.1155 relative to intentional in-flight operation?

On all future type certification projects, the flight manuals should include the appropriate operational limitations and consequence statement for in-flight beta operation.

Is a Beta Lock-out system acceptable for compliance with § 23.1155?

To add an assurance that in-flight beta will not occur, some airplanes have incorporated lock-out systems. These systems remove the ability to do this operation in flight, even if

intentionally commanded. It is important to note that the installation of a beta lock-out system cannot be used instead of the design requirements of § 23.1155 compliance. Also, in some cases, propeller beta operation is used to show compliance with stopping distances in part 23, subpart B. Under subpart B, when means other than wheel brakes are used for determining stopping distances, the means must be "safe and reliable." If beta operation is used to show compliance with stopping distances, the reliability of a system that would prevent in-flight beta operation must be such that this capability, when required, will be available to comply with subpart B, and § 21.21(b)(2) or § 21.101(b). With a system safety analysis, the applicant can determine the required reliability level for the beta lock-out system based on the hazard level (for example, § 23.1309 compliance).

Therefore, for new type certificated airplanes that have a beta lock-out system incorporated or previously certificated airplanes that add a beta lock-out system, the applicant should perform a system safety analysis of the installation of this system. This analysis should consider hazards such as the inability to command beta on one engine of a multiengine airplane. For example, if beta is commanded on both engines during landing roll-out, but only one propeller goes into beta mode, this might adversely affect ground controllability.

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23.1157 Carburetor air temperature controls (Original)

CAR 3 Cross Reference: 3.634

No specific policy is available as of December 31, 2002.

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23.1163 Powerplant accessories (Amendment 23-42)

CAR 3 Cross Reference: 3.635

Paragraph 23.1163(a)

What accessory provisions are included in § 23.1163?

Paragraph (a)(1) refers to provisions for mounting items such as brackets, isolating bushings, belt tension arms, belts, and other hardware up to, but not including, mounting lugs on the accessory. These provisions are to be approved under the engine Type Certificate (TC).

Are there any unique considerations for special purpose, restricted category, single-engine agricultural airplanes using the normal category requirements of part 23 as a certification basis?

Each engine mount accessory must be acceptable for mounting on the engine involved and use the proper provision on the engines for mounting.

Paragraph 23.1163(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1163(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1163(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1163(e)

No specific policy is available as of December 31, 2002.

DRAFT

23.1165 Engine ignition systems (Amendment 23-34)

CAR 3 Cross Reference: 3.636

Paragraph 23.1165(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1165(b)

What are acceptable means of compliance for § 23.1165(b)?

An electrical load analysis should be conducted to ensure that the capacity of the batteries and generator is large enough to meet the highest current demands in the system. The analysis should show that there is sufficient electrical power available from either the battery or the generator to operate all components simultaneously.

Paragraph 23.1165(c)

What are acceptable means of compliance for § 23.1165(c)?

The requirements of § 23.1165(c) should be demonstrated by a test that has been coordinated with the FAA prior to conducting the test.

Paragraph 23.1165(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1165(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.1165(f)

No specific policy is available as of December 31, 2002.

DRAFT

POWERPLANT FIRE PROTECTION

23.1181 Designated fire zones; regions included (Amendment 23-51)

CAR 3 Cross Reference: None

What is the intent of § 23.1181?

The intent of § 23.1181 is to identify areas where a high degree of safety precaution must be taken. These areas are designated fire zones because of the presence of both ignition sources and flammable fluids where a single failure that releases these fluids may result in a fire. Sections 23.1182 through 23.1203 address precautions for areas identified in § 23.1181.

Paragraph 23.1181(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1181(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1181(c)

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No specific policy is available as of December 31, 2002.

Paragraph 23.1181(d)

Can the guidance in § 23.1181 through § 23.1203 be applied to other systems that use combustible materials other than combustion heaters?

Yes, the guidance provided can and should be considered when certifying other equipment using combustible materials. Examples of these systems include the following:

1. Smoke, alcohol and dispensing systems that might carry flammable fluids;
2. Liquid cargo tanks that carry flammable fluids; and
3. Other systems that produce heat/flames such as pyrotechnic systems for rainmakers, flares, chaff dispensers.

23.1182 Nacelle areas behind firewalls (Amendment 23-14)

CAR 3 Cross Reference: None

What are the acceptable means of compliance with § 23.1182?

