SAE Aerospace
An SAE International Group

# AEROSPACE RECOMMENDED PRACTICE

SAE ARP5757

Issued 2008-03

## Guidelines for Engine Component Tests



### RATIONALE

This document provides information and recommendations regarding the design and integration of aircraft electronic engine control systems. It provides previously unavailable guidance on how to substantiate compliance with civil certification regulations and associated advisory material for aircraft engine components.

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# 1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides guidance for substantiating the airworthiness of aircraft engine components. Generally these components are associated with the engine control system, the system or systems that allow the engine to provide thrust or power as demanded by the pilot of the aircraft while also ensuring the engine operates within acceptable operating limits. But these components may also include hardware and systems associated with engine lubrication, engine or aircraft hydraulic or electrical systems, aircraft environmental control systems, thrust reverser control, or similar aircraft or engine propulsion system functions.

This paper develops the concept of using a 26 item matrix of environmental conditions for evaluating aircraft engine component airworthiness. This approach is compatible with current practices used in the industry and has been accepted by engine certification authorities as part of engine certification programs.

## 1.1 Purpose

The purpose of this document is to provide guidance on demonstrating compliance with aircraft engine certification authority requirements for engine components. Many complete engine tests are done as part of the overall engine substantiation and certification process. But often during the engine testing process it is not practical to exercise all of the components of the engine to the extreme environmental limits each will encounter during operation in service. A simple example is during on the ground engine demonstrations the various components may not be exposed to the range of ambient temperature that will exist in the aircraft application. Additional tests or analysis may be required to demonstrate that the component will operate successfully throughout the range of ambient temperature conditions. There are a number other environmental conditions and combinations of conditions that can best be evaluated at the engine component or subsystem level.



This ARP is written to address the engine components associated with a new engine program certification. But the guidance may also be used for validating design changes to previously certified engines. However, when using this ARP for substantiating design changes, all test parameter levels, times, and pass/fail criteria should be reviewed to make sure they are adequate for the already certified engine application.

## 1.2 Field of Application

This document applies to the components of civil certified engines. The components discussed by this ARP may vary from application to application. For this ARP they are defined to include the parts of the engine control and accessory system that are maintained as line replaceable units (LRUs) and are not part of the actual thrust or power generation part of the turbo-machinery of the engine. The control system includes all those components that are part of the speed, power, or thrust control system, fuel delivery and metering system, the engine airflow control system including turbo-machinery variable geometry and air bleed systems, starting and ignition, and any other components associated with fault detection and accommodation of the control systems. The accessory system includes all the components that are part of the engine lubrication delivery and metering system and any other components associated with fault detection and accommodation of those systems. Depending on the specific application other engine accessory systems and components of the thrust reverser and aircraft environmental control systems may be included.

# 2. REFERENCES

## 2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications, FAA documents, and EASA documents shall apply. The applicable issue of other publications shall be as noted in this ARP. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. However, nothing in this document supersedes applicable laws and regulations unless a specific exemption has been obtained. All plans developed from the guidance in this ARP should be reviewed with the applicable airworthiness authority for their acceptance.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

| | |
|---|---|
| MAP749 | Aircraft Turbine Engine Fuel System Component Endurance Procedure (Room Temperature Contaminated Fuel) |
| ARP1401 | Aircraft Fuel System and Component Icing Test |
| AIR1639 | Safety Criteria for Pneumatic Starting Systems |
| AIR4023 | Aircraft Turbine Fuel Contamination History and Endurance Test Requirements |
| AIR4246 | Contaminants for Aircraft Turbine Engine Fuel System Component Testing |
| ARP5107 | Guidelines for Time-Limited-Dispatch (TLD) Analysis for Electronic Engine Control Systems |

2.1.2 EASA Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

CS – E, “Certification Specification for Engines”

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

14 CFR Part 33, "Airworthiness Standards: Aircraft Engines"

Advisory Circular, AC 33.28-1, “Compliance Criteria for 14 CFR §33.28, Aircraft Engines, Electrical and Electronic Engine Control Systems”, issued June 29th, 2001

Advisory Circular, AC 33.28-2, “Guidance Material for 14 CFR §33.28, Reciprocating Engines, Electrical and Electronic Engine Control Systems”, issued August 13th, 2003

Advisory Circular, AC 33.17-1, “Fire Prevention”, issued June 28th, 2002

Advisory Circular, AC 20-104, “Revised Powerplant Engineering Report No. 3A, Standard Fire Test Apparatus and Procedure (For Flexible Hose Assemblies) “, issued April 12th, 1978

Advisory Circular, AC 20-147, “Turbojet, Turboprop, and Turbofan Engine Induction System Icing and Ice Ingestion”, issued 2/02/04

Advisory Circular, AC 33.63-1, “Turbine Engine Vibration”, issued 7/25/07

2.1.4 Industry Publications

Available from International Organization for Standardization, Case postale 56, CH-1211 Geneve 20, Switzerland, 39, iso@iso.ch.

International Standard, ISO 2685, Second edition 1992-12-15, “Aircraft – Environmental test procedure for airborne equipment – Resistance to fire in designated fire zones”, issued December 15th, 1998

International Standard, ISO 2669, Second edition 1995-04-15, “Environmental tests for aircraft equipment – Steady-state acceleration”

Available from RTCA, Inc, 1828 L Street, NW, Suite 805, Washington, DC 20036-5133, USA, Tel: 202-833-9339, www.rtca.org.

RTCA document RTCA DO-160E, “Environmental Conditions and Test Procedures for Airborne Equipment”, issued December 9, 2004

2.1.5 U. S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-E-5007E General Specification for Engines, Aircraft, Turbojet and Turbofan
(This specification is inactive for new designs and should be used for reference only)

MIL-STD-810F Environmental Test Methods

MIL-E-8593A Engines, Aircraft, Turboshaft and Turboprop, General Specification For
(This specification is inactive for new designs and should be used for reference only)

2.2 Acronyms and Definitions

AC Advisory Circular (FAA nomenclature)

AIR SAE Aerospace Information Report

AMC Acceptable Means of Compliance

ARP SAE Aerospace Recommended Practice

ATP Acceptance Test Procedure

°C Degrees Centigrade

CFR Code of Federal Regulations

“Component” is used interchangeable with “equipment” as used in CS E-80. Unless stated otherwise, it includes all controls and accessories of the engine

Containing or conveying is used to describe any component where fluid enters the component or the component is part of a pressure vessel containing the fluid

CS Certification Specification (EASA nomenclature)

EASA European Aviation Safety Authority

| | |
|---|---|
| EEC | Electronic Engine Control |
| EUROCAE | European Organisation for Civil Aviation Equipment |
| °F | Degrees Fahrenheit |
| FAA | Federal Aviation Administration (or Authority) |
| FADEC | Full Authority Digital Engine Control |
| FMEA | Failure Modes and Effects Analysis |
| H | Hour or hours |
| ICA | Instructions for Continued Airworthiness |
| LRU | Line Replaceable Unit |
| JAA | Joint Airworthiness Authorities (of Europe) |
| JAR | Joint Airworthiness Requirement |
| LVDT | Linear Variable Differential Transformer |
| MAP | Aerospace Recommended Practice |
| Min | Minute or minutes |
| RTCA | Entity formerly known as Radio Technical Commission for Aeronautics |

Type Design is the component as identified by the engine Type Certificate

## 3. APPLICABILITY

The applicability of these guidelines is intended primarily for engines certifying to 14 CFR Part 33 or equivalent regulations. The approaches contained herein have been accepted in previous approvals for engines certified to the provisions of 14 CFR Part 33.91. This approach is usually coordinated with an effort to show compliance with 14 CFR 33.28 since the substantiation for engine component tests and engine control systems is interdependent. The approaches are also intended to fulfill the requirements imposed by EASA under CS-E regulations. The acceptability of these approaches should be coordinated with the appropriate certification agency during any new certification effort.



As defined in the SCOPE this ARP is limiting the discussion to those parts of the engine associated with engine controls and accessories. But the guidance may be extended to other parts of the engine or aircraft systems that include similar hardware. When that is done, the guidance in this ARP may require tailoring for the specific function or application and should be coordinated with the appropriate certification agency.

## 4. HISTORICAL PERSPECTIVE

In the United States, law under the Code of Federal Regulations (CFR) defines the requirements for certification of aircraft engines. Within that Code, Title 14 is applicable to Aeronautics and Space, subchapter C deals with Aircraft, and Part 33 provides the Airworthiness Standards for Aircraft Engines. Compliance with the paragraphs of Part 33 is required for certification of aircraft engines.

Many certification tests are conducted on the complete engine assembly. But testing the complete engine assembly may not always expose all parts of the engine to the extreme conditions encountered in service. For this reason 14 CFR 33 regulations make allowance for testing some of the engine hardware off of the engine; or in other words requires individual component or engine sub-system testing. Section 33.91 defines this requirement. The current requirements were last modified in amendment 6 and are repeated below:

14 CFR Part 33 Section 91 Engine component tests

(a) For those systems that cannot be adequately substantiated by endurance testing in accordance with the provisions of Sec. 33.87, additional tests must be made to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.
(b) Temperature limits must be established for those components that require temperature-controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.
(c) Each unpressurized hydraulic fluid tank may not fail or leak when subjected to maximum operating temperature and an internal pressure of 5 p.s.i. and each pressurized hydraulic fluid tank may not fail or leak when subjected to maximum operating temperature and an internal pressure not less than 5 p.s.i. plus the maximum operating pressure of the tank.
(d) For an engine type certificated for use in supersonic aircraft, the systems, safety devices, and external components that may fail because of operation at maximum and minimum operating temperatures must be identified and tested at maximum and minimum operating temperatures and while temperature and other operating conditions are cycled between maximum and minimum operating values.

The EASA regulations have similar requirements defined in or linked to CS-E 20, CS-E 50, and CS-E 80.

In many cases the FAA provides additional guidance material in the form of Advisory Circulars (ACs). But there has never been an AC issued for section 33.91. Although the 33.91 requirement has not changed in many years the method of compliance with the requirement has varied within the industry. In the 1970s and 1980s many engine manufacturers used variations of what is called the 36-item checklist. That list identified the various test requirements that should be considered to ensure the components have been substantiated for all extremes of environmental and engine operating conditions.

With the advent of more electronic controls, usually described as Full Authority Digital Electronic Controls (FADECs), additional requirements for them where added to 14 CFR as Section 33.28. When that became effective in August 1993 some of the testing that was traditionally done to address compliance with 33.91 became more appropriate as compliance with 33.28. The FAA has issued ACs with guidance for compliance with 33.28. With the transition of some substantiation from 33.91 to 33.28 for items unique to electronics, the various tests needed to show compliance with 33.91 was reduced and the checklists changed accordingly. Although most of the environmental substantiation for electrical systems is substantiated under 14 CFR 33.28 for EMI/HIRF/lightning, the verification that the individual components of the system are not damaged due to the electrical currents generated within the electrical system during a lightning strike is done on an individual component test basis as part of compliance with 14 CFR 33.91. That requirement is defined as Pin Injection.



This ARP is specifically structured to offer guidance for compliance of aircraft engine components with the 33.91 requirements. Some of the guidance utilizes the material developed for electrical and electronic engine control system compliance with 33.28. AC 33.28-2 identifies an 18-item list of requirements to be followed for evaluating the component airworthiness of electrical and electronic equipment for the physical environmental limitations for reciprocating engines. Although that AC may be used for electrical and electronic equipment for reciprocating engines, the list is also generally applicable for mechanical, hydraulic, and pneumatic engine components on all aircraft engines. Therefore all of the 18 items from AC 33.28-2 are included in the guidance of this ARP.

Other engine certification agencies around the world have requirements that are similar to those in the United States. The Joint Aviation Agency (JAA) requirement that parallels the FAA requirement for engine components is identified as "JAR-E 80 Equipment". The JAA did provide guidance for compliance with this requirement as part of "Section 2 - Acceptable Means of Compliance and Interpretations – ACJ". ACJ E 80 suggested engine manufactures consider 36 items for demonstrating compliance with the requirement. That list is generally the same as that used within the United States for compliance with 33.91 before the introduction of 33.28.

The European Aviation Safety Agency (EASA) further defined a suggested compliance matrix when it issued its engine certification requirements. These requirements parallel what was in effect with the JAA at the time the Certification Specification for Engines (CS-E) was issued. CS-E 80 is applicable to “Equipment” and is generally the equivalent of 14 CFR 33.91. The Acceptable Means of Compliance (AMC) to CSE-E 80 provides a list of 24 items to consider. Most of the items are applicable to all components but several are highly specialized and limited to only selected components. In addition to those 24 items, the AMC goes on to discuss the possibility of additional special cases. This list is generally the same as the list that has evolved within the US for compliance with 14 CFR 33.91.

The list of items required for compliance with 14 CFR 33.91 as recommended by this ARP is summarized in Table 1. The suggested methods of compliance for each item will be developed in the APPROACH section of this ARP. Table 2 contains a brief summary of the changes to the list for compliance with 14 CFR 33.91 that occurred with the introduction of 14 CFR 33.28.

This ARP utilizes the guidance material available from the FAA, JAA, and EASA and incorporates industry experience to define a method that can be used by most engine manufactures for most aircraft engine applications to demonstrate compliance with FAA regulation 14 CFR 33.91 and EASA regulation CS-E 80.



## 5. APPROACH

The approach followed by this ARP is to identify the test requirements and the certification agency source of the requirement, define the intent of each requirement, and suggest a method of testing or analysis for demonstrating compliance with the requirement. The result is a recommended approach for demonstrating compliance with FAA regulation 14 CFR 33.91 and EASA regulation CS-E 80. Note that 14 CFR 33.91 subparagraphs (c) and (d) are not addressed in this ARP. Sub-paragraph (c) addresses unpressurized fluid tanks and sub-paragraph (d) addresses supersonic aircraft. Neither of these are common occurrences in today’s civil aviation industry. Therefore, this ARP provides no guidance for them and does not include them in the compliance requirement checklist for all components.