In general, compliance with § 23.1182 must be shown by tests that demonstrate the fire-resistant and fireproof properties of the components and their installation. Consideration should be given to component temperature limits, structural properties at elevated temperatures, and the possibility of gaseous emissions from heated components entering the cabin when finding compliance.

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

AC 20-107A, Composite Aircraft Structure

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23.1183 Lines, fittings, and components (Amendment 23-51)**CAR 3 Cross Reference:** 3.638**Related Material**

AC 20-107A, Composite Aircraft Structure

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1183(a)**What is the intent of § 23.1183(a)?**

The intent of § 23.1183(a) is to ensure that lines and components in the fire zone carrying flammable fluids do not fail in a manner that contributes additional fuel to a fire. Compliance with this rule is demonstrated by testing the lines and components under the conditions expected in the event of a fire. Conditions such as worst-case flow rates of fluids and air, lowest dispatchable fluid quantities, and highest fluid and air temperatures should be considered as test parameters.

Can the fire prevention certification of the engine components under 14 CFR part 33, § 33.17 be used to show compliance with § 23.1183?

Components certified with the engine under § 33.17 may or may not meet the requirements in § 23.1183 for a specific airplane installation, depending upon the test/analysis performed to certify them. In particular, the test conditions, such as fluid flow rates and quantities used during the part 33 certification, may not be representative of the conditions expected during a fire in the airplane fire zone. Consequently, the components approved during engine type certification can only be used for compliance with the part 23 installation requirements when the test conditions were equal to or more severe than those expected for the installation. Coordination with the engine manufacturer is generally required to determine the test conditions applicable to the original certification of the components.

To what extent must components be shielded?

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The intent of this requirement is to prevent leaking flammable fluids from contacting ignition sources, including hot surfaces and components that produce electrical arcs. Compliance with this paragraph has been shown by installation of shrouds around the entire high-pressure fuel manifold, installation of shrouds around only the fittings, and installation of spray shields to deflect leaking fuel away from hot surfaces. The level of shielding necessary depends upon the type of leaks possible and the ignition sources.

Shielding should be provided for any component that would be an ignition source if contacted by leaking flammable fluid.

It is possible to have complex shroud arrangements that are difficult to maintain and result in increased incidence of leaks. In addition, sharp spray shield edges may cause damage to fuel lines. Therefore, it is important to carefully consider both the benefits and potential hazards of a given shielding configuration.

Related Material

AC 23-2, Flammability Tests

Paragraph 23.1183(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1189 Shutoff means (Amendment 23-43)

CAR 3 Cross Reference: None

Related Material

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1189(a)

What are the typical means of complying with § 23.1189?

The intent of § 23.1189 is to provide a means to shut off lines containing flammable fluids in the event of a fire in the fire zone to prevent hazardous quantities of fluid from entering into and feeding a fire in the zone. Typically, shutoff valves or flow prevention means located outside the engine fire zone have been used on fuel supply, hydraulic, external oil supply, and deicer lines. If shutoff valves are located within the fire zone, the valves as well as their actuation means, including wiring or cables, are required to be fireproof.

What is considered a hazardous quantity?

The quantity that is considered hazardous depends on the particular engine installation design. It is important to consider the potential fuel, the worst-case state of the fluid, such as mist, and the other fuel sources feeding the fire during the fire event. Ultimately, the intent is to limit the potential fuel sources for the fire such that it loses intensity and self-extinguishes.

Paragraph 23.1189(b)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

AC 23-8B, Flight Test Guide for Certification of Part 23 Airplanes

AC 20-107A, Composite Aircraft Structure

Paragraph 23.1189(c)

No specific policy is available as of December 31, 2002.

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23.1191 Firewalls (Amendment 23-51)

CAR 3 Cross Reference: 3.623, 3.624

Related Material

AC 23-2, Flammability Tests

AC 20-107A, Composite Aircraft Structure

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1191(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1191(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1191(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1191(d)

Reserved.

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Paragraph 23.1191(e)

No specific policy is available as of December 31, 2002.

Paragraph 23.1191(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1191(g)

No specific policy is available as of December 31, 2002.