Unless otherwise noted in the guidance that follows, the test should be structured so the component is operating and providing its normal function as it would on the engine. Then each of the environmental conditions is varied one by one until performance has been successfully demonstrated at the maximum (or minimum) required environmental limits.

Although each test item is discussed individually, at times it may be appropriate to combine various tests. When that is done consideration should be given to ensuring that all of the individual test requirements and pass/fail criteria are incorporated into the combined test. DO-160 provides guidance on acceptable combinations of some of the tests.

Each of the items is defined as a test to be passed. Often it may be shown by analysis that the component would pass the test if it were to be tested. That may be the case when a similar part has already successfully completed the test. For this kind of comparison to be accepted by the certifying agency, the analysis must show that the new and previously tested component are equivalent in design, materials, and construction methods, that the function or operation of the components are similar, and that the data confirms the previous component successfully met the requirements for the new application. This ARP does not discuss specific methods of how that comparative analysis may be done, but does encourage the applicant to review those methods with the certifying agency.

Many of the tests recommended by this ARP have procedures that are adequately defined in existing documents. The most common source of those procedures is “Environmental Conditions and Test Procedures for Airborne Equipment”, which is also known as DO-160, published by RTCA. Revision E published December 9, 2004 is currently applicable. That document was also approved by the European Organisation for Civil Aviation Equipment (EUROCAE) and is also known as RTCA DO-160E/EUROCAE ED-14E. Where no acceptable procedure exists, this ARP provides information on how to develop an acceptable procedure.

This ARP also provides guidance on the selection of appropriate pass/fail criteria for each item. At times those criteria are completely defined. But in most cases, the user must evaluate the function of the component being tested and the implications of that function on engine operation to complete definition of the pass/fail requirements.

The pass/fail criteria usually are divided into two parts; the performance of the part during or after exposure to the test environment and posttest inspection to confirm the component was not damaged during the test. The component specified performance should be met during most tests conducted within the expected environmental and engine operating conditions. In lieu of more specific requirements identified in the following sections or application specific requirements, the guidelines of AC 33.28-1 may be followed. That document defines a fault resulting in greater than 3% thrust loss as unacceptable for engines in installations required to meet the part 25 requirements that include “obstacle clearance”. That requirement is linked to operation at or near maximum engine power; and to consider failures at other operating conditions the pass/fail criteria is often defined as the larger of 3% of thrust or power at the tested condition or 1% of max rated power or thrust. A few of the tests are to show acceptable component performance at extreme conditions or to show that the component will perform reliably for an extended period of time. In those cases, the pass/fail criteria as defined for each item may allow for degraded performance of the component. And in a few cases the only pass/fail criteria involves post test inspection of the component to verify no damage occurred during the test.

Often the pass/fail criteria will refer to passing an acceptance test (ATP) or selected parts of the ATP. That reference is made when the component is expected to totally comply with its specified performance. In those cases all acceptance test parameters that may have been impacted by the environmental test exposure should be included. But the functions normally verified in the ATP that were not exercised during the test may not need to be included in the post test ATP; e.g. things like weight, tests at extreme temperatures, etc. Sometimes there may be an ATP defined with acceptable new part production limits and another ATP for acceptable field service limits. The field service limits may be used for all pass/fail criteria specified within this ARP. However, any significant performance changes within limits should be evaluated for the impact on continuing successful operation of the component. In some cases an equivalent functional test may be substituted for the ATP. To be acceptable, a functional test should provide the same level of verification as would the ATP. As each item is developed, the individual check list item discussions provide more definitive guidance on the pass/fail criteria to be used.



Although 26 different test criteria are discussed, some criteria are not applicable to every component. This ARP defines when the requirement is applicable. And by definition of the intent of the 14 CFR 33.91 requirement, the tests are only required when the engine level testing does not expose the component to the extreme environmental conditions required by the engine application.

General guidance for the conduct of tests including the required order of tests and test accuracies can be found in DO-160 Section 3.

## 5.1 High Temperature

The High Temperature demonstration is to verify that the component can function properly in its maximum temperature environment and to identify any damage caused by exposure to maximum temperature that could lead to component failure. Both AC 33.28-2 and the AMC to CS-E 80 recommend the High Temperature demonstration test for engine components.

Historical guidelines for the High Temperature test are available in MIL-E-5007 paragraph 4.6.2.2.5 and MIL-STD 810 METHOD 501.4. Those requirements may be used to derive an acceptable test procedure. However the temperatures for the test may be tailored to the unique requirements of the specific application. If the component has a different temperature limit for operation than that for non-operating conditions, or has a time limit at the highest temperature limit, the provisions of DO-160, section 4.5.3 and 4.5.4 should be incorporated into the test cycle.

The testing should evaluate both the maximum ambient and internal fluid temperature conditions. Often the maximum ambient and fluid temperatures do not occur at the same operating conditions. In those cases an analysis may be done to define the worst-case conditions to be used during testing; or also acceptable is to subject the component to the maximum ambient and the maximum internal fluid temperatures individually. If testing to the maximums temperatures in separate tests, the non-maximized fluid temperature may be set at a temperature that is more representative of the test condition.

For a lubrication system component, consideration should be given to using an oil that has the most aggressive affect on non-metallic parts such as gaskets and O-rings.

All input variables should be cycled during the test. The test cycle should simulate the functions performed by the component during a typical engine mission cycle or at least the extremes of the functional requirements of a typical engine mission cycle; it should also include demonstration of all other component functions required for engine compliance with 14 CFR 33 requirements (such as engine protection or limiting) at least once every 10 cycles.

Total test time should be at least 100 h.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by component operation at high temperature, and inspection to confirm that no damage has occurred that could lead to failure.

The maximum temperature capability substantiated by this test should be consistent with the declared environment for the engine. Usually that means that the maximum temperature demonstrated during this test is included in the engine installation manual and validated in the installation as part of aircraft certification.

## 5.2 Low Temperature

The Low Temperature demonstration is to verify that the component can function properly in its minimum temperature environment and identify any damage caused by exposure to minimum temperature that could lead to component failure. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Low Temperature Demonstration test for engine components.

Historical guidelines for the Low Temperature test are available in MIL-E-5007 paragraph 4.6.2.2.7 or MIL-STD 810 METHOD 502.4. Those requirements may be used to derive an acceptable test procedure. However the temperatures for the test may be tailored to the unique requirements for the specific application. If the component has a different temperature limit for operation than that for non-operating conditions, or has a time limit at the lowest temperature limit, the provisions of DO-160, section 4.5.1 and 4.5.2 should be incorporated into the test cycle.

The testing should evaluate both the minimum ambient and internal fluid temperature conditions. Often the minimum ambient and fluid temperatures do not occur at the same operating conditions. In those cases an analysis may be done to define the worst-case conditions to be used during testing; or also acceptable is to subject to the component to the minimum ambient and the minimum internal fluid temperatures individually. If testing to the minimum temperatures in separate tests, the non-minimized fluid temperature may be set at a temperature that is more representative of the test condition.

For a lubrication system component, consideration should be given to using the oil with the highest viscosity to achieve the most adverse flow conditions.

All input variables should be cycled during the test. The test cycle should simulate the functions performed by the component during a typical engine mission cycle or at least the extremes of the functional requirements of a typical engine mission cycle; it should also include demonstration of all other component functions required for engine compliance with 14 CFR 33 requirements (such as engine protection or limiting) at least once every 10 cycles.

Some components will begin warming up as soon as they start operating due to self heating. An example is a positive displacement pump in a bypassing fuel system. The Low Temperature demonstration may simulate this temperature affect as long as each new cycle returns to the cold soak ambient conditions.

The test time should be at least 20 h or at least 20 cycles from cold soaked ambient conditions.

The low temperature demonstration should be done after completion of the high temperature demonstration to more appropriately validate design aspects of sealing at very cold temperatures.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by component operation at low temperature, and inspection to confirm that no damage has occurred that could lead to failure.

The minimum temperature capability substantiated by this test should be consistent with the declared environment for the engine. Usually that means that the minimum temperature demonstrated during this test is included in the engine installation manual and validated in the installation as part of aircraft certification.

## 5.3 Room Temperature

The Room Temperature demonstration is to identify any damage caused by extended operation at room temperature that could lead to component failure. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Room Temperature Demonstration test for engine components.

Definition of the test method to show compliance with this requirement may be derived from MIL-E-5007 paragraph 4.6.2.2.6. All input variables should be cycled during the test. The test cycle should simulate the functions performed by the component during a typical engine mission cycle or at least the extremes of the functional requirements of a typical engine mission cycle; it should also include demonstration of all other component functions required for engine compliance with 14 CFR 33 requirements (such as engine protection or limiting) at least once every 10 cycles.

The test time should be at least 300 h.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of all operational or functional parts of a production acceptance test, and inspection to confirm that no damage has occurred that could lead to failure.

## 5.4 Contaminated Fluids

The Contaminated Fluid demonstration is to verify that the engine can function properly in a contaminated fluid environment. Engine components are usually substantiated for operation with contaminated fuel, contaminated engine lubrication oil, and contaminated air. Testing with other contaminated fluids may be applicable if the engine incorporates components that provide functions such as those for aircraft hydraulic or engine thrust reverser systems. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Contaminated Fluid demonstration for engine components.

There is no single industry or military procedure that this ARP recommends using for showing compliance. But a test method may be derived from the guidance available in MIL-E-5007, MIL-E-8593, the AMC to CS-E 670, SAE AIR4023, SAE AIR4246, and SAE MAP749.

The test should incorporate the following features:

a. The contamination levels should be appropriate for the intended installation and engine/aircraft maintenance procedures. Since the fuel contamination is directly linked to the aircraft application fuel system, the constituents and concentrations should be coordinated with the airframer. In lieu of specific application requirements, the maximum contamination levels may be taken from the following:

   1. Fuel contamination from MIL-E-5007 TABLE X or AMC to CS-E 670; or as modified in AIR4246 for ISO specified Arizona Test Dust and/or Carbon Fiber for Composite Material Aircraft. Based on the guidance in AIR4023, the relative proportions of the contamination should be maintained but the total contamination reduced to a total of 8 gm/1000 U.S. gal. Note that AIR4023 is also a good historical discussion of contamination requirements.

   2. Maximum air contamination from MIL-E-5007, 4.6.2.2.6

   3. The maximum contamination levels for engine lubrication oil component testing should be consistent with the system filtration design and the maintenance procedures defined in the Instructions for Continued Airworthiness (ICA). There are no industry standards defining the recommended contamination levels and constituents. Generally the contamination used for components of the engine lubrication system is derived from standards for fuel contamination noted in 5.4.a.1 with salt water and napthanic acid deleted. The solid contaminant levels are also usually reduced from those listed in MIL-E-5007 since engine oil systems are self-contained and less exposed to external environmental contamination.

4. The contamination levels for any fluid other than air, fuel, or engine lubricating oil is dependent on the application and system design and no recommendation for the level of contamination are provided in this ARP.

b. MAP749 defines two acceptable methods of conducting a fuel contamination test; they are the conveyor and slurry injection methods; both are continuous feed methods. It also provides numerous helpful hints and lessons learned.

c. The test cycle should simulate a typical engine mission cycle or at least the extreme conditions of a typical engine mission cycle; it should also include demonstration of all other component functions required for engine compliance with 14 CFR 33 requirements (such as engine protection or limiting) at least once every 10 cycles.

d. The test time is 300 h. And although not a requirement, the Contaminated Fluid demonstration is often combined with the Room Temperature demonstration.

e. As long as the fluid supplied to the component is continuously contaminated to the required levels, the engine system filter(s) may be used or the filtration effectiveness simulated for the test. The filters may be replaced during the test as allowed by the ICA.

f. Components exposed to engine oil should be exposed to the maximum contamination level for the entire test.

g. If a maximum normal (or continuous) level of fuel contamination is also specified for the application, the fuel contamination levels may be reduced to the maximum normal levels between occurrences of maximum contamination testing.

   The test cycle time at the maximum contamination level should be at least equal to the longest flight leg of the aircraft application. There should be multiple exposures to the maximum contamination level; and they may be distributed throughout the total test.

   In lieu of specific application requirements for maximum normal contamination for fuel, the guidance of the AMC to CS-E 670 (1) b may be used. That states that a contamination level of 0.5 g per 4500 L (0.42 g/1000 gallons) is appropriate. The constituents of the contamination should be the same as those in step 5.4.a.1.

h. For air systems, MIL-E-5007, 4.6.2.2.6 suggests the maximum levels be introduced during the first hour and each succeeding 10th hour.

   Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by component operation with contaminated fluid, and inspection to confirm that no damage has occurred that could lead to failure.



## 5.5 Vibration

The Vibration demonstration is to verify that exposure to the vibration environment does not cause structural failures and that the equipment functions properly when exposed to that vibration. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Vibration test for engine components.

The maximum vibration capability substantiated by this test should be consistent with the declared environment for the engine; or of the appropriate zone of the aircraft or pylon if the component is not mounted on the engine. Usually it means that this vibration level is compatible with the recommended in-service maximum unbalance limits for the engine rotors.

If the testing of the component during engine tests substantiates its operating performance during exposure to maximum vibration levels and also accumulates enough cycles during that test to demonstrate that the component requires no life management in service, no additional testing is required. If the engine vibration test substantiates component operational performance capability but not design life, the component vibration test can often be done without the component functioning. That is often the case for components where the high cycle fatigue life not demonstrated by engine test is applicable only to the static mounting and structural parts of the component; and those may be tested without the component functioning.

A recommended test method to show compliance with this requirement is defined in DO-160 Section 8. The appropriate category for engine components is R, U, or U2 depending on whether the engine is for a fixed wing or a helicopter application. Section 8 of DO-160 also provides some guidance on the selection of stair-step, sinusoidal, or random input of the vibration excitation. Chapter 4 of AC 33.63-1 also provides guidance for “External Components” and is directly applicable to the components discussed in this ARP. But in all cases, the vibration levels selected must be compatible with those that occur with the engine operating at any conditions defined in the engine installation manual. Each of those methods may be acceptable as long as the test demonstrates that vibration will not cause high cycle fatigue failure of the component. The number of cycles required for that substantiation may depend on construction of the component and the material endurance fatigue properties. Substantiation of the test levels may be done as part of the component compliance to 33.91 requirements or as part of the overall engine compliance with the requirements of 33.63.