23.1192 Engine accessory compartment diaphragm (Amendment 23-14)

CAR 3 Cross Reference: None

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

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23.1193 Cowling and nacelle (Amendment 23-43)

CAR 3 Cross Reference: 3.625

Related Material

AC 23-2, Flammability Tests

AC 20-107A, Composite Aircraft Structure

AC 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria

Paragraph 23.1193(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1193(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1193(c)**What typical cowling materials are considered fire resistant?**

Cowlings fabricated of Alclad Aluminum Alloy 2024-T3 (minimum 0.032-in. thickness) are considered fire resistant. Materials considered fireproof, per § 23.1191, by definition, are also considered fire resistant.

Many airplanes are constructed from fiber reinforced (carbon, fiberglass, Nomex, Kevlar, etc.) composite materials. These materials vary widely in the composition of the fiber and matrix materials, the lay-up of the fibers, and their processing, all factors that could affect their fire resistance. Because of this, testing of these materials per the methods described in AC 23-2, AC 20-107A, and AC 20-135 is typically required to show compliance with § 23.1193(c).

Can airflow on the exterior of the cowling be used to meet the fire resistant test criteria?

Conduct tests to substantiate alternate materials using an airflow velocity not more than the minimum stall speed of the airplane on the exterior side of the test specimen.

Paragraph 23.1193(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1193(e)

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No specific policy is available as of December 31, 2002.

Paragraph 23.1193(f)

No specific policy is available as of December 31, 2002.

Paragraph 23.1193(g)

No specific policy is available as of December 31, 2002.

23.1195 Fire extinguishing systems (Amendment 23-43)

CAR 3 Cross Reference: None

What methods for complying with the fire extinguishing requirements of § 23.1195 are acceptable?

Ground testing of the engine and APU compartments on the airplane is the accepted method for demonstrating compliance with § 23.1195. The tests should be designed and performed to show that an extinguishing agent concentration sufficient to extinguish fires is attained in all the protected compartments within the nacelle simultaneously. The use of an actual fire during the test is not recommended or required, as this is both dangerous and destructive. Laboratory testing is used to establish the required concentrations of the selected agent to extinguish flames for all of the flammable materials in the protected area per § 23.1197. The concentrations established in the laboratory should be used in the ground testing. The ground test should simulate the worst-case operational conditions under which the extinguishing system would be expected to operate. The instrumentation for the testing should be designed to make sure there is sufficient coverage of the nacelle area. Some of the conditions to consider for the testing include the following:

1. Maximum and minimum airflow in the nacelle

The amount of airflow in the nacelle affects the distribution as well as the concentration of the agent over time.

2. Airflow patterns in the nacelle

The airflow patterns in the nacelle are generally for meeting cooling and venting requirements. An understanding of the patterns is necessary for determining the affects on the extinguishing agent concentrations.

3. Likely fire locations in the nacelle

The likely fire locations should be considered along with the airflows in the nacelle to account for the airflow affects on agent concentration.

4. Maximum and minimum operational temperatures of the extinguishing agent

Minimum operational temperature testing with the typical extinguishing agents cannot be sufficiently simulated with lower pressures in the system because of the presence of multi-phase flow in the system during discharge. These tests should be performed with agent filled containers that have been conditioned at the appropriate temperatures.

Related Material

AC 20-100, General Guidelines for Measuring Fire Extinguishing Agent Concentrations in Powerplant Compartments

Paragraph 23.1195(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1195(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1197 Fire extinguishing agents (Amendment 23-34)

CAR 3 Cross Reference: None

Paragraph 23.1197(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1197(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1199 Extinguishing agent containers (Amendment 23-34)

CAR 3 Cross Reference: None

Paragraph 23.1199(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1199(b)

No specific policy is available as of December 31, 2002.

Related Material

AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions

Paragraph 23.1199(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1199(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1199(e)

No specific policy is available as of December 31, 2002.

DRAFT

23.1201 Fire extinguishing systems materials (Amendment 23-34)

CAR 3 Cross Reference: None

Paragraph 23.1201(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1201(b)

No specific policy is available as of December 31, 2002.

DRAFT

23.1203 Fire detector system (Amendment 23-51)

CAR 3 Cross Reference: None

Paragraph 23.1203(a)

No specific policy is available as of December 31, 2002.

Paragraph 23.1203(b)

No specific policy is available as of December 31, 2002.

Paragraph 23.1203(c)

No specific policy is available as of December 31, 2002.

Paragraph 23.1203(d)

No specific policy is available as of December 31, 2002.

Paragraph 23.1203(e)

No specific policy is available as of December 31, 2002.

Related Material

AC 23-2, Flammability Tests

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