Pass/fail criteria is that the component must be able to function as intended and must be free of any damage and wear beyond the acceptable limits. This can usually be interpreted to mean operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by vibration, and inspection to confirm that no damage has occurred that could lead to failure.



## 5.6 Impact

The Impact demonstration is to verify that the component can function properly when exposed to the impact load conditions experienced during normal aircraft operations. AC 33.28-2 recommends the Impact demonstration for engine components. The AMC to CS-E 80 includes this test as part of its recommendation for Operational shock and Crash Safety.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 7. Components should continue to function normally after exposure to the shock loads. The test method is defined in 7.2. The crash requirements should be reviewed but are typically not required since they are usually less severe than requirements for other engine demonstrations; e.g. ice slab ingestion and fan blade out.

Because duration of the impact pulse is short, the performance of most components during the pulse does not impact the functioning of most modern FADEC engine control systems. In those cases, the component is not required to operate during the exposure to the impacts. If the performance of the component could potentially cause an upset in the engine thrust or power or fail to provide component functions required for engine compliance with 14 CFR 33 requirements (such as engine protection or limiting), the component must be operating and performance monitored during the test and the component performance demonstrated to be within acceptable levels. An example where this may be required would be for signals that may change state and remain in the incorrect position; e.g. latching relays or electrical switches.

Pass/fail criteria should include successful completion of those parts of a production acceptance test that may be impacted by exposure to impact loads, and inspection to confirm that no damage has occurred that could lead to failure. And if applicable, demonstration that no latched signal outputs occurred.

## 5.7 Sustained Acceleration

The Sustained Acceleration demonstration is to verify that the component can function properly when exposed to the expected acceleration forces do to aircraft operations and identify any damage caused by exposure to those forces. AC 33.28-2 recommends the Sustained Acceleration demonstration for engine components.

Substantiation of a component for sustained acceleration involves verifying that it is not damaged by exposure to the loads and that it also performs its intended functions while exposed to those loads. Substantiation may address the two requirements separately.

a. Damage assessment - Many engine control components are exposed to higher “g” loading as part of the vibration and/or impact substantiation than required for sustained acceleration. If that is the case, those tests also demonstrate the component is not damaged by the sustained acceleration loads. If a test were required, it may be derived from MIL-STD-810, Method 513, Procedure I or from ISO 2669.

b. Performance assessment - Substantiation of a component's ability to function when exposed to the forces imposed by sustained acceleration can be done by test or analysis. If analysis for proper function of the component cannot be done, a test may be derived from MIL-STD-810, Method 513, Procedure II or from ISO 2669. The component must be operational for the test, accelerations imposed on the component in each of the 3 axes, and sufficient measurements made during the test to verify proper operation of the component during the test.

   Often, analysis may be used to show that the position of moving parts is not impacted by the additional forces to the degree that the component does not meet its intended function. Many of the moving parts are part of a closed-loop control system. Closed loop means the forces to position the part are variable. As long as sufficient force margin exists within the position control loop, the part will not move when exposed to the additional forces. For these cases, an analysis that shows the available positioning force exceeds that required to maintain the position is an acceptable method of substantiation.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by exposure to sustained acceleration loading, and inspection to confirm that no damage has occurred that could lead to failure.

5.8 Sand and Dust

The sand and dust demonstration is to verify that the component can function properly after exposure to a sand and dust environment. The sand and dust demonstration is applicable to all equipment that is not environmentally sealed. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Sand and Dust demonstration for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 12. The component is not required to operate during the exposure to sand or dust.

Pass/fail criteria should include successful completion of those parts of a production acceptance test that may be impacted by exposure to sand or dust, and inspection to confirm that no damage has occurred that could lead to failure. It should include verification that the sand and dust deposits have not caused clogging or binding of mechanical components, caused electrical malfunction, or other damage does not cause immediate or long-term effects on the proper functioning and structural integrity of the component.

5.9 Fluid Susceptibility

The fluid susceptibility demonstration is to verify that the component can function properly after exposure to specified fluids and identify any damage caused by such exposure that could lead to equipment failure. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Fluid Susceptibility demonstration for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 11. The component is not required to operate during the exposure to the various fluids. Compliance may be shown by test of the individual materials instead of tests of an assembled component. And since aircraft engine components repeatedly use many of the same materials, comparative analysis to previously tested materials is often used for compliance. Tests should only be required when introducing a previously uncertified material to the engine. If a material is known to be susceptible to a fluid, the testing is required to substantiate the material is adequately protected from the fluid when assembled into the component.

Two different test methods are described in DO-160. The Spray test is applicable for those fluids that may contact the components only during maintenance activities. The Immersion test is applicable for those fluids and component combinations that occur during normal engine operation.

Pass/fail criteria should include successful inspection of the component or test specimen to confirm that no damage has occurred that could lead to failure.

5.10 Salt Spray

The salt spray demonstration is to verify proper component operation after exposure to a salt spray environment. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Salt Spray demonstration for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 14. The component is not required to operate during the exposure to salt spray.

Pass/fail criteria should include successful completion of those parts of a production acceptance test that may be impacted by exposure to salt spray, and inspection to confirm that no damage has occurred that could lead to failure. It should include verification that the salt deposits have not caused clogging or binding of mechanical components, caused electrical malfunction, or any corrosion does not cause immediate or long-term effects on the proper functioning and structural integrity of the component.

5.11 Fuel System Icing

The fuel system icing demonstration is to verify the capability of the fuel system to operate in fuel icing conditions. The AMC to CS-E 80 recommends the Fuel System Icing demonstration for engine components.

Compliance with the fuel system icing requirement may be done by demonstrating the design can operate properly in freezing conditions, incorporating fuel heating provisions which maintains the fuel temperature above 32 °F (0 °C), or demonstrating the effectiveness of specified approved fuel anti-icing additives. The certification agencies have generally not accepted the fuel anti-icing additives approach for engines certified for operation on Part 25 aircraft.

Substantiation for fuel system icing may be done on an individual component basis or as an engine fuel system. When the substantiation is for a complete fuel system, the documentation is sometimes provided as part of compliance with 14 CFR 33.67 (b) and not as part of the individual component compliance with 14 CFR 33.91.

There is no industry or military procedure that is directly applicable for showing compliance. However, ARP1401 provides guidance for testing of aircraft systems but specifically exempts the engine from the aircraft fuel system. But some of the guidance in ARP1401 is applicable and when combined with other available guidance can be used to develop a test method.

The following elements should be incorporated into the test plan for fuel system icing.

a. Analysis of the fuel system operation and worst-case fuel and environmental conditions to determine the required test conditions. That analysis should consider the lowest temperature in the aircraft tanks, coldest ambient air conditions, heat added to the fuel (if any) by the aircraft fuel delivery system, heat added to the fuel by operation of the engine fuel system (e.g. from the pumping and metering), heat added from other systems via heat exchangers, and evaluation of all potential fuel system elements that may be impacted by icing in the fuel. For many fuel systems the coldest fuel temperature occurs when accelerating or immediately after the acceleration to high power during on-the-ground accelerations to takeoff power or in the air during an aircraft aborted landing condition. For other types of fuel systems the worst-case condition may occur at other operating conditions. On the ground starting is generally not an engine certification demonstration; however in-the-air starting should be evaluated as one of the potential worst case conditions.

b. The amount of water content in the fuel should be consistent with the worst case of either that specified for the aircraft application or those defined in 14 CFR 33.67. 14 CFR 33.67 (b) (4) (ii) defines the requirement as fuel initially saturated with water at 80 F (27 C) and having 0.025 fluid oz/gal (0.20 mL/L) of free water added and cooled to the most critical conditions for icing likely to be encountered.

c. The test should include operation or simulation of the engine operation at the selected worst-case condition; or provide enough data from the test to adequately evaluate the impact on engine operation.

d. When testing, generally all fuel components with moving parts, filters, screens, and fuel restriction devices should be included in the test. Depending on the specific design of the fuel system components, other components need to be included when they could impact operation in icing conditions.

e. Test time depends on the worst case conditions determined in step 5.11.a. The test time should be at least as long as the exposure exists to fuel icing in the intended application. If the worst-case condition is a steady state condition, the test time usually should be a minimum of 20 min. If the critical condition is a transient event such as occurs during an aircraft takeoff, the test should include simulation of the total time the system is exposed to fuel icing conditions. That time is also likely to be in the order of 15 to 30 min.

Pass/fail criteria should include operation of the fuel system within its specified limits at the tested conditions and inspection or production acceptance tests as required to confirm that no damage has occurred that could lead to failure. In lieu of measuring operation during the test against component specified limits, proper operation of the fuel system can be defined as no loss of thrust or power of the engine, no loss of engine protection or limiting capability, and no faults detected that result in the need for action by the flight crew. In lieu of application specific requirements and using the guidelines of AC 33.28-1, no loss of thrust can be defined as the larger of 3% of thrust or power at the tested condition or 1% of max rated power or thrust.

## 5.12 Induction Icing

The induction icing demonstration is to verify that the component can function properly when the engine inlet is exposed to icing conditions. It is limited to those components exposed to engine gas path or bleed system airflow. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Induction Icing demonstration test for engine components.

Although substantiation for induction icing may be done on an individual component basis, it is also often done as a part of the complete engine demonstration for compliance with 14 CFR 33.68.

When the induction-icing requirement is applicable to components, it most often is applied to engine inlet temperature or pressure sensing systems. If an individual component test is required, the test must simulate the icing conditions that would be critical for the sensor. For these components the test procedure must be developed to meet the requirements of 14 CFR 33.28 (b) and (c). That requires no failure of aircraft-supplied data result in an unacceptable change in power or thrust and no single failure or malfunction or probable combination of failures result in an unsafe condition. Since the output of engine inlet sensors is usually compared to aircraft supplied data and various signal processing strategies are used to validate and select the signals to be used by the control system, any component level induction icing test must consider the impact on the overall thrust setting system. For probes located in the engine inlet, the use of high power icing table points has been shown to provide an adequate demonstration of the probe’s capability in icing.

The induction icing requirement may also be applicable to those components that are exposed to engine bleed air. For these, a component level test must simulate the icing conditions critical to the component. Then the impact of the component's performance during icing is evaluated to determine the impact on engine operation.

There are no industry standards available for induction icing testing to use as a guide for individual component testing. However, AC 20-147 provides extensive guidance on overall engine compliance. Of particular interest for component testing are paragraphs 7.b. on Auto-recovery systems, 8.b.(6) on Sensor fouling, and 11.c. on Engine systems compliance requirements.

Pass/fail criteria should include acceptable operation of the engine as defined by AC 20-147 during the icing conditions or, if defined, operation of the component within its specified limits during icing, successful completion of those parts of a production acceptance test that may be impacted by exposure to icing, and inspection to confirm that any resultant damage is shown to be acceptable for continued in-service use.

## 5.13 Fungus

The fungus demonstration is to verify that no materials supporting the growth of fungus are used in the components. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Fungus demonstration for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 13. The component is not required to operate during the test. Compliance may be shown by test of the individual materials instead of tests of an assembled component. And since aircraft engine components repeatedly use many of the same materials, comparative analysis to previously tested materials is often used for compliance. Tests should only be required when introducing a previously uncertified material to the engine. If a material is known to be susceptible to fungal attack, the testing is required to substantiate the material is adequately protected from fungal growth when assembled into the component.

Pass/fail criteria should include inspection to determine the immediate and long-range effect that fungal growth (if any) has on the physical characteristics of the material. Any fungal growth should also be evaluated for detrimental human factors effects (including health risks).



## 5.14 Temperature and Altitude

The temperature and altitude demonstration is to verify that the component operates per design intent throughout the engine flight envelope. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Temperature and Altitude demonstration for engine control components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 4. The components discussed in this ARP are almost always included in Category D3 that is intended for equipment installed in the power plant compartment of aircraft engines operated up to an altitude of 50,000 ft. One exception would be for an EEC mounted in the aircraft fuselage. The temperature tests and altitude tests are defined and usually conducted separately.

Testing of electrical/electronic components should take into account the source(s) and variation of electrical power for the component. For example, a component that must operate under cold starting conditions should be tested at low input voltages. A high temperature-altitude test should be done at the highest power dissipation mode of operation.

The temperature part of the test is defined in DO-160 paragraphs 4.5.1 through 4.5.4. The pass/fail criteria for all tests include an inspection to confirm that no damage has occurred that could lead to failure. The pass/fail criteria for 4.5.1 and 4.5.3 also includes demonstration that the component can function properly after exposure to the Ground Survival temperatures; that may be done by successful completion of those parts of a production acceptance test that may be impacted by exposure to extreme temperatures. The pass/fail criteria for 4.5.2 and 4.5.4 also includes demonstration that the component can function properly during exposure to those temperatures; that may be done by successful completion of those parts of a production acceptance test that may be impacted by operation at extreme temperatures.

DO-160 also provides guidance on combining the Temperature and Altitude test with the Thermal Cycle Test defined in 5.15.

The In-Flight Loss of Cooling Test is applicable only to equipment installed in the power plant compartment of aircraft engines when they are provide with a dedicated air cooling system.

The altitude part of the test is defined in 4.6. For components without electrical devices, this test is applicable only to those sealed and not exposed to internal fluid pressures that significantly exceed atmospheric pressure (meaning those that are required to comply with the proof and burst pressure requirements). The pass/fail criteria includes demonstration that the component can function properly during exposure to the range of atmospheric pressures and inspection to confirm that no damage has occurred that could lead to failure. Acceptable performance during test may be done by successful completion of those parts of a production acceptance test that may be impacted by altitude variations or an equivalent system functional demonstration.

5.15 Thermal Cycle

The thermal cycle demonstration is to verify that electrical equipment will continue to operate and not fail or be damaged when exposed to temperature cycles and thermal transients consistent with the declared temperature environment. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Thermal Cycle Demonstration test for engine components.

Testing of electrical/electronic components should take into account the source(s) and variation of electrical power for the component. For example, a component that must operate under cold starting conditions should be tested at low input voltages. A high temperature-altitude test should be done at the highest power dissipation mode of operation.

For aircraft engine components, the recommended test method to show compliance with this requirement is defined in DO-160 Section 5, Category A, B, or C. The category is selected based on the specified rate of temperature change. If none is specified, the component should be tested to Category A procedures.

DO-160, paragraph 5.3.1, provides guidance on combining the High Temperature and Low Temperature demonstration with the Thermal Cycle test. That is typically done for electronic controls or electrical sub-components. When it is done, additional cycles are required to provide test substantiation equivalent to what would have been obtained during the 100 h of hot and 20 h of cold testing. For that reason, the number of thermal cycles shall be increased from 2 to at least 10 and the Room Temperature demonstration is not required.

Pass/fail criteria should include proper operation during the test, successful completion of those parts of a production acceptance test that may be impacted by exposure to thermal cycles, and inspection to confirm that no damage has occurred that could lead to failure.

5.16 Explosion Proofness

The explosion proof demonstration is to verify that components cannot be the source of ignition for an explosion of flammable fluids or vapors. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Explosion Proofness demonstration for engine components.

This test/analysis is required for all electrical components that may provide the ignition source for flammable fluids or vapors that could occur during normal and fault conditions. It involves demonstration that the component will not cause a fire by ignition of flammable fluids due to operational arcing or sparking or due to self-ignition caused by high temperatures.

Because the requirement is linked to overall engine and aircraft installation requirements, the test requirement should be reviewed for compatibility with those of 14 CFR 33.17 for engine fire prevention and the applicable aircraft regulations such as 14 CFR 25.1181 and 25.1182 for fire zones and firewalls.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 9.

a. Category A testing is appropriate for components inside of a flammable fluid zone. An explosion within the component must not cause an explosion outside of the component. The required test procedure is defined in 9.7.1.

b. Category E testing is appropriate for components inside of a fire zone. In those cases, the component must not cause an explosion. The required test procedure is defined in DO-160 Section 9.7.2.

Although it at first seems unusual to have a more severe requirement for a component outside of a fire zone than inside of it, a fire zone has additional requirements imposed to ensure safety; e.g. may need to have the capability of detecting and extinguishing a fire. So the consequences are potentially more hazardous for an explosion outside of a fire zone.

For most aircraft engine components, the surface temperatures are far below the auto-ignition levels and if this is true for the specific application no additional testing is required for that part of the requirement.

Hermetically sealed components cannot cause ignition of flammable fluids so the ignition tests required for category A or E are not applicable. Testing of hermetically sealed components is only required when the surface temperature does exceed the auto-ignition levels. The test for that condition is defined in 9.7.3.

Pass/fail criteria are defined in DO-160, 9.7.1.3 and 9.7.2.3 as appropriate. Post test damage to the component is acceptable and the component does not need to be serviceable or repairable after the test.

## 5.17 Humidity

The humidity demonstration is to verify that the component can withstand either natural or induced humid atmospheres. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Humidity demonstration for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 6. That document describes test methods for 3 different categories of equipment. Category B or C is applicable for engine components.

Pass/fail criteria are defined in DO-160, Section 6.3.2, Step 7 and post test inspection. At the end of the exposure period compliance with specified performance of the component must be demonstrated and include successful completion of those parts of a production acceptance test that may be impacted by exposure to humidity, and inspection to confirm that no damage has occurred that could lead to failure.

## 5.18 Waterproofness

The waterproofness demonstration is to verify that the component can withstand the effects of liquid water being sprayed or falling on the equipment or the effects of condensation. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Waterproofness demonstration test for engine components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 10. That document states the test is not applicable to hermetically sealed components; hermetic is defined as a seal that is airtight and permanent. For non-hermetically sealed components, the test is required.

DO-160 Section 10 also defines several potential test methods. Generally, the appropriate test method for engine control components is defined by category W. However, depending on the specific application requirements, category R may be appropriate for components where ambient air is used for cooling and could result in direct impingement on components or where maintenance is likely to occur with the component exposed to rainstorms. When either of those tests is appropriate, DO-160 defines a test where the component is subjected to the appropriate water environment while not operating and then the component must demonstrate proper functioning immediately after exposure to the water.

Pass/fail criteria should include successful completion of those parts of a production acceptance test that may be impacted by exposure to water, and inspection to confirm that no damage has occurred that could lead to failure.

## 5.19 Pin Injection

As previously discussed in the HISTORICAL PERSPECTIVE, most of the environmental substantiation for electrical systems is substantiated under 14 CFR 33.28; specifically for EMI/HIRF/lightning, sub-paragraph (d) requires the control systems have environmental limits defined including those transients caused by lightning strikes. But the verification that the individual components of the system are not damaged due to the electrical currents generated within the electrical system during a lightning strike is done on an individual component test basis as part of compliance with 14 CFR 33.91. That requirement is defined as Pin Injection.

The AMC to CS E-80 does not have a specific recommendation relating to pin injection. But by a reference to AMC 20-1 it suggests that EMI, HIRF, and Lightning be considered. AC 33.28-2 does not include EMI/HIRF/Lightning as one of the “physical” environmental test requirements of TABLE 6-1. But AC 33.28-2 does identify EMI/HIRF/Lightning in the discussion of Electrical Environmental Limitations to be considered.

The recommended test method and guidance on appropriate test levels and waveforms to show compliance with this requirement is defined in DO-160 Section 22.5.1. This test method applies a specified transient waveform(s) directly to the designated pins of the component electrical connector, usually between each pin and case ground. The waveform to be used for the test depends on the specific application and the electrical circuit being tested. The levels should be consistent with the level defined for the intended aircraft application and are usually specified in the engine installation manual.

DO-160 allows an option to testing with the specified waveforms for simple electrical devices that are passive and have no EMI filters or transient voltage suppressors or similar electrical circuit elements that are connected through case ground to the engine aircraft structure. One example would be a linear variable differential transformer (LVDT) used in the control system for feedback position of an actuator. For these simple electrical devices a dielectric withstanding voltage or high potential (hi-pot) test may be used in lieu of the pin injection test if the applied peak voltage test level is at least equal to the peak of the required test voltage.

Since this test is only applicable to electrical circuits, generally the test can be done using only the applicable electrical sub-system or sub-components.

Pass/fail criteria should include demonstration of no degradation of function of the electrical circuit being tested and inspection to confirm that no damage has occurred that could lead to failure. This includes validation that transient suppression devices and filter components remain effective after the completion of the test.

5.20 Power Input

The power input demonstration is to verify the component can accommodate the full range of electrical power inputs declared for the installation. It is limited to electrical/electronic components or components with electrical/electronic sub-components that receive power directly from the aircraft. Both AC 33.28-2 and the AMC to CS-E 80 recommend the Power Input demonstration for engine control components.

The recommended test method to show compliance with this requirement is defined in DO-160 Section 16. Because the purpose of the test is to demonstrate operation with the extremes of aircraft power supplied to the engine when installed on an aircraft, often tailoring of the requirements defined in Section 16 is appropriate. The test levels should be at least as severe as those defined for the aircraft application. Components powered from both airframe supplied and on-engine dedicated power sources should be tested in all appropriate combination of the power sources.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, successful completion of those parts of a production acceptance test that may be impacted by component operation at varying input power conditions, and inspection to confirm that no damage has occurred that could lead to failure.



5.21 Proof Pressure

The Proof Pressure demonstration is to verify that the component can withstand the maximum fluid pressures without damage or exhibit leakage. It is applicable to all components that convey or contain fuel, oil, or high-pressure air. Although this requirement is applicable for air handling components anytime they contain air pressure above ambient, individual manufactures are encouraged to define a more practical basis for when it is applicable. For most current component designs, materials, and environments, high-pressure air can be further defined as pressures exceeding 3 to 5 times ambient air pressure. The AMC to CS-E 80 recommends the Proof Pressure demonstration for engine control components.

The recommended test requirements are defined by CS-E 640 (a) (1) and the AMC to CS-E 640. That information provides the method to determine the required test pressures. The test pressure is selected from calculations based on the maximum working pressure and the normal working pressure.

If the component is exposed to significant static loads in addition to pressure loads, the test must account for them. The engine components that are discussed by this ARP are usually not exposed to significant static loads and those loads do not need to be included in the test or analysis.

The test must account for the operating temperature of the part, properties representative of the material and manufacturing processes, and any adverse geometry conditions allowed by the type design. CS-E 640 (a) and (b) provide specific guidance on determining the required test pressures. The temperature allowance may be done by testing for proof pressure at the temperature associated with the most critical stress case; or alternatively, the test may be done at room temperature if the pressure differential is increased proportionately to the loss of relevant material properties at the higher operating temperature.

Since many components are subjected to varying maximum pressures, the test may be done by individually exposing each of the pressure chambers to its maximum pressure loading. Also, because of the multiple pressure cavities inside some components, the proof pressure test may simulate the maximum differential pressures between the adjacent chambers as long as each chamber is exposed to the more severe condition of chamber to chamber or chamber to external environment differential pressures.

The component test pressures must remain stabilized for at least 1 min.

Pass/fail criteria should include operation of the component within its specified limits at the tested conditions, and inspection to confirm that no damage has occurred that could lead to failure. Operation within specified limits may be demonstrated by successful completion of those parts of an acceptance test that may be impacted by component operation at high fluid pressures; or since this test is often done only on individual parts of the component, by analysis that shows the function of the tested part was maintained during the test.

5.22 Burst Pressure

A The Burst Pressure demonstration is to verify that the component can withstand the maximum fluid pressures without burst or fracture. The Burst Pressure requirement is applicable when the Proof Pressure requirement is applicable. The AMC to CS-E 80 recommends the Burst Pressure demonstration for engine control components.

CS-E 640 (a) (2) and the AMC to CS-E 640 define the recommended test requirements. That information provides the method to determine the required test pressures. The test pressure is selected from calculations based on the maximum working pressure and the normal working pressure. If the component is exposed to significant static loads in addition to pressure loads, the test must account for them. The engine components that are discussed by this ARP are usually not exposed to significant static loads and those loads need not be included in the test or analysis.

The test must account for the operating temperature of the part, properties representative of the material and manufacturing processes, and any adverse geometry conditions allowed by the type design. CS-E 640 (a) and (b) provide specific guidance on determining the required test pressures. The temperature allowance may be done by testing for burst pressure at the temperature associated with the most critical stress case; or alternatively, the test may be done at room temperature if the pressure differential is increased proportionately to the loss of relevant material properties at the higher operating temperature.

Since many components are subjected to varying maximum pressures, the test may be done by individually exposing each of the pressure chambers to its maximum pressure loading. Also, because of the multiple pressure cavities inside some components, the burst pressure test may simulate the maximum differential pressures between the adjacent chambers as long as each chamber is exposed to the more severe condition of chamber to chamber or chamber to external environment differential pressures.

The component test pressures must remain stabilized for at least 1 min.

Pass/fail criteria should include inspection to confirm that component did not exhibit fracture or burst. Leakage past seals and sealing surfaces is allowed but there should be no leakage due to failures of the pressure vessel chamber itself. Post test damage to the component is acceptable and the component does not need to be serviceable or repairable after the test.

5.23 Pressure Cycling

The Pressure Cycling demonstration is to verify that exposure to fluid pressure cycles does not cause structural failures during the expected life of the component. The Pressure Cycling requirement is applicable when the Proof Pressure requirement is applicable. The AMC to CS-E 80 by referencing CS-E 640 (b) suggests Pressure Cycling demonstration for engine control components. However, paragraph 640 (b) of the 24/10/2003 version of CS-E is not applicable to pressure cycles. The JAA regulations did define pressure cycling requirements as part of the fatigue life requirements for pressure loads. Regardless of the certifying agencies current written requirements, this ARP recommends Pressure Cycling test for engine components.

There is no industry or military procedure that is recommended for showing compliance. But a test method may be derived from the guidance available in the AMC to CS-E 640 and should include the following:

a. Sufficient cycles to verify structural capability of the component for its design life.

b. Fluid pressures shall range from a minimum of approximately zero to the Maximum Normal Working pressure defined by the AMC CS-E 640. The cycling does not need to include dwells at the maximum pressure as long as the test pressure reaches the required level. The rate of pressure change between minimum and maximum is arbitrary.

c. The test must account for the operating temperature of the part, properties representative of the material and manufacturing processes, and any adverse geometry conditions allowed by the type design. CS-E 640 (a) and (b) provide specific guidance on determining the required test pressures. The temperature allowance may be done by testing for pressure cycling at the temperature associated with the most critical stress case; or alternatively, the test may be done at room temperature if the pressure differential is increased proportionately to the loss of relevant material properties at the higher operating temperature.

d. Since many components are subjected to varying maximum pressures, the test may be done by individually exposing each of the pressure chambers to its pressure cycling loading. Also, because of the multiple pressure cavities inside some components, the pressure cycling test may simulate the maximum differential pressures between the adjacent chambers as long as each chamber is exposed to the more severe condition of chamber to chamber or chamber to external environment differential pressures.

Pass/fail criteria should include inspection to confirm that component did not exhibit fracture or burst.



5.24 Fire

The overall engine fire prevention requirements are defined in 14 CFR 33.17. Generally, compliance with this requirement requires testing of individual components of the engine and that testing is done as part of the compliance with 33.91. The AMC to CS-E 80 states that the engine control system should comply with the requirements of CS-E 130 (e), which states that engine control system components located in a designated fire zone must be at least fire resistant. AC 33.17-1 also provides significant guidance for the fire requirement.

Guidance for compliance with the Fire requirement for components is derived from the above documents and DO-160, Section 26. The following sub paragraphs a - f address each of the individual recommended practices.

a. All components containing or conveying a flammable fluid are required to comply with this requirement. AMC to CS-E 130 (5) (d) provides guidance on components conveying bleed air. For air handling components the fire test requirement is usually applicable whenever the proof and burst pressure requirements are applicable. (See paragraphs 5.21 and 5.22.) And AMC to CS-E 130 (4) (d) provides guidance on compliance for the electrical components.